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FINAL
CONFIRMATORY SAMPLING APPROACH
NEW BEDFORD HARBOR SUPERFUND SITE
New Bedford Harbor, Massachusetts

July 2002

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New England District
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ABBREVIATIONS AND ACRONYMS

ARCS	Assessment and Remediation of Contaminated Sediments (Program)
AWQC	Ambient Water Quality Criteria
CDA	Compliance Demonstration Area
CDF	Confined Disposal Facility
COC	Chemical of Concern
CSO	Combined Sewer Outfall
cy	cubic yards
DCHH	Direct Contact Human Health (Protection)
DQA	Data Quality Assessment
DQO	Data Quality Objective
EPA	U.S. Environmental Protection Agency
ER	Enrichment Ratio
FSP	Field Sampling Plan
GLNPO	Great Lakes National Program Office
Harbor	New Bedford Harbor
IHH/E	Indirect Human Health and Ecological (Protection)
IJC	International Joint Commission
L	Maximum grid spacing for confirmatory sampling
MCT	Maximum Cumulative Transport
MEHT	Mechanical Excavator Hydraulic Transport
MLLW	Mean Lower Low Water
MU	Management Unit
N	Number of confirmatory samples
NBH	New Bedford Harbor
NOAA	National Oceanic and Atmospheric Administration
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PDFT	Pre-Design Field Test
PNNL	Pacific Northwest National Laboratory
ppm	Parts per million
PSNS	Puget Sound Navel Shipyard
QAPP	Quality Assurance Project Plan
RME	Reasonable Maximum Exposure
ROD	Record of Decision
S	Standard deviation (of sediment PCB concentration)
SedPac	Sediment Priority Action Committee
SMU	Solid Waste Management Unit
SMWG	Sediment Management Workgroup
SQC	Sediment Quality Criterion
SQS	Sediment Quality Standard
TBD	To Be Determined
TERC	Total Environmental Restoration Contract
UCL	Upper Confidence Limit
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Service
VSP	Visual Sample Plan

EXECUTIVE SUMMARY

Foster Wheeler Environmental Corporation (Foster Wheeler) has prepared this report to describe the confirmatory sampling approach for the sediment remediation effort for the New Bedford Harbor (Harbor) Superfund Site under Task Order No. 017 of the U.S. Army Corps of Engineers (USACE) Total Environmental Restoration Contract (TERC) No. DACW33-94-D-0002. This document defines and justifies the design of the approach developed for the confirmatory sampling program and identifies key aspects of its implementation in relation to the dredging and excavation of polychlorinated biphenyl (PCB) contaminated sediment at the Harbor. The confirmatory sampling approach presented in this document reflects a combination of established Project Team consensus elements and recommendations for the other required elements of the program backed up by the supporting rationale and justification.

The effort to develop a confirmatory sampling approach for New Bedford Harbor was begun by establishing a solid foundation. A review was made of all prior post-dredging or post-excavation sediment sampling that has been conducted at the Harbor. The objectives of each of these past sampling efforts and the mechanics of how and how much sampling was conducted during each project was critically reviewed. As part of this review, the confounding effects of site conditions of potential relevance to the confirmatory sampling approach were noted (e.g., bathymetry, weather, resuspension, patterns of Harbor use). In addition, a separate review was made of the use of confirmatory sampling to assess the short-term effectiveness of dredging or excavation at 22 recent environmental remediation sites located throughout the United States, Japan and Sweden. The knowledge gained from this survey and evaluation, relative to the presence or absence of proven approaches, provided a more solid basis and a clearer perspective with which to develop the confirmatory sampling approach for the New Bedford Harbor project. The findings of these reviews and surveys were used to develop the recommendations for many of the central elements of the proposed confirmatory sampling approach.

The confirmatory sampling approach for the Harbor was developed using the U.S. Environmental Protection Agency (USEPA) Data Quality Objective (DQO) process. This process was specifically designed to build common sense and the scientific method into all aspects of designing and conducting sampling programs, and to make best use of the obtainable information. Adopting the DQO process made the planning of the confirmatory sampling program more formal and systematic, and increased the likelihood that the data obtained would be of the right type, quantity, and quality to support the fundamental decision making that must be performed. Principally, this decision making will involve determining whether or not an area achieves its target PCB clean-up level(s) following dredging or excavation. Within this context, other current USEPA guidance and tools were used to develop and refine the approach. Among these was the recently released "Visual Sample Plan" software (PNNL, 2001b). The rationale of many of the central elements of the confirmatory sampling approach are based on background information relating to past work at the New Bedford Harbor site and at other recent environmental dredging sites.

One fundamental step in the DQO process is to clearly define the objective of the sampling to be performed. The definition is as follows:

> **To determine whether or not the sediments left after the dredging or excavation of an area have PCB concentrations at or below the target PCB clean-up level established for that area within the spatial limits (i.e., aerial and depth) and time-frame specified.**

Further, this determination had to be made using a technically valid and publicly defensible approach. The confirmatory sampling program also had to reflect good industry practices and be robust enough to support decision making with the level of confidence required by USEPA Site Managers. Lastly, the confirmatory sampling program had to generate information that could be used to geographically focus

and specify the depth of any supplemental dredging or excavation needed to meet the target PCB clean-up level if it was determined that the level specified for an area had not been achieved by the first pass of dredging or excavation.

Given this objective, a detailed clarification of the Record of Decision (ROD) target PCB clean-up levels, and how they should be interpreted and applied, was developed to further solidify the foundation of the confirmatory sampling program. The different areas of the Harbor include the subtidal areas in the Upper and Lower/Outer Harbor (i.e., north and south of the Coggeshall Street Bridge, respectively); the intertidal saltmarshes; residential areas; beachcombing areas; and the intertidal mudflats. The ROD defined four different numerical target PCB clean-up levels (i.e., 1 ppm, 10 ppm, 25 ppm, and 50 ppm) for application to the various locations of the Harbor. Two of the ROD target clean-up levels, 1 ppm and 25 ppm, are associated with the protection of people from direct contact with possible PCB contamination within the top 1 foot of sediment. The other two ROD target clean-up levels, 10 ppm and 50 ppm, are associated with the protection of people indirectly relative to the ingestion of fish and other marine species that inhabit areas of possible sediment contamination. These target clean-up levels are also associated with the broader goals of improving the ecological health of the Harbor and protecting valuable saltmarsh habitats. These latter target PCB clean-up levels are applicable at all depths within the sediment column. Consequently, many locations at the Harbor have both an applicable direct contact and an indirect contact / ecological improvement-related target PCB clean-up level, each applying to a different depth range of the sediment column at that location.

For direct contact human health target clean-up levels, the 95% UCL of the arithmetic average will be compared to the target clean-up level. For indirect human health / ecological improvement target clean-up levels, the average PCB concentration within the compliance demonstration area (CDA) will be compared to the target clean-up level. The equations used for these calculations are presented in this report.

As the confirmatory sampling approach was developed, it became clear that elements of confirmatory sampling (i.e., sample collection timing, area boundaries for compliance demonstration, responses to demonstrating that PCB levels in an area do not meet the target levels) depend on, or are closely related to, many other aspects of the New Bedford Harbor remediation effort. These included: the results of the PCB sediment characterization work; the general approaches to be employed to either dredge or excavate the contaminated sediments in an area; the overall timing or sequencing of the sediment removal activities; the potential for recontamination of a remediated area by natural or man-induced processes; plans for restoring areas of the harbor; and the long term monitoring program for the Harbor. While some of these confirmatory sampling-related aspects were defined or conceptually specified at the time of this writing, many were not. This "parallel development" tack necessarily resulted in the confirmatory sampling approach being both a potential driver of certain other design efforts and a product that depended on the results of still other design activities. It also became necessary to evaluate some number of alternatives for the undefined portions of the remediation process to bound the missing or undefined remediation aspects sufficiently for a complete confirmatory sampling approach to be proposed and defended at this time.

Another beneficial by-product of the "parallel development" tack was that the confirmatory sampling approach evolved with an explicit awareness of a number of other evolving aspects of the overall remediation plans for the Harbor. These included the consideration, and periodic reconsideration, of the:

- Ongoing PCB characterization and geo-statistical modeling work;
- Maturing dredging and excavation designs (including the various sequencing and general strategies for clean-up);

- Impact of operational constraints on the practicality of the confirmatory sampling approach and the quality of the results likely to be generated (e.g., recontamination);
- How the confirmatory sampling compliance demonstration area boundaries would be linked to realistic dredging and excavation management units;
- Typical thickness of contaminated sediments that must be removed;
- Site restoration plans;
- How the collected data would be used to test compliance with the ROD target PCB clean-up levels and to direct any required supplemental dredging or excavation;
- Ease and practicality of implementing the approach; and the
- Need for flexibility to address unique or unanticipated conditions in the field.

The diverse set of strategies and approaches for dredging or excavating a management unit (MU) at New Bedford Harbor had to be screened or bounded in order to provide a context for further defining the confirmatory sampling approach. MUs will be used throughout the design, implementation, and monitoring activities to evaluate and document remedial action progress, confirmatory sampling, and ultimately long-term environmental monitoring. A CDA is defined as the area within which the test will be made to see if the post-dredging or post-excavation sediment PCB concentrations achieve the applicable target PCB clean-up level(s). Two general operational dredging and excavation approaches are defined in this report to provide a context for specifying a suitable confirmatory sampling approach for demonstrating compliance in a CDA.

Approach 1: Compliance Demonstration Area as a Single Management Unit
Approach 2: Compliance Demonstration Area Covering Multiple Management Units

The first approach would be most applicable if extra care must be taken to minimize the time or the degree of disturbance caused in a particular area (typically a relatively small area). This may be desirable because the area is routinely used by the public and must be taken out of service to be remediated. This may also be desirable if there would be greater financial costs, more operational constraints or requirements, or some greater liability relative to working in that area or in having to go back and subsequently rework that area. The first approach would be well suited to a CDA when one desired to "get in and get out" quickly. The second approach would be most applicable if the overriding concern is to maintain a higher degree of operational efficiency for either the dredging or excavation. This may generally be done by designing to allow for nearly continuous operations in a fairly linear, repetitive scope of work. This approach is most applicable for larger areas that can be addressed at a more deliberate pace.

In addition to these two approaches, a "warm spot" removal dredging or excavation effort may be conducted prior to either of the above approaches to minimize the effects of resuspended contaminated sediment. This initial sediment removal activity would be an extension or continuation of the earlier Hot Spot Removal Action that was conducted at the Harbor. Using this strategy, the most contaminated sediments would be targeted and removed first. A specified intermediate removal depth selected to balance PCB mass removal in the first pass with operational efficiency and removal effectiveness in the second pass of dredging or excavation would be defined for this first phase of removal. Not all areas of the Harbor would be dredged or excavated during the "warm spot" removal step. Similarly, as additional dredging or excavation would be performed in all of the areas worked on during this effort, no confirmatory samples would need to be collected, analyzed or evaluated during the initial step.

The identification and justification of the critical elements of the confirmatory sampling approach are presented in this document. These elements include how many samples must be collected in each CDA,

where they must be collected, and how the resulting data will be used to test compliance with the appropriate ROD target PCB clean-up levels. A statistical approach for identifying the number of required confirmatory samples was employed so that the probability of making the most critical site management decision errors could be explicitly controlled and appropriately minimized given the site management objectives. The statistical parameters were selected to balance the level of confidence in the decision testing, the resulting density of sample collection, the cost of overdredging an area, and the eventual impact of underdredging. Thus, two other important parameters in calculating the number of confirmatory samples in a CDA are the size of the CDA and the type of target PCB clean-up level that applies to that area. This approach was used to estimate the required number of confirmatory samples consistent with current USEPA guidance and a corresponding confirmatory sampling grid spacing for each CDA, as illustrated in the table below.

Table ES-1
Number of Confirmatory Samples and Suggested Grid Spacings for Various Compliance Demonstration Areas Throughout the Harbor

Target PCB Clean-Up Level (ppm)	Size of the Compliance Demonstration Area (acres)	Statistical Input Parameters				Number of Required Confirmatory Samples	Size of Square Sampling Grid (feet)
		Projected Post-Removal Standard Deviation (ppm)	Alpha (unitless)	Beta (unitless)	Delta (ppm)		
1	< 0.5	0.25	0.05	0.20	0.125	**31**	**< 15**
1	0.5 – 1.0	0.25	0.05	0.20	0.125	**31**	**15 – 25**
1	1.0 – 5.0	0.25	0.05	0.20	0.125	**31**	**25 – 50**
25	< 0.1	5	0.05	0.20	5	**9**	**< 15**
25	0.1 – 0.3	5	0.05	0.20	5	**9**	**15 – 25**
25	0.3 – 1.0	5	0.05	0.20	5	**9**	**25 – 50**
25	> 1.0	5	0.05	0.20	5	**9**	**> 100**
10	< 5.0	3	0.05	0.20	1.5	**31**	**< 80**
10	5.0 – 10	3	0.05	0.01	1.5	**75**	**50 – 75**
10	10 – 20	3	0.05	0.01	1.5	**75**	**75 – 100**
50	< 5.0	12	0.05	0.20	12	**9**	**< 150**
50	5.0 – 10	12	0.05	0.01	12	**20**	**100 – 145**
50	10 – 20	12	0.05	0.01	12	**20**	**145 – 225**

The maximum size of the square confirmatory sampling grid, L, is calculated using the following equation:

$$L[ft] = \sqrt{\frac{CDA\ Size[acre] \cdot 43{,}560[ft^2/acre]}{N[number\ of\ confirmatory\ samples]}}$$

The DQO process was carried out, step-by-step, to produce a confirmatory sampling approach that met the stated objectives. Throughout the development process, an effort was made to maintain a good balance between scientific theory, simplicity, and practicality. The confirmatory sampling approach presented in this document reflects a combination of established Project Team consensus elements and recommendations for the other required elements of the program backed up by the supporting rationale and justification. The following is a summary of the principal features of the resulting confirmatory sampling program.

- The testing of post-dredging or post-excavation sediment PCB concentrations against the applicable ROD target clean-up level(s) will be performed within a compliance demonstration area.

- A compliance demonstration area may be a single dredge or excavation management unit, or a small number of adjacent management units with certain shared characteristics.
- The number of confirmatory samples that must be collected within each compliance demonstration area will depend on the type of target PCB clean-up level that applies to that area and a set of technical and policy-based site management parameters. The size of the compliance demonstration area does not affect this calculation.
- The locations of these samples will be determined by the placement of a square confirmatory sampling grid overlaid on the compliance demonstration area. The starting coordinates of this sampling grid will be randomly selected. Samples will be collected at the nodes of this grid framework. A square sampling grid pattern would be convenient to implement in the field, can provide better precision, and ensures more complete coverage of the compliance demonstration area than unrestricted random sampling.
- The square sampling grid framework may be augmented by additional sampling transects to accommodate compliance demonstration areas of a more irregular shape.
- Suitable procedures will be used to ensure that all samples are collected at appropriately random locations within the overall grid framework or along any sampling transects employed.
- Because of the characteristically thin layers of sediment to be removed (typically 1 to 2 feet) and the relatively large areas to be dredged or excavated, sidewall sampling is not a routine component of the confirmatory sampling program.
- When unexpected sediment contamination is encountered such that additional samples must be collected outside the original compliance demonstration area to better define the extent of the contamination, these characterization samples would not automatically meet the DQO requirements of the confirmatory sampling program. An evaluation of the usability of any such characterization data for confirmatory sampling will be made on a case-by-case basis.
- Confirmatory samples will be collected as soon as it is safe and practical to do so following the dredging or excavation in a compliance demonstration area.
- Other sampling or measurements may be made during the dredging or excavation of an area to provide additional information to support field decisions and real time site management needs.
- At each designated confirmatory sampling location, multiple samples will generally be collected at different depths in the sediment column. The surficial sample would be analyzed immediately and used in the compliance demonstration testing. The deeper samples collected at that location would either also be analyzed immediately or archived, depending on the general dredging or excavation approach being applied in that compliance demonstration area and whether the sampling was performed following a first or second pass of sediment removal. Not all deeper (non-surficial) sediment samples collected in residential or beachcombing areas may need to be analyzed to meet the stated DQOs if composite samples are collected concurrently from both layers using a coring device.
- Sediment samples for confirmatory sampling will be collected, analyzed, validated, and managed in much the same way as was done for the PCB Characterization Program.
- If an area is demonstrated to meet its target PCB clean-up level(s), that finding will be documented and no further confirmatory sampling or analysis will be performed for that area.

- If an area is demonstrated to not meet its target PCB clean-up level(s), a supplemental dredging or excavation specification will be developed based on the analytical results in hand. Some of the archived samples may then be analyzed with expedited turnaround if they could support a more tailored or focused supplemental dredging or excavation specification for that area.

1.0 INTRODUCTION

Foster Wheeler Environmental Corporation (Foster Wheeler) has prepared this report to describe the confirmatory sampling approach for the sediment remediation effort for the New Bedford Harbor (Harbor) Superfund Site under Task Order No. 017 of the U.S. Army Corps of Engineers (USACE) Total Environmental Restoration Contract (TERC) No. DACW33-94-D-0002. This document defines and justifies the design of the approach developed for the confirmatory sampling approach to be implemented after the dredging and excavation of polychlorinated biphenyl (PCB) contaminated sediment at the Harbor.

1.1 Purpose

The purpose of this report is to present and document the process used to develop the confirmatory sampling approach to be used to determine if the dredging and excavation to be performed at the Harbor will result in the remaining sediments having PCB concentrations at or below the target PCB clean-up levels defined in the New Bedford Harbor Record of Decision (ROD) (USEPA, 1998).

As this approach was developed, it was clear that elements of confirmatory sampling (e.g., sample collection timing, boundaries of compliance demonstration, responses in the case that PCB levels in an area do not meet the target PCB clean-up levels) are closely related to, many other aspects of the New Bedford Harbor remediation effort. These included: the results of the PCB sediment characterization work; the general approaches to be employed to dredge or excavate the contaminated sediments in an area; the overall timing or sequencing of the sediment removal activities; the potential for recontamination of a remediated area by natural or man-induced processes; plans for restoring areas of the Harbor; and the long term monitoring program for the Harbor. While some of these confirmatory sampling-related aspects were defined or conceptually specified at the time of this writing, many were not. Consequently, this report could not simply be a justification of an approach to confirmatory sampling relative to an established remediation process. It became necessary to evaluate the possible alternatives for the undefined portions of the remediation process to the degree necessary to bound the missing or undefined aspects sufficient for a complete confirmatory sampling approach to be proposed and defended.

In addition, sediment confirmatory sampling programs formally linked to defined data quality objectives have not typically been a component of the hundreds of past environmental dredging or excavation projects in the U.S. Most of the confirmatory sampling programs that have been implemented (which are presented in Appendix B) have generally been on a much smaller scale, over a much shorter time frame, or been conducted on a more adhoc basis with respect to the number and placement of samples. These differences limited the value of these earlier efforts as models for the confirmatory sampling approach for New Bedford Harbor. Because of this, this report includes a considerable amount of relevant background and supporting information to fill, or at least to discuss, the state of information and project consensus that existed at the time of writing. When a principal element of the confirmatory sampling program had not been defined by the ROD, the USEPA Site Managers, or the larger Project Team, a recommendation was made for this element and the rationale for the recommendation was clearly documented. In many cases, care was taken to identify which element or parameter recommendations were based on technical arguments, operational considerations, regulatory specifications or guidances, or Agency discretion. In this way, a comprehensive, self-consistent confirmatory sampling approach could be developed and reviewed.

1.2 Data Quality Objectives Process

A central feature of the development of the confirmatory sampling approach for the New Bedford Harbor site was adhering to the USEPA Data Quality Objective (DQO) process (USEPA, 2000a). The DQO process is a series of planning steps based on the scientific method that is designed to ensure that the type, quantity, and quality of environmental data used in decision-making are appropriate for the intended applications (i.e., the site management decisions that must occur). This approach to data acquisition and analysis builds common sense and the scientific method into all aspects of designing and conducting sampling programs, and makes best use of the obtainable information. The formal DQO framework resulted in the planning of the confirmatory sampling approach to be more systematic and increased the likelihood that the data obtained would yield the kind of information required for making the fundamental decisions – such as whether or not a compliance demonstration area (CDA) achieves its target PCB clean-up levels following dredging or excavation.

Each of the seven steps of this DQO process is briefly introduced below in the context of the confirmatory sampling approach at New Bedford Harbor (Cross-references are also provided to indicate where each issue or step of the process is more fully discussed in this document):

Step 1 - State the Problem – The objective of the confirmatory sampling program is to determine whether the sediments left after the dredging or excavation of an area have PCB concentrations at or below the target PCB clean-up level established for that area within the spatial limits and time frame specified. A detailed discussion of the scope and objectives of the New Bedford Harbor confirmatory sampling program are presented in Section 3.

Step 2 - Identify the Decision – For the confirmatory sampling program, the central decision is whether or not the post-dredging or post-excavation sediment PCB concentrations in each CDA are at or below the applicable target PCB clean-up level(s). A complete description of the New Bedford Harbor ROD-specified target PCB clean-up levels and how they are to be interpreted and applied relative to regulatory compliance is discussed in Section 4.

Step 3 - Identify Inputs to the Decision – Steps 1 and 2 of the DQO process identify the contaminant of interest (i.e., PCBs) and the target PCB clean-up levels developed for various areas of the Harbor based on such factors as the potential for direct contact human exposure and whether the area is vegetated. The inputs required for this step include: identifying and classifying CDAs by target PCB clean-up level; establishing an overall dredging or excavation approach for each CDA; and specifying appropriate sampling techniques and analytical methods. Identifying and classifying CDAs is discussed in Section 4. Aspects of the confirmatory sampling approach related to the dredging or excavation strategies and sequencing are discussed in Section 5. Sampling techniques and analytical methods preferred for confirmatory sampling are discussed in Section 10.

Step 4 - Define the Study Boundaries – The spatial and temporal boundaries of the subareas of the Harbor of particular interest must be defined to ensure that the samples collected are representative of the area for which the compliance decision must be made. The remaining sediment within a CDA are assumed to be relatively homogeneous with respect to PCB concentration and certain sediment physical properties. The spatial boundaries of the CDAs and the temporal sampling considerations (as they relate to dredging or excavation management units (MUs)) for different types of dredging approaches are discussed in Section 5.

Step 5 - Develop a Decision Rule – A decision rule relates the post-dredging or post-excavation sediment PCB concentrations in the CDA to the applicable target PCB clean-up level(s) so that decisions (such as whether or not a particular target PCB clean-up level was met) can be made based

on the results of the confirmatory sampling. The decision rules around which the New Bedford Harbor confirmatory sampling program is developed are presented and discussed in Section 6.

Step 6 - Specify Limits on Decision Errors – Because only a portion of the dredged or excavated area will be sampled in each CDA (i.e., samples cannot be collected from every possible location), the possibility of drawing an incorrect conclusion (i.e., a decision error) from the limited data collected cannot be completely eliminated. However, by using a statistically-based confirmatory sampling approach, the possibility of an incorrect conclusion can be explicitly considered and controlled. Limits on decision errors are set to establish performance goals for the confirmatory sampling program design. These limits have a strong impact on the number of required confirmatory samples that must be collected in each CDA. The specifications for these limits are discussed in Section 7.

Step 7 - Optimize the Design for Obtaining Data – Optimization of the confirmatory sampling approach involves examining all of the factors that affect the decision errors and required sample sizes so that costs and potential risks can be balanced. While all the information necessary to fully "optimize" the data collection design were not available at the time of this writing, an initial balancing of diverse factors and considerations was made. This effort and the resulting impacts on the number of required confirmatory samples are illustrated and discussed further in Section 8. The recommended number of confirmatory samples to be collected for a CDA based on the size of the CDA and the type of target PCB clean-up levels applicable to that CDA.

In addition to presenting all the steps of the DQO process, this document presents background information important for putting the New Bedford Harbor confirmatory sampling approach in the context of past work at the Harbor (see Appendix A) and at other recent environmental dredging sites (see Appendix B). The findings of these reviews and surveys were used to develop the rationales for many of the central elements of the proposed confirmatory sampling approach.

Section 9 briefly presents the data evaluation criteria and methods to be used to analyze the sediment PCB data produced by the confirmatory sampling program. Section 10 identifies and discusses some sampling considerations specific to the site that will affect the implementation of the confirmatory sampling approach. Finally, a checklist is provided in Section 11 to aid in development of site-specific confirmatory sampling plans and documenting key site-management decisions. This checklist provides a bridging tool between the confirmatory sampling planning, tracking the confirmatory activities, and documenting key aspects associated with closeout of the CDA. References used in the document are shown in Section 12.

2.0 BACKGROUND INFORMATION

The information in this section provides context for the confirmatory sampling approach presented in this report. Two main efforts were undertaken. In Section 2.1, past environmental dredging or excavation activities at New Bedford Harbor are summarized, focusing on the identification of:

- The type of post-dredging or post-excavation sediment sampling performed (i.e., core or grab sampling);
- The depth of the post-dredging or excavation sediment layer sampled; and
- The characteristic spacing or spatial density of the samples collected.

In Section 2.2, recent environmental dredging activities at other sites are reviewed and summarized, focusing on the identification of:

- The timing of confirmatory sampling;
- The number and type of confirmatory sampling collected; and
- The short-term effectiveness of the dredging.

The knowledge gained from the information in this section provided a solid basis for the development of the confirmatory sampling approach for the New Bedford Harbor project.

2.1 Summary of Past Environmental Dredging and Excavation Activities at New Bedford Harbor

The sediment sampling aspects of four past environmental dredging or excavation activities that have taken place at New Bedford Harbor were reviewed. These are documented in the following reports:

- New Bedford Harbor Superfund Pilot Study (1988-1989);
- Hot Spot Dredging Effort (1995);
- Pre-Design Field Test (2000); and
- Early Action Removal Action (Area 1) (2001).

A fifth project at New Bedford Harbor, the Commonwealth Electric Cable Relocation Project (2001), also involved dredging. However, this dredging effort was not performed to remove contaminated sediment from the Harbor and did not include post-dredging sediment sampling. The summaries of each of the four listed environmental dredging or excavation efforts focus on identifying: the type of post-dredging or post-excavation sediment sampling performed (i.e., core or grab sampling); the depth of the post-dredging or excavation sediment layer sampled; and the characteristic spacing or spatial density of the samples collected. These summaries are presented in Appendix A.

It must be noted that the sediment sampling performed relative to these past dredging or excavation activities was not necessarily designed or intended to be used for purposes of confirmatory sampling or regulatory compliance. Some sampling was conducted to evaluate the performance of the equipment and to assess other factors. The sampling characteristics associated with these past efforts were reviewed to provide a site-specific perspective and to identify the presence or lack of precedents with regard to how the confirmatory sampling for the principal remediation effort should be conducted.

The following list contains the key findings of this review.

- A review of these prior activities provided a perspective and a useful context for how sampling of this type may best be conducted given the conditions found in the Harbor.
- Sediment sampling performed following the past dredging or excavation activities at New Bedford Harbor was not intended to be used to support regulatory compliance demonstrations. Consequently, the sampling densities, sample depth intervals, and the choice of grab versus composite samples chosen for, or that resulted from, these past activities are only indirectly relevant to the current task of specifying an approach to confirmatory sampling.
- This review also illustrated the effectiveness and relative merits of various sample collection techniques given the types of sediments found in the Upper Harbor, and the sizes of areas from which contaminated sediment has been removed in the past.
- This review highlighted the potential impact on measured post-dredging PCB concentrations of the deposition of contaminated sediment that is resuspended or mobilized by the dredging activity. This possibility must be addressed in the confirmatory sampling approach.
- The Hot Spot Dredging Effort illustrated that a statistically-based post-dredging sampling program was previously used at the Harbor, but that the exact approach is not what would be recommended under current USEPA guidance.

2.2 Survey of Environmental Dredging Activities at Other Sites

This section reviews the recent use of post-dredging confirmatory sampling to assess the short-term effectiveness of dredging or excavation at 22 environmental remediation sites located throughout the United States, and in Japan and Sweden. For each dredging or excavation project, information was obtained, if available, on:

- The location and type of site;
- The primary chemicals of concern (COC);
- The type of removal equipment used (e.g., dredges, excavators, or both);
- The volume of sediment removed;
- The dates of dredging and post-dredging sampling;
- The number and type of sediment samples collected;
- The portion of the sediment column that was sampled (i.e., depth intervals);
- The sediment clean-up goals; and
- The results of physical, chemical, and biological parameters collected to evaluate short-term effectiveness of the remedial dredging or excavation activity [Note: Short-term effectiveness is defined as achievement of goals based on project expectations].

This survey focused specifically on removal or excavation of subaqueous sediments (i.e., mechanical or hydraulic dredging) at these environmental remediation sites. Both of these types of dredges could be used in the remediation of sediments at New Bedford Harbor.

The design of the survey and a tabular summary of the information compiled are presented in Appendix B. The results of the survey are reviewed on a feature-by-feature basis, and comments on the results relative to the confirmatory sampling at New Bedford Harbor are also presented in Appendix B.

The selection of environmental dredging projects for this survey was based on the type of dredging, extent of monitoring programs conducted, and the availability of the necessary information and documentation. The initial screening process involved accessing a broader set of available information on over 50 dredging projects in the United States, Europe and Asia. Specific and general resources for this project review included:

- USEPA regional websites, fact sheets, and publications on clean-up sites;
- Dredging-related websites and journal articles;
- Proceedings from dredging conferences;
- Assessment and Remediation of Contaminated Sediments (ARCS) Program, USEPA's Great Lakes National Program Office (GLNPO) publications;
- Sediment Priority Action Committee (SedPac) and International Joint Commission (IJC) publications;
- White papers published by research groups;
- Sediment Management Workgroup (SMWG) Publications;
- *Contaminated Sediments in Ports and Waterways Cleanup Strategies and Technologies* (NRC 1997);
- Conference Proceedings from the National Symposium on Contaminated Sediments (NRC 1998);
- Draft Sediment Technologies Memorandum for the Lower Fox River, Wisconsin Department of Natural Resources (ThermoRetec, 2001);
- Western Dredging Association newsletters;
- Hudson Watch website (http:\\www.hudsonwatch.com) or (http:\\www.hudsonvoice.com);
- USACE publications and website; and
- Project team experience.

Dredging projects retained after this initial data-gathering phase then had to meet the following additional criteria to be considered relevant to the planning for the New Bedford Harbor project:

1. The dredging performed was environmental dredging for purposes of site remediation as opposed to maintenance or navigational dredging;
2. The remedy was already implemented and not in the planning stages (one exception to this criterion was the Olympic View Removal Action in Tacoma, Washington, which is planned for June of 2002);
3. The contaminants of concern were PCBs, or other persistent chemicals such as PAHs or metals that tend to adhere to sediments containing organic material; and
4. The remedy was a wet excavation project (standing water over the sediments and accessed by barge or from shore). A combination of other technologies in which dredging was at least one of the implemented methods also was considered acceptable.

Based on these criteria, a total of 22 environmental dredging projects were considered sufficiently relevant for further consideration in the context of New Bedford Harbor. The primary features and the confirmatory sampling elements of these projects are compiled and summarized in Appendix B.

The following list contains the key findings of this review.

- Confirmatory sampling has not been a routine part of most of the recently completed environmental (predominantly PCB-related) dredging projects conducted in the U.S. and elsewhere.
- A review of many recent environmental dredging projects allowed a relatively few projects to be identified which included some form of post-dredging sampling of the sediment quality.
- Post-dredging sampling that was done typically was limited to the surficial layer of the sediment exposed by the removal action.
- In none of these projects has the number and distribution of sampling locations been determined using a formal statistically-based sampling approach. Sampling densities across the projects varied greatly.
- The survey indicated an evolving trend regarding how soon confirmatory samples should be collected following dredging and the depth range in the sediment column that should be sampled. These trends were used to recommend values for these elements of the New Bedford Harbor confirmatory sampling approach.
- The New Bedford Harbor project is spatially much larger and ultimately will involve the removal of a greater volume of contaminated sediment over a longer period of time than all but one of the projects surveyed. Thus, the size, context, and duration of the New Bedford Harbor Remediation Project create circumstances and challenges relative to confirmatory sampling that have not arisen during prior smaller and simpler projects.

3.0 CONFIRMATORY SAMPLING APPROACH OBJECTIVE

This section presents the objective of the confirmatory sampling approach and an initial introduction to its principal elements. This corresponds to Step 1 of the DQO process, State the Problem, as discussed in Section 1.2. The overall process of determining whether or not the target PCB clean-up levels have been achieved will be centered on a statistically based sediment sampling effort tailored to the characteristics of each compliance demonstration area. Following dredging or excavation, sediment samples will be collected and analyzed, the quality of the data will be evaluated, and the PCB concentration in the sediments, representative of the compliance demonstration area, will be determined and compared to the target PCB clean-up level specified for that area and sediment layer.

The confirmatory sampling program has been designed to fit within, and be consistent with, a number of other sampling and performance diagnostic initiatives. The relationship between the confirmatory sampling approach and other sampling and measurement activities is summarized in this section relative to their complementary role in determining if the target PCB clean-up levels have been met in an area. The confirmatory sampling objectives are compared and contrasted to those of long term monitoring. The considerations associated with deciding when to sample the post-dredging or post-excavation sediments for purposes of confirmatory sampling are highlighted in consideration of the possible movement and transient behavior of the PCB concentrations in the Harbor sediments that are caused by natural forces and human activity. The specification of these confirmatory sampling approach elements is presented in a subsequent section of this document.

3.1 Objective of the Confirmatory Sampling Program

The objective of the confirmatory sampling program may be stated as follows:

> **To determine whether or not the sediments left after the dredging or excavation of an area have PCB concentrations at or below the target PCB clean-up level established for that area within the spatial limits (i.e., aerial and depth) and time-frame specified.**

The following conditions or requirements further clarify this objective:

- This determination must be made using a technically valid and publicly defensible approach.
- The confirmatory sampling program must reflect good industry practices and support decision making with the level of confidence required by the USEPA Site Managers.
- The confirmatory sampling program must generate information that can be used to geographically focus and specify the depth of any supplemental dredging or excavation needed to meet the target PCB clean-up level if it is determined that the level specified for an area has not been achieved by the first pass dredging or excavation effort.
- The confirmatory sampling program is not designed to confirm or verify the horizontal extent or boundary of the areas containing contaminated sediments. Confirmatory sampling would not be associated with any area that was not previously sampled and analyzed as part of the PCB Characterization effort (see Section 3.5 below). Similarly, confirmatory sampling would only be associated with areas that had undergone some amount of dredging or excavation as part of the remediation effort.

3.2 Indirect Indicators of Achieving the Target PCB Clean-up Levels

Prior to the direct assessment of sediment concentrations and the confirmatory sampling testing and demonstration process, other diagnostic measurement and sampling activities also will be performed to provide indications of whether the target PCB clean-up level was achieved in the area. First, post-dredging or post-excavation sediment elevations will be measured and compared to the design cut elevations. In most areas of the Harbor, pre-removal characterization has provided an estimate of how much sediment must be removed at specific locations in the Harbor to reach a depth where the remaining exposed sediment quality would be likely to meet the applicable PCB target clean-up level. In these cases, sediment surface elevation (bathymetry) measurements will provide a preliminary measure of progress toward achieving the target PCB clean-up level. Second, field-screening techniques may be used to estimate the PCB concentration in the newly exposed sediments during dredging or excavation. Consistent with the precision and accuracy of these techniques, a preliminary assessment can be made of the levels of PCBs in the remaining sediment. These screening measurements can be evaluated statistically to provide a second indication of whether the more direct confirmatory sampling evaluation to follow will show that the target PCB clean-up level has been met in that compliance demonstration area. Visual observations of the physical characteristics of the sediments being removed (i.e., color, sediment type) may also be used in selected portions of the Harbor as an indicator of whether the areas of PCB concentrations above the target clean-up levels have been removed.

Because the ultimate sampling of an area for purposes of determining whether compliance with the target PCB clean-up level has been achieved will be preceded by other efforts that support achieving the same objective, elements of these other efforts will also be linked to confirmatory sampling. Their specification will be consistent with and complement the elements of the overall confirmatory sampling program.

3.3 Relationship of Confirmatory Sampling to Long Term Monitoring

A separate, but directly related, sampling requirement is long term monitoring. Long term monitoring is aimed at evaluating the effectiveness of the remedial dredging and excavation that was performed in terms of reducing the levels of PCBs in the bodies of marine species that are harvested and eaten by people. The long-term monitoring program also is aimed at measuring the degree of improvement in the general quality of the ecological health of the Harbor. In order to perform these evaluations and track changes in ecological metrics, various environmental and biotic media will have to be sampled over time. The sampling and analysis of the concentrations of PCBs in sediments has been and will be a part of the long-term monitoring data collected for this purpose. Given the multiyear nature of the New Bedford Harbor dredging and excavation effort, it is very likely that confirmatory sampling and long term monitoring of sediment PCB levels may be conducted concurrently in different parts of the Harbor.

Both confirmatory sampling and long term monitoring relate to measuring changes in the condition of the environment. However, the changes of most interest and relevance may differ in the two cases. The confirmatory sampling program is focused on the immediate indicated change in the concentration of the PCBs in the sediment. The long-term monitoring program is primarily focused on subsequent changes that will occur in sediments and other environmental media and organisms as the result the immediate changes created in the sediment PCB levels. As was noted, sediment sampling of some form is common to both programs. However, the exact details of when, where, and how to sample and analyze the PCB levels in the sediment must be tailored for each program to meet that program's objective(s).

The confirmatory sampling will be performed to characterize the sediment quality at the point in time just after the dredging or excavation is completed. The long-term monitoring sampling of sediment quality will be conducted repeatedly at prescribed locations over time. Scientific and economic benefits may be

gained by co-locating the sampling for these two purposes at the appropriate times and when the sampling objectives overlap sufficiently. Ensuring a linkage between the two sampling programs should increase the decision making support value of the combined data set relative to the sum of each separately.

3.4 Measuring Sediment PCB Concentrations in a Transient Environment

The timing of the confirmatory sampling is a particularly important element of the program. The timing of the sampling, relative to the completion of the dredging or excavation of the area, impacts the representativeness of the quantified PCB levels. The decision as to when to take the samples is influenced by two main considerations:

1. The effect of the timing on the concentration of PCBs likely to be measured; and
2. The operational and logistical constraints placed on the collection of the samples by the dredging or excavation sequence.

The sediment present at a given location in the Harbor is likely to change over time and, consequently, so may the level of PCBs that would be measured in samples collected at that location over time. The shifting and movement of sediment will be caused by a combination of natural forces and actions initiated by people. Natural forces include storms, wind-induced waves, tidal fluctuations, the prevailing flow of the Acushnet River, and the natural deposition of clean sediment. Sediment movement that is initiated by people may result from the mixing effect of boat propellers and the discharges from combined sewer outfalls (CSOs). The remedial dredging or excavation activity itself also will result in some sediment migration in the form of the sloughing of sediment at the edges of the cuts, the transport and deposition of material released into the water during dredging, and potential surface erosion and run-off from upland areas. The setting and removal of the anchoring system and the movement of the dredging or excavation equipment could also mobilize the sediment. As more time passes after the completion of dredging, the likelihood that these natural and man-initiated processes will occur increases. The more these processes occur, the greater is the probability that the PCB concentration in the sediment at any given location may change. Some of these processes are directional in nature with respect to the movement of sediment (e.g., tides, Acushnet River flow), while others may tend to churn or homogenize the sediment PCB levels in an area (e.g., propeller wash areas and CSOs). Consequently, PCB sediment levels at a particular location may either increase or decrease on average over time, or else fluctuate depending on how much time has passed since dredging or excavation was completed. These aspects of the timing of the sampling were considered in the design of the confirmatory sampling approach.

The dredging and excavation sequence itself may also constrain or limit how soon confirmatory samples may be safely and practically collected following the sediment removal activity. Physical access to the location to be sampled must be safely available, in consideration of the potential hazards of the moving dredges and excavators and their supporting vehicles and equipment. The sampling activity must also be performed so as not to impede or significantly encumber the progress of the dredge or excavator. The timing of the confirmatory sampling, as was noted, must also consider the localized effects of the dredging or excavation equipment on the short term representativeness of the sediment PCB concentrations in the area (e.g., considering resuspension, vehicle wakes upon repositioning).

3.5 Relationship of Confirmatory Sampling to Supplemental Sampling to Clarify the Extent of Contamination

As sediment dredging or excavation progresses, there will likely be instances when the observed conditions were not exactly as expected based on the earlier characterization work. In these instances, additional sediment samples may need to be collected to better identify the horizontal extent of the PCB

contamination present. These samples may be collected in a manner similar to that specified in this confirmatory sampling approach. However, these results would not necessarily be suitable or appropriate for use in the compliance demonstration evaluation for that area. A case-by-case determination would be made as to whether any or all of the additional characterization samples could be used for the compliance demonstration. If the additional characterization sampling indicates that the extent of the PCB contaminated area was appreciably larger than was anticipated, the number of required confirmatory samples and maximum sampling grid spacing would also need to be reviewed.

3.6 Key Points

The following items are the key points of the discussion of the confirmatory sampling objective.

- A clear statement of the objectives of the confirmatory sampling program are critical to specifying an effective and technically consistent approach for confirmatory sampling.
- Sediment sampling to determine its PCB concentrations will be performed for a number of reasons during the remediation effort (e.g., characterizing unexpected conditions, characterizing waste, informing operational decisions, long-term monitoring).
- The sampling collected for purposes of confirmatory sampling must be clearly distinguished from other sampling. This is so that the confirmatory sampling data quality objectives will be met for the confirmatory sampling data collection, and appropriate data quality objectives are achieved for the other data collection efforts.
- There is a recognition that remedial operations can impact the degree of potential reconfirmation in a "cleaned" area resulting from the remediation activities. There is also a recognition that remedial operations can do little to practically control recontamination of "cleaned" areas caused by natural processes and forces (e.g., tidal transport, storm surge, wind-induced waves). Thus, confirmatory samples should be collected as soon as logistically possible.

4.0 APPLICABILITY OF THE ROD TARGET PCB CLEAN-UP LEVELS

This section reviews and summarizes the ROD for the New Bedford Harbor Superfund Site (USEPA, 1998) relative to the target PCB clean-up levels that have been established in sediments in different areas of the Harbor. This corresponds to Step 2 of the DQO process, Identify the Decision, as discussed in Section 1.2. The different areas of the Harbor include the subtidal areas in the Upper and Lower/Outer Harbor (i.e., north and south of the Coggeshall Street Bridge, respectively); the saltmarshes, residential areas, and beachcombing areas; and the intertidal mudflats.

The review presented in Section 4.1 focuses on the:

- Underlying basis of each ROD target PCB clean-up level (i.e., whether it was based on the protection of human health through direct contact with contaminated sediment, or whether it was based on protection of human health through indirect exposure by eating aquatic organisms living in or near the sediment and improvement of the Harbor's ecological habitats;
- Numerical value of that target PCB clean-up level; and
- Depth interval within the sediment column where the target PCB clean-up level must be met and the metric or measure of sediment PCB concentration that is to be compared to the ROD target clean-up level for purposes of judging compliance.

Subsequent to the ROD, a comprehensive wetlands delineation and functional values assessment of the areas in and around the New Bedford Upper Harbor was performed (Foster Wheeler, 2001b). Based on this assessment, a number of different environmental area types were defined (e.g., saltmarshes, mudflats, vegetated upland areas, freshwater wetlands). Section 4.2 describes how each of these assessment classifications relates back to the area types specifically discussed in the ROD. Based on these associations, environmental area type-based target PCB clean-up levels were assigned for each required location within the Harbor where PCB delineation sampling has been performed.

A number of the areas within the Harbor that were known or were anticipated to be associated with direct contact residential or beachcombing exposure were identified in the ROD. Subsequent to the ROD, the boundaries of some of these areas have been slightly modified and other areas of both types have been added by USEPA based on further site inspections and site information. These areas are identified and discussed in Section 4.3.

The ROD defined four different numerical target PCB clean-up levels (i.e., 1 ppm, 10 ppm, 25 ppm, and 50 ppm) for application to the various locations of the Harbor. Two of the ROD target clean-up levels, 1 ppm and 25 ppm, are associated with the protection of people from direct contact with sediments in areas with potential residential or beachcombing exposure. Direct contact with sediments is expected to occur only within the top 1 foot of sediment. The other two ROD target clean-up levels, 10 ppm and 50 ppm, are associated with the protection of human health indirectly, relative to the ingestion of fish and other marine species that inhabit areas of possible sediment contamination. These two ROD target clean-up levels also were established with the broader goal of improving the ecological health of the Harbor and protecting valuable saltmarsh habitats (USEPA, 1998). Thus, these two ROD target clean-up levels are applicable from the surface to any depth in the soil column. Some ROD target clean-up levels are, therefore, based on current or projected future land use and direct contact exposure, while others are based on environmental features or habitat type. Consequently, some locations have both an applicable direct contact human health-based target clean-up level and an indirect contact / ecological improvement target clean-up level, each applying to its own depth range of the sediment column at that location. Section 4.4 describes the various combinations of target PCB clean-up levels that may apply at any

particular location and how the target PCB clean-up levels have been determined for each location at the site.

Section 4.5 provides a graphical and tabular summary of the target PCB clean-up level assignments for all locations of potential interest relative to the remediation effort at New Bedford Harbor.

4.1 Target Clean-up Levels Established in the Record of Decision

The ROD establishes target PCB clean-up levels for five different environmental area types or areas associated with potential exposure of people directly or indirectly to sediment:

1. Subtidal Areas in the Upper and Lower Harbor;
2. Intertidal Saltmarsh Areas;
3. Intertidal Residential Areas;
4. Intertidal Beachcombing Areas; and
5. Other Intertidal Areas in the Upper and Lower Harbor.

The target PCB clean-up levels for each of these area types or areas are discussed individually in the subsections below.

4.1.1 Subtidal Areas in the Upper and Lower Harbor

A baseline ecological risk assessment was completed in 1990 (Ebasco, 1990). This site-specific ecological assessment was performed using Harbor sediment characterization data from three sources:

1. Data collected by BOS from the upper 2 inches (5 cm) of sediment;
2. Data collected by GCA/Alliance Technologies from the upper 8 inches of sediment; and
3. Data collected by NUS collected from the upper 6 inches of sediment.[1]

Mean sediment concentrations in different zones of the Harbor were compared to the lower 95% confidence level of the Interim Sediment Quality Criterion (SQC) that existed at the time, and the maximum sediment concentrations were compared to the SQC central value (assuming a Harbor-specific value of Total Organic Carbon in the sediment).[2] This assessment concluded that PCB contamination in sediment and sediment pore water in many areas of the Harbor was highly toxic to at least some members of all major taxonomic groups. Using different assessment approaches, a 0.1 to 1 ppm range of sediment PCB levels was determined to be protective of marine resources that may serve as a source of food to people.[3] Comparison of these criteria with current PCB levels showed large areas of the Harbor above the upper bound of this range, with almost all of the Upper Harbor at least ten times higher than the 1 ppm threshold.[4] By the time the ROD was written, it was generally believed that achieving the relatively low sediment concentration of 1 ppm in the open water or subtidal areas would likely cause more ecological damage to and negatively impact the target species than the clean-up would ultimately improve. Extensive removal or capping of these areas (estimated at the time to involve approximately 1,000 acres) would be required to meet this 1 ppm level. In addition, there was considerable concern over the resulting destruction of sensitive saltmarsh areas that would occur. After considering these potential impacts, a target PCB clean-up level of 10 ppm (dry weight) was established for the subtidal sediments in the Upper

[1] "Baseline Ecological Risk Assessment, New Bedford Harbor Site, Feasibility Study", Draft Final, April 1990, Section 1.4.1, pages 1-12 to 1-14.
[2] Ibid., page 4-22.
[3] Record of Decision for the Upper and Lower Harbor Operable Unit. New Bedford Harbor Superfund Site, New Bedford, MA, (ROD 2), U.S. Environmental Protection Agency – Region I, September 1998, page 14.
[4] Ibid., page 14.

Harbor (north of Coggeshall Street). Similarly, a target PCB clean-up level of 50 ppm (dry weight) was established for the subtidal sediments in the Lower Harbor (south of Coggeshall Street). A target PCB clean-up level of 50 ppm (dry weight) was also established for all saltmarshes anywhere in the Harbor. These target clean-up levels were judged to meet two of the defined remedial action objectives for the site:[5]

1. To reduce risks to human health by reducing PCB concentrations in seafood, by lowering PCB concentrations in sediment and in the water column.
2. To improve the quality of the seriously degraded marine ecosystem by:
   a. Reducing marine organisms' exposure to PCB contaminated sediment while minimizing consequent harm to the environment; and
   b. Reducing surface water PCB concentrations to comply with chronic Ambient Water Quality Criteria (AWQC) by reducing PCB sediment concentrations.

Target PCB clean-up levels were not specifically prescribed in the ROD to a defined thickness of sediment following the dredging or excavation.[6] The ROD alludes to a future long-term monitoring program that would sample characteristics of the ecological health of the top 2 to 7 cm of sediment.[7] Sediment depths of a foot or more are associated with the bioturbation zones of many marine habitats, especially those with bivalves and polychaetes relative to the summer-winter cycle of the activities of the organism. The appropriate depth interval at which to take confirmatory samples are further discussed in Section 10.

The ROD did not specify what measure of the quality of the exposed sediments in these areas following dredging should or must meet this target PCB clean-up level (e.g., the mean concentration or the 95% Upper Confidence Level of the mean concentration). Specification of this measure is further discussed in Section 6.

4.1.2 Intertidal Saltmarsh Areas

As noted above, there is considerable concern regarding the possible destruction of the Harbor's sensitive saltmarsh areas. After considering the potential impacts of an extensive removal or capping effort, a target PCB clean-up level of 50 ppm was established to apply to all saltmarshes in any area of the Harbor. This target PCB clean-up level was considered to strike a balance between the benefits of removing PCB source material to reduce potential human and ecological exposures and the preservation of existing, sensitive saltmarshes.[8,9] This target clean-up level was not specifically prescribed in the ROD to a defined thickness or portion of the sediment column following the dredging or excavation. The ROD also did not specify what measure of the quality of the exposed sediments in these areas following dredging or excavation should meet this target PCB clean-up level (e.g., the mean concentration or the 95% Upper Confidence Level of the mean concentration).

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[5] Record of Decision for the Upper and Lower Harbor Operable Unit. New Bedford Harbor Superfund Site, New Bedford, MA, (ROD 2), U.S. Environmental Protection Agency – Region I, September 1998, pages 15-16.
[6] Ibid., page 14.
[7] Ibid., page 14.
[8] Ibid., page 44.
[9] Ibid, pages 44 and B-3. The ecologically-driven 50 ppm PCB target clean-up level also was compared to a risk-based value of 40 ppm that was calculated for an adolescent that might periodically enter the relatively less accessible and less attractive industrial shoreline areas 20 days per year for 12 years. The adolescent was assumed to be exposed to contaminated sediment via incidental ingestion (50-mg sediment/day) and dermal absorption. See Appendix B of the ROD.

4.1.3 Intertidal Residential Areas

The ROD established a target PCB clean-up level of 1 ppm (dry weight) for intertidal locations in residential areas near the shoreline of the Harbor. This target PCB clean-up level was applied to the locations where homes directly abut the Harbor and where members of the public (especially children) are likely to come into direct contact with the tidally affected sediments.

Two specific areas of the Harbor were selected to represent the potential for residential exposure. These areas served as the quantitative basis of the calculations performed to establish this risk-based target clean-up level. The first area is located just north of the Wood Street Bridge in New Bedford. This area contains three homes that abut the west shore of the Acushnet River. Paths lead from each of these homes through a thin band of saltmarsh to the Acushnet River. The second area is located around the Veranda Street Inlet in Fairhaven. Homes located in this area have lawns that extend down to the Acushnet River. There is very little slope in this area and the Acushnet River is essentially at the same level as the lawn. This human health risk-based target PCB clean-up level was calculated to be protective of a child up to the age of 6 who would access these sediments as if they were an extension of his/her own backyard. The development of this target PCB clean-up level considered the close proximity of these homes to the sediment, and reflected a frequency of exposure to the sediment of 150 days per year over six years. The assumed exposure frequency of 150 days per year corresponds to the estimated amount of time the ground would not be frozen or covered with snow. In calculating this target clean-up level, only the incidental ingestion (200 mg sediment ingested/day) and dermal absorption pathways were considered, as the inhalation pathway was not expected to contribute significantly to the total risk from the contaminated sediments under this exposure scenario. A value of 1 was used as the target hazard quotient goal for calculating the risk-based target PCB clean-up level. A PCB concentration of 1.2 ppm in the sediment was calculated using these assumptions, which was conservatively rounded down to 1 ppm. This target PCB clean-up level was developed for the surface layer of sediment, which extends from the exposed upper surface down to a maximum depth of 1 foot.[10]

The ROD specified that the 95% Upper Confidence Level on the arithmetic mean PCB concentration in the exposed sediments in these areas following the excavation or dredging should meet this target clean-up level. This specification was made since the 95% Upper Confidence Level on the mean is the statistic typically utilized in assessing reasonable maximum exposure (RME) in risk assessments.[11]

The USEPA has subsequently identified a number of other locations where this residential exposure based target PCB clean-up level should be applied. These locations are identified and discussed in Section 4.3.1.

4.1.4 Intertidal Beachcombing Areas

Certain areas located along the Harbor were judged by USEPA to be popular for beachcombing because of their location and topography (i.e., the sandy areas in or around boat yards). These areas are typically located in non-industrial areas where the potential for residential exposure also does not exist. The ROD established a target PCB clean-up level of 25 ppm (dry weight) for the sediments in these areas.[12]

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[10] Record of Decision for the Upper and Lower Harbor Operable Unit. New Bedford Harbor Superfund Site, New Bedford, MA, (ROD 2), U.S. Environmental Protection Agency – Region I, September 1998, Appendix B – Calculation Supporting Updated Shoreline Cleanup Levels, New Bedford Harbor Site – ROD 2, Sections 3 and 5, pages B-4 and B-5.

[11] Ibid., Appendix B, Section 1d, page B-1.

[12] Ibid., page 44. Note that the actual target PCB clean-up level that is applicable to a beachcombing area will depend on whether the area is vegetated and whether or not it is in the Upper Harbor (see Section 2.2).

Three areas bordering on the Coffin Street Cove in New Bedford were selected to represent the potential for beachcombing exposure that served as the quantitative model for the calculation of this target PCB clean-up level. The first area, the Coffin Street Playground Area, is located adjacent to the Harbor and is bordered by a narrow strip of saltmarsh. The Coffin Street Playground is surrounded by residential homes. It was assumed that older children or adolescents (aged 7-18 years) would access the shoreline and nearby saltmarshes 32 days out of the year for a period of 12 years. This exposure frequency was based on potential exposures two times per week during the summer months of June through August, and one time per week during the months of May and September. In calculating this target PCB clean-up level, only the incidental ingestion (50 mg sediment ingested/day) and dermal absorption pathways were considered, as the inhalation pathway was not expected to contribute significantly to the total risk from the contaminated sediments under this exposure scenario. A value of 1 was used as the target hazard quotient goal for calculating the risk-based target PCB clean-up level.

The second representative area is the Vacant Waterfront Property on Coffin Street Cove. This area remains following the clearing of an old (Pierce) mill complex in 1997. The saltmarshes and shoreline in the Vacant Waterfront Property are similar in characteristics and accessibility to those in the Coffin Street Playground Area. In addition, the city of New Bedford is considering a proposal to build a public park on this property. In view of these factors, the potential for public exposure was assumed to be the same as for the Coffin Street Playground Area. The third area to which the beachcombing target PCB clean-up level was assigned is the Sawyer Street Confined Disposal Facility (CDF) (or Cell 1) Area. Assignment of this target clean-up goal to this area reflects the possibility that the area around this CDF might be converted into a recreational area or park in the future to match the land uses of the other properties bordering on the Coffin Street Cove. As with the Coffin Street Playground Area and the Vacant Waterfront Property, it is likely that the saltmarsh in this area would remain and act as a buffer limiting complete access to the shoreline. Based on the future use scenario, the potential exposures and receptors were assumed to be the same as for the other waterfront properties bordering the Coffin Street Cove.

This 25 ppm PCB target clean-up level was developed for the surface layer of sediment, which extends from the surface down to a maximum depth of 1 foot. The ROD specified that the 95% Upper Confidence Level on the arithmetic mean concentration of the exposed sediments in these areas following the excavation or dredging should meet this target PCB clean-up level. Again, this specification was made since the 95% Upper Confidence Level on the mean is the statistic utilized in assessing exposure in risk assessments.[13]

The USEPA has subsequently identified a number of other locations where this beachcombing exposure based target PCB clean-up level should be applied. These locations are identified and discussed in Section 4.3.2.

4.1.5 Other Intertidal Areas in the Upper and Lower Harbor

The ROD established a target PCB clean-up level of 10 ppm (dry weight) for the intertidal areas in the Upper Harbor that are not associated with residential areas or saltmarshes (any vegetated area). The intertidal areas that are not associated with one of these specified areas are also referred to as the "mudflats". Similarly, the ROD established a target PCB clean-up level of 50 ppm (dry weight) for mudflats in the Lower/Outer Harbor. The rationale behind the development of the target clean-up levels for the intertidal mudflats is the same as was described above for the subtidal sediments. Once again, neither of these target PCB clean-up levels was specifically prescribed in the ROD to a prescribed thickness or depth interval in the sediment column following the dredging or excavation. The higher

[13] Record of Decision for the Upper and Lower Harbor Operable Unit. New Bedford Harbor Superfund Site, New Bedford, MA, (ROD 2), U.S. Environmental Protection Agency – Region I, September 1998, Appendix B, Section 1d, page B-1.

target clean-up level of 50 ppm PCBs was established to reflect that public contact with the intertidal sediments in the Lower/Outer Harbor was not expected to occur due to the presence of physical barriers such as rip-rap, cement walls, or industrial land use.

The ROD did not specify what measure of the quality of the exposed sediments in the mudflat areas following excavation or dredging should meet this target PCB clean-up level (e.g., the mean concentration or the 95% Upper Confidence Level of the mean concentration).

4.2 Defining the Areas of the Harbor with Indirect Human Health / Ecological Improvement Potential

A comprehensive wetlands delineation and functional values assessment of the Upper New Bedford Harbor area was performed in the Fall of 2001 (Foster Wheeler, 2002d). During this survey, a number of different environmental area types (e.g., saltmarshes, vegetated upland areas, and freshwater wetlands) were identified to be present in and around the Upper Harbor. The locations and boundaries of these different areas were delineated and surveyed.

The ROD established target PCB clean-up levels relative to some specific environmental area types, as discussed above. These were:

1. Subtidal areas in the Upper Harbor;
2. Subtidal areas in the Lower or Outer Harbor;
3. Intertidal saltmarshes; and
4. Intertidal mudflats.

As the sediment PCB characterization program progressed and more samples were analyzed, PCBs were detected in additional areas in or near the Harbor that may not be clearly judged to be one of the four ROD environmental area types listed above. In order to determine if remediation activity may be necessary in these areas, a systematic approach was developed to assign a target PCB clean-up level to each environmental area type present in the immediate Harbor vicinity. This approach took the form of establishing a direct relationship between the environmental area types identified during the functional values assessment and the specific environmental area types or areas defined in the ROD.

This relationship depended on only two factors: (1) whether the area was vegetated or not; and (2) whether it was in the Upper Harbor or Lower/Outer Harbor (i.e., north or south of the Coggeshall Street Bridge, respectively). Earlier distinctions between intertidal and "upland" areas were determined to not be as important to meeting the intent and objectives of the ROD as the two factors above. The type of vegetation that may be present in a vegetated area also was judged to be less significant in this regard. The resulting relationship is presented in Table 4-1.

Using these associations, environmental area type-based target PCB clean-up levels can be associated with any required location in the vicinity of the Harbor.

4.3 Defining the Areas of the Harbor with Direct Contact Potential

A number of the areas of the Harbor that were known or were anticipated to be associated with direct contact human residential or beachcombing exposure were identified in the ROD. Subsequent to the ROD, the extent of some of these areas may have been slightly modified and other areas of both types have been added by USEPA based on further site inspections and site information. These areas are identified below.

Table 4-1
Relationship Between the Functional Values Assessment Environmental Area Types and the Environmental Area Types Defined in the ROD

Functional Values Assessment Environmental Area Type	Upper Harbor		Lower / Outer Harbor	
	Vegetated	Unvegetated	Vegetated	Unvegetated
Subtidal Areas		Subtidal Areas in the Upper Harbor [10 ppm]		Subtidal Areas in the Lower Harbor [50 ppm]
Mudflats / Marsh Channels		Intertidal Mudflats in the Upper Harbor [10 ppm]		Intertidal Mudflats in the Lower Harbor [50 ppm]
Beach Bars				
Saltmarshes	Intertidal Saltmarshes [50 ppm]		Intertidal Saltmarshes [50 ppm]	
Freshwater Wetlands				
Upland Vegetated Areas				
Developed Areas[1]				

Note: [1] Includes parking lots, building footprints, and commercial sites.

4.3.1 Areas with the Potential for Direct Contact Exposure in Residential Settings

There are nine areas abutting the Acushnet River or the New Bedford Harbor that have been, or may be, dredged or excavated to which the 1 ppm residential target PCB clean-up level has been assigned. These residential areas, which are shown on Figure 4-1, are:

1. The residential area just north of the Wood Street Bridge [New Bedford] (the primary area used as the exposure model for the development of the residential target PCB clean-up level - see Section 4.1.3);
2. The Veranda Street Inlet Area [Fairhaven] (two geographically separated subareas);
3. The I-195 / Coggeshall Street Inter-Bridge Area [Fairhaven] (selected to be remediated to achieve the residential target clean-up level due to the type of receptors present there and the accessibility of the shoreline to the public);
4. The Early Action Removal Action (Area 1) located north of the Wood Street Bridge [Acushnet] (the 1 ppm target PCB clean-up level was applied to this area which was excavated in April and May of 2001 because of the nearby residential homes);
5. The Cherry Street Area [Fairhaven]*;
6. The Elm Street / Winslow Court Area [Fairhaven]*;
7. Crow Island [Fairhaven]*;
8. The Area North of South Main Street [Acushnet]*; and
9. The Lawson Street Area [Acushnet]*.

*Note: Areas denoted with an asterisk do not show sediment contamination above applicable target PCB clean-up levels relative to the February 26, 2002 PCB Characterization database.

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Site Name: NEW BEDFORD

File Number: FIGURE 4-1, SHEETS 1 - 6

Purpose of Target Sheet:

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AREA DESIGNATIONS ASSOCIATED W/DIFFERENT ROD TARGET CLEAN-UP LEVELS

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In addition to these locations, the 1 ppm residential target PCB clean-up level has been assigned to a number of upland areas that do not directly abut the Acushnet River or the New Bedford Harbor. These locations also are shown on Figure 4-1. These additional residential areas were defined so that every location that was sampled during the sediment PCB characterization program could be assigned an appropriate target clean-up level and be evaluated. It must also be highlighted that the Early Action Removal Action (Area 1) residential area in Acushnet has already been excavated and restored.

4.3.2 Areas with the Potential for Direct Contact Exposure in Beachcombing Areas

Twenty areas abutting the Acushnet River or the New Bedford Harbor that are to be dredged or excavated were assigned the 25 ppm target PCB clean-up level associated with beachcombing. These potential beachcombing areas, which are shown on Figure 4-1, are:

1. The Coffin Street Cove Area [New Bedford] – including the Coffin Street Playground Area, the Vacant Waterfront Property, and the Sawyer Street CDF Area (the primary areas used as the pattern for the development of the beachcombing target clean-up level - see Section 4.1.4);
2. The Early Action Removal Action (Area 1) located north of the Wood Street Bridge [Acushnet];
3. The Marsh Island Shore / West Street Point Area [Fairhaven];
4. The Kyler Seafood Beach Area [New Bedford];
5. The Truro Street Area [New Bedford];
6. The Wood Street Area [New Bedford];
7. The Veranda Street Inlet Area [Fairhaven];
8. The I-195 / Coggeshall Street Inter-Bridge Area [New Bedford];
9. The Shoreline Area North of the Hurricane Barrier [New Bedford]*;
10. The Fort Phoenix State Beach Area (south of the Hurricane Barrier) [Fairhaven]*;
11. The Fairhaven Marina Beach Area [Fairhaven]*;
12. The Pope Island Marina and Park Area [New Bedford]*;
13. The Area North of the Route 6 Bridge [Fairhaven]*;
14. The Bridge Street Area South of Route 6 [Fairhaven]*;
15. The Fairhaven Town Boat Ramp [Fairhaven]*;
16. The New Bedford Public Beach Area [New Bedford]*;
17. Cherry Street Area [Fairhaven]*;
18. The Future Acushnet Park Area [Acushnet];
19. The Future Boat House Area [New Bedford]; and
20. The Palmer Island Area [New Bedford]*.

*Note: Areas denoted with an asterisk do not show sediment contamination above applicable target PCB clean-up levels relative to the February 26, 2002 PCB Characterization database.

It must be highlighted that the Early Action Removal Action (Area 1) beachcombing area in Acushnet has already been excavated and restored.

4.4 Determining Target Clean-up Levels for All Locations of Potential Interest

As described in Sections 4.1.3 and 4.1.4, the 1 ppm and 25 ppm ROD target PCB clean-up levels are associated with the protection of people from direct contact with sediments in areas with the potential for residential or beachcombing exposure. Sections 4.1.1, 4.1.2, and 4.1.5 described how the 10 ppm and 50 ppm ROD target PCB clean-up levels are associated with the protection of people indirectly relative to the ingestion of fish and other marine species that inhabit areas of possible sediment contamination. The 10 ppm and 50 ppm target PCB clean-up levels also were established with the broader goal of improving the ecological health of the Harbor and protecting valuable saltmarsh habitats.

Some ROD target PCB clean-up levels are, therefore, based on current or projected future land use and direct contact exposure, while others are based on habitat type. Consequently, some locations have both an applicable direct contact and an indirect contact/ecological improvement-related target PCB clean-up level, each applying to a different depth range within the sediment column at that location. Figures 4-2 and 4-3 describe how the target PCB clean-up level(s) are assigned to a particular area based on its environmental area type (as determined from the functional values assessment) and the assessment of potential for direct contact residential or beachcombing activity. Figure 4-2 defines the target clean-up level assignment rules for the Upper Harbor, while Figure 4-3 defines the target clean-up level assignment rules for the Lower and Outer Harbor areas.

These rules define how the target clean-up levels are reconciled for a given location when more than one level is applicable based on the characteristics of the location:

1. If two target clean-up levels are associated with the same location and same depth interval in the sediment column, the more stringent (lowest) target PCB clean-up level applies to that interval.
2. The target clean-up levels based on the potential for direct contact human exposure apply only to the top, or most exposed, 12 inches of sediment.
3. The target clean-up levels based on the potential for indirect human exposure or to improve the overall ecological habitat of the Harbor apply throughout the entire sediment column.

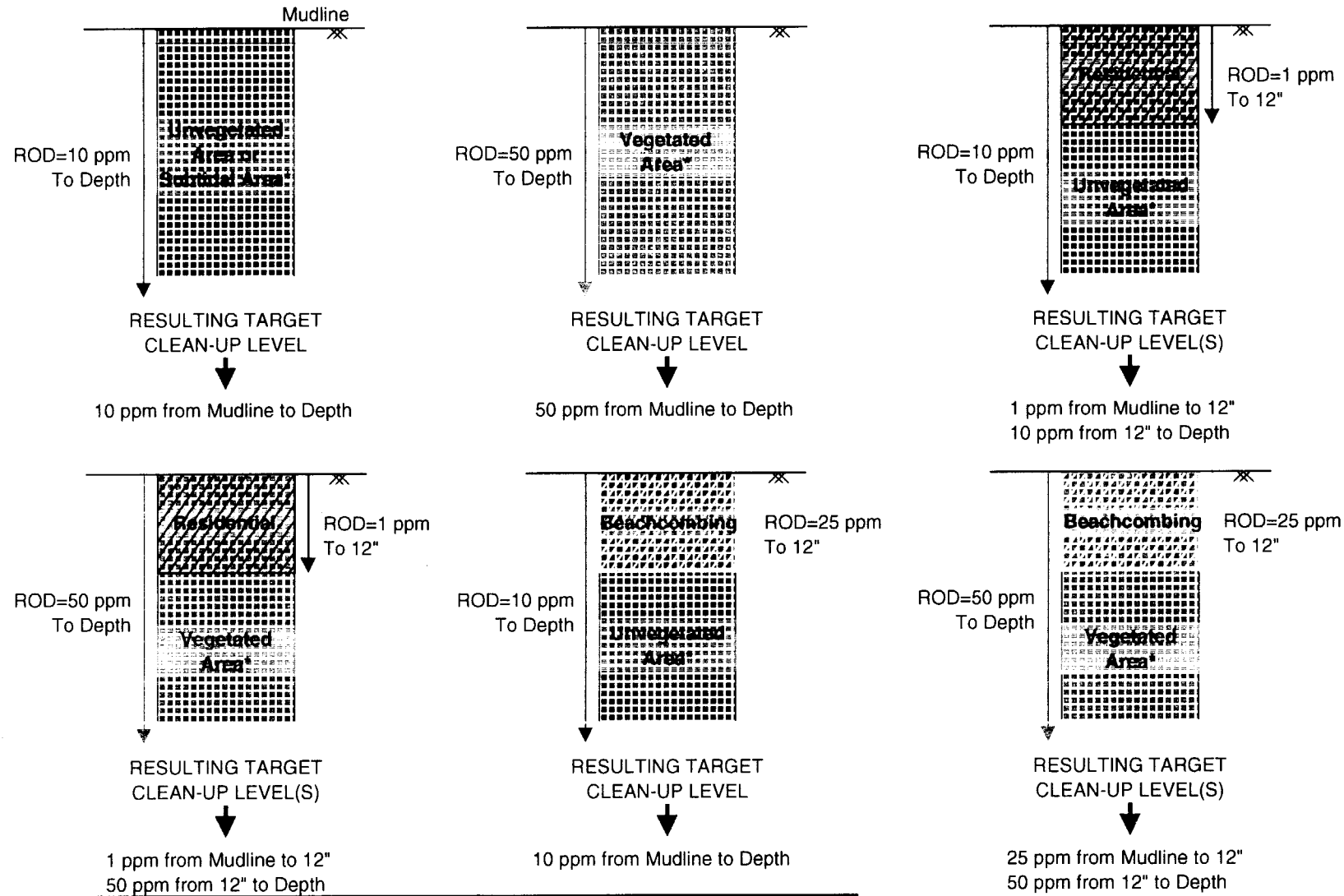
Figures 4-2 and 4-3 each show the six scenarios that are possible at any location in the Harbor, and what the resulting target PCB clean-up level(s) are for each scenario given the application of these three rules. Based on these rules, all locations in or around the Harbor can be associated with one of the five target clean-up levels specifications shown in Table 4-2.

The target PCB clean-up level specifications shown in Table 4-2 assume the following definitions:

- Unvegetated Areas - Includes mudflats, beach bars, marsh channels (a.k.a. mosquito ditches), and subtidal areas.
- Vegetated Areas - Includes saltmarshes, freshwater wetlands, and upland vegetated areas.
- Developed Areas - Includes parking lots, building footprints, and commercial or industrial sites.

Figure 4-2

Target PCB Clean-Up Levels with Depth Resulting from Different Combinations of Environmental Area Type and Potential For Direct Contact Exposure in the Upper Harbor



NOTES:

Direct Contact Human Health-Based Clean-Up Levels

-Residential (1 ppm)

-Beachcombing (25 ppm)

Indirect Human Health-Based / Ecological Improvement Clean-Up Levels

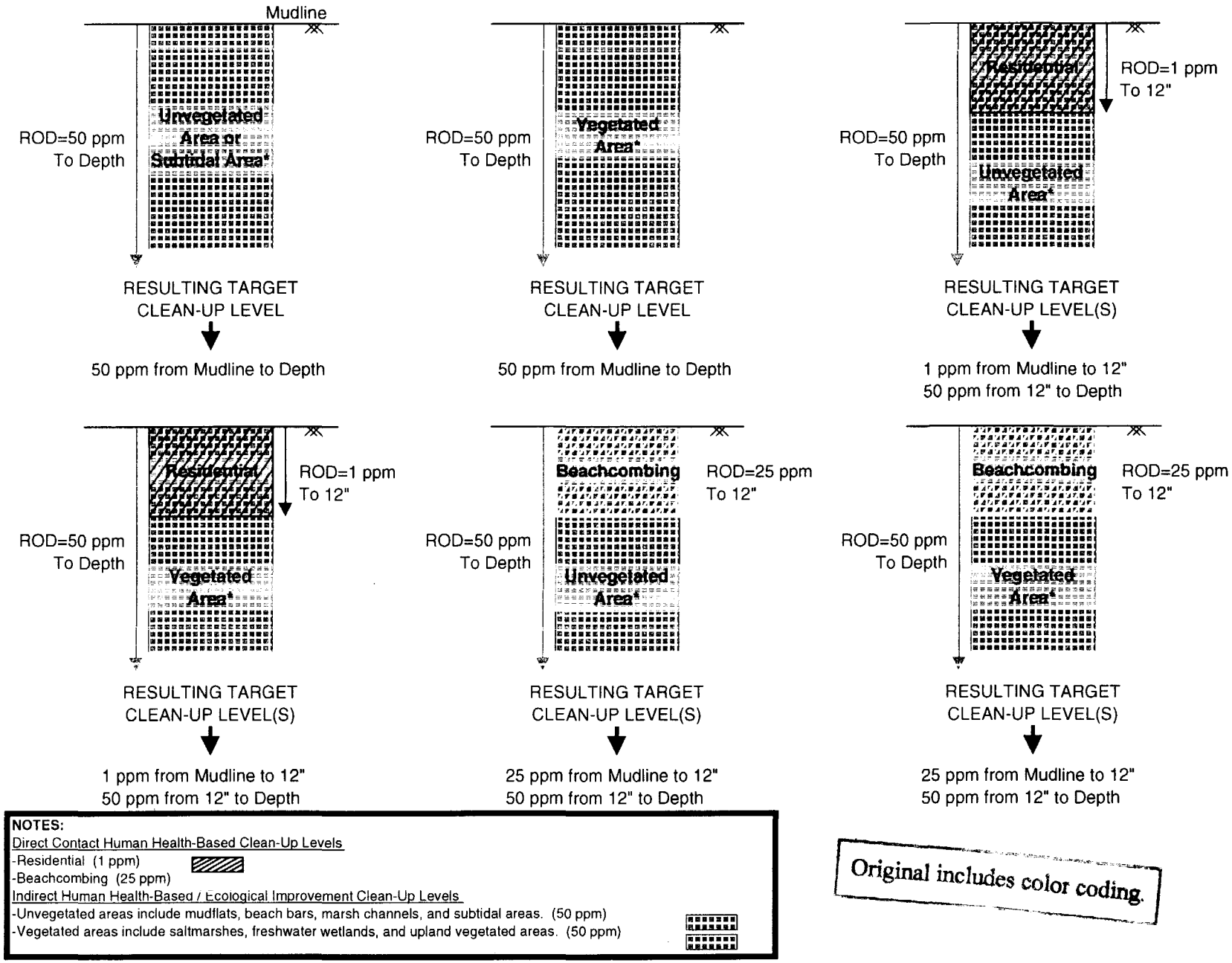
-Unvegetated areas include mudflats, beach bars, marsh channels, and subtidal areas. (10 ppm)

-Vegetated areas include saltmarshes, freshwater wetlands, and upland vegetated areas. (50 ppm)

Original includes color coding.

Figure 4-3

Target PCB Clean-Up Levels with Depth Resulting from Different Combinations of Environmental Area Type and Potential for Direct Contact Exposure in the Lower/Outer Harbor



NOTES:

Direct Contact Human Health-Based Clean-Up Levels

-Residential (1 ppm)

-Beachcombing (25 ppm)

Indirect Human Health-Based / Ecological Improvement Clean-Up Levels

-Unvegetated areas include mudflats, beach bars, marsh channels, and subtidal areas. (50 ppm)

-Vegetated areas include saltmarshes, freshwater wetlands, and upland vegetated areas. (50 ppm)

Original includes color coding.

Table 4-2
The Five Possible Target PCB Clean-Up Level Specifications Applicable to Locations In or Around the New Bedford Harbor

No.	Target Clean-up Level(s) for the Location	Combination of Potential for Direct Contact Exposure, Environmental Area Type, and Harbor Location
1	1 ppm in the top 12 inches / 10 ppm below 12 inches	• Residential Zone in an Unvegetated Area of the Upper Harbor
2	1 ppm in the top 12 inches / 50 ppm below 12 inches	• Residential Zone in a Vegetated Area of the Upper Harbor • Residential Zone in a Vegetated or an Unvegetated Area of the Lower Harbor
3	10 ppm at all depths	• Non-Residential Zone in an Unvegetated Area of the Upper Harbor • Subtidal Area of the Upper Harbor
4	25 ppm in the top 12 inches / 50 ppm below 12 inches	• Beachcombing Zone in an Unvegetated Area of the Lower Harbor • Beachcombing Zone in a Vegetated Area of the Upper or Lower Harbor
5	50 ppm at all depths	• Non-Residential and Non-Beachcombing Zones in a Vegetated Area of the Upper Harbor • Non-Residential and Non-Beachcombing Zones in a Vegetated or an Unvegetated Area of the Lower Harbor • Subtidal Area of the Lower Harbor • Developed Unvegetated Area of the Upper or Lower Harbor

4.5 Key Points

These specifications were applied to all areas of the Harbor where characterization sampling has been performed. The resulting target PCB clean-up level mapping is presented in Figure 4-1 using the sample color coding scheme and terminology used in Figures 4-2 and 4-3. Table 4-3 presents a tabular summary of the target PCB clean-up levels associated with specific areas or zones of the Harbor. Table 4-3 also notes the basis of the target clean-up level, the value of the target clean-up level, the depth or depth interval in the sediment column in which that target clean-up level applies, and the sediment quality characteristic to be compared to the target clean-up level.

The following are the key points of the discussion and assignment of the target PCB clean-up levels to particular areas of the Harbor.

- The assignment of a target PCB clean-up level to a location is a critical step in the entire confirmatory sampling effort.
- A comparison of the sediment PCB characterization data to these target clean-up levels is the principal driver of whether or not and how much sediment must be removed at that location and how much.
- The ROD specifies target PCB clean-up levels for both direct contact human health protection, and for indirect exposure human health and ecological improvement objectives.
- These different target PCB clean-up levels have different statistical measures of the confirmatory sampling data set that they must be compared to.

- The 95% upper confidence limit on the mean of the confirmatory samples taken in the top 12 inches of an area must be less than the direct contact human health protection target clean-up levels for compliance to be demonstrated in that area for that sediment layer.
- The arithmetic mean of the confirmatory samples taken in the upper most layer of the sediment column must be less than the indirect exposure human health and ecological improvement target PCB clean-up levels for compliance to be demonstrated in that area for the entire sediment column.
- Certain locations of the Harbor will need to be checked against both types of target PCB clean-up levels.
- A systematic process for assigning one or a pair of target PCB clean-up levels to a location was defined based on the type of environmental area at that location (as determined by the functional values assessment), whether the location is in the Upper or the Lower/Outer Harbor, and whether it is vegetated or not.

Table 4-3
Summary of the Target PCB Clean-Up Levels for Areas at New Bedford Harbor

Areas Differentiated On the Basis of ROD Target Clean-up Levels	Basis of the Target PCB Clean-Up Level	PCB Target Clean-Up Level Value (ppm)	Applicable Depth in Newly Exposed Sediment	Compliance Measure to Compare to Target Clean-Up Level	Overall Size[1] (Acres)
Subtidal Areas					
– Subtidal Area in the Upper Harbor	IHH/E	10	Whole Column	Area Average	147.1
– Subtidal Area in the Lower/Outer Harbor	IHH/E	50	Whole Column	Area Average	976.9[1]
				Total Subtidal Areas	1,124.0
Intertidal Saltmarsh (Vegetated) Areas					
– Saltmarsh Areas in the Upper Harbor	IHH/E	50	Whole Column	Area Average	44.60
– Saltmarsh Areas in the Lower/Outer Harbor	IHH/E	50	Whole Column	Area Average	53.76
				Total Saltmarsh (VEGETATED) Areas	98.36
Residential Areas (Abutting the Harbor)					
– Area North of Wood Street Bridge [New Bedford]	DCHH	1/50	0 to 1 foot	95% UCL	0.56
– Veranda Street Inlet Area [Fairhaven]	DCHH	1/50	0 to 1 foot	95% UCL	2.96
– I-195 / Coggeshall Street Inter-Bridge Area [Fairhaven]	DCHH	1/50	0 to 1 foot	95% UCL	0.40
– Early Action Removal Area (Area 1)[2] [Acushnet]	DCHH	1/50	0 to 1 foot	95% UCL	0.34
– Cherry Street Area [Fairhaven]*	DCHH	1/50	0 to 1 foot	95% UCL	1.43
– Elm Street / Winslow Court Area [Fairhaven]*	DCHH	1/50	0 to 1 foot	95% UCL	1.24
– Crow Island [Fairhaven]*	DCHH	1/50	0 to 1 foot	95% UCL	1.67
– Area North of South Main Street [Acushnet]*	DCHH	1/50	0 to 1 foot	95% UCL	0.13
– Lawson Street Area [Acushnet]*	DCHH	1/50	0 to 1 foot	95% UCL	0.91
				Total Residential Areas (ABUTTING THE HARBOR)	9.64
Beachcombing Areas					
– Coffin Street Cove Area [New Bedford]	DCHH	25/50	0 to 1 foot	95% UCL	5.30
– Early Action Removal Area (Area 1)[2] [Acushnet]	DCHH	25/50	0 to 1 foot	95% UCL	0.53
– Marsh Island Shore / West Street Point Area [Fairhaven]	DCHH	25/50	0 to 1 foot	95% UCL	9.41
– Kyler Seafood Beach Area [New Bedford]	DCHH	25/50	0 to 1 foot	95% UCL	0.42
– Truro Street Area [New Bedford]	DCHH	25/50	0 to 1 foot	95% UCL	0.51
– Wood Street Area [New Bedford]	DCHH	25/50	0 to 1 foot	95% UCL	0.05
– Veranda Street Inlet Area [Fairhaven]	DCHH	25/50	0 to 1 foot	95% UCL	1.31
– I-195 / Coggeshall Street Inter-Bridge Area [New Bedford]	DCHH	25/50	0 to 1 foot	95% UCL	0.34
– Shoreline Area North of the Hurricane Barrier [New Bedford]*	DCHH	25/50	0 to 1 foot	95% UCL	5.32
– Fort Phoenix State Beach Area [Fairhaven]*	DCHH	25/50	0 to 1 foot	95% UCL	2.60
– Fairhaven Marina Beach Area [Fairhaven]*	DCHH	25/50	0 to 1 foot	95% UCL	2.69
– Pope Island Marina and Park Area [New Bedford]*	DCHH	25/50	0 to 1 foot	95% UCL	5.79
– Area North of the Route 6 Bridge [Fairhaven]*	DCHH	25/50	0 to 1 foot	95% UCL	1.35
– Bridge Street Area South of Route 6 [Fairhaven]*	DCHH	25/50	0 to 1 foot	95% UCL	0.24
– Fairhaven Town Boat Ramp [Fairhaven]*	DCHH	25/50	0 to 1 foot	95% UCL	0.59
– New Bedford Public Beach Area [New Bedford]*	DCHH	25/50	0 to 1 foot	95% UCL	32.40
– Cherry Street Area [Fairhaven]*	DCHH	25/50	0 to 1 foot	95% UCL	1.62
– Future Acushnet Park Area [Acushnet]	DCHH	25/50	0 to 1 foot	95% UCL	0.78
– Future Boat House Area [New Bedford]	DCHH	25/50	0 to 1 foot	95% UCL	0.38
– Palmer Island Area [New Bedford]*	DCHH	25/50	0 to 1 foot	95% UCL	3.35
				Total Beachcombing Areas	74.98
Mudflat (Unvegetated) Areas					
– Mudflats in the Upper Harbor	IHH/E	10	Whole Column	Area Average	46.22
– Mudflats in the Lower Harbor	IHH/E	50	Whole Column	Area Average	TBD[3]
				Total Mudflat (UNVEGETATED) Areas	46.22+[3]

Notes: DCHH = Direct Contact Human Health Protection
IHH/E = Indirect Human Health and Ecological Protection
ROD = Record of Decision
PCB = Polychlorinated Biphenyl
TBD = To Be Determined
CDF = Confined Disposal Facility
UCL = Upper Confidence Limit

[1] Overall sizes shown are acreage within the area boundary, not necessarily the total area requiring dredging or excavation.

[2] Area has already been excavated.

[3] The area of intertidal mudflats in the Lower Harbor has yet to be calculated pending suitable data on the low tide elevation.

*Areas denoted with an asterisk do not show sediment contamination above applicable target PCB clean-up levels relative to the February 26, 2002 PCB Characterization database.

5.0 GENERAL APPROACHES AND STRATEGIES TO DREDGING OR EXCAVATION RELATIVE TO CONFIRMATORY SAMPLING

There are a number of possible approaches and strategies for dredging or excavating an area to remove contaminated sediment. These strategies and approaches vary with respect to their objectives and, consequently, the order and timing of various remedial operations. The order and timing of these remedial operations directly affect:

- Whether the samples are from sediment that may ultimately be the surficial sediment following dredging or excavation (i.e., confirmatory samples), or alternatively "progress" samples to be used to direct subsequent field decisions in areas for which another pass of dredging or excavation is planned or may be needed;
- How the data analyses will be used to support field decision-making;
- Where and when confirmatory samples may be safely collected;
- The representativeness of the collected samples relative to local, post-dredging PCB sediment concentrations;
- How quickly the chemical analyses must be performed to determine whether or not the post-dredging or post-excavation sediment PCB concentrations in the area meet the applicable target PCB clean-up levels;
- How quickly the need for supplemental dredging or excavation must be identified and, if needed, how quickly the specification for the supplemental sediment removal work must be developed to support overall project cost-effectiveness; and
- How and when the data analyses will be used to ultimately support a determination that the target PCB clean-up levels have been met or that no further sediment will need to be removed in that area.

These considerations or constraints are either a core element of a confirmatory sampling program, or have a direct relationship to a core element. Consequently, the diverse set of approaches and strategies for dredging or excavating an area at New Bedford Harbor had to be screened or bounded in order to provide a context for further defining the confirmatory sampling approach. This corresponds to Step 3 of the DQO process, Identify Inputs to the Decision, as discussed in Section 1.2.

5.1 Area Designations Associated with General Dredging or Excavation Approaches

Three operational approaches or strategies for dredging or excavation are defined in this subsection to provide a context relative to which a suitable confirmatory sampling program can be specified. The definitions and descriptions of each approach make use of two terms that refer to subareas of the Harbor: sediment management units and compliance demonstration areas.

5.1.1 Sediment Management Units

The excavation and dredging work at New Bedford Harbor will involve large areas with differing conditions over several years. In order to effectively manage the design and remedial construction activities, the areas to be dredged or excavated will be subdivided into sediment MUs. These MUs will be used throughout the design, implementation, and monitoring activities to evaluate and document remedial action progress.

MUs will be developed based on an assessment of a number of separate criteria (Foster Wheeler, 2002b). A fundamental determination was made that there would be subtidal and mudflat MUs for unvegetated areas below and above the Mean Lower Low Water (MLLW) line, respectively. In addition, there would be other distinct units in vegetated areas. The other criteria or factors to be considered in determining the sizes, boundaries, and number of the MUs are:

- The units will be used to schedule and control the sequence of work and to serve as specific bid items in procurement packages;
- The units will be small enough so that sediment removal work in any MU can be performed and completed in one construction season;
- The depth of standing water and the physical characteristics of the sediment will be used as criteria to select equipment type. Types will include floating only, floating or low ground pressure, and low ground pressure only sediment removal equipment;
- Separate units will be defined for vegetated and unvegetated areas;
- The preference will be that separate units will be defined in the Upper and Lower Harbor (i.e., no MUs crossing under the Coggeshall Street Bridge);
- Separate units will be defined where isolation (e.g., barriers such as sheet piling or dikes) is required;
- Separate units will be defined where the "visual approach" (Foster Wheeler, 2002c) (if demonstrated to be implementable) for the real time checking of the specified design cut elevations will work;
- Construction or operational considerations (i.e., no units will straddle the new Commonwealth Electric Transmission Cables; cable areas may be handled separately, or may be removed during dredging);
- Management units will be small enough to provide flexibility for annual cost control;
- Separate units will be defined for areas with different sediment target PCB clean-up levels;
- Consideration will be given to the pre-dredging or pre-excavation sediment PCB concentrations;
- Consideration will be given to the locations of CSOs and storm drains and the area of their influence on sediment movement and quality; and
- Consideration will be given to the sediment type(s) in an area.

Based on an evaluation of these criteria and conditions, MUs will be defined within the subtidal, mudflat, and intertidal and upland vegetated areas of the Upper, Lower, and Outer Harbors where the sediment PCB Characterization Program has indicated that sediment removal is necessary to meet the target PCB clean-up levels. MUs are likely to range in size from approximately a quarter of an acre up to 5 acres in size.

5.1.2 Compliance Demonstration Areas

A CDA is one of the subareas of the Harbor for which the statistical evaluation will be made to see if the post-dredging or post-excavation sediment PCB concentrations are at or below the target PCB clean-up levels. The boundary of a CDA may coincide with the boundary of one individual MU or a CDA may

encompass a number of contiguous MUs that have the same target PCB clean-up level(s) and possibly other shared characteristics.

5.2 Candidate Dredging or Excavation Approaches and Strategies

There are many concurrent objectives to an environmental dredging or excavation program. However, three specific considerations appear to be most important in the context of the work to be performed at New Bedford Harbor. Defining these considerations corresponds to Step 3 of the DQO process, Identify Inputs to the Decision, as discussed in Section 1.2. Similarly, three overall strategies or approaches to dredging or excavation are currently the primary candidates for application. Which approach may be applied is likely to be determined by which of the three primary considerations is the most important factor for that area. The two dredging or excavation approaches and the additional operational strategy are:

Approach 1	-	Minimizing the Time an Area is Disturbed or Minimizing the Degree of Impact on an Area;
Approach 2	-	Maximizing Operational Efficiency; and
Warm Spot Removal Strategy	-	Minimizing the Potential for Recontamination of "Cleaned" Areas by Initially Removing Sediments with the Highest PCB Concentrations Prior to the Primary Dredging and Excavation Program (Note: This strategy may be applied to particular portions of the Harbor as an initial removal step, followed by either Approaches 1 or 2).

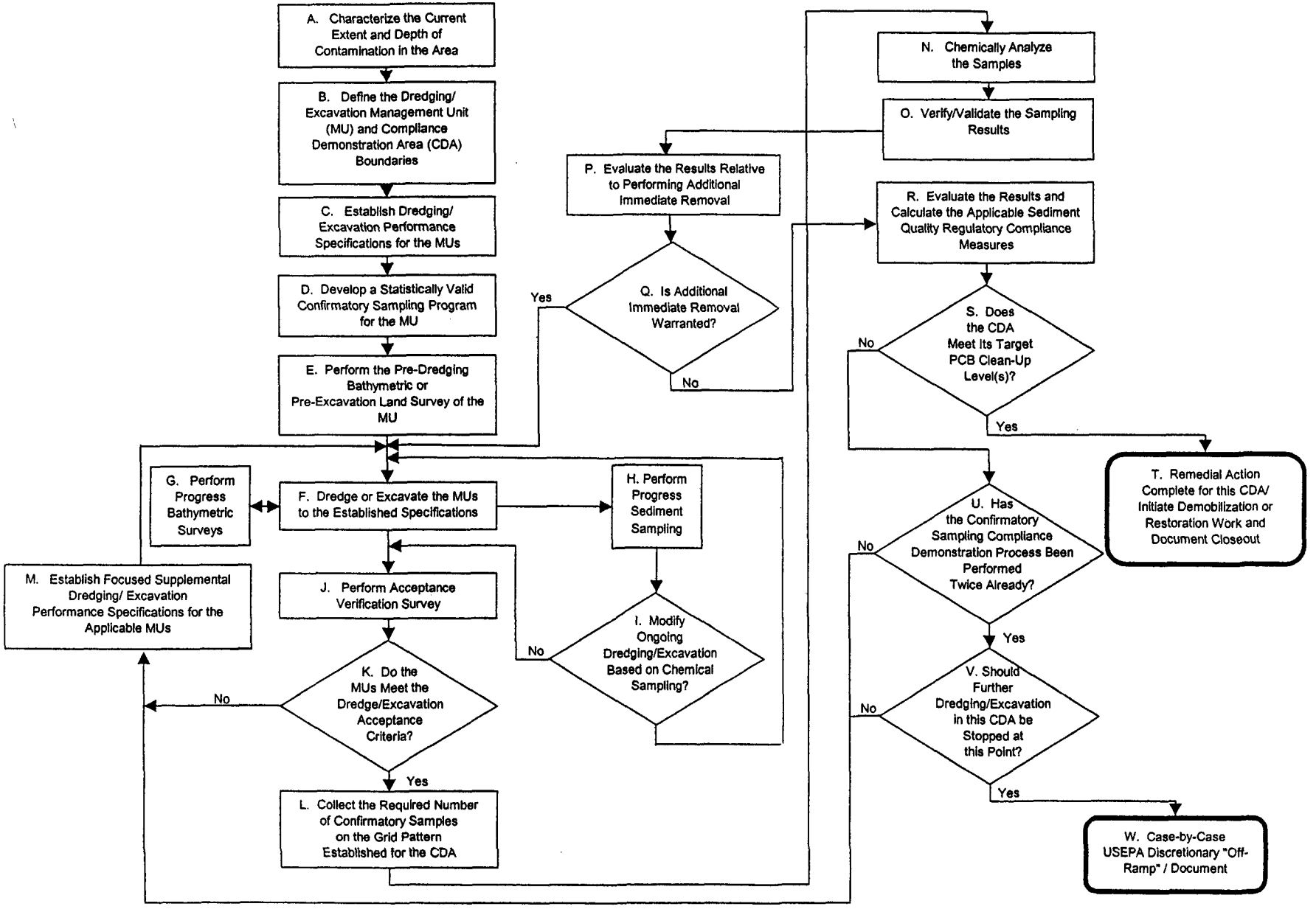
While these approaches are indicated at this time to be well suited to the majority of dredging or excavation requirements at the Harbor, other approaches or variations of one of these approaches may be found to be needed in limited, selected areas and may also be evaluated at a later date.

Approach 1 translates into the case where the CDA is defined to coincide with the boundary of a single MU. Approach 2 translates into the case where the CDA is defined to coincide with the outer envelope of the boundaries of multiple (e.g., four to six) contiguous MUs with the same PCB target clean-up level. The Warm Spot Removal Strategy may be implemented as a first step to either Approach 1 or Approach 2, although it would probably be most advantageous when followed by Approach 2.

It must be emphasized that additional dredging or excavation would necessarily follow the work performed relative to the Warm Spot Removal Strategy. As such, sampling strictly for the purpose of confirmatory sampling would not be appropriate following the dredging or excavation performed relative to this activity. Confirmatory sampling would follow the dredging or excavation associated with Approaches 1 or 2.

Each of the three primary considerations and the dredging or excavation approach or strategy that best addresses that consideration is discussed below. A generalized dredging or excavation flowchart relative to confirmatory sampling is presented in Figure 5-1.

Figure 5-1
Generalized Sediment Removal and Confirmatory Sampling Flowchart for a Compliance Demonstration Area



5.2.1 Approach 1 to Dredging or Excavation – Compliance Demonstration Area as a Single Management Unit

5.2.1.1 Primary Considerations

In some areas, there may be a need to take extra care to minimize the time or the degree of disturbance. This may be desirable because the area is routinely used by the public and must be taken out of service to be remediated. This may also be desirable if there would be greater financial costs, more operational constraints or requirements, or some greater liability relative to working in that area or in having to go back and subsequently rework that area. Under these circumstances, shortening the overall duration of the field effort in that area would be advantageous, so long as the target PCB clean-up levels can first be demonstrated to be met and no further action in that area can be justified. Achieving this objective is facilitated by tailoring the work to achieve specified cuts, while conducting nearly "real-time" progress sampling and chemical analyses. These progress chemical samples and other concurrent monitoring would be used to provide timely feedback to the field operation relative to if, where, and how much additional dredging or excavation is needed within that area for it to meet its target PCB clean-up level(s). This approach results in the greatest likelihood that the target PCB clean-up levels will be met in the shortest overall period of time. However, this approach may require relatively more progress and confirmatory sampling, and more dredge or excavator repositioning time. Together, these characteristics could tend to somewhat increase unit dredging or excavation time and costs.

5.2.1.2 Boundary of the Compliance Demonstration Area

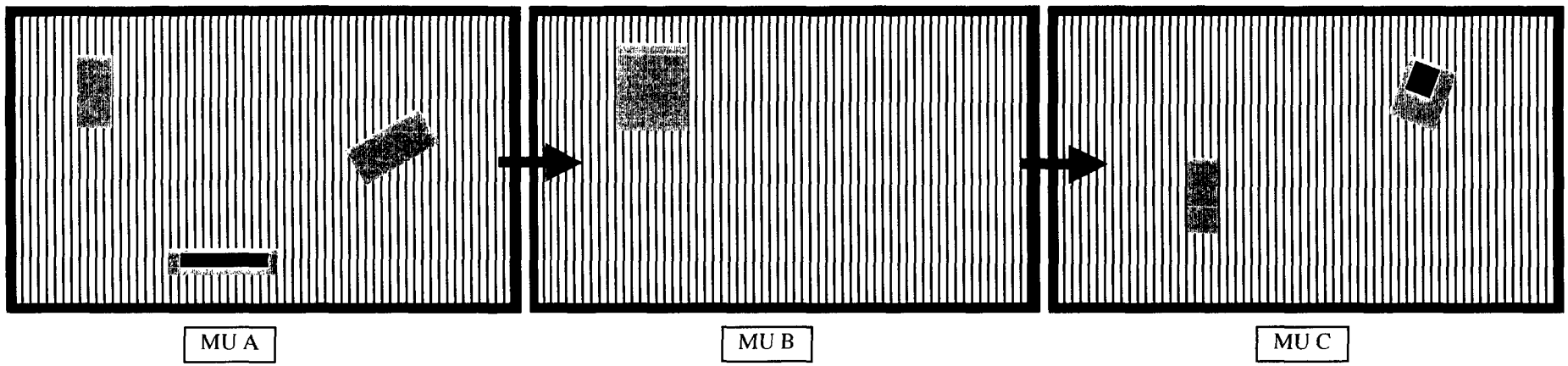
For this approach, the CDA is defined to coincide with the boundary of a single MU. The corresponding sequencing of activities is such that dredging or excavation in the single MU would be started and finished (i.e., dredged or excavated, confirmatory sampled, and found to comply with the target PCB clean-up level(s) for that area) before dredging or excavation with the equipment used in that MU proceeds into the next CDA. It is anticipated that this approach could be implemented in an area over a period of several days or a few weeks.

5.2.1.3 General Order and Timing of Activities Important to Confirmatory Sampling

This section describes Approach 1 in somewhat more detail relative to the factors affecting a confirmatory sampling program that would be tailored to it. Figure 5-2 presents a graphical representation of the overall operation under Approach 1. The general sequence of steps for Approach 1 is as follows [Note: The letters in curly brackets refer to the steps depicted on Figure 5-1, and the numbers reflect the pass of dredging or excavation]:

1. Perform the first pass of dredging or excavation for the entire MU relative to the specified design target elevations {F-1} [Note: Progress chemical sampling or other types of performance monitoring may be performed concurrently for other non-confirmatory sampling purposes] {H-1};
2. Conduct confirmatory sampling of the post-dredging or post-excavation sediment in the MU at the depth(s) required as soon as it is safe and operationally practical to do so {L-1}; [Note: Confirmatory samples and baseline long-term monitoring sediment samples will be co-located at some number of locations to provide a linkage between the two data sets and a means for identifying the degree of recontamination that may be occurring/have occurred];
3. Analyze the confirmatory sediment samples for PCBs in a manner acceptable for use in regulatory compliance demonstration with expedited turnaround time {N-1};

Figure 5-2
Approach 1: Compliance Demonstration Area as a Single Management Unit



KEY
- First Pass of Dredging or Excavation
- Second Pass of Dredging or Excavation
- Third Pass of Dredging or Excavation
- Individual Management Unit Boundary
- Compliance Demonstration Area Boundary

Approach 1:
CDA = Compliance Demonstration Area
MU = Management Unit
CDA A = MU A
CDA B = MU B
CDA C = MU C

4. Using the analytical results for the confirmatory samples collected, determine if any locations warrant immediate additional sediment removal prior to the development of a supplemental dredging or excavation plan based on a comparison of the individual sample results to pre-established action levels {P-1, Q-1};
5. Using the analytical results for the confirmatory samples collected, calculate the measure(s) of sediment PCB concentration for the overall MU (i.e., the CDA) that must be compared to the applicable target PCB clean-up level(s) {R-1};
6. Determine if the overall MU meets the applicable target PCB clean-up level(s) {S-1};
7. If the MU meets the target PCB clean-up level(s), authorize demobilization or restoration work to begin on this MU, as needed, and prepare the necessary regulatory documentation {T-1};
8. If the MU does not meet the target PCB clean-up level(s), specify the locations and depths of supplemental dredging or excavation in that MU that is indicated to be necessary to achieve the target PCB clean-up level(s) [Note: Consider if any archived samples collected from lower depths in the sediment column should be analyzed to refine this specification] {M-1};
9. Perform the second pass of dredging or excavation in the designated portions of that MU identified in the supplemental dredging or excavation plan as soon as possible {F-2} [Note: Progress chemical sampling or other types of performance monitoring may be performed concurrently for other non-confirmatory sampling purposes] {H-2};
10. Conduct confirmatory sampling of the post-dredging or post-excavation sediment at the depth(s) required only in those portions of the MU that were re-dredged or re-excavated during the second pass as soon as it is safe and operationally practical to do so [Note: In an area where recontamination is a special concern, resampling certain locations that were not redredged or re-excavated may be considered] {L-2};
11. Analyze these second pass confirmatory sediment samples for PCBs in a manner acceptable for use in regulatory compliance demonstration with expedited turnaround time {N-2};
12. Using the analytical results for these second pass confirmatory samples together with the confirmatory sampling results for the portions of the MU that did not receive a second pass of dredging or excavation, calculate the measure(s) of sediment PCB concentration for the overall MU (i.e., the CDA) that must be compared to the applicable target PCB clean-up level(s){R-2};
13. Determine if the overall MU now meets the applicable target PCB clean-up level(s) {S-2};
14. If the MU meets the target PCB clean-up level(s), authorize demobilization or restoration work to begin on this MU, as needed, and prepare the necessary regulatory documentation {T-2};
15. If the MU does not now meet the target PCB clean-up level(s), discuss the situation and the available data with the USEPA Site Manager {V-2};
16. If, upon review of the available information, the USEPA Site Manager determines that another pass of dredging or excavation is not warranted, demobilize or begin restoration work on this MU, as needed, and prepare the necessary regulatory documentation {T-2};
17. If, upon review of the available information, the USEPA Site Manager determines that another pass of dredging or excavation is warranted, specify the locations and depths of focused supplemental dredging or excavation in that MU that is indicated to be necessary to achieve the target PCB clean-up level(s) [Note: Consider if any archived samples collected

from lower depths in the sediment columns should be analyzed to improve this specification] {M-3};

18. Perform the third, or final, pass of dredging or excavation in the designated portions of that MU consistent with the focused supplemental dredging or excavation plan {F-3} [Note: Progress chemical sampling or other types of performance monitoring may be performed concurrently for other non-confirmatory sampling purposes] {H-3};
19. Conduct confirmatory sampling of the post-dredging or post-excavation sediment at the depth(s) required only in those portions of the MU that were re-dredged or re-excavated during the third pass as soon as it is safe and operationally practical to do so {L-3};
20. Analyze these confirmatory sediment samples for PCBs in a manner acceptable for use in regulatory compliance demonstration with expedited turnaround time {N-3};
21. Demobilize or begin restoration work on this MU (CDA), as needed {T-3};
22. Using the analytical results for these third pass confirmatory samples together with the confirmatory sampling results for the portions of the MU that did not require a third or second pass of dredging or excavation, calculate the measures of sediment PCB concentration for that MU (i.e., CDA) that must be compared to the applicable target clean-up level(s) {R-3};
23. Determine if the MU now meets the applicable target PCB clean-up level(s) {S-3};
24. If the MU meets the target PCB clean-up level(s), prepare the appropriate documentation {T-3};
25. If the MU does not now meet the target PCB clean-up level(s), prepare the necessary "off ramp" documentation as directed by the USEPA Site Manager {W}; and
26. Determine, through consultation with the USEPA Site Manager, whether the archived samples for this MU should be discarded or if they should be retained for an additional period of time.

It should be highlighted relative to the steps outlined above that a third pass of dredging or excavation in an MU is not expected to be a frequent occurrence, and no fourth passes are envisioned. It also should be highlighted that once a CDA (in this case a single MU) has been determined to have met its applicable target PCB clean-up level(s) or the USEPA Site Manager has determined that no further work in that area is warranted, confirmatory sampling and remedial dredging or excavation in that MU is considered to be complete. At that point, no additional dredging or excavation in that area would be anticipated.

5.2.1.4 Principal Advantages and Disadvantages

In summary, the principal advantages of implementing Approach 1 include:

- Minimizes the duration of disturbance to an individual MU since the dredging or excavation and confirmatory sampling could be completed most expeditiously; and
- Quickly and effectively addresses areas of residual contamination above the target PCB clean-up levels that are identified by the confirmatory sampling before local conditions change significantly.

The potential disadvantages of implementing Approach 1 include:

- May lower production rates due to down time if dredgers or excavators must wait on samplers and analytical results, or samplers must wait on dredgers or excavators to clear an area;
- Requires significant coordination among differently tasked groups; and
- May result in higher overall unit removal or processing cost due to lower production rates, additional operation and management cost, and higher analytical costs.

5.2.2 Approach 2 to Dredging or Excavation – Compliance Demonstration Area Covering Multiple Management Units

5.2.2.1 Primary Considerations

There is always a desire to maintain a high degree of operational efficiency for either the dredging or excavation. This may generally be done by designing to allow for nearly continuous operations in a fairly linear manner relative to a scope of work that does not keep changing. Achieving this objective is facilitated by organizing the work around straightforward rules and specifications, with little or no "real time", site-specific sediment chemistry data analysis and feedback to the field operation. This approach places more importance on achieving specified cut elevations in meeting water quality criteria constraints. Under this arrangement, production rates, in terms of the volume of sediment removed and processed, would generally be higher and progress quicker assuming sufficient dewatering capacity. Together, these characteristics may tend to lower costs. While Approach 2 exhibits these benefits or advantages, it leaves less opportunity for fine tuning the work in real time and results in somewhat greater uncertainty that the target PCB clean-up levels will be shown to have been met after the dredging or excavation is performed.

It must be emphasized that efforts will continuously be made to improve dredge efficiency and production rates, but these efforts will not be made at the expense of adversely affecting water quality. Operational parameters for acceptable water quality will be set (outside the scope of this document) and the dredging must be performed so that these parameters are not exceeded.

5.2.2.2 Boundary of the Compliance Demonstration Area

For this approach, the CDA is defined to coincide with the outer envelope of the boundaries of multiple (e.g., four to six) contiguous MUs with the same target PCB clean-up level(s). The approach is based on a dredging sequence where a set of MUs in a contiguous area would be dredged or excavated and evaluated for purposes of compliance with the target PCB clean-up levels as one overall area (i.e., the CDA). A first pass of dredging or excavation would be performed throughout all of the MUs of the CDA, one after another, during one working season. Confirmatory samples would be collected following the dredging or excavation when it was safe and operationally practical to do so. The analytical results from these samples would be obtained within standard (non-expedited) turnaround times. Once the analytical data for all the MUs are received and analyzed, a determination would be made as to whether the entire CDA met the applicable target PCB clean-up level(s) for that area. If the overall CDA does not meet the applicable target PCB clean-up level(s) for that area at this point, a supplemental dredging or excavation plan would be developed that would identify the locations and depths within the CDA that must be further dredged or excavated. This area to be re-dredged or re-excavated could be one or more portions of any of the MUs that comprise that CDA. This specification would be based on the sediment PCB levels throughout the entire CDA, not just within any single component MU. This supplemental work would be performed later in that work season (if practical) or at the beginning of the following work season. Under this approach, dredging or excavation may be performed in more than one MU, or even CDA, at the

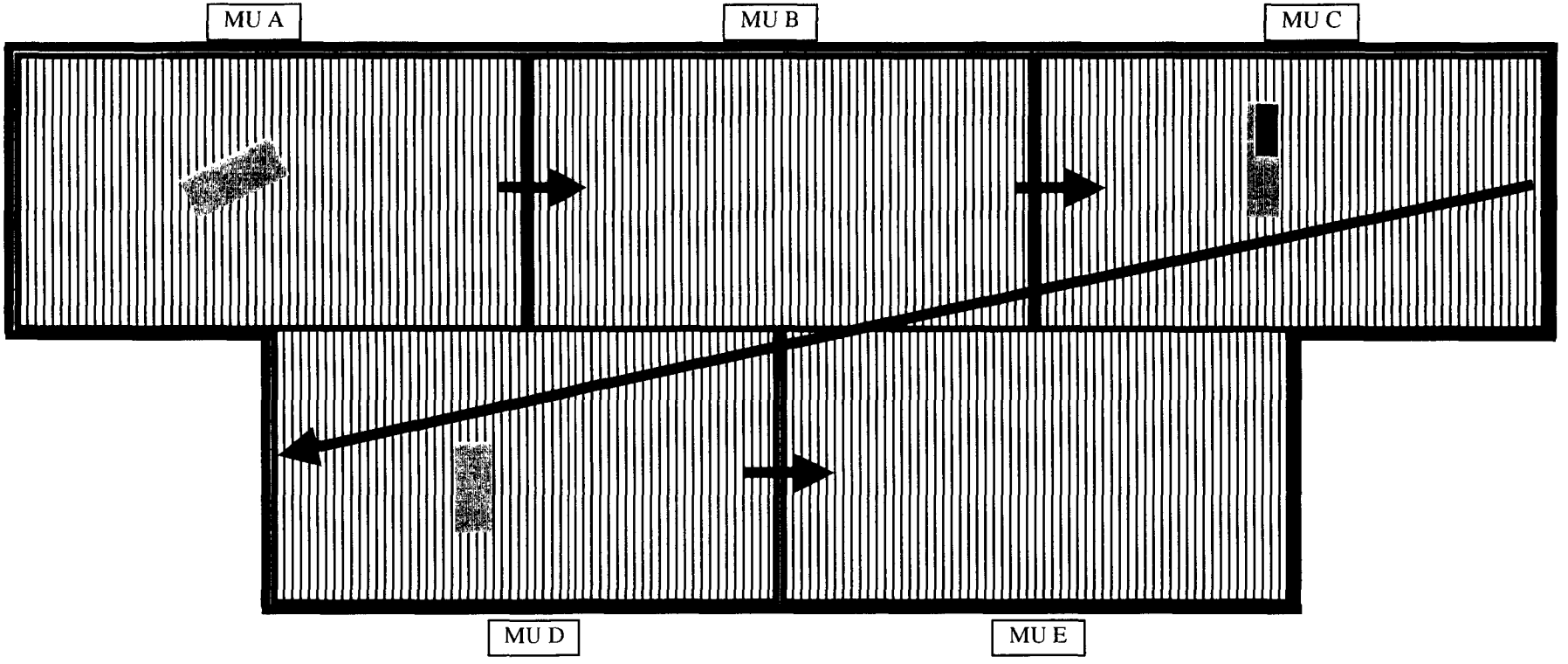
Harbor before the confirmatory sampling process and demonstration efforts are completed for another CDA. This approach may be most suitable for areas where the PCB contamination is spread over large subtidal areas where there are few or no routine users of the area. It is anticipated that this approach would be implemented in a CDA over a period of months or a calendar year.

5.2.2.3 General Order and Timing of Activities Important to Confirmatory Sampling

This section describes Approach 2 in somewhat more detail relative to the factors affecting a confirmatory sampling program that would be tailored to it. Figure 5-3 presents a graphical representation of the overall operation under Approach 2. The general sequence of steps for Approach 2 is as follows [Note: The letters in curly brackets refer to the steps depicted on Figure 5-1, and the numbers reflect the pass of dredging or excavation]:

1. Perform the first pass of dredging or excavation for the entire CDA (multiple MUs) relative to the specified design target elevations within a single work season {F-1} [Note: Progress chemical sampling or other types of performance monitoring may be performed concurrently for other non-confirmatory sampling purposes] {H-1};
2. Conduct confirmatory sampling of the post-dredging or post-excavation sediment in the CDA at the depth(s) required as soon as it is safe and operationally practical to do so (typically within a day or two of the dredging or excavation) [Note: Confirmatory samples and baseline long-term monitoring sediment samples will be co-located at some number of locations to provide a linkage between the two data sets and a means for identifying the degree of recontamination that may be occurring/have occurred] {L-1};
3. Analyze the confirmatory sediment samples for PCBs in a manner acceptable for use in regulatory compliance demonstration with standard turnaround time {N-1};
4. Using the analytical results for the confirmatory samples collected, determine if any locations warrant immediate additional sediment removal prior to the development of a supplemental dredging or excavation plan based on a comparison of the individual sample results to pre-established action levels {P-1, Q-1}
5. Using the analytical results for the confirmatory samples collected, calculate the measure(s) of sediment PCB concentration for the overall CDA that must be compared to the applicable target PCB clean-up level(s) {R-1};
6. Determine if the overall CDA meets the applicable target PCB clean-up level(s) {S-1};
7. If the CDA meets the target PCB clean-up level(s), prepare the necessary regulatory documentation {T-1};
8. If the CDA does not meet the target PCB clean-up level(s), specify the locations and depths of supplemental dredging or excavation in that CDA (considering locations of residual contamination in any of its MUs) that is indicated to be necessary to achieve the target clean-up level(s) [Note: Consider if any archived samples collected from lower depths in the sediment column should be analyzed to refine this specification] {M-1};
9. Perform the second pass of dredging or excavation in the designated portions of that CDA identified in the supplemental dredging or excavation plan as soon as practical or at the beginning of the following work season {F-2} [Note: Progress chemical sampling or other types of performance monitoring may be performed concurrently] {H-2};

Figure 5-3
Approach 2: Compliance Demonstration Area Covering Multiple Management Units



KEY
- First Pass of Dredging or Excavation
- Second Pass of Dredging or Excavation
- Third Pass of Dredging or Excavation
- Individual Management Unit Boundary
- Compliance Demonstration Area Boundary

Approach 2:
CDA = Compliance Demonstration Area
MU = Management Unit
CDA A = MU A + MU B + MU C + MU D + MU E

10. Conduct confirmatory sampling of the post-dredging or post-excavation sediment at the depth(s) required only in those portions of the CDA that were re-dredged or re-excavated during the second pass as soon as it is safe and operationally practical to do so {L-2};
11. Analyze these second pass confirmatory sediment samples for PCBs in a manner acceptable for use in regulatory compliance demonstration with expedited turnaround time{N-2};
12. Using the analytical results for these second pass confirmatory samples together with the confirmatory sampling results for the portions of the CDA that did not receive a second pass of dredging or excavation, calculate the measure(s) of sediment PCB concentration for the overall CDA that must be compared to the applicable target PCB clean-up level(s) {R-2};
13. Determine if the overall CDA now meets the applicable target PCB clean-up level(s) {S-2};
14. If the CDA meets the target PCB clean-up level(s), authorize demobilization or restoration work to begin on this CDA, as needed, and prepare the necessary regulatory documentation {T-2};
15. If the CDA does not now meet the target PCB clean-up level(s), discuss the situation and the available data with the USEPA Site Manager {V-2};
16. If, upon review of the available information, the USEPA Site Manager determines that another pass of dredging or excavation is not warranted, demobilize or begin restoration work on this CDA, as needed, and prepare the necessary regulatory documentation {T-2};
17. If, upon review of the available information, the USEPA Site Manager determines that another pass of dredging or excavation is warranted, specify the locations and depths of focused supplemental dredging or excavation in that CDA that is indicated to be necessary to achieve the target PCB clean-up level(s) (considering locations of residual contamination in any of its MUs) [Note: Consider if any archived samples collected from lower depths in the sediment columns should be analyzed to improve this specification] {M-3};
18. Perform the third, or final, pass of dredging or excavation in the designated portions of that CDA consistent with the focused supplemental dredging or excavation plan within the same work season {F-3} [Note: Progress chemical sampling or other types of performance monitoring may be performed concurrently] {H-3};
19. Conduct confirmatory sampling of the post-dredging or post-excavation sediment at the depth(s) required only in those portions of the CDA that were re-dredged or re-excavated during the third pass as soon as it is safe and operationally practical to do so {L-3};
20. Analyze these confirmatory sediment samples for PCBs in a manner acceptable for use in regulatory compliance demonstration with standard turnaround time {N-3};
21. Demobilize or begin restoration work on this CDA, as needed {T-3};
22. Using the analytical results for these third pass confirmatory samples together with the confirmatory sampling results for the portions of the CDA that did not require a third or second pass of dredging or excavation, calculate the measures of sediment PCB concentration for that CDA that must be compared to the applicable target clean-up level(s) {R-3};
23. Determine if the CDA now meets the applicable target PCB clean-up level(s) {S-3};
24. If the CDA meets the target PCB clean-up level(s), prepare the appropriate documentation {T-3};
25. If the CDA does not now meet the target PCB clean-up level(s), prepare the necessary "off ramp" documentation as directed by the USEPA Site Manager {W}; and

26. Determine, through consultation with the USEPA Site Manager, whether the archived samples for this CDA should be discarded or if they should be retained for an additional period of time.

It should be highlighted relative to the steps outlined above that a third pass of dredging or excavation in a CDA is again not expected to be a frequent occurrence, and no fourth passes are envisioned. It also should be highlighted that once a CDA (in this case a set of multiple MUs) has been determined to have met its applicable target PCB clean-up level(s) or the USEPA Site Manager has determined that no further work in that area is warranted, confirmatory sampling and remedial dredging or excavation in that CDA is considered to be complete. At that point, no additional dredging or excavation in that area would be anticipated.

5.2.2.4 Principal Advantages and Disadvantages

In summary, the principal advantages of implementing Approach 2 include:

- Maximizes production rates for dredgers or excavators during the first pass since there will be nearly continuous sediment removal and processing during this period;
- Can be more cost-effective since standard analytical turnaround times can be used following the more sampling intensive first pass and less oversight and management costs would be required; and
- May lessen the degree or extent of recontamination of a clean MU by nearby areas that have not yet been remediated (due to the natural or man-induced mixing of sediments).

The disadvantages of implementing Approach 2 include:

- Second pass dredging or excavation may be less effective at bringing the CDA into compliance if the residual areas of highest contamination identified during the confirmatory sampling conducted in the previous season have moved or been covered over by natural forces (e.g., tides or storms during the time lag); and
- Individual MUs are not finished until the entire CDA with which it is associated is finished.

5.2.3 Warm Spot Removal Strategy

5.2.3.1 Primary Considerations

There is a concern (as discussed in Section 3.4) regarding the potential for the recontamination by resuspended and redeposited contaminated sediment of areas of the Harbor that have been cleaned.[1] This occurrence is viewed as one of the greatest potential threats to not achieving the target PCB clean-up levels. This contaminated material may be released by the remediation operations themselves, or may be mobilized by natural processes (e.g., storm surge, tides, or wind-induced wave transport). Depending on the manner of the release or resuspension of the contaminated sediment, the impact of its migration and redeposition is greatest when the PCB concentration in the mobilized sediment is highest. In recognition of this, an additional operational strategy has been proposed in which the contaminated sediment is removed in two steps. The first removal step would be an extension or continuation of the prior Hot Spot Removal Action (see Appendix A). Using this strategy, the most contaminated sediments in the Harbor would be targeted for removal first. An intermediate removal depth selected to balance PCB mass

[1] "Initial Dredging Basis of Design/Design Analysis Report. New Bedford Harbor Superfund Site. Draft." Foster Wheeler Environmental Corporation. March 2002.

removal in the first pass with operational efficiency and removal effectiveness in the second pass of dredging or excavation would be defined for the first removal step. This approach would typically result in a ratcheting down of the Hot Spot Removal Action maximum post-dredging PCB sediment concentration of 4,000 ppm.

The first pass of sediment removal targeted in this manner will not result in all of a CDA being dredged or excavated during the first removal step. Similarly, as additional dredging or excavation would be performed in all of the areas addressed during the first removal step, no confirmatory samples would need to be collected, analyzed or evaluated during the first step. A set of progress monitoring activities (see Section 3.2) could be conducted, however, to guide and adjust the on-going field effort, if needed. Confirmatory sampling would come back into play during the second removal step (i.e., via the implementation of Approach 1 or 2). The dredging or excavation approach to be applied to an area that does not meet the Warm Spot criteria would then be determined by the considerations noted previously.

If a Warm Spot was in an area that was routinely used by the public and had to be taken out of service to be remediated to the interim PCB contamination level, it is most likely that Approach 1 may be the preferred option from the outset. Similarly, if there would be significantly greater financial costs, more operational constraints or requirements, or greater liability relative to going back and subsequently reworking the former Warm Spot area during a second removal step, it again appears most likely that Approach 1 may be preferred from the outset. The corresponding confirmatory sampling approach would then be tailored to the order and timing of this operational approach. In most other cases, however, Approach 2 would be the preferred approach to be employed to follow-up the Warm Spot Removal Action. In this case, the confirmatory sampling approach to be employed would be tailored to the order and timing of Approach 2.

A Warm Spot removal approach also may be the preferred sediment removal strategy should certain limited annual funding scenarios be realized. The level of available annual funding for dredging or excavation may become the deciding factor in the selection of the overall sediment removal strategy. Significantly limited funding would tend to make the Warm Spot removal approach more logical and practical than the other approaches that would generally be sequentially applied in a north-to-south program.

It must be emphasized that additional dredging or excavation would necessarily follow the sediment removal work performed under the Warm Spot Removal Action strategy. As such, sampling for strictly for the purpose of confirmatory sampling would not be appropriate. Progress chemical sampling, however, is likely to be warranted in many cases. Confirmatory sampling would follow the dredging or excavation associated with Approaches 1 or 2.

5.2.3.2 Boundary of the Sediment Removal Activity

The Warm Spot Removal Action will be performed in all areas of the Harbor where the PCB concentration is indicated to be higher than the specified intermediate PCB target level. This boundary would be determined based on an analysis of the PCB Characterization data.

5.2.3.3 General Order and Timing of Activities Important to Confirmatory Sampling

The Warm Spot Removal Strategy, as was noted above, is not strictly an alternative to Approaches 1 or 2, but a supplementary initial phase of either approach. Figure 5-4 presents a graphical representation of the principal sequencing concepts associated with the Warm Spot Removal Strategy. As noted, the first pass of dredging or excavation selectively targets an intermediate removal depth. No confirmatory sampling would be associated with this first pass effort, as the remaining surficial sediments will be subsequently removed during the planned second step. Progress chemical sampling or other types of performance monitoring may be performed during or immediately following the first step for non-confirmatory sampling purposes.

The second step depicted on Figure 5-4 would be performed using either Approach 1 or Approach 2, depending on the circumstances of the area. The selection of an approach for the second step, including the boundaries of the CDAs relative to the identified MUs, would be confirmed at this point in the process. Some resuspension of sediment during this first step would be of less concern since these areas and much of the area immediately surrounding them would be planned for further dredging and excavation anyway.

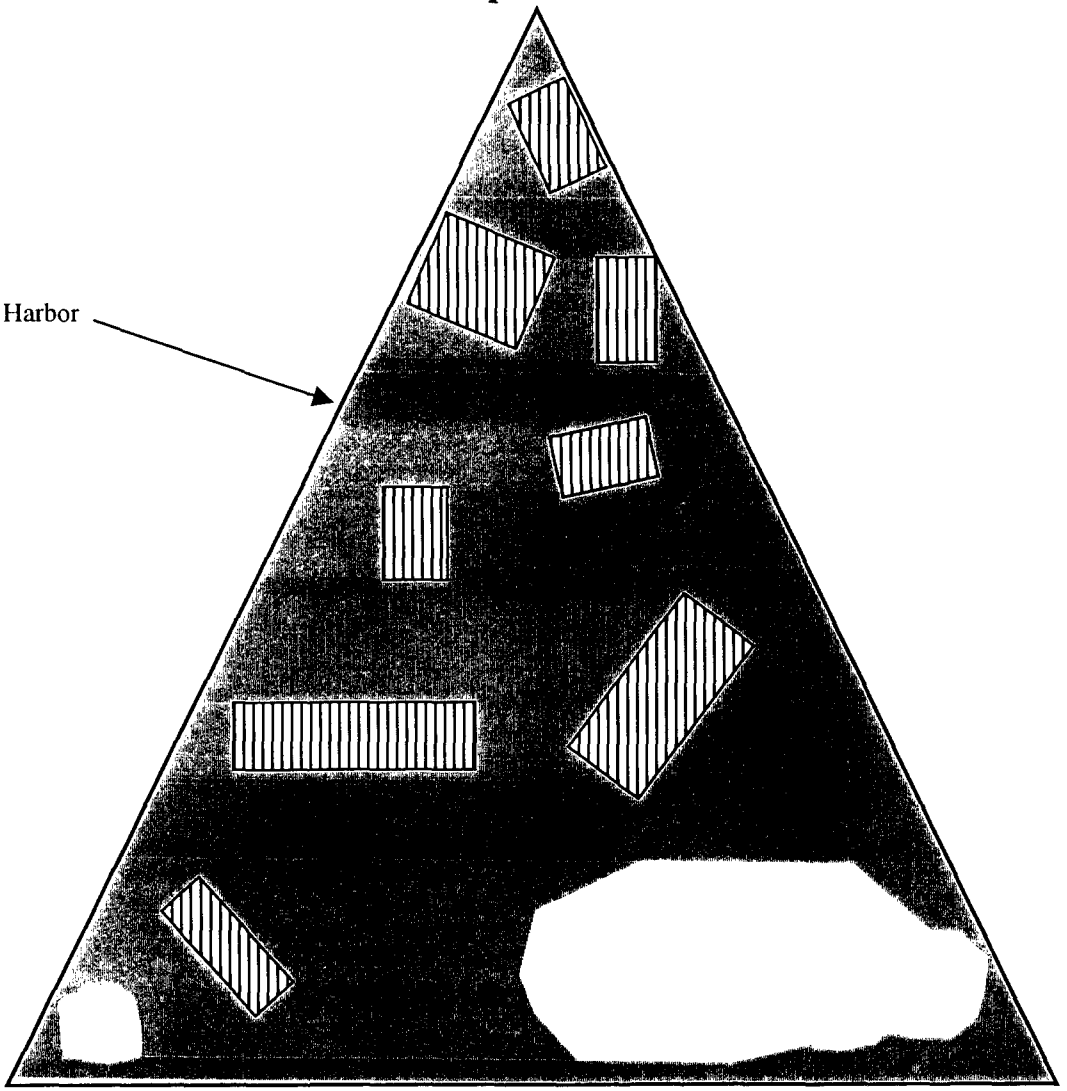
To the extent that resuspension and sediment migration (potentially from contaminated areas into areas that have already achieved the target PCB clean-up level(s)) cannot be practically controlled (e.g., as the result of storms or wind-induced wave transport), its potential impact relative to meeting the target PCB clean-up levels will be reduced as the PCB levels in the pre-dredging or pre-excavation sediment is lower. Minimizing the time between the dredging and the confirmatory sampling and testing also will help to reduce the impacts.

5.3 Relationship of Backfilling to Confirmatory Sampling

As a part of the site restoration process, clean backfill material may be placed in some dredged or excavated intertidal and upland areas. This backfill may be placed for the purpose of restoring the location to its original grade, to prevent or minimize erosion and stabilize the area, or to effect adjustments/improvements in the local habitat (e.g., promoting one species of vegetation over another). The thickness of this backfill layer will depend on the depth of the dredging or excavation performed and the site restoration plans and objectives. Depending on the exact location within the Harbor, the thickness of backfill could range from a few inches to more than a foot. Another important aspect of the backfilling is its timing. Some site restoration and backfilling will follow immediately after the verification that the dredging or excavation has achieved the specified cut elevations. In other cases, the restoration of an area may be delayed such that a few months or a year or more may pass before the backfill is placed. The thickness and the timing of the placement of the backfill must be considered relative to what confirmatory sampling is required there.

Backfill taken from a source that has been tested and certified as being "clean" (i.e., with PCB concentrations less than 1 ppm) will not be resampled after placement if the thickness of emplaced backfill is greater than or equal to the thickness of the surficial sediment layer specified for the applicable target PCB clean-up level for that area. For residential or beachcombing areas, the minimum backfill thickness to eliminate the need to confirmatory sample this surficial material in the field is 12 inches. As such, a layer of clean backfill less than 12 inches thick would need to be confirmatory sampled, as would the sediment layer below the backfill.

Figure 5-4
Warm Spot Removal Strategy to Minimize the Effects of Resuspended Contaminated Sediment



--First step targeted at sediments exceeding a specified PCB concentration

--Second step over large section of the Harbor using either Approach 1 or Approach 2 to establish compliance demonstration areas

KEY
- First Step of Dredging or Excavation
- Second Step of Dredging or Excavation
- Area not to be dredged

As the target PCB clean-up levels associated with indirect contact human health protection or ecological improvement must apply throughout the entire sediment column (i.e., at all depths), a 6 inch composite sample must be collected from the sediment just below the deepest extent of the backfill layer. The mean of the resulting PCB concentrations would need to be compared to either the 10 ppm or 50 ppm target PCB clean-up level, as applicable. It is also asserted that, lacking direct evidence to the contrary, post-removal PCB concentrations in the sediment column decrease with depth. Consequently, if the shallowest post-removal sample at a location meets the 10 ppm or 50 ppm target PCB clean-up level, the whole sediment column will be assumed to also comply and no confirmatory sampling and analysis for sediment at deeper depths will be performed.

When the backfill is not placed immediately after dredging or excavation, an uncertainty arises with respect to which target PCB clean-up level should apply to the newly exposed surficial sediment (the material that ultimately would be covered by clean backfill). During the presumably short period of time that this material is exposed, direct contact human exposure may be a possibility. However, this period of time would be short relative to the period of exposure that formed the basis of the risk-based direct contact target PCB clean-up levels (i.e., 6 to 12 years). Consequently, it is asserted that this temporarily exposed surficial sediment should be confirmatory sampled and the results compared to the applicable indirect contact human health protection and ecological improvement target PCB clean-up level (not the direct contact target clean-up levels). If the backfill is ultimately never placed, this location would need to be reassessed ensuring protectiveness relative to direct contact human exposure to PCBs.

5.4 Summary and Key Points of the Different Approaches and Strategies

In consideration of these general approaches and strategies, the two approaches outlined above display advantages and features of operational dredging or excavation flexibility relative to a broad range of circumstances. As noted, these two general approaches differ most with regard to the trade-off between start-to-finish site disturbance time (and the level of certainty associated with demonstrating compliance with the target PCB clean-up levels) and operational efficiency. In certain circumstances, preferable performance requires short start-to-finish periods of site disturbance and the minimization of impacts on the activities of the public. In other circumstances, dredging or excavation activities will be performed in areas of the Harbor with little human disturbance or in a manner that is less obstructive to the public or adjacent property owners. In these cases, the sediment removal activities can be implemented with a more systematic or deliberate approach that tends to maximize the effective use of resources and operational efficiency. Because the sediment remaining after the dredging or excavation associated with either of these two approaches would potentially be the ultimate post-dredging or post-excavation material, the confirmatory sampling program must address each one of these approaches.

The following are the key points of the general dredging or excavation approaches or strategies described in this section.

- The approach or strategy used for dredging or excavation will be selected to achieve the remediation objectives for that area.
- The level of available annual funding for the project may become the deciding factor in the selection of the overall sediment removal strategy.
- Each approach or strategy results in a specific order and timing of the principal remedial operations.
- The order and timing of these operations affects a number of core elements of a confirmatory sampling approach, or have a direct effect on the preferred specification for a core element.

- Operational dredging or excavation management units and regulatory compliance demonstration areas are defined. Management units are boundaries for specifying and managing the business and operational aspects of the sediment removal activity. A compliance demonstration area is the boundary within which achievement of the target PCB levels would be tested. A compliance demonstration area may be one or a combination of management units, depending on the overall dredging or excavation approach being applied in that area.
- Two alternative approaches, one to minimize overall area disturbance time and one to maximize operational efficiency, were identified to represent the broader spectrum of options. A complementary strategy also is described, where sediments with the highest levels of PCB contamination are removed prior to performing the dredging or excavation designed to achieve the target PCB clean-up levels. This strategy would serve to lessen the impact of potential sediment transport into and recontamination of a "cleaned" area.
- Separate confirmatory sampling approaches are required to be compatible and defensible with each overall dredging or excavation approach selected in consideration of the timing and sequencing of operations and the remedial objectives to be met.

6.0 DECISION RULE FOR STATISTICAL DESIGN

The remaining sections of this report identify and justify the critical elements of the New Bedford Harbor confirmatory sampling approach and provide a tool to aid in the development of area-specific confirmatory sampling plans based on this approach. These elements include how many samples must be collected in each CDA, where they must be collected, and how the resulting data will be used to test compliance with the target PCB clean-up levels that are applicable to that CDA.

A statistical analysis framework was used to define or recommend a number of these confirmatory sampling approach elements. This technique is derived from the statistical field of hypothesis testing, and allows specified data quality objectives to be used to estimate the minimum number of required confirmatory samples and the maximum sampling density or spacing for each CDA. This statistical analysis and its results are presented in Sections 6 through 9 of this report.

In this section, the decision rule that was identified for the statistical analysis used to calculate the minimum number of required confirmatory samples is defined, as is the regulatory compliance hypothesis to be statistically tested. Defining this rule and hypothesis corresponds to Step 5 of the formal DQO process, Develop a Decision Rule. The purpose of this step is to define the statistical parameter (sediment PCB concentration) of interest, specify the appropriate target PCB clean-up level, and integrate the previously specified DQO process outputs into a single statement that describes the logical basis for determining if the stated hypothesis is true or not.

6.1 Hypothesis Formation

Decisions based on the confirmatory sampling results will be made based on whether or not the CDA is demonstrated to meet the applicable target PCB clean-up level(s). When viewed in this way, two types of incorrect decisions (or decision errors) are possible:

1. Deciding incorrectly that the CDA meets the applicable target PCB clean-up level(s) when, in fact, the sediment PCB concentration in the CDA exceeds these levels; and
2. Deciding incorrectly that the CDA does not meet the target PCB clean-up level(s) when, in fact, the sediment PCB concentrations in the CDA are at or below these levels.

The first type of decision error is called a Type I error and the statistical chance of this type of error occurring is referred to quantitatively as alpha. The second type of decision error is called a Type II error and the statistical chance of this type of error occurring is referred to quantitatively as beta. Type I and Type II decision errors are discussed in more detail in Section 7. The statistical probability or chance of making either one of these two types of decision errors can be controlled curing the design of the sampling plan by applying the principles of hypothesis testing.

In classical hypothesis testing, the form and exact phrasing of the hypothesis to be tested is generally determined by the decision error of greatest concern. This hypothesis reflects the default assumption that must be proven to be incorrect on the basis of, in this case, the results of the confirmatory sampling, if one is to decide that the opposite of that hypothesis is really true. The specific formulation of this hypothesis must consider the Type I decision error requirements, because alpha can be controlled most directly. As failing to protect human health and the environment is the greatest potential concern, the most appropriate hypothesis for the New Bedford Harbor confirmatory sampling approach is that the CDA <u>does not meet</u> its applicable target PCB clean-up level(s). Defining the hypothesis in this way puts the burden of proof on the confirmatory sampling to provide sufficient data of high quality to disprove the assumed condition

of the hypothesis and demonstrate that the sediment PCB concentrations characteristic of the area are at or below the applicable target clean-up level(s).

6.2 Statement of Decision Rule

For the New Bedford Harbor confirmatory sampling approach, the statistical formulation of the decision rule depends on the measure of the sediment PCB concentration associated with the target clean-up level as related to the statistical hypothesis test. Section 4 presented that the ROD specifies that the 95% upper confidence limit (UCL) of the arithmetic mean sediment PCB concentration in a CDA be less than the target PCB clean-up levels that are based on direct contact human health exposure (i.e., for residential or beachcombing areas). For the target PCB clean-up levels based on indirect human health exposure and ecological improvement, the Project Team established a decision rule that requires the arithmetic average sediment PCB concentration in a CDA to be less than the specified target clean-up level.

Formally stated, the hypothesis for the New Bedford Harbor remediation program (which is symbolized as H_o to denote the "null" or default hypothesis) is:

> **H_o: The average post-dredging or post-excavation PCB concentration in the sediment of the CDA exceeds the applicable target PCB clean-up level(s).**

The "alternative" hypothesis is the inference that must be drawn if the null hypothesis is shown to not be true (which is symbolized as H_a). For decisions associated with the residential or beachcombing target PCB clean-up levels that require the 95% UCL of the arithmetic average be less than 1 or 25 ppm, respectively, is:

> **$H_{a(95\%UCL)}$: The average post-dredging or post-excavation PCB concentration in the sediment of the CDA does not exceed the lower bound of the "gray region".**

The "gray region" is a range of PCB concentrations that represents an effective lowering of the regulatory target PCB clean-up level due to the inherent sampling and analytical variability in the confirmatory sampling results. Within this range, the measured PCB concentration on a CDA is difficult to clearly distinguish from the target clean-up level due to inherent variability. The "gray region" is discussed and illustrated in more detail in Section 7.3.

The "alternative" hypothesis for decisions not associated with the residential or beachcombing target PCB clean-up level (i.e., for the 10 or 50 ppm target clean-up levels), is:

> **$H_{a(average)}$: The average post-dredging or post-excavation PCB concentration in the sediment of the CDA does not exceed the applicable target PCB clean-up level(s).**

As can be seen, the "alternative" hypothesis defined for decisions involving the 95% UCL of the arithmetic average and the arithmetic average itself are similar, but not identical. This is because of the difference in the quantitative sediment quality measure that has been established as the compliance metric for the two cases. The alternate hypothesis for the direct contact human health target PCB clean-up levels (i.e., 1 and 25 ppm), captures the stricter requirement dictated by the DQOs for that case relative to the case where the area-weighted average is the compliance metric. The "alternative" hypothesis is accepted when the null hypothesis is rejected on the basis of the statistical test performed using the confirmatory sampling data. Rejection of the null hypothesis and acceptance of the "alternative" hypothesis means that the CDA has been statistically demonstrated to be "clean".

6.3 Key Points

The following are the key points related to establishing the decision rule for the statistical design.

- A statistical analysis can be performed to specify the minimum number of samples that must be collected within each CDA and where the samples must be collected in order to meet explicitly defined data quality objectives.
- This statistical analysis relative to the specification of the confirmatory sampling approach is part of an overall DQO process defined by USEPA. The process involves a series of planning and analysis steps that increase confidence that the data collected and analyzed will be sufficient and of adequate quality for the site management decision making that must occur.
- The statistical analysis is based on the principles of hypothesis testing. In this type of analysis, a hypothesis or assumption is put forward, information is collected and analyzed to decide if the hypothesis is supported by the data or it is not.
- The site management decision that must be made based on the confirmatory sampling is whether or not the sediment PCB concentration in a CDA meets the applicable target PCB clean-up level(s).
- The null hypothesis or default assumption chosen to test, relative to confirmatory sampling, was that the post-dredging or post-excavation sediment PCB concentrations in the compliance demonstration area exceed the applicable target PCB level(s).
- As such, the CDA is assumed to be "dirty" until demonstrated to be "clean" by the confirmatory sampling.
- Given this hypothesis, two types of decision errors may occur: (1) deciding incorrectly that the CDA meets the target PCB clean-up levels, when, in fact, it does not (i.e., a Type I error); or (2) deciding incorrectly that the CDA does not meet the applicable goals when, in fact, it does (i.e., a Type II error).
- The confirmatory sampling approach was designed to control the likelihood of these errors given the PCB concentrations exhibited in the Harbor sediments and other project decision-making requirements.

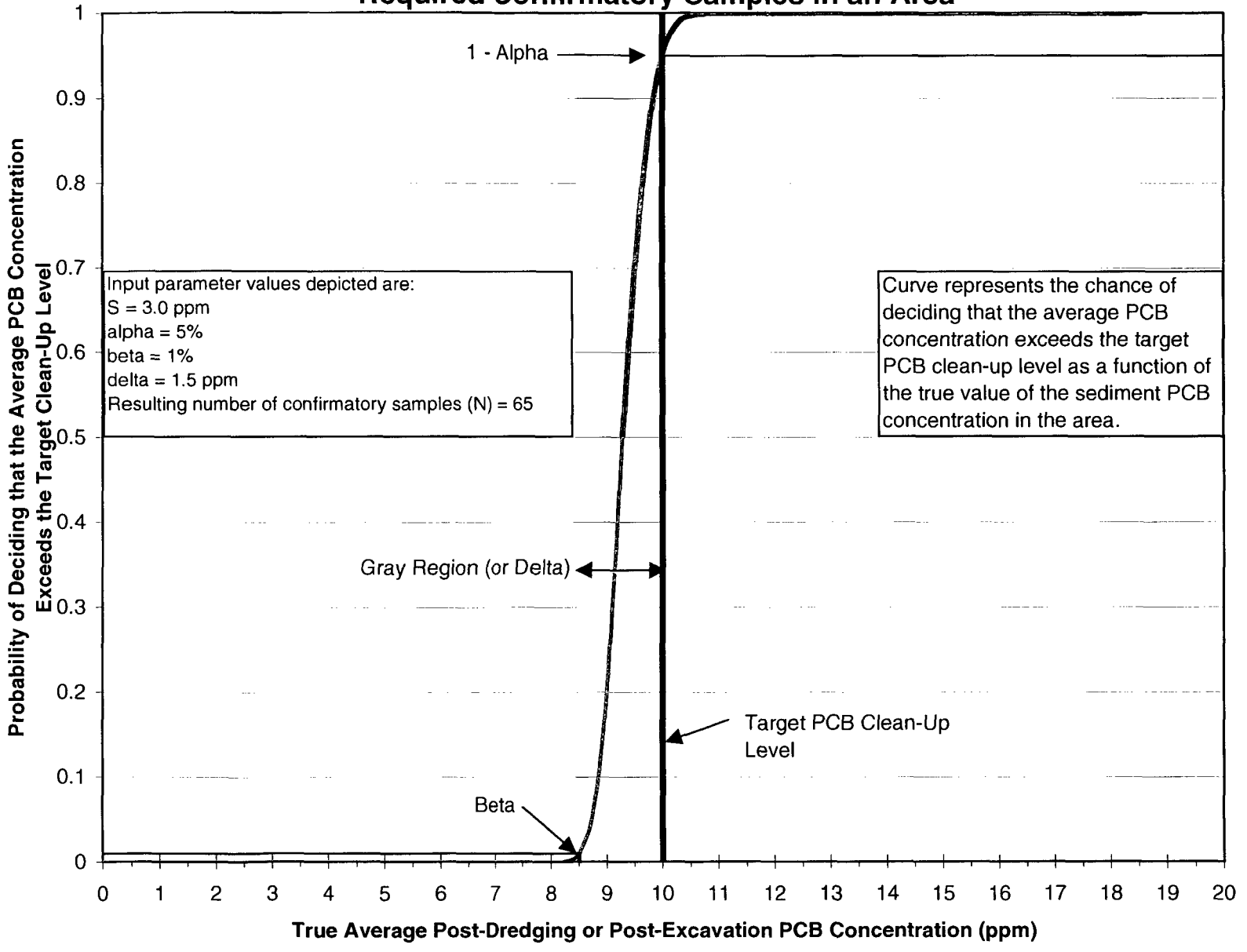
7.0 SPECIFICATION OF DECISION ERROR RATES

The number of confirmatory samples that must be collected in a CDA to achieve the a set of stated DQOs can be calculated by assigning values for four input parameters: alpha; the standard deviation of the post-dredging or post-excavation sediment concentrations; the width of the "gray region" (also called delta), and beta for each target PCB clean-up level. This section discusses the relationship among these parameters relative to developing a confirmatory sampling approach, and recommends values for these critical inputs to the statistical evaluation. This section corresponds to Step 6 of the DQO process, Specify Limits on Decision Errors, as discussed in Section 1.2.

There is a direct relationship between the probabilities of occurrence of the Type I or Type II errors (i.e., alpha and beta, respectively) and the number of confirmatory samples collected and analyzed within a specific CDA. Increasing the number of samples collected typically results in a decrease in the probabilities of making both types of decision errors. In addition, there is an inherent trade-off between alpha and beta. For a given number of confirmatory samples, a higher alpha results in a decrease in the probability of making a Type II decision error (beta), if all other relevant parameters are held constant. This particular trade-off reflects a situation where allowing more area to be judged to be clean when it really is dirty (i.e., increasing alpha), results in a lower probability of deciding to clean up an area when it is not necessary (i.e., less over-dredging or over-excavation). The probability of a Type II error is a function of the difference between the true mean of the PCB concentration in the area and the applicable target PCB clean-up level. The closer the true mean PCB concentration in an area is to the target clean-up level, the more likely it is that a Type II error will occur.

In addition to the two parameters, alpha and beta, it is necessary to specify a "gray region" of PCB concentrations in order to calculate the minimum number of samples required to be collected within a particular CDA. The concept of the "gray region" was introduced in Section 6. The width of the gray region is measured in units of PCB concentration, and is referred to as the "shift" or the parameter delta. These concepts and relationships are illustrated graphically in Figure 7-1. This gray region represents the range of mean sediment concentrations for the CDA for which a decision maker would be willing to erroneously conclude that a clean CDA was still dirty with a relatively high probability. The gray region is the range of mean PCB concentrations less than the target PCB clean-up level for which a Type II error is considered to be tolerable. It must be noted that this parameter is generally established based on regulatory policy or the USEPA Site Manager's assessment, and it is not a technical criterion. The existence of the gray region is a practical reality due to the spatial variability that is inherent to sediment PCB concentrations. The unavoidable imprecision resulting from the sample collection and PCB measurement techniques contributes to the variability typically displayed in the confirmatory sampling data. The consequence of this variability is that a decision may be practically "too close to call" when the true, but unknown, mean PCB concentration in the CDA is close in magnitude to the applicable target PCB clean-up level. Acceptable limits of alpha and beta can be assigned to control the occurrence of Type I and Type II errors above and below the gray region, respectively. The gray region is bounded on the high side by the target PCB clean-up level. The lower bound of the gray region is selected during the DQO process on the basis of project tolerance to the occurrence of a Type II error due to imprecision. As shown in Figure 7-1, the Type II error rate is equal to beta at the lower bound of the gray region. Within the gray region the Type II error rate can be seen to be substantially higher than beta. The actual probability of a Type II error is traced out by the positively sloped S-curve (i.e., it ranges from beta up to 1-alpha at the target PCB clean-up level). Given this definition of the gray region, it can be seen that only Type II decision errors can occur in the gray region. The absolute value of delta (in units of PCB concentration) has less impact on the number of samples required than the "relative shift", which is defined as the ratio of delta (or the width of the gray region) to the estimated standard deviation of the post-dredging or post-excavation PCB concentration distribution (i.e., S). The relative shift is a unitless measure of the resolution of the confirmatory sampling data. Relative shifts less than 1 (i.e., delta < standard deviation) characteristically require a large number of samples to detect.

Figure 7-1
Relationship Among the Statistical Input Parameters and the Target PCB Clean-Up Level in the Statistical Model for Calculating the Minimum Number of Required Confirmatory Samples in an Area



Relative shifts greater than 3 are generally easier to detect. An overly optimistic estimate of the post-dredging or post-excavation PCB concentration standard deviation should not be used in this type of analysis, as the consequence of taking fewer samples than are needed given the actual variability will likely result in the DQOs not being met and unnecessary additional remediation (i.e., Type II errors).

Each of the statistical input parameters is discussed below.

7.1 Alpha

The values of alpha and beta chosen for the New Bedford Harbor confirmatory sampling approach should reflect the consequences associated with making the corresponding decision error. If the consequences of making a Type I decision error increase in roughly linear fashion as the magnitude of the decision error increases, a relatively higher level of alpha may be acceptable. In practical terms, the higher the true average residual PCB sediment concentration is above the target clean-up level, the smaller is the chance the average of the confirmatory sampling results would be below the target PCB clean-up level (i.e., resulting in a Type I error). A specified alpha is the maximum probability that the mean of the confirmatory sampling results is below the target PCB clean-up level, when the true mean is just above the target PCB clean-up level. The actual probability that a dirty CDA is judged to be clean decreases below this value of alpha as the true average PCB concentration in the CDA is further above the target PCB clean-up level. This is because it becomes less and less likely that the confirmatory sampling data for a CDA would have a mean below the target clean-up level as the true mean of the CDA gets further above the clean-up level. A 5% Type I error rate is implicit in the 95% UCL approach described in the ROD. Therefore, an alpha of 0.05 (or 5%) is considered to be consistent with aspects of the ROD and is recommended for use in the statistical analysis.

7.2 Standard Deviation

Some estimate of the variability and statistical distribution of the post-dredging or post-excavation data is needed as an input to the statistical evaluation. The smaller the variability in the PCB concentrations in the post-removal sediment within each CDA, the smaller the number of confirmatory samples required to control the decision errors to specified levels. This variability has several sources, including temporal and spatial variability as well as sampling and analytical variability (i.e., the variability introduced in the act of collecting a sample or in analytical measurement). Sampling and analytical variability are generally small relative to the spatial and temporal variability in PCB concentrations in sediments throughout an area. Controlling this component of variability is primarily addressed within the Quality Assurance Project Plan (QAPP)[1]. Analytical variability can become an issue when the analytical precision or detection limits approach the target PCB clean-up level. This is not a concern relative to laboratory analysis for PCBs and the New Bedford Harbor target clean-up levels. Temporal variability is minimized by collecting data from within a CDA within as short a time as possible following the dredging or excavation. Temporal issues are also discussed in Section 3 of this report. Dividing the overall study area into CDAs that are relatively homogeneous in post-remediation PCB concentration also reduces spatial variability. Nonetheless, there are obvious physical constraints on how much this source of variability can be reduced. As such, it must be explicitly considered.

Estimates for variability as inputs to subsequent steps of the DQO process and calculations of the number of confirmatory samples required to meet the DQOs were developed based on a review of previous assumptions used for this site and an analysis of the PCB Characterization data. The statistical measure generally used to describe this variability is the standard deviation (S). The S of interest is the square root

[1] Foster Wheeler, 2001. Quality Assurance Project Plan, New Bedford Harbor Superfund Site. November.

of the variance of the confirmatory sampling data obtained at the projected final cut elevation. The S reflects spatial heterogeneity and sample collection and analytical measurement variability.

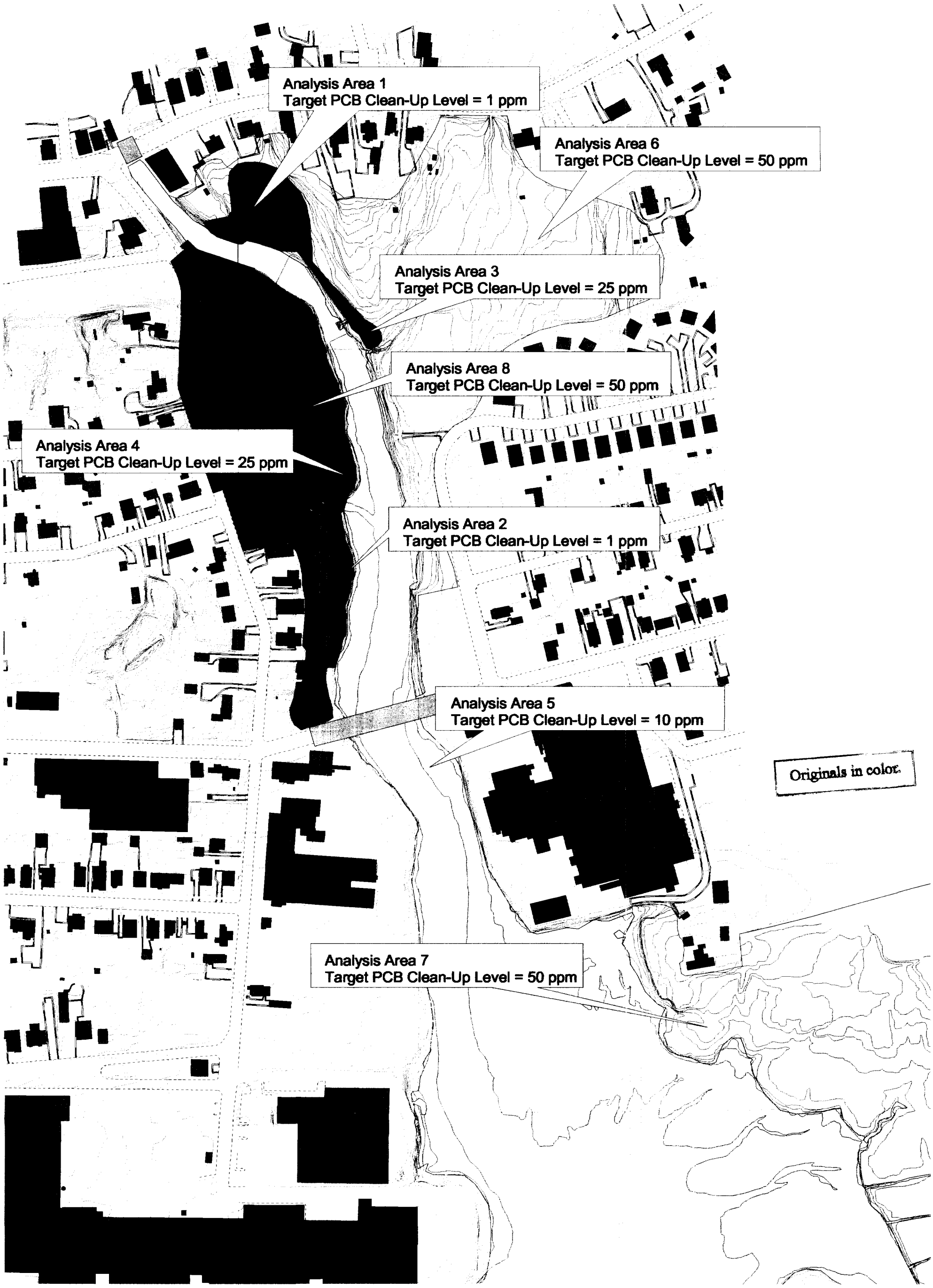
During the Hot Spot Removal Effort (see Appendix A), a statistically designed post-dredging sampling program was developed and implemented. This sampling plan was based on USEPA guidance for hot spot characterization that was in force at that time. The assumption made in the design of this sampling program was that S was equal to 0.3 times the mean PCB sediment concentration. This assumption was applied in the context of the relatively large range of variability associated with the hot spots (where typical sediment PCB concentrations exceeded 4,000 ppm). It should be highlighted that assuming a larger S for the confirmatory sampling calculation for a CDA results in a greater number of samples being required to meet a given set of DQO.

Within the PCB Characterization database (including samples collected after the Hot Spot Removal Effort), many sample locations exhibited "clean" samples found below "dirty" samples (where "clean" refers to samples below the applicable target PCB clean-up level at that location and "dirty" refers to samples above the target PCB clean-up level at that location). Conceptually, after dredging or excavating to the depth required to remove the "dirty" material, the concentration in the "clean" sample directly below that would be an estimate of the sediment PCB levels a confirmatory sample would measure (assuming no recontamination). Thus, an analysis of groups of these samples was performed within a number of areas around the Harbor with the goal of estimating S. Groups of "post-removal" samples were identified for eight different analysis areas, each area having a specific target clean-up level. The average and standard deviation of the projected "post-removal" samples from each of these areas were then calculated. The areas are shown on Figure 7-2 and the results of the calculations are presented in Table 7-1.

Table 7-1
Mean and Standard Deviation of the Projected "Post-Removal" Sediments in Areas with Different Target PCB Clean-Up Levels
(Based on the PCB Characterization Data)

Analysis Area	Target PCB Clean-Up Level (ppm)	Number of "Post-Removal" Samples in Data Set	Mean of Samples (ppm)	Standard Deviation of Samples (ppm)	Standard Deviation/ Target PCB Clean-Up Level (unitless)
1	1	7	0.36	0.25	0.25
2	1	4	0.17	0.22	0.22
3	25	5	6.9	5.0	0.20
4	25	4	0.64	0.34	0.014
5	10	37	3.7	2.8	0.28
6	50	13	1.5	1.7	0.034
7	50	8	10	12	0.24
8	50	23	2.3	9.8	0.20

It can be seen from Table 7-1 that the mean of the "clean" samples below the "dirty" samples is typically well below the target PCB clean-up level designated for that area. It should also be noted that a linear relationship appears to exist between the S of the samples and the target PCB clean-up level (see the similarity in the ratios presented in the last column). A larger target PCB clean-up level would be associated with a wider range of concentrations because of the larger difference between the target PCB clean-up level and a non-detect value.



Analysis Area 1 Target PCB Clean-up Level = 1 ppm
Analysis Area 2 Target PCB Clean-up Level = 1 ppm
Analysis Area 3 Target PCB Clean-up Level = 25 ppm
Analysis Area 4 Target PCB Clean-up Level = 25 ppm
Analysis Area 5 Target PCB Clean-up Level = 10 ppm
Analysis Area 6 Target PCB Clean-up Level = 50 ppm
Analysis Area 7 Target PCB Clean-up Level = 50 ppm
Analysis Area 8 Target PCB Clean-up Level = 50 ppm

N

100 0 100 200 Feet

FOSTER WHEELER
FOSTER WHEELER ENVIRONMENTAL CORPORATION
133 FEDERAL STREET, BOSTON, MASSACHUSETTS 02110

NEW BEDFORD HARBOR SUPERFUND SITE
BRISTOL COUNTY, MASSACHUSETTS

FIGURE 7-2
Locations of the Analysis Areas Used to Estimate the Standard Deviation of the Post-Dredging and Post-Excavation PCB Sediment Data

MA STATE PLANE
NAD 83 FEET
NGVD 29
1 FOOT CONTOUR INTERVAL
5 FOOT INDEX CONTOUR INTERVAL

DRAFT: MARCH 21, 2002

P:\GIS\WBH\WORKDIR\11x17_analysis_areas.apr

Compliance with the target PCB clean-up levels is to be evaluated based on the arithmetic mean or the 95% UCL of the arithmetic mean of the post-removal PCB concentration. Adopting this measure of the sediment PCB concentration assumes that the arithmetic average is a reasonable estimate of central tendency, that is, the center of the distribution. This assumption is valid if either the underlying PCB concentration distribution is normally distributed or is based on a large number of samples even if the underlying distribution itself is not normally distributed. The reasonableness of this assumption was evaluated based on an analysis of the eight data sets used in the analysis summarized in Table 7-1 using the Analyze-It software statistical tools. The results of the evaluations of the distributions of PCB concentrations in each analysis area are provided in Appendix C. Based on this evaluation, the assumption that the post-removal sediment PCB concentrations in a CDA will be normally distributed is reasonable.

7.3 Delta

Delta, as was previously noted, is the width of the gray region. As discussed in Section 7.0 (third paragraph and Figure 7-1), the probability of a Type II error increases substantially within the gray region. How much this probability increases is a function of the true mean of the post-excavation or post-dredging PCB concentration and the form of the "alternative" hypothesis (refer to Section 6.2). For the $H_{a(95\%UCL)}$ approach, a Type II error can occur in two different ways. One way is when the average of the confirmatory sampling results is below the applicable target PCB clean-up level but the 95% UCL of the average is not below the target PCB clean-up level. The 95% UCL is closer to the average when the number of confirmatory samples, N, is larger. This is a consequence of many factors. First, because N is in the denominator of the factor that is the difference between the 95% UCL and the mean (see Section 7.4.2), and when computing the factor, S is divided by the square root of N. Second, the t-value used as a multiplicative parameter in this factor is smaller as N increases (the formula for the UCL is provided in Section 7.4.2). Consequently, in this situation additional confirmatory samples could be collected to increase N, and bring the 95% UCL closer to the mean. This reduces the probability of this form of Type II error. The other way a Type II error can occur is when, just due to chance, the confirmatory samples happen to come from areas of relatively higher concentrations than the overall average of the CDA. For the $H_{a,(average)}$ approach, Type II errors can occur only for this latter reason.

Because the Type II error rate increases substantially within the gray region, it is important to select a value of delta that minimizes the likelihood that the average of the confirmatory sampling data set will fall within the gray region. This can be achieved by over-excavating or over-dredging such that the anticipated average is well below the gray region, or it can be achieved by selecting a value of delta that is reasonably small relative to the target PCB clean-up level. As discussed previously in Section 7.0, if the latter approach is selected, then the required number of confirmatory samples, N, increases. In general, it is desirable that delta is between 1 and 3 times S, but for the 1 and 10 ppm target PCB clean-up levels this is not practical as the gray region would become relatively large as compared to the target clean-up level. If the gray region is too large there would be a fairly high probability that the post-dredging or post-excavation average PCB concentration would fall within the gray region, potentially leading to the need to collect additional samples or unnecessary sediment removal. In larger CDAs, the cost of over-excavating or over-dredging is likely to far exceed the cost of collecting additional samples. Marginal over-dredging or over-excavation may not be prohibitive in a small CDA that may be associated with a residential or beachcombing area that requires remediation. Again, specification of the parameter delta is typically a policy decision, supported by some amount of cost-benefit analysis.

7.4 Beta

The Type II error rate is the risk of deciding that additional sediment removal is needed when the CDA actually already meets the target PCB clean-up level(s). For the $H_{a,(95\%UCL)}$ approach, the Type II error rate at the lower bound of the gray region is equal to beta (see Figure 7-1). Within the gray region the Type II error rate at the target clean-up level increases to 1-alpha. For the $H_{a,(average)}$ approach, the Type II error rate is equal to beta at the lower bound of the gray region, but reaches a maximum of only 50% at the target PCB clean-up level (Note: This case is not depicted on Figure 7-1). Beta is selected based on the desired Type II error rate at the lower bound of the gray region.

The costs associated with a Type II decision error are typically non-linear and vary depending upon the characteristics of the CDA and the approach to excavation or dredging applied in that CDA. If it is expected that a CDA will be so thoroughly remediated that any remaining PCBs are at concentrations that are well below the target PCB clean-up level, a relatively larger value of beta may be appropriate. However, as this situation is difficult to project in advance with high confidence (especially for the lower target PCB clean-up levels) and over-dredging or over-excavation at New Bedford Harbor is generally a much greater financial risk than is the collection and analysis of a few additional sediment samples, specifying a relatively larger value for beta is generally not recommended. Given the review of the PCB Characterization data, mean PCB concentrations farther below the target clean-up levels may be observed for 25 and 50 ppm areas. In this case, a somewhat higher value of beta may be justifiable. Where the anticipated average post-removal PCB concentration is expected to be very near the target PCB clean-up level, a relatively lower value of beta is usually required. This is because the confirmatory sampling results for these CDAs have a substantial likelihood of falling within the concentration range defined by the gray region, and beta should be minimized to avoid unnecessary remediation costs.

7.4.1 Decision Errors for Indirect Human Health and Ecological Improvement Target PCB Clean-up Levels

As discussed in Sections 4.1.1, 4.1.2, and 4.1.5, the 10 ppm and 50 ppm target PCB clean-up levels are based on indirect exposure human health risks and ecological improvement. Therefore, the average post-excavation or post-dredging PCB concentrations in these areas should be less than the target clean-up level. Many of the CDAs for these areas may be relatively large and associated with correspondingly greater remediation costs. Therefore, beta should be specified at a relatively small value. This is particularly of concern for large unvegetated or subtidal areas where the target PCB clean-up level is only 10 ppm, while the estimated S and delta are 3 and 1.5 ppm, respectively (see Section 8.1). In these areas, if the average post-excavation or post-dredging PCB concentration is greater than the lower bound of the gray region (or greater than 10 – 1.5 = 8.5 ppm), the probability of a Type II error ranges from beta up to 0.5. Just below the lower bound of the gray region the chance of a Type II error decreases from beta to nearly zero as a consequence of changes in S and N. The larger S is, the further downward this area extends. The smaller N is, the further downward this area extends. As S is fairly high, it is desirable to have a low beta and a high N. In consideration of these factors, the recommended beta for the 10 ppm target clean-up level areas is 0.01 (1%).

Based on the available data set, it is likely that the post-dredging PCB concentrations within the CDAs with a 50 ppm target clean-up level are more likely to result in average concentrations below 50 ppm. If this is so, delta for these areas can potentially be somewhat higher, possibly equal to the standard deviation. The highest estimated S for an analysis area with target PCB clean-up level of 50 ppm was 12 (see Table 7-1). Therefore, the recommended value for S and for delta is 12. This means that if the average post-dredging or post-excavation PCB concentration is really less than 50-12=38 ppm, the highest probability of a Type II error is equal to beta. If the average PCB concentration is really between 38 and 50 ppm, the chance of making a Type II decision error ranges from beta up to 50% (if the average

concentration is exactly 50 ppm). Because these areas are more likely to be larger and may be more costly to excavate or dredge, beta again should be minimized.. Therefore, acceptable levels of beta are generally recommended to be on the order of 0.01 or 0.05 (i.e., 1% to 5%).

7.4.2 Decision Errors for Direct Contact Human Health Target PCB Clean-Up Levels

Achievement of the residential and beachcombing target PCB clean-up levels (1 and 25 ppm, respectively) is to be evaluated by comparing the 95% UCL for the arithmetic mean to the target PCB clean-up level. This is mathematically equivalent to the hypothesis testing example where alpha = 0.05 using the One-sample t-Test and a null hypothesis that the true mean exceeds the target clean-up level. The formula for the upper one-sided 95% confidence limit for the true mean PCB concentration (where the true standard deviation is estimated by S) is:

$$UCL_{0.95} = \bar{X} + t_{0.95,N-1} \cdot \left(S/\sqrt{N}\right) \qquad \text{(which must be less than C)}$$

Where:

$UCL_{0.95}$	=	the upper one-sided 95% confidence limit of the mean PCB concentration in the CDA (i.e., the 95% UCL value)
$\bar{X}$	=	the arithmetic average of the confirmatory samples collected in the CDA
$t_{0.95,N-1}$	=	t-statistic value for 1-alpha equal to 0.95 with N-1 degrees of freedom
S	=	standard deviation of the confirmatory samples
N	=	number of confirmatory samples collected and analyzed
C	=	the target PCB clean-up level

The One-sample t-Test statistic, which would be used to perform hypothesis testing, would be calculated as:

$$t = \left(\bar{X} - C\right) / \left(S/\sqrt{N}\right)$$

and the null hypothesis is rejected (that is the unit is considered to be clean) when t is less than $-t_{0.95,N-1}$ (i.e., the negative of the t-statistic value defined above).

The residential and beachcombing CDAs are likely to be relatively smaller and less than 10 acres in size. Areas actually requiring sediment removal in any one of these CDAs is likely to be half an acre or less. The overall cost of over-dredging or over-excavation in a small CDA may not be considered excessive in most of the residential or beachcombing areas in consideration of other operational and site management factors. For the 1 ppm areas, the recommended value for delta is 0.125, or one-half of the highest estimated S (0.25 ppm – see Section 8.1). This corresponds to a reasonably small gray region. For the 25 ppm target clean-up level, the anticipated post-excavation or post-dredging average PCB concentration is expected to be farther below the target PCB clean-up level. Therefore, for the 25 ppm target clean-up level, the recommended value for delta is equal to the highest observed S, or 5 ppm. In consideration of all pertinent factors, a larger beta for these small areas may be more acceptable and more consistent with the overall operational philosophy. As discussed previously, Type II errors can be addressed by taking additional samples if the average of the confirmatory samples is below the target PCB clean-up level but the 95% UCL is above the target PCB clean-up level. Therefore, the recommended beta for the 10 ppm and 25 ppm target PCB clean-up levels is 0.20 (20%).

7.5 Key Points

The following are the key points relative to the specification of decision error rates and the other statistical input parameters.

- The hypothesis testing analysis allows an equation to be developed for the minimum number of confirmatory samples required to be collected and analyzed in a CDA to meet specified data quality objectives.
- This equation depends on four principal parameters and an assumption about whether the post-dredging or post-excavation PCB concentration distribution in the sediments in "parametric" (i.e., is normal (bell curve) or lognormal (skewed bell curve)) or not (this is discussed further in Section 8.0).
- As not assuming a "parametric" concentration distribution from the confirmatory samples results in a slightly larger number of required samples, a non-parametric distribution was conservatively assumed for these calculations.
- Two of the four principal statistical inputs to the equation are the probabilities of making a Type I and a Type II decision error, referred to as alpha and beta, respectively. Alpha was considered from a number of perspectives (primarily human health protectiveness and regulatory precedence) and a value of 0.05 (5%) was recommended for this parameter. Alpha is a policy parameter that must be confirmed by the USEPA Site Manager.
- Beta is related to the probability of deciding that a "clean' area is "dirty" and unnecessarily performing supplemental dredging or excavation. As such, beta is a control on cost risk and is typically selected based on a cost-benefit analysis. A simple qualitative cost-benefit analysis was conducted and one of two values of beta, 0.01 (1%) or 0.20 (20%), was recommended based on the size of the CDA, operational circumstances, and USEPA Site Manager preferences. Beta is partially a policy parameter that must be confirmed by the USEPA Site Manager.
- The third principal parameter is the projected standard deviation in the post-removal confirmatory sampling PCB concentration results for the CDA. This standard deviation must reflect the total sampling and analytical variability in the samples collected following dredging or excavation. This parameter was estimated based on an analysis of the pre-dredging and pre-excavation PCB Characterization data. Care was taken to not knowingly underestimate the standard deviation, as this would lead to a low number of required confirmatory samples that may not be sufficient for meeting the DQOs given actual site conditions. The calculation of the number of required confirmatory sample is very sensitive to the assumed standard deviation. Recommendations for the standard deviation were made for each target PCB clean-up level based on the analysis of the Harbor-specific PCB Characterization data.
- The fourth principal parameter is the "gray region", a range of sediment PCB concentrations just below the specified target PCB clean-up level within which, given the inherent variability in the confirmatory sampling data, it may be "too close to call" whether the area is "dirty" or "clean". As the hypothesis to be tested puts the burden of proof on the sampling (i.e., the CDA is assumed dirty until demonstrated to be clean), there is an appreciable likelihood of deciding to further dredge or excavate a clean area when the areas' true average PCB concentration is close to the target PCB clean-up level. The number of required confirmatory samples also is very sensitive to the width of the gray region. Great intolerance to drawing an incorrect conclusion given the inherent variability (i.e., a narrow gray region), causes the

number of required confirmatory samples to increase dramatically. A greater tolerance of potentially dredging or excavating areas that really do not need it (i.e., accepting a wider gray region) leads to a reduction in the number of required confirmatory samples. Upon consideration of this parameter, values of delta were recommended relative to the value of the standard deviation. A gray region equal in width to the standard deviation was recommended for the two highest target PCB clean-up levels, while a gray region equal to 1/2 the standard deviation was recommended for the two lowest target PCB clean-up levels. Delta is partially a policy parameter that must be confirmed by the USEPA Site Manager.

8.0 STATISTICAL DESIGN FOR CALCULATING THE NUMBER OF REQUIRED CONFIRMATORY SAMPLES AND SAMPLE SPACING

This section continues the implementation of the DQO process and describes Step 7, Optimize the Design for Obtaining Data, as discussed in Section 1.2. The estimates of the recommended number of samples for each target PCB clean-up level and the corresponding sampling spacings for different size CDAs are presented in this section.

8.1 Sample Size Estimates for Target PCB Clean-Up Levels

For situations where the decision statement is "Is the true mean PCB concentration in the post-removal sediments less than the applicable target PCB clean-up level?", the appropriate statistical test is the One-sample t-Test (USEPA QA/G-9[1]). The other situations where the decision statement is "Is the 95% UCL of the arithmetic mean PCB concentration in the post-removal sediments less than the applicable target PCB clean-up level?" also can be treated as an estimation problem, but this approach does not allow for the explicit evaluation and control of beta. Therefore, sample sizes were estimated using the hypothesis testing (not statistical testing) approach, with the null hypothesis structured to correspond to the 95% UCL approach, as described previously in Section 7.

The computer program Visual Sample Plan (VSP) (PNNL, 2001b) was used to calculate the minimum number of confirmatory samples required to be collected in a CDA in order to demonstrate with a certain level of confidence that the CDA had or had not achieved the applicable target PCB clean-up level. VSP was used to implement a relationship that takes into account the anticipated variability and specified decision error limits in calculating the number of samples required to test an assumed hypothesis (see Sections 6 and 7). The mathematical assumptions needed to perform this test are specified in the Visual Sample Plan Models and Code Verification (PNNL, 2001a). These required assumptions are that the data:

- Are representative of the study site (i.e., CDA);
- Are not spatially or temporally correlated; and
- Have a symmetric (but not necessarily normal) distribution.

The equation used by VSP to calculate the minimum number of samples needed for the One-sample t-Test (assumed parametric distribution for the samples collected within a CDA) is the following:

$$N = \frac{S_{total}^2 \cdot \left(Z_{1-\alpha} + Z_{1-\beta}\right)^2}{\Delta^2} + 0.5 \cdot Z_{1-\alpha}^2$$

The equation used by VSP to calculate the minimum number of samples needed for an alternate test (appropriate for CDAs with PCB concentrations that are not necessarily parametric in nature – i.e., the Wilcoxon Signed Ranks Test) is the following. [Note that the equation is equivalent to the equation for the One-Sample t-Test, with a 16% increase to account for the additional samples required to test a non-parametric distribution]:

$$N = 1.16 \cdot \left[\frac{S_{total}^2 \cdot \left(Z_{1-\alpha} + Z_{1-\beta}\right)^2}{\Delta^2} + 0.5 \cdot Z_{1-\alpha}^2 \right]$$

[1] "Guidance for Data Quality Assessment: Practical Methods for Data Analysis, USEPA QA/G-9, QA00 Update", USEPA, July 2000

Where:

N	=	the minimum required number of confirmatory samples that should be collected from the CDA
S_{total}	=	the estimated standard deviation of the post-removal PCB concentrations in the confirmatory samples (reflecting both sampling and analytical variability) [ppm]
$Z_{1-\alpha}$	=	the value from the standard normal distribution for which the proportion of the distribution to the left of $Z_{1-\alpha}$ is $1-\alpha$, where α is the probability of a Type I error (i.e., alpha)
$Z_{1-\beta}$	=	the value of the standard normal distribution for which the proportion of the distribution to the left of $Z_{1-\beta}$ is $1-\beta$, where β is the probability of a Type II error (i.e., beta)
Δ	=	the width of the "gray region" or delta (see Figure 7.1) [ppm]

A brief sensitivity analysis was performed to determine which of these four statistical input parameters has the greatest effect on the number of confirmatory samples. The table summarizing this analysis is included as Appendix D. Based on this sensitivity analysis, it was determined that the standard deviation, delta, and beta were the most sensitive parameters in this equation with respect to determining the minimum number of required confirmatory samples for a CDA.

VSP was used to calculate the required number of samples for each of the target PCB clean-up levels using the previously described values for alpha, beta, the width of the gray region (delta) and estimates of the variability in the confirmatory samples (S). The results of these calculations are presented in Table 8-1. Conservative estimates of S and delta were selected to ensure that the specified alpha and beta are achieved. In addition to sample size estimates based on normality, sample sizes also were estimated for the assumption of a non-parametric data distribution. Although available data indicate that normality is a reasonable assumption (and that parametric statistical analysis is appropriate), it is possible that the actual confirmatory sampling data may warrant non-parametric statistical analysis. As non-parametric estimates of the number of required confirmatory samples are only slightly larger than parametric estimates, it is recommended that the non-parametric number of samples be collected. If, as anticipated, the confirmatory sampling data is in fact normally distributed, then the power of the resulting parametric statistical tests will be higher and beta will be smaller than the specified beta.

Table 8-1
Initial Sample Size Estimates for Various Estimates of Beta

Target PCB Clean-Up Level (ppm)	Estimated Post-Removal Standard Deviation [1] (ppm)	Alpha [2] (unitless)	Delta (ppm)	Beta (unitless)	Number of Required Confirmatory Samples	
					Parametric Distribution	Non-Parametric Distribution
1	0.25	0.05	0.125 [3]	0.2	27	31
1	0.25	0.05	0.125 [3]	0.1	36	42
10	3.0	0.05	1.5 [3]	0.05	45	52
10	3.0	0.05	1.5 [3]	0.01	65	75
25	5	0.05	5 [4]	0.2	8	9
25	5	0.05	5 [4]	0.1	10	12
50	12	0.05	12 [4]	0.2	8	9
50	12	0.05	12 [4]	0.05	13	15
50	12	0.05	12 [4]	0.01	18	20

Notes:
[1] Highest value from the site-specific study for Analysis Areas with each target PCB clean-up level (see Table 7-1 - 10 ppm standard deviation of 2.8 rounded up to 3.0)
[2] Protective value consistent with ROD 95% UCL approach
[3] Set at a value less that Delta/Standard Deviation = 1 (Delta/Standard Deviation =0.5) to further minimize Type II errors for the lowest target PCB clean-up levels
[4] Set at a value such that Delta/Standard Deviation = 1

8.2 Optimizing the Statistical Design

In the last step of the DQO process, the minimum required confirmatory sample size estimates from the previous step are evaluated relative to available resources, and if necessary the DQOs are revised, such that the sampling program is adjusted to meet the specified constraints, consistent with the available resources. This evaluation may include considering techniques to further reduce sampling or analytical variability (S), adopting a different value of delta, or considering higher decision error rates (alpha and beta). Lastly, a corresponding confirmatory sampling grid design is identified. An initial effort to consider and balance these factors was made with the goal of recommending a scientifically defensible and practical number of confirmatory samples. This initial analysis is described below. A more formal or detailed evaluation may be desired by the USEPA Site Manager once more details of the remediation operations and their associated costs are known.

8.2.1 Optimizing S and Delta

It is apparent from Table 8-1 that beta noticeably impacts the number of confirmatory samples required, N. Specifically, lowering beta results in higher N, especially when delta is less than S, as in the case of the 1 and 10 ppm clean-up levels. Although S may be decreased or delta increased, the values shown in Table 8-1 represent reasonably conservative estimates for these parameters. The estimates for S are based on the site-specific PCB Characterization data and, as discussed previously, overly-optimistic estimates of S should be avoided or the DQOs may not be met. Variability (and consequently, S) can be reduced by defining CDAs such that the distribution of PCB concentrations within their boundaries is more homogeneous. This approach is a part of the planned design for dredging or excavation. Using composite sampling, which is a type of physical averaging, can also reduce S. This option has been explored relative to project needs and has been found to have some advantages in certain circumstances. However, spatial compositing of samples prior to chemical analysis has not been selected as the default sampling approach. The recommended method of sample collection is such that individual samples are collected to be representative of the 6 inch or one foot sediment depth interval at a particular location as discussed in Section 10. As such, the samples are a vertical composite of a 6 inch or one foot interval. If delta is increased, the width of the gray region increases. If the gray region is wider, then the average concentration of PCBs in each CDA would need to be even lower (i.e., below the target PCB clean-up level minus delta) to be able to judge that CDA to be clean. The values shown in Table 8-1 are believed to represent the largest values of delta that might reasonably be acceptable to the USEPA Site Manager and the site stakeholders.

8.2.2 Optimizing Alpha and Beta

It is apparent from the equations shown in Section 8.1 that the physical size of the CDA does not have a direct impact on the calculation of the minimum number of confirmatory samples required, unless the physical size is considered indirectly in the selection of alpha or beta. The ROD effectively established alpha at 0.05. But as may be recalled from Section 7.3, the choice of beta impacts the potential for unnecessary remediation costs. Ideally the choice of beta should reflect the magnitude of this cost. As this cost is a function of both the type of excavation or dredging required and the size of the area being addressed, beta may be justifiably higher for relatively small areas or for areas where the type of excavation or dredging required is relatively less expensive. Conversely, beta should be minimized for larger areas or areas requiring relatively expensive dredging or excavation techniques. Recommended values of beta for each of the combinations of target PCB clean-up levels for different sized CDAs are presented in Table 8-2.

Table 8-2
Number of Confirmatory Samples and Suggested Grid Spacings for Various Compliance Demonstration Area Sizes

Target PCB Clean-Up Level (ppm)	Size of the Compliance Demonstration Area (acres)	Statistical Input Parameters				Number of Required Confirmatory Samples	Size of Square Sampling Grid (feet)
		Projected Post-Removal Standard Deviation (ppm)	Alpha (unitless)	Beta (unitless)	Delta (ppm)		
1	< 0.5	0.25	0.05	0.20	0.125	**31**	**< 15**
1	0.5 – 1.0	0.25	0.05	0.20	0.125	**31**	**15 – 25**
1	1.0 – 5.0	0.25	0.05	0.20	0.125	**31**	**25 – 50**
25	< 0.1	5	0.05	0.20	5	**9**	**< 15**
25	0.1 – 0.3	5	0.05	0.20	5	**9**	**15 – 25**
25	0.3 – 1.0	5	0.05	0.20	5	**9**	**25 – 50**
25	> 1.0	5	0.05	0.20	5	**9**	**> 100**
10	< 5.0	3	0.05	0.20	1.5	**31**	**< 80**
10	5.0 – 10	3	0.05	0.01	1.5	**75**	**50 – 75**
10	10 – 20	3	0.05	0.01	1.5	**75**	**75 – 100**
50	< 5.0	12	0.05	0.20	12	**9**	**< 150**
50	5.0 – 10	12	0.05	0.01	12	**20**	**100 – 145**
50	10 – 20	12	0.05	0.01	12	**20**	**145 – 225**

Note: The maximum size of a square confirmatory sampling grid, L, is calculated using the following equation:

$$L[ft] = \sqrt{\frac{CDA\ Size[acre] \cdot 43{,}560[ft^2/acre]}{N[number\ of\ confirmatory\ samples]}}$$

For samples locations within CDAs less than 5 acres with the 1/50 target PCB clean-up level areas, only 1 out of every 3 non-surficial samples collected would need to be analyzed to achieve the stated beta and other DQOs.

8.3 Selection of Sampling Grid Design

The statistical methods discussed in this report assume that the sampling is conducted randomly, that is any point within the CDA has an equal chance of being selected as a confirmatory sampling location. Two selection methods are typically employed to randomly select sampling locations: simple random sampling or grid sampling. Grid sampling is preferred for the work at New Bedford Harbor as it is generally convenient to implement in the field, can provide better precision, and ensures more complete coverage of the CDA than unrestricted random sampling. The selection of grid sampling also is consistent with USEPA guidance (USEPA, 2000c). The whole project area has been geo-referenced to the Massachusetts State Plane grid system. This site-wide reference framework provides a number of operational benefits. Using this established framework, a pattern of square confirmatory sampling grids of a specified size will be defined. As previous data collection efforts and remedial actions have utilized this square (northing and easting) reference grid system, it is desirable to continue to utilize a compatible approach for the confirmatory sampling approach. Consequently, although a triangular grid system is slightly more efficient, the benefits of a consistent co-ordinate system are judged to outweigh the modest gains in efficiency.

A square confirmatory sampling grid pattern will be superimposed on the CDA. The anchor point or starting position for this sampling grid will be selected using a random process. The length, L, of the side of the square used to generate the pattern becomes the distance between sampling locations, as samples will be collected from the nodes of this grid pattern within the boundary of the CDA. The minimum number of required confirmatory samples, N (calculated based on the statistical tests), is used to determine the maximum spacing, L, of the gridlines.

$$L[ft] = \sqrt{\frac{CDA\ Size[acre] \cdot 43{,}560[ft^2/acre]}{N[number\ of\ confirmatory\ samples]}}$$

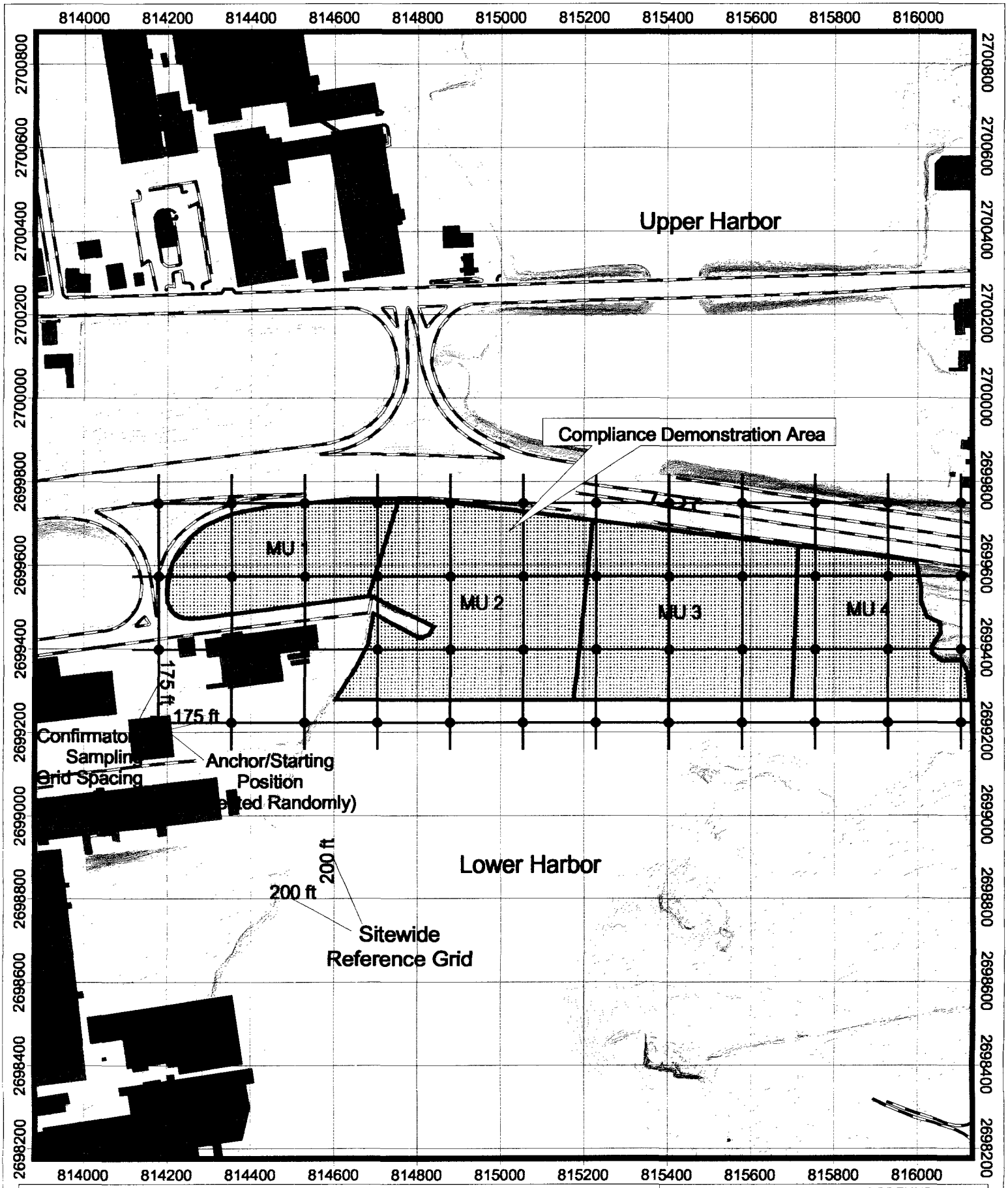
After L is determined, the anchor point or starting position for this sampling grid will be selected using a random process. The first node of the confirmatory sampling grid will be placed at this anchor point. The rest of the confirmatory sampling grid will be constructed by drawing more north-south and east-west grid lines spaced L feet apart relative to this starting position. An illustration of this process of randomly anchoring and constructing a square confirmatory sampling grid pattern for a CDA is presented in Figure 8-1.

If identified sampling locations (i.e., grid nodes) cannot be surveyed (either because they are inaccessible or fall beyond the limits of the CDA), additional points may be identified using the same process used to determine the starting point, until the required number of sampling locations are specified. If the grid constructed in this manner identifies more than the required number of sampling locations, typically those few additional samples should be collected. A less preferred approach is to randomly eliminate sampling points until the required N is achieved. For operational simplicity, the same grid will be used for both surface and subsurface sampling locations, even though it may result in the collection of more subsurface samples that are statistically required to achieve the stated DQOs for the target PCB clean-up level at the greater depths.

8.3.1 Recommended Grid Spacing

Grid spacings, L, were calculated for each of the target PCB clean-up levels using higher levels of beta for smaller sized CDAs, as discussed above in Sections 7 and 8. The computed grid spacings ranged from 13.7 feet up to 1,458 feet. For operational simplicity, these 31 different grid spacings were rounded down to characteristic ranges for different CDA acreages. These results are presented in Table 8-2. Any square grid spacing smaller than the maximum value calculated using the DQO inputs would meet the DQO requirements.

These calculated grid spacings are relatively comparable to the sampling densities that resulted from previous investigations and interim remedial actions. For example, the Early Action Removal Action focused on residential and beachcombing areas. The effective grid spacing that resulted from the Early Action Removal Action sampling program was 40 feet. The calculated grid spacings for confirmatory sampling range from 15 to 50 feet for the 1 ppm PCB target clean-up level for residential areas depending on the size of the CDA. Grid sampling was not used during the Hot Spot Removal Action but the sampling density corresponds to effective grid spacings of 20 to 71 feet in the Upper Harbor. The calculated grid spacings for confirmatory sampling range from 50 to 100 feet for the 10 ppm PCB target clean-up level applicable to subtidal areas and unvegetated mudflats in the Upper Harbor. The sampling density from the site characterization of the Lower or Outer Harbor equates to an effective grid spacing of 50 to 175 feet. The calculated grid spacings for confirmatory sampling under these same conditions range from 100 to 200 feet for the 50 ppm target PCB clean-up level.



LEGEND

- Confirmatory Sampling Points
- Extraneous Portion of Sampling Grid
- Confirmatory Sampling Grid
- 200 ft Sitewide Reference Grid
- Roads
- Contours
- Buildings

100 0 100 200 Feet

NEW BEDFORD HARBOR SUPERFUND SITE
BRISTOL COUNTY, MASSACHUSETTS

Figure 8-1
Example Confirmatory Sampling
Grid Spacing for N=20

SHEET 1 of 1

DRAFT: MAR 20, 2002

MA STATE PLANE
NAD 83 FEET
NGVD 29

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When a CDA involves an unusual geometry, such as incorporating a series of marsh channels extending out from a mudflat area, additions to the regular square grid sampling pattern will be required. In the case of the marsh channels, the square confirmatory sampling grid pattern established for the mudflat area would be supplemented by a series of confirmatory sampling transects that run down along the midline of each channel starting from the uppermost extent of known contamination in each. Confirmatory samples would then be collected at the uppermost extent, and every "L" feet, as appropriate (see Table 8-2) down the channel until the transect intersects with the regular square grid pattern associated with the rest of the CDA. If the channel is sufficiently wide, a random selection process can be employed to direct the taking of the confirmatory sample at a point along the transect at the centerline, or immediately off to the right or left of the centerline within the channel. The number of confirmatory samples associated with these marsh channel transects would add to the number of samples required for the contiguous unvegetated mudflat area in order to meet the stated DQOs. Other unusual geometries would be handled in a similar manner on a case-by-case basis as they arise.

8.3.2 Refusal at the Identified Confirmatory Sampling Location

A confirmatory sampling pattern for a CDA may call for a sample to be collected at a node of the grid framework where a suitable and sufficient sample cannot be obtained because of the presence of bedrock or large rocks or cobbles (including shore stabilizing rip-rap or construction debris). If a suitable and sufficient sample cannot be collected at a specific location (because of sampling device refusal or poor sample recovery), the following procedure should be followed to locate an alternative sampling location in the same general area:

1. Randomly select a major compass direction – For example, using a shuffled deck of playing cards, drawing a heart would represent the direction "ahead" along the confirmatory sampling grid. Drawing a diamond represents the "back" direction, a club represents the direction to the "right" and a spade represents the direction to the "left".
2. Randomly select a distance from the original unsuccessful sampling point – The face value of the selected card also dictates the number of feet out from the original point in the selected direction where another attempt should be made to collect the sample (i.e., aces represent 1 foot and queens represent 12 feet).
3. If the new location is outside the CDA boundary or crosses another line of the confirmatory sampling grid, ignore that card and pick another.
4. Return to the original point and try the location associated with the newly drawn card. For example, an 8 of clubs would indicate an attempt should be made to take a sample at a location eight feet to the right of the point where the sample could not be initially collected.
5. Repeat this process until a suitable sample is collected.

In some cases along shorelines, a random adjustment in position relative to all four directions may not be appropriate. In such cases, taking a confirmatory sample at the nearest possible (non-random) location either along the shoreline or away from the water may be more appropriate to the local circumstances. These situations would be addressed on a case-by-case basis.

8.3.3 Sample Collection

At each such location, an attempt must be made to obtain a representative sample of the sediment. For rock areas in residential or beachcombing areas, consideration should be given to collecting material that is physically accessible through direct contact and within the depth range relevant to the target PCB clean-up level(s) applicable to that CDA. Surface sampling of the debris or rip-rap (e.g., with wipe

samples or by scarifying the surface and analyzing the recovered material) is not considered to be an anticipated part of the confirmatory sampling approach. Individual rocks larger than 2 inches should be removed from the sample and discarded prior to the sample being sent to the laboratory for chemical analysis (i.e., the same process used during PCB characterization program). It is asserted that confirmatory samples need to be collected only within areas that have been dredged or excavated as part of the remediation effort. As such, sediment located beneath or near rip-rap retaining walls or debris piles that were not disturbed to maintain structural stability and protecting building or property will not be considered a part of a CDA and will not be sampled in the context of demonstrating compliance with the applicable target PCB clean-up levels in an adjacent area. Sampling may be performed in such areas for purposes other than confirmatory sampling, such as documenting existing conditions.

8.3.4 Contamination Discovered Outside the CDA

When unexpected contamination is encountered such that additional samples must be collected outside the original CDA to better define the extent of the contamination, these characterization samples would not automatically meet the DQO requirements of confirmatory sampling. An evaluation of the usability of any such characterization data for confirmatory sampling will be made on a case-by-case basis.

8.4 Key Points

The following are the key points relating to calculating the required number of confirmatory samples required to meet the stated DQOs and the corresponding sampling grid spacing.

- Equations were identified for estimating the minimum number of confirmatory samples required to be collected and analyzed in a CDA to meet specified DQOs.
- The relevant calculations were performed using recently released USEPA computer software called Visual Sample Plan.
- The relationship for a non-parametric distribution of confirmatory sampling results in a CDA was selected to be a little conservative (i.e., require a slightly higher number of samples to be collected) given the uncertainties involved.
- The recommended parameters were input to the statistically-derived equation to calculate the minimum required number of confirmatory samples to meet the specified DQOs.
- A sensitivity analysis was conducted to observe the effect of various input parameter values on the number of required confirmatory samples.
- Final parameter recommendations were made based on this analysis (see also Section 7.0).
- Confirmatory samples will be collected on the nodes of a square sampling grid pattern, where the grid size is determined by the number of samples required for the particular CDA and the size of the CDA. Such a grid system would promote more complete coverage of an area being sampled and is relatively simple to implement. To maintain the required element of randomness in the sampling, this sampling grid will be anchored relative to the boundary of the CDA by using a random number generator to select an anchor or starting point. The rest of the sampling points will be the remaining nodes of the sampling grid within the CDA boundary.
- Confirmatory sampling grid spacings were calculated using the statistical relationship and the recommended input parameters developed using the DQO process. These maximum spacings depend on the target PCB clean-up level associated with the area, the size of the

compliance demonstration area, and the specified probability of making a Type II decision error (beta).

- The calculated confirmatory sampling grid spacing resulting from the recommended input values were compared to the prior post-dredging and post-excavation sampling performed at the New Bedford Harbor and at other recent environmental dredging projects, and were found to exhibit a logical relationship.
- An approach was proposed for confirmatory sampling with more unusual geometries, such as associated with marsh channels or elongated protrusions from a more centralized area.
- An approach also was proposed for handling cases where a confirmatory sample is to be collected at a point where a suitable and sufficient sample cannot be obtained (e.g., a refusal of the sampling device).
- Sediment sampling to better characterize PCB contamination found outside of the CDA was differentiated from confirmatory sampling from the standpoint of meeting the DQOs for the confirmatory sampling program.

9.0 DATA EVALUATION FOR COMPLIANCE TESTING

The data life cycle is generally made up of three steps: planning, implementation, and assessment. The focus of this report up to this point has been on planning. Implementation will be addressed in part in Section 11 and in the field data collection and associated QA/QC plans. The two major components of the assessment phase focus on data validation / verification and data quality assessment. The Data Quality Assessment (DQA) process provides a formal framework for statistical evaluation to determine if the data obtained are of the right type, quality, and quantity to support their intended use. According to USEPA (USEPA, 2000b), the five steps of the DQA include: (1) review of the DQOs and design; (2) preliminary data review; (3) selection of the statistical test; (4) verification of the assumptions of the statistical test; and (5) draw conclusions. A detailed discussion of these steps is beyond the scope of this report.

The following discussion on how the confirmatory sampling data will be used to calculate the required PCB concentration measures to be used in the compliance demonstration evaluation is included because considering how the collected data will be used is a direct objective of the DQO process.

9.1 Indirect Human Health and Ecological Improvement Target Clean-up Levels

For the CDAs that have target PCB clean-up levels of either 10 or 50 ppm, the requirement for compliance is that the average PCB concentration within the CDA is below the target clean-up level.

If $X_1, X_2, ..., X_N$ represent the N confirmatory sampling results for a CDA in terms of PCB concentration, then the sample mean, $\overline{X}$, will be calculated as:

$$\overline{X} = \frac{(X_1 + X_2 + ... + X_N)}{N}$$

If $\overline{X}$ is less than the applicable target PCB clean-up level (i.e., either 10 or 50 ppm), then no further action is required. If $\overline{X}$ is greater than the target PCB clean-up level, then an additional response may be required.

9.2 Human Health Target Clean-Up Levels

As discussed in previous sections, the appropriate test for compliance relative to the 1 and 25 ppm target PCB clean-up levels is that the 95% UCL of the arithmetic mean is below the applicable target PCB clean-up level. The parametric statistical test used to test hypotheses involving the mean of the confirmatory samples collected in a CDA is the One-sample t-Test. The primary assumptions required for validity of the One-sample t-Test are that the sample is a random sample and that the sample mean, $\overline{X}$, is approximately normally distributed. Because $\overline{X}$ and S are very sensitive to outliers, the data should be reviewed for outliers (e.g., one or two values that are considerably higher than the others). If there are outliers in a small data set (e.g., for CDAs with a target PCB clean-up level of 25 ppm and N =9), then the t-test should not be used. Instead, the Wilcoxon signed rank test may be used. This test is slightly less powerful than the t-test and is more difficult to perform. The t-test is robust to moderate violations of the assumption of normality for large N (e.g., 1 ppm target clean-up level CDAs where N = 31).

If these requirements are met, the following formula can be used to compute the 95% UCL:

Let X_1, X_2, ..., X_N, represent the N confirmatory sampling results for a CDA in terms of PCB concentrations. The sample mean, $\overline{X}$, will be calculated as:

$$\overline{X} = \frac{(X_1 + X_2 + \ldots + X_N)}{N}$$

The standard deviation, S, will then be calculated as:

$$S = \sqrt{\frac{\left(X_1^2 + X_2^2 + \ldots + X_N^2\right) - \left(\left(X_1 + X_2 + \ldots + X_N\right)^2 / N\right)}{N-1}}$$

If the data are normally distributed, the 95% UCL will then be calculated as:

$$95\%\,UCL = \overline{X} + \left(t_{1-\alpha}\right) \cdot \left(S/\sqrt{N}\right)$$

Values of t for 1-α (where α=0.05) for the various N are provided in Table 9-1.

If the 95% UCL is less than the applicable target PCB clean-up level, then no further action is required. If the 95% UCL is greater than the target clean-up level but $\overline{X}$ is less than the target clean-up level, one option would be to collect more samples. If $\overline{X}$ is greater than the target PCB clean-up level, then an additional response may be indicated.

9.3 Key Points

The following are the key points relative to quantitatively assessing the results of the confirmatory sampling.

- Once collected, the analytical results for the confirmatory samples will be used to calculate the measures of the sediment PCB concentration that are to be compared to the applicable target clean-up levels for a given CDA.
- The ROD specifies that the 95% upper confidence level of the arithmetic mean be used as the sediment PCB concentration measure to be compared to the target PCB clean-up levels associated with the protection of people from direct contact exposure to contaminated sediments (i.e., the 1 ppm residential area target PCB clean-up level and the 25 ppm beachcombing area target PCB clean-up level).
- The Project Team decided that the arithmetic mean, or average, should be used as the sediment PCB concentration measure to be compared to the target PCB clean-up levels associated with the protection of people through indirect exposure to contaminated sediments (via the ingestion of marine species) or with ecological improvement (i.e., the 10 ppm and 50 ppm target PCB clean-up levels). Given the collection of confirmatory samples according to a regular square grid (see Section 8.3), this average will be an area-weighted average of conditions within the CDA.
- The recommended approach for calculating the arithmetic mean and the 95% upper confidence level are presented.

Table 9-1
Critical Values of the Student's t Distribution

Degrees of Freedom (N-1)	$t_{1-\alpha}$ where α=0.05
5	2.015
6	1.941
7	1.895
8	1.860
9	1.833
10	1.812
11	1.796
12	1.782
13	1.771
14	1.761
15	1.753
16	1.746
17	1.740
18	1.734
19	1.729
20	1.725
21	1.721
22	1.717
23	1.714
24	1.711
25	1.708
26	1.706
27	1.703
28	1.701
29	1.699
30	1.697
40	1.684
60	1.671
120	1.658
Infinity	1.645

Source: Dixon and Massey, 1969.

10.0 OTHER SAMPLING OR MEASUREMENT CONSIDERATIONS

10.1 Purpose of Other Sampling or Measurement Considerations

There are a number of additional parameters or elements directly influencing the overall confirmatory sampling program that relate principally to the detailed specification of how the sediment samples will be collected, chemically analyzed for PCBs, validated, or how other measurements of geographic locations or elevations should be made. The requirements and specifications for these types of measurements and their associated operational procedures will be detailed in a modification to the existing project-specific Field Sampling Plan (FSP) and/or the existing project-specific QAPP by those who have developed and maintained those sitewide reference documents. As such, it is outside the scope of this document to formally specify or prescribe these elements here. However, to a greater or lesser degree, the specification of these implementation issues directly affects the defensibility of the confirmatory sampling approach and the quality of the results of the confirmatory sampling program.

Because of these linkages, a number of these sampling and measurement-related considerations have been compiled and considered as part of this effort. This compilation draws on many of the studies that have been performed or are ongoing that have been tasked specifically with evaluating the issues below for the New Bedford Harbor project and developing a recommended approach or procedure. A summary of this compilation is presented in Table 10-1. This table identifies each of these sampling or measurement-related parameters, lists the preferred value of the parameter or approach to be employed from the perspective of confirmatory sampling, and the rationale and comments that explain the basis for this preference. It is envisioned that this table will be considered when the project-specific FSP and QAPP are modified for the confirmatory sampling associated with future remedial dredging or excavation efforts.

Table 10-1 addresses the following topics and parameters:

Analytical Issues:

- Baseline Laboratory Analytical Method for PCBs;
- Required/Achievable Analytical Turnaround Times;
- Field Screening / Immunoassay Testing;
- Use of an Off-Site vs. On-Site Analytical Laboratory;
- Baseline Sample Extraction Method for PCBs; and
- Validation of Data Used for Regulatory Compliance Demonstration.

Progress Monitoring Issues:

- Progress Bathymetric Survey;
- Progress Land Survey;
- Progress Chemical Sampling; and
- Technique for Confirmation of Specified Dredging and Excavation Depth.

Sample Collection Issues:

- Depth in the Newly Exposed Sediment Where the Applicable Target PCB Clean-Up Level(s) Must Be Achieved;
- Sample Compositing and Collection Protocol;
- Technique for Collecting Only Near Surface Sediment Samples in Standing Water;
- Technique for Collecting Both Near Surface and Deeper Sediment Samples in Standing Water at the Same Time;

- Technique for Collecting Only Near Surface Sediment Samples in Upland or Exposed Intertidal Areas;
- Technique for Navigation and Positioning on Confirmatory Sampling Locations; and
- Confirmatory Sample Identification Protocol.

10.2 Key Points

The following are the key points presented about the other sampling or measurement considerations as they relate to confirmatory sampling.

- There are a number of other sampling or measurement considerations or specifications that directly influence the overall confirmatory sampling program, but which are not unique to, or would be solely driven by, the confirmatory sampling to be performed.
- These parameters or elements will be addressed in a modification to the existing project-specific field Sampling Plan or the Quality Assurance Project Plan.
- This confirmatory sampling approach document highlights these parameters and elements and their linkages to the confirmatory sampling program so that the impact of the final specification of these parameters and elements on confirmatory sampling will be considered appropriately at that time.
- A number of analytical issues, progress monitoring issues, and sample collection issues were highlighted as having direct or indirect impact on confirmatory sampling.
- Whenever possible, preferred values or approaches relative to these parameter or elements were identified to be consistent with established approaches or protocols for recent or ongoing sampling or measurements (such as the sitewide PCB Characterization Program).
- Required analytical turnaround time and the potential use of an on-site (versus an off-site) analytical laboratory for meeting dredging and excavation operational constraints are key unresolved specifications.

Table 10-1
Summary of Other Sampling or Measurement Parameters, Preferred Values or Approaches Relative to Confirmatory Sampling, and Supporting Rationale or Comments

Confirmatory Sampling Element	Preferred Value or Approach Relative to Confirmatory Sampling	Rationale / Comment
ANALYTICAL ISSUES		
Baseline Laboratory Analytical Method for PCBs	• USEPA 8082, Reporting the 18 NOAA Congeners	1. Consistency would suggest the use of the same quantification approach and regression relationship that was used for the PCB Characterization Program. 2. This is the analytical method that is now being used for the laboratory analyses of sediment samples at New Bedford Harbor. 3. A New Bedford Harbor-specific regression relationship has been established between the Sum of the 18 NOAA Congeners and the Total PCB concentration [Total PCBs = 2.5 x Sum of the 18 NOAA Congeners + 0]. (Foster Wheeler, 2001a)
Required Analytical Turnaround Time	• As soon as practical (within 48 to 72 hours) for all samples associated with General Dredging or Excavation Approach 1 or any second pass analyses associated with either Approach • Standard 21 days for all first pass analyses associated with General Approach 2 and all third pass analyses	1. Fastest turnaround time for an off-site laboratory is probably 72 hours (available at approximately a 200% premium cost). 2. Fastest turnaround time for an on-site laboratory or field screening sample may be 48 hours (due mainly to the elimination of the sample shipping time; Most other steps are similar and take comparable periods of time to perform). 3. An intermediate turnaround time of 5 days may also be available (at roughly a 50% cost premium). 4. Currently, routine, non-premium analytical cost is based on a negotiated 21 day turnaround. 5. Costs and minimum turnaround time will depend somewhat on the number of samples being requested and the ability to predict significant changes in the number of samples being sent to the laboratory. 6. Analytical cost may (at times) not be a significant factor relative to the greater cost of delayed field operation decisions while waiting for results. 7. This factor is negotiable if current laboratory contracts are re-bid.
Field Screening / Immunoassay Testing	• Potential for use during the first pass to determine if additional material should be removed in specific portions of the MU prior to the actual confirmatory sampling to be subsequently performed (especially in an area where the specified cut was least certain) • Potential for use during the implementation of General Dredging or Excavation Approach 3 to provide an initial indication of the remaining PCB concentrations	1. Usefulness and possible roles must be matched to performance: minimal false negatives (will adequately indicate if sample is "clean"), but exhibits a high false positive rate (may indicate that a sample is "dirty" when it is actually "clean"). 2. Use of immunoassay techniques would still require some percentage of the samples to be verified by off-site laboratory analysis (possibly 20%). 3. Use of immunoassay techniques may be cheaper than off-site analysis (USEPA 8082). Immunoassay costs approximately $60 - $120 / sample. 4. Might be able to get 48 hour turnaround with field screening, but probably not with off-site laboratory analysis. 5. Not likely to be acceptable as the data to be used for formal compliance testing and demonstration without a significant independent verification effort. 6. Use for quick dredging decision making could save money and time relative to doing the additional dredging at a somewhat later time. 7. There is a trade-off between taking more samples using a crude (i.e., less precise) analytical method vs. taking fewer samples using a more precise method [this is because the overall decision error is affected by the total standard deviation of the samples, which includes both sampling heterogeneity and analytical measurement variability, and is affected by how close the remaining PCB levels are to the target clean-up level]. 8. There is also a trade-off between taking more samples (i.e., duplicates or replicates) when using the less precise analytical method vs. taking fewer samples and using a more precise analytical method.

Table 10–1 – *Continued*

Confirmatory Sampling Element	Preferred Value or Approach Relative to Confirmatory Sampling	Rationale / Comment
Off-Site vs. On-Site Analytical Laboratory	• To Be Determined	1. A separate evaluation is currently being conducted to establish this trade-off under various circumstances. (Foster Wheeler, 2002a) 2. Final determination will depend on the number of samples needed within a specific timeframe.
Baseline Sample Extraction Method for PCBs	• Soxhlet (or Equivalent)	1. The Soxhlet method is included as the preferred method of extraction for sediment PCB sample analysis identified in SW-846. 2. Other methods (e.g., the Sonication extraction method) may be used with appropriate government approval. 3. The Soxhlet method cannot be performed effectively at an on-site laboratory.
Validation of Data Used for Compliance Demonstration	• A Multi-Component Combination of: - Correlation Studies, - Split Sampling and Independent Analysis, - Documentation of Formal Quality Control Procedures (100% of samples), and - Spot Check Verification/ Validation with: Tier I = 25% Tier II = <5% Tier III = 0%	1. Tier I is the lowest level of data validation; Tier III involves the greatest effort and resources to evaluate the data. 2. Tier I data validation can take from a day or two to a week per data package, depending on the availability of the Validator, the number of samples in the data package, and the number of analyses performed. 3. Tier II data validation can take from 3 to 4 days to two weeks per data package, depending on the availability of the Validator, the number of samples in the data package, and the number of analyses performed. 4. Data validation will need to be expedited to the greatest extent possible whenever the analytical turnaround time is expedited. 5. Currently, all off-site laboratory sediment sampling results are Tier I validated and 5% is also Tier II validated (i.e., this is consistent with the PCB Characterization program). 6. Initially, 10% of the off-site laboratory sediment sampling results were Tier II validated, but this was dropped to 5% after the laboratory had shown good performance over an extended period of time. 7. Will utilize as much of the past supporting efforts and rationale from the PCB Characterization program as possible.
PROGRESS MONITORING		
Progress Bathymetric Survey	• At end of the dredging day or before dredging the following morning	1. Should be performed as soon as possible after dredging to minimize the effects of sediment movement and sloughing. 2. Should be performed soon enough to provide timely and representative information.
Progress Land Survey	• At end of the excavation day or before excavation the following morning	1. Should be performed as soon as possible after excavation and before conditions change. 2. Should be performed soon enough to provide timely and representative information. 3. Slightly longer lag times following upland excavation may be practical.
Progress Chemical Sampling (i.e., field screening/ Immunoassay testing or laboratory analysis)	• During dredging or excavation activities	1. If performed in a subtidal area, it should be performed as soon as possible following the progress bathymetric survey of one section of the MU or after the post-survey of an MU is complete and considered acceptable. 2. This information may be used to make cost-saving "real-time" operational decisions. 3. Progress chemical sampling results not produced by screening methodologies may be determined to be suitable for use for regulatory compliance testing on a case-by-case basis.
Technique for Confirmation of Dredging and Excavation Depth in each MU	• Survey-Grade Fathometer	1. Used to evaluate acceptance of an MU. 2. Accuracy of < 30 cm (0.5 feet). 3. Can be used to produce spot elevation map or contour map at user-defined spacings. 4. Can be used for progress, pre-dredging or pre-excavation, and post-removal surveys of each MU.

Table 10–1 – *Continued*

Confirmatory Sampling Element	Preferred Value or Approach Relative to Confirmatory Sampling	Rationale / Comment
Technique for Navigation and Positioning on Station Locations	• Differential Global Positioning System	1. Accuracy of ± 1 m. 2. Can use HYPACK software to integrate with fathometer. 3. Also provides visual display of the MU and survey lines.
SAMPLE COLLECTION		
Depth in the Newly Exposed Sediment Where the Applicable Target PCB Clean-Up Level(s) must be achieved	• The interval from 0 – 1 foot in the sediment column (i.e., mudline to 12 inches depth) for target PCB clean-up levels associated with direct contact human exposure (i.e., the residential 1 ppm level or the beachcombing 25 ppm level).	1. The sediment column depth interval associated with the direct contact human health based ROD target PCB clean-up levels was specified in the ROD. 2. Target PCB clean-up levels for the surficial layer will be assumed to be met if documented clean backfill is placed to a thickness equal to or greater than the depth interval associated with the target PCB clean-up level (i.e., 12 inches). 3. The Project Team agreed to test for compliance with the direct contact human exposure requirements using composite samples collected over the top 6 inches (instead of 12 inches) as a conservative approach that also simplifies the field procedures.
	• Any depth in the sediment column where PCB concentrations are above the target clean-up levels associated with indirect human exposure or ecological improvement (i.e, the 10 ppm and 50 ppm levels). Post-dredging or post-excavation PCB concentrations in the sediment will be assumed to decrease with depth. Compliance with the indirect human exposure or ecological improvement target PCB clean-up levels will be tested using composite samples from the uppermost 6 inches of sediment	1. The sediment column depth interval associated with the indirect human health-based and ecological improvement ROD target PCB clean-up levels was not specified in the ROD. 2. The default USEPA Region 1 sediment surface layer thickness for purposes of ecological risk assessment = 0 to 12 inches based on the typical thickness of ecological bioturbation zones. 3. The site-specific Baseline Ecological Risk Assessment for New Bedford Harbor was performed using sediment data collected from depth intervals of 0 to 2, 6, and 8 inches. 4. The post-dredging and post-excavation sediment sampling performed previously at New Bedford Harbor (but not explicitly for confirmatory sampling) was from the sediment column depth intervals of 0 to 0.8 inches, 0 to 3 inches, 0 to 6 inches, and 0 to 12 inches. 5. The post-dredging and post-excavation surficial sediment sampling performed recently at the surveyed environmental dredging remediation projects (see Appendix B) involved composite samples from the sediment column as follows: - 0 to ≤3 inches = 31% of sites - 0 to ≤6 inches = 85% of sites (i.e., includes 0 to ≤3 inches sites) - 0 to a maximum depth >6 and ≤12 inches = 15% of sites 6. The long term monitoring sediment sampling performed previously at New Bedford Harbor was from the sediment column depth interval of 0 to 4 inches. 7. There may be operational benefits to maintaining consistency across all CDAs or between the confirmatory sampling and the long term monitoring programs.

Table 10–1 – *Continued*

Confirmatory Sampling Element	Preferred Value or Approach Relative to Confirmatory Sampling	Rationale / Comment
Sample Compositing and Collection Protocol	• A 0-12 inches composite for first and second passes in residential or beachcombing areas, with two 6 inches composites below and contiguous with the surficial sample. • A 0-6 inches composite for first passes in all other areas, with two 6 inches composites below and contiguous with the surficial sample. • On any third pass, collect only the surficial samples identified above.	1. Composite depth for the residential or beachcombing area samples is specified in the ROD. 2. Composite depth for the other target PCB clean-up levels was discussed and approved by USEPA Site Managers and the Project Team. 3. For first or second pass sampling in an area where either general dredging or excavation Approach 1 or 2 is being applied, immediately send the surficial sample and the sample most immediately below it for analysis and archive the remaining deeper sample; Consider analyzing the archived sample after evaluating the results for the other two samples. 4. For any third pass sampling in an area where either Approach 1 or 2 is being applied, send only the surficial sample for analysis and archive the remaining deeper samples. 5. Discard all remaining archived samples from a CDA after it has been demonstrated to meet its applicable target PCB clean-up level(s). 6. There is no current plan to perform sidewall sampling in intertidal or upland areas as part of a confirmatory sampling. 7. Spatial compositing of collected samples prior to chemical analysis may be considered for specific circumstances, but is not the recommended primary approach.
Technique for Collecting Only Near Surface Sediment Samples in Standing Water	• van Veen, Ponar, or Ekman Dredge (Grab)	1. Small, lightweight devices that could be mounted / operated from a small boat with an A-frame or a davit with a winch. 2. Would not require a specialized subcontractor. 3. Could typically take about 18 samples per day. 4. The van Veen, Ponar and Ekman dredges (and to the lesser extent the Vibracore) could tend to push "fluff" out of the way (due to its "bow wake") when lowered into position. 5. Could lose some sample material when being withdrawn from the water. 6. Could also use this technique to sample much of the intertidal areas at high tide. 7. The central portion of the material collected in a Box Corer may be the best preserved sample for the surficial sediment material. 8. The size and weight of a Box Corer probably may require a larger vessel. 9. Must establish appropriate decontamination procedure.
Technique for Collecting Both Near Surface and Deeper Sediment Samples in Standing Water at the Same Time	• Vibracore, or possibly a Box Corer	1. Can collect a coherent sample down to 1 ½ to 2 feet (deeper with a Vibracore). 2. Sample retrieved using this method could then be subsampled to obtain a surficial sample and the lower portions could be subsampled to get a deeper sample from the sediment column for immediate analysis or archiving. 3. The size and weight of a suitably sized Box Corer probably may require a larger vessel. 4. Could typically take about 10 to 12 samples per day. 5. Must establish appropriate decontamination procedure.

Table 10–1 – *Continued*

Confirmatory Sampling Element	Preferred Value or Approach Relative to Confirmatory Sampling	Rationale / Comment
Technique for Collecting Only Near Surface Sediment Samples in Upland or Exposed Intertidal Areas	• Hand Auger (Bucket Auger)	1. Relatively lightweight. 2. Easy to use. 3. Worked well for the PCB Characterization Program sampling conducted to date.
Sample Identification Protocol	• C-####-XXXX (Further definition of this format is in progress at the time of this writing.)	1. Similar format to what was used in the PCB Characterization Program. 2. First letter "C" designates "confirmatory sample". 3. Four digit number (####) represents unique identifier. 4. Depth of sample code (XXXX) must be reconsidered to allow "current" depth to be tracked relative to "original" depth (i.e., depth relative to pre-removal mudline) in consideration of multiple dredging or excavation passes and associated sampling at the same location.

11.0 DEVELOPMENT OF AN AREA-SPECIFIC CONFIRMATORY SAMPLING PLAN

Previous sections of this report have presented the recommended approach for confirmatory sampling at the New Bedford Harbor site, and the justification for the recommended elements of that approach. In some cases, the recommended confirmatory sampling approach would depend on:

- Which overall dredging or excavation approach was being implemented in the compliance demonstration area (i.e., Approach 1 or Approach 2, or either one preceded by a Warm Spot Removal Action);
- Which pass of dredging or excavation was being performed (i.e., first, second, or third);
- Site-specific circumstances or critical remediation objectives; and
- Professional judgment.

It is clear that an effective tool or procedure was needed to identify and track the consideration of each of these factors during the development and implementation of a confirmatory sampling plan for a specific area being remediated. In addition, a mechanism was needed for documenting the reasons and rationale for the many decisions that will be made by various parties in the process of developing this plan, and by the USEPA Site Manager as the clean-up progresses. Documentation of this type will be critical to effective and defensible site management and public review, and greatly facilitates the ultimate closeout of an area relative to the sediment removal phase of the overall remediation process.

Figure 11-1 presents a working draft of a "Checklist for Developing a Confirmatory Sampling Plan for a Compliance Demonstration Area" (Revision 0) that provides an initial aid to this required planning and documentation. This checklist has eight topical sections pertaining to the remediation of a particular compliance demonstration area:

1 Identification Information;

2 Type of Environmental Area / Applicable Target PCB Clean-Up Levels;

3 Overall Dredging or Excavation Approach;

4 First Pass of Dredging or Excavation;

5 Second Pass of Dredging or Excavation (If needed);

6 Third Pass of Dredging or Excavation (If needed);

7 USEPA Site Manager Discretionary Off-Ramp; and

8 Compliance Demonstration Area Closeout.

The working draft checklist is designed to be completed largely by checking boxes and inserting short response text. The key elements of a confirmatory sampling plan (as defined previously in the earlier sections of this report) are presented relative to the operational stage or topical heading to which they apply. Section numbers, referring to this report, are included to facilitate cross-referencing to more information or discussion in this report relating to that confirmatory sampling element or topic. This draft of the checklist is designed to prompt for a minimum amount of required detail and documentation. A greater level of detail or more back-up information or rationale could be included as circumstances dictate. It is anticipated that this checklist will be further refined and modified to meet project needs and requirements as these elements are refined.

FIGURE 11-1
CHECKLIST FOR DEVELOPING A CONFIRMATORY SAMPLING PLAN
FOR A COMPLIANCE DEMONSTRATION AREA
New Bedford Harbor Superfund Site
[Working Draft - Revision 0]

---

1. Identification Information *(Refer to Section 5)*

- **Compliance Demonstration Area (CDA)** _____

- **Management Unit(s)** **Size [acres]**

_____ _____
_____ _____
_____ _____
_____ _____
_____ _____
_____ _____
_____ _____
_____ _____

- **Total Size of Compliance Demonstration Area** _____ [acres]

---

2. Type of Environmental Area / Applicable Target PCB Clean-Up Level *(Refer to Section 4)*

- **Target PCB Clean-Up Level (TPCUL)** (shown in parenthesis)
(TPCUL from mudline to 12" below the mudline / TPCUL from 12" below the mudline to all greater depths) or
(TPCUL from mudline to all greater depths)

Upper Harbor
- ☐ Residential / Unvegetated Area (1 ppm / 10 ppm)
- ☐ Residential / Vegetated Area (1 ppm / 50 ppm)
- ☐ Beachcombing / Unvegetated Area (10 ppm)
- ☐ Beachcombing / Vegetated Area (25 ppm / 50 ppm)
- ☐ Unvegetated Area or Subtidal Area (10 ppm)
- ☐ Vegetated Area (50 ppm)

Lower / Outer Harbor
- ☐ Residential / Unvegetated Area (1 ppm / 50 ppm)
- ☐ Residential / Vegetated Area (1 ppm / 50 ppm)
- ☐ Beachcombing / Unvegetated Area (25 ppm / 50 ppm)
- ☐ Beachcombing / Vegetated Area (25 ppm / 50 ppm)
- ☐ Unvegetated Area or Subtidal Area (50 ppm)
- ☐ Vegetated Area (50 ppm)

---

3. Overall Dredging or Excavation Approach Implemented *(Refer to Section 5)*

☐ Approach 1 ☐ Approach 2

Was the implementation of this approach preceded in this CDA by a Warm Spot Removal Action?
☐ Yes ☐ No

Figure 11-1 – *Continued*

4. First Pass of Dredging or Excavation

- **Number of Confirmatory Samples / Confirmatory Sampling Grid Spacing** ***(Refer to Section 8)***

(↓ Check all that apply in this CDA)

	Target PCB Clean-Up Level [ppm]	Size of the CDA [acres]	Statistical Input Parameters				Number of Required Confirmatory Samples (N)	Range of Confirmatory Sampling Grid Spacing [feet]	Maximum Confirmatory Sampling Grid Spacing (L) [feet]
			Post-Removal Standard Deviation [ppm]	Alpha (Type I) [unitless]	Beta (Type II) [unitless]	Delta (Gray Region) [ppm]			
☐	1	< 0.5	0.25	0.05	0.20	0.125	31	< 15	_____
☐	1	0.5 – 1.0	0.25	0.05	0.20	0.125	31	15 – 25	_____
☐	1	1.0 – 5.0	0.25	0.05	0.20	0.125	31	25 – 50	_____
☐	25	< 0.1	5	0.05	0.20	5	9	< 15	_____
☐	25	0.1 – 0.3	5	0.05	0.20	5	9	15 – 25	_____
☐	25	0.3 – 1.0	5	0.05	0.20	5	9	25 – 50	_____
☐	25	> 1.0	5	0.05	0.20	5	9	> 100	_____
☐	10	< 5.0	3	0.05	0.20	1.5	31	< 80	_____
☐	10	5.0 – 10	3	0.05	0.01	1.5	75	50 – 75	_____
☐	10	10 – 20	3	0.05	0.01	1.5	75	75 – 100	_____
☐	50	< 5.0	12	0.05	0.20	12	9	< 150	_____
☐	50	5.0 – 10	12	0.05	0.01	12	20	100 – 145	_____
☐	50	10 – 20	12	0.05	0.01	12	20	145 – 225	_____

The **confirmatory sampling grid spacing, L,** is calculated using the following equation:

$$L[ft] = \sqrt{\frac{CDA\ Size\,[acres] \cdot 43{,}560\,[ft^2/acre]}{N\,[number\ of\ confirmatory\ samples]}}$$

Final confirmatory sampling grid spacing to obtain the N required confirmatory samples within the boundary of the CDA: _____ [feet]

- ***Starting Point / Anchoring Coordinates of the Confirmatory Sampling Grid System*** (Identified randomly) ***(Refer to Section 8)***

Northing_____ Easting_____

(Attach map with the confirmatory sampling grid overlaid on the CDA. Attach table with appropriate number of samples with their northing and easting coordinates (i.e., the nodes of the grid within the CDA).)

- Is confirmatory sampling required within a subarea of this CDA with an **unusual geometry**?

☐ Yes ☐ No

If Yes, explain how the confirmatory sampling locations were selected for this subarea: _____

_____

_____

_____

_____

- **Depth of Confirmatory Samples to be Collected** ***(Refer to Section 10)***

Will excavated portions of the CDA be immediately backfilled with clean material? ☐ Yes ☐ No

Depth of clean backfill _____ [inches]

NOTE: If backfill is at least 12 inches thick across the entire CDA for residential or beachcombing areas, then confirmatory sampling is not required for the 0 to 12 inch surficial sediment layer. The appropriate number of samples at the top of the remaining lower layer (vegetated or unvegetated areas) should still be collected at the spacing (density) specified above based on the clean-up level for the lower layer and the area of the CDA.

Top Layer (New surface layer)

☐ 0 to 6 inches (for vegetated or unvegetated areas only or for vegetated or unvegetated areas beneath residential or beachcombing areas with at least 12 inches of clean backfill)

☐ 0 to 12 inches (for residential or beachcombing areas without at least 12 inches of clean backfill)

Number of samples_____

☐ Analyze ☐ Archive

Analytical Turnaround Time

☐ Expedited turnaround time (approx. 3 days)

☐ Standard turnaround time (approx. 21 days)

☐ Other (specify) _____

Second Layer (Sediment layer directly below the Top Layer)

☐ 6 to 12 inches ☐ 12 to 18 inches

Number of samples_____

☐ Analyze ☐ Archive

Analytical Turnaround Time

☐ Expedited turnaround time (approx. 3 days)

☐ Standard turnaround time (approx. 21 days)

☐ Other (specify) _____

Third Layer (Sediment directly below the Second Layer)

☐ 12 to 18 inches ☐ 18 to 24 inches

Number of samples_____

☐ Analyze ☐ Archive

Analytical Turnaround Time

☐ Expedited turnaround time (approx. 3 days)

☐ Standard turnaround time (approx. 21 days)

☐ Other (specify) _____

- **Sampling Technique** ***(Refer to Section 10)***

☐ Hand Auger ☐ van Veen, Ponar, or Ekman Dredge ☐ Vibracore ☐ Box Corer

- **Analytical Laboratory Name** ***(Refer to Section 10)***

☐ On-site ☐ Off-site _____

- **Analytical Method** ***(Refer to Section 10)***
  ☐ EPA 8082 ☐ Other_____

- **Level of Validation** ***(Refer to Section 10)***
  ☐ Tier I (_____%) ☐ Tier II (_____%) ☐ Tier III (_____%)

- **Calculation of Sediment Concentration Compliance Measures** ***(Refer to Section 9)***
  (Attach table with calculations)

  - Arithmetic Mean of Samples Taken Within CDA (0 to 6 inch depth interval)
    _____ [ppm PCBs]

  - 95% UCL of Arithmetic Mean of Samples Taken Within CDA (0 to 12 inch depth interval)
    _____ [ppm PCBs]

  - Arithmetic Mean of Samples Taken Within CDA (12 to 18 inch depth interval)
    _____ [ppm PCBs]

- **Has compliance with the applicable Target PCB Clean-up Level(s) been demonstrated?** ***(Refer to Section 4)***

☐ Yes (Go to 8 - "Closeout") ☐ No (Go to 5 - "Second Pass")

---

5. Second Pass of Dredging or Excavation (if needed)

- **Number of grid nodes to be addressed by the second pass dredging or excavation**_____
  (Attach map showing second pass supplemental dredging or excavation areas and affected confirmatory sampling nodes)

	Sample Depth	Number of Samples	Analyze or Archive?	Analytical Turnaround Time
Top Layer	_____	_____	_____	_____
Second Layer	_____	_____	_____	_____
Third Layer	_____	_____	_____	_____

- **Sampling Technique** ***(Refer to Section 10)***
  ☐ Hand Auger ☐ van Veen, Ponar, or Ekman Dredge ☐ Vibracore ☐ Box Corer

- **Analytical Laboratory Name** ***(Refer to Section 10)***
  ☐ On-site ☐ Off-site _____

- **Analytical Method** ***(Refer to Section 10)***
  ☐ EPA 8082 ☐ Other_____

- **Level of Validation** ***(Refer to Section 10)***
  ☐ Tier I (_____%) ☐ Tier II (_____%) ☐ Tier III (_____%)

Figure 11-1 – *Continued*

- **Calculation of Sediment Concentration Compliance Measures** ***(Refer to Section 9)***
  (Attach table with calculations)

  - Arithmetic Mean of Samples Taken Within CDA (0 to 6 inch depth interval)
    _____ [ppm PCBs]

  - 95% UCL of Arithmetic Mean of Samples Taken Within CDA (0 to 12 inch depth interval)
    _____ [ppm PCBs]

  - Arithmetic Mean of Samples Taken Within CDA (12 to 18 inch depth interval)
    _____ [ppm PCBs]

- **Has compliance with the applicable Target PCB Clean-up Level(s) been demonstrated?** ***(Refer to Section 4)***

  ☐ Yes (Go to 8 - "Closeout")

- **Did the USEPA Site Manager determine that additional supplemental dredging or excavation in this CDA was not warranted?**

  ☐ Yes (Go to 7 - "Off Ramp") ☐ No (Go to 6 - "Third Pass")

---

6. Third Pass of Dredging or Excavation (if needed)

- **Number of grid nodes to be addressed by the third pass dredging or excavation**_____
  (Attach map showing third pass supplemental dredging or excavation areas and affected confirmatory sampling nodes)

	Sample Depth	Number of Samples	Analyze or Archive?	Analytical Turnaround Time
Top Layer	_____	_____	_____	_____
Second Layer	_____	_____	_____	_____
Third Layer	_____	_____	_____	_____

- **Sampling Technique** ***(Refer to Section 10)***
  ☐ Hand Auger ☐ van Veen, Ponar, or Ekman Dredge ☐ Vibracore ☐ Box Corer

- **Analytical Laboratory Name** ***(Refer to Section 10)***
  ☐ On-site ☐ Off-site _____

- **Analytical Method** ***(Refer to Section 10)***
  ☐ EPA 8082 ☐ Other_____

- **Level of Validation** ***(Refer to Section 10)***
  ☐ Tier I (_____%) ☐ Tier II (_____%) ☐ Tier III (_____%)

- **Calculation of Sediment Concentration Compliance Measures** ***(Refer to Section 9)***
  (Attach table with calculations)

  - Arithmetic Mean of Samples Taken Within CDA (0 to 6 inch depth interval)
    _____ [ppm PCBs]

  - 95% UCL of Arithmetic Mean of Samples Taken Within CDA (0 to 12 inch depth interval)
    _____ [ppm PCBs]

  - Arithmetic Mean of Samples Taken Within CDA (12 to 18 inch depth interval)
    _____ [ppm PCBs]

- **Has compliance with the applicable Target PCB Clean-up Level(s) been demonstrated?** ***(Refer to Section 4)***

  ☐ Yes (Go to 8 - "Closeout")

- **Did the USEPA Site Manager determine that additional supplemental dredging or excavation in this CDA was not warranted?**

  ☐ Yes (Go to 7 - "Off Ramp") ☐ No (Go to 8 - "Closeout")

---

7. USEPA Site Manager Discretionary Determination ("Off-Ramp")

Provide rationale for why further supplemental dredging or excavation was not performed in this CDA:

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

(Go to 8 - "Closeout")

---

8. CDA Closeout

- **Develop Compliance Demonstration Report**

  - Write Statement of Finding
  - Attach Data
  - Attach Calculations
  - Include Relevant Signatures

12.0 REFERENCES

Davidson, J.R., J.E. Wilson, N.L. Hassig, and R.O. Gilbert. 2001. Visual Sample Plan, Version 1.0, User's Guide. Prepared for the U.S. Environmental Protection Agency with the U.S. Department of Energy, Washington D.C. Prepared by Battelle Pacific Northwest National Laboratory, Richland, Washington. March 2001.

Dixon and Massey, 1969. Introduction to Statistical Analysis. Third Edition. McGraw-Hill Book Company. Table A-5.

Ebasco Services, Inc. (Ebasco), 1990. Draft Final Ecological Risk Assessment. New Bedford Harbor Site Feasibility Study. April.

Foster Wheeler, 2001a. Technical Memorandum Comparison of PCB NOAA Congener with Total Homologue Group Concentrations. New Bedford Harbor Superfund Site. May.

Foster Wheeler, 2002a. Evaluation of On-Site and Off-Site Analytical Methods for PCBs in Sediment. Draft Technical Memorandum. New Bedford Harbor Superfund Site. March.

Foster Wheeler, 2002b. Initial Dredging Basis of Design. Design Analysis Report. New Bedford Harbor Superfund Site. Draft. March.

Foster Wheeler, 2002c. Visual Approach to PCB Contamination Characterization. Draft Technical Memorandum. New Bedford Harbor Superfund Site. March.

Foster Wheeler, 2002d. Final Wetland Delineation and Functions and Values Report for Restoration Design. New Bedford Harbor Superfund Site. April.

NRC, 1997. Contaminated Sediment in Ports and Waterways: Cleanup Strategies and Technologies. National Research Council. National Academy Press, Washington D.C.

NRC, 1998. Conference Proceedings 19 from the National Symposium on Contaminated Sediments, May 27–29, 1998. National Research Council.

ThermoRetec. 2001. Draft Sediment Technologies Memorandum for the Lower Fox River. Wisconsin Department of Natural Resources Lower Fox River and Green Bay Feasibility Study. Prepared for the Wisconsin Department of Natural Resources. Prepared by ThermoRetec, Inc., Seattle, Washington. July 13, 2001.

Pacific Northwest National Laboratory (PNNL), 2001a. Visual Sample Plan (VSP) Models and Code Verification. February.

PNNL, 2001b. Visual Sample Plan. Version 1.0 Software. March.

United States Environmental Protection Agency (USEPA), 1998. Record of Decision for the Upper and Lower Harbor Operable Unit. New Bedford Harbor Superfund Site. New Bedford, MA. (ROD 2). Region I. September.

USEPA, 2000a. Data Quality Objectives Process for Hazardous Waste Site Investigations. Final. USEPA QA/G-4HW. January.

USEPA, 2000b. Guidance for Data Quality Assessment. Practical Methods for Data Analysis. USEPA QA/G-9, QA00 update. July.

USEPA, 2000c. Guidance for Choosing a Sampling Design for Environmental Data Collection. USEPA QA/G-5S, Peer Review Draft. August.

APPENDIX A

SUMMARY OF PRIOR ENVIRONMENTAL DREDGING AND EXCAVATION ACTIVITIES AT NEW BEDFORD HARBOR

This appendix reviews the sediment sampling aspects of four past environmental dredging or excavation activities that have taken place at New Bedford Harbor. These are documented in the following reports:

- New Bedford Harbor Superfund Pilot Study [1988-1989];
- Hot Spot Dredging Effort [1995];
- Pre-Design Field Test [2000]; and
- Early Action Removal Action (Area 1) [2001].

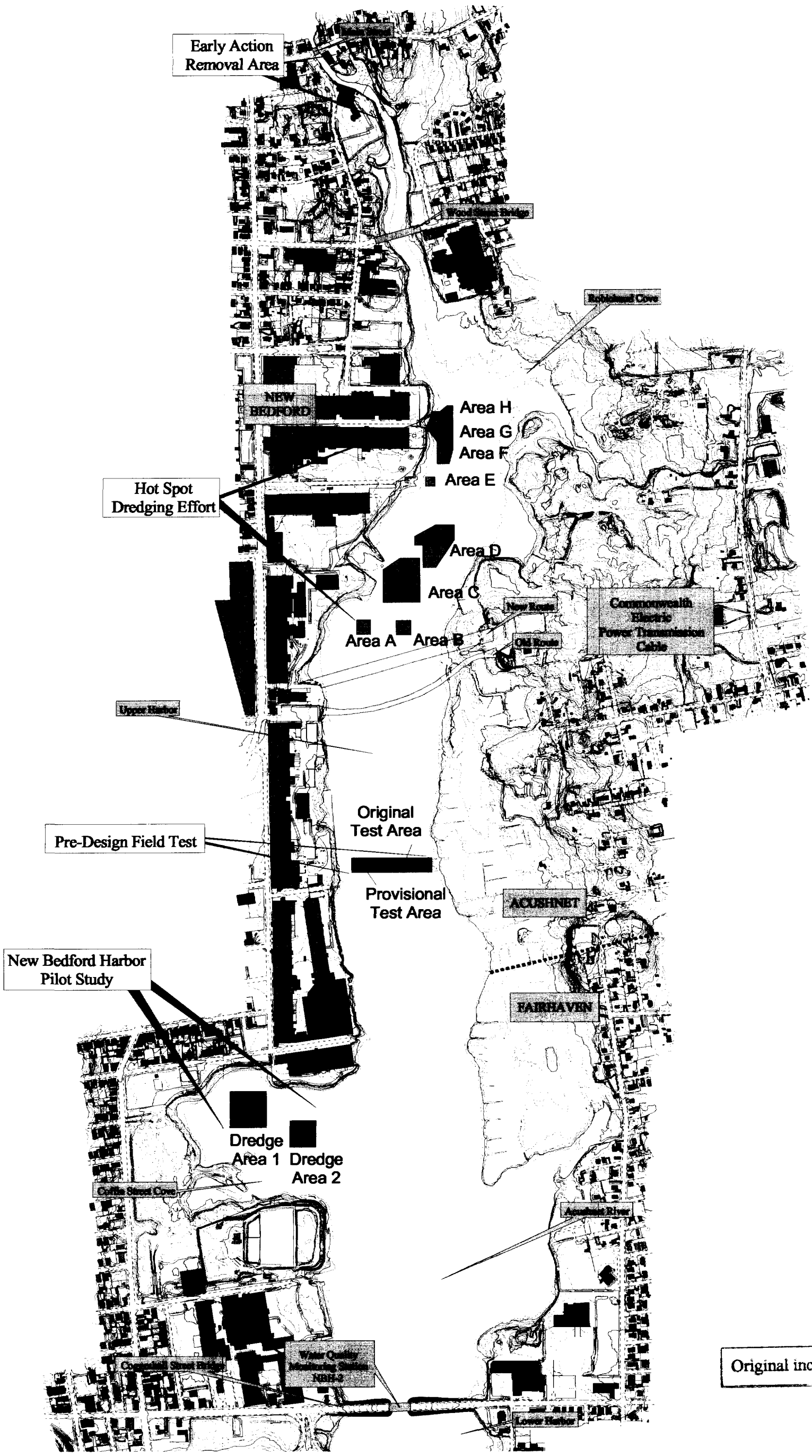
A fifth project at the New Bedford Harbor, the Commonwealth Electric Cable Relocation Project [2001], also involved dredging. However, this dredging effort was not performed to remove contaminated sediment from the Harbor and did not include post dredging sediment sampling. The summaries of each of the four listed environmental dredging or excavation efforts focus on identifying: the type of post-dredging or post-excavation sediment sampling performed (i.e., core or grab sampling); the depth of the post-dredging or excavation sediment layer sampled; and the characteristic spacing or spatial density of the samples collected.

It must be noted that the sediment sampling performed relative to these past dredging or excavation activities was not necessarily designed or intended to be used for purposes of confirmatory sampling or regulatory compliance. Some sampling was conducted to evaluate the performance of the equipment and to assess other factors. The sampling characteristics associated with these past efforts were reviewed to provide a site-specific perspective and to identify the presence or lack of precedents with regard to how the confirmatory sampling for the principal remediation effort should be conducted.

A.1 New Bedford Harbor Superfund Pilot Study

A pilot scale field test was performed in the Upper Acushnet River Estuary from May 1988 to February 1989. The pilot study area was broken into two dredging areas within the Coffin Street Cove located 2,000 feet north of the Coggeshall Street Bridge on the New Bedford side of the Acushnet River. Dredging Area 1 was a square 250 feet on a side (1.43 acres in size), while Dredging Area 2 was a square 180 feet on a side (0.75 acres in size) (see Figure A-1). This field test was performed to determine if contaminated sediments could be removed by conventional or specially designed dredging equipment without causing unacceptable releases and mobilization of contaminants. The techniques of three hydraulic dredges (cutterhead, horizontal auger, and Matchbox) were evaluated. Ten thousand cubic yards of sediment were removed from the Upper Harbor, of which 2,900 cubic yards were contaminated.

The cutterhead and the Matchbox dredges were held stable by a set of stern spuds (anchor posts) set into the sediment. Anchor cables were placed in position and were used to control the swing of the cutterhead. The dredge advanced by the alternate raising and lowering of the stern spuds at the end of the lateral swing. This permitted the dredge to move forward in a zigzag fashion. The major operational problem observed with the cutterhead and Matchbox dredges involved the depth of water in the Coffin Street Cove relative to the setting of the swing anchors. Due to the very shallow depths in many parts of the dredging areas, only small workboats could operate, limiting the ability to lift and maneuver heavy swing anchors. An additional operational concern with the Matchbox dredge was associated with the plugging of the dredgehead with debris and sediment.



Original includes color coding.

Previous Dredging/Excavation Actions

- Early Action Removal Area (Area 1)
- Hot Spot Dredging Effort
- New Bedford Harbor Pilot Study
- Pre-Design Field Test
- Commonwealth Electric Power Transmission Cable

N

500 0 500 1000Feet

FOSTER WHEELER

FOSTER WHEELER ENVIRONMENTAL CORPORATION
133 FEDERAL STREET, BOSTON, MASSACHUSETTS 02110

NEW BEDFORD HARBOR SUPERFUND SITE
BRISTOL COUNTY, MASSACHUSETTS

FIGURE A-1
Past Dredging Locations and Associated Sediment Sampling in the New Bedford Harbor

MA STATE PLANE
NAD 83 FEET
NGVD 29
1 FOOT CONTOUR INTERVAL
5 FOOT INDEX CONTOUR INTERVAL

DRAFT: FEB 12, 2002

P:\GIS\NBH\WORKDIR\11x17_dredged_areas.apr

The cutterhead dredge made one pass over Dredging Area 1 and removed a layer of sediment that averaged 1.5-feet thick. Thirty-two sediment cores were taken in Dredging Area 1 following the dredging from the top 3 inches of the newly exposed sediment. These 32 cores were composited into 8 samples for analysis. PCB concentrations ranged from 8.2 to 189 ppm, with an average of 80.5 ppm. The post-dredging sediment sampling was conducted with a coverage of approximately 16 samples/acre or the equivalent of one sample being taken per grid assuming a regular square grid network with grids approximately 51 feet on a side (see Table A-3). The characteristic width of cut was 60 feet.[1] In Dredging Area 2, the cutterhead made two passes over the area and removed a 1.1-foot layer of sediment on average. On the second pass, the dredge was positioned to remove only the surface layer of sediment. In Dredging Area 2, 16 sediment cores were taken from the top 3 inches of the newly exposed sediment. These 16 cores were composited into 4 samples for analysis. PCB concentrations ranged from 0.5 to 153 ppm, with an average of 8.6 ppm.

The Matchbox dredge made two passes over Dredging Area 2, removing 6 inches per swing with 2 swings per pass. This resulted in the removal of a sediment layer of 1.5-feet average thickness. Sixteen sediment cores were taken in Dredging Area 2 from the top 3 inches of the newly exposed sediment. These 16 cores were composited into 4 samples for analysis. PCB concentrations ranged from 3 to 9.6 ppm, with an average of 5.4 ppm. The post-dredging sediment sampling was conducted with a coverage of approximately 29 samples/acre or the equivalent of one sample being taken per grid assuming a regular square grid network with grids approximately 39 feet on a side (see Table A-3). The characteristic width of cut was 60 feet.[2] Mechanical problems were encountered in Dredging Area 1 and contaminant removal was not evaluated.

The horizontal auger dredge or the "Mudcat" (Ellicott SP-915) requires workboats for it to be moved into position and to be hooked up to its cable system. This dredge advances by winching itself along a single cable line and is capable of digging while proceeding in either a forward and reverse direction. Two operational problems were encountered using this type of dredge setup. First, the dredge was susceptible to being blown off-line by high winds. Secondly, it was at times difficult to locate suitable sites to hook up the 4-point cable system. The Mudcat made 4 passes over both Dredging Areas 1 and 2. This resulted in the removal of an average 1.0-foot layer of sediment in Dredging Area 1 and a 1.2-feet layer of sediment in Dredging Area 2. The residual PCB concentration in the sediment in Dredging Area 1 averaged 66.4 ppm. The post-dredging sediment sampling was conducted with a coverage of approximately 20 samples/acre or the equivalent of one sample being taken per grid assuming a regular square grid network with grids approximately 46 feet on a side (see Table A-3). The characteristic width of cut was 9 feet.[3]

A sampling device was installed on each dredgehead and surface water sampling was conducted while the dredges operated to determine the degree of sediment resuspension and contaminant release from each of these dredges. These water samples were analyzed for total suspended solids. These data were used together with the dredge's swing speed and water depth to estimate the sediment suspension rate. The cutterhead dredge proved to be the most effective at minimizing resuspension, while the horizontal auger (Mudcat) dredge was the least effective, as shown in Table A-1.

---

[1] "New Bedford Harbor Superfund Pilot Study – Evaluation of Dredging and Dredged Material Disposal", U.S. Army Corps of Engineers, New England Division, May 1990, Appendix 1, pages 1-1 and 1-11.
[2] Ibid., Appendix 1, pages 1-18, 1-20 and 1-24, May 1990.
[3] Ibid., Appendix 1, pages 1-17 and 1-45.

Table A-1
Comparison of Sediment Resuspension Rates Measured for Each Tested Dredge During the New Bedford Harbor Superfund Pilot Study - Evaluation of Dredging and Dredged Material Disposal[4]

Dredge Type	Range of Average Resuspension Rates (grams/sec)
Cutterhead	8.5 – 60.5
Matchbox	26.2 – 78.4
Horizontal Auger	187 – 690

The sediment and contaminant transport was evaluated for each of the dredges by establishing fifteen stations around each of the dredge work areas. These stations were sampled to detect if there was a plume of suspended material moving away from the point of dredging. Samples were taken hourly from each of these stations, around each of the dredges, and composited. These composited samples were then analyzed for PCBs and metals. A well-defined plume of suspended material never developed around any of the dredges. The results of all three dredges indicated that the sediment and contaminant movement away from the point of dredging was limited.

A.2 Hot Spot Dredging Effort– Evaluation of Dredging and Dredged Material Disposal[5]

The areas of hot spot sediment contamination were generally located in a shallow portion of tidal estuarine area where Acushnet River merges with Upper New Bedford Harbor. Dredging of these hot spot sediments took place between April 1994 and September 1995. Approximately 14,000 cubic yards of sediments were removed from eight separate hot spot areas (identified as Areas A through H)[6] which covered a total of approximately 5 acres (see Figure A-1). The dredged sediments were placed in an interim confined disposal facility (CDF) located off of Sawyer Street.

Two of the principal objectives of this hot spot dredging were:[7]

1. To remove a significant percentage of PCBs in the Upper Harbor without causing significant additional risks to human health or the environment.
2. To avoid additional remediation in the Lower Harbor as a result of the hot spot dredging program (i.e., the resuspension and transport of contamination from an area of high contamination to areas of low contamination).

Sediment sampling was conducted both prior to and following the dredging of the hot spot locations. The pre-dredging samples were collected for purposes of site characterization and to aid in the specification of the initial dredging depths in the various areas. These samples were taken with a core sampler, typically over 6-inch to 1-foot depth intervals (e.g., 0 to 1 foot, 12 inches to 18 inches, 1 to 2 feet). Samples were, at times, collected from multiple depths or depth ranges at the same location for purposes of better estimating the thickness of the contaminated sediments at that location.[8] Grab samples also were collected in some of the areas.

---

[4] "New Bedford Harbor Superfund Pilot Study – Evaluation of Dredging and Dredged Material Disposal", U.S. Army Corps of Engineers, New England Division, May 1990, Appendix 1, pages 1-12, 1-17 and 1-24.
[5] "Report on the Effects of the Hot Spot Dredging Operations – New Bedford Superfund Site", March 14, 1997.
[6] It must be noted that no dredging or sediment removal was ultimately performed in Area B due to its proximity to the existing Commonwealth Electric transmission cable.
[7] Ibid., page 2-1.
[8] Scope of Work and associated Attachment 6, Project file notes of Jay MacKay.

Post-dredging sampling was performed to determine whether the dredging had reduced the exposed surficial sediment PCB concentration to less than the target concentration of 4,000 ppm. The confirmatory sampling program was designed to minimize the possibility that sediments that should be dredged (i.e., sediments that actually had a PCB concentration greater than 4,000 ppm) were left in place.[9] A statistically based sampling and analysis program was designed to achieve this objective. This program was patterned on the USEPA guidance document "Verification of PCB Spill Cleanup by Sampling and Analysis."[10]

The basic elements of this overall approach included:

1. Identifying the number of individual locations to sample within each hot spot area;
2. Grouping these individual locations according to a recommended compositing scheme (as per the USEPA guidance) for purposes of limiting the number of samples actually analyzed by the laboratory;
3. Collecting and archiving the individual samples and forming the specified number of composite samples according to the selected compositing scheme;
4. Having the composite samples analyzed at the laboratory;
5. Identifying a statistically-based "high" and "low" concentration decision criteria against which to compare the composite sampling results (i.e., to conclude that the sediment concentration at some location within the area is greater than 4,000 ppm or that the sediment concentrations in the area are demonstrably less than 4,000 ppm);
6. Defining and implementing the follow-up action rules:
   - No further dredging in the area if the measured composite sample result for the area is less than the "low" concentration decision criterion;
   - Re-dredging the area if the measured composite sample result for the area is greater than the "high" concentration decision criterion;
   - Analyze the archived individual samples for the area when the measured composite sample result falls between the "low" and "high" concentration decision criteria;
   - Identify and focus re-dredging in the area when the measured composite sample result falls between the "low" and "high" concentration decision criteria; and
   - Resample re-dredged areas.

Additional details relative to each of these elements is presented below.

The sampling and analysis procedure outlined in the cited USEPA guidance involved selecting the number of point locations to be sampled based on a regular hexagonal reference grid. Given a hexagonal grid, the smallest number of corner/node points is 7 (6 outer corners and the center point). The next two smallest hexagons have 19 and 37 corner/node points, respectively. The guidance recommends a number of sample points based on the size of the area to be sampled.[11] Seven sample points were specified for

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[9] "Questions Concerning Sampling Protocol for Verifying Sediment PCB Concentrations After "Hot Spot" Remediation", FAX from Skip Nelson, USEPA Narragansett to Jay McKay, USACE, October 1, 1992.

[10] "Verification of PCB Spill Cleanup by Sampling and Analysis", U.S. Environmental Protection Agency, USEPA-560/5-85-026, Section IV – Guidelines for Sampling and Analysis, August 1985.

[11] "Verification of PCB Spill Cleanup by Sampling and Analysis", U.S. Environmental Protection Agency, *USEPA-560/5-85-026*, Section IV – Guidelines for Sampling and Analysis, August 1985, Table 4, page 17. It should be noted that the sample sizes selected for each hot spot area did not exactly match the recommendations presented in this table. However, a number of individual samples lower than what was recommended was adopted for the hot spots in consideration of the typical sizes of the hot spots and the relatively small size of the target spill area that was designed to be located using the reference approach in the guidance.

Hot Spot Areas A, B, E, F, and H, while 19 sample points were specified for the larger Hot Spot Areas C, D, and G. The reference procedure assumes that this number of samples will be taken at randomly selected locations from within the area to be sampled. In order to identify these random locations, a regular square grid 10 feet on a side was laid out relative to each of the hot spot areas. The requisite number of samples was then located using a random selection process. These locations were then evaluated in terms of their spatial pattern and the degree of overall coverage of the hot spot area they afforded.

The USEPA reference procedure included the feature of further compositing the individual grab samples prior to laboratory analysis. This element of the process resulted in some savings of analytical cost while sufficient information was collected to support the required decision-making. As per the reference guidance, the 7 individual grab samples collected in each of the five smaller hot spot areas were combined into 2 composite samples for analysis (one that combined 3 of the individual grab samples and one that combined the other 4 individual grab samples).[12] The three hot spot areas for which 19 individual grab samples were collected were composited into 6 samples (five that combined 3 of the individual grab samples and one that combined the other 4 individual grab samples).

A statistical relationship was used to define the criteria for comparing the results of the analyses of the composite samples to determine if the 4,000-ppm PCB target concentration had been achieved. As was noted, the confirmatory sampling program for the Hot Spot Dredging Effort was designed to minimize the chance that sediments with a PCB concentration greater than 4,000 ppm were not removed. The statistically based decision criteria were calculated using the following removal action-specific values or assumptions:

- Maximum target sediment PCB concentration (4,000 ppm);[13]
- Post-dredging data set would be normally distributed;
- Post-dredging data set would be characterized by a relative standard deviation of 30% (i.e., standard deviation ÷ mean = 0.3);
- Analytical accuracy (approximately 100%); and
- The required confidence level was 95% (such that the standard normal distribution coefficient (Z) was 1.645).

The following calculated criterion was used to decide whether re-dredging was necessary in an area:[14]

If the measured concentration in a single composite sample was less than 2,026 ppm[15] PCBs (i.e., the "high" concentration decision criterion), there was 95% confidence that the PCB clean-up goal of 4,000 ppm was satisfied in that area and that none of the individual samples exceeded 4,000 ppm (at that confidence level). These criteria were calculated but were not used for decision-making during the Hot Spot Dredging Effort:

- If the measured concentration in a single composite sample comprised of 3 individual samples was less than 675 ppm (i.e., the "low" concentration decision criterion: 2026 ÷ 3),

[12] Because of the small size of Area A, only 2 individual samples were collected and combined into 1 composite sample.
[13] Total PCBs or Total Aroclors (expressed in ppm) were compared to a target concentration based on this value. The Total PCB concentration was estimated by summing the measured concentrations of the BZ52, BZ101, BZ118, BZ153, and BZ138 congeners (expressed in ppb), multiplying the sum by 7.99864, subtracting 9612 from the product, and dividing the result by 1,000 to convert the concentration to ppm.
[14] Scope of Work and associated Attachment 6, Project file notes of Jay MacKay.
[15] Portions of an area with a measured PCB concentration very near this exact value were sometimes re-dredged or not in consideration of other operational factors.

then all 3 individual samples can be judged to be below 4,000 ppm PCBs at this level of confidence.

- If the measured concentration in a single composite sample comprised of 4 individual samples was less than 506 ppm (i.e., the "low" concentration decision criterion: 2026 ÷ 4), then all 4 individual samples can be judged to be below 4,000 ppm PCBs at this level of confidence.

Using this procedure and these decision criteria, the sediment sampling and analysis activities summarized in Table A-2 were performed in each hot spot area in support of decision-making about the need to re-dredge within an area.

The post-dredging sediment sampling in the hot spot areas was conducted with a coverage of between 9 and 109 samples/acre (depending on the specific hot spot area) or the equivalent of one sample being taken per grid, assuming a regular square grid network with grids between 20 and 71 feet on a side (see Table A-3 for the characteristic values for each individual hot spot area).

In order to verify that the dredging operations did not present undue risks to human health or the environment, extensive air and surface water quality monitoring also was performed throughout the duration of the dredging. For the water quality monitoring, station NBH-2 was used (see Figure A-1 for location). Station NBH-2 is a five-point sampling array located at the Coggeshall Street Bridge, which separates the Upper and Lower Harbors. This location was chosen to monitor the migration of contaminants since one of the objectives of the hot spot dredging was to avoid the transport of contaminated sediment from the Upper Harbor to the Lower Harbor. Water samples were taken at thirteen separate locations at the multi-point station NBH-2 (5 locations within NBH-2 were sampled at multiple depths), at each six-inch rise or fall in the tidal fluctuation. The samples were composited to form one sample for the ebb tide and one sample for the flood tide and were analyzed for PCBs and metals. Based on the results of the hot spot water quality data, there was minimal net transport of PCBs during the dredging. This analysis was used to develop a maximum cumulative transport (MCT) criterion value for PCBs. The mass of PCBs transported out of the Upper Harbor during this time period was significantly less than the amount considered sufficient to require additional remediation in the Lower Harbor.[16] Sampling of biota to determine the degree of contaminant uptake and toxicity tests also were performed.[17]

An air-monitoring program also was designed and implemented to monitor the potential impacts of the hot spot remedial activities on the air quality. Previous studies had indicated locally elevated airborne PCB levels around the hot spot area.[18] To monitor the air quality, sixteen stations were placed around the Harbor 6 feet above ground (with the exception of 2 stations that were 10 feet above ground). The locations of these stations reflected the predominant southwesterly wind direction during the summer, when more PCB volatilization is expected. Due to the high degree of public concern about the dredging operations, airborne PCB data was made available to the public on a quick turnaround basis. The air stations sampled the air around either the interim CDF (i.e., the Sawyer Street CDF) or the area where the dredging activity was occurring. The monitored air concentrations were compared to a tiered series of action levels that were established to manage the potential air impacts.

The discharge of treated water from the interim CDF was measured and tracked relative to established discharge limits for certain metals and PCBs.

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[16] "Report on the Effects of the Hot Spot Dredging Operations – New Bedford Superfund Site", March 14, 1997, page 2-12.
[17] Ibid., page 2-6.
[18] "Draft Ambient Air Monitoring Program, Acushnet River Estuary, New Bedford, Massachusetts", NUS Corporation, Volume 1, February 1986.

Table A-2
Summary of Sediment Sampling and Analysis Activities and Resulting Decision-Making During the Hot Spot Dredging Effort

Hot Spot Area	Principal Actions Taken
A	▪ Pre-dredging sampling (cores) ▪ Dredging ▪ Collecting 2 post-dredging core samples ▪ Analysis of 1 composite sample ▪ No re-dredging required
B	▪ Due to the proximity of Area B to the existing Commonwealth Electric transmission cable, it was ultimately decided to not dredge this area as part of this effort.
C	▪ Pre-dredging sampling (cores) ▪ Dredging ▪ Collecting 19 post-dredging grab samples ▪ Analysis of 6 composite samples ▪ No re-dredging required
D Western Area	▪ Pre-dredging sampling (core and grab) ▪ Dredging ▪ Collecting 7 post-dredging grab samples ▪ Analysis of 2 composites ▪ One composite exceeded "high" concentration criterion ▪ Analysis of archived individual grab samples associated with that composite ▪ Re-dredging in 1 of 3 individual sample areas
D Eastern Area	▪ Pre-dredging sampling (core and grab) ▪ Dredging ▪ Collecting 12 post-dredging grab samples ▪ Analysis of 4 composites ▪ No re-dredging required
E	▪ Pre-dredging sampling ▪ Dredging ▪ Collecting 7 post-dredging grab samples ▪ Analysis of 2 composites ▪ No re-dredging required
F	▪ Pre-dredging sampling ▪ Dredging ▪ Collecting 7 post-dredging grab samples ▪ Analysis of 2 composites ▪ No re-dredging required
G	▪ Dredging in 2 lanes (no pre-dredging sampling) ▪ Analysis of 2 core samples in these lanes ▪ No re-dredging required in these lanes ▪ Pre-dredging sampling ▪ Analysis of 6 composites ▪ Re-dredging in 3 composite areas ▪ Analysis of 3 new composites ▪ Re-dredging in 2 new composite areas
H	▪ Pre-dredging sampling ▪ Dredging ▪ Collecting 7 post-dredging grab samples ▪ Analysis of 2 composites ▪ No re-dredging required

A.3 Pre-Design Field Test - Dredge Technology Evaluation Report[19]

A Pre-Design Field Test (PDFT) was conducted in August of 2000 to determine site-specific dredge performance values for use in developing a full-scale remediation plan. The evaluation of dredge efficiency relative to PCB removal had multiple goals. One objective was to evaluate the dredge's ability to remove contaminated sediment to a given depth horizon specified in the dredging plan. The dredge performance was shown to be highly accurate in this regard. Comparison of the target dredge volume with the actual volume of sediment dredged yielded an overdredging value of only 16%, with a vertical accuracy +/- 4 inches relative to achieving the intended accuracy.[20]

A second objective was to determine how effectively this new dredging technology could remove contaminated sediments relative to a depth projected to achieve a 10-ppm PCB concentration horizon. The PDFT had no explicit requirement to leave a final sediment concentration of 10-ppm PCB, as this activity was a field test and not a remedial operation.[21] The PDFT dredge area was 100 feet by 550 feet, with the long axis oriented east west in the Upper Harbor approximately 3,700 feet north of the Coggeshall Street Bridge. This area was found to have an appropriate range of sediment PCB concentrations and a suitable range of water depth for the necessary testing.

The dredge system used was a Mechanical Excavator Hydraulic Transport (MEHT) system developed in cooperation with Bean Environmental LLC. The dredge system consisted of a portable, shallow draft barge platform, a hydraulic excavator with a sealed environmental clamshell bucket, a water recirculation system, and a discharge pipeline for transport of the slurry. Attached to the dredge platform was a four-point anchoring system with two manually operated, dual-drum diesel winches, selected for dredge mobility and positioning.[22]

To facilitate the evaluation of pre-dredging and post-dredging sediment PCB concentrations, a grid of 30 sampling points was defined in the original 100-feet by 400-feet dredging test area, and 10 additional locations were located within the provisional test area (an additional 100-feet by 150-feet in size) located immediately to the west of the original area (see Figure A-1). Spacing between each sampling point was designed to allow for adequate characterization of the pre-dredging PCB concentrations within the test area. This spacing also allowed for the performance of statistically valid comparisons between pre-dredging and post-dredging concentrations to assess the ability of the dredge to achieve target clean-up levels.[23] The pre-dredging sediment sampling was conducted with a coverage of approximately 33 samples/acre or the equivalent of one sample being taken per grid assuming a regular square grid network with grids approximately 36 feet on a side (see Table A-3).

The pre-dredging sediment core samples were collected between June 13 and 16, 2000, allowing time for the laboratory analyses to be complete so the results could be incorporated into the dredging plan. The pre-dredging samples were collected at most of the 30 locations within the original 100 feet by 400 feet test area. The cores were split into 1-foot sections and were collected to a depth of 4 feet (pre-dredging) and 2 feet (post-dredging). For the pre-dredging samples, maximum depths less than 4 feet were obtained if the core could not be driven to that depth or if the soft black surficial layer was noted as being less than 4 feet. All pre-dredging locations were sampled at the 0 feet to 1 foot and 1 foot to 2 feet depth intervals.

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[19] "Final Pre-Design Field Test Dredge Technology Evaluation Report - New Bedford Harbor Superfund Site, New Bedford, MA", Prepared by Foster Wheeler Environmental Corporation, August 2001.
[20] Ibid., Executive Summary, page ES-5.
[21] Ibid., Executive Summary, Page ES-5.
[22] Ibid., pages 2-4 and 2-5.
[23] Ibid., Appendix J, page J-2.

Table A-3
Summary of Post-Dredging Sampling Characteristics Associated with Past Environmental Dredging Activities at the New Bedford Harbor Superfund Site

Prior New Bedford Harbor Dredging Activity [d]	Type of Post-Dredging Sediment Sampling Performed	Depth of Post-Dredging Sediment Sampled	Characteristic Density of Samples Collected (samples/acre)	Effective Square Sampling Grid Spacing (feet)	Size of Dredged/ Sampled Areas (acres)
New Bedford Harbor Superfund Pilot Study [1988/1989]					
– Cutterhead – Dredging Area 1	Core	0 to 3 inches	16	51	0.81 Dredged 0.48 Sampled
– Matchbox - Dredging Area 2	Core	0 to 3 inches	29	39	0.46 Dredged 0.24 Sampled
– Mudcat - Dredging Area 1	Core	0 to 3 inches	20	46	0.40
Hot Spot Dredging Report [1995]					
Area A	Grab	0 to 3/6 inches[a]	9 (4.3)[b]	71[c]	0.23
Area B	This area was not ultimately dredged during this effort				0.23
Area C	Grab	0 to 3/6 inches	9 (2.9)	69	2.07 {1.66}
Area D	Grab	0 to 3/6 inches	14 (4.4)	56	1.38 {1.22}
Area E	Grab	0 to 3/6 inches	85 (24)	23	0.08 {0.10}
Area F	Grab	0 to 3/6 inches	18 (5.3)	49	0.38 {0.36}
Area G	Grab	0 to 3/6 inches	24 (7.7)	42	0.78 {0.64}
Area H	Grab	0 to 3/6 inches	109 (31)	20	0.06 {0.14}
Pre-Design Field Test [2000]	Core Grab	1 feet intervals 0 to 0.8 inch	33 Not Applicable	36 Not Applicable	1.26
Early Action Removal Area (Area 1) [2001]	Grab	0 to 12 inches (1 sample 12 to 24 inches)	28	40	0.70

Notes: The post-dredging or post-excavation sampling performed was not designed or necessarily intended to be used for confirmatory sampling relative to regulatory compliance.

[a] Scope of work initially targeted a surface sediment layer depth of 0 to 3 inches. However, actual sampling conducted is reported to represent conditions in the top 6 inches of sediment.

[b] First number is the density of individual locations sampled. The second number is the density of composite samples analyzed.

[c] Grid spacing is based on the density of collected individual samples from the previous columns.

[d] No post-dredging sampling of PCB sediment concentrations was performed during the Commonwealth Electric Cable Relocation project [2001] (see Section A.5).

All but 8 of the 30 locations also were sampled over the 2 feet to 3 feet depth interval, and only 5 of the 30 locations were sampled over the 3 feet to 4 feet depth interval.[24] Longer cores (greater than 4 feet) were collected with respect to 10 pre-dredging samples to ensure that the soft black surficial material was fully penetrated. The core barrel was manually driven into the sediment. A piston, fixed at the sediment/water interface, placed the sample under negative pressure during retrieval, allowing for recovery of a nearly undisturbed sediment sample.[25]

The pre-dredging sediment samples were analyzed for the 18 PCB congeners selected by the National Oceanographic and Atmospheric Administration (NOAA) and expressed as a total PCB concentration using a site-specific empirical relationship developed for the New Bedford Harbor sediments.[26]

[24] "Final Pre-Design Field Test Dredge Technology Evaluation Report - New Bedford Harbor Superfund Site, New Bedford, MA", Prepared by Foster Wheeler Environmental Corporation, August 2001, Figure 2-1.
[25] Ibid., Appendix J, page J-3.
[26] Ibid., page 4-1.

Post-dredging sediment core samples were collected at the designated sampling stations (the same ones used for pre-dredging sampling) when the dredging was complete using the same methodology as was used in the pre-dredging sampling. The post-dredging sediment samples also were analyzed for the 18 NOAA PCB congeners.

The surficial sediments had been shown to have a high silt-clay content and a high water content. Consequently, it was anticipated that they might re-contaminate the dredged test area. To assess surficial sediment conditions and the degree of recontamination that may have occurred, additional post-dredging grab samples were collected at other locations in the test area within the first 0 to 0.8 inches (0 to 2 cm) immediately after dredging. These post-dredging grab-sampling locations were not specified prior to dredging, but were determined as the sampling crew worked around the shifting dredge-anchor system. These sediment grab samples were obtained using a petite-ponar sampler and were generally collected as soon as practicable after dredging was completed, generally the same day as the dredging and often within several hours of the dredging. The sampling device typically collected the first 6 inches of exposed sediment, from which a sample from the top 0.8 inches was taken for analysis. A differential global positioning system was used to position the grab samples, along with a Trimble Real Time Kinematic system. The navigational coordinates for each sample were pre-entered into the system. Once the vessel was at a given sampling point, fine level positioning adjustments were made using the 3-point mooring system to achieve the 2-foot accuracy requirements. To prevent the possibility of maneuvering operations impacting the bottom sediments, anchors for each line were set well outside the footprint for the evaluation area and buoyant mooring line was utilized.

Post-dredging PCB concentrations in the surficial grab samples (0 to 0.8 inches) ranged from 0.47 to 470 ppm PCBs, and were generally above 100 ppm. PCB concentrations in the in the upper 1 foot of the newly exposed sediment cores ranged from 0.67 to 130 ppm PCBs, and were generally less than 7 ppm.[27] Post-dredging PCB concentrations in the surficial grab samples were significantly higher than in the 0 feet to 1 foot composite core samples collected relative to the newly exposed sediment surface at 16 of the 18 locations where both types of samples were collected.[28]

Relative to the second objective of the PDFT to determine how effectively this new dredging technology could remove contaminated New Bedford Harbor Sediments relative to the depth indicated to achieve a 10 ppm PCB concentration horizon, the dredge was reported to perform well. The average sediment concentration in the upper foot of the test area was reduced from 857 ppm to 29 ppm.[29] The PCB mass remaining after the dredging appeared to reside entirely in a thin surface veneer and was attributed to recontamination of the dredged area rather than incomplete removal. Potential recontamination mechanisms were reported to include material sloughing down slope along the sides of a dredged cut, material mobilized during bucket impact and retrieval, material mobilized during anchor wire or spud repositioning, resuspension due to assist vessels, and general transport related to tides and meteorological events.

Adjustments to dredging and operational controls for full-scale dredging were expected to lead to corresponding reductions in the influence of many of these mechanisms on post-dredging sediment quality.

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[27] "Final Pre-Design Field Test Dredge Technology Evaluation Report - New Bedford Harbor Superfund Site, New Bedford, MA", Prepared by Foster Wheeler Environmental Corporation, August 2001, page 4-2.
[28] Ibid., page 4-2.
[29] Ibid., Executive Summary, page ES-5.

A.4 Early Action Removal Action (Area 1)[30]

Between March and April of 2001, sediments were excavated from a residential area in the far Upper Harbor near Main Street in Acushnet. This area, called the Early Action Removal Area (Area 1), was approximately 0.7 acres (approximately 30,000 feet^2) in size, was excavated and backfilled. Baseline sediment characterization sampling was performed two weeks later, as part of a long-term sampling program designed to monitor the PCB concentrations in the sediments that wash into or are redeposited in this area during the next 2 years. The residences located on the properties that make up this area are relatively close to the Acushnet River and exposed sediment, and the population potentially exposed to the sediments includes young children (ages 0-6). Given these potential exposure conditions, the residential ROD target PCB clean-up level of 1 ppm in the top foot of sediment was applied to this area by the USEPA.

Twenty three sampling points (identified with sample identifiers EAC-##) were placed approximately 50 feet apart over the area that was excavated and backfilled. Surface backfill material/sediment grab samples (in the depth range of 0 – 1 foot) were collected at these locations. Two samples were taken at depths of 0-1 foot and 1-2 feet in one location (EAC-30), in an area that was not backfilled. Three samples were taken around sample EAC-30 (EAC-30N, EAC-30E, and EAC-30S) for further characterization of this location. All samples taken were analyzed for PCBs. The post-excavation and backfilling baseline characterization sampling was conducted with a coverage of approximately 28 samples/acre or the equivalent of one sample being taken per grid assuming a regular square grid network with grids approximately 40 feet on a side (see Table A-3).

A.5 Commonwealth Electric Cable Relocation Project

In the summer and fall of 2001, the Commonwealth Electric power transmission cable that runs from the Acushnet Substation in Acushnet west under the Upper Harbor to a point near the eastern end of Belleville Road in New Bedford was moved (see Figure A-1). This project involved dredging the sediments along the new route to create a channel into which a concrete conduit was placed. The new power transmission line was placed through this conduit. The material dredged during this effort was temporarily stockpiled underwater in containment structures adjacent to the dredge channel, and was later replaced on top of or around the concrete conduit. No post-dredging chemical sampling of these sediment was performed.

[30] Personal communications with Ray Francisco, Foster Wheeler Site Remediation Manager, New Bedford Harbor Superfund Site, September 2001.

APPENDIX B

SURVEY OF RECENT ENVIRONMENTAL DREDGING ACTIVITIES AT OTHER SITES

This section reviews the recent use of post-dredging confirmatory sampling to assess the short-term effectiveness of dredging or excavation at 22 environmental remediation sites located throughout the United States, and in Japan and Sweden. For each dredging or excavation project, information was obtained, if available, on:

- The location and type of site;
- The primary chemicals of concern (COC);
- The type of removal equipment used (e.g., dredges, excavators, or both);
- The volume of sediment removed;
- The dates of dredging and post-dredging sampling;
- The number and type of sediment samples collected;
- The portion of the sediment column that was sampled (i.e., depth intervals);
- The sediment clean-up goals; and
- The results of physical, chemical, and biological parameters collected to evaluate short-term effectiveness of the remedial dredging or excavation activity [Note: Short-term effectiveness is defined as achievement of goals based on project expectations].

This survey focused specifically on removal or excavation of subaqueous sediments (i.e., mechanical or hydraulic dredging) at these environmental remediation sites. Both of these types of dredges could be used in the remediation of sediments at New Bedford Harbor.

The design of the survey and a tabular summary of the information compiled are presented in this section. The results of the survey are reviewed on a feature-by-feature basis, and comments on the results relative to the confirmatory sampling at New Bedford Harbor are presented.

B.1 Project Selection

The selection of environmental dredging projects for this survey was based on the type of dredging, extent of monitoring programs conducted, and the ready availability of the necessary information and documentation. The initial screening process involved accessing a broader set of available information on over 50 dredging projects in the United States, Europe and Asia. Specific and general resources for this project review included:

- USEPA regional websites, fact sheets, and publications on clean-up sites;
- Dredging-related websites and journal articles;
- Proceedings from dredging conferences;
- Assessment and Remediation of Contaminated Sediments (ARCS) Program, USEPA's Great Lakes National Program Office (GLNPO) publications;
- Sediment Priority Action Committee (SedPac) and International Joint Commission (IJC) publications;
- White papers published by research groups;
- Sediment Management Workgroup (SMWG) Publications;
- *Contaminated Sediments in Ports and Waterways Cleanup Strategies and Technologies* (NRC 1997);
- Conference Proceedings from the National Symposium on Contaminated Sediments (NRC 1998);

- Draft Sediment Technologies Memorandum for the Lower Fox River, Wisconsin Department of Natural Resources (ThermoRetec, 2001);
- Western Dredging Association newsletters;
- Hudson Watch website (http:\\www.hudsonwatch.com) or (http:\\www.hudsonvoice.com);
- USACE publications and website; and
- Project team experience.

Dredging projects retained after this initial data-gathering phase had to meet the following additional criteria to be considered relevant to the planning for the New Bedford Harbor project:

1. The dredging performed was environmental dredging for purposes of site remediation as opposed to maintenance or navigational dredging;
2. The remedy was already implemented and not in the planning stages (one exception to this criterion was the Olympic View Removal Action in Tacoma, Washington, which is planned for June of 2002);
3. The contaminants of concern were PCBs, or other persistent chemicals such as polycyclic aromatic hydrocarbons (PAHs) or metals that tend to adhere to sediments containing organic material; and
4. The remedy was a wet excavation project (standing water over the sediments and accessed by barge or from shore). A combination of other technologies in which dredging was at least one of the implemented methods also was considered acceptable.

Based on these criteria, a total of 22 environmental dredging projects were considered sufficiently relevant for further consideration in the context of New Bedford Harbor. The primary features and the confirmatory sampling elements of these projects are compiled and summarized in Table B-1. Project-specific references are presented in the reference list attached to Table B-1. These references are keyed to and are cited in the table.

B.2 Survey results

B.2.1 General Results of the Survey

The results of the post-dredging monitoring review are summarized in the "Notes" column of Table B-1 and in the discussion that follows.

Sediment contaminant concentrations were measured in 20 of 22 projects reviewed for this survey. At the time of this writing, chemical data were not available for review for two of the 20 projects. Surficial sediment samples (generally taken in the top 6 inches) were collected for post-dredging monitoring at 12 project sites, deeper samples (≥ 1 foot) were collected at 3 sites, and the sampling depth was not specified for the 7 other projects. The number and location of post-dredging sampling points for each project were selected either randomly or within specified dredge management unit or cell boundaries. A statistically based approach to specifying the number and location of post-dredging sampling points was not employed at any of these sites.

Biological monitoring was performed at four sites (i.e., Waukegan Harbor, Black River, Lake Jarnsjon Sweden, and Minamata Bay Japan). This monitoring included fish/shellfish tissue and bioassay toxicity testing. Physical monitoring, including bathymetry or other bottom topography measurements (e.g., poling), was conducted in 18 of the 22 projects.

Table B-1
Survey of Environmental Dredging Projects and Post-Dredging Confirmatory Sampling Approaches

Site Name, Location [reference]	Primary COCs	Removal Equipment	Sediment Volume (cy)	Dredging Dates	Confirmatory Sampling Dates	Number of Samples	Sample Depth Interval	Notes
Grasse River, Massina, NY [1, 2]	PCBs	Mechanical with silt curtains and oil booms	390 (boulders) 2643 (sediment)	Jul. 1995 – Sep. 1995	Sep. 1995	3 surface samples	0-3 in (pre-dredging); 0-6/7 in (post-dredging)	– Hot Spot Dredging Reduction in PCBs from 176 to 97 mg/kg. Boulders prevented removal of residual contaminated sediments. – A post-dredging bathymetric survey was conducted, including a visual description of surface sediments.
Manistique Harbor, MI [3]	PCBs	Hydraulic with silt curtains	130,000	1995-1998	1997 & 1998	Not Available	0-3 in	– Comparison between 1993 sediment characterization and 1997 and 1998 post-dredging sampling. 1993–16.5 mg/kg 1997–25.4 mg/kg 1998–29.4 mg/kg – Average surface concentrations increased after dredging. Repeated dredging to remove residual contaminated sediment.
Terminal 18 - East Waterway, Harbor Island, WA [4, 5]	PCBs, PAHs, TBT, DDT	Mechanical	219,600	Dec. 1999 – Feb. 2000	Mar. 2000	12 surface samples	Upper 10 cm	– Objective was to meet WA State SQS. Nine of twelve samples failed chemical concentration standards and all but one of the 12 stations failed bioassay criteria. – Post-dredging bathymetric surveys were conducted.
Olympic View Resource Area, Tacoma, WA (Removal Action) [6]	Dioxins, Metals, PCBs, PAHs	Mechanical – Excavation with clamshell	6,500	Jun. 2002 (planned)	--	15 surface samples (planned)	Upper 10 cm (planned)	– Objective to meet Commencement Bay/Nearshore Tideflat SQOs, WA SQS for mercury, and 20 ng/kg for dioxin. – Progress and post-dredging bathymetric surveys are planned.

Table B–1 – *Continued*

Site Name, Location [reference]	Primary COCs	Removal Equipment	Sediment Volume (cy)	Dredging Dates	Confirmatory Sampling Dates	Number of Samples	Sample Depth Interval	Notes
Puget Sound Naval Shipyard Pier D, Bremerton, WA [7]	PCBs, PAHs, Metals	Mechanical – Clamshell from barge	53,400	Oct. 1994 – Mar. 1995	Dec. 1994; Mar. 1995 Sampled immediately after dredging and completed for each side of pier.	10 surface samples at 200-foot intervals	Upper 2 cm	– Of the 10 stations, six stations had metal concentrations above the WA State CSL, and one station exceeded the SQS. of the 10 stations, three stations had PCB concentrations above the CSL and six stations exceeded the SQS. The concentrations of chemicals in the surface sediments were similar between the pre- and post-dredging sampling with some metal concentrations measured at slightly lower concentrations after dredging. (Likely due to "fluff"). – A final post-dredging bathymetric survey was conducted.
Sitcum Waterway Commencement Bay/Nearshore Tideflat, Tacoma, WA [8]	Metals, PAHs	Hydraulic with Cutterheads and Mechanical – Clamshell	127,500	Oct. 1993 – Sep. 1994	Sep. 1994	24 locations	0 to 1 foot	– Five discrete samples exceeded the SQOs (one to three analytes each) with ERs ranging from 1.04 to 2.09. This means that maximum concentrations were one to two times higher than protective thresholds. The 95% UCL of the mean sediment concentration for each analyte was less than the SQO with the exception of arsenic at one location (59 mg/kg and ER = 1.03). This area was re-dredged and supplemental verification samples were below the SQOs. – A post-dredging bathymetric survey was conducted.
Wyckoff Facility/West Harbor Operable Unit, Eagle Harbor, WA [9]	Mercury PAHs	Mechanical – Clamshell	6,000	Apr. 1997 – Oct. 1997	During dredging 1997	Multiple locations at 50-foot grid spacings	0-10 cm	– A chemical exceedance for sediments was determined by three criteria: The area-weighted average concentration must be less than 5 mg/kg mercury; less than 20 percent of individual samples can exceed 5 mg/kg mercury; and no individual sample can exceed 10 mg/kg (ER = 2). All post-dredging samples met compliance criteria. – A post-dredging bathymetric survey was conducted.

Table B–1 – *Continued*

Site Name, Location [reference]	Primary COCs	Removal Equipment	Sediment Volume (cy)	Dredging Dates	Confirmatory Sampling Dates	Number of Samples	Sample Depth Interval	Notes
Ruck Pond, Cedar Creek – Milwaukee Estuary, Cedarburg, WI [10]	PCBs	Surface Water Diversion and "Dry Excavation"	6,000	Jun. 1994 – Oct. 1994	Oct. 1994	Not Available	Residual sediment above bedrock	– Post-removal residual PCB concentrations were reported to be up to 300 ppm compared with concentrations pre-dredging as high as 150,000 ppm. – A post-dredging sounding survey was conducted.
Outboard Marine Construction Site, Waukegan Harbor, IL [11]	PCBs	Mechanical	50,000	Completed Feb. 1992	Apr. 1996	19	Upper 6 cm	– USGS and USEPA conducted a post-remediation evaluation of the toxicity and bioaccumulation of contaminants in Waukegan Harbor sediments. The results show that the remediation at Waukegan Harbor successfully lowered concentrations of PCBs at the site and the study found the harbor sediment to be less toxic than harbor sediment prior to remediation. Post-dredging PCB levels were generally below 10 ppm (baseline levels between 50-500 ppm and >500 ppm). – A post-dredging bathymetric survey was conducted.
Port of Portland - T4 Pencil Pitch, Portland, OR [12, 13]	Coal Tar, PAHs, Metals	Mechanical – Clamshell	35,000	Dec. 1994 – Jan. 1995	Jan. 1995	30	Not Available	– The chemical analyses by IR scanning indicated that the pencil pitch levels had been reduced to below the specified 0.5 percent (by weight) in all of the dredged areas. Additionally, the concentrations of trace metals and PAHs showed a substantial reduction in concentrations relative to the pre-dredging levels. – Post-dredging bathymetric surveys were conducted.
Detroit River – Tributary, Monguagon Creek, MI [14]	2,4 DP	Mechanical – Backhoe	16,000	Jan. 1997 – Summer 1997	Nov. 1997	14	Composited 2-3 surface grabs at each location	– Original plan was to remove all sediment down to lake bottom clays. Decided to double check for presence of COC. No information on residual concentrations available at the time of this writing.
Niagara River, NY [14]	PCBs	Mechanical	21,800	1996-1998	No confirmatory sampling	None	Not Applicable	– Used pre- and post-dredging bathymetric surveys to confirm dredging depth.

Table B–1 – *Continued*

Site Name, Location [reference]	Primary COCs	Removal Equipment	Sediment Volume (cy)	Dredging Dates	Confirmatory Sampling Dates	Number of Samples	Sample Depth Interval	Notes
GM Foundry/St. Lawrence River, Massena, NY [15]	PCBs	Hydraulic and Mechanical – Clamshell	14,000	Mar. 1995 – Nov. 1995	Nov. 1995	Multiple samples from each quadrant during multiple removal attempts	3-6 in single samples in each of 6 quadrants (cells)	– 1 ppm criteria for PCBs. Range of residual PCBs after last removal 2.5 to 2.9 ppm in 5 cells and 27 ppm in 1 cell (which was capped). – A post-dredging bathymetric survey was also conducted.
Bayou Bonfouca, Slidell, LA [16]	PAHs	Mechanical – Crane mounted clamshell	169,000	Nov. 1993 – Jul. 1995	No confirmatory sampling	None	Not Applicable	– USACE completed pre- and post-dredging bathymetric surveys only.
Black River, Northwest OH [17, 18]	PAHs	Mechanical – Environmental clamshell	60,000	Fall 1989 – Dec. 1990	2 years later	Not Available	Not Available	– Surface sediment concentrations increased from pre-dredging concentrations. May be attributed to "fluff" layer of higher PAH concentrations on surface. – Also, fish samples were collected and analyzed immediately after dredging. Reduced fish liver neoplasm deformities were achieved.
Ford Outfall - River Raisen, Monroe, MI [19]	PCBs	Mechanical – Environmental clamshell and digging bucket	27,000	Jul. 1997 – Sep. 1997	Sep. 1997; 1998	14 samples, 1 at the center of each cell 20 samples collected	0-10 cm grab 0-6 in and 0-18 in grab	– 7 of 14 cells had insufficient sediment to sample. 4 of 14 cells sediment concentration less than 10 ppm (0.5 to 7 ppm). The remaining 3 were higher (12 to 20 ppm). – Most samples below 10 ppm. – Pole soundings were used after dredging.
Lake Jarnsjon, Sweden [20]	PCBs	Hydraulic dredge with auger	157,000	May 1993 – Nov. 1993 & Summer 1994	1996	5 samples in each of 54 areas	0-2 cm	– 5 samples from each area were averaged. – Average concentration range from 0.01 to 0.85 ppm PCBs that was a 97% reduction from maximum and 99% from average baseline. – Fish tissue samples were also collected in 1996.
Lower Fox River – Deposit N, Kimberly, WI [21, 22]	PCBs	Hydraulic – 8 in Moray/Utra cutterhead dredge	8,175	Oct. 1998 – Dec. 1998 & Aug. 1999 – Oct. 1999	Oct. 1999 (immediately after dredging)	Numerous, wherever sediments were found on bedrock	Surface grabs collected by divers	– Average concentration was 7.5 ppm and maximum of 43 ppm. Residual material was considered "fluff." These concentrations were near those measured pre-dredging. – A post-dredging bathymetric survey was conducted.

Table B–1 – *Continued*

Site Name, Location [reference]	Primary COCs	Removal Equipment	Sediment Volume (cy)	Dredging Dates	Confirmatory Sampling Dates	Number of Samples	Sample Depth Interval	Notes
Lower Fox River – SMU 56/57, Green Bay, WI [22, 23]	PCBs	Hydraulic with horizontal auger	31,346	Aug. 1999 – Dec. 1999	After dredging	13 subunits sampled (100 feet x 100 feet each unit)	4 to 12 in	– Sample concentrations ranged from 32 to 280 ppm (baseline 2 to 5 ppm). 1-ppm level was target. – A post-dredging bathymetric survey was conducted.
Lower Fox River – SMU 56/57, Green Bay, WI [22, 23]	PCBs	Hydraulic with horizontal auger	50,316	Aug. 2000 – Nov. 2000	After dredging	53 subunits sampled (100 x 100 feet); One to five samples collected from each unit	Upper 4 in	– Sample concentrations ranged from non-detect to 9.5 ppm with average of 2.2 ppm. 1-ppm level was target. Surface was amended with a 6-inch sand cap. – A post-dredging bathymetric survey was conducted.
Minamata Bay, Kyusha Island, Japan [24]	Mercury	Hydraulic with suction heads (no cutter)	1,025,000	Jun. 1983 – Dec. 1987	Not Available	59 locations; 200 m grid system; 4 sampling points in each grid	Surficial sediment	– Average concentrations per location ranged from 0.91 mg/kg to 8.99 mg/kg with overall average of 4.60 mg/kg. Criteria was 25 mg/kg (baseline ranged from 25 mg/kg to >600 mg/kg). – Bottom topography was monitored during and after dredging. Also, fish samples were collected after dredging and tissue mercury concentrations exceeded the 0.4-mg/kg criteria.
Port of Vancouver Copper Spill, Vancouver, WA [25]	Copper	Hydraulic – Small cutter-head pipeline	1,900	Jul. 1990 – Aug. 1990	Aug. 1990	35 locations; 1 sample per grid cell	Surficial sediment	– Post-dredging sediment sampling revealed that three cells in the dredge prism grid still had copper concentrations in excess of 1,300 ppm. – Post-dredging bathymetric surveys were conducted within three working days following the completion of dredging.

Table References

1. BBL, 1995. Non-Time-Critical Removal Action Documentation Report, Volume 1 (Grasse River Study Area, Massena, New York). Blasland, Bouck & Lee, Inc., Massena, New York. December 1995.
2. GE/AEM/BBL. 1995. Grasse River - Project 1 (Hot Spot). Major Contaminated Sediment Site Database. Website. http://www.hudsonwatch.com.
3. BBL. 1998. Post-Dredging Sediment Sampling of Manistique Harbor. Syracuse, New York. April 1998.
4. Windward Environmental. 2000. Terminal 18 Deepening Project, Post-Dredge Monitoring, Sampling and Analysis Plan. Prepared for the Port of Seattle, Seattle, Washington. Prepared by Windward Environmental, LLC., Seattle, Washington. March 2000.
5. Windward Environmental. 2001. Post-Dredge Monitoring of Port of Seattle East Waterway Deepening Stage 1 Dredging Area. Prepared for the Port of Seattle, Seattle, Washington. Prepared by Windward Environmental, LLC., Seattle, Washington. January 2001.
6. Hart Crowser/Pentec Environmental. 2001. Final (100 Percent) Design, Construction Quality Assurance Plan, Olympic View Resource Area Removal Action. Prepared for the City of Tacoma, Washington. Prepared by Hart Crowser, Inc., Seattle, Washington. December 10, 2001.

Table B–1 – *Continued*

7. Beak. 1995. Pier D Long-term Monitoring Final Report: 1995 Sampling and Analysis, U.S. Navy Puget Sound Naval Shipyard, Bremerton, Washington. Prepared for RCI Environmental, Inc. and Department of the Navy. May 1995.
8. Hart Crowser. 1994. Data Report: Post-Construction Sediment Quality Sampling and Analysis Results in Phase 1 Area, Sitcum Waterway Remediation Project. Prepared for the Port of Tacoma, Tacoma, Washington. August 5, 1994.
9. de Maximis. 1998. Project Completion Report, Eagle Harbor Superfund Site, West Harbor Operable Unit Soil and Sediment Remediation. Prepared by de Maximis, Inc., Hart Crowser, Wilder Construction, and Hartman Consulting Corporation. April 13, 1998.
10. Praeger et al. 1996. Remediation of PCB-Containing Sediments Using Surface Water Diversion "Dry Excavation": A Case Study. Wat. Sci. Tech. Vol. 33, No. 6. Pp. 239-245. Published by Elsevier Science Ltd.
11. USEPA, 1999. Waukegan Harbor Area of Concern. U.S. Environmental Protection Agency. Website. http://www.epa.gov/glnpo/aoc/ waukegan.html.
12. State of Oregon, 1995. Material Removal/Fill Permit No. 8820 for the Port of Portland. Oregon Division of State Lands. August 29, 1995.
13. Hartman Associates Inc. 1995. Water Quality Monitoring During Dredging and Disposal of Sediments from Terminal 4 Slip 3 in Portland Harbor, Final Report. April 28, 1995.
14. USEPA. 2000. Update for Areas of Concern. Realizing Remediation II. An Updated Summary of Contaminated Sediment Remediation Activities at Great Lakes Areas of Concern. USEPA Region 5, Great Lakes National Program Office. July 2000.
15. BBL. 1996. St. Lawrence River Sediment Removal Project Remedial Action Completion Report. BBL Environmental Services, Inc., Massena, New York. June 1996.
16. GE/AEM/BBL, 1999. Bayou Bonfouca, Major Contaminated Sediment Site Database. Website. http://www.hudsonwatch.com.
17. Baumann, P. C., and J. C. Harshbarger. 1998. Long-term trends in liver neoplasm epizootics of brown bullhead in the Black River, Ohio. Environmental Monitoring and Assessment. October. 53(1):213–223.
18. GE/AEM/BBL. 1998. Major Contaminated Sediment Site Database. Website. http://www.hudsonwatch.com.
19. MDEQ. 1998. PCB Sediment Investigation: River Raisin Area of Concern, Monroe, Michigan 1995, 1997 and 1998. Michigan Department of Environmental Quality Surface Water Quality Division Staff Report No. MI/DEQ/SWQ-99/108.
20. Bremle, G. and P. Larsson, in press. Long-term variations of PCBs in the water of a river in relation to precipitation and internal sources. Environmental Science and Technology.
21. Water Resources Institute. 2000. Evaluation of the Effectiveness of Remediation Dredging: The Fox River Deposit N Demonstration Project November 1998 - January 1999. Prepared for the Fox River Remediation Advisory Team. University of Wisconsin - Madison. WRISR 00-01. June 2000.
22. Paulson, 2000. Personal communication between Mark Herrenkohl of Foster Wheeler Environmental Corporation and Bob Paulson of Wisconsin DNR regarding the Deposit N and SMU 56/57 pilot dredging projects. January 10, 2002.
23. Montgomery Watson, 2000. Draft Summary Report, Sediment Removal Demonstration Project, Sediment Management Unit 56/57, Fox River, Green Bay, Wisconsin. April 2000.
24. Hosokawa, Y. 1993. Remediation work for mercury contaminated bay-experiences of Minamata Bay project, Japan. Water Sci. Tech. 28: (8,9) 339-348.
25. Century West Engineering, 1990. Draft Verification Sampling Summary for Bulk Loading Facility, Port of Vancouver. Prepared for Port of Vancouver, Vancouver, Washington. October 11, 1990.

Table Acronyms

2,4-DP	2-(2,4-dichlorophenoxy) propanoic acid	PAH	Polyaromatic Hydrocarbon
cm	centimeter	PCB	Polychlorinated Biphenyl
CSL	Cleanup Screening Levels	ppm	parts per million
cy	cubic yard	SQO	Sediment Quality Objectives
DDT	p,p'-Dichlorodiphenyltrichloroethane	SQS	Sediment Quality Standard
USEPA	US Environmental Protection Agency	TBT	Tributyltin
ER	Enrichment Ratio	UCL	Upper Confidence Level
in	inch	USGS	United States Geological Survey
m	meter		

Either sediment chemistry or bathymetry was noted as part of the post-dredging sampling and monitoring in each of the projects presented in Table B-1. Monitoring of bathymetry and sediment chemistry are reasonable and direct methods to measure attainment of specified dredging or excavation elevations and achievement of chemical sediment criteria or target clean-up levels. Although not used as commonly, fish tissue data also served to measure attainment of project goals in some dredging projects. Tissue sampling, when performed, was more for purposes of long-term monitoring.

A total of 11 of the 22 surveyed projects successfully reduced the maximum detected concentrations in the surface sediments:

- Three projects with post-dredging concentrations similar to the pre-dredging baseline concentrations were the Black River, the Puget Sound Naval Shipyard (PSNS), and the Lower Fox River Deposit N sites.
  - At the Black River site, however, the long-term remedial action objective of reduced fish liver neoplasm deformities was achieved.
  - For the PSNS and Deposit N projects, a majority of the known volume of contaminated sediment was removed. However, a portion of the remaining sediment may have been recontaminated with residual resuspended sediments referred to as "fluff".
- In the cases of the Terminal 18 site in Seattle, the GM Foundry site in New York, and the Lower Fox River Deposit SMU 56/67 sites, post-dredging sampling results did not meet project goals or were above pre-dredging baseline levels.
- For the 1999 and 2000 SMU 56/57 projects, a majority of the known volume of contaminated sediment was removed. However, a small portion was left in place because of policy and field decisions, and not because of dredging equipment limitations (ThermoRetec, 2001). As a result of not completely removing the entire deposit, sediments with elevated concentrations of contaminants became exposed and were subsequently covered with a 6-inch sand cap.
- There were no post-dredging chemical data available to review for the Detroit River, Niagara River, and Bayou Bonfouca sites.

B.2.2 Feature-By-Feature Results of the Survey

The following presents additional findings of the survey on a feature-by-feature basis, as compiled from Table B-1.

<u>Chemicals of Concern</u>

The breakdown of the chemicals of concern (COCs) for the surveyed projects is as follows:

PCBs Only	50.0 %
PCBs + Other	13.6 %
PAHs + Other	22.7 %
Other	13.6 %

PCBs are the only COC for the New Bedford Harbor Project.

Type of Removal Equipment Used

The breakdown of the type(s) of dredging or excavation equipment used in the surveyed projects is as follows:

Mechanical	50.0 %
Hydraulic	31.8 %
Mechanical + Hydraulic	9.1 %
Dry Excavation	9.1 %

At this time, the type of removal equipment to be used has not been specified for the New Bedford Harbor Project. A combination of technologies is likely to be employed.

Volume of Sediment Removed

The breakdown of the volume of sediment dredged or excavated as part of the surveyed projects is as follows:

< 5,000 cy	9.1 %
5,000 - 10,000 cy	18.2 %
10,000 - 50,000 cy	31.8 %
50,000 - 100,000 cy	13.6 %
100,000 - 250,000 cy	22.7 %
250,000 - 1,000,000 cy	0.0 %
>1,000,000 cy	4.5 %

The current estimate of the volume of sediments that must be dredged or excavated at New Bedford Harbor is 500,000 cubic yards (cy).

Year Dredging was Completed

The breakdown of the year in which the environmental dredging or excavation was completed for the surveyed projects is as follows:

1987	4.5 %
1990	9.1 %
1992	4.5 %
1994	13.6 %
1995	22.7 %
1997	13.6 %
1998	9.1 %
1999	9.1 %
2000	9.1 %
2002 (projected start)	4.5 %

While some localized hot spot areas and areas of relatively higher exposure potential have already been dredged or excavated (see Appendix A), the primary New Bedford Harbor dredging and excavation effort is projected to begin in the summer of 2002.

Type of Confirmatory Sample Collected

The breakdown of the type of confirmatory sample collected during the surveyed projects is as follows:

Surface Grab	68.2 %
Surface Composite	9.1 %
Surface Down to Bedrock	4.5 %
Unspecified	9.1 %
None	9.1 %

Compliance with the ROD target PCB clean-up levels requires the confirmation of sediment PCB concentrations at the surface and at greater depths in the sediment column (see Section 4).

Depth of Confirmatory Sample Collected

The breakdown of the depth or depth interval in the sediment column from which the confirmatory samples were collected during the surveyed projects is as follows:

0 to 0.79 inches (2 cm)	9.1 %
0 to 2.36 inches (6 cm)	4.5 %
0 to 3 inches	4.5 %
0 to 4 inches	22.7 %
0 to 6 inches	4.5 %
0 to 12 inches	4.5 %
3 inches to 6 inches	4.5 %
6 inches to 12 inches	4.5 %
0 to Bedrock	4.5 %
Unspecified	27.3 %
None	9.1 %

The depth interval(s) in the sediment column from which the post-dredging samples were collected during the past environmental dredging and excavation activities at New Bedford Harbor were: 0 inches to 0.8 inches; 0 inches to 3 inches, 0 inches to 6 inches; and 0 inches to 12 inches (see Appendix A).

When Confirmatory Samples Were Collected

The breakdown of the when the confirmatory samples were collected during the surveyed projects is as follows:

During Dredging	4.5 %
Immediately After Dredging	22.7 %
Within 1 Month of Completing Dredging	36.4 %
Within 3 Months of Completing Dredging	4.5 %
2 Years After Completing Dredging	9.1 %
4 Years After Completing Dredging	4.5 %
Unspecified	4.5 %
None	9.1 %

Post-dredging samples that were collected up 2 to 4 years after the completion of dredging or excavation are more likely associated with a long term monitoring objective, rather than a confirmatory sampling objective.

Characteristic Spacing of Confirmatory Samples

The breakdown of the characteristic density of the confirmatory sampling (in terms of the size of an effective square sampling grid) for the surveyed projects is as follows:

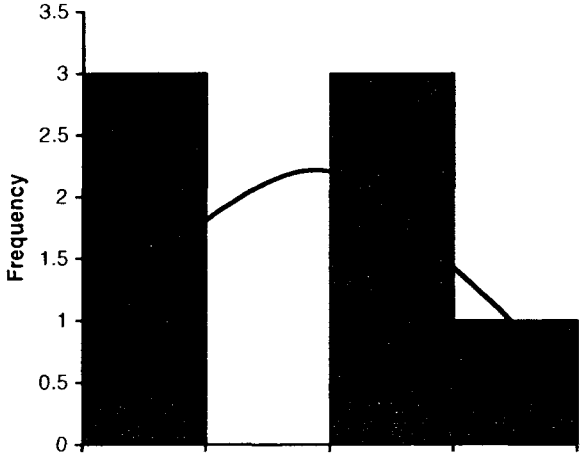
50 feet	4.5 %
100 feet	9.1 %
164 feet (50 meters)	4.5 %
200 feet	4.5 %
1 per Cell or Area	13.6 %
Unspecified	54.6 %
None	9.1 %

The equivalent range of the effective square sampling grid size for the post-dredging performed as part of the past environmental dredging and excavation activities at New Bedford Harbor was 20 feet to 71 feet (see Appendix A).

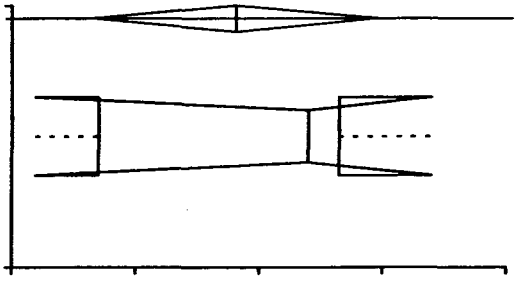
APPENDIX C

TEST OF NORMALITY OF PROJECTED "POST-REMOVAL" SEDIMENT SAMPLES IN THE ANALYSIS AREAS BASED ON PRE-REMOVAL PCB CHARACTERIZATION DATA

Test	**Continuous summary descriptives**
	Residential East
Performed by	Melanie Weed
Date	11 February 2002

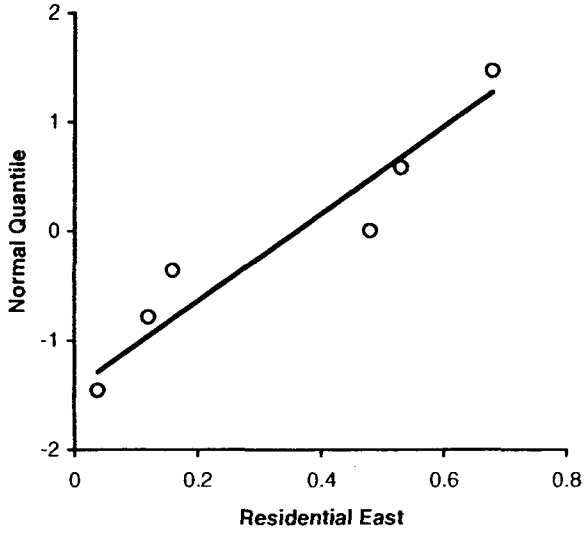


n	7 (cases excluded: 30 due to mi
Mean	0.363
95% CI	0.131 to 0.594
Variance	0.0626
SD	0.2503
SE	0.0946
CV	69%



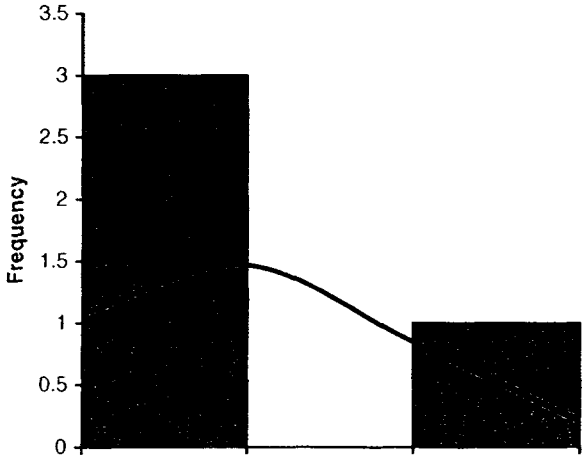
Median	0.480
98.4% CI	0.038 to 0.680
Range	0.642
IQR	0.39

Percentile	
2.5th	-
25th	0.140
50th	0.480
75th	0.530
97.5th	-

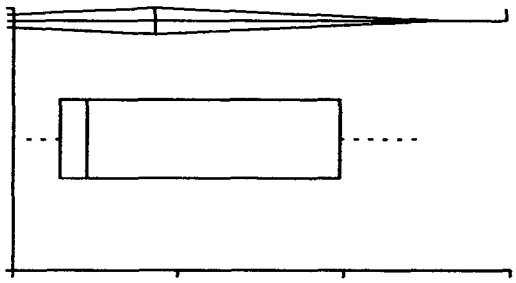


	Coefficient	p
Shapiro-Wilk	0.8843	0.2461
Skewness	-0.2052	-
Kurtosis	-2.0510	-

Test	**Continuous summary descriptives**		
	Residential West		
Performed by	Melanie Weed	**Date**	11 February 2002

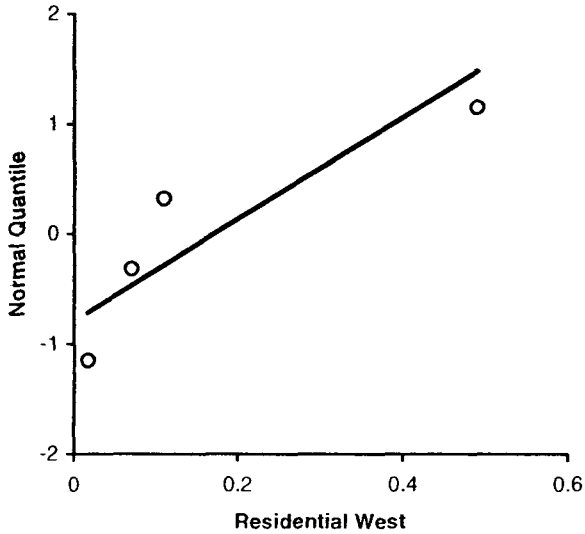


n	4 (cases excluded: 33 due to m
Mean	0.172
95% CI	-0.171 to 0.515
Variance	0.0465
SD	0.2156
SE	0.1078
CV	126%



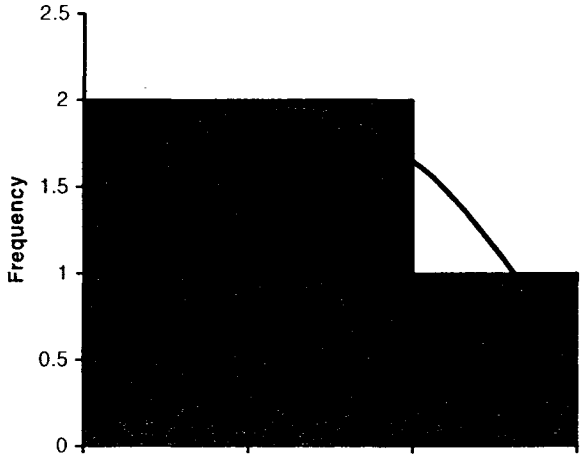
Median	0.090
95% CI	- to -
Range	0.473
IQR	0.33825

Percentile	
2.5th	-
25th	0.057
50th	0.090
75th	0.395
97.5th	-

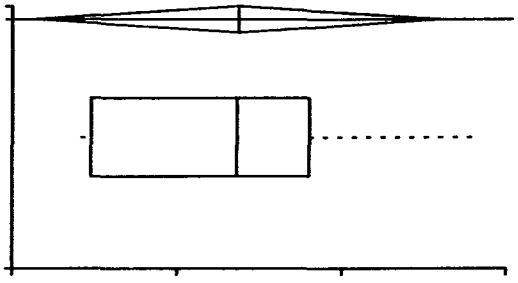


	Coefficient	p
Shapiro-Wilk	0.7894	0.0846
Skewness	1.8130	-
Kurtosis	-	-

Test	**Continuous summary descriptives**
	Beachcombing East
Performed by	Melanie Weed
Date	11 February 2002

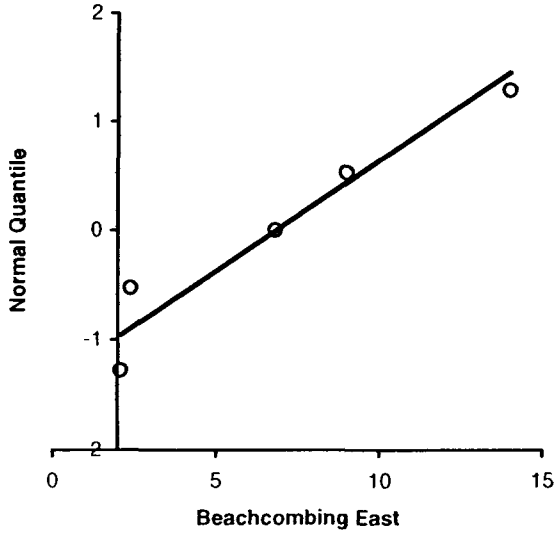


n	5 (cases excluded: 32 due to mi
Mean	6.860
95% CI	0.711 to 13.009
Variance	24.5280
SD	4.9526
SE	2.2149
CV	72%



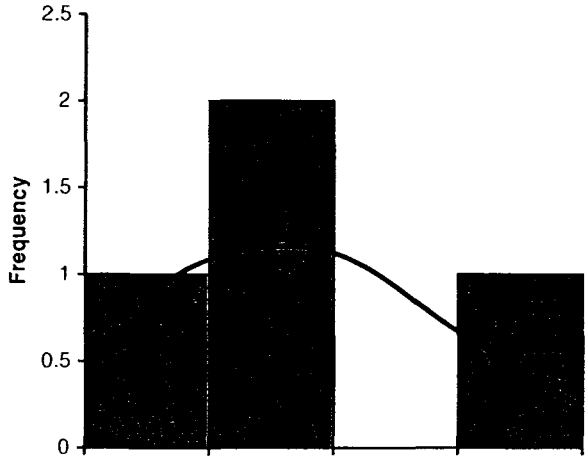
Median	6.800
95% CI	- to -
Range	11.9
IQR	6.6

Percentile	
2.5th	-
25th	2.400
50th	6.800
75th	9.000
97.5th	-

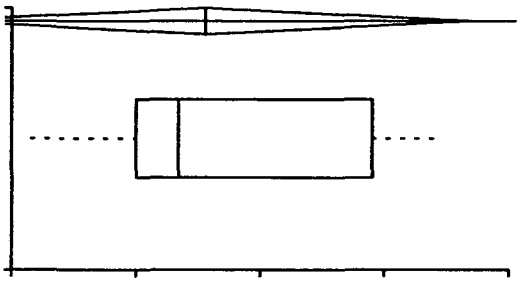


	Coefficient	p
Shapiro-Wilk	0.9203	0.5318
Skewness	0.6079	-
Kurtosis	-0.6679	-

Test	**Continuous summary descriptives**
	Beachcombing West
Performed by	Melanie Weed
Date	11 February 2002

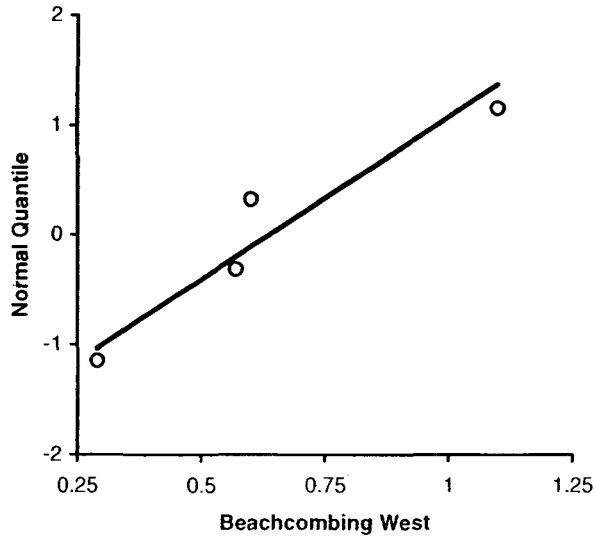


n	4 (cases excluded: 33 due to m
Mean	0.640
95% CI	0.104 to 1.176
Variance	0.1135
SD	0.3369
SE	0.1685
CV	53%



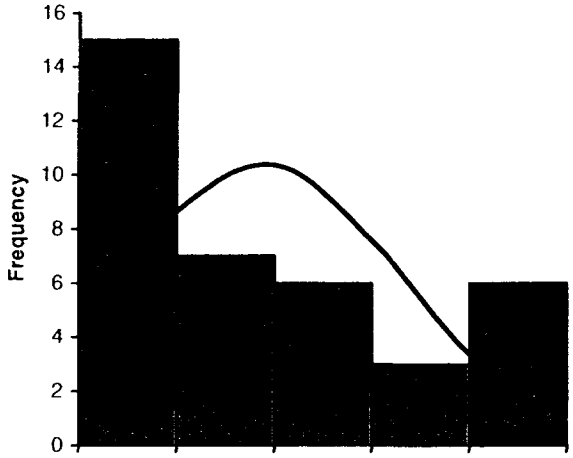
Median	0.585
95% CI	- to -
Range	0.81
IQR	0.475

Percentile	
2.5th	-
25th	0.500
50th	0.585
75th	0.975
97.5th	-

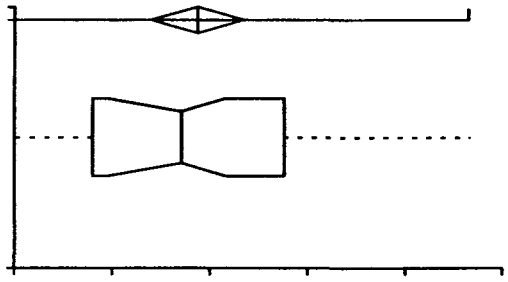


	Coefficient	p
Shapiro-Wilk	0.9262	0.5725
Skewness	0.9420	-
Kurtosis	-	-

Test	**Continuous summary descriptives**
	10 ppm
Performed by	Melanie Weed
Date	11 February 2002

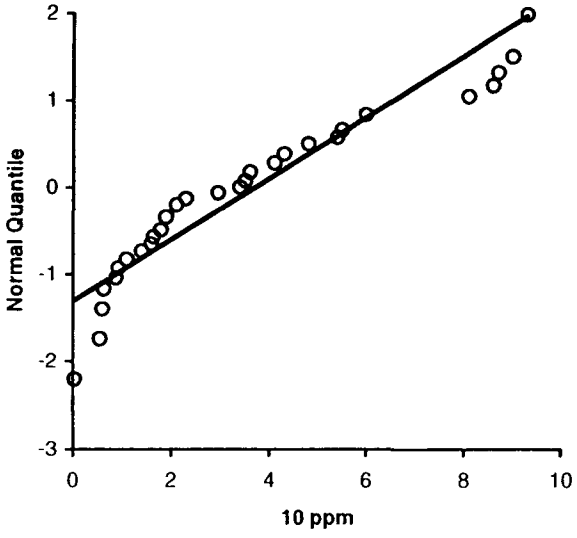


n	37
Mean	3.739
95% CI	2.792 to 4.685
Variance	8.0561
SD	2.8383
SE	0.4666
CV	76%



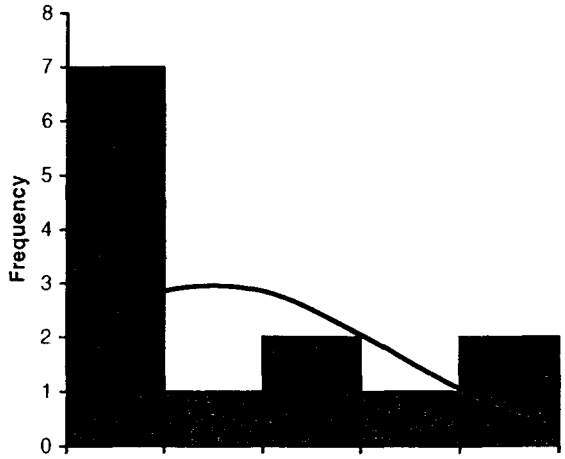
Median	3.400
95.3% CI	1.900 to 4.300
Range	9.259
IQR	3.9

Percentile	
2.5th	-
25th	1.600
50th	3.400
75th	5.500
97.5th	-

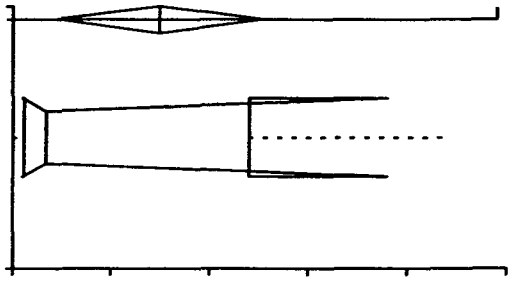


	Coefficient	p
Shapiro-Wilk	0.8998	0.0029
Skewness	0.7084	0.0687
Kurtosis	-0.6436	0.3457

Test	**Continuous summary descriptives**
	50ppm East
Performed by	Melanie Weed
Date	11 February 2002

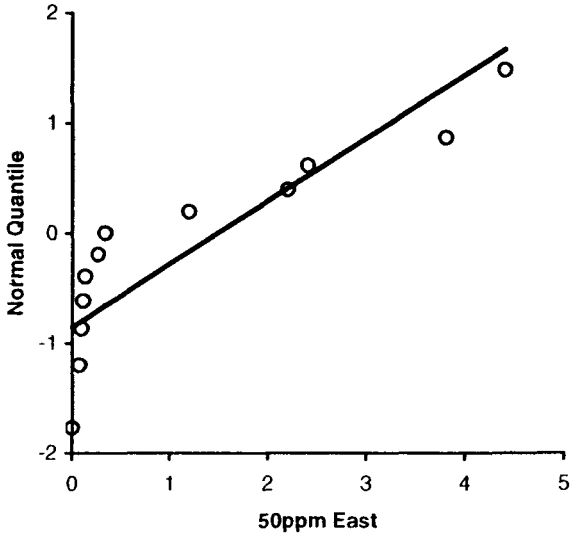


n	13 (cases excluded: 24 due to mi
Mean	1.493
95% CI	0.440 to 2.546
Variance	3.0373
SD	1.7428
SE	0.4834
CV	117%



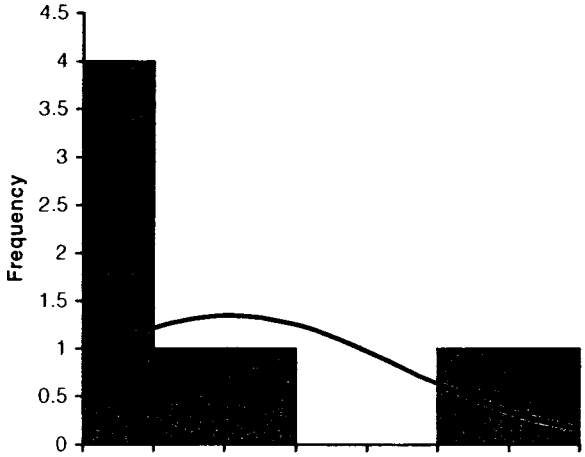
Median	0.340
97.8% CI	0.092 to 3.800
Range	4.398475
IQR	2.29

Percentile	
2.5th	-
25th	0.110
50th	0.340
75th	2.400
97.5th	-

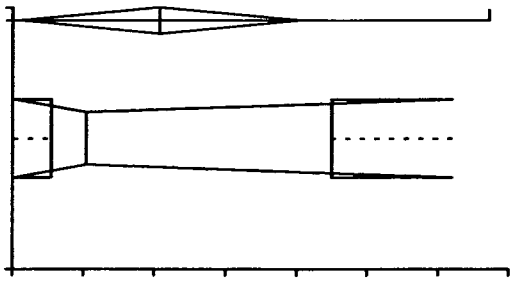


	Coefficient	p
Shapiro-Wilk	0.7877	0.0049
Skewness	0.8369	0.1663
Kurtosis	-0.9963	-

Test	**Continuous summary descriptives**
	50ppm South
Performed by	Melanie Weed
Date	11 February 2002

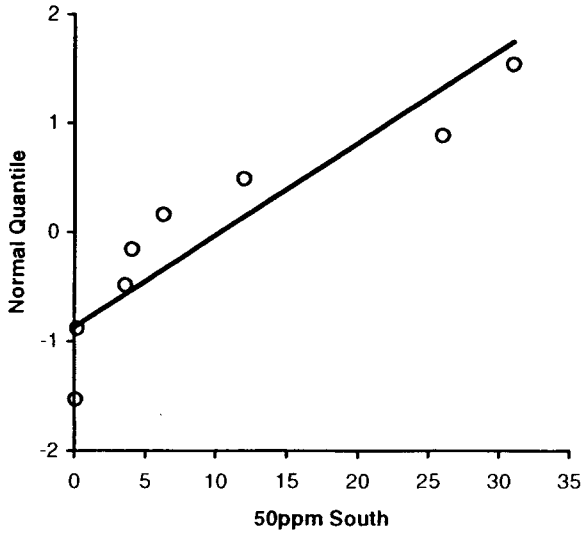


n	8 (cases excluded: 29 due to mi
Mean	10.414
95% CI	0.507 to 20.321
Variance	140.4201
SD	11.8499
SE	4.1896
CV	114%



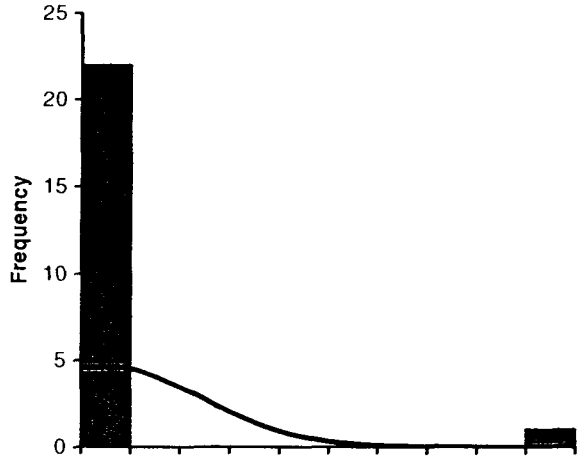
Median	5.200
99.2% CI	0.120 to 31.000
Range	30.88
IQR	19.7525

Percentile	
2.5th	-
25th	2.748
50th	5.200
75th	22.500
97.5th	-

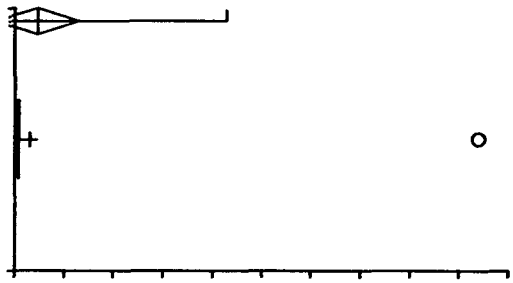


	Coefficient	p
Shapiro-Wilk	0.8231	0.0502
Skewness	1.1124	0.1374
Kurtosis	-0.2955	-

Test	**Continuous summary descriptives**
	50ppm West
Performed by	Melanie Weed
Date	11 February 2002

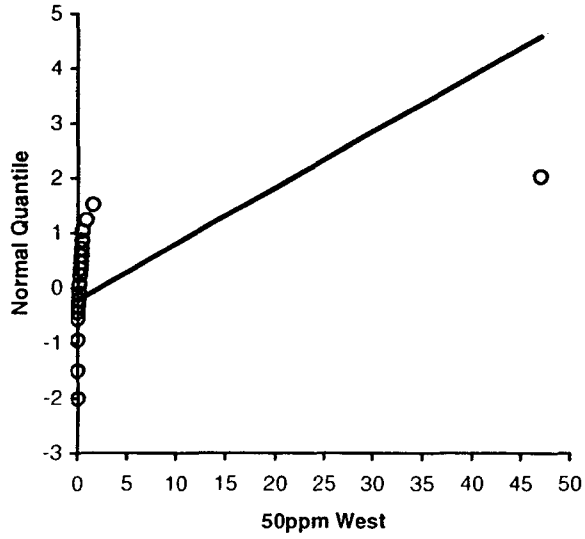


n	23 (cases excluded: 14 due to mi
Mean	2.278
95% CI	-1.940 to 6.497
Variance	95.1640
SD	9.7552
SE	2.0341
CV	428%



Median	0.160
96.5% CI	0.015 to 0.370
Range	46.998775
IQR	0.3821

Percentile	
2.5th	-
25th	0.008
50th	0.160
75th	0.390
97.5th	-



	Coefficient	p
Shapiro-Wilk	0.2383	<0.0001
Skewness	4.7859	<0.0001
Kurtosis	22.9332	<0.0001

APPENDIX D

ANALYSIS OF THE SENSITIVITY OF THE STATISTICAL INPUT PARAMETERS ON THE MINIMUM NUMBER OF REQUIRED CONFIRMATORY SAMPLES

Table D-1
Sensitivity Analysis of the Parameters Used in Calculation of the Number of Required Confirmatory Samples Within a Compliance Demonstration Area

Target PCB Clean-Up Level (ppm)	Type I Decision Error Probability (unitless)	Type II Decision Error Probability (unitless)	Width of the "Gray Region" (ppm)	Standard Deviation (ppm)	Number of Required Confirmatory Samples
1	0.05	0.10	0.33	0.2	6
1	0.05	0.10	0.15	0.2	20
1	0.05	0.15	0.33	0.2	5
1	0.05	0.15	0.15	0.2	17
10	0.05	0.10	3.3	2	6
10	0.05	0.10	1.5	2	20
10	0.05	0.15	3.3	2	5
10	0.05	0.15	1.5	2	17
25	0.05	0.10	8.2	5	6
25	0.05	0.10	3.75	5	20
25	0.05	0.15	8.2	5	5
25	0.05	0.15	3.75	5	17
50	0.05	0.10	16	10	6
50	0.05	0.10	7.5	10	20
50	0.05	0.15	16	10	5
50	0.05	0.15	7.5	10	17

Notes:

The null hypothesis (H_o) is stated as:
The average post-dredging or post-excavation PCB concentration in the sediment of the CDA exceeds the applicable target PCB clean-up level(s).

The equation used by VSP to calculate the minimum number of required confirmatory samples, assuming a non-parametric distribution) is:

$$N = 1.16 \cdot \left[\frac{S_{total}^2 \cdot \left(Z_{1-\alpha} + Z_{1-\beta}\right)^2}{\Delta^2} + 0.5 \cdot Z_{1-\alpha}^2 \right]$$

Where:

N = the minimum required number of confirmatory samples that should be collected from a single CDA

S_{total} = the computed estimate of true total standard deviation (includes sampling and analytical components)

$Z_{1-\alpha}$ = the value from the standard normal distribution for which the proportion of the distribution to the left of $Z_{1-\alpha}$ is $1-\alpha$, where α is the probability of a Type I error

$Z_{1-\beta}$ = the value of the standard normal distribution for which the proportion of the distribution to the left of $Z_{1-\beta}$ is $1-\beta$, where β is the probability of a Type II error

Δ = the width of the "gray region" or delta