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Total Environmental Restoration Contract

New England Division

USACE Contract No. DACW33-94-D-0002

FOSTER WHEELER ENVIRONMENTAL CORPORATION

THE BIOENGINEERING GROUP, INC.

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TO: John Scott, FWENC
FROM: Cynthia Jensen, TBG
RE: Preliminary Cost Estimate for Restoration Design
DATE: November 19, 2002

Attached are preliminary cost estimates for the conceptual design for restoration of wetland areas 3, 4, 6, and 9. These estimates are based on the preliminary estimates of required cubic yards of fill, linear feet and area of stabilization treatments, and area and density of plantings. Inflation costs are not included in the estimate.

The subtotal for fill includes the costs of overdredge and topsoil fill, earthwork, and subgrade preparation. The subtotal for stabilization includes the costs of coir fascines, vegetated coir mattresses (VCM), erosion control blankets, and stream (intertidal creek) restoration. The subtotal for planting includes the cost of plantings only. Finally, the subtotal for "other" includes the costs of mobilization, stormwater and pollution prevention (SWPP), access, overhead, and 20% contingency.

	Wetland					
	3	4	6	9	Total	Percent
Fill	126,000	115,000	18,850	170,000	429,850	9%
Stabilization	393,383	770,110	61,298	380,636	1,605,427	34%
Planting	147,000	281,750	4,655	56,350	489,755	10%
Other	588,883	1,031,154	67,995	536,394	2,224,425	47%
Total	1,255,266	2,198,014	152,798	1,143,380	4,749,457	100%

SITE 3	UNIT	QTY	PRICE	COST
Overdredge Fill (mudflat)	CY	5500	$20.00	$ 110,000.00
Earthwork/Subgrade Prep.	SY	16000	$1.00	$ 16,000.00
20" Fascine	LF	1750	$50.00	$ 87,500.00
12" Fascine w/ VCM	LF	3633	$51.00	$ 185,283.00
Stream Restoration	LF	804	$150.00	$ 120,600.00
Planting	ACR	6	$24,500.00	$ 147,000.00
Mobilization, SWPP, Access	15%			$ 99,957.45
SUB-TOTAL				$ 766,340.45
Overhead, Profit and Bond	36.50%			$ 279,714.26
Contingency	20%			$ 209,210.94
TOTAL				**$ 1,255,265.66**

SITE 4	UNIT	QTY	PRICE	COST
Overdredge Fill (mudflat)	CY	2000	$20.00	$ 40,000.00
Earthwork/Subgrade Prep.	SY	30000	$0.50	$ 15,000.00
Topsoil Placement	CY	2000	$30.00	$ 60,000.00
20" Fascine	LF	5633	$50.00	$ 281,650.00
12" Fascine w/ VCM	LF	5460	$51.00	$ 278,460.00
Erosion Control Blanket	SY	6000	$5.00	$ 30,000.00
Stream Restoration	LF	1200	$150.00	$ 180,000.00
Planting	ACR	11.5	$24,500.00	$ 281,750.00
Mobilization, SWPP, Access	15%			$ 175,029.00
SUB-TOTAL				$ 1,341,889.00
Overhead, Profit and Bond	36.50%			$ 489,789.49
Contingency	20%			$ 366,335.70
TOTAL				**$ 2,198,014.18**

SITE 6	UNIT	QTY	PRICE	COST
Overdredge Fill (mudflat)	CY	100	$5.00	$ 500.00
Earthwork/Subgrade Prep.	SY	1700	$1.00	$ 1,700.00
Topsoil Placement	CY	555	$30.00	$ 16,650.00
20" Fascine	LF	548	$50.00	$ 27,400.00
12" Fascine w/ VCM	LF	498	$51.00	$ 25,398.00
Erosion Control Blanket	SY	1700	$5.00	$ 8,500.00
Planting	ACR	0.19	$24,500.00	$ 4,655.00
Mobilization, SWPP, Access	10%			$ 8,480.30
SUB-TOTAL				$ 93,283.30
Overhead, Profit and Bond	36.50%			$ 34,048.40
Contingency	20%			$ 25,466.34
TOTAL				**$ 152,798.05**

SITE 9	UNIT	QTY	PRICE	COST
Overdredge Fill (mudflat)	CY	2400	$20.00	$ 48,000.00
Earthwork/Subgrade Prep.	SY	11000	$1.00	$ 11,000.00
Topsoil Placement	CY	3700	$30.00	$ 111,000.00
20" Fascine	LF	2600	$50.00	$ 130,000.00
12" Fascine w/ VCM	LF	3836	$51.00	$ 195,636.00
Erosion Control Blanket	SY	11000	$5.00	$ 55,000.00
Planting	ACR	2.3	$24,500.00	$ 56,350.00
Mobilization, SWPP, Access	15%			$ 91,047.90
SUB-TOTAL				$ 698,033.90
Overhead, Profit and Bond	36.50%			$ 254,782.37
Contingency	20%			$ 190,563.25
TOTAL				**$ 1,143,379.53**

USACE CONTRACT NO. DACW33-94-D-0002
TASK ORDER NO. 17
MODIFICATION NO. 22
TOTAL ENVIRONMENTAL RESTORATION CONTRACT

DRAFT FINAL
RESTORATION BASIS OF DESIGN/
DESIGN ANALYSIS REPORT (90%)
REMEDIAL DESIGN FOR
NEW BEDFORD HARBOR SUPERFUND SITE
New Bedford, Massachusetts

November 19, 2002

Prepared for

Foster Wheeler Environmental Corporation
133 Federal Street
Boston, MA 02110

Prepared by

The Bioengineering Group, Inc.
18 Commercial Street
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Revision	Date	Prepared By	Reviewed By	Approved By	Pages Affected
0	11/19/02	G. Cademartori C. Jensen M. Silva T. Whall	TBG Reviewers		

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APPENDICES

Appendix A. Analysis of Alternatives
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ACRONYMS USED IN TEXT

ARAR Applicable, Relevant and Appropriate Requirement
CERCLA Comprehensive Environmental Response, Compensation and Liability Act of 1980
CSO Combined sewer overflow
CY Cubic yards
DEP MA Department of Environmental Protection
MHHW Mean higher high water
MHW Mean high water
MLLW Mean lower low water
MLW Mean low water
NBHTC New Bedford Harbor Trustee Council
NOAA US National Oceanic and Atmospheric Administration
PCB Poly-chlorinated biphenyls
ROD Record of Decision
USACE US Army Corps of Engineers
USEPA US Environmental Protection Agency
WPA MA Wetlands Protection Act

1.0 INTRODUCTION

This Restoration Basis of Design/Design Analysis Report (Restoration BD/DA) has been prepared for Foster Wheeler Environmental Corporation (Foster Wheeler Environmental) as part of the Remedial Design of Operable Unit 1, Upper and Lower Harbor, New Bedford Harbor Superfund Site, New Bedford Harbor, Massachusetts (Figure 1), under Task Order No. 17, Subtask 20.94, of the U.S. Army Corps of Engineers (USACE) New England Total Environmental Restoration Contract. The Restoration BD/DA outlines the restoration of habitats impacted by the dredging and excavation associated with cleanup activities in the Upper Harbor. Areas that will be impacted are identified in the Final Dredging Basis of Design/Design Analysis Report (Dredging BD/DA, Foster Wheeler Environmental 2002b) and the Final Excavation Basis of Design/Design Analysis Report (Excavation BD/DA, Foster Wheeler Environmental 2002c).

1.1 Purpose of Report

The purpose of this Restoration BD/DA is to describe the conceptual design of the restoration plan for the intertidal and upland habitats in the Upper Harbor that are impacted by the cleanup of New Bedford Harbor, which is contaminated with poly-chlorinated biphenyls (PCBs).

1.2 Site History

Between the 1940s and 1970s several manufacturing facilities on the western shoreline of New Bedford Harbor discharged industrial wastes into harbor waters directly or via the municipal sewer system, resulting in widespread contamination of adjacent coastal environments. Heavy metals and organic contaminants including PCBs were discharged. Due to the identification of PCB contamination, the New Bedford Harbor estuary was added to the U.S. Environmental Protection Agency's (USEPA) National Priorities List and is scheduled for remediation under Superfund legislation. The harbor bottom, mudflats, salt marshes and some adjacent upland habitats have been contaminated. The highest concentrations of PCBs have been found in the Upper Harbor, north of the I-195 Bridge. USEPA has set a PCB concentration action limit of 50 ppm in the vegetated intertidal. Sediments in areas contaminated above this action limit are to be removed by dredging and excavation. Remediation plans have targeted approximately 66 acres of intertidal areas, including 20 acres of salt marsh, for dredging/excavation (Figure 2). Under the Remedial Design, dredged/excavated intertidal areas are to be restored. The restoration activities described herein are intended to restore those areas impacted by cleanup activities.

1.3 Restoration Objectives

Under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), the overall goal of cleanup and restoration is to restore areas damaged by the release of hazardous substances to "a baseline or comparable condition." Areas impacted by cleanup are located in intertidal and adjacent upland habitats. "Baseline conditions" are those conditions described in the Final Wetland Delineation and Functions and Values Report for Restoration Design of the New Bedford Harbor Superfund Site (Foster Wheeler Environmental 2002a). Specific goals for the cleanup and restoration of the New Bedford Harbor Superfund Site are articulated in the Record of Decision (ROD) (USEPA 1998), which sets forth the agreed-upon cleanup remedy. Other goals and guidance that have been articulated in the restoration design process are included in the list below.

- "Salt marsh areas that are excavated to remove sediment PCBs above site cleanup levels will be regraded and revegetated to approximate the original conditions of the area remediated. Erosion protection will be provided in these areas as appropriate to prevent bank scouring and erosion. The salt marsh areas impacted [by the remedy] will be monitored over time to ensure the success of the remedial salt marsh restoration efforts (ROD p 31),"

- Consider the ecological value of mudflats as habitat and feeding grounds for both marine and upland wildlife in the restoration design,
- Baseline or comparable conditions may be actual, former conditions, or conditions in which ecological structure, functions, and values are restored on a net basis across specific sites,
- Restore impacted wetlands on a 1:1 net basis for functions (physical, biological, and chemical) and values (benefits to human community),
- Use Wetland Delineation and Functions and Values Report (Foster Wheeler Environmental 2002a) as basis of alternative plans and basis of design of recommended alternative,
- Minimize re-engineering of site topography,
- Emulate pre-cleanup soils, slopes, and hydrology,
- Use in-kind restoration activities as basis for overall restoration design,
- Maximize use of onsite marsh peats and sediments in restoration of intertidal areas.

Note that in this report the following terms are used.

- "Intertidal habitats" include vegetated and unvegetated intertidal areas.
- "Vegetated intertidal" areas lie above mean lower low water (MLLW) and are generally covered with emergent vegetation.
- "Unvegetated intertidal" areas include mudflats, which are generally above MLLW and below mean higher high water (MHHW) with no emergent vegetation, as well as beach and tidal creek areas.
- "Subtidal" areas are below MLLW.
- "Existing" area is the area existing prior to any cleanup activities.
- "Impacted" area is the area that is dredged or excavated under cleanup.
- "Final" area is the area remaining after cleanup and restoration. The final area will include (1) unimpacted areas, (2) impacted areas that have been restored, and (3) impacted areas that have not been restored.

1.4 Restoration Approach

The approach of the restoration design includes the following steps:

- Identify objectives of restoration activities,
- Assess existing (pre-cleanup) conditions,
- Predict conditions that will result after cleanup, based on Dredging and Excavation BD/DAs (Foster Wheeler Environmental 2002b, 2002c),
- Clarify baseline or comparable conditions to which areas impacted by cleanup will be restored,
- Identify opportunities and constraints to restoration,
- Clarify assumptions,
- Develop conceptual restoration design,
- Develop monitoring plan to assess progress towards restoration objectives.

2.0 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARS)

New Bedford Harbor remediation activities will impact, or have the potential to impact, resources that are protected by Federal, State and Municipal policies, legislation, and regulations. These ARARS were identified in the ROD with their impact on the harbor cleanup discussed. Table 1 lists these ARARS and discusses their applicability to the overall restoration effort.

Table 1. List of Applicable, Relevant or Appropriate Requirements Pertaining to Restoration Activities.

ARAR	LEGAL CITATION	SCOPE	ACTIONS TO BE TAKEN TO COMPLY WITH ARAR
FEDERAL ARARS			
Floodplain Management – Executive Order 11988	40 CFR Part 6, Appendix A	Federal agencies are required to reduce the risk of flood loss, minimize impact of floods, and restore and preserve the natural and beneficial values of floodplains.	Restoration activities will occur within the 100 year floodplain. The restoration design will avoid or minimize loss of flood storage capacity. It will be implemented in accordance with flood protection measures.
Wetland Protection – Executive Order 11990	40 CFR Park 6, Appendix A	Federal agencies are required to avoid adversely impacting wetlands whenever possible, minimize wetland destruction and preserve the value of wetlands.	Restoration will restore net ecological structure, functions and values of intertidal and upland wetland resource areas impacted by cleanup.
Fish and Wildlife Coordination Act	16 USC Part 661 et seq.; 40 CFR 6.302 (g)	Requires consultation with appropriate agencies to protect fish and wildlife when Federal actions may alter waterways. Must develop measures to prevent, minimize, and mitigate potential loss to the maximum extent possible.	Appropriate agencies will be consulted prior to restoration to find ways to minimize any adverse effects to fish and wildlife from restoration activities. Restoration activities will be scheduled to avoid impacts to migratory, anadromous fish.
Endangered Species Act	16 USC Part 1531 et seq.; 40 CFR 6.302 (h)	Requires consultation with appropriate agencies if a Federally- listed species or its habitat may be affected by a Federal action.	Appropriate agencies will be consulted to find ways to minimize adverse effects of restoration activities on Federally listed species or their habitat. There are no Federally listed species known to use the Upper Harbor area; however, the roseate tern is known to use areas in the Lower and Outer Harbor.
National Historic Preservation Act of 1966 (as amended) Preservation of Historical and Archaeological Data Act of 1974	16 USC 469 et seq.	Requires assessing potential impacts to cultural resources that are eligible for, nominated to, or listed on the National Register of Historic Places. Requires recovering and preserving significant historical or archeological data when such data is threatened by a Federal action or Federally licensed action, which alters any terrain where such data is located.	Archaeological surveys have been completed in compliance with these acts. Potential impacts from dredging and excavation have been assessed. Restoration activities will not impact cultural, historic, and archaeological resources.
Coastal Zone Management Act of 1972	16 USC Parts 1451 et seq.	Requires that any actions must be conducted in a manner consistent with State approved coastal zone management programs.	The entire site is located in a coastal zone management area. Restoration activities will be consistent with the State coastal zone management program to the extent possible.
Clean Water Act, Section 401	33 USC 1251 et seq.	Regulates discharges into navigable waters in order to protect surface water quality. Authority to implement delegated to MA Department of Environmental Protection (DEP). See MA Water Quality Certification below.	See MA Water Quality Certification below
Clean Water Act, Section 402 National Pollution Discharge Elimination System	33 USC 1342; 40 CFR 122-125, 131, 14 CMR 3.00	Sets standards for point and non-point discharges of wastewater into surface water bodies. Sets ambient water quality criteria that must be met. Sets forth process by USEPA and MA DEP for granting General Permits, Group Permits and Individual Permits. In MA USEPA issues permits and MA DEP certifies permit conditions. Regarding stormwater discharges, USEPA has issued two General Permits in MA for (1) construction sites > 5 acres, and (2) industrial activities. Projects falling under the General Permits must submit a Notice of Intent, including a Stormwater Pollution Plan, and notify the USEPA within 48 hours prior to construction. The Plan must be kept onsite and the best management practices outlined in the Plan must be implemented.	Activities under CERCLA do not require National Pollutant Discharge Elimination System stormwater discharge permits, but they must meet its substantive requirements. Restoration activities will not include dewatering activities and/or discharge of water to surface waters.

Table 1 continued.

ARAR	LEGAL CITATION	SCOPE	ACTIONS TO BE TAKEN TO COMPLY WITH ARAR
Clean Water Act, Section 404 and Rivers and Harbors Act of 1899, Section 10.	33 USC 401-426; 40 CFR 230	Controls discharges of dredged or fill material in wetlands and water bodies in order to restore and maintain the chemical, physical and biological integrity of US waters (Federally-defined wetlands and water bodies). Requires coordination with and approval by USACE for dredging in US waters and/or construction of structures in US waters. USACE has issued a Programmatic General Permit to MA, under which three categories are set forth. Projects that impact < 5,000 sq ft of a Federally-defined wetland or water body are nonreporting and fall under Category I. Projects that impact > 5,000 sq ft but < 1 acre must file a permit application and be reviewed by Federal agencies for a Category II permit. Projects that impact > 1 acre require an Individual Permit, which is a Category III permit.	The overall remedy of dredging/excavation and restoration was approved under CERCLA. Although permits will not be required, restoration activities must meet the substantive requirements of Section 404. Restoration activities will be designed and implemented under the direction of USACE. Restoration activities will entail filling dredged and excavated sites as mitigation to impacts from dredging and excavation for cleanup purposes. Restoration will restore ecological structure, functions and values. Under restoration, there will be no net increase in harbor elevations due to fill activities. During restoration activities: (1) equipment that minimizes sediment disturbance and migration will be used, (2) silt screens/curtains and other appropriate methods that confine suspended particulates and minimizes turbidity will be used. Restoration activities will not interfere with navigation within the harbor.
STATE ARARS			
MA Water Quality Certification for Discharge of Dredged of Fill Material, Dredging, and Dredged Material Disposal in Waters of the U.S. within the Commonwealth (MA administration of Clean Water Act Section 401)	21 MGL 26-53; 314 CMR 9.00	Outlines procedures for MA administration of Clean Water Act Section 401 for discharges in the waters of the US within MA. Discharge is not permitted if there is a practicable alternative with less adverse impact on aquatic ecosystems. Potential adverse impacts to wetlands and land under water must be minimized and mitigated. Activities must comply with State Surface Water Quality Standards. A Water Quality Certification is required when a Federal permit (Clean Water Act 404/Section 10) is needed for filling wetlands or waterways. Projects with impacts to areas < 5,000 sq ft are reviewed and approved by the local Conservation Commission. Projects with impacts to areas > 5,000 sq ft are reviewed by MA DEP Division of Water Quality Control and are issued a Major Water Quality Certification.	The overall remedy of dredging/excavation and restoration is approved. The purpose of restoration is to mitigate the adverse impacts of dredging and excavation. Restoration will entail filling dredged and excavated sites to restore ecological structure, functions and values. Under restoration, there will be no net increase in harbor elevations due to fill activities. Restoration activities will not entail dewatering or the discharge of water. Potential impacts of restoration will be minimized through construction controls.
MA Environmental Policy Act	30 MGL 61; 301CMR 11.00	State equivalent of National Environmental Policy Act. Sets forth a process of environmental impact analysis and public review of State projects. Applicable to projects directly undertaken by State agencies; private projects seeking permits, funds or lands from the State; and any projects that will dredge, fill or alter > 1 acre of wetland. Does NOT apply to private projects requiring local approval only. Review is based upon an Environmental Notification Form and/or Environmental Impact Report. Upon approval by the MA Office of Environmental Policy Act, the project is issued a Certificate.	Under CERCLA, the cleanup remedy was reviewed and approved by the State.

Table 1 continued.

ARAR	LEGAL CITATION	SCOPE	ACTIONS TO BE TAKEN TO COMPLY WITH ARAR
MA Public Waterfront Act Waterways Licenses Law	91 MGL 1.00 et seq.; 310 CMR 9.00	Defines private property rights in tidal areas to mean low water. Defines public access rights to tidal land between mean low and mean high water for the purposes of fishing, fowling and navigation. Public access rights extend to mean high water in tidal bodies and ordinary high water in nontidal bodies. Access rights are also extended to "filled tidelands," i.e. to the historic high water in areas filled as long ago as the 1640s. Requires Waterways License from MA DEP Division of Waterways for activities that will occur below mean high water in flowed or filled tidelands.	Restoration, like dredging and excavation, will result in temporary, unavoidable impacts to public access rights to water and to water dependent users. Alternative access will be available. Overall, public access to tidal resource areas will increase as an outcome of cleanup. Permit is not required.
MA Wetlands Protection Act	131 MGL 40; 310 CMR 10	Prohibits damage to inland wetland, river, and coastal resource areas within 100 feet buffer zones (25 feet in designated urban areas). Sets forth MA Stormwater Management Policy. Sets forth a process of notification and review of proposed projects in and adjacent to wetland resources by local Conservation Commissions, which issue an Order of Conditions where appropriate. In New Bedford, the regulated areas (1) extend 25 feet inland from the riverfront, (2) within 100 feet of coastal wetlands, and (3) the land between mean low water and the landward boundary of the 100 year flood. In Acushnet and Fairhaven, the regulated areas extend to areas within 100 feet of any wetland resource area. Prohibits projects from adversely impacting wetland resources including but not limited to: impeding or obstructing fish migration, changing volume or rate or flow of water within the fish run, or impair the capacity of the spawning or nursery habitat; marine fisheries, marine habitat, water quality, circulation, distribution of sediment grain size; protection from storm damage and erosion; flood storage capacity; submerged aquatic vegetation, e.g. eelgrass; shellfish beds.	The cleanup entails otherwise prohibited actions in resource areas; however the restoration activities will restore and mitigate these actions. Restoration activities in fish migration and spawning areas will be avoided during the March 15 – June 15 anadromous fish spawning period. An erosion and sedimentation control plan will be implemented to prevent any soil erosion during the restoration process. Restored or replicated intertidal areas will be monitored for 10 years to document their ecological recovery. If restoration will have any detrimental effects on Federally or State-listed species, the MA Natural Heritage and Endangered Species Program will be consulted to determine any needed mitigation measures.
MA Endangered Species Act	131A MGL; 321 CMR 10.00	Prohibits the taking of State-listed species and damage to their habitat.	The MA Natural Heritage and Endangered Species Program will be consulted in the design of restoration to determine whether priority habitats or State-listed species occur in the project area and to minimize any potential impacts.

Table 1 continued.

ARAR	LEGAL CITATION	SCOPE	ACTIONS TO BE TAKEN TO COMPLY WITH ARAR
MA Coastal Zone Management Act	301 CMR 21	Sets policy for coastal zone areas, including policies on water quality, habitat, protected areas, coastal hazards, ports, public access, energy, ocean resources, and growth management. Standards inherent in policies are codified in relevant State regulations, e.g. Wetlands Protection Act. Policies applicable to restoration activities include policies on habitat (# 1, 2), coastal hazards (# 1), and public access (# 1). Sets forth a process of Coastal Zone Management Act Consistency Review to ensure that projects within the coastal zone comply with coastal zone policies. A Consistency Review is required when a project needs a Federal permit and/or when a project requires review by MA Office of Environmental Policy Act.	The entire site is located in a coastal zone management area. Cleanup restoration will be consistent with the standards codified in the relevant State regulations to the extent possible. Restoration will restore and protect coastal resources as required by habitat policy; will restore and enhance storm damage prevention and flood control benefits of vegetated intertidal per coastal hazard policy; and will accommodate and enhance public use and access to public recreation sites per public access policy.
MUNICIPAL ARARS			
Town of Fairhaven Wetland Protection By-Law		Prohibits damage to wetland resource areas, extending to 100 feet of such areas.	The Fairhaven Conservation Commission will be consulted on the design and implementation of restoration activities.

The following sections summarize the major legal, regulatory and programmatic requirements pertaining to the restoration of intertidal and upland areas impacted by cleanup activities.

2.1 Record of Decision (ROD) Requirements

In Section *X. The Selected Remedy* Part *D. Saltmarsh Excavation, Restoration and Monitoring* of the ROD, it is stated that salt marsh areas that are excavated to remove sediment above the site cleanup level of 50 ppm will be regraded and revegetated to approximate the original or existing conditions of the area remediated. Furthermore, erosion protection will be provided as appropriate to prevent bank failure due to erosion and scour. Lastly, the impacted areas restored are to be monitored over time to ensure the success of restoration efforts. The ROD, as well as the Regulatory Compliance Plan (Foster Wheeler Environmental 2000), outline the ARARS pertaining to the restoration design of impacted wetland areas detailed below.

2.2 Federal Clean Water Act (§404b) (Section 401 Certification)

This Restoration BD/DA has been developed as the mitigation measure required under 40 CFR 230.75, for the in-kind replacement and restoration of salt marsh that will be disturbed during dredging/excavation associated with cleanup activities. The restoration plan will be designed in accordance with the Memorandum of Agreement between the USEPA and the Department of the Army concerning the determination of mitigation under the Clean Water Act Section 404 (b)(1) guidelines. The memorandum states that the objective of mitigation should provide, at a minimum, one for one (1:1) functional replacement (i.e. no net loss of values), with an adequate margin of safety to reflect the expected degree of success associated with the restoration plan. Section 404b guidelines under the Clean Water Act mandate that no discharge of fill material may occur within the waters of the United States (including wetlands) when there is a practicable, less damaging alternative. As well, it requires that all practicable steps be taken to minimize impacts and to mitigate for unavoidable impacts. The needed and selected remedial alternative has been formulated after a thorough review of alternatives. The selected alternative has been chosen to both reduce health risks and minimize environmental damage.

To comply with the guidelines, a wetland functions and values assessment has been performed utilizing the USACE Highway Methodology of assessing wetland functions (Foster Wheeler Environmental 2002a). The mitigation plan is to be designed to restore or replace disturbed salt marsh areas on a 1:1 ratio for wetland functions and values. However, in accordance with the Section 404 (b)(1) guidelines, if the functions and values identified within the area being impacted are demonstrably low and the likelihood of success associated with the mitigation proposal is high, the ratio may be less than 1:1.

2.3 Massachusetts Wetlands Protection Act Regulations

Under the Massachusetts Wetlands Protection Act (WPA) regulations, the destruction of any portion of a salt marsh from fill and dredging activities is prohibited. However, there are no performance standards or policy guidelines specifically applicable to the restoration and replication of salt marsh. To substantively comply with the WPA, disturbed salt marsh will be replicated or restored at a proposed 1:1 ratio for wetland functions and values. An erosion and sedimentation control plan will be implemented to minimize and control soil erosion during the construction and re-vegetation process, and a monitoring plan will be established for restored salt marsh areas. Furthermore, Foster Wheeler Environmental and the USACE will consult with the Massachusetts Department of Environmental Protection (DEP) to incorporate to the greatest extent practicable any substantive requirements of the DEP.

In addition, according to 310 CMR 10.37, projects within coastal wetlands which will have any adverse effect on habitat of rare species, that is within areas mapped as Estimated Habitat of State-Listed Rare Wetlands Wildlife, will not be permitted. Foster Wheeler Environmental assumes that USACE will consult with the Massachusetts Natural Heritage and Endangered Species Program to determine if the proposed project will have any adverse effect on State listed species and to determine any recommended mitigation measures for remedial activities.

2.4 Local Bylaws

Massachusetts town/city Conservation Commissions were granted the authority to administer the WPA (310 CMR 10.04) and adopt additional bylaws/regulations for its implementation. The proposed restoration activities will take place within the city of New Bedford and the towns of Acushnet and Fairhaven, Massachusetts. The New Bedford and Acushnet Conservation Commissions, as of this date, do not have an additional Wetlands Protection Bylaw and therefore solely enforce the rules and regulations of the WPA. However, the Fairhaven Conservation Commission has adopted its own bylaw that employs supplemental wetland protection regulations. To ensure substantive requirements are met for work proposed within the jurisdiction of the WPA and the Fairhaven Wetlands Protection Bylaw, the Conservation Commissions will be consulted.

3.0 SITE CONDITIONS (UPPER HARBOR)

Meeting the requirements of the above-mentioned ARARS requires an understanding of existing conditions, while also considering potential changes in the reasonably foreseeable future. The intertidal areas targeted for restoration are part of both the larger Acushnet River and Buzzards Bay watersheds, and therefore they will be considered in this context. The wetland restoration design is founded upon an understanding of regional and local geological formations, hydrology, existing ecological communities, and the response of these communities to local and regional chemical, biological, and physical processes.

3.1 Physical Environment

New Bedford Harbor and the surrounding Acushnet River watershed are included in the larger Buzzards Bay watershed, which encompasses 10 coastal towns and 8 non-coastal towns in southern Massachusetts.

New Bedford Harbor shares many characteristics with adjacent embayments in the region, as they were all formed by the same geologic processes and are maintained by a similar climate, land processes, and tidal fluctuations.

3.1.1 Geomorphology of the Buzzards Bay Region

Although New Bedford Harbor has a glacial origin, marine processes are the dominant natural forces maintaining and, to a certain extent, modifying its form. However, the harbor also has been subject to, and continues to be modified by, human activities ranging from development in the watershed, to physical alteration of the shorelines and harbor bottom, and even to the modifications in tidal exchange with Buzzards Bay by the construction of a hurricane barrier.

3.1.2 Acushnet River Watershed and Adjacent Landuse

The watershed surrounding New Bedford Harbor is named after the Acushnet River which flows south about 2.5 miles (4 km) from the New Bedford Reservoir before emptying into the Upper Harbor (Figure 3). Freshwater input to the harbor from the river is relatively small (NUS 1984). Freshwater also enters the harbor in the form of precipitation, unidentified groundwater flows, and surface runoff supplied by the surrounding 18.5 sq. mi. (48 sq. km) watershed. Incoming waters from Buzzards Bay generally have a salinity of 31-33 ppt, but lower harbor salinities are due to dilution by freshwater. An analysis of landuse in the watershed indicates that less than 15% of the land area is developed, potentially limiting surface water runoff inputs to the harbor (VHB 1996). However, most of this development is in the lower watershed immediately adjacent to the harbor (Figure 4).

3.1.3 Climate

Wind, precipitation, and air temperatures have a significant influence on the magnitude of freshwater inputs, as well as the structure of biotic communities within the harbor and greater watershed. Ocean breezes (in summer) and the heat store in the harbor waters (in fall and winter) serve to moderate both summer and winter temperatures in the New Bedford Harbor area. Mean annual air temperature in New Bedford is 50°F (10°C). The highest monthly average temperature of 72°F (22°C) occurs in July, and the lowest of 30°F (-1°C) in January (Battelle Memorial Institute 1990). The New Bedford Harbor region typically has four distinct seasons. The limiting factor to plant growth in the area is cold.

Both rain and snowfall are evenly distributed throughout the seasons (approximately 4 inches (10 cm) /month). Regional annual precipitation amounts vary from 30 to 40 inches (76-102 cm) per year inland to up to 50 inches (127 cm) per year in some of the coastal areas such as New Bedford Harbor. Spring is usually short; summers are mild and humid along the coasts and cooler inland at higher elevations. Winters are long and can be severe, with heavy snow and sometimes ice storms. Storms tend to come from the West and South except for the occasional classic "Nor'easter," which is a strong, windy storm coming up the Atlantic coast and dropping large amounts of rain or snow.

Last frost dates range from the end of April along the coast to early June at inland locations. First frost dates tend to be from early September to the end of October. Therefore the frost-free growing season ranges from 120 to 180 days. Memorial Day, along with the traditional planting day for annual and vegetable gardens, in many areas governs the beginning of restoration activities. In fall the growing season can be extended into November and December, especially along the coast, but the short days rarely provide the needed energy for new growth. Perennials survive best in areas with cool summers and snow covered winters. Extreme cold events can cause ice formation and potentially damaging ice scour in coastal wetland systems such as New Bedford Harbor. Climate will therefore be considered in the specification of planting windows and surface stabilization to combat adverse winter and storm conditions.

3.1.4 New Bedford Harbor Bathymetry

As mentioned in Section 3.1.1 the general geometry of New Bedford Harbor was shaped by the action of glaciers and subsequent marine processes. However, the bathymetry, or depth distribution, has been extensively modified by periodic dredge and fill activities over the past two centuries. The most recent depiction of the bathymetry of the harbor is shown on a National Oceanic and Atmospheric Administration (NOAA) nautical chart of New Bedford Harbor (Figure 5). The main channel is clearly evident, extending from the Wood Street Bridge, passing under various bridges spanning the harbor, and exiting the harbor via the hurricane barrier. The increase in average depth of the harbor is also due to the loss of intertidal area by bridge and wharf construction and by wetland filling associated with industrial expansion in the harbor area. Presently five bridges span New Bedford Harbor including from north to south: Tarkiln Road Bridge, Wood Street Bridge, Coggeshall Street Bridge, I-195 Bridge and the New Bedford-Fair Haven Bridge (Figure 6). These structures have certainly modified local circulation and sediment patterns and the harbor's wave regime, all of which must be considered in intertidal restoration.

3.1.5 Freshwater Inputs

The largest freshwater source to New Bedford Harbor is the Acushnet River. The mean annual discharge rate and input volume over a tidal cycle have been estimated at less than 1% of the tidal prism, which is the volume of water between mean low water (MLW) and mean high water (MHW) (NUS 1984). Due to the lack of a significant freshwater inflow, the harbor is generally well mixed. Anadromous fish spawn in the Acushnet River, up to the point where passage is blocked. Implementation of restoration activities immediately downstream of the river's mouth will need to be scheduled to minimize disruption to upstream and downstream migration of fish.

As mentioned earlier, other sources of freshwater include precipitation, small streams on the eastern edge of harbor, overland surface flow during storms, stormwater drainage through outfalls, and overflows from combined sewer outfalls (CSOs). The eastern streams contribute less than 2% of the mean annual discharge of the Acushnet River (NUS 1984). Overflows from CSOs are of concern because they concentrate runoff into high velocity discharges, and they are sources of nutrients, sediments, and pollutants. These impacts can physically alter the area surrounding an outfall and lead to changes in wetland plant communities. Restoration design must accommodate both baseflows and stormflows in streams, intertidal creeks, stormdrains, and CSOs on a site-by-site basis.

3.1.6 Tidal Dynamics

New Bedford Harbor is classified as a low energy, microtidal estuary flooded by mixed, semi-diurnal tides. The tide enters the harbor via a hurricane barrier protecting the harbor from potentially damaging storm waves and surges associated with extreme low-pressure systems. Due to the number of tidal constrictions (bridges and the hurricane barrier itself) and the shallowness of the northern part of the harbor, the tidal signal is distorted or attenuated to a certain extent. The mean range in Buzzards Bay is estimated at 4.65 feet (1.42 m). However, averaged measurements in the vicinity of the Coggeshall Street Bridge in the inner harbor reveal a reduced range of 3.7 feet (1.1 m). When these two ranges are compared to a common datum such as NGVD it appears that the MHW elevation is the same, and that the difference in the tide ranges is on the low water end due to the inability of the harbor to completely drain before the propagation of the next high tide (USACE 1990). Figure 7 contains the most accurate tidal datums for the Upper Harbor (USACE 1999). These datums are of extreme importance to the restoration design of intertidal areas. Understanding the relationship between the proposed restoration areas and their elevation with respect to the tides is essential.

Tidal currents are the principal driver of circulation patterns in the harbor. One of the primary reasons for the retention of contaminants in the harbor is the harbor's tidal asymmetry, with flood current velocities generally higher than ebb currents (Summerhayes *et al.* 1977). This translates to a net influx, or trapping, of material delivered to the harbor both from oceanic and freshwater sources. Currents in the Upper Harbor in the vicinity of the majority of the proposed dredging and excavation operations are relatively low (less than 1 ft/s (0.3 m/s) (Battelle Memorial Institute 1990).

Current measurements near the Coggeshall Street Bridge demonstrate the effect of tidal constrictions on the relatively weak flow field. During maximum ebb conditions a current velocity of 6 ft/s (1.83 m/s) has been measured (Battelle Memorial Institute 1990). In essence the water exiting the culvert created by the bridge creates a jet, influencing both the transport of water and suspended solids. Eddies and gyres are also generated, which create settlement and retention areas in the adjacent shoreline areas with reduced currents. This evidence of low current velocities near impacted wetland areas aids in defining stabilization needs.

3.1.7 Salinity Gradient

Horizontal salinity gradients have been documented in New Bedford Harbor (SES 1988). The salinity of Buzzards Bay water is fairly constant at 31 ppt, although seasonal fluctuations of +/- 1 ppt may exist. Horizontal salinity gradients are strongest near freshwater sources, such as the Acushnet River to the north. The location and extent of emergent and nearshore coastal plant communities are largely governed by salinity regimes and inundation frequency. These factors will be considered in selecting restoration target species.

3.1.8 Nutrients

Excess nutrients in an estuarine system can lead to algal blooms. Algal blooms can be of concern in the restoration of intertidal systems for several reasons. With respect to submerged aquatic vegetation and intertidal vegetation, algal blooms can result in increased turbidity to the point of limiting light penetration and macrophytic growth. This potential is not of major concern with respect to the proposed restoration of intertidal habitats as they are regularly exposed. To date no beds of submerged aquatic vegetation have been identified within the Upper Harbor.

3.2 Biological Environment

A wide variety of habitat types are contaminated with PCBs, which were discharged directly into harbor waters or indirectly via the municipal sewer system. Due to fluctuating surface water levels and tidal circulation patterns, contaminants have been found above and beyond immediate subtidal and intertidal environments. Existing plant communities, and to a certain extent animal communities, are reviewed in this section. This review summarizes the current habitat distribution and expected impacts from cleanup, and helps target the proposed restoration efforts among habitat types.

3.2.1 Habitats

Table 2 summarizes the areas of the wetland habitats delineated in the Upper Harbor, based on the Final Wetland Delineation and Functions and Values Report for Restoration Design by Foster Wheeler Environmental (2002a), and the areas that will be impacted by dredging and excavation. Anticipated impacts are based on data from Foster Wheeler Environmental that shows depth and location of contamination. Figure 8 is a general profile identifying the position and elevation of coastal wetland habitats. These habitats will be discussed in a landward progression beginning with subtidal habitats and concluding with *Phragmites* marsh and upland bordering habitats.

Table 2. Area of Existing and Impacted Habitat Types in Upper Harbor. Existing area based on Foster Wheeler Environmental (2002a). Impacted area based on May 2002 dredging depth data provided by Foster Wheeler Environmental.

Habitat Type	Existing Area (acres)	Percent of Total Area	Impacted Area (acres)	Percent of Habitat Type Impacted
Vegetated Intertidal				
Palustrine Forested	0.03	0%	0.00	0%
Palustrine Scrub/shrub	0.74	1%	0.00	0%
Palustrine Emergent Marsh	0.49	0%	0.00	0%
Phragmites Marsh	6.50	6%	3.06	47%
Scrub/shrub	11.81	11%	1.39	12%
High Marsh	21.57	21%	8.54	40%
Low Marsh	16.06	16%	11.61	72%
Subtotal Vegetated Intertidal	*57.20*	*55%*	*24.60*	*43%*
Unvegetated Intertidal				
Beach	2.04	2%	1.72	84%
Creek	0.60	1%	0.41	67%
Mudflat	43.36	42%	39.16	90%
Subtotal Unvegetated Intertidal	*46.01*	*45%*	*41.28*	*90%*
Total Area	**103.21**	**100%**	**65.88**	**64%**

3.2.1.1 Subtidal Habitat

Approximately 155 acres of subtidal habitat occur north of I-195. Figure 9 is a hypsographic curve displaying the depth distribution of subtidal habitat and intertidal habitats north of I-195. This portion of the harbor is dominated by depths generally less than 12 feet (4 m) relative to MLLW. Greater depths are found in the main channel. The areal extent of restoration activities is limited to intertidal habitats.

3.2.1.2 Mudflats and Tidal Creeks

Between the permanently submerged subtidal habitats of the harbor and the surrounding upland watershed lie a variety of habitats defined by the frequency, depth, and duration at which they are inundated by the tides. Mudflats are those areas that are periodically exposed in the elevation range of approximately MLLW to MHHW. There are approximately 43 acres of mudflat in the Upper Harbor (Foster Wheeler Environmental 2002a), which comprises 42% of the intertidal zone (Table 2). Generally mudflats lie between subtidal and salt marsh areas. However, drainage ditches dug for mosquito control and tidal creeks may also function as mudflats (Photograph 1). Total tidal creek habitat is about 0.6 acres.

The intertidal habitat type most affected by cleanup activities is mudflat, with 90% of mudflat area disturbed (Table 2). These mudflats are composed primarily of fine-grained muds and sandy muds with numerous shell fragments (Bellmer 1988). The composition, elevation, and distribution of these substrates are important to the structure of macrobenthic faunal and floral communities. The most common algal species inhabiting these areas are sea lettuce (*Ulva lactuca*) and rockweed (*Fucus spp.*) (SES 1988). Shellfish found in these habitats include quahog (*Mercenaria mercenaria*), soft-shelled clam (*Mya arenaria*), bay scallop (*Argopecten irradians*), oyster (*Crassostrea virginica*), surf clam, (*Spisula solidissima*), and blue mussel (*Mytilis edulis*). In addition to shellfish, mudflats also support a diverse community of other invertebrates, which serves as a food source for macro-invertebrates, fish,

and shorebirds. Table 3 lists other invertebrates found in mudflats of New Bedford Harbor (Bellmer 1988). The ecological functions of these areas are discussed in Section 3.3 (Summary of Wetland Functions and Values Assessment). One function of particular interest is that mudflats are potential shellfish concentration areas. There are no known studies of shellfish densities in the Upper Harbor; however, the MA Division of Marine Fisheries conducted an extensive survey of quahog densities by size class in the Lower and Outer Harbors in 1999 (Whittaker 1999). In the Lower Harbor (called Inner Harbor in the study), the density of all size class quahogs combined was 6.3 quahogs per square foot. The commercial value to fisherman was estimated at $11.5 million.

Table 3. Mudflat Invertebrate Community.

Common Name	Scientific Name
Bar-gilled mud worm	*Streblospio benedicti*
Freckled paddle worm	*Eteone heteropoda*
Swift-footed worm	*Podarke obscura*
Cerratulid worm	*Tharyx acutus*
Whip mud worm	*Polydora ligni*
Thread worm	*Mediomastus ambiseta*
Annelid worm	*Tubificoides sp.*
(No common name)	*Weteromastus filiformis*
Trumpet worm	*Pectimaria gouldii*
Lumbrinarid thread worm	*Lumbrinerus tenis*
Common clamworm	*Nereis succinea*
Eroded basketshell snail	*Nassarius obsoletus*
Odostone pyramid shell	*Odostomia seminuda*
Hard clam or quahog	*Mercenaria mercenaria*
Dwarf surf clam	*Mulinia lateralis*
Fragile wedgeclam	*Tellina agiluis*
Sylid worm	*Brania welfleectensis*
Capitellid thread worm	*Capitella capitella*
(No common name)	*Eobrolgus spinosus*

3.2.1.3 Beach and Hard Substrate Intertidal Habitat

Just over two acres of beach habitat are delineated in the harbor north of I-195, most of which (1.7 acres) will be impacted by cleanup (Table 2). In general beaches are composed of sand, cobble, and gravel sized sediments. Beaches are most often associated with moderate to high-energy environments, which is uncommon in the protected Upper Harbor. Beaches of recreational value are located on shorelines seaward of the hurricane barrier. The beach areas in the Upper Harbor are most likely not natural and were probably created by placement of dredged materials. Plant diversity in these environments is naturally low due to a limited number of species that can survive and successfully compete in a low organic, saline, shifting sandy substrate. Common species found in the beach areas include beach grass (*Ammophila beviligulata*), beach pea (*Lathyrus maritimus*), and beach rose (*Rosa rugosa*).

Most of the hard substrate habitat in the harbor is also associated with human intervention. Much of the western shoreline has been developed and fortified with a combination of riprap and retaining wall structures. These hardened shorelines provide habitat for a variety of sessile organisms, such as barnacles, mollusks, and crustaceans. Table 4 lists the dominant organisms commonly found in hard substrate areas.

Table 4. Hard Substrate Intertidal Faunal Community.

Common Name	Scientific Name
Acorn barnacle	*Semibalanus balanoides*
Large rock barnacle	*Balanus balanus*
Little green crab	*Carcinus maenas*
Rock crab	*Cancer irroratus*
Long-clawed hermit	*Pagurus longicarpus*
Common periwinkle	*Littorina littorina*
Round periwinkle	*Littorina obtusata*
Rough periwinkle	*Littorina saxatilis*
Blue mussel	*Mytilus edulis*
Horse mussel	*Modiolus modiolus*
Slipper shell	*Crepidula fornicata*
Clam worm	*Nereis virens*

3.2.1.4 Low Salt Marsh

Approximately 16 acres of low salt marsh occur north of the I-195 Bridge, of which 72% will be impacted by cleanup activities (Table 2). The low marshes are regularly flooded by tides twice daily, because they lie between MLW and MHW (Foster Wheeler Environmental 2002a). In New Bedford Harbor low marsh areas are limited to a narrow band at the water's edge and along some creek banks (Photograph 2). Plant diversity is naturally low in this marsh zone, and *Spartina alterniflora* dominates the vegetation. In contrast, animal diversity is extremely high. *Spartina alterniflora* forms tall and large plants that create structural habitat complexity and that have a high rate of primary production, which helps support the base of estuarine food webs. It is difficult to develop an inventory of fauna that use the low marsh environment, because many species use the low marsh their entire lives, while others use it for only one life stage. Table 5 lists animal species that are known to use both high and low marsh habitats. This list is a compilation of various natural resource inventories undertaken in New Bedford Harbor, including vertebrate and invertebrate marine species (Bellmer 1988, IEP 1988, SES 1988). Many upland species also utilize salt marshes at lower stages of tide, and these species have been inventoried in previously referenced studies.

Table 5. Marsh Dependent Animal Species.

Common Name	Scientific Name
Barnacle	*Balanus sp.*
Nereid worm	*Nereis succinea*
Trumpet worm	*Pectinaria gouldii*
Gem	*Gemma gemma*
Tellin	*Tellina agilis*
Little surf clam	*Mullina lateralis*
Jingle shell	*Anomia simplex*
Soft-shelled clam	*Mya arenaria*
Macoma clam	*Macoma balthica*
Hard-shelled clam	*Mercenaria mercenaria*
Ribbed mussel	*Geukensia demissa*
Common Periwinkle	*Littorina littorea*
Mudsnail	*Ilyanassa obsolete*
Coffee bean snail	*Melampus bidentatus*

Table 5 continued.

Common Name	Scientific Name
Isopods	*Isopoda*
Amphipods, Scud	*Amhpipoda*
Mud fiddler crab	*Uca pugnax*
Green crab	*Carcinus maenus*
Mackerel	*Scomber scombrus*
Pollack	*Pollachius virens*
Alewife	*Alosa psuedoharengus*
Bluefish	*Pomatomus saltatrix*
Blue-back herring	*Alosa aestivalis*
Mummichog	*Fundulus herteroclitus*

3.2.1.5 High Salt Marsh and Scub/Shrub Wetlands

The high marsh habitat in the Upper Harbor generally lies between MHW and the elevation of the highest spring tides (MHHW). Because of its elevation the high marsh is irregularly flooded, i.e. less than daily. Above the I-195 Bridge, 22 acres of high salt marsh have been delineated, of which 40% will be impacted by cleanup (Table 2). More than 95% of the delineated high marsh habitat is present in the wetland areas on the eastern shore of the Upper Harbor, mainly in wetland area 4 (19 acres). The reason for the lack of high marsh habitat on the western shoreline is due to the commercial and industrial development of the western shore, where many acres of wetlands were filled (VHB 1996). As development progressed seaward, high marsh environments were the first to be destroyed. Some low marsh habitats were spared and still exist on the western shore.

The dominant plant species found in the high marsh is salt hay or salt meadow cordgrass (*Spartina patens*), which often forms signature cowlicks when exposed (Photograph 3). However, other species, such as spikegrass (*Distichlis spicata*) and blackgrass (*Juncus gerardii*), may be found as co-dominants or in monospecific stands. Other species found in lesser densities and quantities include: sea lavender (*Limonium carolinianum*), sea orach (*Atriplex patula*), seaside goldenrod (*Solidago sempervirens*), and slender leaved aster (*Aster tenuifolius*). In localized, high soil salinity areas, such as pannes and creek borders, both stunted *Spartina alterniflora* and glasswort (*Salicornia spp.*) can be found (Table 6). Some of the species distribution in the high marsh can be attributed to elevational differences, but for the most part distribution is believed to be the result of interspecific competition (Bertness and Ellison 1987). This suggests that restoration should reproduce topographic complexity and allow for natural redistribution of species after planting.

Scrub/shrub wetlands occur on the border between the high marsh and upland and often contain salt tolerant grasses and shrubs such as switchgrass (*Panicum virgatum*), groundsel tree (*Baccharis halimifolia*), and marsh elder (*Iva frutescens*). Again, distance from the water's edge is less important than elevation in determining the presence or distribution of these species. Twelve acres of scrub/shrub wetlands were delineated in the Upper Harbor, of which 1.4 acres will be impacted (Table 2).

Table 6. High Marsh and Marsh/Upland Border Species

Common Name	Scientific Name
Salt meadow cordgrass	*Spartina patens*
Smooth cordgrass	*Spartina alterniflora*
Spikegrass	*Distichlis spicata*
Blackgrass	*Juncus gerardii*
Sea lavender	*Limonium carolinianum*
Sea orach	*Atriplex patula*
Seaside goldenrod	*Solidago sempervirens*
Slender leaved aster	*Aster tenuifolius*
Glasswort	*Salicornia spp.*
Switch grass	*Panicum virgatum*
Groundsel tree	*Baccharis halimifolia*
Marsh elder	*Iva frutescens*

3.2.1.6 *Phragmites* Marsh

Approximately 6.5 acres of common reed (*Phragmites australis*) have been delineated north of I-195 Bridge, of which 3.1 acres will be impacted (Table 2). Most of this habitat type is concentrated in the Prouteau Cove area on the east side of the harbor (Figure 3). *Phragmites australis* has been a component in coastal bordering environments for over 2000 years (Orson *et al.* 1987). However, because of its expansion in tidally restricted areas during the past few decades, it is now considered an invasive species.

3.2.1.7 Palustrine Emergent Wetland

Approximately 0.5 acres of palustrine emergent wetlands were delineated in the Upper Harbor within or adjacent to the intertidal area (Table 2). However, none of this habitat will be impacted by cleanup. Table 7 contains the species identified in these wetlands.

Table 7. Palustrine Emergent Wetland Species.

Common Name	Scientific Name
Silky dogwood	*Cornus amomum*
Jewelweed	*Impatiens capensis*
Sensitive fern	*Onoclea sensibilis*
Eastern Joe-pye-weed	*Eupatorium dubium*
Spotted Joe-pye-weed	*Eupatorium maculatum*
Arrow-leaved tearthumb	*Polygonium sagittatum*
Cattail	*Typha spp.*
Fox sedge	*Carex vulpinoidea*
Creeping bent grass	*Agrostis stolonifera*
Switch grass	*Panicum virgatum*
Canada rush	*Juncus canadensis*
Water plantain	*Alisma plantage-aquatica*

3.2.1.8 Palustrine Scrub/Shrub Wetland

Approximately 0.7 acres of palustrine scrub/shrub wetlands were delineated in the Upper Harbor within or adjacent to intertidal areas. Less than 1% of this habitat type will be impacted (Table 2). Table 8 contains species identified in these wetlands.

Table 8. Palustrine Scrub/Shrub Species.

Common Name	Scientific Name
Viburnum	*Viburnum recognitum*
Gray birch	*Betula populifolia*
Highbush blueberry	*Vaccinium corymbosum*
Black chokeberry	*Pyrus melanocarpa*
Black gum	*Nyssa sylvatica*
Cinnamon fern	*Osmunda cinnamomea*
Poison ivy	*Toxicodendron radicans*

3.2.1.9 Palustrine Forested Wetland

The wetland class with the smallest area identified in the Upper Harbor area is palustrine forested wetland, which accounts for 0.03 acres. These wetlands were found near the border between wetlands and uplands, north of Prouteau Cove. These areas are dominated by red maple (*Acer rubrum*), black gum (Nyssa sylvatica), viburnum (*Viburnum recognitum*), and poison ivy (*Toxicodendron radicans).* None of this habitat will be impacted by cleanup (Table 2).

3.3 Landform Analysis

A landform analysis was performed utilizing a combination of field visits and the spatial and three dimensional analyst tools of Arcview® GIS. Of particular interest were habitat types, slopes, and elevations in areas to be impacted by cleanup activities, as well as predicted elevations and slopes post-dredging/excavation. Table 9 lists GIS data layers in the Foster Wheeler Environmental database used in landform analysis. The areal extent of impacted habitats was estimated by intersecting the dredge depth layer with the wetland resources layer. Stabilization needs were estimated by examining the location and depth of dredging/excavation with respect to existing topography and habitat distribution.

Table 9. Data Layers Used in GIS-Based Landform Analysis. All data provided by Foster Wheeler Environmental.

Description	Data Layer
Delineated wetlands	wetland_resources.shp (4/3/02)
Existing topography	upper_topography.shp (5/16/02)
Existing topography, Wetland 6	EAST_SHORE.dgn (10/22/02)
Existing bathymetry	lower_bathymetry.shp (5/16/02)
Dredging depth (Z* data; domains 1A, 1B, 1C, 2)	z-d1a.shp (5/2/02)
Residential/beachcombing zones	direct_exposure.shp (5/2/02)

3.2.1 Erosional Conditions

Field identification of erosional conditions is critical to the restoration design of intertidal habitats for several reasons. Damage by waves may be periodic and require a long term monitoring effort to fully define the wave regime of the system. Erosional features are direct evidence of past exposure. By examining slopes and shoreline morphology physical stress may be approximated. Slopes at the interface between mudflat and low marsh as high as 2.5V:1H have been calculated in the GIS-based landform analysis. The slopes encountered in these areas are well above the maximum angle of repose that can be achieved by grading non-cohesive sediments of sand, silt, or clay size. The reason for the existence of these slopes in the salt marsh areas is due to the reinforcing properties of the belowground growth of salt marsh vegetation.

3.2.2 Surface Drainage Patterns

Surface drainage patterns in the Upper Harbor vegetated intertidal areas are sheet flow over high and low marsh or channelized flow in tidal creeks. In addition, some high, low, and *Phragmites* marsh areas are drained by shallow mosquito control ditches, generally spaced at a 100-foot (30.4 m) interval (Photograph 4). In general, surface drainage patterns in the vegetated intertidal areas can be restored by the restoration of existing elevations and intertidal creek morphologies.

3.4 Wetlands Functions and Values Assessment

As referenced in previous sections, a Wetland Functions and Values Assessment of the Upper Harbor was conducted by Foster Wheel Environmental in the summer and fall of 2001 using the USACE Highway Methodology, Wetland Functions and Values, Descriptive Approach (USACE 1995). In the assessment of functions and values and discussion of wetland resources, the delineated wetlands were broken down into 14 wetland areas north of the I-195 Bridge, by geographic location (Figure 10 and Table 10). This framework has been used in the conceptual design of alternatives (although adjacent mudflats were divided among enumerated vegetated wetland areas), analyses, identifying both constraints and opportunities on geographic basis, and in quantifying restoration benefits.

Table 10. Area of Existing and Impacted Habitat Types Within Wetlands 1-13 and the Early Action Site in Upper Harbor. Existing area based on Foster Wheeler Environmental (2002a). Impacted area based on May 2002 dredging depth data provided by Foster Wheeler Environmental.

Wetland Area	Habitat Type	Existing Area (acres)	Impacted Area (acres)	Percent of Wetland Area Impacted
Early Action Site				
	Low Marsh	0.19	0.00	
	High Marsh	0.18	0.02	
	Creek	<0.01	<0.00	
	Subtotal Early Action	*0.37*	*0.02*	*5%*[1]
Wetland Area 1				
	Phragmites Marsh	0.19	0.01	
	Low Marsh	0.19	0.12	
	Mudflat	1.44	1.21	
	Subtotal Wetland 1	*1.82*	*1.33*	*73%*
Wetland Area 2				
	Phragmites Marsh	0.03	0.02	
	Low Marsh	0.08	0.06	
	Mudflat	2.74	2.73	
	Subtotal Wetland 2	*2.85*	*2.81*	*99%*

Table 10 continued.

Wetland Area	Habitat Type	Existing Area (acres)	Impacted Area (acres)	Percent of Wetland Area Impacted
Wetland Area 3				
	Palustrine Forested	0.03	0.00	
	Palustrine Scrub/shrub	0.74	<0.01	
	Palustrine Emergent	0.39	0.00	
	Phragmites Marsh	4.99	2.70	
	Scrub/shrub	0.35	0.32	
	High Marsh	2.14	1.69	
	Low Marsh	2.02	1.60	
	Beach	0.05	<0.01	
	Creek	0.18	0.17	
	Mudflat	14.17	14.03	
	Subtotal Wetland 3	*25.06*	*20.53*	*82%*
Wetland Area 4				
	Phragmites Marsh	0.48	0.06	
	Scrub/shrub	11.22	1.05	
	High Marsh	18.53	6.43	
	Low Marsh	8.11	6.19	
	Beach	0.91	0.84	
	Creek	0.32	0.14	
	Mudflat	8.50	8.07	
	Subtotal Wetland 4	*48.07*	*22.79*	*47%*
Wetland Area 5				
	High Marsh	0.16	0.00	
	Low Marsh	0.71	0.35	
	Beach	0.15	0.09	
	Mudflat	1.78	1.13	
	Subtotal Wetland 5	*2.80*	*1.57*	*56%*
Wetland Area 6				
	Low Marsh	0.27	0.19	
	Mudflat	0.39	0.23	
	Subtotal Wetland 6	*0.66*	*0.43*	*65%*
Wetland Area 7[1]				
	Phragmites Marsh	0.30	0.00	
	Low Marsh	0.09	<0.01	
	Beach	0.06	0.00	
	Creek	0.01	0.01	
	Mudflat	0.07	0.00	
	Subtotal Wetland 7	*0.53*	*0.01*	*1%*[1]
Wetland Area 8				
	Low Marsh	0.14	0.13	
	Beach	0.65	0.65	
	Mudflat	0.50	0.47	
	Subtotal Wetland 8	*1.30*	*1.26*	*97%*

Table 10 continued.

Wetland Area	Habitat Type	Existing Area (acres)	Impacted Area (acres)	Percent of Wetland Area Impacted
Wetland Area 9				
	Phragmites Marsh	0.30	0.09	
	Scrub/shrub	0.10	0.00	
	High Marsh	0.32	0.18	
	Low Marsh	1.76	1.47	
	Beach	0.11	0.07	
	Mudflat	5.52	5.43	
	Subtotal Wetland 9	*8.10*	*7.24*	*89%*
Wetland Area 10				
	Palustrine Emergent	0.06	0.00	
	Subtotal Wetland 10	*0.06*	*0.00*	*0%*
Wetland Area 11				
	Palustrine Emergent	0.04	0.00	
	Subtotal Wetland 11	*0.04*	*0.00*	*0%*
Wetland Area 12				
	Phragmites Marsh	0.04	0.02	
	Scrub/shrub	0.14	0.01	
	Low Marsh	2.29	1.26	
	Beach	0.12	0.06	
	Creek	0.01	0.01	
	Mudflat	6.67	4.44	
	Subtotal Wetland 12	*9.27*	*5.80*	*63%*
Wetland Area 13				
	Phragmites Marsh	0.17	0.17	
	High Marsh	0.24	0.24	
	Low Marsh	0.21	0.21	
	Creek	0.08	0.08	
	Mudflat	1.58	1.41	
	Subtotal Wetland 13	*2.28*	*2.10*	*92%*
Total Area		**103.21**	**65.88**	**64%**

[1] Dredging and Excavation BD/DAs (Foster Wheeler Environmental 2002b, 2002c) do not specify additional cleanup in the Early Action Site and in wetland 7.

Functions and values were assessed within each wetland area. There are several ways in which the functions and values can be considered in the restoration design. Functions and values of all wetland areas can be pooled and the most frequently occurring identified (Figure 11). From this analysis the following functions and values occur in twelve or more of the wetland areas:

- Fish and shellfish habitat,
- Sediment/toxicant retention,
- Nutrient removal,
- Sediment/shoreline stabilization.

Other approaches that can be applied are identifying and weighting the less frequent or unique functions and values, or those attributed to the largest wetland areas. Regardless of the breakdown and analysis, several conclusions remain the same. There are few differences among the identified fourteen areas with respect to principal functions. Second, each of the functions and values considered is dependent on the present wetland size, soils, and vegetation. Therefore, maintaining wetland acreage and community distribution, replanting existing native species, and emulating or using existing soils is the most practicable approach to achieving the restoration of functions and values of impacted areas on a 1:1 net basis.

Table 11. Summary of Principal Functions and Values, Based on Foster Wheeler Environmental (2002a).

Wetland Function	**Wetland Area**														
	Early Action	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**Mud flat**
Fish and Shellfish Habitat	X	X	X	X	X	X	X	X	X	X			X	X	X
Sediment/Toxicant Retention	X	X	X	X	X	X	X	X	X	X			X	X	X
Nutrient Removal	X	X	X	X	X	X	X	X	X	X			X	X	
Production Export					X										
Sediment/Shoreline Stabilization	X	X	X	X	X	X	X	X	X	X			X	X	
Wildlife Habitat				X	X						X			X	X
Endangered Species Habitat															X
Groundwater Recharge/Discharge											X				

4.0 BASIS OF DESIGN AND DESIGN CRITERIA

Analysis of existing conditions, anticipated impacts from dredging/excavation, and restoration goals and guidelines embodied in ARARs circumscribe what will need to be restored in the New Bedford Upper Harbor. Design criteria are the design parameters and constraints that must be considered to ensure that the specific project goals and objectives are met. The term "design criteria" refers to the quantitative measures of wetland components that provide the desired wetland functions. The restoration design is focused on restoring functions and values of wetlands, as defined and described in Foster Wheeler Environmental (2002a).

4.1 Location and Areal Extent of Habitats to be Restored

The location of areas affected by remedial activities is shown in Figure 2. To understand the impact of cleanup on wetlands the May 2002 delineation of contamination (area and depth of required dredging) was overlain on the map of wetland areas and habitats (Foster Wheeler Environmental 2002a). Table 2 summarizes the areal extent of excavation expected in each habitat type and the percentage of each habitat type that will be impacted.

Most of the dredging/excavation will occur in the unvegetated intertidal, where 39 acres of mudflats, representing 90% of all mudflats, will be affected. In the vegetated intertidal, 12 acres of low marsh, 9 acres of high marsh, and 3 acres of *Phragmites* marsh will be affected. Across the Upper Harbor, 90% of the unvegetated intertidal and 43% of the vegetated intertidal will be impacted.

4.2 Size of Restoration Units

In terms of wetland restoration and erosion control, the size and location of restoration units should be based upon the length of time required for the implementation of major design components, including filling, finish grading, installation of stabilization measures, and planting. Working in wet, tidal conditions will dictate the method and times of construction for much of the proposed work and will directly affect how the working units will be determined. Working units will also need to be coordinated with the working units established in the dredging and excavation designs.

4.3 Donor Substrates and Subgrade Soils

Substrates are critical components of intertidal areas. They serve as a biological interface to support macro- and micro-invertebrates and microbial populations, a medium for plant growth, and they facilitate water quality improvements. Subgrade soils form the structural vessel in which the intertidal area is formed. By definition the substrate lies above the subgrade soil. Donor substrate will be required in some locations to provide the proper elevations and/or substrate to promote growth by the desired salt marsh plant species. The design criteria for donor substrates include the following.

4.3.1 Emulate Existing Substrate to the Extent Practicable

The existing marsh peat is classified as organic soil with an organic matter content of approximately 20 to 30% by weight. To date, there has probably not been a successful creation of a functioning, organic soil-based, peat building wetland system. Therefore, it is not reasonable or practical to restore existing intertidal (marsh) substrates in-kind. The design focuses on major attributes of existing substrate.

4.3.2 Provide Suitable Substrate for Plant Propagation (Vegetated Intertidal)

Based on previous studies of salt marsh restoration and experience in New England marsh restoration sites, the ideal substrates for vegetated intertidal habitats are fine-grained soils (silty clay), with 80-90% by weight passing through a No. 10 sieve (Garbish 1986) and organic matter content greater than 4%. Substantial organic matter amendments (10 to 50%) are not necessary at the time of construction. Current monitoring data indicate that substrates with more than 3% organic matter content may be able to support the initial microbial population necessary to support normal intertidal substrate functions. Also, a greater amount of organic material incorporated in a mineral substrate may affect the cohesion and structure of soils and affect its ability to provide mechanical support and a stable rooting medium for plants. Fine-grained soils have low permeability, permitting the retention of standing water or the saturation of soils, thus providing a competitive advantage to halophytes (Mitsch and Gosselink 1993).

Case studies where substrate materials have been applied successfully (Gilbert 1995) show that 6-12 inches (15-30 cm) of substrate material over a prepared subgrade is sufficient for most emergent and scrub/shrub wetland systems. A minimum of 12 inches (30 cm) in depth of clean inorganic/organic material is recommended by Garbish (1986). Based on the above criteria, proposed substrates for vegetated intertidal habitats are a sandy topsoil with 3–7% organic matter, with a median particle size of 0.02 inches, and a thickness of 12 inches (30 cm), where required. Optimum compaction rate is 85%.

Subgrade soil will be used in areas where the excavated/dredged grade following cleanup is greater than 12 inches (30 cm) below the desired final grade. Subgrade will be used to raise the ground elevation and to serve as structural support for the substrate. If construction vehicles are used to haul and spread the subgrade soil, soil may be compacted to levels that will inhibit plant root growth and root penetration. Therefore, it is recommended to conduct compaction tests to monitor the compaction of the final subgrade. Compaction should not be greater than 90-92% of standard Proctor maximum dry density (Goldsmith *et al.* 2001).

Areas impacted by dredging and/or excavation that remain at elevations suitable for restoration target plant species will be amended as necessary, and will be scarified to promote gas exchange. No further treatment for these areas is anticipated.

4.3.3 Provide Suitable Substrate for Faunal Recolonization (Mudflat)

Figure 12 summarizes the known sediment grain size distribution. Sediments in mudflats are dominated by sands and silts with smaller fractions of clay and gravel. When the data is arranged by sample depth, no trend is apparent (Figure 13). Another sediment characteristic that is important to wetland restoration design for intertidal habitats is organic content. The average organic content of the samples from the Phase IIIa and IIIb sampling effort is 8%, with a range of 2% to 29% (data supplied by Foster Wheeler Environmental). These data demonstrate the tremendous variability in sediment organic content and support less stringent criteria for organic content of donor substrates for non-vegetated intertidal habitats. Based on the above criteria, proposed substrates for mudflats are silty sand with at least 4% organic matter content by weight. For this conceptual design, it is assumed that clean overdredge material will meet these requirements, however, this assumption must be validated when overdredge material is available for testing.

4.3.4 Cover Direct Contact Areas with Clean Topsoil

In direct contact areas, i.e. areas located in designated residential and beachcombing zones, the confirmatory sampling plan specifies that these areas be covered with 1 ft of clean topsoil.

4.4 Slopes

Slopes are another major consideration in the development of wetland habitats. The design criteria for slopes include the following.

4.4.1 Emulate Existing Slopes to the Extent Practicable

Existing slopes for the vegetated intertidal habitat range from 1V:5H to 1V:30H and for the mudflat habitat range from 1V:15H to 1V:300H approximately.

4.4.2 Provide Suitable Slope for Vegetation Establishment

Broome *et al.* (1988) recommended slopes of 1V:100H to 1V:30H for marsh establishment. Gentle slopes dissipate wave energy over a greater area, thereby decreasing erosion and disruption to plantings. However, slopes that are too flat will decrease drainage, potentially leading to waterlogging and hypersaline conditions (Broome 1990, Normandeau Associates 1992). Of four projects evaluated by Reimold and Cobler (1986) in New England, three had problems, because the slopes were too steep. These authors recommended the emulation of existing slopes where practicable, and constructing slopes ranging from 1V:5H to 1V:15H, where emulation of existing slopes is not practicable, to increase vegetation diversity and slope stability.

4.4.3 Provide Stable Slopes

Newly placed substrate will be exposed to tidal motion. This may create a rapid change in water level adjacent to the slope, causing slope failure. The maximum slope estimated to be stable, without consideration for factors involving the reinforcement effect of plant roots, is 1V:5H. Therefore, any slope flatter than 1V:5H will be considered geotechnically stable, based on infinite slope analysis

including horizontal seepage forces. This analysis does not include erosional forces due to overland flow, which are expected to be minimal due to the shallow gradient of the marsh.

4.5 Elevations

Proper elevations are crucial for the establishment of native intertidal plant species, which are specialized for different frequencies and duration of tidal inundation. For example, the difference in elevation between the marsh edge and the bordering upland may be only 4-6 inches (10-15 cm) (Lefor *et al.* 1987).

The final elevations specified in the restoration grading plans are critical and should be based upon the elevation requirements of the desired habitat type. Final design elevations must take into account anticipated settlement and consolidation of the substrate and subgrade. Exposed peats, which will serve as existing subgrade soils in some areas, may settle 5%. Topsoil may settle 10 to 20%. For example, a 12 inch (30 cm) thick fill may settle by 1.2 to 2.4 inches (3-6 cm). To achieve the final design elevations it will be necessary to compact fill material used for subgrade (92%) and substrate (85%).

The zonation of the marsh plant species is related to elevations with respect to tidal ranges and water levels. Although a model of intertidal zonation is shown in Figure 8, the recent wetland delineation performed by Foster Wheeler Environmental demonstrates that habitats are often distributed in a mosaic pattern rather than in distinct bands parallel to the shoreline edge. Three elevations have been identified (using the wetland resources and topography data layers) as critical and must be observed during restoration. These elevations separate important components of the wetland system. They are mudflat, low marsh, and high marsh. The elevation ranges are:

- Mudflat: -1.44 feet to 1 foot (NGVD),
- Low marsh: 1.00 to 2.5 feet (NGVD),
- High marsh: 2.5 feet to 3.5 (NGVD).

4.6 Target Species

The target species are derived from those identified in habitats that will be disturbed by cleanup activities. However, the list of target species is a subset of observed species due to the difficulty of propagating and planting certain species (Table 12). The plants listed have been successfully used in other salt marsh restoration projects in the New England area. All planting elevations will need to be verified in the field and are only displayed for comparative purposes.

Table 12. Target Species and Planting Elevations.

Scientific Name	Common Name	Zone (Elevation Range)
Spartina alterniflora	Smooth cordgrass	Low marsh (1.0-2.5 ft NGVD)
Spartina patens	Salt meadow cordgrass	High marsh (2.5-3.5 ft NGVD)
Juncus gerardii	Blackgrass	High marsh (2.5-3.5 ft NGVD)
Distichlis spicata	Spikegrass	High marsh (2.5-3.5 ft NGVD)
Panicum virgatum	Switchgrass	Border (4.0-5.0 ft NGVD)

The spacing of plants is important to the success of re-establishment of vegetation. Hybrid planting schemes with zones planted 12, 18, and 24 inches (30, 46, 61 cm) on center will be designed with closer spacing in fringe marsh areas and wider spacing in marsh interior areas.

4.7 Invasive Species Control

Salt marsh vegetation may be absent as a result of competitive exclusion by invasive species, often *Phragmites*. Therefore to promote restoration, it is often necessary to prevent re-colonization by *Phragmites*. In many cases, restoration of tidal inundation by lowering grade may gradually reduce *Phragmites* without further intervention. Past marsh restoration projects have demonstrated that if a hydroperiod with a minimum flooding frequency of eight times per month is established, *Phragmites* establishment may be impeded.

In areas near freshwater inputs, such as stormdrain outfalls, manipulation of elevation alone may not be effective. In these situations, the freshwater drainage can be diverted away from the saltmarsh. Alternatively, salt concentration swales can be excavated (24 inches (61 cm) wide by 36 inches (91 cm) deep) at the upland edge of tidal marshes. These swales are then connected to natural tidal creeks. This system drains freshwater and increases saltwater flow into the back marsh, raising soil salinity, and helps to control the establishment of *Phragmites*.

4.8 Bank Stability

Slopes greater than 1V:5H will need stabilization measures. Intertidal vegetated and unvegetated areas will have design slopes lower than 1V:5H (Section 4.4), and no stability problems are anticipated. However, steep slopes are typically encountered at the interfaces between mudflats and low marsh, between low marsh and high marsh, and along tidal creeks. The presence of these short, steep slopes is primarily due to the presence of vegetation and associated roots, which support slopes greater that 1V:5H.

These interfaces need to be emulated to achieve suitable elevations for desired habitats to develop. Temporary stabilization measures, such as bioengineering treatments, can be designed to stabilize the interface until vegetation is established and root reinforcement takes place.

Biodegradable materials, such as coconut fiber (coir) fascines, blankets, and mattresses are recommended at the mudflat/low marsh interface and, if necessary, at the low marsh/high marsh interface. The difference in elevation at the interface should not be greater than 12 inches (30 cm), because this is the approximate limit of root penetration.

The tidal creek banks will be stabilized using soil lifts wrapped in biodegradable material, such as coir fabric. This temporary bioengineering treatment will hold the banks until plants are established. The geometry of the tidal creeks should be emulated, therefore it is important to document the existing cross sections, planforms, and slopes.

Larger coir fascines will be used at the subtidal/mudflat interface to stabilize the toe of the slopes created when mudflat areas are filled with overdredge material. While these coir fascines will not revegetate at this location, they will provide slope stabilization during the critical period of settlement of mudflat material and revegetation of the marsh areas.

4.9 Implementation (Access, Construction, and Staging)

Soil compaction and rutting by construction vehicles can dramatically undermine the achievement of the intended functions and values of the restored salt marsh. Therefore, during restoration activities it is recommended to use low-ground-pressure equipment, and/or operate equipment off of temporary construction mats. In lieu of temporary construction mats, temporary roads can be constructed using crushed stone over geotextile fabric.

Specifications have been prepared for the North of Wood Street Restoration Design. Much of the information in these specifications will be applicable to the work south of Wood Street, including information on bioengineering techniques and planting specifications. However, some modifications to method of construction, earthwork, and bank stabilization will be required south of Wood Street, along with additional work for water pollution control and staging.

While the restoration earthwork north of Wood Street will be done after streamflow in the Acushnet River has been diverted, it is assumed that all work at locations south of Wood Street will be done without water diversions ("in the wet"). The type of equipment used to perform work in the wet will be different.

Staging and access will require significant attention to the tides. Placement of fill in low and high marsh areas and bioengineering work should be done as tides are receding. Most work with land-based equipment will need to be done at low tides. Planting should be done above the tide level, as the tide rises. Areas to receive overdredge material may be more accessible by barge at times when the tide is higher.

The addition of water pollution control measures to the work south of Wood Street will need a series of specifications to reduce the risk of contamination in adjacent areas. Tidally inundated areas that will be disturbed or that will receive donor substrates will need to be contained within turbidity control devices in order to prevent migration of sediment. Upland areas that will be disturbed will need erosion controls.

The specifications for the area north of Wood Street do not include details related to mudflat restoration, as no mudflats will be restored in that area. Therefore, specifications for mudflat restoration will need to be included in the construction document package for the area south of Wood Street.

5.0 RESTORATION DESIGN

Based on the identification and analysis of alternatives (Appendix A), a restoration plan for the Upper Harbor was developed. This plan includes (1) a 100% design for the area north of the Wood Street Bridge and (2) a final conceptual design for the areas lying between the Wood Street and I-195 Bridges. Under this restoration plan, the wetland functions and values of the Upper Harbor will be restored on a 1:1 net basis across the Upper Harbor (i.e. among all wetland sites in the Upper Harbor) to the most practicable extent possible. Wetlands were designated for restoration based on the following major criteria:

- Areas where non-replacement would result in severe erosion,
- Areas in which hydrologic connections are impacted (intertidal creeks),
- Areas where sediment/soil is removed on residential property,
- Areas where sediment/soil is removed in or near public parks or other public access areas,
- Areas in beachcombing and residential zones that require 1 ft of topsoil for the purpose of the confirmatory sampling plan.

The design specifies restoration of wetland areas 1, 3, 4, and 6 (see Figure 10) on the eastern edge of the Upper Harbor and wetland areas 9 and 13 on the western edge, including some mitigation in these areas for intertidal habitat lost in the unrestored wetland areas (2, 5, 8, and 12). Four wetland areas (7, 10, 11, and the Early Action Site) will not be impacted by cleanup activities. Note that the Early Action Site was remediated and restored in 2001.

Table 13. Restoration Plan for Each Wetland Area. Based on identification and analysis of alternatives described in Appendix A.

Wetland Area	Restoration Plan (see Appendix A)
Early Action	Restored in 2001
1	Restored, except mudflat
2	Not restored
3	Restored
4	Restored
5	Not restored
6	Restored, except mudflat
7	Not impacted by cleanup
8	Not restored
9	Restored
10	Not impacted by cleanup
11	Not impacted by cleanup
12	Not restored
13	Restored, except mudflat

5.1 Area North of Wood Street Bridge

A 100% restoration design was completed for the wetland areas north of the Wood Street Bridge, in the northernmost reach of the Upper Harbor, in October 2002. This harbor area included the Early Action Site and wetland areas 1 and 13 (Figure 10). The restoration goal for this area of the harbor was 1:1 restoration of vegetated intertidal habitats and no restoration of mudflat.

The restoration design for this area was completed under an accelerated schedule, because dredging/excavation of this area began in November 2002. The restoration plan was based on the final dredging/excavation grading plan and project workplan, both of which were supplied by Foster Wheeler Environmental. The restoration design drawings (grading plans in planview and cross-section, planting plans, and treatment details) and specifications are available from Foster Wheeler Environmental.

Dredging/excavation north of the Wood Street Bridge will be undertaken "in the dry." A temporary berm will be built across the harbor just to the south of the bridge, in order to prevent harbor waters from flowing northward into this area. Water flowing into this area from the Acushnet River will be diverted around the work area. Dredging/excavation, restoration grading, and stabilization will begin in the fall of 2002, and restoration planting will be conducted in the following spring of 2003. A portion of the materials used to build the berm and temporary haul roads in the channel bottom will be used as subgrade fill material to help bring impacted areas up to the desired restoration elevation. In addition, because the wetland areas north of Wood Street lie in residential and beachcombing zones, 1 ft of clean manufactured wetland topsoil mix will be placed over impacted, vegetated intertidal and upland areas. This is required to meet the needs of the confirmatory sampling protocol.

5.1.1 Early Action Site

The dredging/excavation plan for the Wood Street area does not specify additional dredging/excavation on or around the Early Action Site. Restoration, which took place in 2000 and 2001, is currently being monitored by Foster Wheeler Environmental. Recovery of upland and saltmarsh areas is expected to continue. No additional losses or conversions of habitat are anticipated.

5.1.2 Wetland 1

In wetland 1 the impacted *Phragmites* marsh will be restored as high marsh; low marsh will be restored as low marsh; and mudflat will convert to subtidal (Figure 14.1). The *Phragmites* marsh that occurs in this area is likely the result of stormwater runoff from the adjacent parking lot and River Street. In order to decrease the risk of recolonization by *Phragmites*, the stormwater drainage in this area should be examined and managed. Given that an area immediately to the east of the wetland will be used as a staging area for construction, restoration of the staging area upon demobilization will present an opportunity to modify the drainage pattern with minor re-grading.

5.1.3 Wetland 13

Most of wetland 13 (92%) will be impacted by cleanup (Table 10). The impacted *Phragmites* marsh, high marsh, and half of the low marsh (0.1 acres) will be restored as high marsh, resulting in a net increase in high marsh (Figure 14.2). The remaining, impacted low marsh will be restored to low marsh. Some impacted mudflat (0.1 acres) will be restored to low marsh, so that there will be no loss of low marsh. In some areas of the final low marsh footprint, post-excavation grade will be less than –0.5 ft. In these areas, a coir fascine will be placed at the mudflat/low marsh interface and the area landward of the fascine will be backfilled. Subgrade fill will be placed up to an elevation of –0.5 feet, and then manufactured wetland topsoil mix will be placed on top of subgrade to reach the desired final elevation. The remaining, impacted mudflat will not be restored and consequently will convert to subtidal.

The presence of *Phragmites* marsh in this area is most likely due to stormwater runoff from adjacent properties, and it is likely that restoration grading will modify this drainage pattern. However, this needs to be confirmed with closer inspection in the field during construction, and if not the case, then minor additional grading should be sufficient to re-direct the freshwater inputs that appear to cause the *Phragmites* invasion.

Restoration of the area below the CSO outfall includes several treatments: (1) the stilling basin will be enlarged to prevent ongoing bank failure on the bank opposite the outfall, (2) the banks of the drainage channel will be graded to a shallower slope to decrease the risk of further erosion, and (3) the stilling basin and drainage channel will be rock-lined to prevent further scouring.

5.2 Area South of Wood Street

Because cleanup of the area south of the Wood Street Bridge will take place over a number of years, the restoration design for this area was developed to the conceptual level only. Unlike the area north of Wood Street, no dredging/excavation grading plans were available on which to base the restoration design. Rather, the restoration plan is based on the expected area and depth of dredging due to contamination levels (Figure 2) and on the overall plan described in the Final Excavation and Dredging BD/DAs (Foster Wheeler Environmental 2002b, 2002c). It is expected that as specific areas are targeted for construction, updated contamination data and actual dredging/excavation grading plans will be available on which to base final restoration designs for each wetland area.

The area south of Wood Street includes wetland areas 2, 3, 4, 5, and 6 on the eastern edge and wetland areas 7, 8, 9, 10, 11, and 12 on the western edge (Figure 10). The conceptual design specifies restoration of wetlands 3, 4, 6, and 9. Restoration treatments include filling and finish grading, stabilization, and planting. The following section describes these treatments generally, and Figure 15 graphically shows typical cross-sections with treatments. Later sections describe specific restoration activities and outcomes in each wetland area. Critical assumptions of the design are highlighted. Subsequent design work will need to revisit and validate these assumptions before proceeding.

5.2.1 Filling and Finish Grading

After dredging/excavation to remove contaminated sediment and soil, areas to be restored will be filled, compacted where necessary, and finish graded to the design elevation (Figure 15.1 and 15.2). As explained in earlier sections, in order to restore different intertidal habitat types, it is critical that precise final elevations as specified in the design are achieved. In addition, within each restored habitat type, the design slope is also critical in stabilizing the new surfaces, creating positive drainage, and ensuring natural tidal flushing needed to sustain saltmarsh vegetation. In restored mudflat areas, the slope of placed fill material (at time of placement) will be 1V:15H. In restored low and high marsh, the slope will be generally less than 1V:30H, except where habitat types transition and the slope may reach 1V:10H.

The conceptual design for these wetland areas specifies two types/sources of fill material: (1) overdredge material and (2) manufactured wetland topsoil mix. Unlike the planned restoration for the area north of Wood Street, subgrade fill will not be used. Overdredge material will be used as fill in impacted mudflat areas when the elevation of these areas is to be restored to existing mudflat elevations. This design assumes that overdredge material from below the contamination zone in the harbor subtidal will be available at the time and location of the restoration activity. If overdredge material is not available in sufficient quantity and at the needed location, mudflat restoration must be decreased in scope. The amount of mudflat that can be restored is directly related to the availability of overdredge material as fill.

Manufactured wetland topsoil mix (hereafter referred to as "topsoil") will be used as fill under several circumstances, and it will be a manufactured wetland soil mix from an offsite source. First, impacted areas in residential or beachcombing zones will be covered with at least 1 ft of topsoil to meet the confirmatory sampling plan (Figure 15.2). Second, topsoil will be placed where needed, if local depressions result from dredging/excavation, and if they cannot be eliminated by grading alone. Restoration grading should achieve positive drainage in the areas to be restored; therefore localized depressions need to be eliminated either by grading or filling with topsoil. Topsoil fill will also be used in impacted areas to be replanted with vegetation, if the existing subgrade (post dredging/excavation) is unsuitable for re-establishment of the target vegetation. However, in almost all cases it is anticipated that the existing subgrade will most likely be peat. This should provide a suitable substrate for re-establishment of vegetation, provided sufficient time is allowed between dredging/excavation and re-planting for the subgrade to acclimatize to its newly exposed position. It is expected that allowing the subgrade to overwinter will be sufficient to allow acclimatization; however, soil testing to confirm this before replanting is recommended. The suitability of the remaining subgrade, if exposed peat, will also depend on its thickness. Finally, topsoil and/or grading work will be required landward of fascine-stabilized mudflat/low marsh interfaces to level this area before placement of coir mattresses and replanting. This will prevent entrapment of water and should increase the establishment success of the new plants. Generally, impacted low marsh area is only restored to low marsh where fill is not required.

5.2.2 Stabilization

It is assumed that the area south of the Wood Street Bridge will be dredged/excavated and restored in the wet. Therefore appropriate erosion control measures will be needed during construction. It is also assumed that in any management unit, dredging/excavation, restoration filling and grading, and stabilization will take place during one construction season, and that restoration planting will take place in the following spring planting season. This will require measures to stabilize treated areas over the winter. Areas filled with topsoil will need to be temporarily stabilized with coir blankets to prevent loss of topsoil. (Note that it is assumed that the confirmatory sampling plan will require the immediate placement of topsoil in beachcombing and residential zones. If not required, it would be preferable to delay the placement of topsoil until the following spring, immediately before planting.) The coir

fascines, described below, that will stabilize the mudflat/low marsh and low marsh/high marsh interfaces, will suffice to stabilize these areas and prevent loss of fill material during the winter before restoration is completed.

In areas where mudflat and low marsh are to be restored through filling, the subtidal/mudflat and mudflat/low marsh interfaces will need to be stabilized (Figures 15.1 and 15.2). Without stabilization, placed fill material will be at risk of erosion. At the subtidal/mudflat interface, 20 inch diameter coir fascines will be secured in place. Because these fascines will be under water most of the time, they will not be planted with vegetation. The area landward of the interface will be filled with overdredge material to achieve appropriate mudflat elevations. At the mudflat/low marsh interface, 12 inch diameter coir fascines will be secured to stabilize that elevational transition. This will not only prevent loss of newly placed topsoil fill into the harbor, but it will also increase the chances of survival for plant material at this edge condition, as coir fascines are excellent planting substrates. In beachcombing and residential zones, these fascines will be placed during construction, because topsoil will be placed over the saltmarsh at that time. In non-beachcombing and non-residential areas, the fascines at the mudflat/low marsh interface (and the topsoil fill landward of the fascines) do not need to be placed until the following spring. In which case, coir blankets will not be required for protection over the winter.

5.2.3 Planting

Plant roots provide a significant stabilizing strength to intertidal sediments/soils. Plant aboveground growth decreases the erosive force of moving water and helps trap sediments and floating organic matter, which in turn promotes growth of vegetation. To protect the impacted intertidal from the physical forces present in the Upper Harbor, it is essential that vegetation become re-established as quickly as possible. The restoration design specifies planting of desired appropriate species in the 12 inch coir fascines that will stabilize the mudflat/low marsh interfaces, in pre-vegetated coir mattresses in low marsh areas, and with plugs, whole plants, and seed in low and high marsh areas (Figures 15.1 and 15.2). Specific planting seasons for recommended plant species are indicated in the specifications in the 100% design package for the area north of Wood Street.

If construction scheduling allows sufficient time for restoration planting to be completed before the end of the summer, every effort should be made to do so, instead of waiting until the following spring to plant. It is critical that planting be completed by September 1st to allow time for plants to establish before winter. If this is possible, then pre-vegetated coir fascines can be used and the coir blankets can be replaced with pre-vegetated coir mattresses. However, impacted low and high marsh areas that will not receive topsoil will need to overwinter before being planted in order to allow their exposed peat to acclimatize to aerobic conditions.

5.2.4 Impacted *Phragmites* Stands

In wetlands 2, 3, 4, 9, and 12, existing stands of *Phragmites* will be impacted by cleanup and excavated to varying depths. Diminishing the recolonization by *Phragmites* in these areas is desirable from the point of view of improving native plant and animal habitat in the Upper Harbor. Based on inspection of aerial photography, it appears that the existing stands of *Phragmites* occur where soils have been disturbed, and/or where stormwater runoff introduces freshwater inputs into the vegetated intertidal. In order to decrease the likelihood of recolonization, it is recommended that these areas be investigated in the field and possible point sources of stormwater runoff identified. Once identified, opportunities for source control, although out of the scope of the restoration plan, could be explored. If runoff sources cannot be reduced, consideration should be given to redirecting the stormwater away from the marsh vegetation through regrading and/or to promoting flushing by saltwater by installing salt concentration swales connected hydrologically to abutting low marsh and mudflat areas. In any case, excavated

Phragmites stands should not be filled, except in residential and beachcombing zones, where topsoil fill is required. Specific recommendations for each wetland are included below.

5.2.5 Wetland 2

Under the restoration plan, wetland 2 will not be restored (Figures 14.3, 16.1, and 17.1), except for a small stand of *Phragmites* marsh directly south of the Wood Street Bridge. This stand lies within a beachcombing zone and therefore after dredging/excavation, 1 ft of topsoil fill will be placed. The area will need to be protected with a coir blanket or hydroseeded, until the following spring when it can be planted as high marsh. Local inputs of freshwater at that location should be investigated to prevent the future recolonization of *Phragmites* at this location. The impacted low marsh is expected to return to low marsh vegetation on its own, because it will remain at an appropriate elevation for low marsh. Depending on how close the dredging will come to the armored shoreline, more of the existing low marsh may remain. Over 1.6 acres of mudflat will convert to subtidal (Figure 14.3)

The *Phragmites* marshes that occur at the boundary with wetland 3 are probably sustained by stormwater runoff from nearby roads and parking lots. The impacted stands of *Phragmites* marsh will likely be re-colonized by *Phragmites*, unless the freshwater inputs to these areas are managed.

5.2.6 Wetland 3

Wetland 3 is a priority area for restoration, and it provides opportunity to mitigate for loss of habitat in other wetland areas (Figures 14.4, 16.2, and 17.1). A dominant habitat type in this wetland is *Phragmites* marsh. More than half of the *Phragmites* marsh will be impacted, of which one half (1.35 acres) will be restored as high marsh and the remaining (1.35 acres) as low marsh (Figure 14.4). The presence of *Phragmites* may be in response to freshwater inputs, such as stormwater runoff, or promoted by disturbed soils. In some areas it is growing at the same elevation as high marsh species. It is not recommended that this species be replanted, but rather the freshwater inputs, if confirmed by field investigation, should be managed. If the source of stormwater runoff cannot be reduced, its input to the saltmarsh should be redirected. Where non-impacted *Phragmites* stands will border impacted and restored areas (restored to high marsh), the plan specifies a salt concentration swale landward of the restored area, between it and the bordering *Phragmites* stand, to promote flushing of saltwater into the area. This salt concentration swale would be connected to existing natural drainage features with a bottom elevation equal to approximately mid tide level (0.7 ft NGVD, which is 2 ft (0.6 m) above MLLW).

All of the impacted high marsh (with the exception of high marsh bordering intertidal creeks) will convert to low marsh elevation and be planted with low marsh vegetation (Figure 17.1). Most of the impacted low marsh will remain at a low marsh elevation and be restored with appropriate vegetation. However, a small area (0.1 acres) of low marsh will convert to mudflat elevation. Consequently there is a net increase (over existing) of over 2.5 acres of low marsh habitat (Figure 14.4).

Wetland 3 also contains several intertidal creeks and streams. These areas are characterized by steeply sloped banks. Three dimensional analysis of existing topography indicates slopes as high as 2V:1H are present along the banks. Altering creek channel morphology would alter both water and sediment delivery to local marsh areas. Therefore, it is recommended that natural creek morphologies and grades be emulated and maintained (Figure 15.3). Soil lifts wrapped in biodegradable material will be used to provide temporary stability along the bank, giving plants time to develop belowground root and rhizome networks, which would eventually stabilize the bank. This treatment avoids the loss of bank habitat associated with the installation of hardened revetments. As well, tidal creeks migrate over time due to the natural variability of hydrodynamic conditions. Hardened structures would result in static creek morphology that is unable to respond to such natural processes. Intertidal creeks and the high and low

marsh vegetation that surrounds them will be restored on a 1:1 basis. Therefore impacted high marsh in these areas will be restored to high marsh.

Almost all of the mudflat in wetland 3 will be impacted, but in this priority area the plan specifies complete mudflat restoration by placing a coir fascine at the subtidal/mudflat interface and backfilling the mudflat with overdredge material to mudflat elevation. The elevation of the restored mudflat will slope gradually in elevation from -1.5 feet to 0.5 feet, where it will transition into low marsh habitat.

There are opportunities in this wetland to create additional mudflat in the southern portion of wetland 3, by extending the mudflat westward into the harbor channel(Figure 16.2). This could be an area in which loss of mudflat in other areas could be mitigated.

5.2.7 Wetland 4

Wetland 4 contains the majority of the total wetland area delineated in the harbor. Similar to wetland 3, wetland 4 is a priority area for restoration, and it also provides opportunity to mitigate for loss of habitat in other wetland areas (Figures 14.5, 16.3, and 17.2). Most of the dredging and excavation activity in this area will occur in high and low marsh and its adjacent mudflat. Impacted high and low marsh may expose underlying peat and may not need to be backfilled for the successful re-establishment of marsh vegetation. Therefore, restoration activities in this area will be focused at the interface between mudflat and low marsh.

Three stands of *Phragmites* marsh in the Veranda Avenue Cove will be impacted. The northernmost stand will be restored to high marsh elevation and planted with high marsh vegetation. The other two stands lie in a residential zone, which requires the placement of 1 ft of topsoil. These areas will be replanted as high marsh. It is likely that all three *Phragmites* marsh stands are sustained by stormwater runoff. To protect the investment in high marsh planting, it is recommended that the possible sources of freshwater inputs be identified and managed. If the source of input cannot be decreased, it is recommended that the areas be graded to divert the freshwater inputs or a salt concentration swale could be incorporated into the final design.

Approximately 75% (6.4 acres) of the existing high marsh will be impacted, and as a consequence will convert to low marsh elevation and be planted with low marsh vegetation (Figure 14.5). Despite the restoration of impacted *Phragmites* marsh to high marsh, the area involved is quite small (0.06 acres), so that the overall change in high marsh to low marsh in wetland 4 is a net change of 6.4 acres. Restoration of the 6.4 acres back into high marsh would require approximately 10,000 CY of topsoil fill.

Approximately 75% of the existing low marsh will be impacted, of which most (5.0 acres) will remain at an appropriate elevation for low marsh and will be replanted as such. Some low marsh (1.2 acres) will convert to mudflat. These low marsh losses will be more than offset by the conversion of over 5 acres of high marsh to low marsh, resulting in a net gain of over 5 acres of low marsh in wetland 4.

All of the mudflat in wetland 4 will be restored, plus there will be an additional 1.2 acres of mudflat resulting from a conversion of low marsh to mudflat. There are opportunities to create additional mudflat along the edge of wetland 4, between the Veranda Avenue Cove and the border of wetland 3 (Figure 16.3). Approximately 5,000 CY of overdredge fill material would be required to create a new 20 ft wide band of mudflat along this approximately 4,000 linear ft edge (1.8 acres). Given that the design specifies fascines at the subtidal/mudflat interface, the marginal cost of placing these fascines further into the harbor and placing more overdredge to create additional mudflat is relatively low. Therefore this is a priority area for additional mudflat restoration if that is desired.

5.2.8 Wetland 5

Under the restoration plan, wetland 5 will not be restored (Figures 14.6, 16.4, and 17.2). Half of the low marsh in this wetland will be impacted (0.4 acres), and most of this low marsh (0.3 acres) will convert to mudflat (Figure 14.6). Most of the mudflat will be impacted (1.1 out of 1.8 acres), and most of this will convert to subtidal elevation, resulting in a net loss of mudflat in this wetland. However, sediments appear to accumulate naturally in this area on account of the Coggeshall Street Bridge and its effects on water circulation. Despite no restoration, it is likely that sediments will accumulate in this area over time, resulting in the eventual recovery of some mudflat area.

Under any potential future re-development of this site, it is recommended that moving the footprint of the building(s) and parking lot(s) away from the harbor's edge should be strongly considered (Figure 3). This would create opportunity to restore a continuous fringe of low marsh habitat along the entire border of wetland 5. Care would need to be taken to ensure that stormwater runoff does not drain directly to low marsh habitat. Alternatively, stormwater best management practices to promote infiltration of parking lot runoff could be installed as a buffer.

5.2.9 Wetland 6

Wetland 6 supports low marsh and mudflat habitat, both of which will be impacted by cleanup. Because several residential properties form the harbor's edge in this area, and because the area is in the residential and beachcombing zones, the impacted low marsh areas will be restored (Figure 14.7, 16.4, 17.3). All of the impacted low marsh will receive 1 ft of topsoil and will be restored as low marsh. About half of the impacted mudflat will be restored to mudflat. The remaining half will not be restored and will convert to subtidal.

5.2.10 Wetland 7

The Final Dredging and Excavation BD/DAs (Foster Wheeler Environmental 2002b, 2002c) do not include excavation or dredging in wetland 7. Therefore, no restoration is required in this wetland.

5.2.11 Wetland 8

The restoration plan specifies no restoration in this wetland. Of the impacted low marsh areas, about half (0.06 acres) will remain at a low marsh elevation (Figures 14.8, 16.4, and 17.3). It is anticipated that low marsh vegetation will gradually re-establish. The remaining impacted low marsh (0.06 acres) will convert to mudflat.

This wetland includes two "beach" areas with rocky, gravelly substrate. The zonation of habitats in this wetland, from harbor to upland, is subtidal, mudflat, beach, fringing low marsh, beach, and then upland. The portion of beach that lies between the upland and the fringing low marsh is anticipated to convert to low marsh. It is assumed that dredging/excavation of the rocky substrate will expose a more natural substrate that will be suitable for recolonization by low marsh plants. The beach that is seaward of the fringing low marsh is expected to convert to subtidal. Impacted mudflat will convert to subtidal, although a small amount (0.06 acres of the total 0.13 acres) of low marsh will convert to mudflat. Overall, no restoration in this wetland will result in loss of low marsh, beach and mudflat habitat.

5.2.12 Wetland 9

Wetland 9 is a restoration priority under the restoration plan (Figures 14.9, 16.5, and 17.4). Because it lies within the beachcombing zone, all impacted areas will receive 1 ft of topsoil fill. Most of the *Phragmites* marsh areas will not be impacted. A small area (0.09 acres) of impacted *Phragmites* marsh

will be restored to high marsh vegetation. All impacted high marsh will remain at a high marsh elevation and will be restored as such. In addition, about 0.2 acres of high marsh will be created from an impacted low marsh area that will receive 1 ft of fill. This will result in a slight net gain in high marsh habitat of 0.3 acres across the wetland. Most of the impacted low marsh will remain at a low marsh elevation and will be replanted with low marsh vegetation. All but 0.5 acres of the 5.4 impacted acres of mudflat will be restored. These 0.5 acres of "lost" mudflat will be restored to low marsh to make up for losses there. This will be achieved by placing the coir fascine at the low marsh/mudflat interface slightly seaward of the existing interface. Additional mudflat will be created seaward of the existing mudflat/subtidal interface to compensate.

There are additional opportunities in this wetland to create more mudflat by filling seaward with overdredge fill material (Figure 16.5). If this were to be done, it would be more cost-effective to prioritize those subtidal areas that require less dredging and hence would require less fill. There is also opportunity in this wetland to expand low and high marsh through additional filling of mudflat areas. This wetland, like wetland 12, has been impacted by extensive development over the centuries. The limited amount of existing high marsh relative to existing low marsh in this area is due to wetland loss associated with increased seaward development.

5.2.13 Wetland 10

The Final Dredging and Excavation BD/DAs (Foster Wheeler Environmental 2002b, 2002c) do not include excavation or dredging in wetland 10. Therefore, no restoration is required in this wetland.

5.2.14 Wetland 11

The Final Dredging and Excavation BD/DAs (Foster Wheeler Environmental 2002b, 2002c) do not include excavation or dredging in wetland 11. Therefore, no restoration is required in this wetland.

5.2.15 Wetland 12

No restoration is proposed for wetland 12, and there no residential/beachcombing areas that require 1 ft of topsoil fill (Figure 14.10, 16.6, and 17.4). The straight and armored western shoreline is the result of fill and development over the past three centuries. Typically, paved surfaces lead to the water's edge with only a narrow band of low marsh remaining, where greater marsh expanse historically existed. This area of the shoreline also has several CSOs discharging directly into the harbor, which may compromise any installed restoration elements. The soils below vegetated intertidal areas are a mix of marine-delivered sediment and rubble. Long-term stabilization needs, post-cleanup, are described in the Final Dredging and Excavation BD/DAs.

Approximately 1.3 acres of low marsh will be impacted, of which 0.3 acres will remain at low marsh elevation and likely recover as low marsh vegetation. The remaining 1.0 acres of low marsh will convert to mudflat. All of the impacted mudflat (4.4 acres) will convert to subtidal. Across the wetland, there will be a net loss of 1.0 acres of low marsh and 3.5 acres of mudflat. These 3.5 acres of "lost" mudflat represent the bulk of the 5.0 acre net loss of mudflat in the Upper Harbor.

There is some opportunity in wetland 12 to restore low marsh and mudflat by filling areas that received only shallow dredging. However, these areas of shallow excavation are not continuous (Figure 2), and restoration of these areas would result in fragmented areas of habitat with relatively low function and value.

Under potential future re-development of properties along wetland 12, pushing back the building and parking lot footprints should be strongly considered (Figure 3). This would provide opportunity to create

an upland border and bands of high and low marsh, or simply a wide band of continuous fringing low marsh by cutting back the existing shoreline. This would likely be more cost-effective and achieve greater ecological benefits than filling seaward to restore intertidal habitat. These measures would not only restore saltmarsh acreage, but also would provide much-needed water quality treatment for runoff, a potential greenway for public access, and an upland wildlife corridor.

5.3 Expected Net Result of Cleanup and Restoration over the Upper Harbor as a Whole

To estimate the expected net result of cleanup and restoration, habitat areas within each wetland must be closely tracked (Figure 14). Existing habitat in each wetland may or may not be impacted by dredging and excavation. The impacted habitat may or may not be restored, depending on the restoration plan for each wetland. Impacted habitat area that is not restored may remain as its original habitat type, or it may convert to a different (lower elevation) habitat type. Impacted area that is restored, may be restored to its original habitat type or may be restored to a different (lower elevation) habitat type. Table 14 shows existing area and anticipated final area after cleanup and restoration, within each wetland, taking into account habitat conversions with or without restoration (Figure 14). Figure 18 shows the post-restoration distribution of habitat types in plan view for the whole Upper Harbor.

Final conditions range from 32% of the original wetland area remaining in wetland 8 to 100% in wetland 9. Table 14 summarizes the percent of existing wetland area remaining as intertidal after cleanup and restoration. Across the Upper Harbor as a whole, 90% of the original extent of intertidal wetland area will remain as intertidal wetland.

Table 14. Final Area Remaining After Cleanup and Restoration, per Wetland Area.

Wetland Area	Habitat Type	Existing Area (acres)	Final Area After Cleanup and Restoration (acres)[1]	Percent of Existing Area Remaining as Intertidal After Cleanup and Restoration
Early Action Site[2]				
	Low Marsh	0.19	0.18	
	High Marsh	0.18	0.19	
	Creek	<0.01	<0.01	
	Subtotal Early Action	*0.37*	*0.37*	*100%*
Wetland Area 1				
	Phragmites Marsh	0.19	0.18	
	High Marsh	0.00	0.01	
	Low Marsh	0.19	0.19	
	Mudflat	1.44	0.24	
	Subtotal Wetland 1	*1.82*	*0.62*	*34%*
Wetland Area 2				
	Phragmites Marsh	0.03	0.01	
	High Marsh	0.00	0.02	
	Low Marsh	0.08	0.08	
	Mudflat	2.74	1.10	
	Subtotal Wetland 2	*2.85*	*1.21*	*43%*

Table 14 continued.

Wetland Area	Habitat Type	Existing Area (acres)	Final Area After Cleanup and Restoration (acres)[1]	Percent of Existing Area Remaining as Intertidal After Cleanup and Restoration
Wetland Area 3				
	Palustrine Forested	0.03	0.03	
	Palustrine Scrub/shrub	0.74	0.74	
	Palustrine Emergent	0.39	0.39	
	Phragmites Marsh	4.99	2.29	
	Scrub/shrub	0.35	0.03	
	High Marsh	2.14	1.88	
	Low Marsh	2.02	5.21	
	Beach	0.05	0.05	
	Creek	0.18	0.18	
	Mudflat	14.17	14.41	
	Subtotal Wetland 3	*25.06*	*25.20*	*100%*
Wetland Area 4				
	Phragmites Marsh	0.48	0.42	
	Scrub/shrub	11.22	10.17	
	High Marsh	18.53	12.69	
	Low Marsh	8.11	13.82	
	Beach	0.91	0.07	
	Creek	0.32	0.32	
	Mudflat	8.50	10.58	
	Subtotal Wetland 4	*48.07*	*48.06*	*100%*
Wetland Area 5				
	High Marsh	0.16	0.16	
	Low Marsh	0.71	0.50	
	Beach	0.15	0.06	
	Mudflat	1.78	1.06	
	Subtotal Wetland 5	*2.80*	*1.78*	*64%*
Wetland Area 6				
	Low Marsh	0.27	0.27	
	Mudflat	0.39	0.27	
	Subtotal Wetland 6	*0.66*	*0.54*	*82%*
Wetland Area 7[2]				
	Phragmites Marsh	0.30	0.30	
	Low Marsh	0.09	0.09	
	Beach	0.06	0.06	
	Creek	0.01	0.01	
	Mudflat	0.07	0.07	
	Subtotal Wetland 7	*0.53*	*0.53*	*100%*

Table 14 continued.

Wetland Area	Habitat Type	Existing Area (acres)	Final Area After Cleanup and Restoration (acres)[1]	Percent of Existing Area Remaining as Intertidal After Cleanup and Restoration
Wetland Area 8				
	Low Marsh	0.14	0.33	
	Beach	0.65	<0.00	
	Mudflat	0.50	0.09	
	Subtotal Wetland 8	*1.30*	*0.42*	*32%*
Wetland Area 9				
	Phragmites Marsh	0.30	0.21	
	Scrub/shrub	0.10	0.10	
	High Marsh	0.32	0.61	
	Low Marsh	1.76	2.06	
	Beach	0.11	0.11	
	Mudflat	5.52	5.02	
	Subtotal Wetland 9	*8.10*	*8.10*	*100%*
Wetland Area 10[3]				
	Palustrine Emergent	0.06	0.06	
	Subtotal Wetland 10	*0.06*	*0.06*	*100%*
Wetland Area 11[3]				
	Palustrine Emergent	0.04	0.04	
	Subtotal Wetland 11	*0.04*	*0.04*	*100%*
Wetland Area 12				
	Phragmites Marsh	0.04	0.04	
	Scrub/shrub	0.14	0.13	
	Low Marsh	2.29	1.41	
	Beach	0.12	0.06	
	Creek	0.01	0.01	
	Mudflat	6.67	3.18	
	Subtotal Wetland 12	*9.27*	*4.83*	*52%*
Wetland Area 13				
	Phragmites Marsh	0.17	<0.00	
	High Marsh	0.24	0.51	
	Low Marsh	0.21	0.22	
	Creek	0.08	0.08	
	Mudflat	1.58	0.18	
	Subtotal Wetland 13	*2.28*	*0.98*	*43%*
Total Area		**103.21**	**92.73**	**90%**

1 Final area includes (1) unimpacted areas, (2) impacted areas that have been restored, and (3) impacted areas that have not been restored.

2 Dredging and Excavation BD/DAs (Foster Wheeler Environmental 2002b, 2002c) do not specify additional cleanup in the Early Action Site and in wetland 7.

3 Wetlands 10 and 11 will not be impacted by cleanup.

A similar comparison of existing and final areas by habitat type shows that across the Upper Harbor as a whole, 97% of the vegetated intertidal and 81% of the unvegetated intertidal remains after cleanup and

restoration. The net loss of intertidal habitat is spread across all impacted habitat types, excluding low marsh and intertidal creeks. Under the restoration design, a net increase of 52% of low marsh area is expected. Table 15 summarizes the percentage of existing area that remains as intertidal after cleanup and restoration by habitat type.

Table 15. Existing Area and Final Area Remaining After Cleanup and Restoration per Habitat Type.

Habitat Type	Existing Area (acres)	Final Area After Cleanup and Restoration (acres)[1]	Percent of Existing Area Remaining as Intertidal After Cleanup and Restoration
Vegetated Intertidal			
Palustrine Forested[2]	0.03	0.03	100%
Palustrine Scrub/shrub[2]	0.74	0.74	100%
Palustrine Emergent Marsh[2]	0.49	0.49	100%
Phragmites Marsh	6.50	3.46	53%
Scrub/shrub	11.81	10.42	88%
High Marsh	21.57	16.05	74%
Low Marsh	16.06	24.35	152%
Subtotal vegetated	*57.20*	*55.54*	*97%*
Unvegetated Intertidal			
Beach	2.04	0.40	20%
Creek	0.60	0.60	100%
Mudflat	43.36	36.19	83%
Subtotal unvegetated	*46.01*	*37.19*	*81%*
Total Area	**103.21**	**92.73**	**90%**

1 Final area includes (1) unimpacted areas, (2) impacted areas that have been restored, and (3) impacted areas that have not been restored.
2 Not impacted by cleanup.

The net loss of high marsh will likely decrease the risk of *Phragmites* invasion of newly restored areas, because low marsh (which is the general result of impacts to high marsh) are less vulnerable to invasion by *Phragmites* and less suitable for its growth if it were to invade. In most cases, localized gains in high marsh area come from excavation of *Phragmites* marsh and its subsequent conversion/restoration to high marsh (wetlands 3, 4, 9 and 13) and from impacted low marsh in residential/beachcombing zones where 1 ft of topsoil fill will be placed (wetlands 9 and 13). Losses of high marsh result from conversion/restoration to low marsh (wetlands 3 and 4). Gains in low marsh are generally the result of conversion and/or restoration of high marsh to low marsh (wetlands 3 and 4), with some restoration of mudflat to low marsh in wetlands 9 and 13. Localized losses of low marsh result from conversion to mudflat (wetlands 3, 4, 5, 8, and 12). Loss of mudflat is in all cases from conversion to subtidal elevations (Figure 14).

5.4 Preliminary Cost Analysis

The preliminary cost estimate for the restoration plan for the area between the Wood Street and Coggeshall Street Bridges is $4.7 million, not including inflation. Across all four restored wetlands, approximately 9% of the costs are for topsoil and overdredge fill materials, 34% for stabilization measures (including creek restoration), and 10% for planting materials. The remaining 47% is for costs associated with access, mobilization, stormwater and pollution prevention, overhead, and contingency (20%). Stabilization costs, specifically the cost of coir fascines ($50 per linear foot), are sizable. Stone toes could be installed instead of coir fascines; however, the cost difference is not significant. The

difference in ecological benefits is high, however, because placement of stone toes effectively removes its footprint from contributing to the wetland's ecological structure and function. Given that cleanup and restoration will proceed over a number of years, it would be worthwhile to experiment early on with mudflat and low marsh restoration without the use of coir fascines to determine if there are any circumstances under which they can be omitted from the design and by which cost-savings can be achieved. In addition, because stabilizing the subtidal/mudflat and mudflat/low marsh interfaces is relatively costly, the marginal cost of expanding the mudflat area to be filled and restored in areas designated to receive fascines, is relatively low. In other words, given the relatively high cost of the fascines, it is worthwhile to place them so as to restore as broad a swath of mudflat as possible.

Table 16. Preliminary Cost Estimate of Restoration. Costs do not include inflation.

Wetland Area	**Percent of Existing Area Remaining as Intertidal After Cleanup and Restoration**	**Restoration Cost (in 000's)**
3	99%	$1,255
4	96%	$2,198
5	60	No Restoration
6	52%	$ 152
7	100%	No Impact
8	32%	No Restoration
9	100%	$1,143
10	100%	No Impact
11	100%	No Impact
12	51%	No Restoration
Total	**87%**	**$4,749**

5.5 Monitoring of Recovery of Impacted Intertidal Habitats

After the final restoration plan is developed, a monitoring plan should be developed to monitor progress towards restoration goals and targets. The basic elements of a monitoring plan are described in Appendix B.

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FIGURES

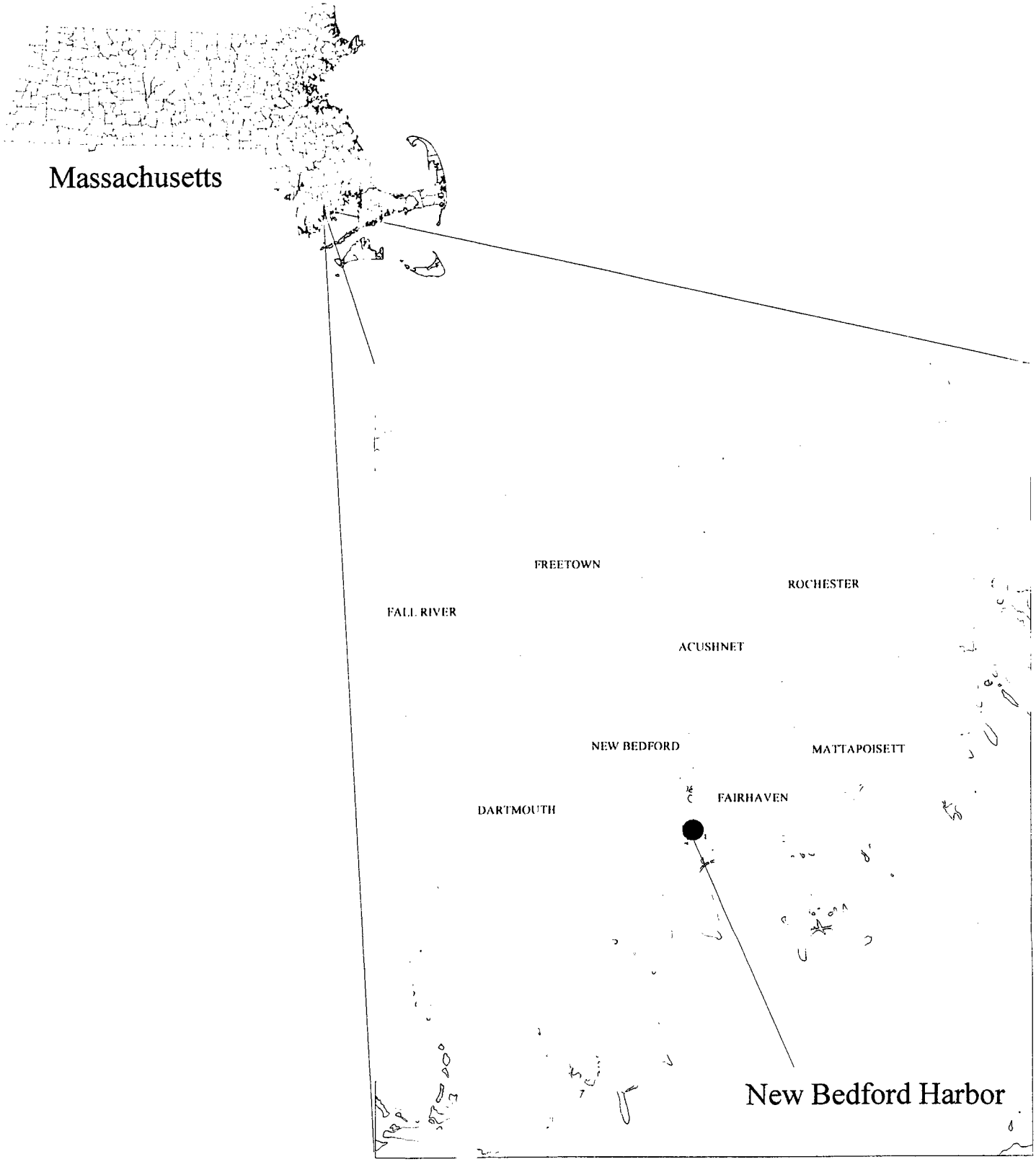

Figure 1

NEW BEDFORD HARBOR SUPERFUND SITE
Restoration Basis of Design/
Design Analysis Report
December 2002
New Bedford Harbor Locator Map

2 0 2 4 6 Miles

Base data supplied by the Massachusetts Executive Office of Environmental Affairs, MassGIS.

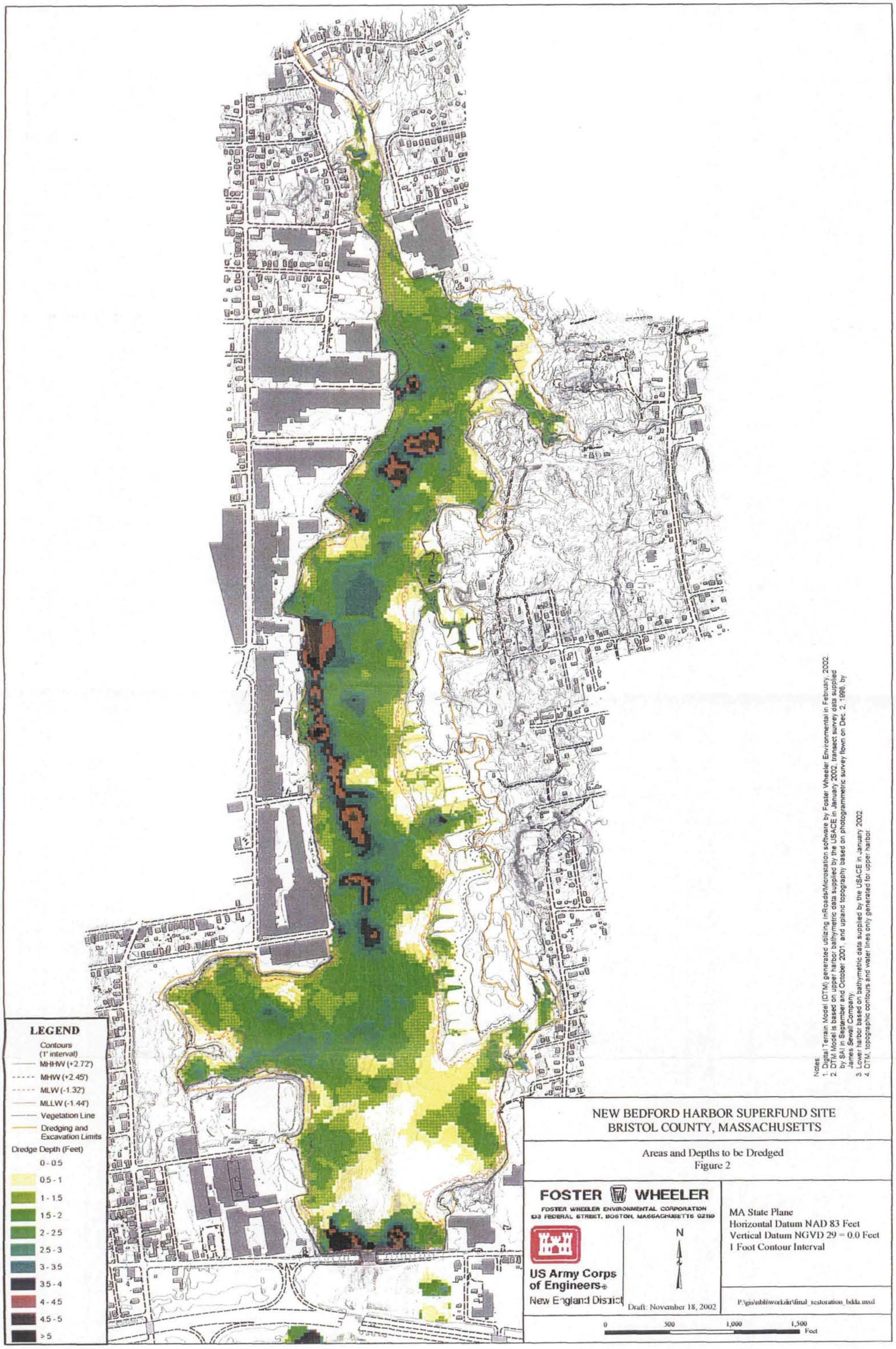
LEGEND
Contours (1' interval)
MHHW (+2.72')
MHW (+2.45')
MLW (-1.32')
MLLW (-1.44')
Vegetation Line
Dredging and Excavation Limits
Dredge Depth (Feet)
0 - 0.5
0.5 - 1
1 - 1.5
1.5 - 2
2 - 2.5
2.5 - 3
3 - 3.5
3.5 - 4
4 - 4.5
4.5 - 5
> 5
Notes:
1. Digital Terrain Model (DTM) generated utilizing InRoads/Microstation software by Foster Wheeler Environmental in February, 2002.
2. DTM Model is based on upper harbor bathymetric data supplied by the USACE in January 2002, transect survey data supplied by SAI in September and October 2001, and upland topography based on photogrammetric survey flown on Dec. 2, 1996, by James Sewall Company.
3. Lower harbor based on bathymetric data supplied by the USACE in January 2002.
4. DTM, topographic contours and water lines only generated for upper harbor.
NEW BEDFORD HARBOR SUPERFUND SITE
BRISTOL COUNTY, MASSACHUSETTS
Areas and Depths to be Dredged
Figure 2
FOSTER WHEELER
FOSTER WHEELER ENVIRONMENTAL CORPORATION
133 FEDERAL STREET, BOSTON, MASSACHUSETTS 02110
US Army Corps of Engineers
New England District
N
Draft: November 18, 2002
MA State Plane
Horizontal Datum NAD 83 Feet
Vertical Datum NGVD 29 = 0.0 Feet
1 Foot Contour Interval
P:\gis\nbh\workdir\final_restoration_bdda.mxd
0
500
1,000
1,500
Feet

Figure 3

NEW BEDFORD HARBOR SUPERFUND SITE

Restoration Basis of Design/
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December 2002

Place Names in Upper Harbor

0 500 1000 Feet

Digital New Bedford North and New Bedford South USGS 7.5 Minute Topographic Quadrangles produced by the Massachusetts Executive Office of Environmental Affairs, MassGIS.

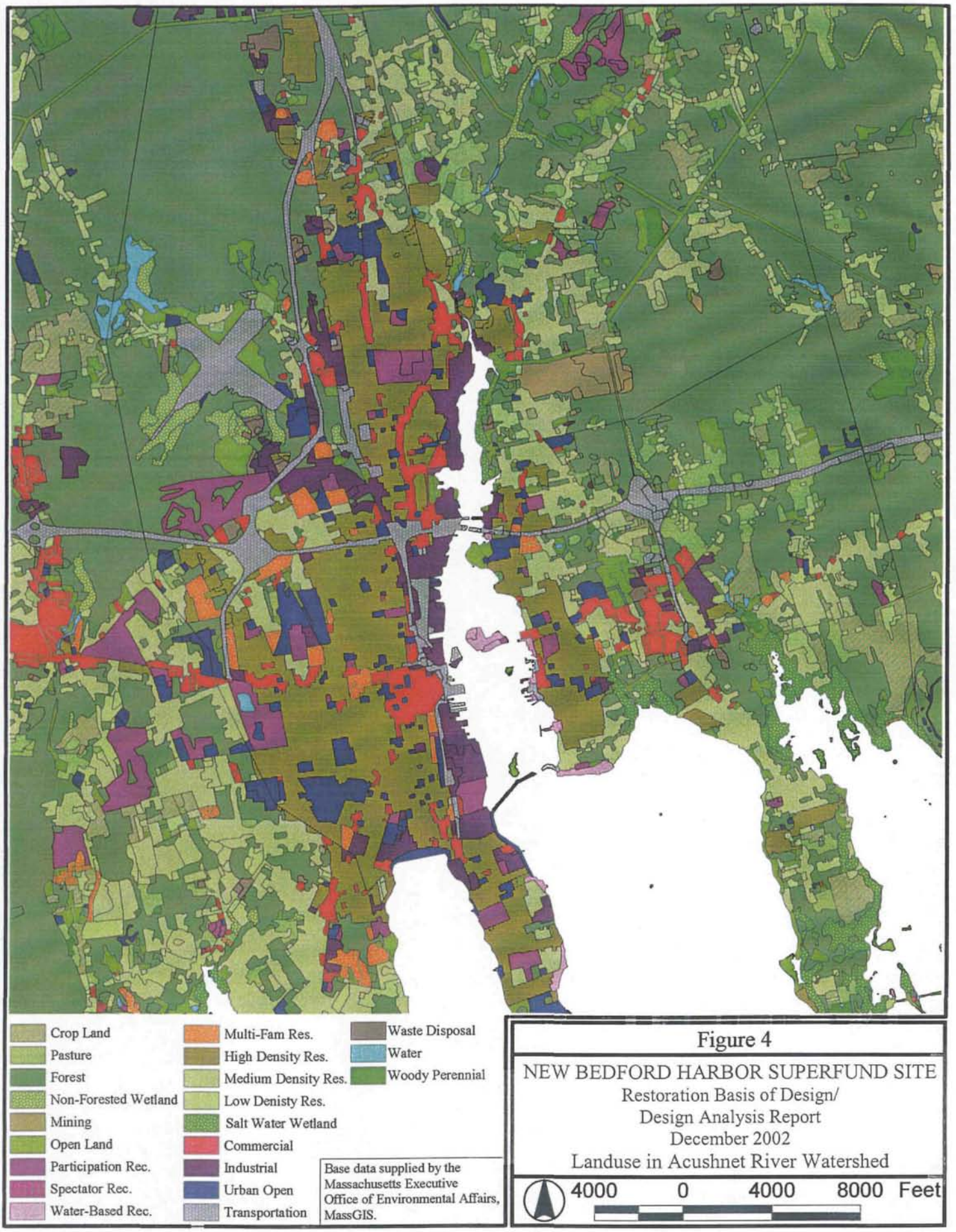
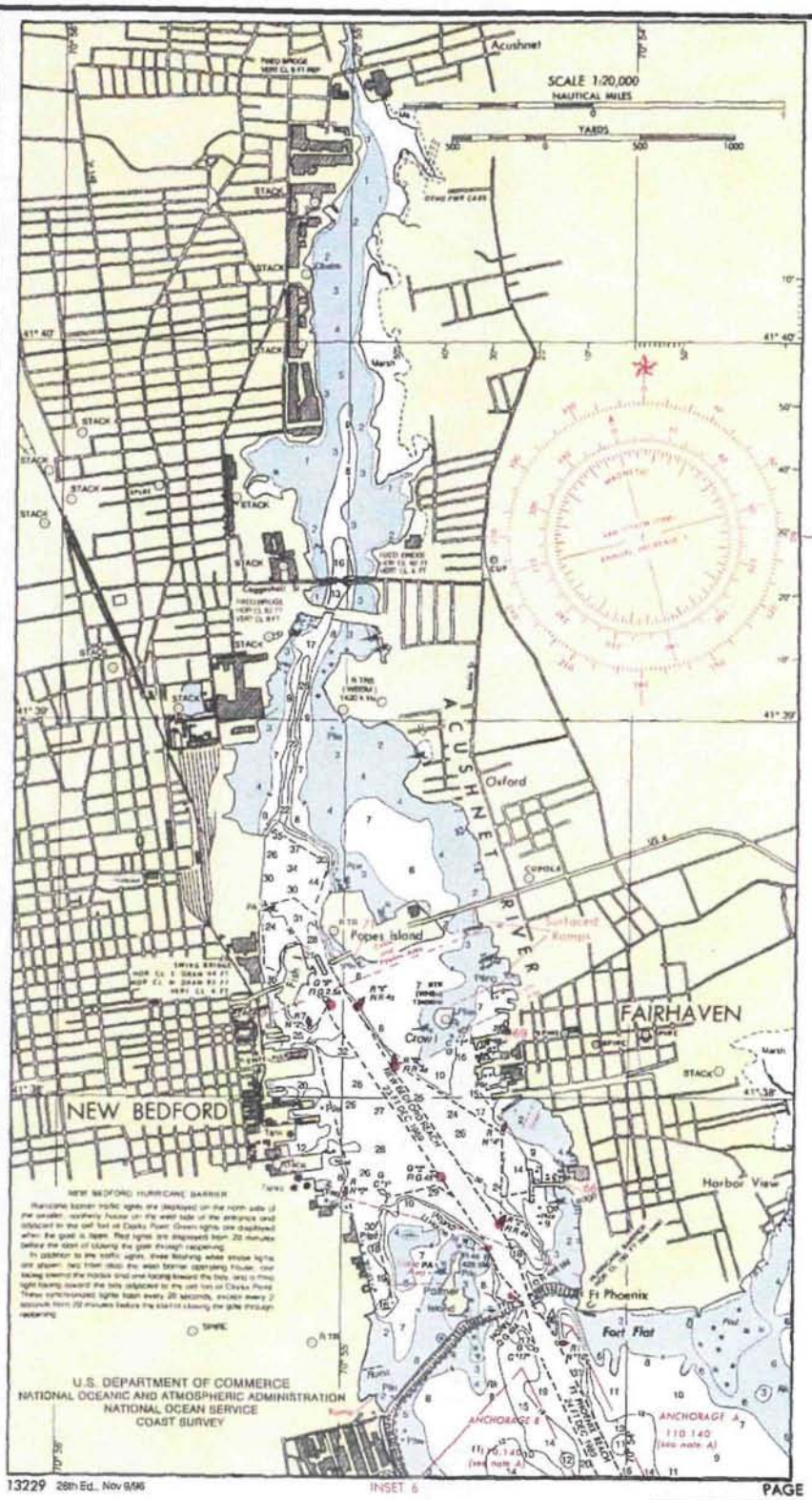


Figure 4

NEW BEDFORD HARBOR SUPERFUND SITE
Restoration Basis of Design/
Design Analysis Report
December 2002
Landuse in Acushnet River Watershed



CAUTION
SUBMARINE PIPELINES AND CABLES

Charted submarine pipelines and submarine cables and submarine pipeline and cable areas are shown as:

Pipeline Area Cable Area

Additional uncharted submarine pipelines and submarine cables may exist within the area of this chart. Not all submarine pipelines and submarine cables are required to be buried, and those that were originally buried may have become exposed. Mariners should use extreme caution when operating vessels in depths of water comparable to their draft in areas where pipelines and cables may exist, and when anchoring, dragging or trawling.

Covered wells may be marked by lighted or unlighted buoys.

CAUTION
CHANGES in BUOYAGE

Mariners are advised that authorized aids to navigation are being changed to conform to maritime standards of the International Association of Lighthouse Authorities Maritime Buoyage System, Region B. Significant changes are: Black port hand buoys in green; black and white vertically striped buoys to red and white vertically striped buoys; and lateral lights from white to red or green all approximate. Changes to aids to navigation will be announced in the Defense Mapping Agency's Hydrographic/Topographic Center weekly Notice to Mariners and the U.S. Coast Guard Local Notice to Mariners.

CAUTION
WARNINGS CONCERNING LARGE VESSELS

The "Rules of the Road" state that recreational boats shall not impede the passage of a vessel that can navigate only within a narrow channel or fairway. Large vessels may appear to move slowly due to their large size but actually transit at speeds in excess of 12 knots, requiring a great distance in which to maneuver or stop. A large vessel's superstructure may block the wind with the result that sailboats and sailboards may unexpectedly find themselves unable to maneuver. Bow and stern waves can be hazardous to small vessels. Large vessels may not be able to see small craft close to their bows.

RULES OF THE ROAD
(ABRIDGED)

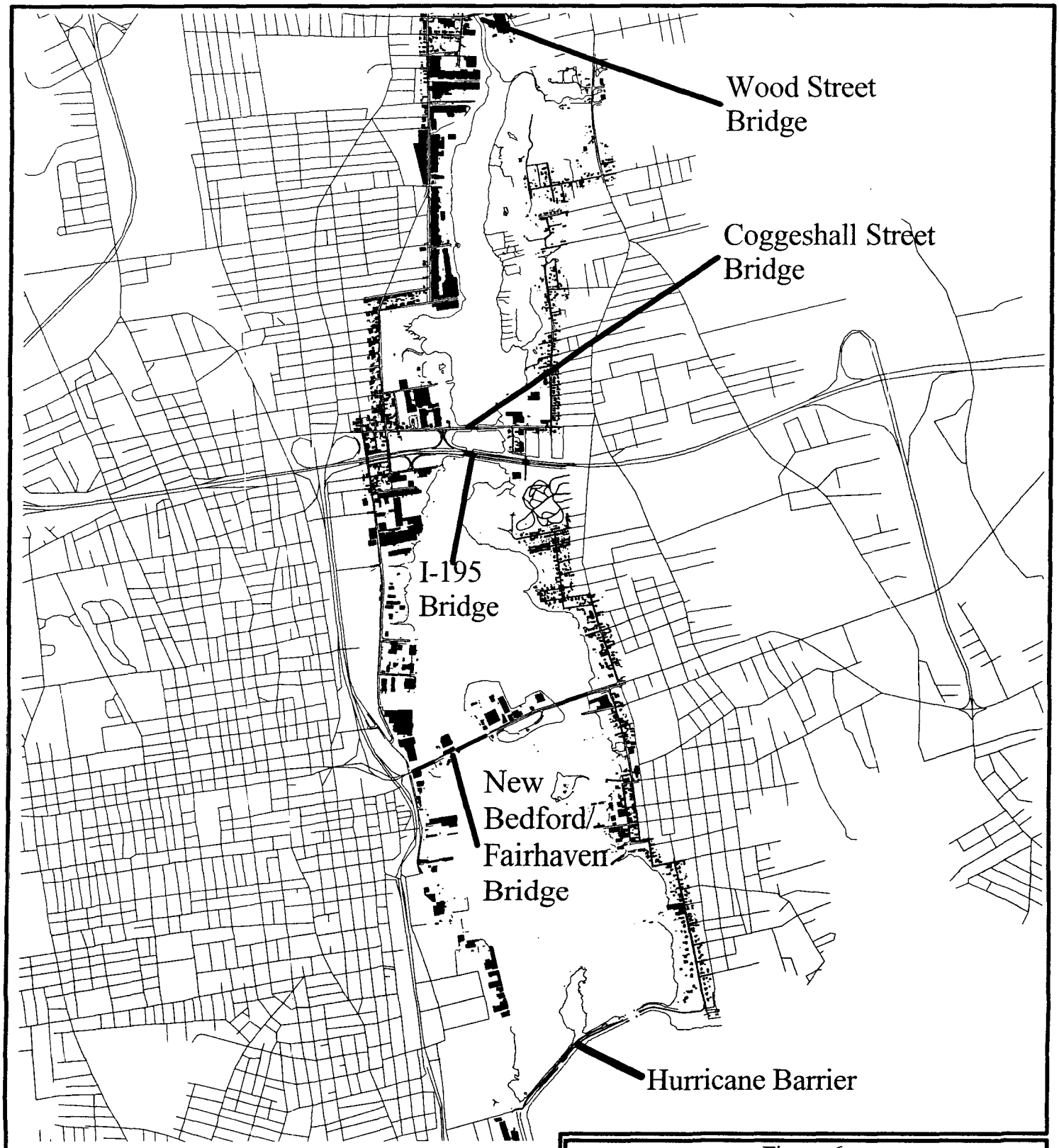
Motorless craft have the right-of-way in almost all cases.
Sailing vessels and motorboats less than sixty-five feet in length, shall not hamper, in a narrow channel, the safe passage of a vessel which can navigate only inside the channel.
A motorboat being overtaken has the right-of-way.
Motorboats approaching head to head or nearly so should pass port to port.
When motorboats approach each other at right angles or obliquely, the boat on the right has the right-of-way in most cases.
Motorboats must keep to the right in narrow channels, when safe and practicable.
Mariners are urged to become familiar with the complete text of the rules of the road in U.S. Coast Guard publication "Navigation Rules."

13229 26th Ed., Nov 9/96 INSET 6 PAGE G

Figure 5

NEW BEDFORD HARBOR SUPERFUND SITE
Restoration Basis of Design/
Design Analysis Report
December 2002
New Bedford Harbor Nautical Chart

2000 0 2000 4000 Feet

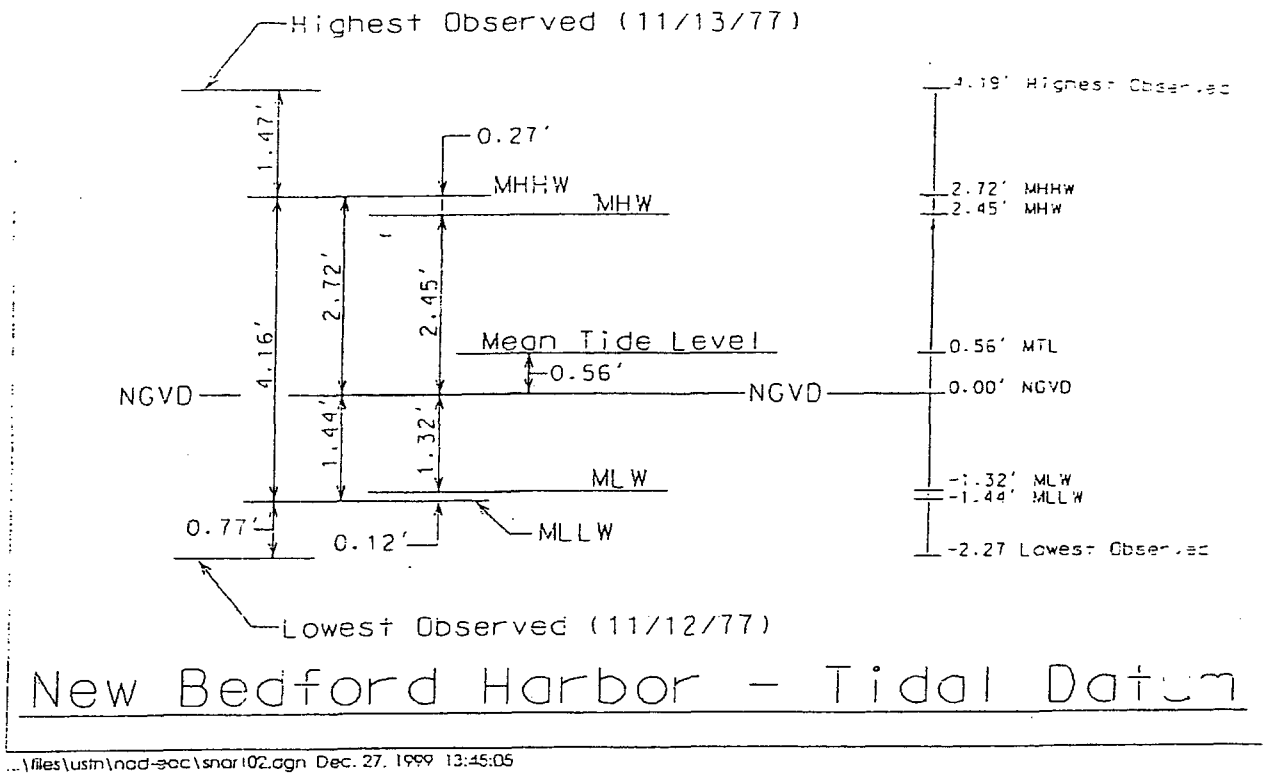


Based on data supplied by Foster Wheeler Environmental Corporation, September 2001.

Figure 6

NEW BEDFORD HARBOR SUPERFUND SITE
Restoration Basis of Design/
Design Analysis Report
December 2002
Bridges Spanning New Bedford Harbor

2000 0 2000 4000 Feet



..\files\usfn\nad-sac\snar102.dgn Dec. 27, 1999 13:45:05

USACE CONTRACT NO. DACW33-94-D-0002
TOTAL ENVIRONMENTAL RESTORATION CONTRACT
TASK ORDER NO.0017 - NEW BEDFORD HARBOR SUPERFUND SITE
NEW ENGLAND TIDAL REFERENCE - ELEVATIONS FOR NEW BEDFORD HARBOR

Figure 7

NEW BEDFORD HARBOR SUPERFUND SITE
Restoration Basis of Design/
Design Analysis Report
December 2002
New Bedford Harbor Tidal Datums

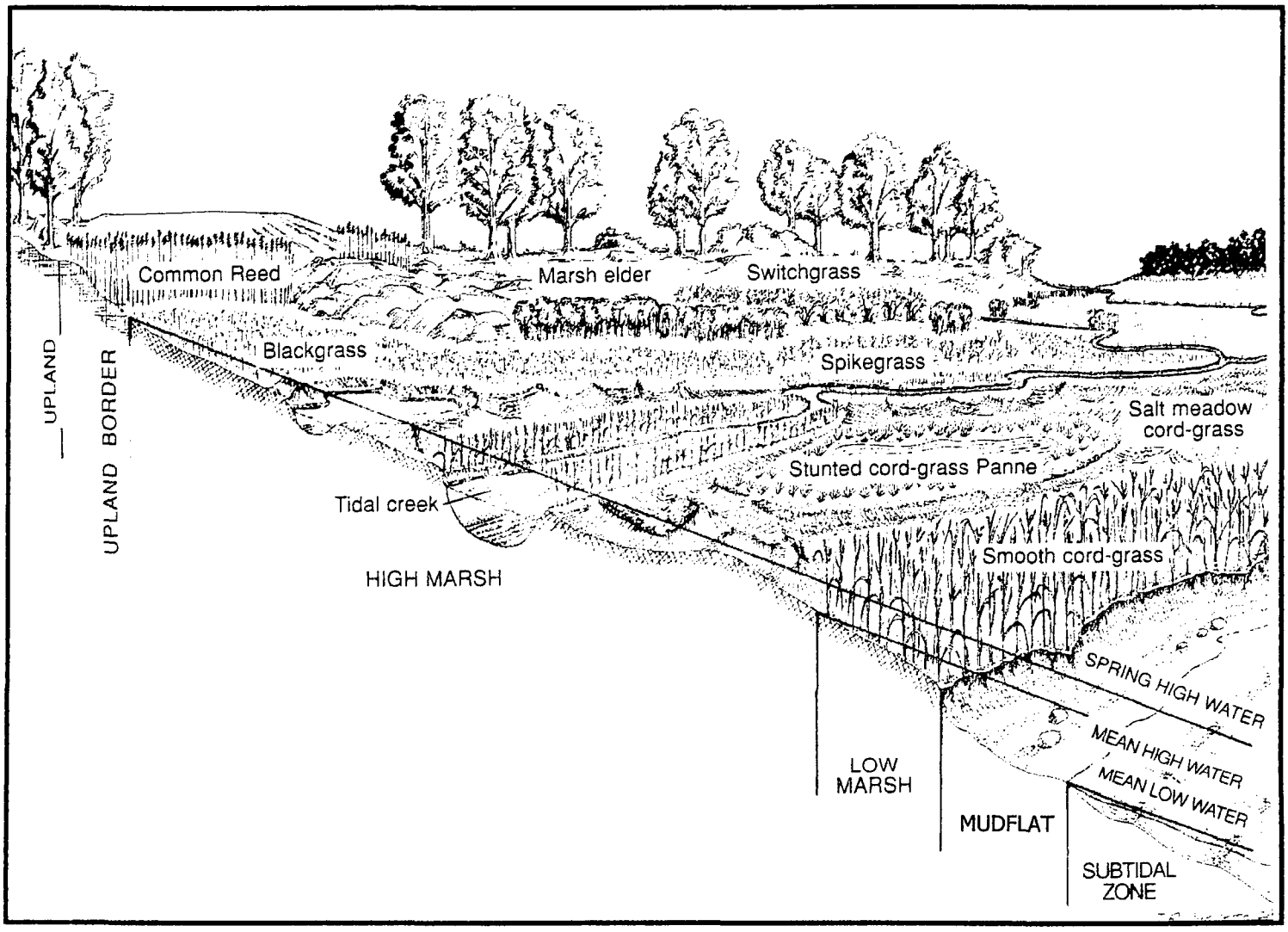
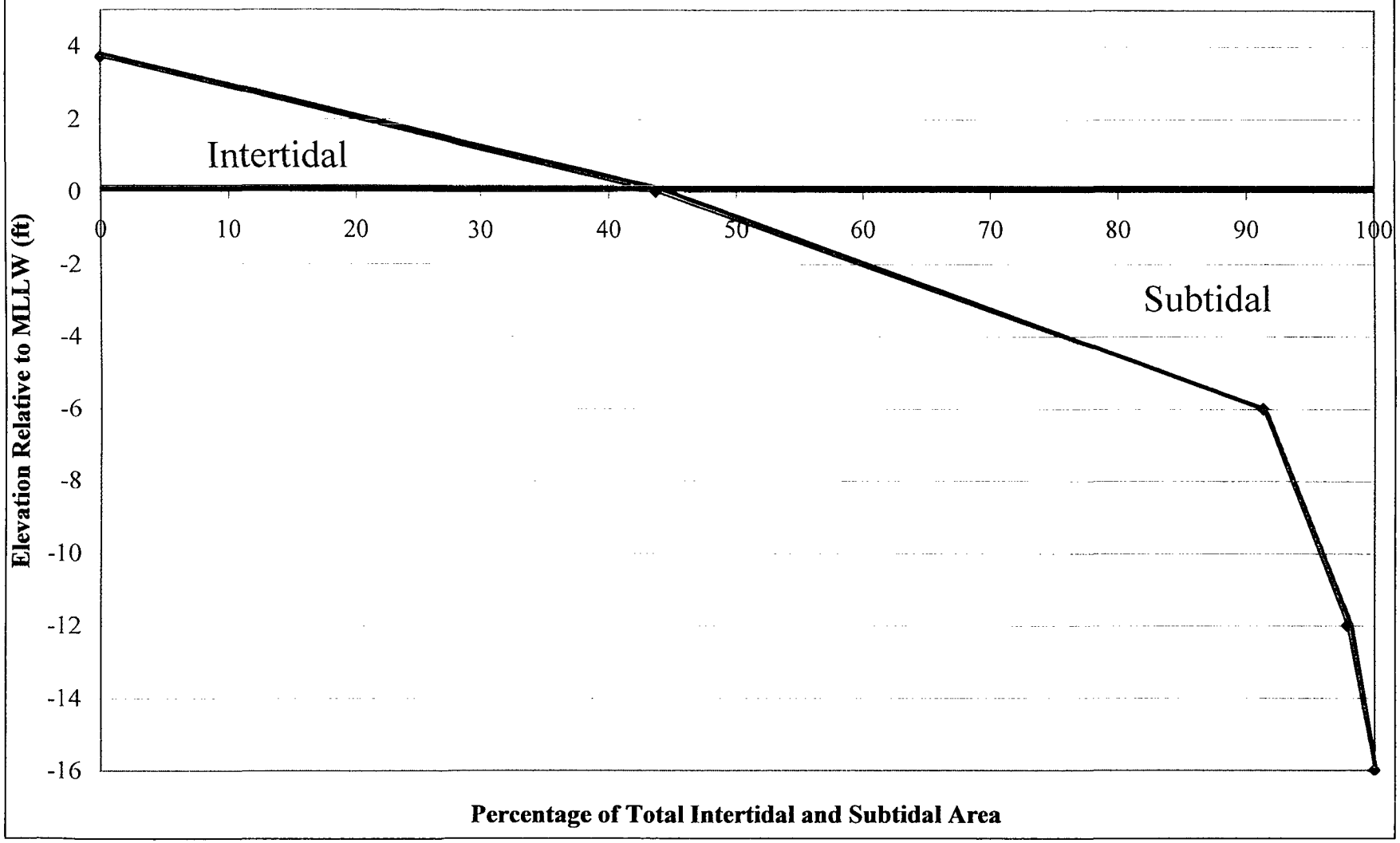


Figure 8

NEW BEDFORD HARBOR SUPERFUND SITE
Restoration Basis of Design/
Design Analysis Report
December 2002
Graphic Representation of a Typical
New England Intertidal Wetland Profile

Figure 9. Depth Distribution North of I-195



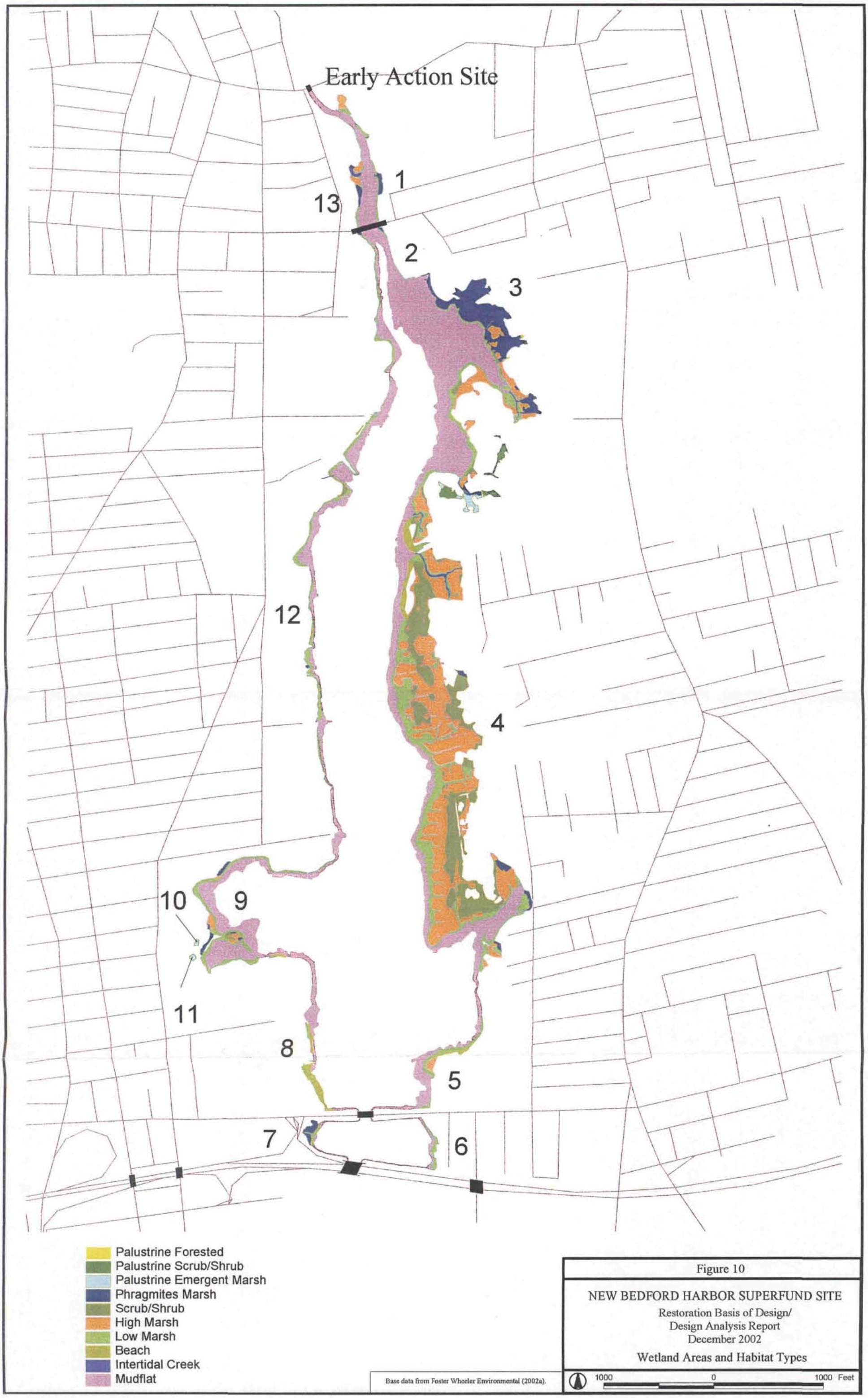


Figure 10

NEW BEDFORD HARBOR SUPERFUND SITE

Restoration Basis of Design/
Design Analysis Report
December 2002

Wetland Areas and Habitat Types

Figure 11. Frequency of Functions and Values

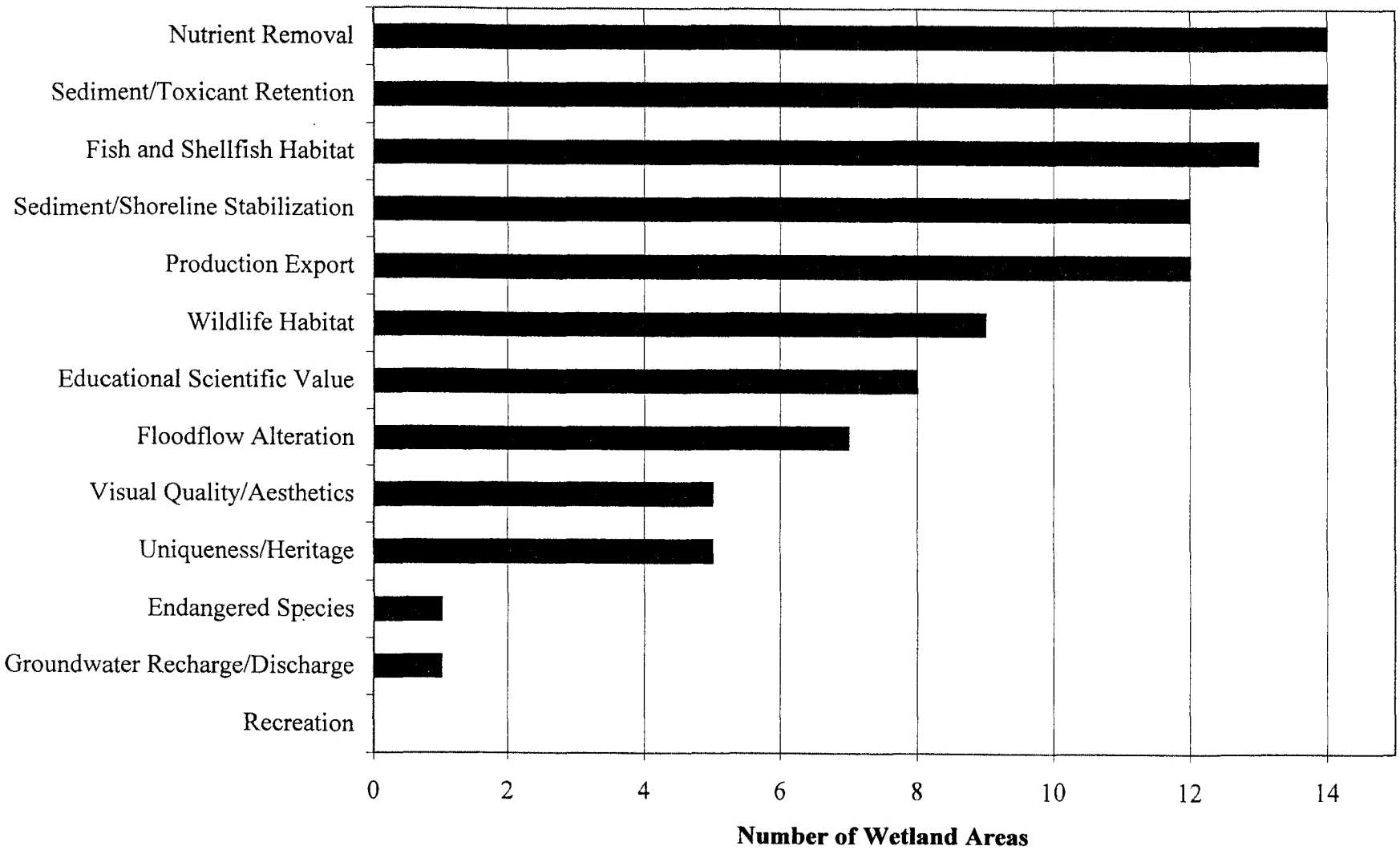
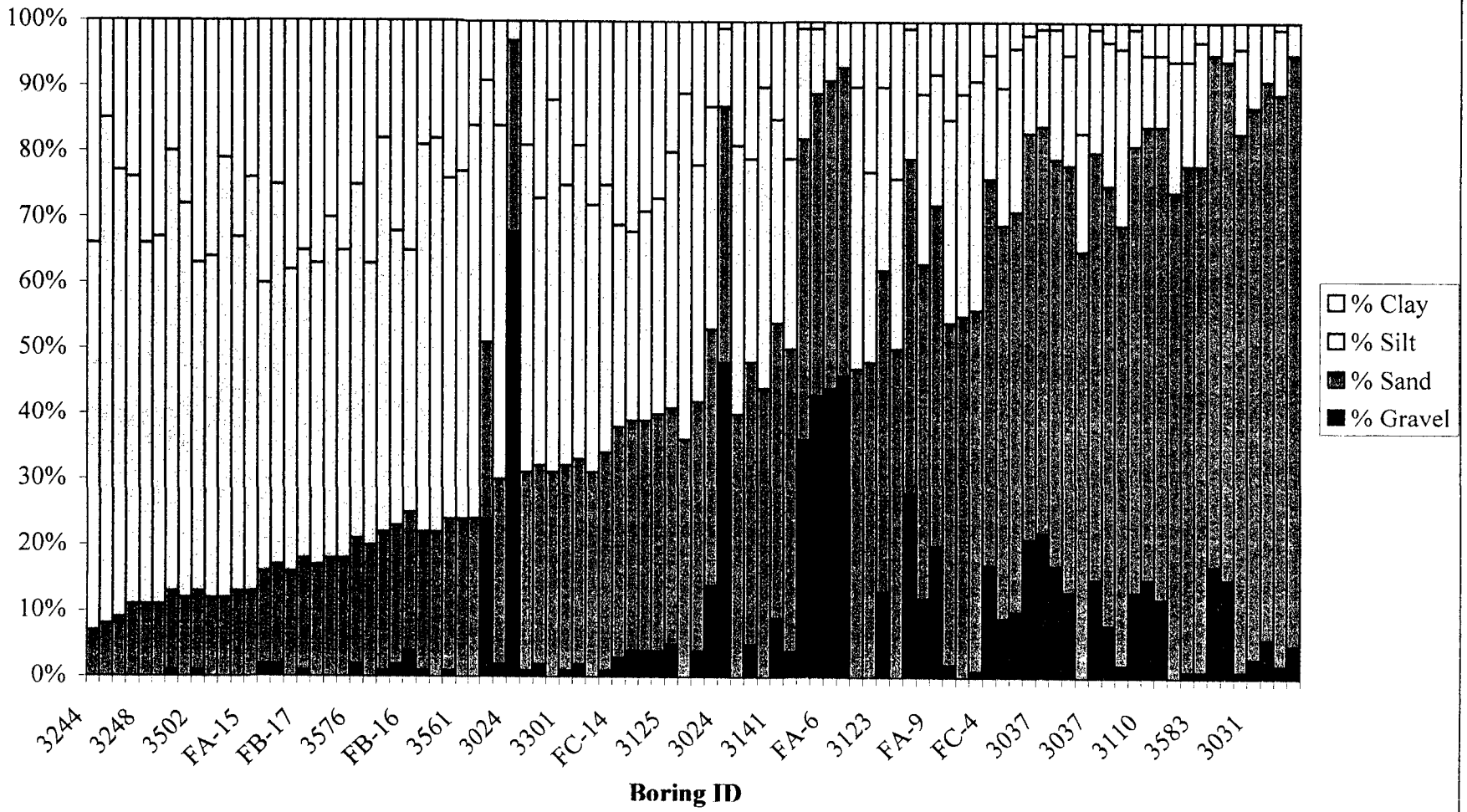
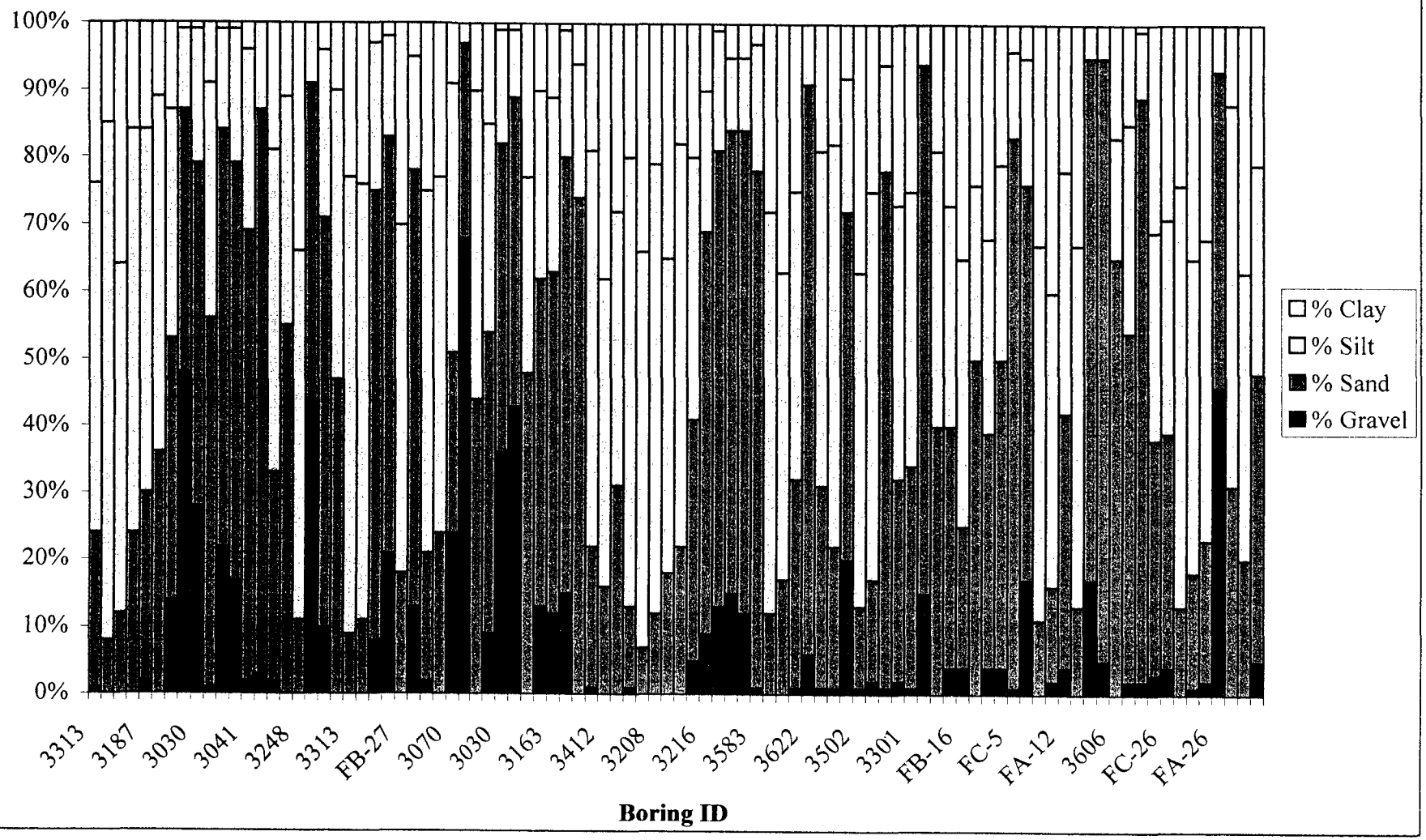


Figure 12. Sediment Grain Size Analysis of Subtidal and Non-Vegetated Intertidal Habitats



Note All Boring Identification Numbers Could Not Be Displayed On X-axis. Artificial Trend Created By Arranging Data By % Sand.

Figure 13. Grain Size Distribution Shallow to Deep Subsurface Samples



Note All Boring Identification Numbers Could Not Be Displayed On The X-axis. Borings Arranged By Sample Bottom Depth.

Figure 14.1. "Fate" of Impacted Areas (in acres) in Wetland 1. Figure shows conversions of habitat types due to impacts and restoration treatments, where applied.

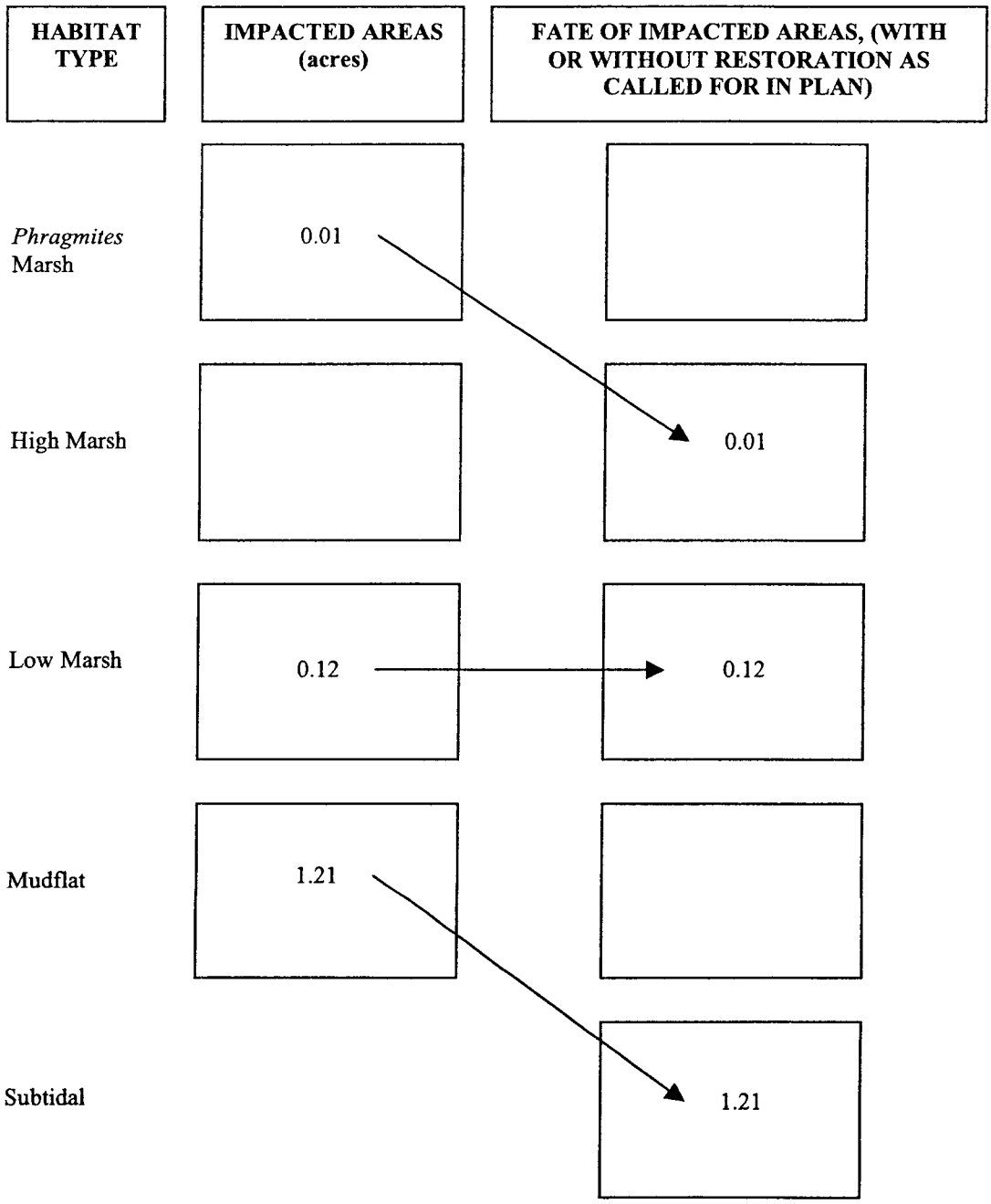


Figure 14.2. "Fate" of Impacted Areas (in acres) in Wetland 13. Figure shows conversions of habitat types due to impacts and restoration treatments, where applied.

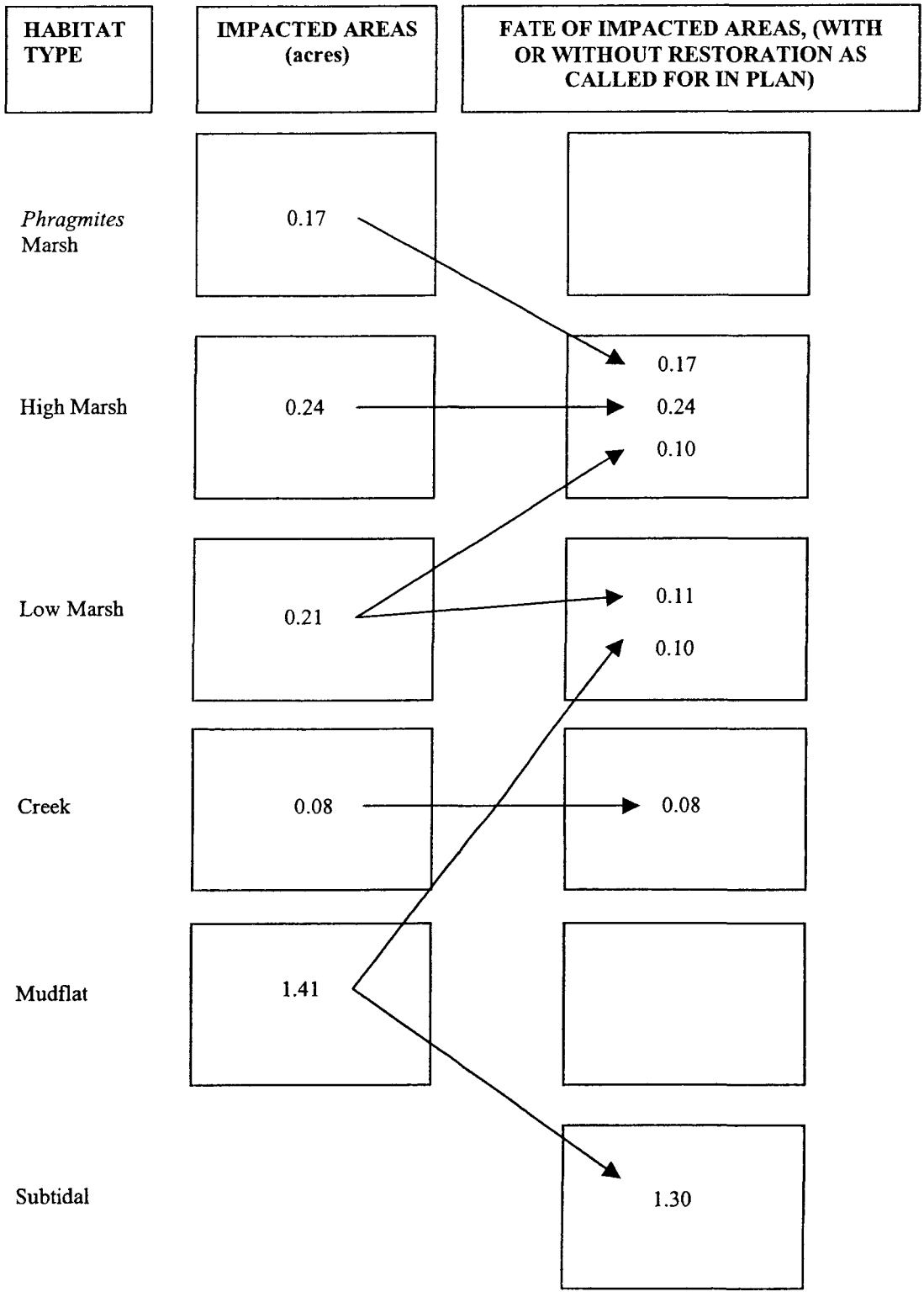


Figure 14.3. "Fate" of Impacted Areas (in acres) in Wetland 2. Figure shows conversions of habitat types due to impacts and restoration treatments, where applied.

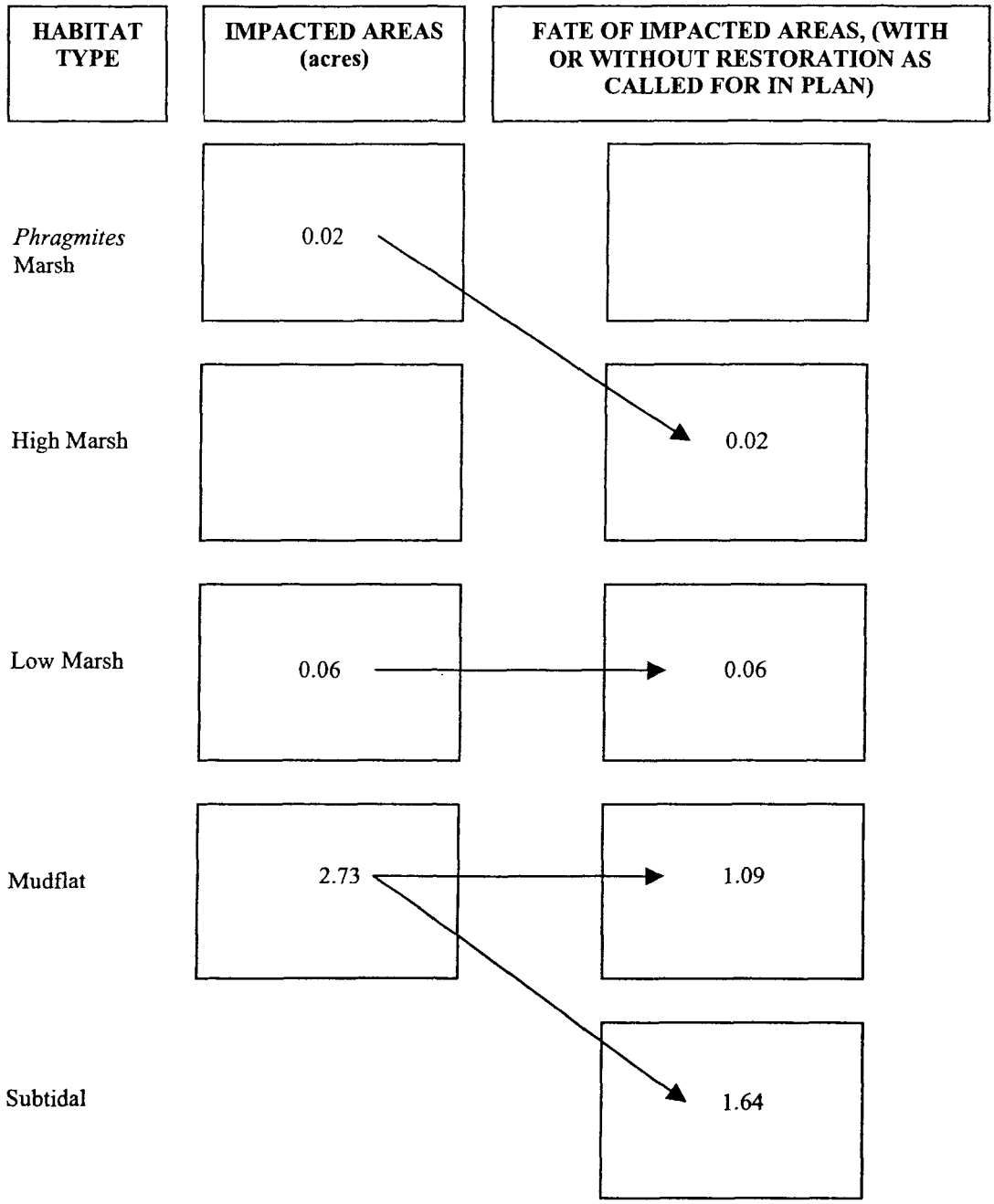


Figure 14.4. "Fate" of Impacted Areas (in acres) in Wetland 3. Figure shows conversions of habitat types due to impacts and restoration treatments, where applied.

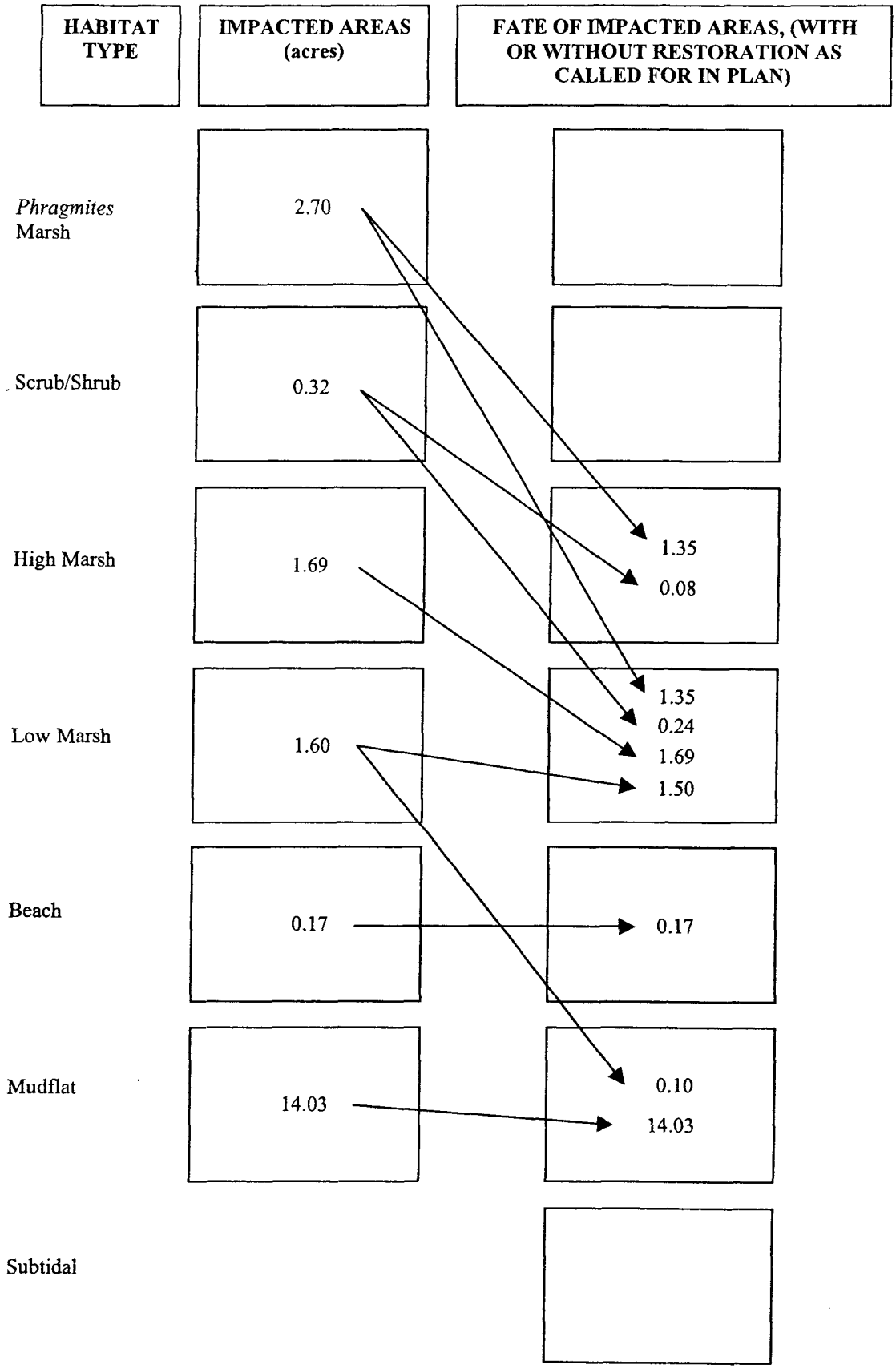


Figure 14.5. "Fate" of Impacted Areas (in acres) in Wetland 4. Figure shows conversions of habitat types due to impacts and restoration treatments, where applied.

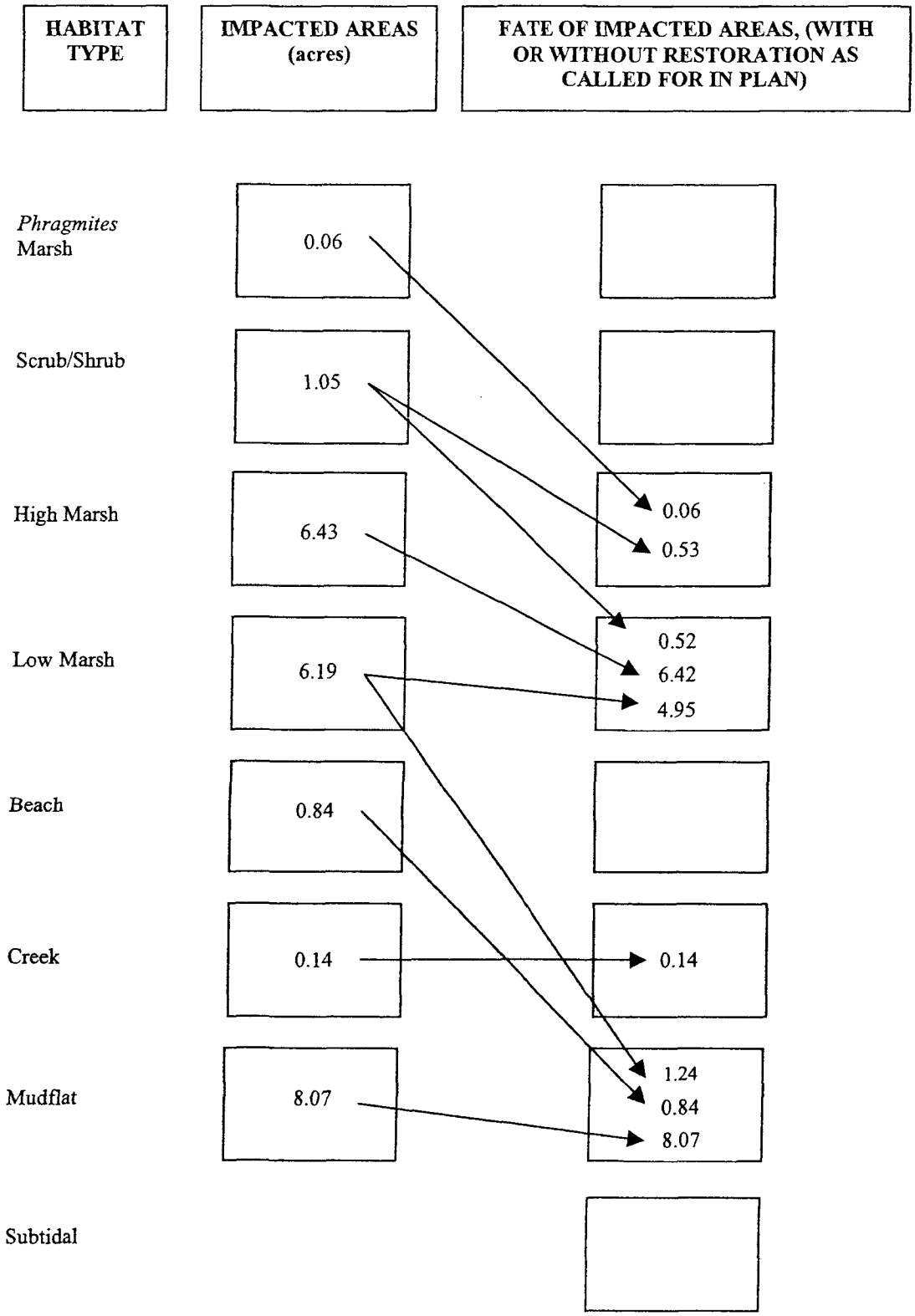


Figure 14.6. "Fate" of Impacted Areas (in acres) in Wetland 5. Figure shows conversions of habitat types due to impacts and restoration treatments, where applied.

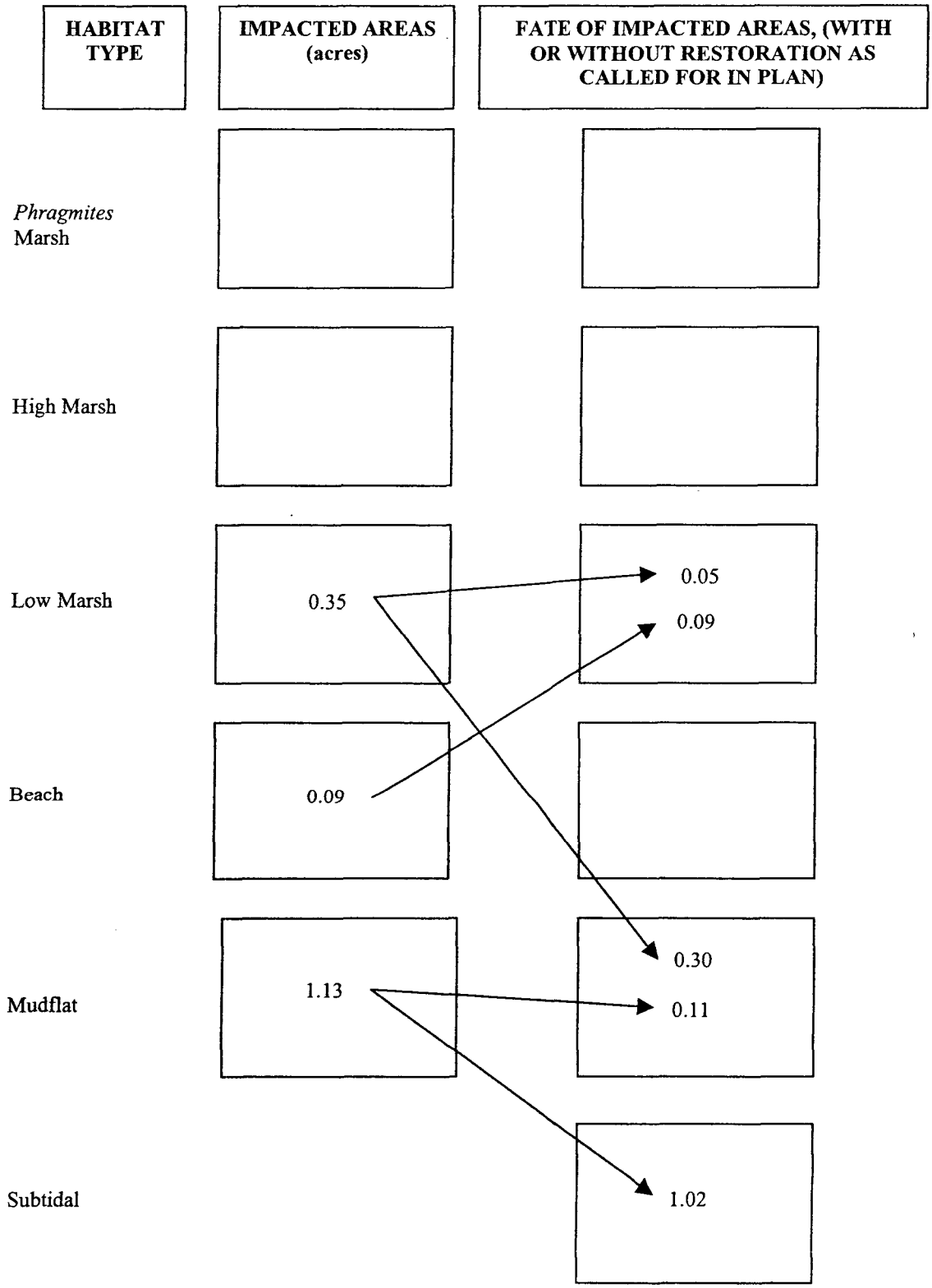


Figure 14.7. "Fate" of Impacted Areas (in acres) in Wetland 6. Figure shows conversions of habitat types due to impacts and restoration treatments, where applied.

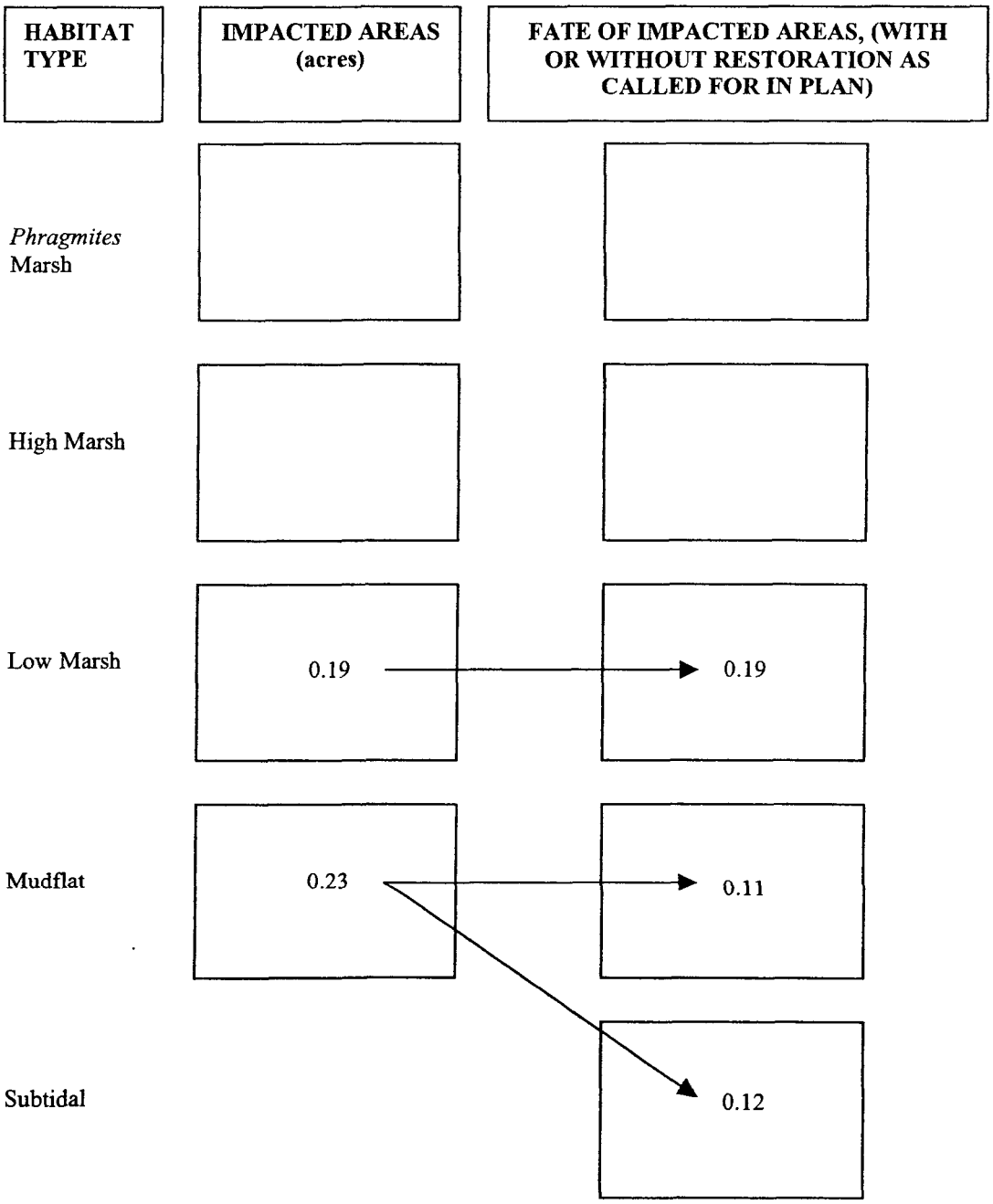


Figure 14.8. "Fate" of Impacted Areas (in acres) in Wetland 8. Figure shows conversions of habitat types due to impacts and restoration treatments, where applied.

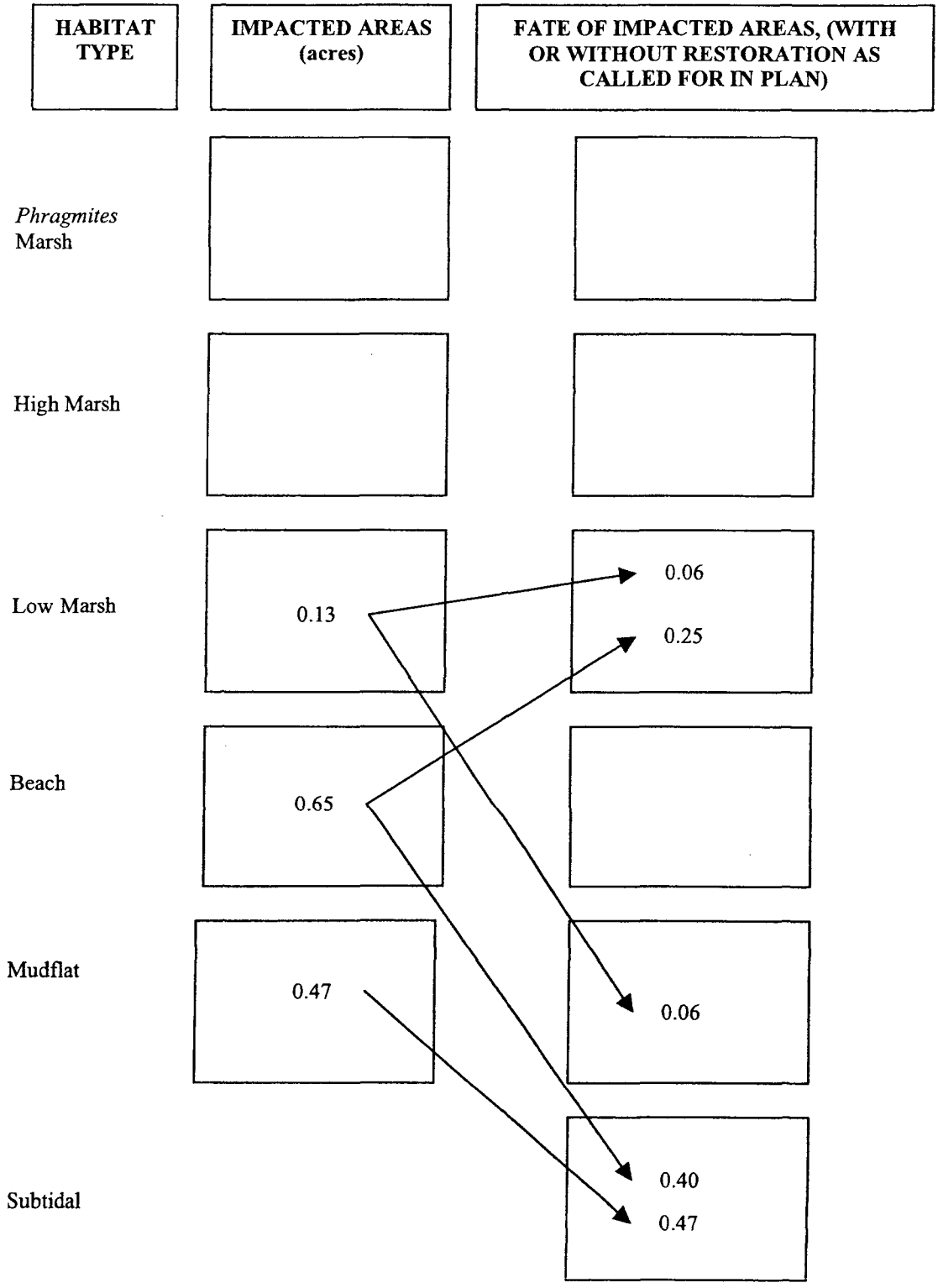


Figure 14.9. "Fate" of Impacted Areas (in acres) in Wetland 9. Figure shows conversions of habitat types due to impacts and restoration treatments, where applied.

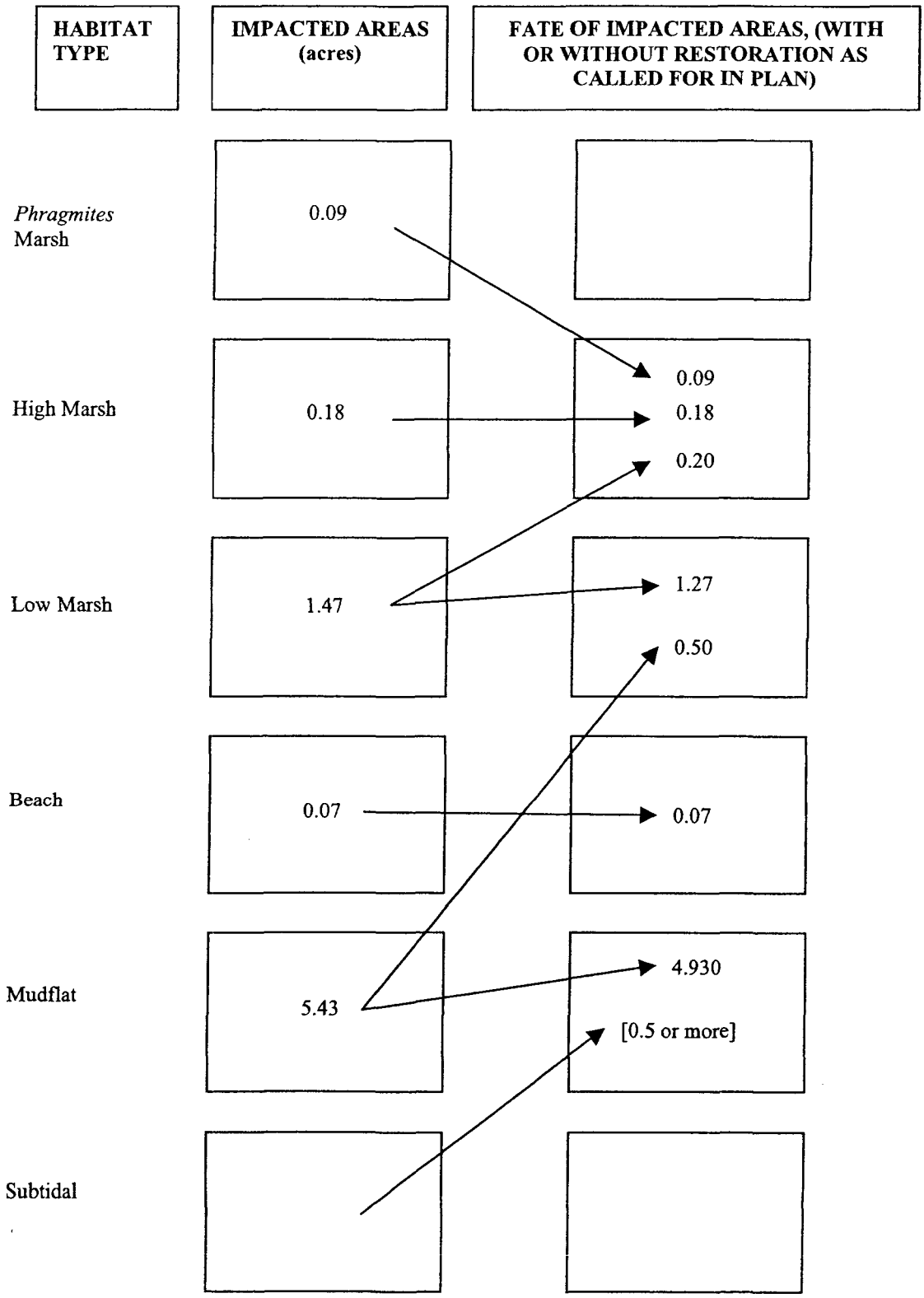
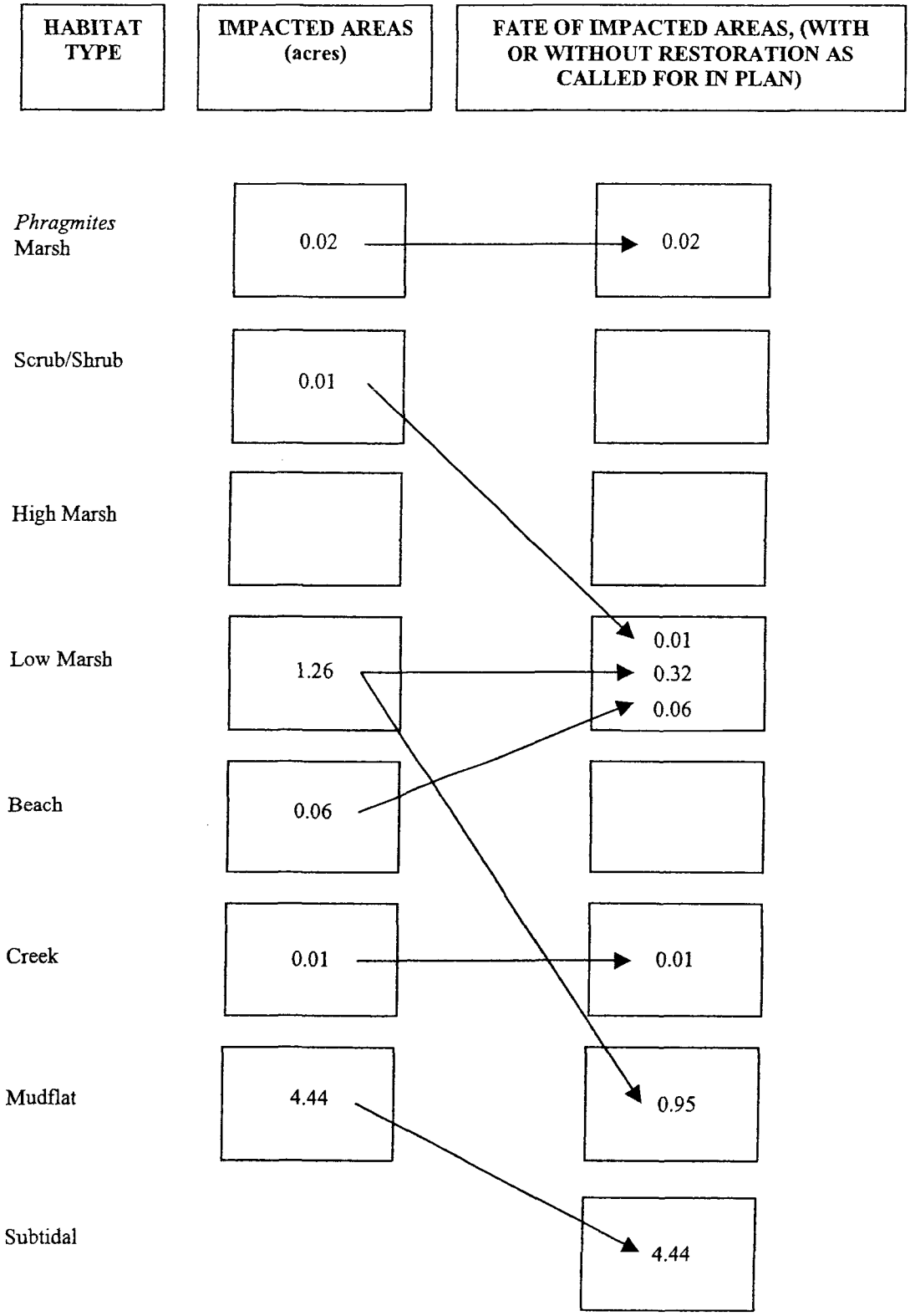
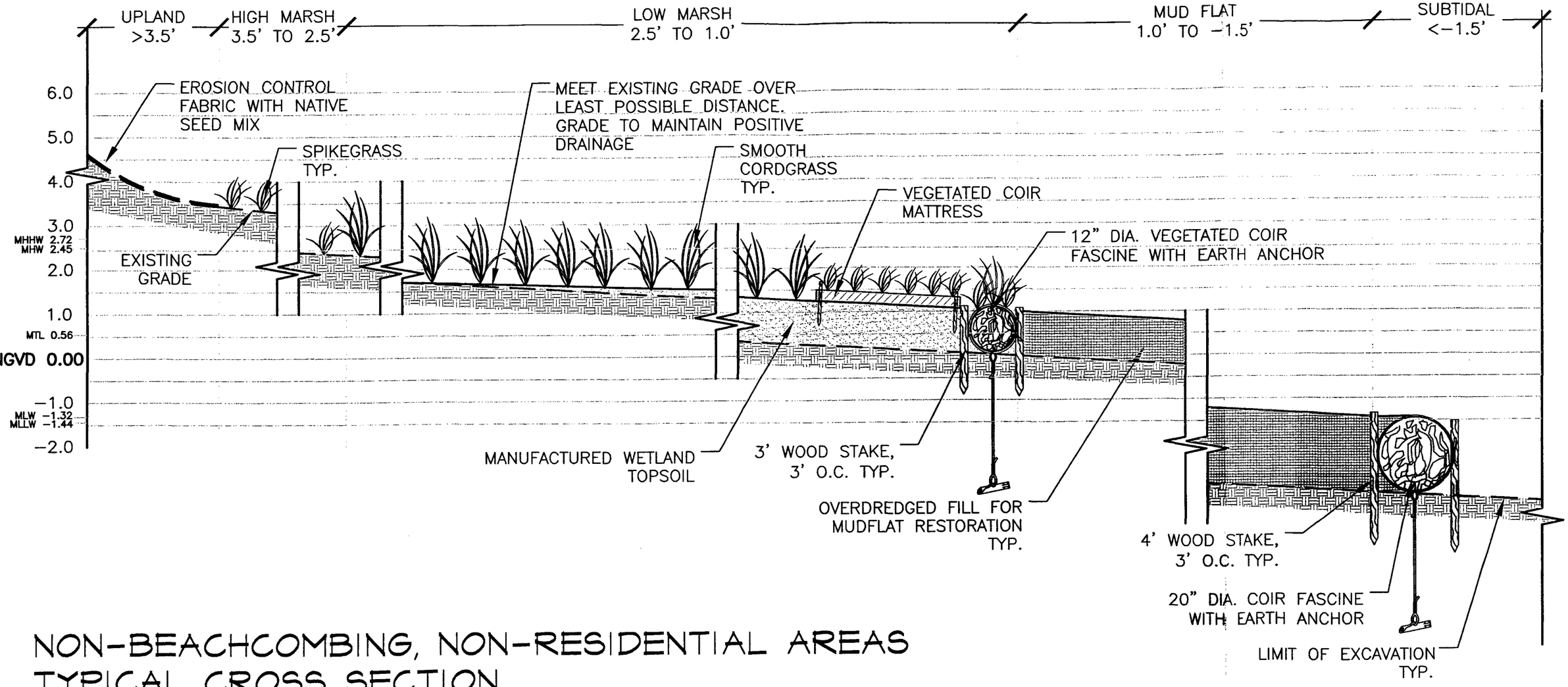


Figure 14.10. "Fate" of Impacted Areas (in acres) in Wetland 12. Figure shows conversions of habitat types due to impacts and restoration treatments, where applied.





NON-BEACHCOMBING, NON-RESIDENTIAL AREAS TYPICAL CROSS SECTION

NOT TO SCALE

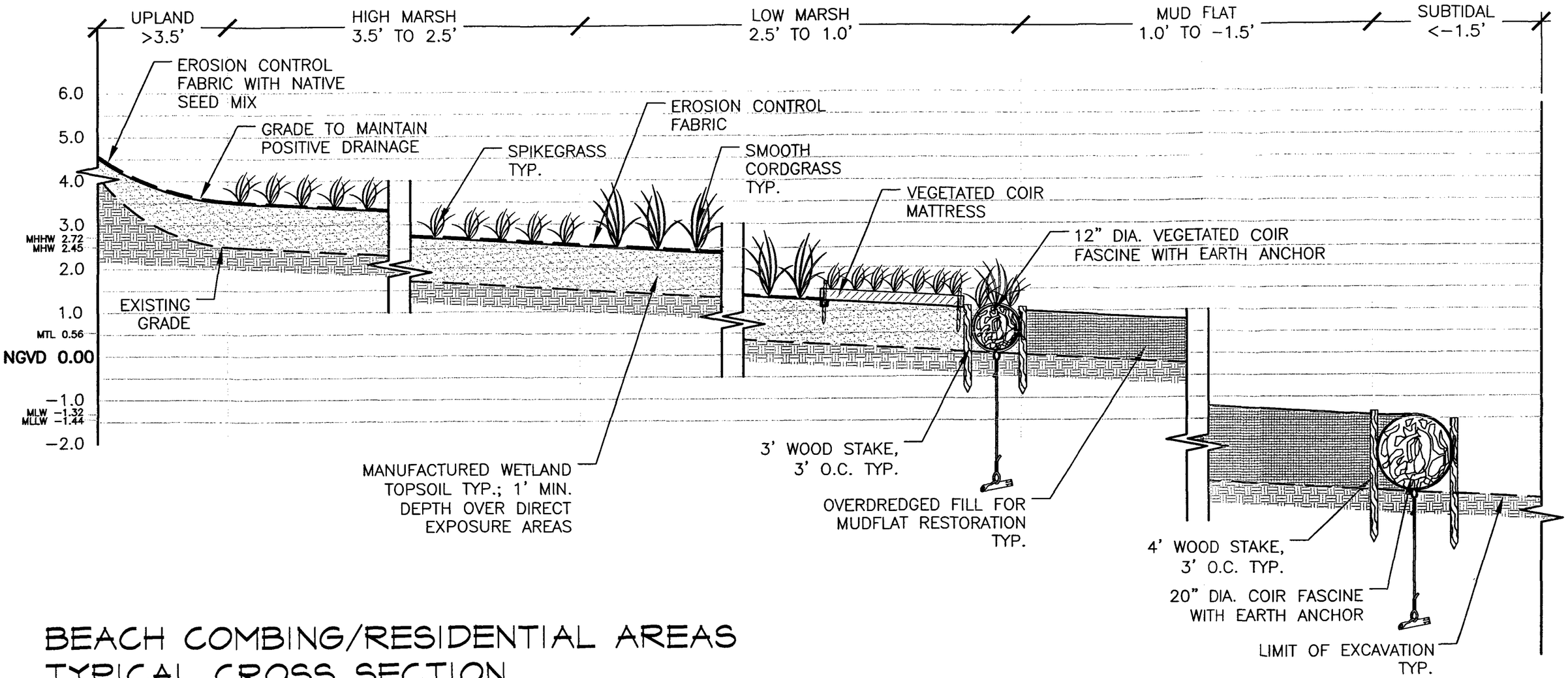
FIGURE 15.1

NEW BEDFORD HARBOR SUPERFUND SITE

Restoration Basis of Design/
Design Analysis Report
November 2002

Typical Cross Section for Restoration Treatment in Non-Beachcombing, Non-Residential Areas

Not to Scale



BEACH COMBING/RESIDENTIAL AREAS TYPICAL CROSS SECTION

NOT TO SCALE

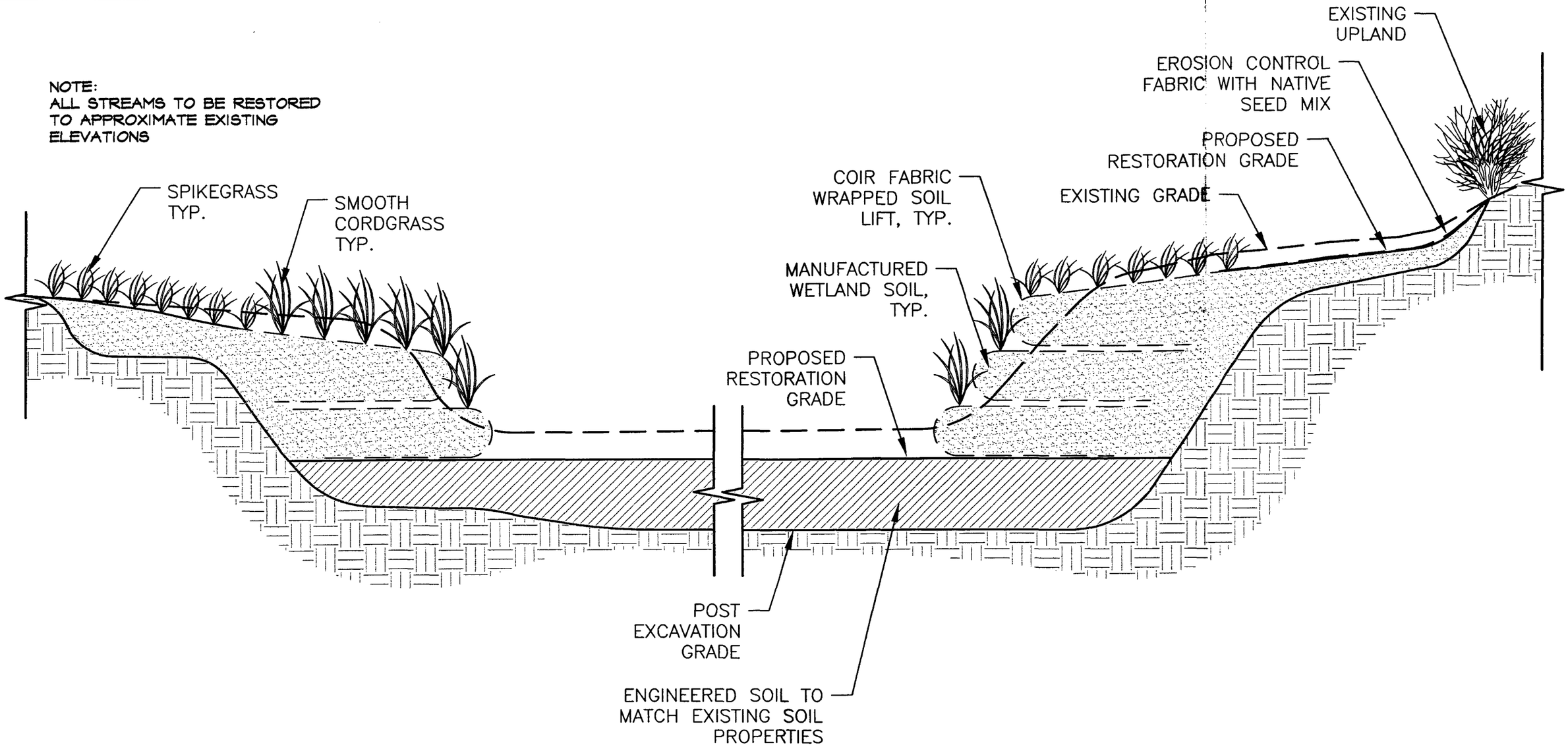
FIGURE 15.2

NEW BEDFORD HARBOR SUPERFUND SITE

Restoration Basis of Design/
Design Analysis Report
November 2002

Typical Cross Section for Restoration Treatment in Beachcombing, Residential Areas

Not to Scale



STREAM RESTORATION - TYPICAL CROSS SECTION

NOT TO SCALE

FIGURE 15.3

NEW BEDFORD HARBOR SUPERFUND SITE

Restoration Basis of Design/
Design Analysis Report
November 2002

Typical Cross Section for Stream Restoration Treatment

Not to Scale

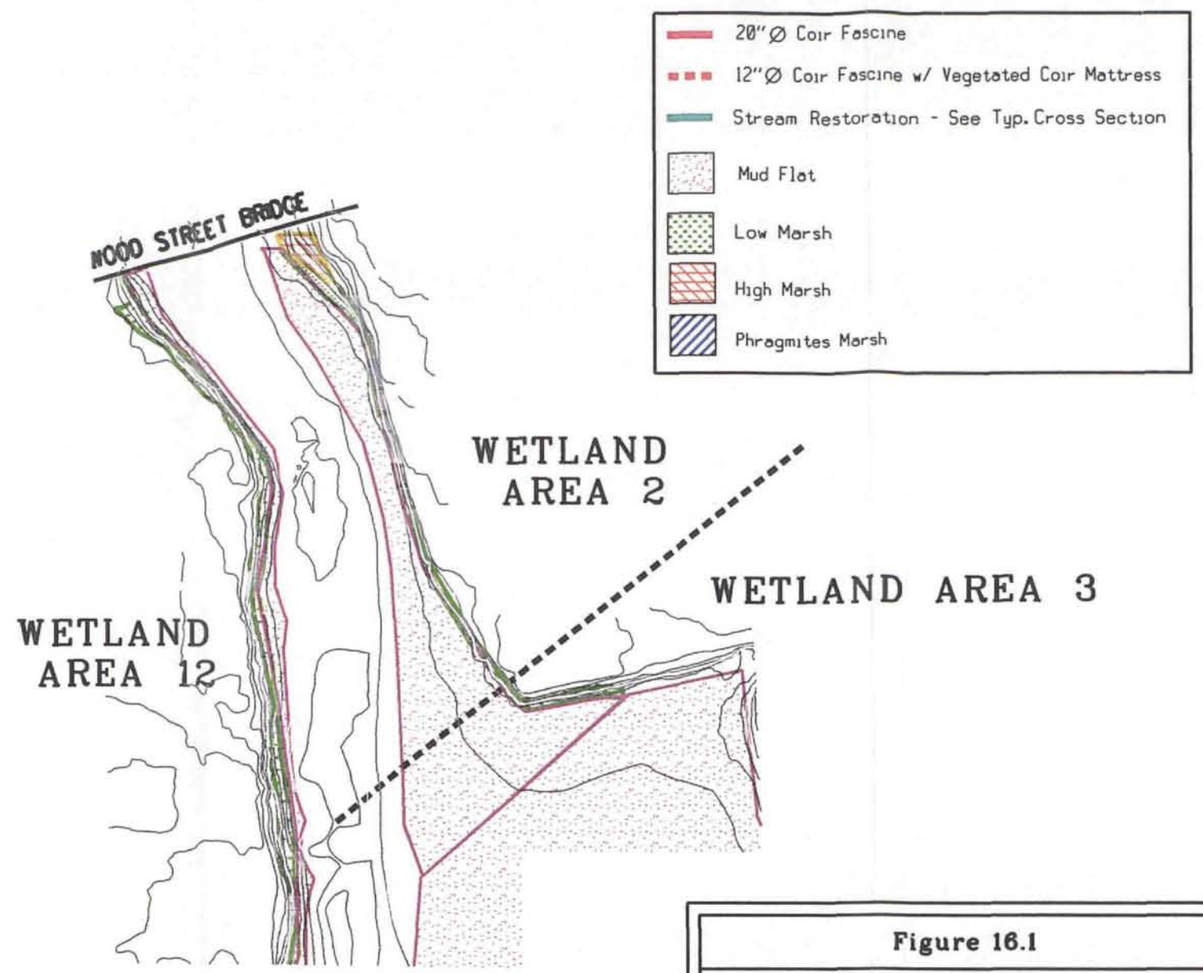


Figure 16.1

NEW BEDFORD HARBOR SUPERFUND SITE

Restoration Basis of Design/
Design Analysis Report
November 2002

Final Distribution of Habitat Types in Plan View
Wetland Area 2

30 0 60 120 180 FEET

Topographic information provided by Foster Wheeler Environmental Co.

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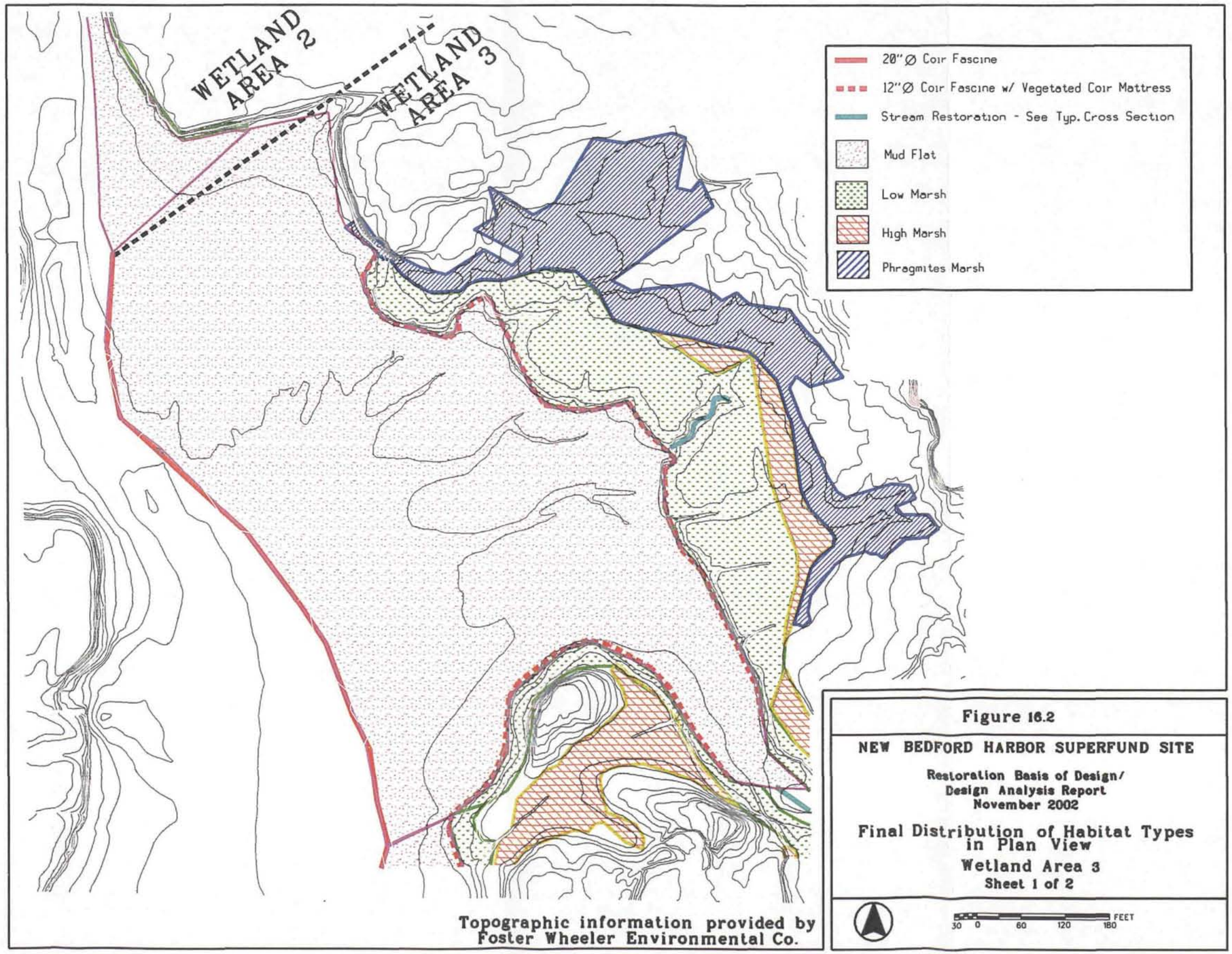

Figure 16.2

NEW BEDFORD HARBOR SUPERFUND SITE

Restoration Basis of Design/
Design Analysis Report
November 2002

Final Distribution of Habitat Types in Plan View

Wetland Area 3

Sheet 1 of 2

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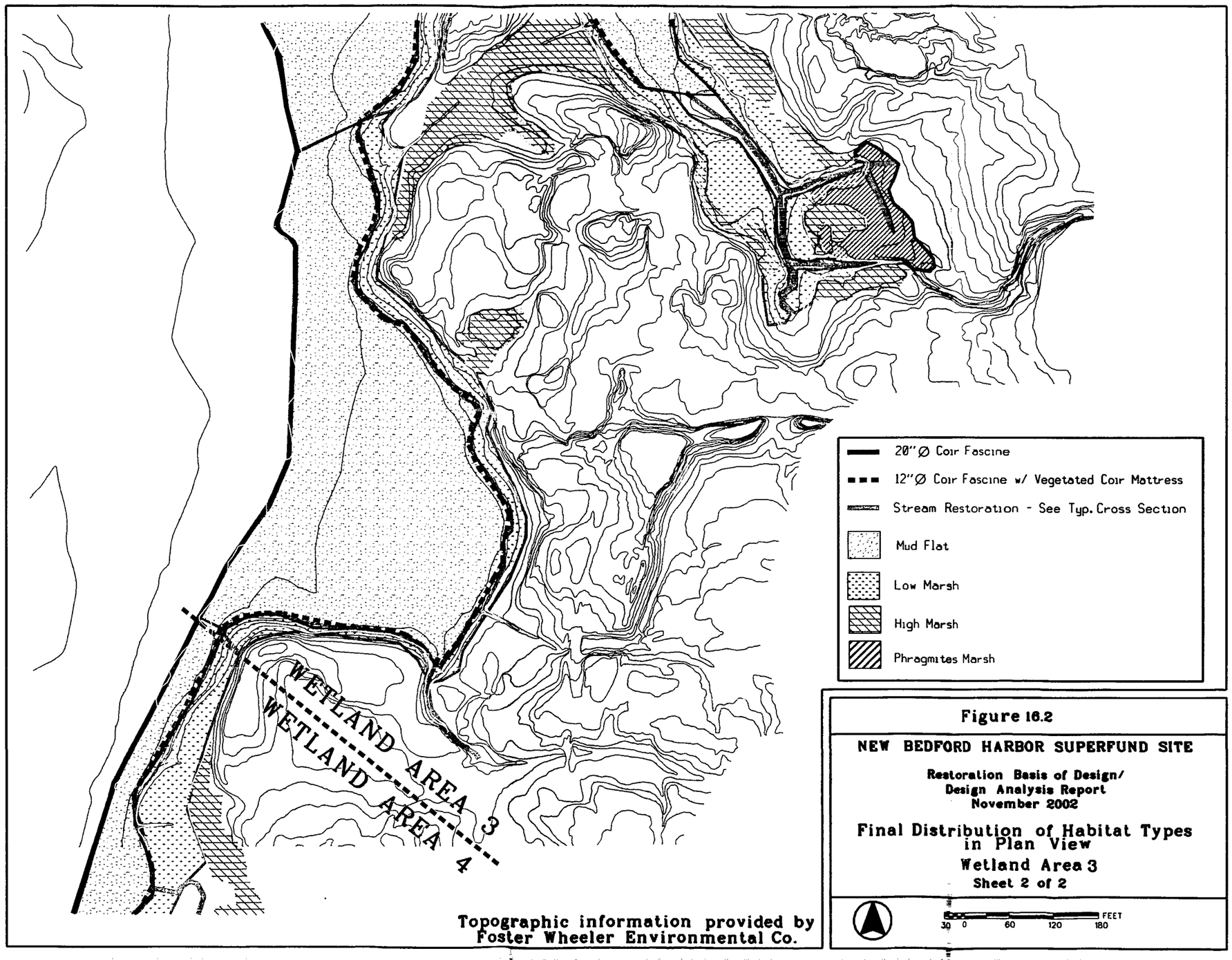

Figure 16.2

NEW BEDFORD HARBOR SUPERFUND SITE

Restoration Basis of Design/
Design Analysis Report
November 2002

Final Distribution of Habitat Types in Plan View

Wetland Area 3

Sheet 2 of 2

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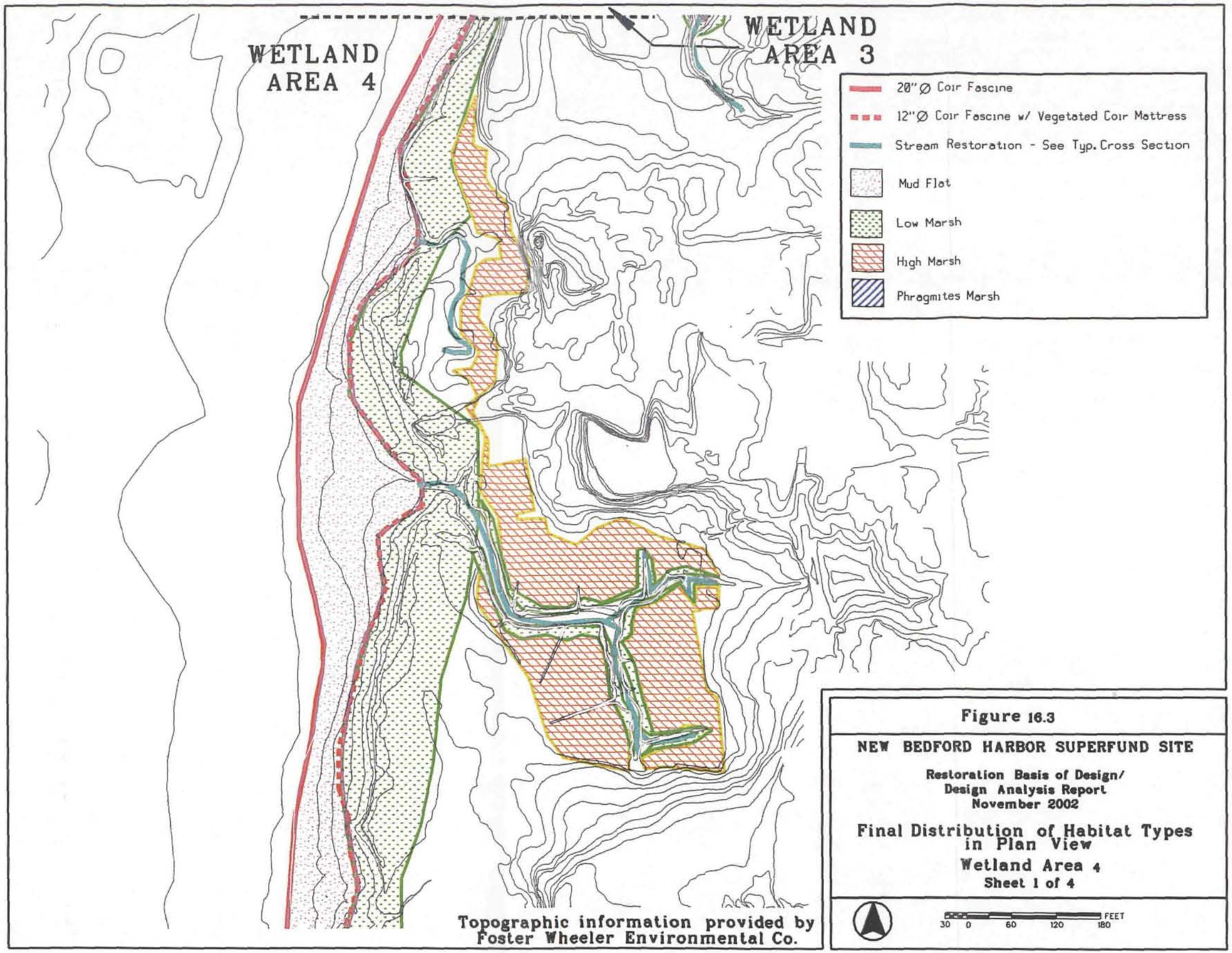

Figure 16.3

NEW BEDFORD HARBOR SUPERFUND SITE

Restoration Basis of Design/
Design Analysis Report
November 2002

Final Distribution of Habitat Types in Plan View

Wetland Area 4

Sheet 1 of 4

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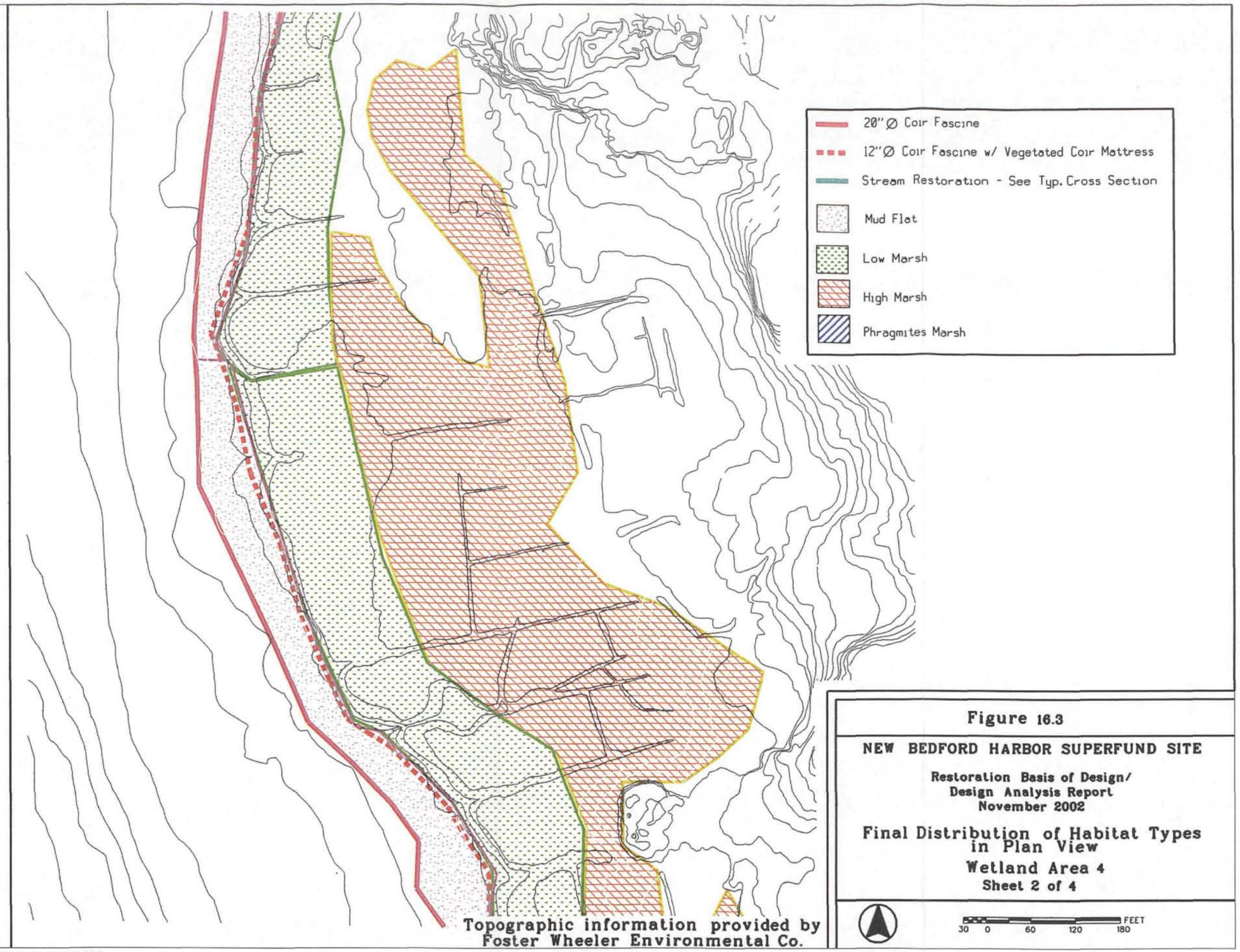

Figure 16.3

NEW BEDFORD HARBOR SUPERFUND SITE

Restoration Basis of Design/
Design Analysis Report
November 2002

Final Distribution of Habitat Types in Plan View

Wetland Area 4

Sheet 2 of 4

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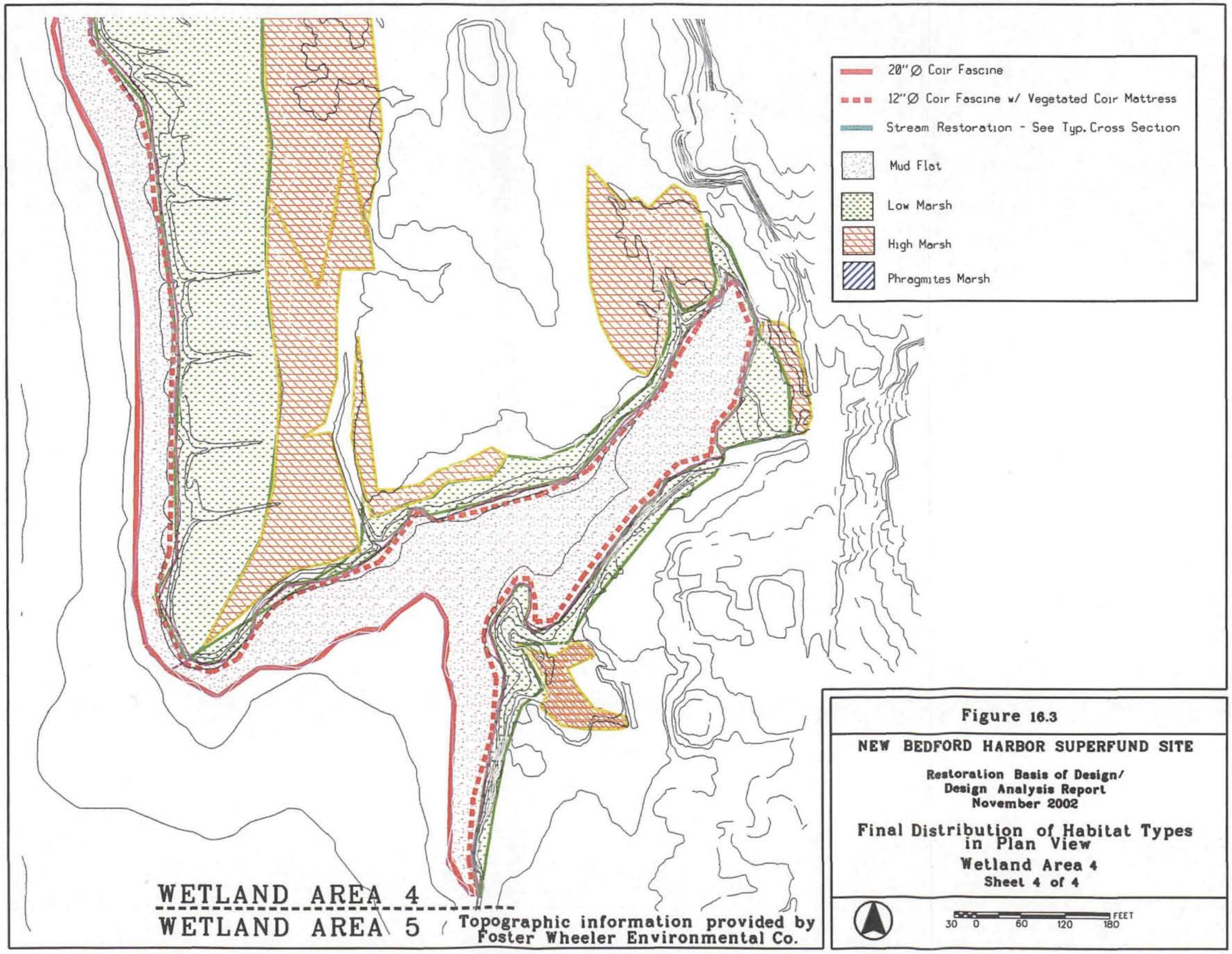

Figure 16.3

NEW BEDFORD HARBOR SUPERFUND SITE

Restoration Basis of Design/
Design Analysis Report
November 2002

Final Distribution of Habitat Types in Plan View

Wetland Area 4

Sheet 4 of 4

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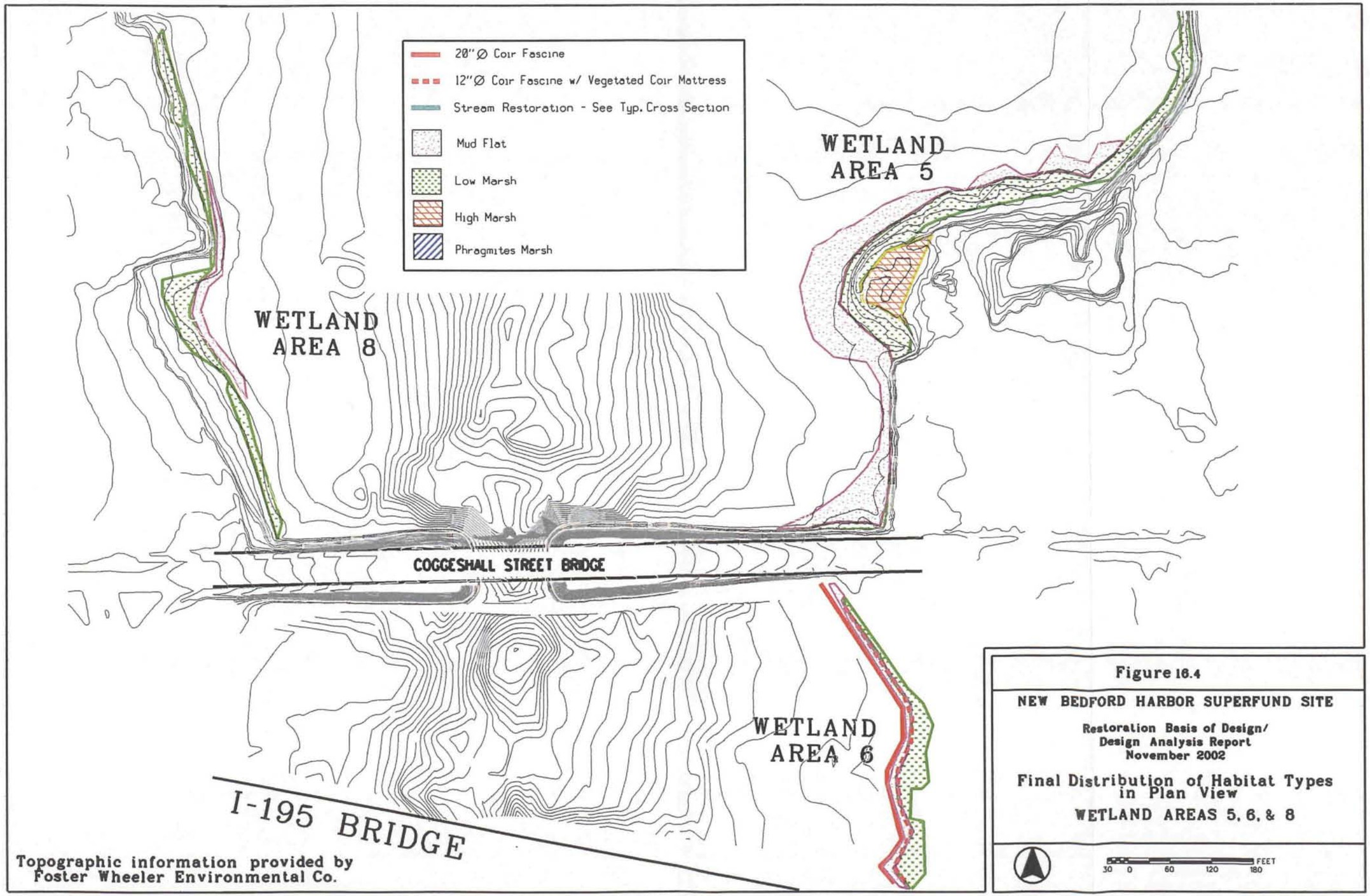

Figure 16.4

NEW BEDFORD HARBOR SUPERFUND SITE

Restoration Basis of Design/
Design Analysis Report
November 2002

Final Distribution of Habitat Types in Plan View

WETLAND AREAS 5, 6, & 8

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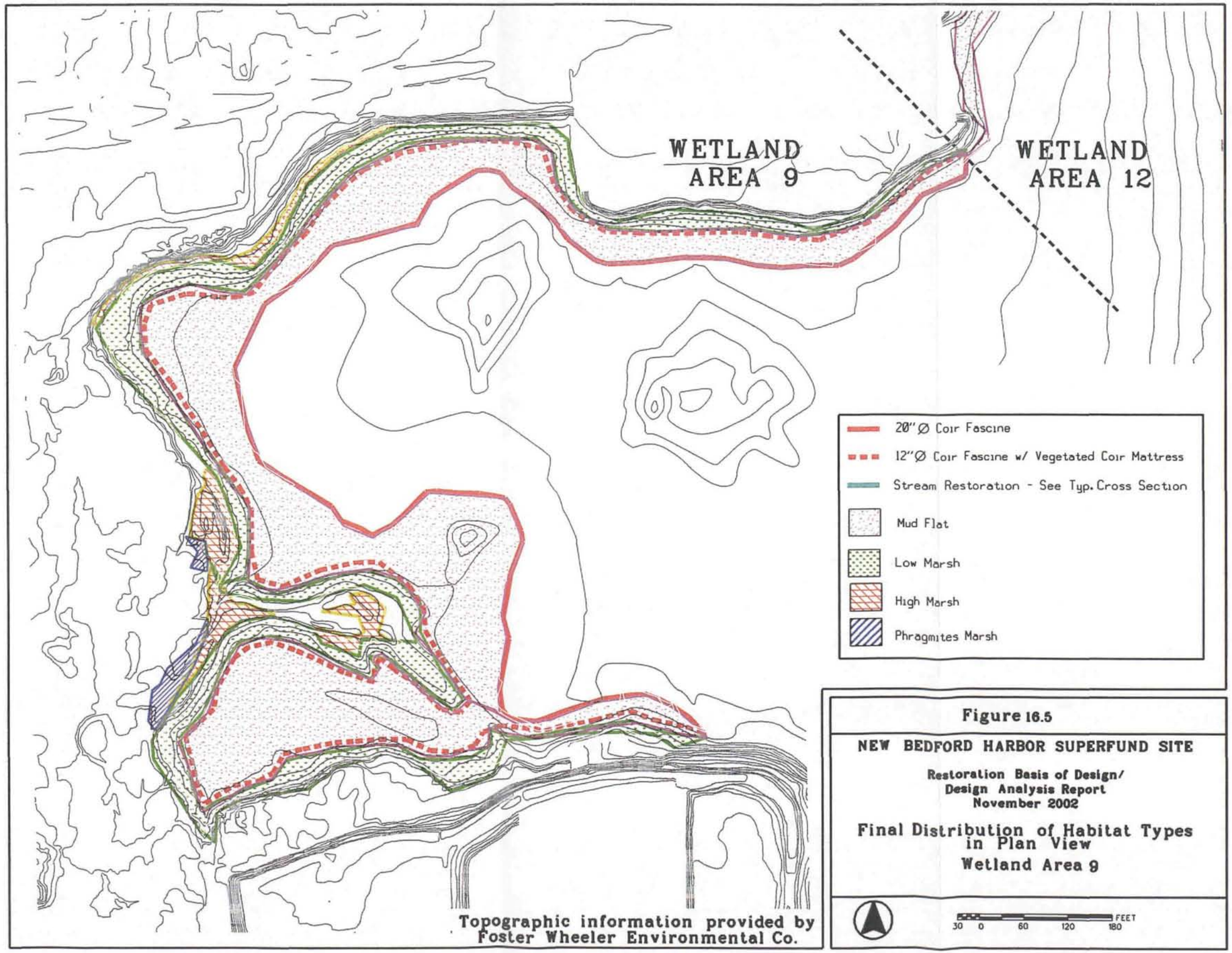

Figure 16.5

NEW BEDFORD HARBOR SUPERFUND SITE

**Restoration Basis of Design/
Design Analysis Report
November 2002**

Final Distribution of Habitat Types in Plan View

Wetland Area 9

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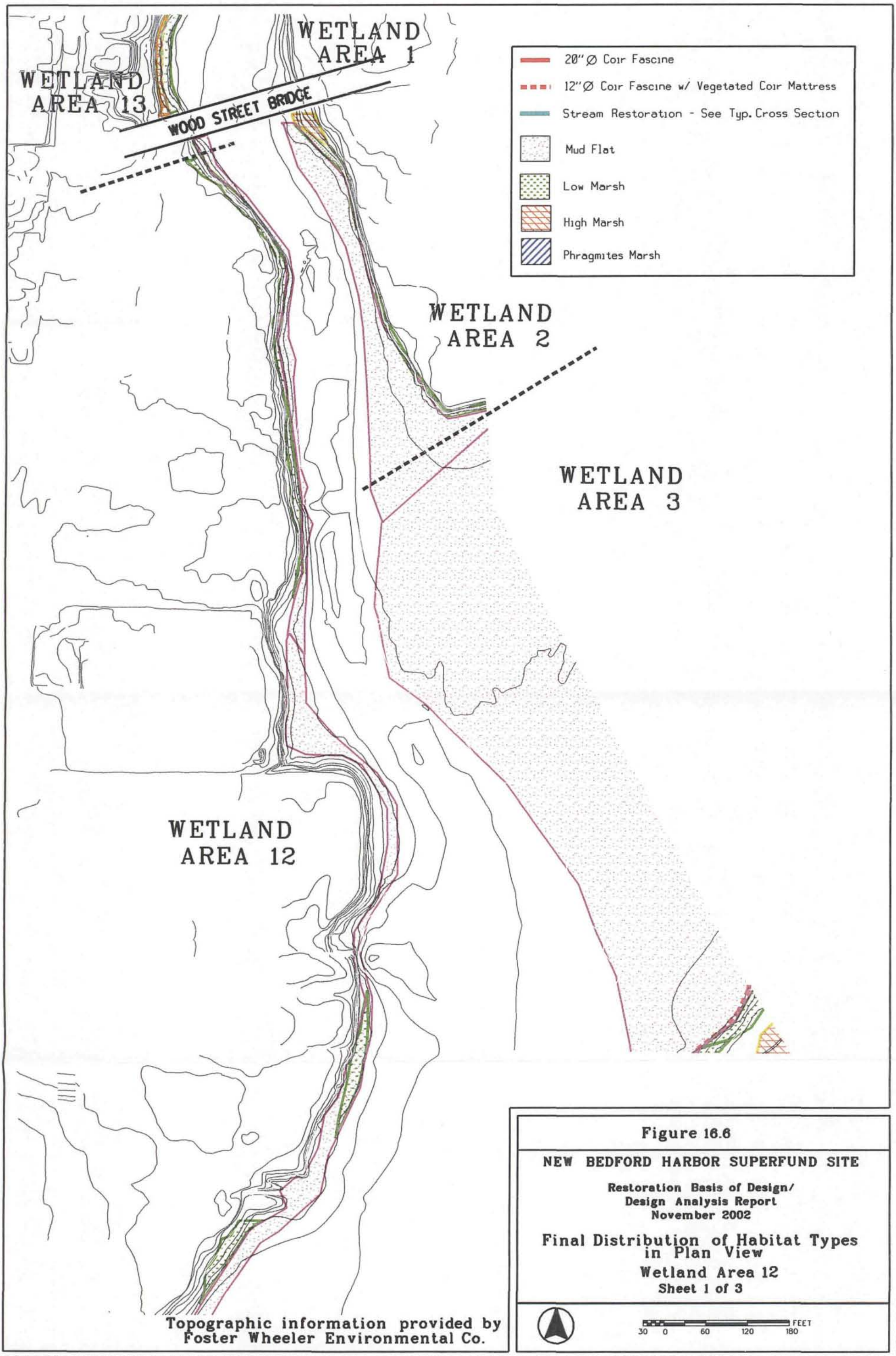

Figure 16.6

NEW BEDFORD HARBOR SUPERFUND SITE

Restoration Basis of Design/
Design Analysis Report
November 2002

Final Distribution of Habitat Types in Plan View

Wetland Area 12

Sheet 1 of 3

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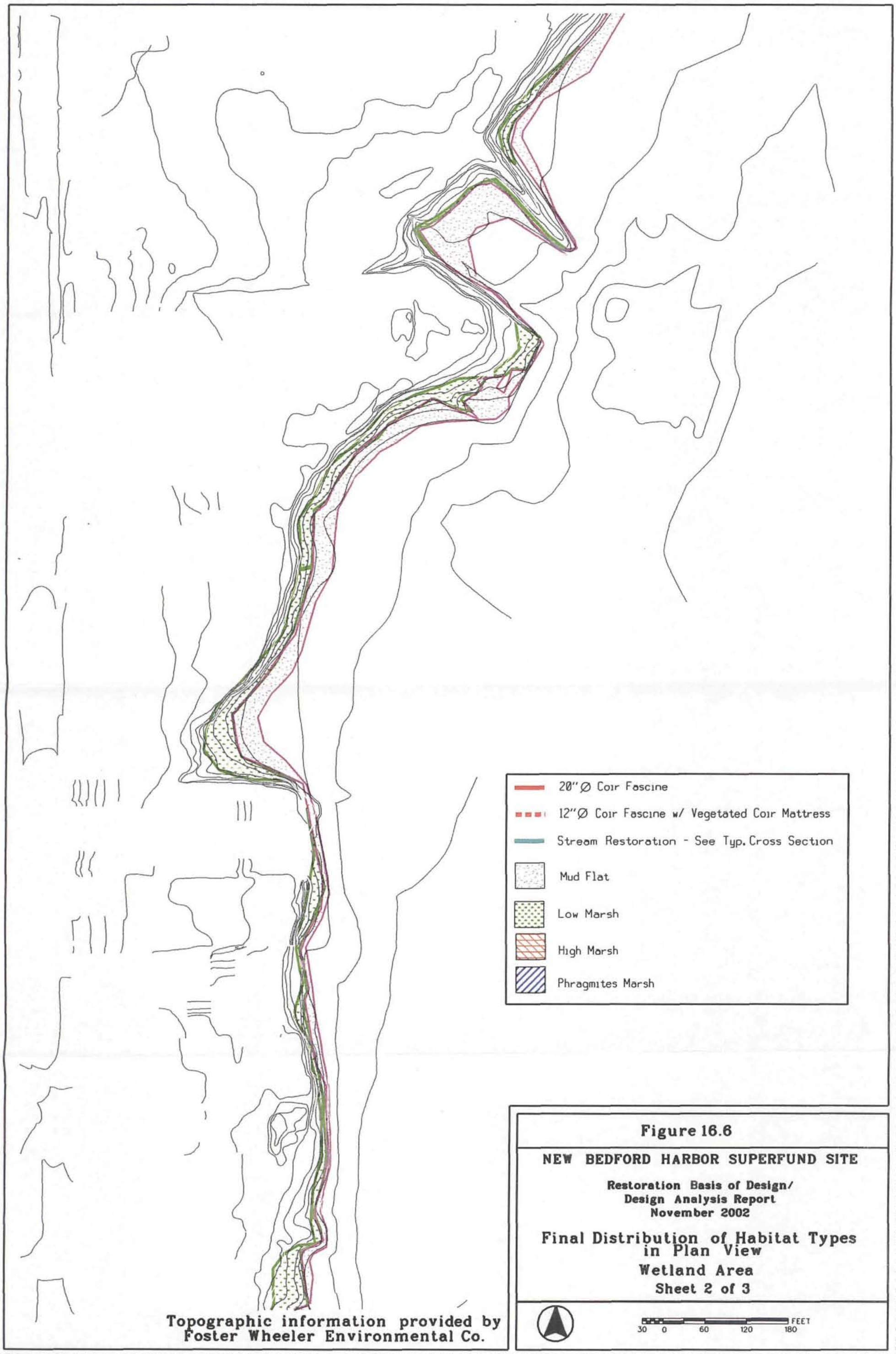

Figure 16.6

NEW BEDFORD HARBOR SUPERFUND SITE

Restoration Basis of Design/
Design Analysis Report
November 2002

Final Distribution of Habitat Types in Plan View

Wetland Area

Sheet 2 of 3

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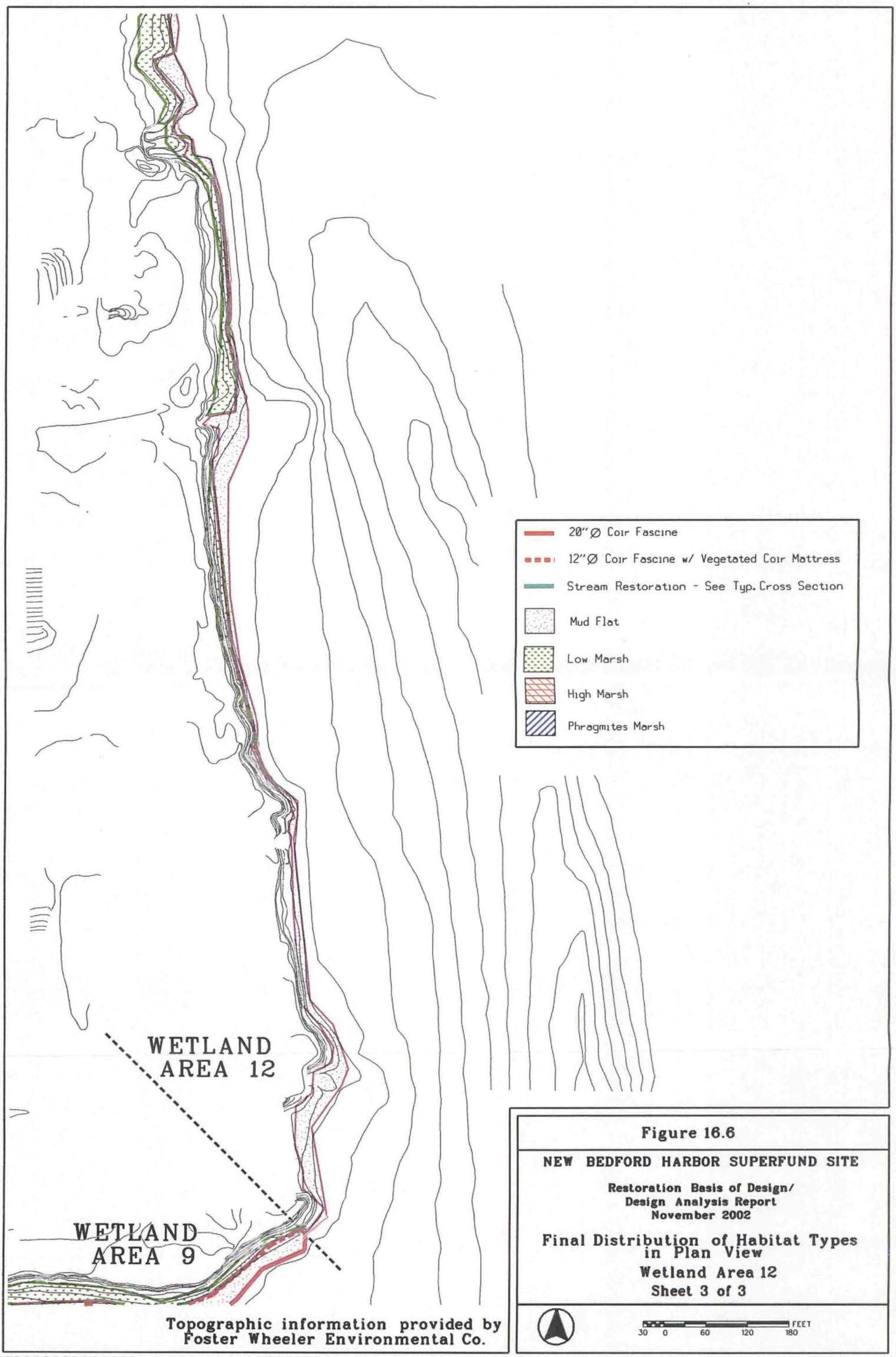

Topographic information provided by Foster Wheeler Environmental Co.

Figure 16.6

NEW BEDFORD HARBOR SUPERFUND SITE

Restoration Basis of Design/ Design Analysis Report November 2002

Final Distribution of Habitat Types in Plan View

Wetland Area 12

Sheet 3 of 3

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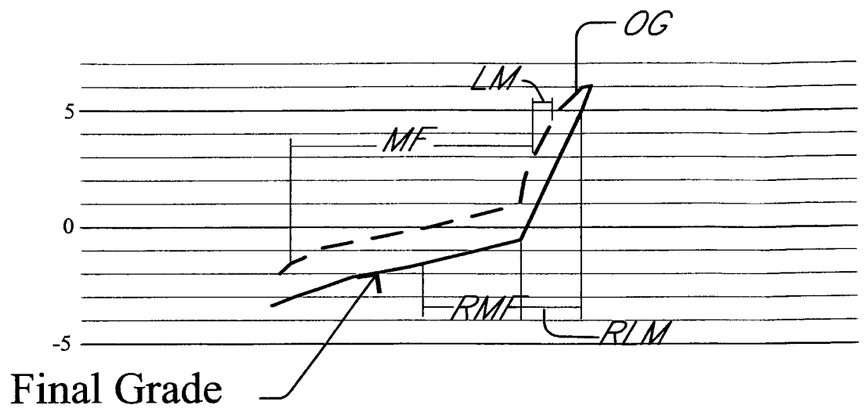
LEGEND

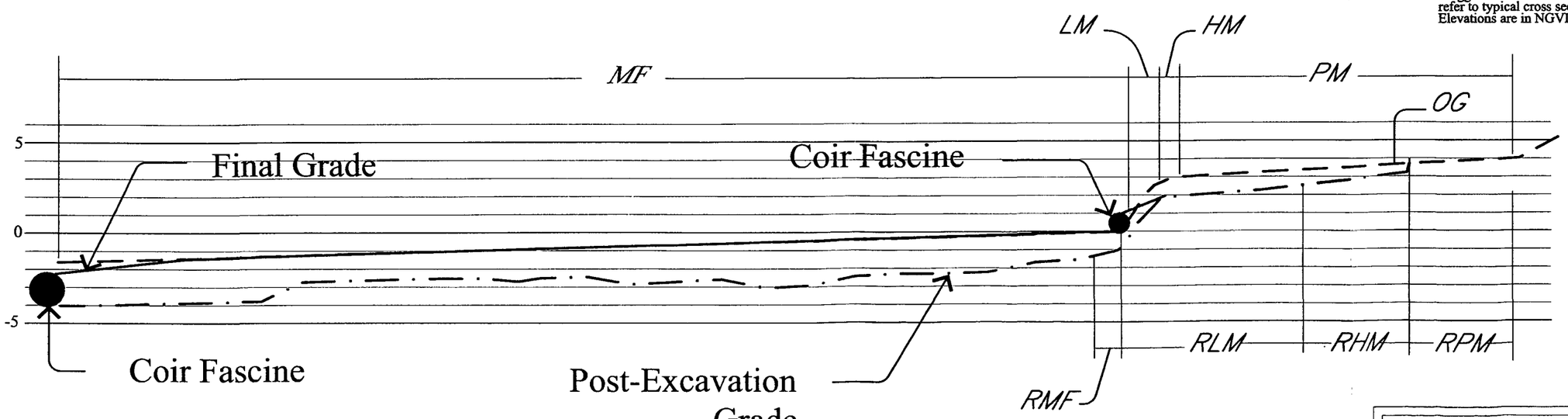
OG	ORIGINAL GRADE
MF	EXISTING MUD FLAT
LM	EXISTING LOW MARSH
HM	EXISTING HIGH MARSH
PM	EXISTING PHRAGMITES MARSH
BCH	EXISTING BEACH
RMF	REMAINING/RESTORED MUD FLAT
RLM	REMAINING/RESTORED LOW MARSH
RHM	REMAINING/RESTORED HIGH MARSH
RPM	REMAINING PHRAGMITES MARSH
- - -	ORIGINAL GRADE
— · —	POST-EXCAVATION GRADE (WHERE RESTORATION WILL OCCUR)
———	FINAL GRADE

NOTE: All cross sections have a vertical exaggeration of 10V:1H for graphic clarity. Please refer to typical cross sections for more information. Elevations are in NGVD.



WETLAND AREA 2

10V:1H



WETLAND AREA 3

10V:1H

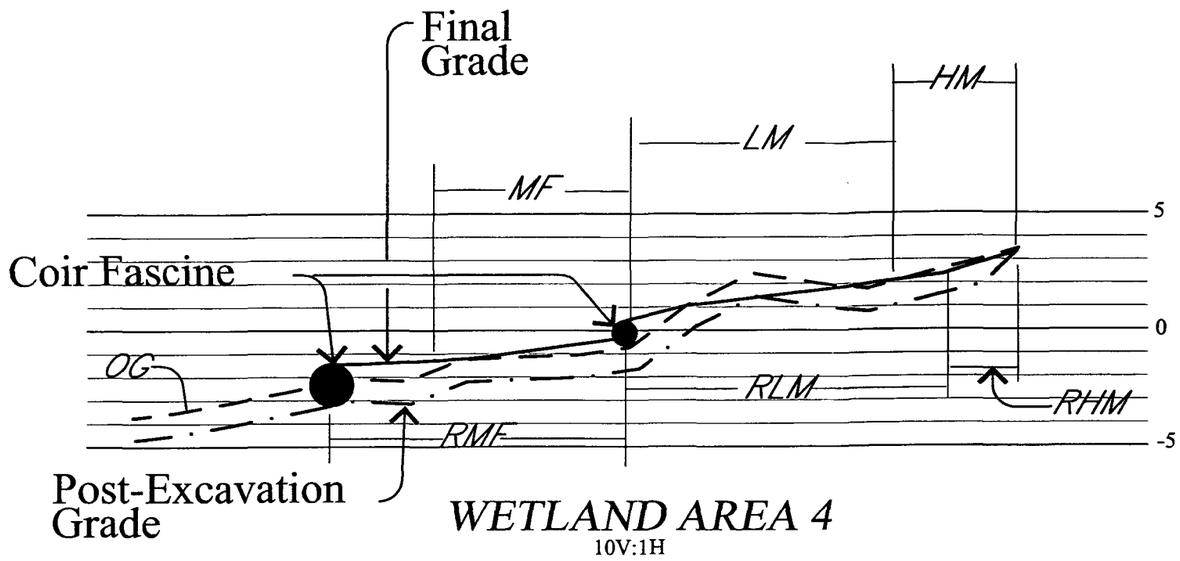
FIGURE 17.1

NEW BEDFORD HARBOR SUPERFUND SITE

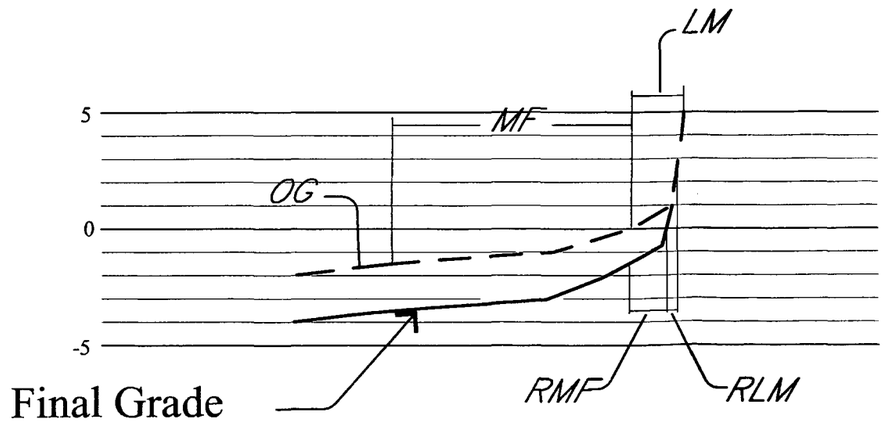
Restoration Basis of Design/
Design Analysis Report
November 2002

Typical Cross Sections for Existing and Final Wetland Habitat Distribution in Wetland Areas 2 and 3

Not to Scale



WETLAND AREA 4
10V:1H



WETLAND AREA 5
10V:1H

LEGEND

OG	ORIGINAL GRADE
MF	EXISTING MUD FLAT
LM	EXISTING LOW MARSH
HM	EXISTING HIGH MARSH
PM	EXISTING PHRAGMITES MARSH
BCH	EXISTING BEACH
RMF	REMAINING/RESTORED MUD FLAT
RLM	REMAINING/RESTORED LOW MARSH
RHM	REMAINING/RESTORED HIGH MARSH
RPM	REMAINING PHRAGMITES MARSH
- - -	ORIGINAL GRADE
— · —	POST-EXCAVATION GRADE (WHERE RESTORATION WILL OCCUR)
———	FINAL GRADE

NOTE: All cross sections have a vertical exaggeration of 10V:1H for graphic clarity. Please refer to typical cross sections for more information. Elevations are in NGVD.

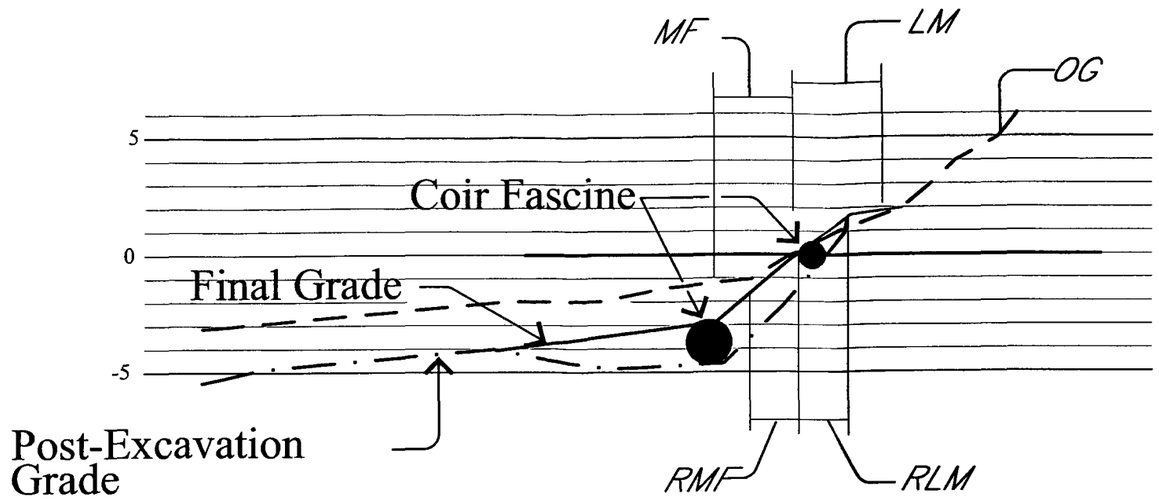
FIGURE 17.2

NEW BEDFORD HARBOR SUPERFUND SITE

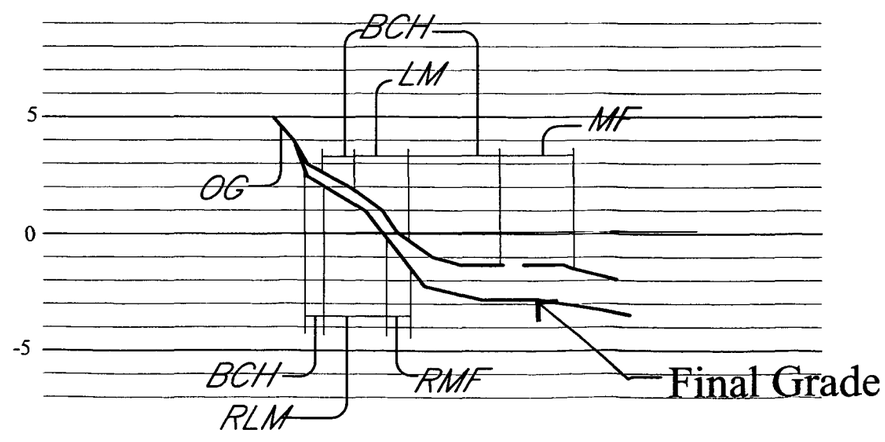
Restoration Basis of Design/
Design Analysis Report
November 2002

Typical Cross Sections for Existing and Final Wetland Habitat Distribution in Wetland Areas 4 and 5

Not to Scale



WETLAND AREA 6
10V:1H



WETLAND AREA 8
10V:1H

LEGEND

OG	ORIGINAL GRADE
MF	EXISTING MUD FLAT
LM	EXISTING LOW MARSH
HM	EXISTING HIGH MARSH
PM	EXISTING PHRAGMITES MARSH
BCH	EXISTING BEACH
RMF	REMAINING/RESTORED MUD FLAT
RLM	REMAINING/RESTORED LOW MARSH
RHM	REMAINING/RESTORED HIGH MARSH
RPM	REMAINING PHRAGMITES MARSH
- - -	ORIGINAL GRADE
— · —	POST-EXCAVATION GRADE (WHERE RESTORATION WILL OCCUR)
———	FINAL GRADE

NOTE: All cross sections have a vertical exaggeration of 10V:1H for graphic clarity. Please refer to typical cross sections for more information. Elevations are in NGVD.

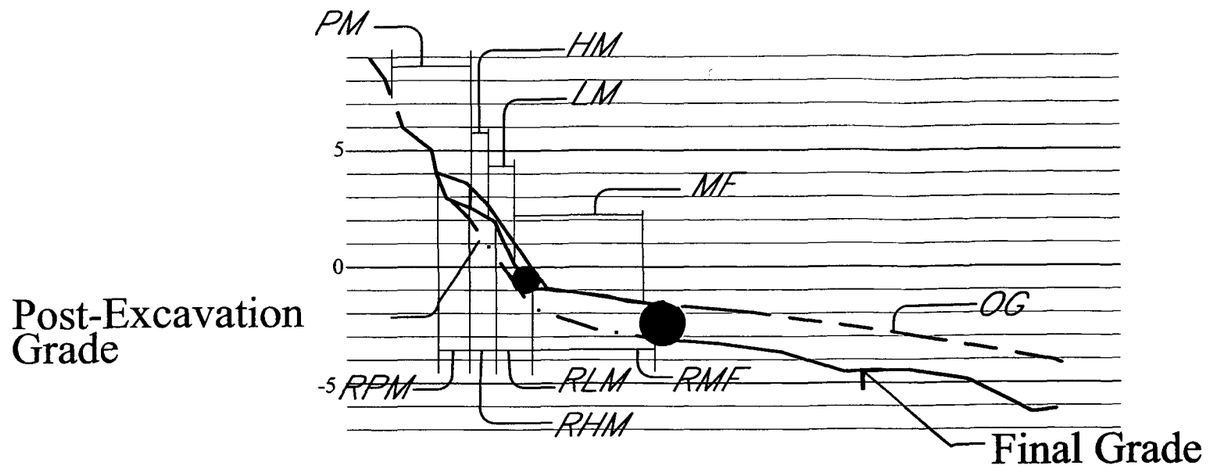
FIGURE 17.3

NEW BEDFORD HARBOR SUPERFUND SITE

Restoration Basis of Design/
Design Analysis Report
November 2002

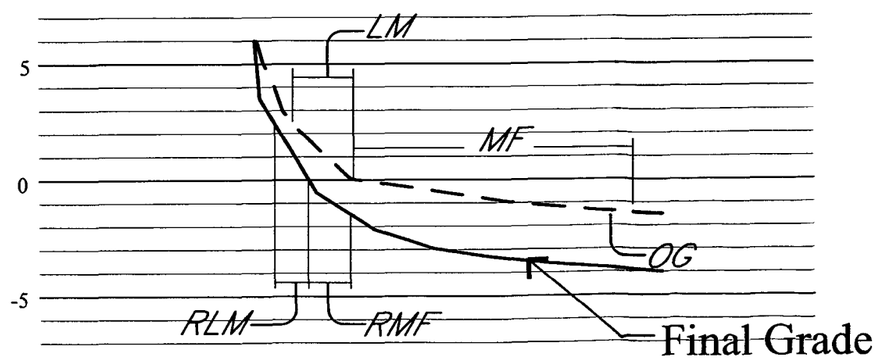
Typical Cross Sections for Existing and Final Wetland Habitat Distribution in Wetland Areas 6 and 8

Not to Scale



WETLAND AREA 9

10V:1H



WETLAND AREA 12

10V:1H

LEGEND

OG	ORIGINAL GRADE
MF	EXISTING MUD FLAT
LM	EXISTING LOW MARSH
HM	EXISTING HIGH MARSH
PM	EXISTING PHRAGMITES MARSH
BCH	EXISTING BEACH
RMF	REMAINING/RESTORED MUD FLAT
RLM	REMAINING/RESTORED LOW MARSH
RHM	REMAINING/RESTORED HIGH MARSH
RPM	REMAINING PHRAGMITES MARSH
- - -	ORIGINAL GRADE
— · —	POST-EXCAVATION GRADE (WHERE RESTORATION WILL OCCUR)
——	FINAL GRADE

NOTE: All cross sections have a vertical exaggeration of 10V:1H for graphic clarity. Please refer to typical cross sections for more information. Elevations are in NGVD.

FIGURE 17.4

NEW BEDFORD HARBOR SUPERFUND SITE

Restoration Basis of Design/
Design Analysis Report
November 2002

Typical Cross Sections for Existing and Final Wetland Habitat Distribution in Wetland Areas 9 and 12

Not to Scale

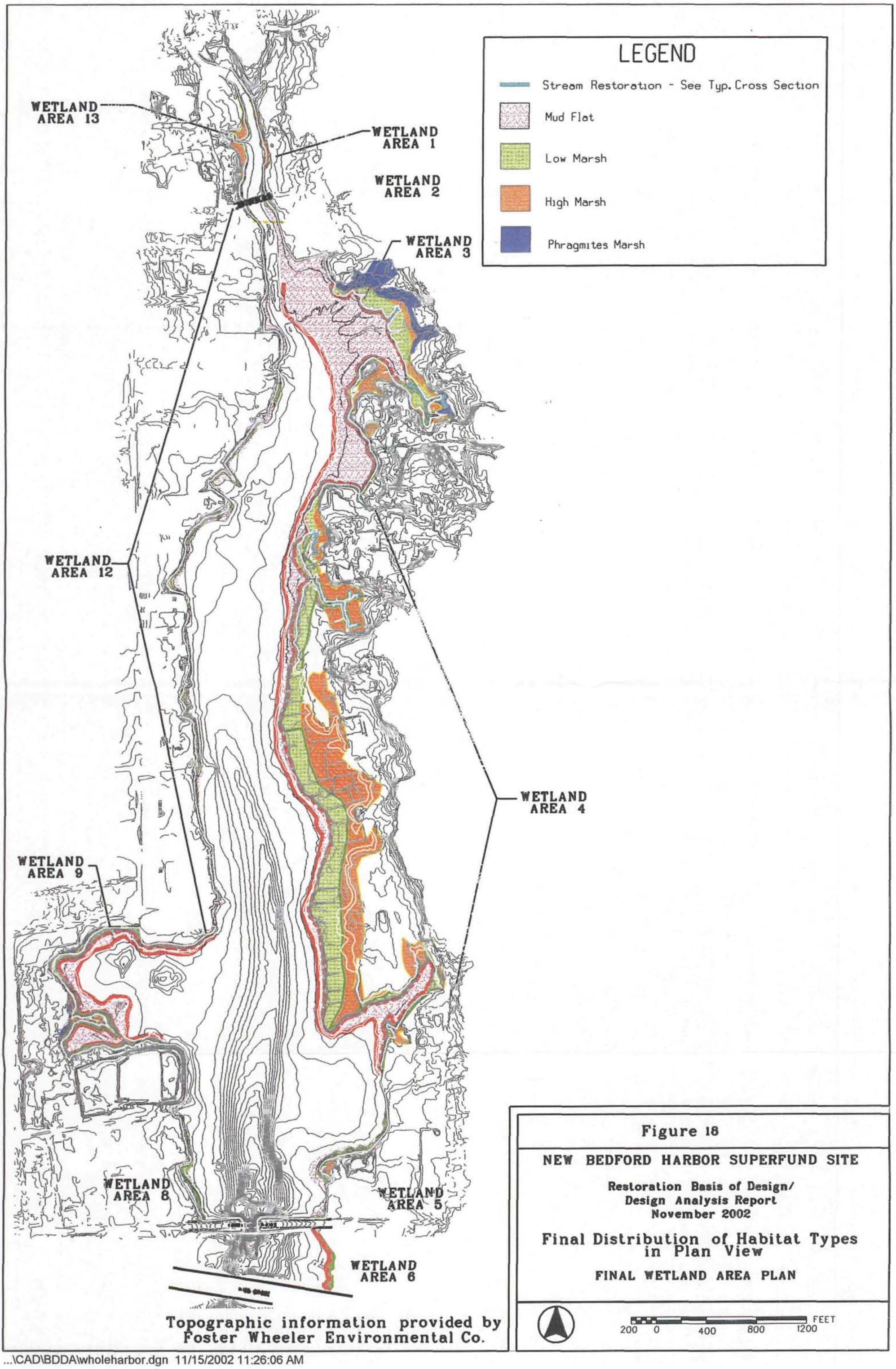


Figure 18

NEW BEDFORD HARBOR SUPERFUND SITE

Restoration Basis of Design/
Design Analysis Report
November 2002

Final Distribution of Habitat Types in Plan View

FINAL WETLAND AREA PLAN

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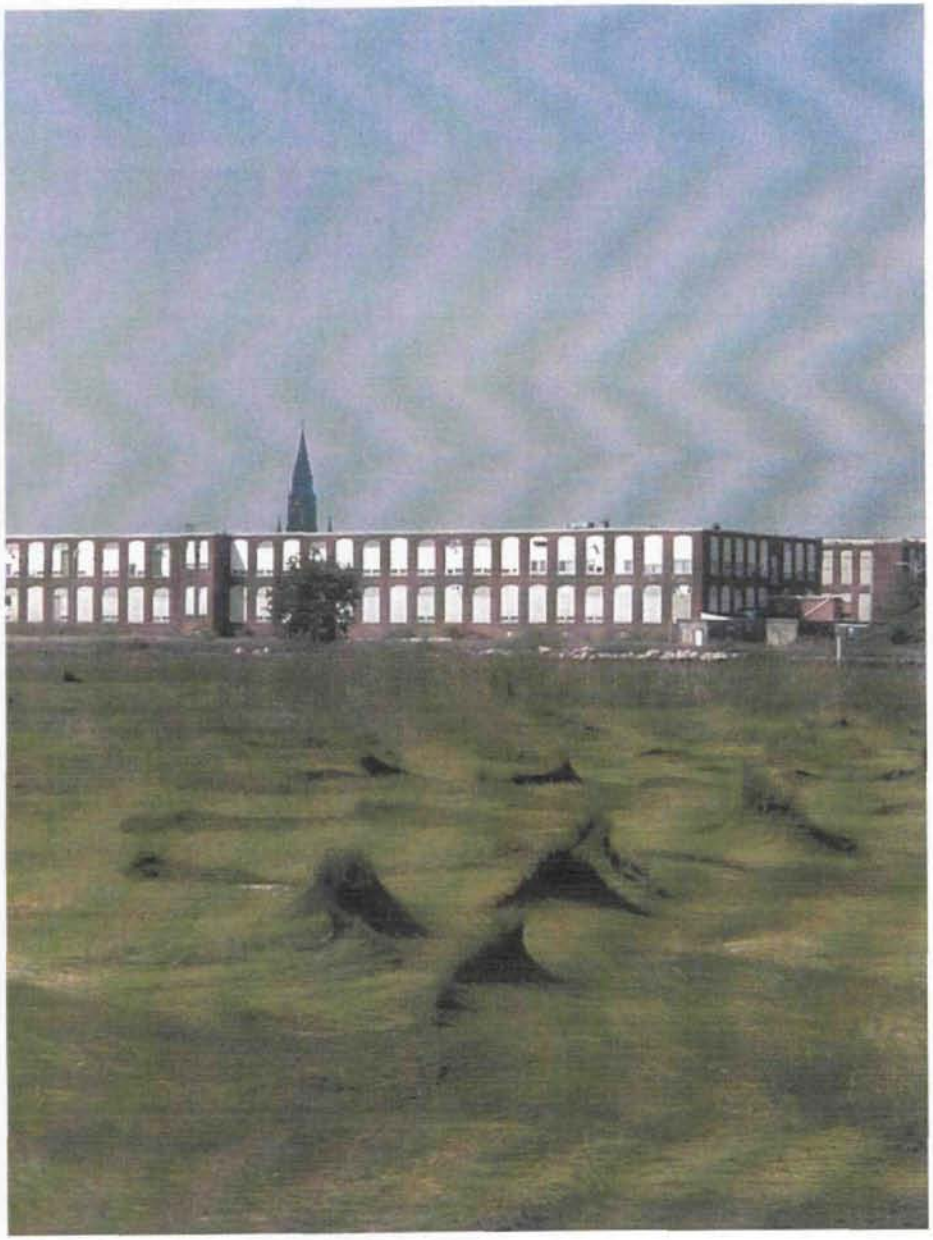
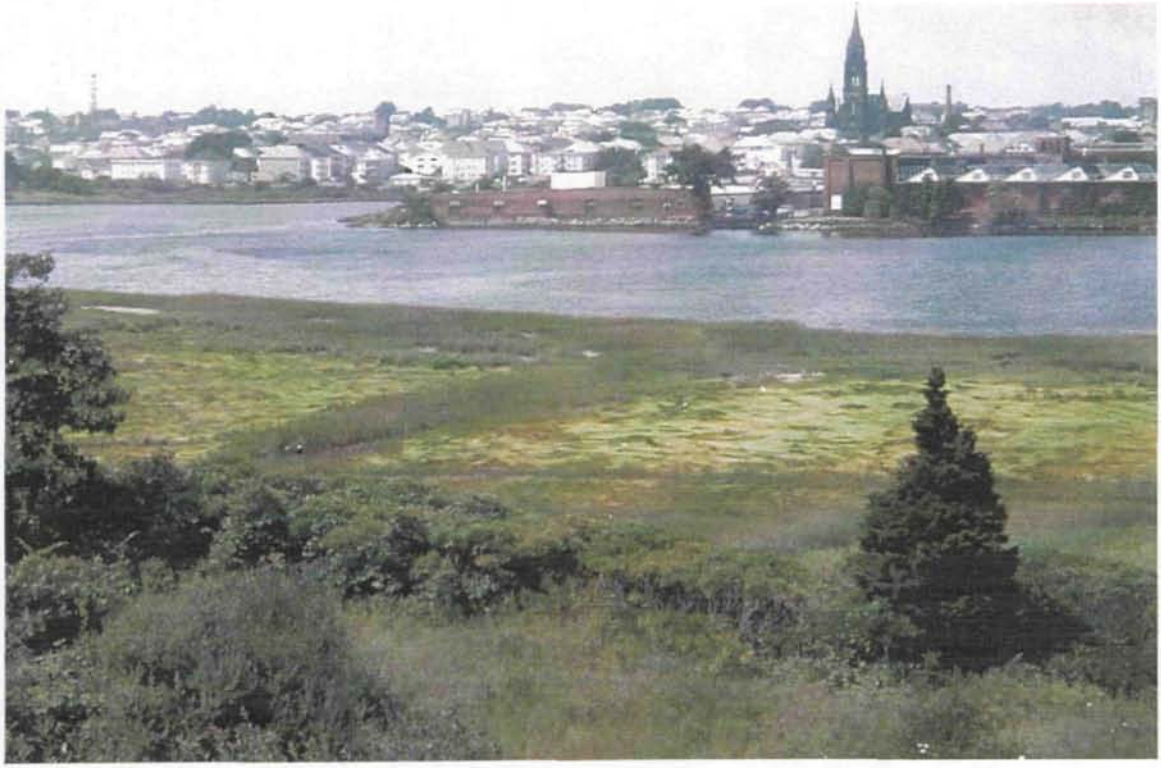
PHOTOGRAPHS

Photograph 1. Mosquito Control Ditch in Wetland 4.

Photograph 2. Low Marsh Fringing Open Water in Wetland 4.



Photograph 3. Dominant High Marsh species *Spartina patens.*



Photograph 4. Birdseye View of Wetland 4 Highlighting Network of Man-made Mosquito Ditches and Habitat Diversity.

APPENDIX A

ANALYSIS OF ALTERNATIVES

ANALYSIS OF ALTERNATIVES

As an initial step in developing a restoration plan for the Upper Harbor, three alternatives were developed. Their costs and ecological benefits were compared with respect to the agreed-upon restoration goal for the Upper Harbor (i.e. 1:1 net replacement of functions and values across the Upper Harbor).

The data used in this analysis was in some cases older data than what was available for the final restoration plan. Table A-1 lists the data sets used in the alternatives analysis. Based on this data, the area of existing habitat types (Table A-2) and the area and depth of dredging/excavation (Table A-3) were determined.

Table A-1. Data Layers Used in GIS-Based Landform Analysis of Alternatives.

Data Layer	Description
wetland_resources.shp	Wetland resources delineated by Foster Wheeler Environmental (2001)
coastal_bank_final_10-25-01.shp	Identified during wetland delineation Foster Wheeler Environmental (2001)
bathy_acoe_new21221.shp	Generated with USACE data
contours.shp	Generated from aerial photographic interpretation
dredgequantity.shp	Supplied by USACE (December 2000)

Table A-2. Table 2. Delineated Habitat Types in Upper Harbor. (Based on Foster Wheeler Environmental (2001)).

Habitat Type	Pre-cleanup Area (acres)	Percent of Total Area
Palustrine Forested	0.03	0.03%
Palustrine Scrub/shrub	0.74	0.72%
Palustrine Emergent Marsh	0.67	0.65%
Phragmites Marsh	6.50	6.29%
Scrub/shrub	11.81	11.42%
High Marsh	21.38	20.68%
Low Marsh	16.04	15.51%
Subtotal Vegetated Intertidal	*57.18*	*55.29%*
Beach	2.08	2.01%
Stream (Creek)	0.60	0.58%
Mudflat	43.54	42.11%
Subtotal Unvegetated Intertidal	*46.23*	*44.71%*
Total Area	**103.40**	**100.0%**

Table A-3. Area and Depth of Expected Excavation and Dredging by Habitat Type. Dredge quantity is in one foot (0.3 m) increments. (Based on December 2000 dredge quantity datalayer and Foster Wheeler Environmental (2001).)

Habitat Type	Pre-cleanup Area (acres)	Dredge 1 ft (acres)	Dredge 2 ft (acres)	Dredge 3 ft (acres)	Dredge 4 ft (acres)	Total Habitat Impacted (acres)	Percent of Habitat Type Impacted
Palustrine Forested	0.03	0.00	0.00	0.00	0.00	0.00	0.00%
Palustrine Scrub/Shrub	0.74	0.01	0.00	0.00	0.00	0.01	1.84%
Palustrine Emergent Marsh	0.67	0.10	0.06	0.00	0.02	0.17	25.78%
Phragmites Marsh	6.50	2.26	0.68	0.20	0.00	3.14	48.31%
Scrub/Shrub	11.81	0.97	0.07	0.00	0.00	1.04	8.84%
High Marsh	21.38	4.22	0.18	0.15	0.00	4.55	21.27%
Low Marsh	16.04	3.23	1.83	1.31	0.07	6.44	40.14%
Subtotal Vegetated Intertidal	*57.18*	*10.79*	*2.82*	*1.66*	*0.09*	*15.36*	*26.86%*
Beach	2.08	0.53	0.15	0.00	0.07	0.75	35.93%
Stream (Creek)	0.60	0.06	0.18	0.11	0.00	0.35	57.58%
Mudflat	43.54	20.27	9.19	3.19	0.24	32.89	75.54%
Subtotal Unvegetated Intertidal	*46.23*	*20.33*	*9.37*	*3.30*	*0.24*	*33.24*	*71.90%*
Total Area	**103.40**	**31.12**	**12.19**	**4.95**	**0.33**	**48.60**	**47.00%**

The following sections describe the three alternative approaches that were developed. Each alternative was carried through a concept level design and preliminary cost estimate at the level of the whole harbor (Upper Harbor).

Alternative 1

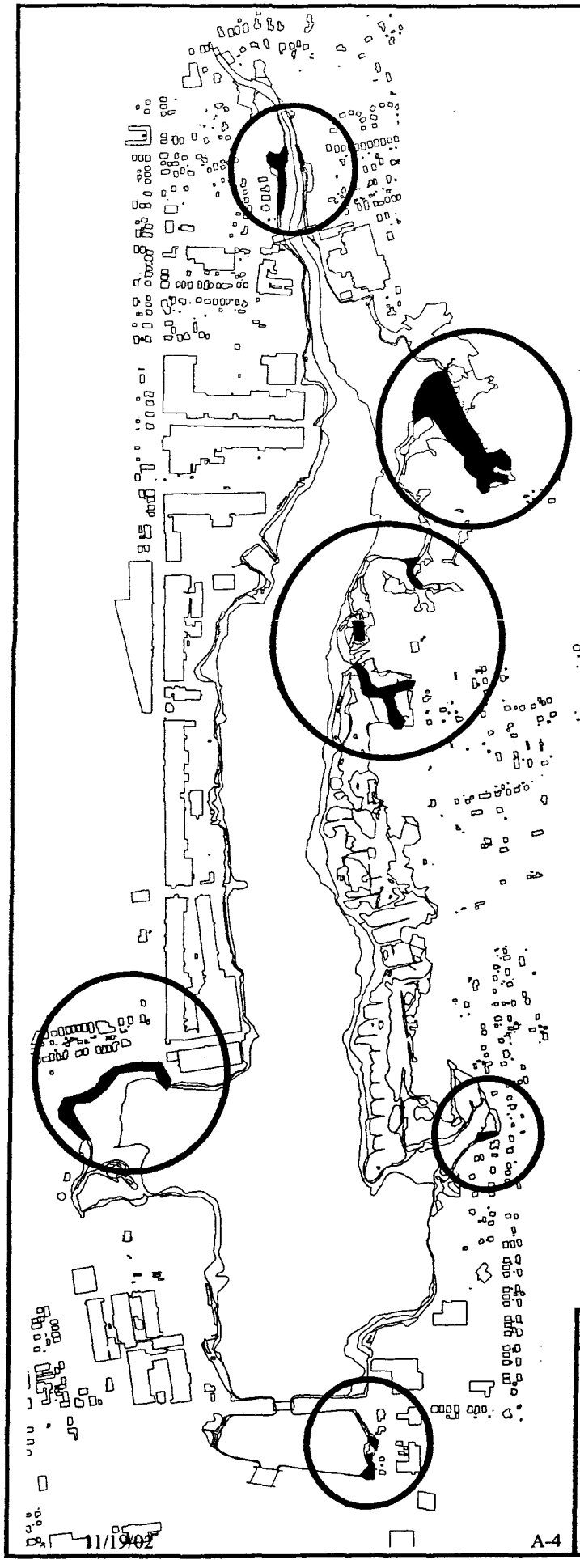
Under alternative 1 only limited areas would be restored to their pre-cleanup conditions. For most areas, adjacent unimpacted intertidal habitats would be relied upon to act as source populations for the colonization and revegetation of impacted mudflat and marsh areas. The elevation of much of the mudflat area impacted by the cleanup activities would remain within the intertidal range post cleanup, and the sediment trapping nature of the Upper Harbor would be relied upon to both rebuild and expand mudflat areas. Some areas, primarily at the mudflat/low marsh interface, would require backfilling,

stabilization, and/or replanting. Listed below are critical areas in which such restoration elements would be applied:

- Areas where non-replacement would result in severe erosion,
- Areas in which hydrologic connections are impacted (tidal creeks),
- Areas where sediment/soil is removed on residential property,
- Areas where sediment/soil is removed in or near public parks or other public access areas.

This alternative ensures that functions and values of the unimpacted habitats are maintained, and that the impacted areas are greatly improved by the removal of PCB contamination. A portion of total intertidal habitat (20-30%) may be converted to subtidal habitat under the current dredging/excavation plan. If mudflats were dredged more than 2 feet (0.6 m), the resulting surface elevation would be below MLLW, or subtidal. As well, 1 foot (0.3 m) dredging of lower mudflats would also result in conversion to subtidal. Shallow subtidal habitat (1-3 feet (0.3-0.9 m) below MLLW) can fulfill many of the same functions as existing mudflats, such as nutrient removal, sediment/toxicant retention, and providing fish and shellfish habitat. Some new mudflat habitat may also be created when vegetated habitats are excavated and not replanted. This areal loss of intertidal habitat is outweighed by the benefits of contaminant removal. The potential for recovery of vegetated habitats is high, but recovery may not occur in an acceptable time frame, and it may not be possible to estimate resulting total intertidal vegetated habitat at the close of any monitoring period.

Stabilization would primarily include bioengineering treatments that incorporate the use of native vegetation, coir and other natural products, and geotextile fabrics. Stabilization with hard structures may also be used where necessary due to hydrologic forces. Where needed to stabilize slopes, native plants would be replanted either through seed mixes, whole plant plugs, or by the installation of vegetated coir mattresses and fascines. Sites which would be restored (i.e. backfilled, graded, planted) under this alternative include the residential properties in wetlands 6 and 13, the areas adjacent to the public parks in Coffin Avenue Cove (wetland 9, where Riverside Park is to be developed), and tidal creeks throughout the Upper Harbor. Figure A-1 highlights these sites and provides a brief summary of the extent and estimated materials and labor cost of restoration activities. Table A-4 summarizes estimated construction costs.



Restoration Design Elements

- 13,000 CY Total (Subgrade and Topsoil)
- 4,860 LF of Stabilization Treatments
- 4.55 Acres Planted with Appropriate Wetland Vegetation

Total Cost Estimate
(Materials and Labor): $1,300,000

Figure A-1

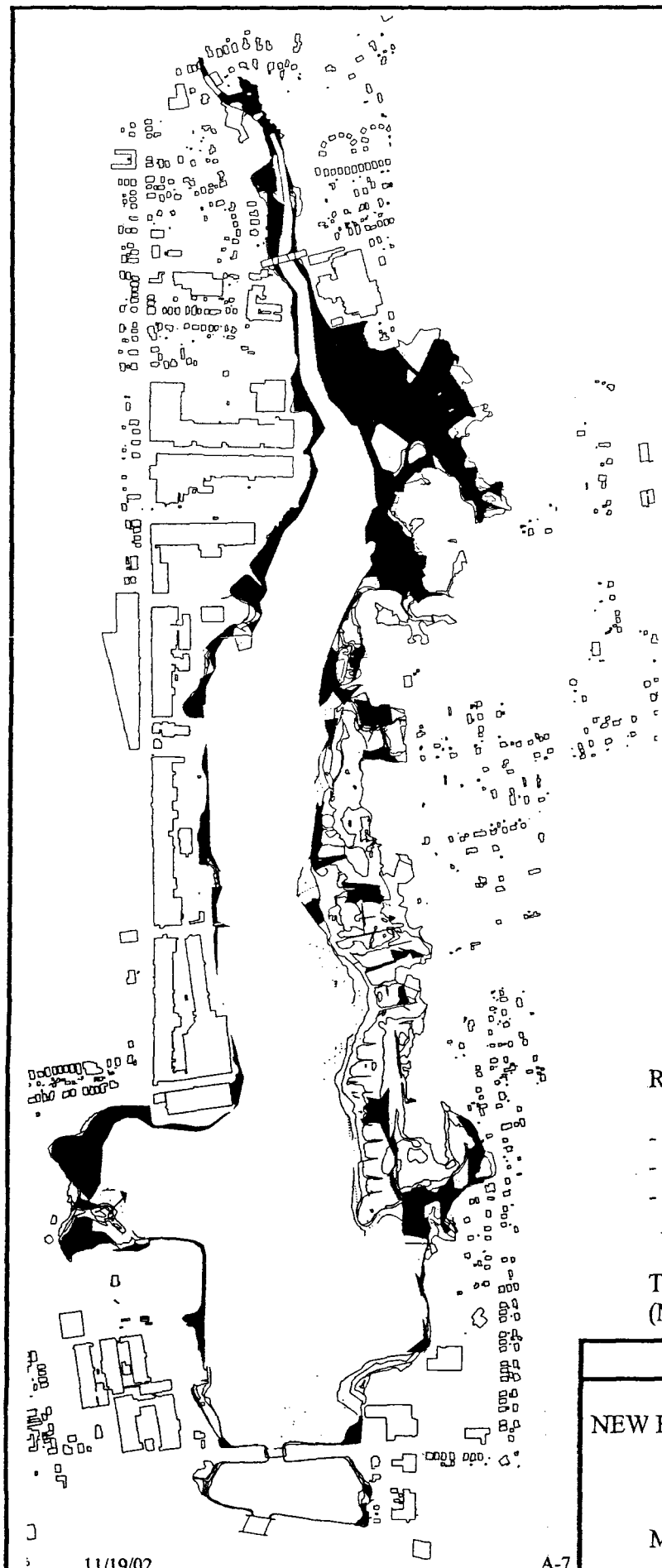
NEW BEDFORD HARBOR SUPERFUND SITE
Restoration Basis of Design/
Design Analysis Report
December 2002
Map of Alternative 1 Restoration Sites

Table A-4. Preliminary Construction Cost Estimate for Alternative 1. Costs include materials and labor and exclude inflation and contingencies.

ITEM	UNIT	QTY	PRICE	TOTAL
Permits	LS	LS		$ 12,000.00
Mobilization	LS	LS		$ 7,000.00
Water Pollution Prevention (inc. turbidity control)	LS	LS		$ 24,000.00
Access	LS	LS		$ 10,000.00
Dewatering	LS	LS		$ 24,000.00
Grading Operations				
Survey Control - 2 Person Crew	DAY	20	$ 600.00	$ 12,000.00
Excavation (swales or as needed)	CY	500	$ 6.00	$ 3,000.00
Fill - Import and Place, inc. compaction	CY	6920	$ 20.00	$ 138,400.00
Fill - Overdredged Material	CY	0	$ 20.00	$ -
Substrate Preparation	AC	4.55	$ 1,500.00	$ 6,825.00
Topsoil - Import and Place - 12" depth	CY	6163	$ 50.00	$ 308,150.00
Add'l cost for specialized equipment	LS	LS		$ 45,637.50
Grading Total				**$ 514,012.50**
Bank Stabilization				
Rock Placement	CY	318.5	$ 30.00	$ 9,555.00
12" Coir Fascine	LF	3185	$ 25.00	$ 79,625.00
Vegetated Coir Mattress	LF	3185	$ 13.50	$ 42,997.50
Coir-wrapped lifts w/ live material	LF	318.5	$ 23.00	$ 7,325.50
Erosion Control - mulch, seed, etc	LS	LS	$36,000.00	$ 36,000.00
Bank Stabilization Totals				**$ 175,503.00**
Stream Bank Restoration/Stabilization				
Includes combination of coir fascines, vegetated coir mattress, geotextiles, rock and live material	LF	1675	$ 150.00	$ 251,250.00
Stream Bank Restoration Total				**$ 251,250.00**
Wetland Planting				
Wetland Planting	AC	4.55	$42,000.00	$ 191,100.00
Upland Planting	LS	LS		$ 19,110.00
Goose Fencing	LF	3185	$ 3.00	$ 9,555.00
Planting Total				**$ 219,765.00**
Monitoring/Plant Replacement	YR	3	$ 5,000.00	**$ 15,000.00**
Preliminary Total				**$ 1,252,530.50**

Alternative 2

Under alternative 2 both the footprint and elevation of all impacted areas would be restored to their pre-cleanup condition. This alternative assumes that restoration of the areal extent of habitats would also restore their functions and values. Therefore, a practicable means of achieving 1:1 replacement of functions and values is to return impacted areas to existing grade and emulate existing plant distributions by replanting. This objective simplifies the quantification of certain elements of the restoration design in terms of fill required and planting schemes. Approximately the same amount of fill would be required that is dredged and excavated (approximately 120,000 CY). As well, from the analysis of habitats impacted, approximately 15.5 acres of vegetated intertidal would require regrading and replanting to ensure their 1:1 replacement. The functional replacement of mudflat areas would also be achieved by backfilling and stabilizing mudflat/subtidal interfaces as needed. Figure A-2 highlights these sites and provides a brief summary of the extent and estimated materials and labor cost of restoration activities. Table A-5 summarizes estimated construction costs.



Restoration Design Elements

- 120,000 CY Total (Subgrade and Topsoil)
- 30,000 LF of Stabilization Treatments
- 15.36 Acres Planted with Appropriate Wetland Vegetation

Total Cost Estimate
(Materials and Labor): $6,600,000

Figure A-2

NEW BEDFORD HARBOR SUPERFUND SITE
Restoration Basis of Design/
Design Analysis Report
December 2002
Map of Alternative 2 Restoration Sites

Table A-5. Preliminary Construction Cost Estimate for Alternative 2. Costs include materials and labor and exclude inflation and contingencies.

ITEM	UNIT	QTY	PRiCE	TOTAL
Permits	LS	LS		$ 15,000.00
Mobilization	LS	LS		$ 15,000.00
Water Pollution Prevention (inc. turbidity control)	LS	LS		$ 50,000.00
Access	LS	LS		$ 20,000.00
Dewatering	LS	LS		$ 50,000.00
Grading Operations				
Survey Control - 2 Person Crew	DAY	60	$ 600.00	$ 36,000.00
Excavation (swales or as needed)	CY	1500	$ 6.00	$ 9,000.00
Fill - Import and Place, inc. compact.	*CY*	*12093*	*$ 20.00*	*$ 241,860.00*
Fill - Overdredged Material	CY	80548	$ 20.00	$ 1,610,960.00
Substrate Preparation	AC	15.36	$ 1,500.00	$ 23,040.00
Topsoil - Import and Place - 12" depth	CY	24780	$ 50.00	$ 1,239,000.00
Add'l cost for specialized equipment	LS	LS		$ 151,290.00
Grading Total				**$ 3,311,150.00**
Bank Stabilization				
Rock Placement	CY	2852.3	$ 30.00	$ 85,569.00
12" Coir Fascine	LF	28523	$ 25.00	$ 713,075.00
Vegetated Coir Mattress	LF	28523	$ 13.50	$ 385,060.50
20" Diameter Coir Fascine (at mudflat-subtidal interface	LF	15773	$ 50.00	$ 788,650.00
Coir-wrapped lifts w/ live material	LF	2852.3	$ 23.00	$ 65,602.90
Erosion Control - mulch, seed, etc	LS	LS	$ 50,000.00	$ 50,000.00
Bank Stabilization Totals				**$ 2,087,957.40**
Stream Bank Restoration/Stabilization				
Includes combination of coir fascines, vegetated coir mattress, geotextiles, rock and live material	LF	1675	$ 150.00	$ 251,250.00
Stream Bank Restoration Total				***$ 251,250.00***
Wetland Planting				
Wetland Planting	AC	15.36	$ 42,000.00	$ 645,120.00
Upland Planting	LS	LS		$ 64,512.00
Goose Fencing	LF	28523	$ 3.00	$ 85,569.00
Planting Total				**$ 795,201.00**
Monitoring/Plant Replacement	YR	3	$ 12,000.00	**$ 36,000.00**
Preliminary Total				**$ 6,631,558.40**

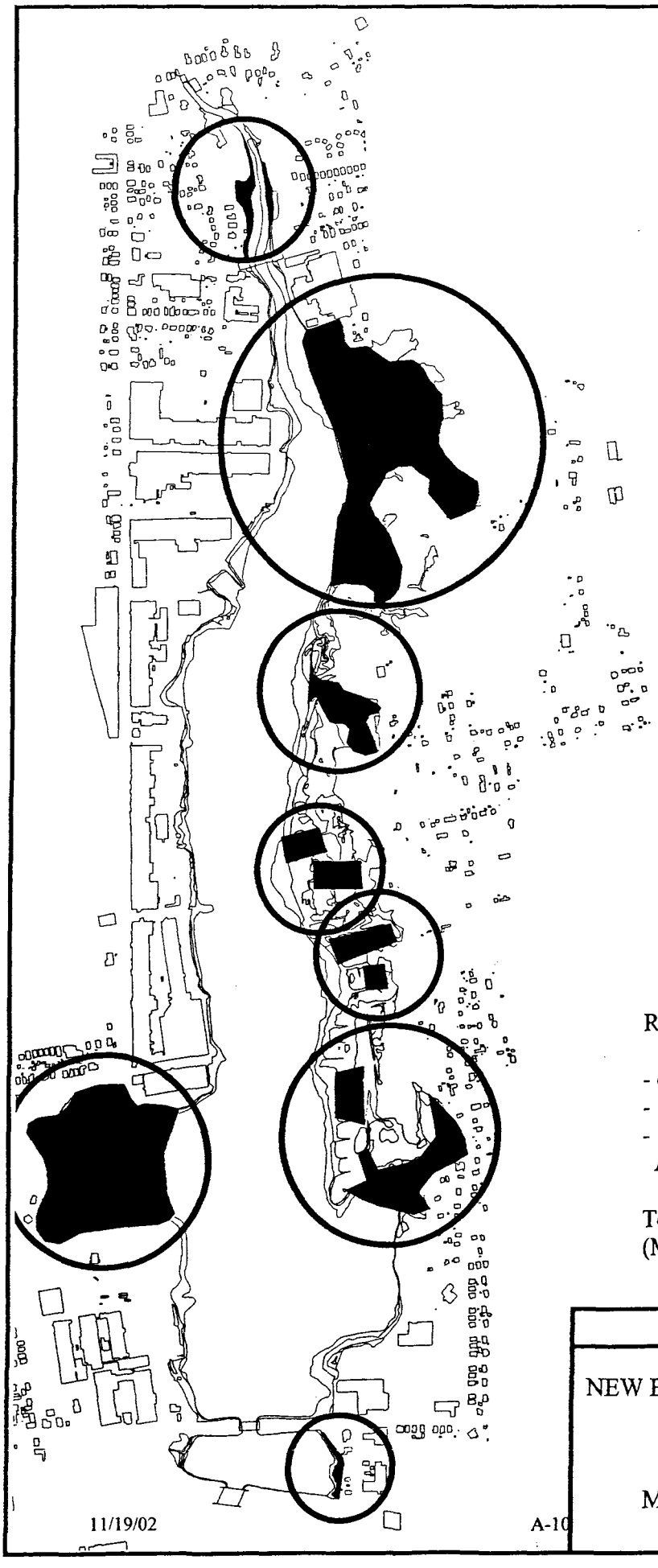
Alternative 3

Under alternative 3 wetland functions and values of the Upper Harbor would be restored on a net basis across wetland areas. This alternative would restore functions and values without necessarily replicating the actual existing grade and distribution of each area affected (as in alternative 2). This alternative may be more practicable and technically feasible by including "out-of-kind" elements, such as marsh and mudflat expansion in certain areas, and re-distribution of some plant species through unrestored changes in grade and subsequent conversion of habitat type, such as conversion of high marsh to low marsh.

This alternative also recognizes that the restoration of some impacted areas may not perform desired functions. Knutson *et al.* (1986) found that created fringing shoreline marshes less than 20 feet (6 m) wide were not effective at providing shoreline stabilization. If low marsh areas were replicated along the shorelines of wetlands 1, 5, 8, and 12, they may not adequately protect the shoreline from erosion, and their establishment may not be ensured. Not only are the fringing low marshes in these areas less than 20 feet (6 m) wide in most locations, but these areas are also severely contaminated and will be deeply excavated (many spots will be excavated 3 feet (0.9 m)). Even if these areas are restored, they may provide little value for shoreline stabilization. Under alternative 3, impacted vegetated areas that are not restored would be balanced by expansion of vegetated intertidal habitat in other areas.

Natural marsh peats have been ranked as the best substrate for marsh planting (Shisler and Charett 1984). Use of donor substrates from off-site increases the risk of poor vegetation re-establishment. Therefore, it is proposed that where marsh peats are exposed post-cleanup, and where surface elevation remains in the upper intertidal range, surfaces would be replanted with appropriate high or low marsh species. This would both maximize potential for successful revegetation and minimize the need for donor substrate from off-site sources.

Figure A-3 highlights restoration sites under alternative 3 and provides a brief summary of the extent and estimated materials and labor cost of restoration activities. Table A-6 summarizes estimated construction costs. Note that not all areas are returned to pre-cleanup grade, nor is work performed in all areas impacted.



Restoration Design Elements

- 62,000 CY Total (Subgrade and Topsoil)
- 19,000 LF of Stabilization Treatments
- 15.36 Acres Planted with Appropriate Wetland Vegetation

Total Cost Estimate
(Materials and Labor): $3,900,000

Figure A-3

NEW BEDFORD HARBOR SUPERFUND SITE
Restoration Basis of Design/
Design Analysis Report
December 2002
Map of Alternative 3 Restoration Sites

Table A-6. Preliminary Construction Cost Estimate for Alternative 3. Costs include materials and labor and exclude inflation and contingencies.

ITEM	UNIT	QTY	PRICE	TOTAL
Permits	LS	LS		$ 15,000.00
Mobilization	LS	LS		$ 15,000.00
Water Pollution Prevention (inc. turbidity control)	LS	LS		$ 50,000.00
Access	LS	LS		$ 20,000.00
Dewatering	LS	LS		$ 50,000.00
Grading Operations				
Survey Control - 2 Person Crew	DAY	60	$ 600.00	$ 36,000.00
Excavation (swales or as needed)	CY	1500	$ 6.00	$ 9,000.00
Fill - Import and Place, inc. compact.	CY	5982	$ 20.00	$ 119,640.00
Fill - Overdredged Material	CY	45000	$ 20.00	$ 900,000.00
Substrate Preparation	AC	15.36	$ 1,500.00	$ 23,040.00
Topsoil - Import and Place - 12" depth	CY	11280	$ 50.00	$ 564,000.00
Add'l cost for specialized equipment	LS	LS		$ 71,568.00
Grading Total				**$ 1,723,248.00**
Bank Stabilization				
Rock Placement	CY	1720.6	$ 30.00	$ 51,618.00
12" Diameter Coir Fascine	LF	17206	$ 25.00	$ 430,150.00
Vegetated Coir Mattress	LF	17206	$ 13.50	$ 232,281.00
20" Diameter Coir Fascine (at mudflat-subtidal interface	LF	3270	$ 50.00	$ 163,500.00
Coir-wrapped lifts w/ live material	LF	1720.6	$ 23.00	$ 39,573.80
Erosion Control - mulch, seed, etc	LS	LS	$ 50,000.00	$ 50,000.00
Bank Stabilization Totals				**$ 967,122.80**
Stream Bank Restoration/Stabilization				
Includes combination of coir fascines, vegetated coir mattress, geotextiles, rock and live material	LF	1675	$ 150.00	$ 251,250.00
Stream Bank Restoration Total				**$ 251,250.00**
Wetland Planting				
Wetland Planting	AC	15.36	$ 42,000.00	$ 645,120.00
Upland Planting	LS	LS		$ 64,512.00
Goose Fencing	LF	17206	$ 3.00	$ 51,618.00
Planting Total				**$ 761,250.00**
Monitoring/Plant Replacement	YR	3	$ 12,000.00	**$ 36,000.00**
Preliminary Total				**$ 3,888,870.80**

Alternatives Analysis

Total estimated materials and labor cost is $1.3 million for alternative 1, $6.6 million for alternative 2, and $3.9 million for alternative 3 (see Tables A-4, A-5, and A-6). The direct ecological benefits achieved by removing PCB-contaminated sediments and restoring impacted areas in the Upper Harbor include improved sediment and water quality; restored aquatic habitat; restored intertidal habitat; and restored adjacent upland habitat. Cleanup will also have significant positive benefits beyond the harbor environment and into Buzzards Bay and beyond. Removal of contaminated sediments will reduce further migration of contamination into the Lower and Outer Harbors and Buzzards Bay. In addition, habitat restoration that improves shellfish production, anadromous fish spawning, fish nursery functions, and habitat for migratory birds in the Upper Harbor will lead to "downstream" ecological improvements in areas to which these species migrate or disperse.

The anticipated ecological benefits vary among the three alternatives. Under all three alternatives, the same quantity and distribution of contaminated sediment will be dredged/excavated. Therefore, the three alternatives do not differ with respect to the direct ecological benefits of contaminant removal, such as decreases in contaminant concentration in the sediment and the water column; decreases in further migration of contamination into the Lower and Outer Harbor and Buzzards Bay; and decreases in biological toxicity impacts on the plant and animal life in and around the Upper Harbor. Reduction in these impacts should result in increases in survival, growth, and reproduction of plant and animal life.

The three alternatives do differ in three significant ways after cleanup and restoration: (1) the amount of intertidal and upland habitat that will be present, (2) the distribution of intertidal and adjacent upland areas among different habitat types, and (3) the functions and values of the remaining intertidal areas.

The amount of unvegetated and vegetated intertidal habitat that will be impacted and the amount that will remain are summarized in Table A-7. In alternative 1, since naturalization would be relied upon to revegetate much of the impacted vegetated habitats, all resulting non-vegetated areas are categorized as mudflats. These areas would function as such, until colonized by wetland vegetation. All estimates are based on the existing habitat distribution (Foster Wheeler Environmental 2001).

Cleanup will impact approximately 49 of the 103 intertidal acres in the Upper Harbor. Under alternative 2, all of the pre-cleanup amount of intertidal habitat would remain following restoration. Under alternative 1, 71 acres (69% of the original intertidal area) would remain following restoration. Under alternative 3, 88 acres (85% of the original extent of intertidal area) would remain following restoration.

Table A-7. Amount of Intertidal Habitat Before and After Cleanup and Restoration Under the Three Alternatives. (Based on December 2000 dredge quantity datalayer and Foster Wheeler Environmental (2001).)

Habitat Type	**Pre-cleanup (acres)**	**Habitat Impacted by Cleanup (acres)**	**Post-restoration (Remaining, Unimpacted Area + Restored Area) (acres)**		
			Alt 1	**Alt 2**	**Alt 3**
Palustrine Forested	0.03	0.00	0.03	0.03	0.03
Palustrine Scrub/Shrub	0.74	0.01	0.74	0.74	0.74
Palustrine Emergent Marsh	0.67	0.17	0.67	0.67	0.67
Phragmites Marsh	6.50	3.14	3.36	3.36	3.36
Scrub/Shrub	11.81	1.04	10.77	11.81	10.77
High Marsh	21.38	4.55	16.83	23.38	23.38
Low Marsh	16.04	6.44	9.60	17.18	18.23
Subtotal Vegetated Habitat	*57.18*	*15.36*	*42.01*	*57.18*	*57.18*
Beach	2.08	0.75	1.33	2.08	2.08
Stream (Creek)	0.60	0.35	0.60	0.60	0.60
Mudflat	43.54	32.89	27.00	43.54	28.04
Subtotal Unvegetated Habitat	*46.23*	*33.24*	*28.94*	*46.23*	*30.73*
Total	**103.40**	**48.60**	**70.94**	**103.40**	**87.91**
Percent of Total Pre-cleanup Area Remaining/Restored			69%	100%	85%
New Shallow Subtidal Habitat			32.46	0	15.49

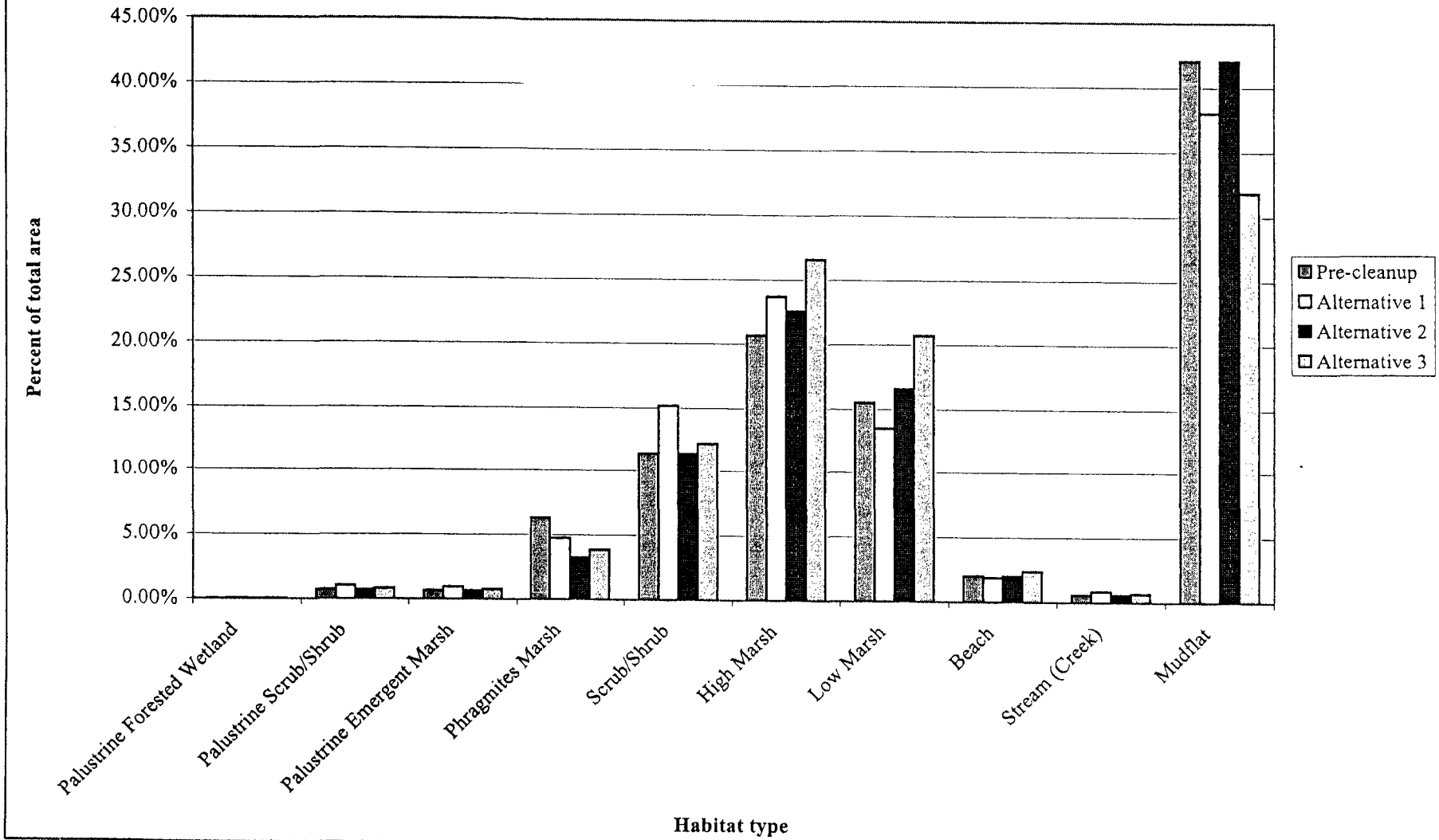
As discussed earlier (Table A-3), contamination and cleanup impacts are not equally distributed among habitat types (Tables A-8). Although 47% of the Upper Harbor intertidal will be dredged/excavated, much more of the unvegetated intertidal (72%) will be impacted than the vegetated intertidal (27%). Of the vegetated habitats, *Phragmites* marsh (48%) and low marsh (40%) will be the most impacted. Restoration effort is also not equally distributed among habitat types among the three alternatives. Under alternative 1 there is a decrease in the relative proportion of mudflat and low marsh. Under alternatives 2 and 3, the relative proportions of low marsh and high marsh increase and that of *Phragmites* marsh decreases. The difference between alternatives 2 and 3 is that these functions and values are achieved under alternative 2 by extensive restoration efforts and no net loss of mudflats, whereas under alternative 3, functions and values are achieved by some loss of mudflat that comes with an overall cost savings.

Table A-8. Relative Proportion of Intertidal Habitat Types Before and After Cleanup and Restoration Under the Three Alternatives. (Based on December 2000 dredge quantity datalayer and Foster Wheeler Environmental (2001).)

Habitat Type	**Pre-cleanup (% of total area)**	**Habitat Impacted by Cleanup (% of habitat type)**	**Post-restoration (% of total area)**		
			Alt 1	**Alt 2**	**Alt 3**
Palustrine Forested	0.03%	0.00%	0.04%	0.03%	0.03%
Palustrine Scrub/Shrub	0.72%	1.84%	1.05%	0.72%	0.84%
Palustrine Emergent Marsh	0.65%	25.78%	0.95%	0.65%	0.77%
Phragmites Marsh	6.29%	48.31%	4.74%	3.25%	3.82%
Scrub/Shrub	11.42%	8.84%	15.18%	11.42%	12.25%
High Marsh	20.68%	21.27%	23.72%	22.61%	26.60%
Low Marsh	15.51%	40.14%	13.53%	16.62%	20.74%
Subtotal Vegetated Habitat	*55.29%*	*26.86%*	*59.21%*	*55.29%*	*65.05%*
Beach	2.01%	35.93%	1.88%	2.01%	2.37%
Stream (Creek)	0.58%	57.58%	0.85%	0.58%	0.69%
Mudflat	42.11%	75.54%	38.06%	42.11%	31.90%
Subtotal Unvegetated Habitat	*44.71%*	*71.90%*	*40.79%*	*44.71%*	*34.95%*
Total	**100%**	**47.00%**	**100%**	**100%**	**100%**

Figure A-4 shows the distribution of intertidal area among habitat types under the three restoration alternatives. Despite the differential effects of restoration under the three alternatives, mudflat would remain the single most abundant habitat type, as it is currently. High marsh, low marsh, and scrub/shrub would remain the dominant vegetated intertidal habitat types.

Figure A-4. Relative Proportions of Habitats Pre-cleanup and Under Three Alternatives



Using the principal functions and values identified in the Upper Harbor (Foster Wheeler Environmental 2001), the resulting functions and values post-cleanup were estimated and compared among alternatives (Table A-9). In summary, under alternative 2, 117% of the original functions and values would be restored. Under alternative 1, 83% of pre-cleanup functions and values would be restored, and under alternative 3, 103% would be restored.

Table A-9. Principal Intertidal Functions and Values Expected Under the Three Alternatives, Compared with Pre-cleanup Levels. (Based on December 2000 dredge quantity datalayer and Foster Wheeler Environmental (2001).)

Functions and Values	**Pre-cleanup (acres)**	**Alternative 1 (acres)**	**Alternative 2 (acres)**	**Alternative 3 (acres)**
Shellfish Habitat[1]	60.19	37.21	61.33	46.87
Fish Nursery Habitat[2]	60.19	37.21	61.33	46.87
Toxicant Retention[3]	57.18	42.01	57.18	57.18
Nutrient Removal[4]	27.88	20.19	26.74	26.74
Shoreline Stabilization[5]	5.93	4.90	5.93	5.98
Wildlife Habitat[6]	92.77	64.20	95.91	80.42
Rare, Endangered, Protected Species Habitat[7]	0	potential	potential	potential
Production Export[8]	21.38	16.83	23.38	23.38
Recreation[9]	0	49.01	49.01	49.01
Uniqueness/Heritage	0	potential in site 3 or 4	potential in site 3 or 4	potential in site 3 or 4
Total Functions and Values Acres	325.51	271.55	380.80	336.45
% of Pre-cleanup Functions & Values		**83%**	**117%**	**103%**

1 Acres of mudflat, low marsh, and tidal creeks.
2 Acres of mudflat, low marsh, and tidal creeks.
3 Acres of vegetated intertidal.
4 Acres of high marsh and *Phragmites* marsh.
5 Acres of stable shoreline. Area derived by multiplying the length of stable shoreline that has a buffer of 20 feet (6 m or more) of vegetated habitat by 20 feet. A 20 foot (6 m) vegetated border is considered adequate to attenuate tidal, wind, and wave energies.
6 Acres of mudflat, low marsh, high marsh, and scrub/shrub.
7 Acres of habitat used by rare, endangered or protected species.
8 Acres of high marsh in wetlands 3 and 4.
9 Acres of impacted intertidal that currently have recreational value that cannot be realized due to PCB-contamination (from Foster Wheeler Environmental 2001). These acres would be available for recreation after cleanup.

This section compares the cost of alternative plans with the functions and values achieved to determine the most cost-effective alternative. Table A-10 summaries the cost/benefit values achieved under the different alternatives, where the index of benefit is number of acres providing specific functions and values. The cost per "functions and values acre" is $4,614 for the minimal restoration activities of

alternative 1, $11,559 under alternative 3, and $17,416 under alternative 2. The incremental cost/benefit (incremental to alternative 1) for alternative 3 is $40,616 and for alternative 2 is $49,236.

Table A-10. Cost/Benefit and Incremental Cost Analysis for the Three Alternatives. Benefit is measured in "functions and values" acres (see Table A-9). Alternatives are ordered by increasing cost for the incremental analysis.

	Alternative 1	**Alternative 3**	**Alternative 2**
Cost	$1,253,000	$3,889,000	$6,632,000
Function & Value (F&V) Benefit	271.55 F&V acres	336.45 F&V acres	380.80 F&V acres
Cost/F&V Benefit	$4,614/F&V acre	$11,559/F&V acre	$17,416/F&V acre
Incremental Cost (incremental to alt 1)		$2,636,000	$5,379,000
Incremental F&V Benefit (incremental to alt 1)		64.90 F&V acres	109.25 F&V acres
Incremental Cost/Incremental F&V Benefit		$40,616	$49,236

Constraints

There are several factors that may constrain the restoration work and its success, including:

- Loss of soil structural support and stability provided by the root structure of marsh plants removed during cleanup,
- Creation of conditions post-cleanup and restoration that favor invasion by *Phragmites,*
- Loss of mudflat stability where subtidal areas are not backfilled.

Existing marsh forms are maintained by the root structures of marsh plants, which cannot be mimicked. Therefore, new slopes, soils and planting schemes must be designed to compensate for the structural support lost in the absence of established plants. Enhanced stabilization may be needed at the interfaces between marsh and mudflat, if mudflats are not restored to pre-cleanup elevations.

Plant spacing is designed to ensure establishment; however at the border between the high marsh zone and upland, even dense planting schemes leave a considerable amount of bare surface area unvegetated and suitable for colonization by *Phragmites.* Due to its growth form, *Phragmites* has the ability to rapidly expand into the border between tidal marsh and upland plant communities.

In areas where the subtidal is deeply excavated, resulting in a steep transition between subtidal and mudflat, there is a continuing risk of loss of mudflat through slumping. To prevent further loss of mudflat, restoration must include stabilization measures between the subtidal and mudflat zones in these areas of steep transitions.

Opportunities

A number of opportunities that may enhance restoration activities have been identified, including:

- Onsite source of fill,
- Marsh excavation that does not fully remove accumulated peats,
- Excavation in *Phragmites* marshes,

- Natural sediment accumulation,
- Complementary restoration activities by others.

Restoration would require a large amount of uncontaminated fill. The source of fill material has not been identified yet. It is expected that the cost of acquiring fill and hauling it to the Superfund site would be significant. Opportunities to use clean material excavated, dredged, or overdredged from the site should be identified. USACE is currently characterizing some clean sediment and examining whether it would be suitable as fill material in the restoration of one or more habitat types. A determination of suitability would depend on the results of the characterizations of these clean sediments as well as existing marsh soils, when they become available, and an analysis of the costs of any needed amendments.

The inability to mimic natural marsh peat structure was mentioned in the previous section as a design constraint. However, in some cases excavation in the marsh areas will not remove the full depth of the existing, underlying peats. In these cases where peats remain after excavation, planting directly in these peats, rather than backfilling, may be sufficient to restore the marsh. However, this requires that the post-excavation elevation is appropriate for marsh habitat. Planting in remaining marsh peats may have the greatest chance for successful establishment, and this will reduce the amount of fill required.

Impacted *Phragmites* areas may also present an opportunity. Excavation and replanting with an alternative plant community may serve to contain the further spread of *Phragmites* invasion and locally enhance habitat value. Several studies have been conducted to assess the habitat impact of the invasion of *Phragmites* in the marsh landscape (Marks *et al.* 1994, Havens *et al.* 1997). A general conclusion has been that *Phragmites* offers very little in terms of habitat for avian and marine fauna alike. This claim has been cited as justification for the removal and replacement of *Phragmites* with *Spartina* species in restoration projects.

The Upper Harbor is a relatively low energy environment, and several areas are naturally accumulating sediment. These areas can be targeted for mudflat and low marsh expansion, and restoration techniques can be employed that would accelerate these natural processes. The beach areas in the Upper Harbor are most likely not natural and were probably created by placement of dredged materials. Thus, these beach areas might be places where habitat is not restored to its pre-cleanup condition, but rather to an alternative habitat that may serve to increase wetland functions and values.

Finally, restoration activities are planned by a number of agencies and public organizations, many of which will be funded through the New Bedford Harbor Trustees Council (NBHTC). NBHTC oversees the use of restoration funds obtained through settlement with the polluters for damages to the environment. There will be many opportunities to ensure that restoration activities are complementary and more cost effective on an overall basis.

APPENDIX B

MONITORING PLAN

MONITORING PLAN

A monitoring plan will be developed as part of the final restoration design. This section details plan elements that should be addressed in the final monitoring plan.

The primary purpose of monitoring is to provide data that will be used to improve project implementation and to increase the likelihood of achieving project goals. An investment in monitoring should be made in projects that have the means and structure to manage implementation and results over a period of time after initial inputs are made. For example, if there is no capacity in real time to correct factors that are impeding success and to take advantage of new opportunities, monitoring is not a worthwhile investment. Regardless if a project has the means and structure to invest in all "real time" monitoring, end-of-project results often must be evaluated. Evaluation of results after a specified period of time is often a legal requirement to certify that a project has complied with specific environmental regulations.

Before a final monitoring plan is developed, USEPA will need to clarify in which elements of monitoring they will invest. Basic elements of monitoring include the following:

- Measure inputs and outputs,
- Measure progress (in real time) towards restoration goal(s),
- Identify problems that may impede restoration and new opportunities that may facilitate restoration,
- Validate assumptions on which the restoration plan is based,
- Incorporate feedback on progress into ongoing restoration management using an adaptive management approach,
- Assess whether the overall restoration goal is met (certify end-of-project results),
- Capture the experience gained in the restoration project and make it available in a useful form to help others engaged in related restoration efforts.

Construction monitoring should include monitoring to ensure that construction contractors perform to agreed-upon standards, i.e. whether inputs have been achieved. For this restoration it will be critical to ensure that:

- Specified fill material is used in the correct locations,
- Design elevations are achieved,
- Stabilization treatments are installed correctly,
- Plant materials meet required quality standards,
- Correct species are planted in the right locations, at specified densities.

It is recommended that contracts for plant installation include standards for establishment success over a three-year period of time. This will require post-construction monitoring to measure that establishment targets are met and replacement plantings are installed where and when necessary.

Post-construction monitoring should include monitoring of the following through time:

- Elevations of impacted and restored areas – is subsidence occurring? Why?
- Stability (measured by erosion rates) shoreward of mudflat/low marsh and low marsh/high marsh interfaces.
- Vegetation establishment in bare and pre-planted coir fascines and mattress.
- Percent cover by species in impacted and restored (planted) areas.

Assumptions need to be validated. If assumptions fail to hold true, corrective action may be required. Examples of key assumptions of the restoration design include:

- Peat substrates that are exposed through excavation are suitable as planting substrates for marsh species without placement of fill material.
- Newly exposed peat substrates need to acclimatize overwinter before being suitable as planting substrates for marsh species.
- Increasing saltwater inputs and decreasing freshwater inputs to areas infested with *Phragmites* (prior to excavation) will increase the likelihood of post-restoration establishment of high marsh species.
- Impacted mudflats will be naturally re-colonized with desirable benthic organisms.
- Impacted but unrestored areas at low marsh and high marsh elevations will be naturally recolonized with desirable marsh vegetation.
- Operations of the Hurricane Barrier remain as they are.

General conditions that are known to impede or enhance habitat recovery should also be monitored to assist in analysis and interpretation of results. These include rainfall, storm events, freshwater inputs (flow of Acushnet River and intertidal creeks), tidal highs and lows, fires, CSO discharge parameters (size, frequency, location of discharges and water quality), and nutrient concentrations in harbor water should be monitored.

Finally, to measure the success of the restoration effort, a monitoring plan should include indicators that reflect the overall goal of the restoration design. In this project, the overall goal of the project is to restore function and value to the impacted intertidal habitats. Relevant, specific, measurable indicators of ecological function and value need to be selected, and specific restoration targets need to be agreed-upon for specific wetland areas. The wetlands delineation and functions and value study (Foster Wheeler Environmental 2002) identified the principal ecological functions and values provided by the Upper Harbor wetlands. The following table lists those functions and values and examples of measurable indicators.

Function or Value	**Examples of Indicators of Function or Value**
Shellfish Habitat	Quahog density
Fish Nursery Habitat	Use of habitat by fish (spawning; feeding by juveniles)
Toxicant Retention	Concentration of toxicants in live plant materials and sediments
Nutrient Removal	Plant production per unit area
Shoreline Stabilization	Percentage of shoreline stabilized by vegetation; Change in creek channel cross section; Change in shoreline geometry
Wildlife Habitat	Use by specific animal species; Aerial cover by vegetation;
Rare, Endangered, or Protected Species Habitat	Number of observations of rare, endangered, or protected animal species; Population size; Observations of breeding activity
Production Export	Plant production per unit area
Recreation	Use of area by public

Restoration targets should:

- Be specific to habitat types within wetland areas (1-13),
- Establish a timeframe over which progress is achieved,
- Identify achievable progress levels,
- Measurable with low levels of observer bias (i.e. objective not subjective measures),
- Meaningful with respect to restoration of desired functions and values of site.

For example, illustrative targets for restoration of shellfish and fish habitat might include (1) quahog density in restored mudflat in wetland 3 is 25% of the density of quahogs at a reference site in the Lower

Harbor within 3 years and 50% within 5 years, and (2) fish fry numbers in restored low marsh and high marsh sites at 50% of numbers at reference site within 5 years.

Clear descriptions of methods and data analysis will be developed. Emphasis should be placed on methods that are objective, so that changes in observers will not lead to bias in the results. It is critical that appropriate sample sizes and sampling intensities are chosen so that adequate degrees of freedom are available in the planned statistical analysis of results. Depending on the indicators and targets developed and whether reference sites will be used, baseline data may need to be collected before cleanup and during the period between cleanup and the implementation of restoration activities.

An adequate budget should be developed to support the monitoring activities, data analysis, report-writing, and dissemination of the results. Efforts can also be made to engage educational and research institutions in complementary research projects. Given the large scope of the cleanup and restoration activities in New Bedford, there may be sufficient interest in long-term results to justify regular meetings or conferences to share and review results of monitoring and other research. Provisions must be made to make monitoring data publicly accessible, and ideally an institution should be chosen to host the body of research results that will be produced over the short and long-term.

The collection and analysis of monitoring data ideally should be undertaken by the party responsible for the ongoing management of the restoration. Results of the monitoring should feed directly into timely decisions regarding maintenance and management of restoration work. If the party monitoring progress is different from the party responsible for ongoing management and maintenance, then a robust mechanism to share information between the parties must be developed and implemented.

Regarding the length of monitoring needed, it should be considered that if at the end of a set period (e.g. 5 years), the function and value targets have been achieved, the effort could be declared successful and monitoring may end. Longer-term monitoring, if necessary, could be less intensive and/or reduced in scope to focus on the targets not yet achieved.

Finally, the monitoring plan will specify the reports that are to be prepared, a clear assignment of responsibilities for preparation and review, and an appropriate schedule. Examples of reports that will be produced include:

- Baseline conditions post-cleanup,
- Construction monitoring,
- Post-installation plant establishment and replacement,
- Annual monitoring of outputs,
- Periodic evaluation of progress towards restoration goals, e.g. after year 5, 10, and 15,
- Photographic documentation of site conditions.