HUDSON RIVER PCBs REASSESSMENT FS

APPENDIX F

HABITAT REPLACEMENT PROGRAM DESCRIPTION

APPENDIX F
HABITAT REPLACEMENT

1. INTRODUCTION

This discussion presents conceptual measures intended to mitigate disturbances to aquatic and wildlife habitat resulting from implementation of a remedial alternative. The remedial alternative categories -- No Action, Monitored Natural Attenuation, Removal, and Capping with Dredging -- have been described in detail in this FS. The remedial alternative that would result in habitat disturbance requiring replacement measures are Removal and Capping with Dredging. These alternatives may potentially pose some or all of the following habitat disturbances:

- Removal or capping of substrate used as spawning and foraging habitat by fish and benthic invertebrate species;
- Displacement of benthic organisms;
- Loss of vegetation communities;
- Loss of freshwater wetlands acreage and wetland functional values; and
- Disturbance of riparian habitat and shoreline stability.

The remaining discussion on habitat replacement is organized as follows:

- Section 2 provides a general habitat description of the Upper Hudson River;
- Section 3 focuses on the objectives of the replacement;
- Section 4 presents the replacement concepts and their implementation; and
- Section 5 explores concepts for habitat replacement monitoring, evaluation, and adaptive management to confirm that the replacement objectives are achieved.

2. HABITAT DESCRIPTION

The Upper Hudson River is entirely freshwater and non-tidal and, in the context of this Feasibility Study, extends from the Federal Dam at Troy (RM 153.9) to the former Fort Edward Dam (RM 194.8). This area includes deeper water environments as well as shallower littoral zones characterized by aquatic vegetation and backwaters. Specific habitats include forested shoreline wetlands and transitional uplands, vegetated backwaters (emergent marsh and scrub-shrub wetlands), offshore shoals and channel, rock piles, tailwater, and major tributaries.

The river provides diverse habitats for all trophic levels of the river's ecosystem. Plants, plankton, aquatic invertebrates, fish, amphibians, reptiles, birds, and mammals use the Hudson River for feeding, reproduction, and shelter. In addition to the aquatic communities associated with the river, animals living in riparian, wetland, floodplain, and upland communities are also dependent on the river.

During the August 1992 ecological field sampling effort, a baseline vegetative survey was performed at nine stations in the Upper Hudson River. A plant ecologist conducted the survey by identifying dominant submergent and emergent vegetation observed in intertidal, bank, and upland areas, when possible. A list of species identified throughout the field investigation is provided in Table B-6 of the Baseline Ecological Risk Assessment (USEPA, 1999).

Similar plants were present at the nine Upper Hudson River stations, including nearly all the same dominant submergent plants (*e.g.*, wild celery, water chestnut). The most prevalent aquatic plant noted was water chestnut (*Trapa natans*), which was abundant along nearly the entire river. Water chestnut is an introduced species, whose rosettes of floating leaves crowd together in mats, choking freshwater shallows, limiting boat access, and shading out other submergent vegetation (Stanne *et al*., 1996). Some locations in the Upper Hudson (*e.g.*, side channel around Griffin Island) were inaccessible due to the thick mats of water chestnut encountered during the ecological sampling. While it is an invasive species, water chestnut beds may harbor large populations of invertebrates and young fish.

Emergent species (*e.g.*, arrow arum, pickerelweed) were located at about half the stations sampled. Generally, areas of the river with reduced flow velocity allow fine-grained sediments to settle out, providing favorable conditions for plant growth. Vegetation observed on the river bank varied, but a majority of locations included silver maple (*Acer saccharinum*) and white ash (*Fraxinus americana*).

As indicated in Table 2-2 of the Revised ERA (USEPA 2000), the dominant macroinvertebrates found in the 1992 ecological sampling were isopods, midges, worms, amphipods, and clams. Vertebrates potentially found in or along the Upper Hudson River are also listed in Section 2 of the Revised ERA. Fish and fish aggregations observed in the Upper Hudson (NYSDEC, 1989) are listed in Tables 2-1 and 2-2. Amphibians, reptiles, birds, and mammals potentially found along the Hudson River are listed in Tables 2-3 to 2-6 of the Revised ERA (USEPA, 2000).

For the purpose of discussing conceptual habitat replacement measures, the physical habitats of the river have been delineated into the following zones:

- **Deep river** - areas of the river that are deeper than the photic zone (*i.e*., depth to light penetration), defined here as a depths exceeding six feet. The substrate of the deep open river zone is largely characterized as “non-cohesive” and is not vegetated.

- **Shallow river** - open waters of the river that are within the photic zone (*i.e*., depths less than six feet). A mixture of substrate types (cohesive and non-cohesive) are present in the shallow river.

- **Emergent wetlands** - emergent wetlands that occur in areas of the river with reduced flow velocity (vegetated backwaters) that allow fine-grained sediments to settle out.

- **River bank** - the riverine shoreline or riparian zone (vegetated and non-vegetated).

3. HABITAT REPLACEMENT OBJECTIVES

This section presents specific objectives of the habitat replacement concepts.

3.1 Restore Fish Habitat

The Removal and Capping with Dredging alternatives would disturb the riverine and wetland habitats that fish utilize for spawning, shelter, and foraging. Specific goals of habitat replacement are to provide *substrate* suitable for fish spawning habitat and adequate *cover* to serve as shelter and foraging habitat.

3.1.1 Substrate

The textural composition of the substrate influences the survival and emergence of the embryos of many fish species. Substrate texture affects the pore size and permeablilty of the sediments, which, in turn, regulate intragravel water velocity and oxygen transport to incubating embryos and control intragravel movement of newly hatched fish (Colorado Cooperative Fishery Research Unit, 1984).

The ideal spawning habitat for many species is a combination of certain hydraulic conditions and a complex mixture of sediment sizes. Fish seek substrate that is free of boulders (because nests cannot be formed in them), low in fine (cohesive) sediments (which reduce permeability), and high in gravel (which is permeable and can be moved). Some fine sediments may be important to protect eggs and larvae from predators and high subsurface velocities, and to keep them in the substrate during floods. Substrate type is not so critical to nest builders and guarders (*e.g.*, species of sunfish) as it is to other species that do not guard the eggs but cover them and leave. Many fish species require a vegetation substrate to which eggs stick during embryo development (Colorado Cooperative Fishery Research Unit, 1984).

3.1.2 Cover

Places where fish rest, hide, and feed are cover. Cover serves to visually isolate fish, which increases the number of territories in the same place. Less commonly, cover is defined as vegetation growing over the substrate. Although vegetative cover may not provide concealment, it is necessary for reproduction of some species. Morphological features such as large rocks, pocket pools and deep pools, and undercut banks; and aquatic and overhanging vegetation, riparian communities that provide material for brush piles, and logs define the amount and type of cover (Colorado Cooperative Fishery Research Unit, 1984).

3.2 Replace Benthic Habitat and Encourage Recolonization

A second objective of the habitat replacement concept is to replace substrate that serves as habitat for benthic macroinvertebrates. Benthic macroinvertebrates process organic materials contributing to energy and nutrient recycling but, more importantly, they serve as the foundation in aquatic food chains. The provision of a variety of benthic habitat types (*i.e.*, sand, gravel, and rooted vegetation that epifaunal invertebrates may colonize) would encourage the recolonization of a diverse benthic invertebrate community. Substrate heterogeneity and stability are the key factors in providing for increased abundance and species richness of colonizing benthic invertebrate communities.

3.3 Replace Vegetation Communities

A third objective of the habitat replacement concept is to replace vegetation communities that are disturbed during remediation activities. These communities include rooted and non-rooted aquatic vegetation, as well as shoreline trees. Vegetation is a key component of the riverine environment, being the primary producer and a significant factor in maintaining channel stability. Vegetation fixes solar radiation, making this energy available for a wide range of herbivores including invertebrates, fish, birds, and mammals. The aquatic vegetation can be important in aerating the water, providing shelter, and providing a spawning or egg-laying medium for fish and freshwater invertebrates. Emergent and marginal plants provide shelter and nesting habitat for a variety of fauna including birds and invertebrates. The vegetation is also important in the consolidation of the river bed and banks (Wade, P.M. in Peats and Calow, 1996).

3.4 Replace Wetlands

A fourth objective is to replace wetlands of at least equal value to those disturbed during implementation of a remedy The replaced wetlands would be designed to provide several functions and values; specifically, wildlife habitat, flood control, and water quality improvement at levels equivalent to those currently provided by the existing wetlands.

3.5 Stabilize Shorelines

The final objective of the habitat replacement concept is to provide for bank stability following implementation of remediation activities. Bank stability has an influence on the habitat quality of the river. Bank erosion contributes silt, which reduces light penetration, smothers fish eggs and benthic macroinvertebrates, fills pools, and may cause oxygen depletion in the water column. Slope, substrate type, soil-binding by vegetation roots, bank rock content, and extent of disturbance determine bank stability. Banks with well-developed riparian vegetation are protected from erosion and provide a source of food for small fish (Colorado Cooperative Fishery Research Unit, 1984). Small fish use slower water along margins of rivers and depend on terrestrial organisms from shoreline vegetation for food because most aquatic drift organisms escape them.

4. REPLACEMENT CONCEPTS

Habitat replacement concepts have been formulated for the following four zones typical of the stretch of the Hudson River extending from the Federal Dam to Rogers Island:

- Deep river,
- Shallow river,
- Emergent wetlands, and
- River bank.

Habitat replacement concepts have not been formulated for deep river areas with bottom depths greater than 12 feet. At depths below 12 feet, areas subject to the removal of PCB-contaminated sediments would not be capped or backfilled. For this reason and due to the absence of rooted aquatic vegetation at these depths, opportunities for replacement would be limited, would incur additional costs, and would accrue only marginal ecological benefits. Estimated quantities and costs for planting and seeding replacement are presented in Table F-1.

4.1 Deep River Habitat Replacement

Deep river areas are characterized by bottom depths below the photic zone, the illuminated water column and river bottom to which photosynthesis is restricted. The depth of light penetration in the Upper Hudson River varies on both temporal and spatial scales. However, for the purpose of formulating habitat replacement concepts, the typical depth of the photic zone is assumed to be approximately six feet. Therefore, deep river habitat replacement concepts pertain to river areas with post-backfilling depths ranging between 6 and 12 feet.

Habitat replacement objectives for the deep river zone are to:

- replace fish habitat, and
- replace benthic habitat and encourage recolonization.

Habitat replacement methods applicable to the deep river zone are limited. Due to the absence of sufficient light levels for photosynthesis, establishment of rooted aquatic vegetation is not an option. The need to maintain the navigability of the river, and avoid the creation of obstructions and hazards to boat traffic, precludes the extensive deployment of hard structures. For these reasons, appropriate replacement methods are restricted to the placement of suitable substrate and the limited deployment of boulder clusters.

4.1.1 Backfill Materials and Placement

Most of the remediated area within the deep river zone would be backfilled with a one-half-foot deep layer of gravel over a one-half-foot deep layer of sand. (For the purpose of calculating remediation costs, this backfill cross-section is assumed for all remediation areas in this zone.) The intent is to return the river bottom to a stable, well-sorted substrate, often a critical requirement for fish spawning and secondary production by aquatic insects. Although a gravel substrate would be suitable for most fish species in this zone, the ideal spawning habitat for many species is a complex mixture of sediment sizes. Therefore, a one-foot deep layer of sand would be placed in some locations to create a mosaic of substrates. Backfill comprising fine sediments would not be placed in the deep river zone. However, over time silt and fine sands would be transported into the backfilled areas by currents, gradually increasing the heterogeneity of the substrates.

4.1.2 Boulder Clusters

Clusters of boulders would be placed in selected locations, primarily to provide cover to serve as fish shelter and foraging habitat. In locations with higher average flows, generally those exceeding two feet per second, boulder clusters would also create scour holes and areas of reduced velocity immediately down river from the boulders. Boulder clusters would be placed only on gravel backfill, where they would be most effective; not on sand backfill, where they would tend to be buried by transported sediment. To preclude conflicts with the use of the river for navigation, boulder clusters would be placed within depressions on the river bottom, both natural depressions and those resulting from sediment removal and backfilling operations.

4.2 Shallow River Habitat Replacement

The shallow river zone comprises river areas within the photic zone, generally extending between bottom depths down to six feet and the shoreline, but excludes emergent wetlands and river banks. This zone encompasses both shallow water areas within the main and secondary river channels, and shoals, bars and partially enclosed, sheltered coves adjacent to the channels. It includes both predominantly unvegetated areas, and areas containing rooted submerged or rooted floating aquatic vegetation. (Areas dominated by emergent vegetation comprise the emergent wetland zone; its replacement is discussed in Subsection 4.3, below.)

Habitat replacement objectives for the shallow river zone are to:

- replace fish habitat,
- replace benthic habitat and encourage recolonization, and
- replace vegetation communities.

The availability of sufficient light for photosynthesis enables the employment of habitat replacement methods that require the establishment of rooted aquatic vegetation, to replace vegetation removed during remediation and restore its habitat value. As for the deep river zone, the maintenance of navigation must be considered. The placement of obstructions or hazards to both commercial and recreational craft must be avoided; therefore, the extensive deployment of hard structures is precluded.

4.2.1 Backfill Materials and Placement

The remediated area within the shallow river zone would be backfilled with two substrate cross-sections:

- one-half foot deep layer of gravel over a one-half foot deep layer of sand, and
- a one-foot deep layer of sand.

Alternating patches of the two substrate cross-sections would be placed in the remediation area to form a mosaic of surface substrates, creating a mixture of sediment sizes. The actual location of substrate placement within the shallow river zone would be delimited during the project design phase. (For the purpose of calculating remediation costs, it is assumed that about one-half of the remediation area would be backfilled with a one-half-foot deep layer of gravel over a one-half-foot deep layer of sand, and one-half would be backfilled with a one-foot deep layer of sand.) Although backfill comprising fine sediments would not be placed in this zone, over time silt and fine sands would be transported into the backfilled areas by currents, gradually increasing the heterogeneity of the substrates.

4.2.2 Boulder Clusters

Clusters of boulders would be placed on gravel backfill in selected locations. To preclude conflicts with the use of the river for navigation, boulder clusters would be placed within depressions on the river bottom.

4.2.3 Rooted Aquatic Vegetation

To replace aquatic vegetation communities within the shallow river zone, patches within the remediation area would be planted with rooted aquatic vegetation. River currents in the shallow river zone preclude the establishment of non-rooted vegetation. Species selected would be limited to non-invasive rooted submerged and rooted floating aquatic vegetation, currently occurring in or native to the Upper Hudson River. Species that are valuable to fish and wildlife would be planted and include the following representative candidate species:

- rooted submerged aquatic vegetation such as spatterdock (*Nuphar advena*), long-leaved pond weed (*Potamogeton nodosus*), redhead grass (*P. perfoliatus*), and wild celery (*Vallisneria americana*); and

- rooted floating aquatic vegetation such as fragrant water lily (*Nymphea odorata*), water smartweed (*Polygonum amphibium*), and duck potato (*Sagittaria latifolia*).

Only locations backfilled with the sand substrate cross-section would be planted to rooted aquatic vegetation; gravel surface substrates would not be planted. Planting on sand surface substrates would be implemented to establish a mosaic of vegetation cover, both in terms of species composition and plant cover density. Plant cover densities ranging between 0 and 100 percent would be targeted. Plant materials (species, planting stock, and availability), planting locations, and planting densities would be specified during the project design phase.

4. 3 Emergent Wetland Habitat Replacement

Emergent wetlands are characterized by erect, rooted, herbaceous hydrophytic plants, excluding mosses and lichens. This vegetation is present for most of the growing season in most years. Emergent wetlands occur in areas of the river with reduced flow velocity that allow fine-grained sediments to settle out. While there are forested riparian wetlands adjacent to the river, remediation activities would not occur there and therefore, this habitat replacement concept does not address forested wetlands.

Habitat replacement objectives for emergent wetlands are to:

- replace fish habitat,
- replace benthic habitat and encourage recolonization,
- replace vegetation communities, and
- replace wetlands, specifically:
  - re-establish wetland function and values (habitat, flood control, water quality), and

-- re-create habitat diversity through provision of emergent marsh with interspersed deep water pools, and scrub-shrub wetland habitat.

4.3.1 Emergent Marsh

Following remediation activities, the area would be regraded to achieve pre-remediation elevations. The area would be subsequently revegetated through broadcasting of seed coupled with selected plantings as appropriate. Species that are valuable to fish and wildlife would be established and include the following representative candidate species:

- persistent emergents such as cattails (*Typha* spp.), bulrushes (*Scirpus* spp.), saw grass (*Cladium jamaicense*), and sedges (*Carex* spp.);

- broad-leaved emergents such as dock (*Rumex mexicanus*), waterwillow (*Decodon verticillatus*), and many species of smartweeds (*Polygonum* spp.); and

- nonpersistent emergents such as wild rice (*Zizania aquatica*), arrow arum (*Peltandra virginica*), pickerelweed (*Pontederia cordata*), and arrowheads (*Sagittaria* spp.).

Interspersed within the emergent marsh would be pockets of deep pools of varying size. These pockets would be vegetated with floating vascular plants such as water lettuce (*Pistia stratiotes*), and rooted vascular aquatic plants including horned pondweed (*Zannichellia palustris*), ditch grasses (*Ruppia* spp.), and wild celery (*Vallisneria americana*).

4.3.2 Scrub-Shrub Wetlands

Along the shoreline fringe of the emergent marshes, scrub-shrub wetlands would be established. Shrub-scrub wetlands are dominated by woody vegetation less than 6 m (20 feet) tall. The vegetation includes true shrubs, young trees, and trees or shrubs that are small or stunted because of the hydric conditions. Typical candidate species would include alders (*Alnus* spp.), willows (*Salix* spp.), buttonbush (*Cephalanthus occidentalis*), red osier dogwood (*Cornus stolonifera*), honeycup (*Zenobia pulverulenta*), and young trees of species such as red maple (*Acer rubrum*) or black spruce (*Picea mariana*).

4.4 River Bank Habitat Replacement

River banks immediately adjacent to sediment removal locations may require stabilization to control bank erosion, slumping, and sloughing. Replacement objectives for the river bank zone are to:

- replace vegetation communities, and
- stabilize shorelines.

For the purpose of calculating remediation costs, the stabilization methods employed are assumed to be a function of the depth of sediment removal in the river adjacent to each shoreline segment. Specifically, the following strategy has been applied:

- adjacent to river locations where less than 2 feet of sediment would be removed, no bank stabilization would be employed;

- adjacent to locations where 2 or 2.5 feet of sediment would be removed, dormant mattresses of plant materials would be employed to stabilize the river banks; and

- adjacent to locations where 3 or more feet of sediment would be removed, timber or log revetments in combination with plant material mattresses would be employed.

However, the actual river bank stabilization method to be employed along each shoreline segment will be specified during the project design phase. Both vegetative methods and structural-vegetative methods would be employed, the choice being dependent on the extent of bottom sediment removal in the adjacent river and the magnitude of erosive forces.

4.4.1 Vegetative Methods

Vegetative methods would be employed on river banks adjacent to locations where bottom sediments would be removed to only shallow depths (estimated to be less than approximately three feet), along shorelines subject to low or moderate erosion. Vegetative methods that may be employed are the following (Federal Interagency Stream Restoration Working Group, 1998):

- **Bank shaping and planting** - Regrading river banks to a stable slope, placing topsoil and other materials needed for sustaining plant growth, and selecting, installing, and establishing appropriate plant species.

- **Dormant post plantings** - Plantings of cottonwood, willow, poplar, or other species embedded vertically into river banks to reduce flow velocities near the slope face and trap sediment.

- **Brush mattresses** - Combination of live stakes, live facines, and branch cuttings installed to cover and physically protect river banks; eventually to sprout and establish numerous individual plants.

- **Vegetated geogrids** - Alternating layers of live branch cuttings and compacted soil with natural or synthetic geotextile materials wrapped around each soil lift to rebuild and vegetate eroded river banks.

Where moderate scour by currents or ice is anticipated at the toe of the river bank, vegetative methods (to stabilize the upper bank) would be used in combination with structural-vegetative methods employed as toe protection. Along banks subject to higher magnitudes of toe erosion, vegetative methods may be employed in combination with structural methods (rock riprap or stone toe protection) to protect the toe or lower slope of the river bank.

4.4.2 Structural-Vegetative Methods

Adjacent to locations where bottom sediments would be removed to greater depths (about three feet or greater), structural-vegetative methods would be employed. Structural-vegetative methods also would be employed on river banks adjacent to locations where bottom sediments would be removed to shallow depths, but the shoreline is subject to high erosion. Structural-vegetative methods that may be employed are the following (Federal Interagency Stream Restoration Working Group, 1998):

- **Vegetated gabions** - Wire-mesh, rectangular baskets filled with small to medium size rock and soil and laced together to form a structural toe or sidewall. Live branch cuttings are placed on each consecutive layer between the rock filled baskets to take root, consolidate the structure, and bind it to the slope.

- **Rock riprap with joint plantings** - Live stakes tamped into joints or openings between rocks which have been installed on a slope or while rock is being placed on the slope face.

- **Live cribwalls** - Hollow, box-like interlocking arrangements of untreated log or timber members filled above baseflow with alternate layers of soil material and live branch cuttings that root and gradually take over the structural functions of the wood members.

Where appropriate, structural-vegetative methods would be used in combination with soil bioengineering systems and vegetative plantings to stabilize the upper bank and provide a regenerative source of river bank vegetation.

5. MONITORING AND ADAPTIVE MANAGEMENT CONCEPTS

Habitat replacement monitoring, evaluation, and adaptive management would be undertaken to assess the success of the implemented habitat replacement actions and attainment of the habitat replacement objectives. A monitoring plan will be developed to assess the performance of the habitat replacement actions relative to the replacement objectives, and provide information that can be used to improve the implementation and performance of the actions. Information obtained through monitoring would be evaluated to confirm that the replacement actions are achieving the objectives. Adaptive management would facilitate the identification of problems, selection of corrective actions, and execution of midcourse corrections to the replacement actions during their implementation.

5.1 Monitoring Concepts

Rivers and associated wetland habitats are complex, highly productive systems with diverse and abundant populations of animals and plants. To attempt to measure and understand every component of habitat functioning is beyond the scope of normal operating guidelines. However, early diagnoses of failing ecological functions are difficult to recognize, the most appropriate adjustments are not well understood, and the results of alterations may not be evident for long-time periods. Consequently, a long-term monitoring plan would be essential to develop an information base for continuous comparisons of functional status and biological integrity of the replaced habitats (Hammer, 1992).

The monitoring plan need not be elaborate or lengthy but it must provide clear documentation of monitoring objectives, organizational and technical responsibilities, specific tasks, methods and basic instructions, quality assurance procedures, schedules, reports, and resource requirements (Hammer, 1992). Since the life of the project would span many years and numerous personnel changes, written documentation would be essential so that data sets are at least comparable if collection or analysis procedures change, as would likely happen. A carefully defined monitoring plan should be available to serve as a benchmark for data collection throughout the life of the project (Hammer, 1992).

The monitoring program would include pre-construction baseline monitoring, monitoring during construction, and post-construction long-term monitoring.

5.1.1 Pre-Construction Baseline Monitoring

Biotic inventories (plants, benthic invertebrates, and fish and wildlife species) should be conducted to establish pre-remediation conditions. This baseline monitoring would result in animal species lists, descriptions of the structure of plant communities, and quantitative plant and animal data for selected areas of the river. A community-based Habitat Suitability Index (HSI) model (developed for riverine and riparian systems) could be utilized to provide a quantified assessment of existing wildlife habitat conditions, and a projection of expected conditions for up to 50 years into the future.

5.1.2 Monitoring During Construction

Construction activities would be in progress during the final baseline study sampling period. Plant inventories would be completed prior to implementation of remediation activities. Animal inventories would occur within and outside of impact areas, prior to and during implementation of remediation activities. Further, plantings/seedling survival studies would be conducted at regular intervals. Monitoring would emphasize survival, growth, and species composition. An ecologist would be present during major construction events to ensure that there were no unnecessary impacts to wildlife or other elements of the ecosystem.

5.1.3 Post-Construction Long-term Monitoring

Long-term monitoring and reports on the habitat replacement effort would be prepared annually. Permanent transects and/or sampling sites would be established from which to conduct biotic inventories. As with the baseline studies, community-based HSI models would be used during long-term monitoring to assess the progress of wildlife habitat development. A river habitat quality analysis would be conducted annually. Physical habitat structure would be measured along a series of transects. These measurements would be compared to pre-remediation conditions. Fish and benthic macroinvertebrate samples would be collected within the same sample reaches, and Index of Biotic Integrity (IBI) and Macroinvertebrate Biotic Index (MBI) scores calculated.

5.2 Evaluation and Adaptive Management Concepts

A habitat replacement evaluation and adaptive management program will be formulated during the project design phase, concurrent with formulation of the monitoring plan. Habitat replacement evaluation would determine whether the replacement actions are achieving the specified replacement objectives. This would facilitate the identification of problems before they become prohibitively complex or expensive to correct.

Habitat replacement evaluation and adaptive management in combination would enable the adjustment or redesign of habitat replacement actions, based on their success or failure in one location, before they are executed in other locations later during replacement implementation. Adaptive management would entail adjusting habitat replacement implementation as new information becomes available (Federal Interagency Stream Restoration Working Group, 1998).

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Table F-1
Habitat Replacement Vegetation Seeding/Planting Quantities and Costs
Quantity and Cost Assumptions

Shallow River Habitat Replacement

Planting	Unit	Unit Cost	Planting Cost (per plant)	Spacing (Ft O.C.)	Quantity Per Acre		Per Acre Cost
Deep Pools	Plant	$1.00	$2.00	2	10,890		$32,670

Emergent Wetland Habitat Replacement

Seeding	Unit	Unit Cost	Coverage (SF)	Quantity Per Acre	Materials Cost	Seeding Cost (per acre)	Per Acre Cost
Wetland Rush/Bulrush Mix	pound	$225.00	43,560	1.0	$225	$2,600	$2,825
Wetland Grass Seed Mix	pound	$7.50	2,900	15.0	$113	$2,600	$2,713

Planting	Unit	Unit Cost	Planting Cost (per plant)	Spacing (Ft O.C.)	Quantity Per Acre		Per Acre Cost
Marsh	Plant	$0.50	$2.00	2	10,890		$27,225
Deep Pools	Plant	$1.00	$2.00	2	10,890		$32,670
Scrub-Shrub	Plant	$1.00	$2.00	5	1,742		$5,227

River Bank Restoration

Seeding	Unit	Unit Cost	Coverage (SF)	Quantity Per Acre	Materials Cost	Seeding Cost (per acre)	Per Acre Cost
Erosion Control Mix	pound	$20.00	1,245	35.0	$700	$2,600	$3,300

Planting	Unit	Unit Cost	Planting Cost (per plant)	Spacing (Ft O.C.)	Quantity Per Acre		Per Acre Cost
Shrub Plantings	Plant	$1.00	$2.00	5	1,742		$5,227

Notes:
Ft O.C. - Feet on Center
SF - Square feet