E.

INCREMENTAL COST ANALYSIS

The following incremental analysis was conducted in order to measure the benefits of the proposed alternatives for the Mill River Ecosystem Restoration Project and additive measures relative to their costs. Since the objective of the Section 206 program is to restore degraded habitat, the desired output is the restoration of the historical riverine habitat with its associated anadromous fisheries as well as improvement of associated water quality and riparian habitat in the Mill River. The Alternatives evaluated include the No Action plan and three alternatives (Alternative 2, 3, and 4) composed of features that are mutually exclusive (one feature would not or can not be done without another) and have the potential to restore river functions. These primary Alternatives specifically address restoration efforts in the Mill Pond Park reach, restoration of which is the primary goal of this project. In addition, there are four Additive Measures that can provide added improvements to project restoration goals. The Additive Measures habitat improvements can be added to Alternatives 2, 3, and 4 in any combination in a linear fashion (they are not mutually exclusive). A description of the No Action plan, Alternatives and Additive Measures as listed below:

Alternatives

No Action plan – No Federal action would be undertaken to restore the degraded conditions in the project area with the No Action plan.

Alternative 2 – This alternative includes the removal of the dam, walls and accumulated sediment and the restoration of the river channel.

Alternative 3 – This alternative includes the removal of the dam, walls and accumulated sediment and the creation of step pools in the riverway.

Alternative 4 – This alternative includes leaving the dam in place and partial removal of the walls, removal of accumulated sediment and the installation of a fish ladder.

Additive Measures

Removal of Fish Passage Blockage at the Pulaski Street Bridge – Concrete blocks (remnants of a former dam) which block fish passage at low tide would be removed from the river channel.

Tidal Restoration – *Phragmites* dominated floodplains would be restored through removal of invasive species, regrading and replanting with native salt marsh vegetation (0.8 acres).

Riparian Corridor Restoration – Poor quality riparian habitat would be restored through removal of invasive species, regrading and replanting native vegetation (1.53 acres).

Freshwater Wetland Restoration – A freshwater marsh would be restored in a parking lot at the JM Wright Technical School (1.0 acre).

Benefit Analysis

To determine the existing habitat conditions and the benefits of restoration activities, individual values (used as an index of habitat quality) were assigned to seven habitat criteria for each Alternative and Additive Measure. Values ranging from 0 to 1 were assigned with a value of 0 as the poorest condition, and a value of 1 as the optimal condition. The assigned value for each habitat criteria was then multiplied by a weighting factor (acres) to determine "Habitat Units" (HU's) for each Alternative. The HU's calculated for the No Action plan represent existing habitat conditions or the future without project conditions.

The seven habitat criteria used in this benefits analysis include: aquatic habitat, improvement of water quality, restoration of anadromous fisheries, riparian corridor habitat, habitat for migratory birds, habitat for wetland species, and native habitat diversity. The first three habitat criteria (water quality, aquatic habitat, and habitat for anadromous fisheries) were further broken down into basic requisites for aquatic life (the requisites were averaged to calculate the value for the habitat criteria). Each habitat criterion value was multiplied by the number of acres affected by the individual Alternative or Additive Measure to determine Habitat Units (HU's). HU's for each habitat criteria were then added to determine total HU's for each Alternative or Additive Measure.

For the No Action plan and Alternatives 2, 3, and 4, weighted acreage represent acres specifically in the Mill River Park area for each habitat criterion (with the exception of anadromous fish habitat which takes into account the entire restored reach of 5.2 miles). Acreage figures for Additive Measures represent the site-specific areas proposed for restoration (again, with the exception of anadromous fish habitat which takes into account the entire restored reach of 5.2 miles). HU's for the No Action plan represent the habitat value of existing conditions in the Mill River Park area and HU's for Alternatives 2, 3 and 4 represent the expected habitat value of the Mill River Park with implementation of each alternative. For additive measures, the habitat value of the existing condition was considered so that HU's represent the increase in habitat value should the action be undertaken. Although proposed restoration improvements have some ecological benefits outside of the proposed restoration sites (i.e. water quality, wildlife habitat, etc.), the majority of the benefit occurs on-site. Quantitative and qualitative habitat changes are necessary to determine cost-effective restoration measures through the incremental analysis methodology. See Table E-1 to view the assigned habitat values.

The habitat criteria used to determine HU's for the incremental analysis are discussed below:

Requisites for Aquatic Habitat

Spawning Substrate – The Mill Pond currently has vertical walls on both banks. The pond bottom consists of fine particles that have settled out of the slow moving water. This is not ideal spawning habitat for many riverine fishes. In addition, the low flow, warmer temperatures and lack of emergent rocks and riffles limits its use by riverine/coldwater fishes. The removal of the walls will allow the creation of a more natural river morphology, which will increase shallow littoral areas with overhanging vegetation, which could be utilized by fish. The removal of the dam and creation of in-stream pool-riffle complexes will increase the suitability of the area for spawning. The removal of the dam and restoration of a more natural riverine morphology would increase scour, exposing coarser substrate more suitable for fish spawning and forage.

Instream Cover – This is a necessary component for all types of fish habitat. Fish need cover (or structure) in order to hide during times of inactivity. Predator species need places to hide while stalking prey. Smaller fish and/or juveniles need cover to hide from larger predators and feed. In addition, most areas of cover also provide substrate for aquatic invertebrates, which are necessary as food items. The presence of the retaining walls at the pond edges prevents the establishment of emergent plant species at the water's edge, which would provide additional cover.

Forage – Larger predator fishes require forage species for food supply. Due to the water quality conditions discussed earlier and the fact that the existing fishery is marginal, forage is likely to be limited. As water quality improves (from the increased flow from dam removal) it is expected that the existing fish population would improve to the maximum potential of the available habitat. Rock riffle and pool habitat with a fine sediment bottom could provide holding areas for smaller forage fish.

Benthic Invertebrates – As noted in the instream cover section, low flows and resulting low dissolved oxygen level have an impact on benthic invertebrates - food items used by many fish. With the removal of the dam and dredging of the sediment accumulated upstream, more suitable substrate will become available, due to the exposure of the benthic habitat to increased flows and higher levels of dissolved oxygen.

These four requisites were averaged and then scaled to generate a value for Aquatic Habitat according to the formula:

$$AQ = \frac{SS+IC+FO+BI}{4}$$

Where:
SS = Spawning Substrate
AQ = Aquatic Habitat
IC = Instream Cover
FO = Forage, and
BI = Benthic Invertebrates.

Requisites for Water Quality

Dissolved Oxygen – Existing data for the upstream reach of the Mill River shows dissolved oxygen levels to be in excess of 10 mg/L (USGS study, Appendix K). No data exist for dissolved oxygen levels within the Mill Pond. However, site observations suggest that dissolved oxygen levels may be quite low. The pond is subject to low flows and high loading of decaying organic matter, raising biochemical oxygen demand and temperature, while lowering dissolved oxygen levels. Dissolved oxygen will improve with increased flow (i.e. due to aeration), which will occur with dam removal.

Temperature – Water temperature of the project area reach (2.5 miles) will generally decrease with the removal of the impoundment.

Flow – As noted previously, increased flow will provide better aeration, reduce warming, and increase flushing in the Mill Pond. This will generally increase the suitability of fish habitat.

These three requisites were averaged and then scaled to generate a value for Water Quality according to the formula:

$$WQ = \frac{DO+T+F}{3}$$

Where:

WQ = Water Quality
DO = Dissolved Oxygen
T = Temperature
F = Flow.

Habitat Requisites for Target Anadromous Fish Species

In addition to the general habitat requisites listed above, the requisites specific to target anadromous fish species that are expected to change with the removal of the dam are given below. These are upstream passage and spawning habitat. It is assumed that with the dam in place there would be no fish passage. Therefore, the main difference between Alternatives would be on the overall ability to pass fish upstream, as well as the upstream spawning habitat to become available in the affected reach. As noted previously, the effects of the dam removal on actual riverine conditions were factored into the general requisites, listed above.

Two target anadromous species were selected for this evaluation, based upon their existing and historical population in the river as well as their ecological importance. They are alewife and blueback herring. These species are known to have historically inhabited the Mill River and spawned in various upstream locations. For this study, alewife and blueback herring were given equal weight. A discussion of these values for each species under all of the various Alternative conditions is presented below.

Alewife

1. **Upstream Passage** – The removal of the Main Street Dam will give these fish access to the upstream reach of the Mill River. A restored river channel as provided in Alternative 2 will provide the optimum environment for upstream passage. The creation of riffle sequences will impede fish passage to some extent. The installation of a fish will allow alewife to pass upstream. However, a fish ladder will not pass fish as efficiently as unimpeded access through removal of the dam.

2. **Spawning Habitat** – Alewife prefer to spawn in slow-moving water (Reback and Brady 1996). The pools created in Alternative 3 would serve as excellent spawning grounds for alewife. The restoration of a natural river channel would also create still areas, although not as prominently. Slow-moving water is also retained in Alternative 4, but the poor water quality associated with this Alternative would likely impede spawning.

Blueback Herring

1. **Upstream Passage** – The removal of the Main Street Dam will give these fish access to the upstream reach of the Mill River. A restored river channel as provided in Alternative 2 will provide the optimum environment for upstream passage. The creation of riffle sequences as in Alternative 3 will impede fish passage to some extent. The installation of a fish ladder in Alternative 4 will allow blueback herring to pass upstream. However, a fish ladder will not pass fish as efficiently as unimpeded access through removal of the dam.

2. **Spawning Habitat** – Blueback Herring prefer to spawn in swift water. The natural river channel with pool and riffle sequences are preferred with step pools favored somewhat less. The retention of the pond and use of a fish ladder rather than dam removal in Alternative 4 will strongly limit the ability of blueback herring to spawn.

These four requisites were averaged and then scaled to generate a value for Anadromous Fisheries Habitat according to the formula:

$$AF=\frac{AP+AS+BP+BS}{4}$$

Where:

AF = Anadromous Fisheries Habitat
AP = Alewife Upstream Passage
AS = Alewife Spawning Habitat
BP = Blueback Herring Upstream Passage
BS = Blueback Herring Spawning Habitat

The remaining four habitat criteria were evaluated by selecting appropriate values from 0 to 1 in accordance with the following descriptions:

Riparian Corridor Habitat – The value of riparian corridor habitat is optimal with a diverse hardwood canopy to provide good shading to the river and an abundance of native shrubs and herbaceous vegetation in the understory. The presence of non-native invasive species and limited shade rendering canopy was valued lower as these traits reduce the quality of the riparian corridor.

Habitat for Native Wetland Species – Valuable characteristics are considered to include numerous wetlands with diverse flora and fauna, wetlands that area hydrologically connected to the river and an abundance of native species. As wetland vegetation becomes limited or highly degraded and pollution tolerant species are evident, the value of the habitat is reduced.

Native Habitat Diversity - Numerous interconnected and diverse habitat types, with native habitats well established are considered to be optimal characteristics of this habitat criteria. As habitat types diminishes and/or are isolated in an area, the value of the habitat is reduced.

Habitat for Migratory Birds - The value of the habitat for migratory birds is valued high is migratory birds are seen or documented using the site and there is acceptable habitat for multiple species. A lack of habitat or limited pockets of habitat suitable for migratory birds and no documentation of use is valued less.

Table E-1 provides the assigned and derived values for each of the seven habitat criteria that are applied to the No Action plan, Alternatives 2,3, and 4 and the Additive Measures. Habitat Units ranged from 3.3 for the No Action plan to 43.9 for Alternative 2, which had the highest level of habitat improvement. Additive Measures provide additional habitat improvements in the project area of 1.8 for removal of the fish blockage, 3.1 for tidal wetland restoration, 5.1 for riparian corridor restoration and 4.8 for freshwater wetland creation. The habitat unit values of these additional measures are subject to at least some restorative action occurring at the Mill Park reach, and they are intended to be added to the HU values of the alternatives (except for the No Action plan) in a linear fashion to achieve a more comprehensive restoration goal.

The rationale and formulas used to derive acres of affected area is included as an addendum to Table E-2. In general, the weighted acreage for the No Action plan and Alternative 2, 3 and 4 represent acres specifically affected by project activities in the Mill River Park area for each habitat criterion (with the exception of anadromous fish habitat which takes into account the entire restored reach of 5.2 miles, Stamford Harbor to north of Arden Lane at river mile 5.22). Acreage figures for Additive Measures represent the site-specific areas proposed for restoration within the project area (with the exception of anadromous fish habitat which takes into account the entire restored reach of 5.2 miles, Stamford Harbor to north of Arden Lane at river mile 5.22).

Alternative 2 had the highest score. The restoration actions proposed to the Mill River Park area in this alternative are most comparable to the biologic community found in a healthy watershed. A diverse array of species within a balanced community will be found on the site with the implementation of this alternative. Alternatives 3 and 4 scored lower than Alternative 2. Restoration of the site following the design of Alternatives 3 or 4 would not create as much species or community diversity or provide optimum conditions for anadromous fish passage. The No Action plan scored substantially lower than all the other outlined plans. With this alternative the physical characteristics of the site would not change. The restoration of the project area using the actions proposed in Alternative 2 with all four Additive Measures provides the most comprehensive restoration project and meets the project restoration goals.

Table E-1

Habitat Units Per Alternative for Selected Habitat Criteria

Alternative:			No Action			2			3			4		
	Criteria	Scale	Rating	Acres	HU	Rating	Acres	HU	Rating	Acres	HU	Rating	Acres	HU
Mill Pond Site Aquatic Habitat	Spawning Substrate	0 - 1	0.25			1			0.5			0.25		
	Instream Cover	0 - 1	0.25			1			0.75			0.75		
	Forage	0 - 1	0.25			0.75			0.75			0.5		
	Benthic Invertebrates	0 - 1	0.25			1			0.5			0.5		
	total	0 - 1	0.25	3.5	**0.9**	0.9375	1.8	**1.7**	0.625	1.8	**1.1**	0.5	2.6	**1.3**
Mill Pond Site Water Quality	Dissolved Oxygen	0 - 1	0.25			1			0.75			0.25		
	Temperature	0 - 1	0.25			1			0.5			0.25		
	Flow	0 - 1	0.25			0.75			0.25			0.25		
	total	0 - 1	0.25	3.5	**0.9**	0.9167	1.8	**1.7**	0.5	1.8	**0.9**	0.25	2.6	**0.7**
Alewife Habitat	Upstream Passage	0 - 1	0			0.9			0.7			0.65		
	Spawning Habitat	0 - 1	0			0.75			1			0.25		
Blueback Herring	Upstream Passage	0 - 1	0			0.9			0.7			0.65		
	Spawning Habitat	0 - 1	0			0.75			0.5			0.25		
Habitat for Anadromous Fish (Combined Mean)		0 - 1	0	31.5	**0.0**	0.825	31.5	**26.0**	0.725	31.5	**22.8**	0.45	31.5	**14.2**
Riparian Corridor		0 - 1	0.25	1.3	**0.3**	1	4	**4.0**	0.75	4	**3.0**	1	2.9	**2.9**
Habitat for Native Wetland Species		0 - 1	0.25	0.1	**0.0**	0.75	0.5	**0.4**	0.75	0.5	**0.4**	0.75	0.45	**0.3**
Native Habitat Diversity		0 - 1	0	4.8	**0.0**	0.75	5.8	**4.4**	0.75	5.8	**4.4**	0.5	5.5	**2.8**
Habitat for Migratory Birds		0 - 1	0.25	4.8	**1.2**	1	5.8	**5.8**	1	5.8	**5.8**	0.75	5.5	**4.1**
Total Aquatic Habitat Benefit (Habitat Units as weighted acres):					**3.3**			**43.9**			**38.4**			**26.2**

Table E-1 (continued)

Additive Measures - Incremental Effect Over No Action (Without Project)

Increases in Habitat Units when added to Alternatives (not including No-Action)

Additive Measure:			Removal of Fish Passage Blockage at Pulaski St Bridge			Tidal Wetland Restoration			Riparian Corridor Restoration (Including Invasive Plant Removal)			Freshwater Wetland Creation		
	Criteria	Scale	Rating	Acres	HU	Rating	Acres	HU	Rating	Acres	HU	Rating	Acres	HU
Site-Specific Aquatic Habitat	Spawning Substrate	0 - 1	0.25			0.25			0.25			0.75		
	Instream Cover	0 - 1	0.25			0.5			0.5			0.75		
	Forage	0 - 1	0.25			0.75			0.75			0.75		
	Benthic Invertebrates	0 - 1	0.25			0.75			0.75			0.75		
	total	0 - 1	0.25	0.2	**0.1**	0.5625	0.8	**0.5**	0.5625	1.53	**0.9**	0.75	1	**0.8**
Site-Specific Water Quality	Dissolved Oxygen	0 - 1	0			0.25			0.25			0.75		
	Temperature	0 - 1	0.25			0.25			0.25			0.75		
	Flow	0 - 1	0.25			0.25			0.25			0.75		
	total	0 - 1	0.1667	0.2	**0.0**	0.25	0.8	**0.2**	0.25	1.53	**0.4**	0.75	1	**0.8**
Alewife Habitat	Upstream Passage	0 - 1	0.1			0			0			0		
	Spawning Habitat	0 - 1	0			0			0			0		
Blueback Herring	Upstream Passage	0 - 1	0.1			0			0			0		
	Spawning Habitat	0 - 1	0			0			0			0		
Habitat for Anadromous Fish (Combined Mean)		0 - 1	0.05	31.5	**1.6**	0	0.8	**0.0**	0	0.8	**0.0**	0	0.8	**0.0**
Riparian Corridor		0 - 1	0.25	0.1	**0.0**	0.75	0.8	**0.6**	0.75	1.53	**1.1**	1	1	**1.0**
Habitat for Native Wetland Species		0 - 1	0.25	0.1	**0.0**	0.75	0.8	**0.6**	0.25	1.53	**0.4**	0.75	1	**0.8**
Native Habitat Diversity		0 - 1	0.25	0.2	**0.1**	0.75	0.8	**0.6**	0.75	1.53	**1.1**	0.75	1	**0.8**
Habitat for Migratory Birds		0 - 1	0.25	0.2	**0.1**	0.75	0.8	**0.6**	0.75	1.53	**1.1**	0.75	1	**0.8**
Total Aquatic Habitat Benefit (Habitat Units as weighted acres):					**1.8**			**3.1**			**5.1**			**4.8**

Table E-2. Rationale for Weighted Acreage Figures

Criteria	Primary Alternatives							
	No Action		2		3		4	
	Description	Acres	Description	Acres	Description	Acres	Description	Acres
Mill Pond Site Aquatic Habitat	Mill Pond is 3.5 ac.	3.50	Proposed river 70ft. X 1100ft. (restored river length) divided by 43569 sq.ft/ac. = 1.8 ac.	1.80	Proposed river 70ft. X 1100ft. (restored river length) divided by 43569 sq.ft/ac. = 1.8 ac.	1.80	3.5ac. (Mill Pond) minus 1.8ac. (river ac. Alt 2&3) = 2.6ac. Walls sloped 1:3 reduces pond size.	2.60
Mill Pond Site Water Quality	Mill Pond is 3.5 ac.	3.50	Proposed river 70ft. X 1100ft. (restored river length) divided by 43569 sq.ft/ac. = 1.8 ac.	1.80	Proposed river 70ft. X 1100ft. (restored river length) divided by 43569 sq.ft/ac. = 1.8 ac.	1.80	3.5ac. (Mill Pond) minus 1.8ac. (river ac. Alt 2&3) = 2.6ac. Walls sloped 1:3 reduces pond size.	2.60
Habitat for Anadromous Fish	Fish passage opens 5.2 mi. Av. river width is 50 ft. (5280ft./mi.x5.2 mi.)x50ft. divided by 43560 sq.ft./ac. =31.5	31.50	Fish passage opens 5.2 mi. Av. river width is 50 ft. (5280ft./mi.x5.2 mi.)x50ft. divided by 43560 sq.ft./ac. =31.5	31.50	Fish passage opens 5.2 mi. Av. river width is 50 ft. (5280ft./mi.x5.2 mi.)x50ft. divided by 43560 sq.ft./ac. =31.5	31.50	Fish passage opens 5.2 mi. Av. river width is 50 ft. (5280ft./mi.x5.2 mi.)x50ft. divided by 43560 sq.ft./ac. =31.5	31.50
Riparian Corridor	25' each side (50ft.total) X 1100ft. Mill Pond length (includes upland) divided by 43560 sq.ft./ac = 1.3 ac.	1.30	80' each side (includes upland)(160ft.total) x1100ft. (Mill Pond length) divided by 43560sq.ft./ac.= 4.0ac.	4.00	80' each side (includes upland)(160ft.total) x1100ft. (Mill Pond length) divided by 43560sq.ft./ac.= 4.0ac.	4.00	5.8ac.(Alt2&3 1.8 ac. river and 4.0ac. riparian) minus 2.6ac.(Alt 4 pond) =3.2ac.x.9 (10%wall remain to support dam)= 2.9 ac.	2.90
Habitat for Native Wetland Species	Small amount of accumulated sediment supports wetland vegetation	0.10	10ft. each side (20ft total) x1100(Mill Pond length) divided by 43560 sq.ft./ac = 0.5 ac.	0.50	10ft. each side (20ft total) x1100(Mill Pond length) divided by 43560 sq.ft./ac = 0.5 ac.	0.50	0.5 ac.(Alt 2&3 ac. Habitat for Wetland Species) x.9 (10% of walls remain to support dam) = 0.45ac.	0.45
Native Habitat Diversity	3.5ac.(Alt 1 Aquatic Habitat) + 1.3ac. (Alt 1 Riparian Corridor) = 4.8 ac.	4.80	1.8 ac. (Alt 2 Aquatic Habitat) + 4.0ac. (Alt 2 Riparian Corridor) = 5.8 ac.	5.80	1.8 ac. (Alt 3 Aquatic Habitat) + 4.0ac. (Alt 3 Riparian Corridor) = 5.8 ac.	5.80	1.8 ac. (Alt 2&3 Aquatic Habitat) + 4.0ac. (Alt 2&3 Riparian Corridor) = 5.8 ac.x.9 (10% of walls remain to support dam) = 5.5ac.	5.50
Habitat for Migratory Birds	3.5ac.(Alt 1 Aquatic Habitat) + 1.3ac. (Alt 1 Riparian Corridor) = 4.8 ac.	4.80	1.8 ac. (Alt 2 Aquatic Habitat) + 4.0ac. (Alt 2 Riparian Corridor) = 5.8 ac.	5.80	1.8 ac. (Alt 3 Aquatic Habitat) + 4.0ac. (Alt 3 Riparian Corridor) = 5.8 ac.	5.80	1.8 ac. (Alt 2&3 Aquatic Habitat) + 4.0ac. (Alt 2&3 Riparian Corridor) = 5.8 ac.x.9 (10% of walls remain to support dam) = 5.5ac.	5.50

Table E-2 (continued). Rationale for Weighted Acreage Figures (Page 1 of 2)

Criteria	Additional Measures							
	Removal of Fish Passage at Pulaski St Bridge		Tidal Wetland Restoration		Riparian Corridor Restoration (Including Invasive Plant Removal)		Freshwater Wetland Creation	
	Description	Acres	Description	Acres	Description	Acres	Description	Acres
Site-Specific Aquatic Habitat	130ft. (river width at Pulaski Street Bridge) x 75ft.(length of concrete blocks in riverway) divided by 43560 sq.ft./ac. = .20ac. (rounded)	0.20	0.4ac. (Site Location 2) plus 0.4ac. (Site Location 6) = 0.8ac.(See DPR Table 13 for site locations.)	0.80	0.15 ac. (Site 9) plus 1.02 ac. (Site 10) plus 0.36ac. (Site 18) = 1.53ac. (See DPT Table 13 for site locations.)	1.53	1.0ac. (Site 17 - JM Technical School)(See DPR Table 13 for site locations.)	1.00
Site-Specific Water Quality	130ft. (river width at Pulaski Street Bridge) x 75ft.(length of concrete blocks in riverway) divided by 43560 sq.ft/ac. = .20ac. (rounded)	0.20	0.4ac. (Site Location 2) plus 0.4ac. (Site Location 6) = 0.8ac. (See DPR Table 13 for site locations.)	0.80	0.15 ac. (Site 9) plus 1.02 ac. (Site 10) plus 0.36ac. (Site 18) = 1.53ac. (See DPT Table 13 for site locations.)	1.53	1.0ac. (Site 17 - JM Technical School)(See DPR Table 13 for site locations.)	1.00
Habitat for Anadromous Fish	Fish passage opens 5.2 mi. Av. river width is 50 ft. (5280ft./mi.x5.2 mi.)x50ft. divided by 43560 sq.ft./ac. =31.5ac.	31.50	0.4ac. (Site Location 2) plus 0.4ac. (Site Location 6) = 0.8ac.(See DPR Table 13 for site locations.)	0.80	Approximately half of the 1.53ac. of restored wetland will be available for anadromous fish passage through regrading.	0.80	The freshwater wetland will not be available to anadromous fish for passage or spawning.	0.00
Riparian Corridor	50 ft. (25ft. each side of riverway) x 75ft. (length of concrete blocks) divided by 43560sq.ft./ac. = 0.1ac.(Note: Pulaski Street Bridge abutments restrict vegetative growth outside riverway.)	0.10	0.4ac. (Site Location 2) plus 0.4ac. (Site Location 6) = 0.8ac.(See DPR Table 13 for site locations.)	0.80	0.15 ac. (Site 9) plus 1.02 ac. (Site 10) plus 0.36ac. (Site 18) = 1.53ac. (See DPT Table 13 for site locations.)	1.53	1.0ac. (Site 17 - JM Technical School)(See DPR Table 13 for site locations.)	1.00

Table E-2 (continued). Rationale for Weighted Acreage Figures (Page 2 of 2)

Criteria	Additional Measures							
	Removal of Fish Passage at Pulaski St Bridge		Tidal Wetland Restoration		Riparian Corridor Restoration (Including Invasive Plant Removal)		Freshwater Wetland Creation	
	Description	Acres	Description	Acres	Description	Acres	Description	Acres
Habitat for Native Wetland Species	50 ft. (25ft. each side of riverway) x 75ft. (length of concrete blocks) divided by 43560sq.ft./ac. = 0.1ac.(Note: Pulaski Street Bridge abutments restrict vegetative growth outside riverway.)	0.10	0.4ac. (Site Location 2) plus 0.4ac. (Site Location 6) = 0.8ac.(See DPR Table 13 for site locations.)	0.80	0.15 ac. (Site 9) plus 1.02 ac. (Site 10) plus 0.36ac. (Site 18) = 1.53ac. (See DPT Table 13 for site locations.)	1.53	1.0ac. (Site 17 - JM Technical School)(See DPR Table 13 for site locations.)	1.00
Native Habitat Diversity	130ft. (width of riverway at Pulaski St.) x 75ft. (concrete blocks in riverway) divided by 43560 sq.ft./ac. = 0.2ac.(rounded)(Note: Pulaski Street Bridge abutments restrict vegetative growth outside of riverway.)	0.20	0.4ac. (Site Location 2) plus 0.4ac. (Site Location 6) = 0.8ac.(See DPR Table 13 for site locations.)	0.80	0.15 ac. (Site 9) plus 1.02 ac. (Site 10) plus 0.36ac. (Site 18) = 1.53ac. (See DPT Table 13 for site locations.)	1.53	1.0ac. (Site 17 - JM Technical School)(See DPR Table 13 for site locations.)	1.00
Habitat for Migratory Birds	130ft. (width of riverway at Pulaski St.) x 75ft. (concrete blocks in riverway) divided by 43560 sq.ft./ac. = 0.2ac.(rounded)(Note: Pulaski Street Bridge abutments restrict vegetative growth outside of riverway.)	0.20	0.4ac. (Site Location 2) plus 0.4ac. (Site Location 6) = 0.8ac.(See DPR Table 13 for site locations.)	0.80	0.15 ac. (Site 9) plus 1.02 ac. (Site 10) plus 0.36ac. (Site 18) = 1.53ac. (See DPT Table 13 for site locations.)	1.53	1.0ac. (Site 17 - JM Technical School)(See DPR Table 13 for site locations.)	1.00

The predicted habitat value for each proposed alternative was significantly better than the habitat value of the No Action plan. The improved habitat value expected after project completion was calculated by subtracting the habitat value of the No Action plan from the score of the other alternatives. The habitat improvement over the No Action plan are compared to the costs of each alternative to determine the most appropriate and cost-effective plan as outlined in Table E-3.

Incremental Analysis

The costs of the alternative restoration plans are compared with the environmental benefits, within the framework of an incremental cost analysis, to identify the most cost effective alternatives. An incremental cost analysis examines how the costs of additional units of environmental output increase as the level of environmental output increases. For this analysis, the environmental outputs are measured in habitat units. The analysis is in accordance with IWR Report 95-R-1, Evaluation of Environmental Investments Procedures Manual-Interim: Cost Effectiveness and Incremental Cost Analyses, May 1995; and ER 1105-2-100, Planning Guidance Notebook, Section 3-5, Ecosystem Restoration, April 2000. The program IWR-PLAN, developed for the Institute for Water Resources (IWR), was used to conduct the analysis.

Displaying cost effective solutions can identify an incremental cost curve. Cost effective solutions are those increments that result in same output, or number of habitat units, for the least cost. An increment is cost effective if there are no others that cost less and provide the same, or more, habitat units. Alternatively, for a given increment cost, there will be no other increments that provide more habitat units at the same, or lower, cost.

Management plans to improve environmental conditions in the Mill River and Mill Pond includes restoring the river channel, creation of step pools and the installation of a fish ladder. Project description, project cost, and the number of habitat units created by each plan are shown in Table E-3. Costs are discounted at an interest rate of 5 5/8 %. This interest rate, as specified in the Federal Register, is to be used by Federal agencies in the formulation and evaluation of water and land resource plans for the period October 1, 2003 to September 30, 2004. The project economic life is considered to be 50 years.

Table E-3. Alternatives Cost and Output

No	Description	Cost	HU
		($000)	
1	No Action	1,925.6	3.3
2	Restore River Channel	4,727.4	43.9
3	Create Step Pools	6,801.4	38.4
4	Install Fish Ladder	6,558.0	26.2
5	Remove Fish Passage Blockage at Pulaski Bridge	213.1	1.8
6	Tidal Restoration	399.7	3.1
7	Riparian Corridor Restoration	119.0	5.1
8	Freshwater Wetland Creation	817.7	4.8

Alternative 1 is the no action alternative. Alternative 2 provides for restoration of the river channel along with removal of the dam, walls, and sediments. Alternative 3 would create step pools as well as remove the dam, walls, and sediments. Alternative 4 leaves the dam in place but removes walls and accumulated sediment. This alternative would install a fish ladder. Alternatives numbered 5 through 8 are additive measures to alternatives 1 through 4. These measures are the removal of fish passage blockage at the Pulaski Bridge, tidal restoration, riparian corridor restoration, and creation of freshwater wetlands. These measures are not analyzed independently, but only in conjunction with the major alternatives 2, 3, and 4.

Table E-4. Project Cost ($000)

No.	Description	First Cost	IDC	Investment Cost	O&M	Monit. Cost	Project Cost
1	Without Project	0.0	0.0	0.0	1,925.6	0.0	1,925.6
2	Restore River Channel	4,486.0	117.5	4,603.5	83.1	40.8	4,727.4
3	Create Step Pools	4,629.0	121.2	4,750.2	2,008.7	42.5	6,801.4
4	Install Fish Ladder	4,378.0	114.7	4,492.7	2,025.4	39.9	6,558.0
5	Remove Fish Passage Blockage	206.0	5.4	211.4	0.0	1.7	213.1
6	Tidal Restoration	370.0	9.7	379.7	16.6	3.4	399.7
7	Riparian Corridor Restoration	99.0	2.6	101.6	16.6	0.8	119.0
8	Freshwater Wetland Creation	774.0	20.3	794.3	16.6	6.8	817.7

Project cost derivation is shown in Table E-4. First cost includes real estate cost as well as construction cost and associated overhead. Interest during construction (IDC) is then calculated assuming a construction period of 12 months for each alternative. This is an economic cost and not a financial cost. It needs to be estimated for purposes of project justification, however it is not a financial cost that will need to be cost shared. Essentially, IDC represents the opportunity cost of funds tied up in investments, before these investments begin to yield benefit. Once project benefit starts IDC cost stops.

Combining total first cost and IDC results in investment cost. Annual operation and maintenance (O & M) and monitoring costs are then added to investment cost to arrive at total project cost. The derivation of O & M cost is show in Table E-5. Monitoring cost is one percent of first cost assumed to occur in years 2, 3 and 4 of project life. The discounted sum for each alternative is shown in Table E-4.

Table E-5. Project O & M Cost.

					Discount.
		Interval	Amount	Discount	Amount
No.	Description	(yrs)	($000)	Factor	($000)
1	Without Project	10,20,30,40,50	1,500.0	1.28373	1,925.6
2	Restore River Channel	yearly	5.0	16.62554	83.1
3	Create Step Pools				2,008.7
		10,20,30,40,50	1,500.0	1.28373	1,925.6
		yearly	5.0	16.62554	83.1
4	Install Fish Ladder				2,025.4
		10,20,30,40,50	1,500.0	1.28373	1,925.6
		yearly	6.0	16.62554	99.8
5	Remove Fish Passage Blockage	none	0.0		0.0
6	Tidal Restoration	yearly	1.0	16.62554	16.6
7	Riparian Corridor Restoration	yearly	1.0	16.62554	16.6
8	Freshwater Wetland Creation	yearly	1.0	16.62554	16.6

All alternatives would require expenditures for operations and maintenance (O & M) over the life of the project. For Alternatives 1, 3, and 4 it is anticipated that $1,500,000 will be expended every 10 years over the project life to dredge the pond. Alternatives 2 and 3 will require $5,000 in annual O & M, and Alternative 4 will require $6,000 in annual O & M. Alternatives 6, 7, and 8 will require $1,000 in annual maintenance.

Figure E-1.

Figure E-1 shows all cost effective plans and best buy plans. Of the 50 increments analyzed, 9 were cost effective and 4 were best buy. In Figure E-1, alternatives are arrayed along the horizontal axis by increasing number of habitat units with corresponding project cost shown on the vertical axis. These plans are displayed in Table E-6. Alternatives 3, create step pools and 4, install fish ladder are not cost effective when compared to Alternative 2, restore river channel, because Alternative 2 provides more habitat units than these others at a lower cost. This can be readily seen by reference to Table E-3. Alternative 2 dominates Alternatives 3 and 4.

Table E-6. Cost-Effective Plans

Alternatives	HU	Cost
		($000)
1	3.3	1,925.6
2	43.9	4,727.4
2+7	49.0	4,846.4
2+5+7	50.8	5,059.5
2+6+7	52.1	5,246.1
2+5+6+7	53.9	5,459.2
2+5+7+8	55.6	5,877.2
2+6+7+8	56.9	6,063.8
2+5+6+7+8	58.7	6,276.9

Alternative 1 is the no action plan. There is cost associated with this alternative as dredging of the pond will be required if no action is taken. Alternative 2 is river channel restoration. The remaining alternatives add in various combinations of Alternatives: 5 (removal of fish passage blockage), 6 (tidal restoration), 7 (riparian corridor restoration), and 8 (freshwater wetlands creation).

Figure E-2. Incremental Cost of Best-Buy Plans compared to Habitat Unit outputs.

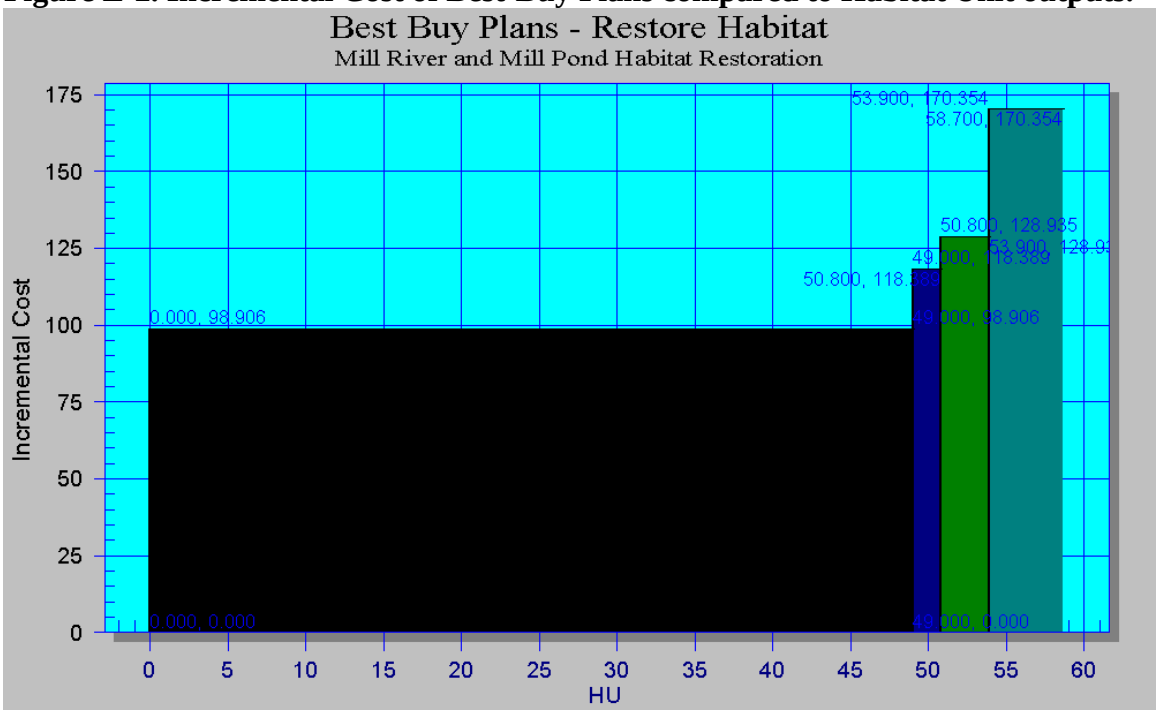

Figure E-2 shows best buy plans that comprise the incremental cost curve. As in Figure E-1, the horizontal axis represents habitat units created by each project. However, the vertical axis represents the incremental cost per incremental output as output increases with project size. Best buy plans are a subset of cost effective plans. For each best buy plan there are no other plans that will give the same level of output at a lower incremental cost. There are four best buy plans.

Increments that comprise the best buy plan curve are described in Table E-7. This is the incremental cost curve that is the desired result. The change in cost and output is compared in the incremental cost curve. Incremental cost is the increase in cost of each successive plan. Incremental output is the increase in output of each successive plan. Incremental cost per output is the change in cost per incremental output when proceeding to plans with higher output. It is the incremental cost divided by the change in output. Table E-7 shows incremental cost, incremental output and incremental cost per incremental output. Usually the without project alternative, or the no action alternative, is a best buy plan. However, for this analysis the without project alternative results in a cost of $1,925,600 for O & M over the 50 year period. As can be seen in Figure E-1 the without project alternative is cost effective, but not a best buy.

Table E-7. Incremental Cost Curve of Best Buy Plans

Alternatives	HU	Cost ($000)	Avg. Cost ($000/HU)	Inc. Cost ($000)	Inc. Output	Inc. Cost Per Output ($000)
2+7	49.0	4,846.4	98.9	4,846.4	49.0	98.9
2+5+7	50.8	5,059.5	99.6	213.1	1.8	118.4
2+5+6+7	53.9	5,459.2	101.3	399.7	3.1	128.9
2+5+6+7+8	58.7	6,276.9	106.9	817.7	4.8	170.4

The question that is asked at each increment is whether the additional gain in environmental benefit is worth the additional cost. The first increment provides an additional 49 HU with an incremental cost of $98,900 per HU. This increment would restore the river channel and provide for riparian corridor restoration. The second increment would add the removal of the fish passage blockage at the Pulaski Bridge to the first increment. The second increment would provide an additional 1.8 HU at an incremental cost of $118,400 per HU. The third increment would add tidal wetland tidal restoration to the second increment. This increment would provide an additional 3.1 HU at an incremental cost of $128,900 per HU. The fourth, and final, increment would provide an additional 4.8 HU with an incremental cost of $170,400 per HU. The fourth increment adds freshwater wetland creation to the third increment.

National Economic Development Benefits Account

Alternatives 2 and 3 would reduce flooding in the reaches of the Mill River upstream of the Main Street Dam. For the 100-year event water surface levels will be lowered by between 2.0 and 2.6 feet between the removed dam and Broad Street located approximately 1100 feet upstream (See Appendix B).

References

Reback, K.E. and P. Brady. 1996. A survey of the Neponset River to determine its potential for anadromous fish development. MA Division of Marine Fisheries, Sportfisheries Program.