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**BUSSEY LAKE: DEMONSTRATION STUDY OF INCREMENTAL
ANALYSIS IN ENVIRONMENTAL PLANNING**

by

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PREFACE

For many years, U.S. Army Corps of Engineers (USACE) field planners have been required to include an incremental cost analysis in their environmental mitigation, and now restoration, planning efforts. Although some general guidance has been provided, e.g., Engineer Circular 1105--2-185, March 11, 1988, it has often been criticized as overly simplified and not responsive to real world planning applications. Recently, Mr. Ken Orth, of the USACE Institute for Water Resources (IWR), Policy and Special Studies Division, developed more detailed procedures entitled Nine EASY Steps - Corps Incremental Cost Analysis for Fish and Wildlife Habitat (Review Draft), 17 April 1993. As part of the development process, the USACE St. Paul District was requested to test these procedures using data from a recently completed planning study conducted as part of their Upper Mississippi River Environmental Management Program. The results of that demonstration study are reported herein. Although these procedures are most helpful in analyzing alternative measures that can be combined, such as in the Bussey Lake Demonstration, they can also be used when the alternatives are more discrete, independent plans. Subsequent to St. Paul District's completion of their demonstration study report, the Nine EASY Steps procedures were slightly revised. An Addendum to the St. Paul District report was prepared by IWR which incorporates these revisions using data from the original report. That Addendum is also reported herein. The development of the Nine EASY Steps and additional procedural guidance for cost effectiveness and incremental analysis is an on-going effort. Any comments on the procedures described in this report are welcomed and should be forwarded to IWR.

This report was prepared as part of the USACE Evaluation and Formulation of Environmental Projects Work Unit, within the Planning Methodologies Research Program. Mr. William Hansen and Mr. Darrell Nolton of the USACE Water Resources Support Center (WRSC), IWR, manage this Work Unit under the general supervision of Mr. Michael Krouse, Chief, Technical Analysis and Research Division; Mr. Kyle Schilling, Director, IWR; and Mr. Kenneth Murdock, Director, WRSC. Mr. Robert Daniel, Chief of the Economic and Social Analysis Branch (CECW-PD) and Mr. Brad Fowler, Economist (CECW-PD) served as Technical Monitors for Headquarters, USACE.

The work was performed by the USACE St. Paul District, Planning Division. Mr. Bruce Carlson of the Economics, Social and Recreation Branch was the primary author in collaboration with Mr. Gary Palesh of the Water Resources Branch. Mr. John Shyne of the Environmental Resources Branch provided analytical support. The Addendum was prepared by Mr. William Hansen and Mr. Ridgley Robinson, IWR.

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BUSSEY LAKE: DEMONSTRATION STUDY FOR INCREMENTAL ANALYSIS

OBJECTIVES OF THIS DEMONSTRATION

Engineering Circular 1105-2-185 and the (draft) Incremental Cost Analysis Primer for Environmental Resources Planning provide conceptual background and general guidance for conducting incremental cost analysis for environmental (fish and wildlife habitat) restoration, mitigation, and protection planning. Although some hypothetical examples are presented, neither document provides an example based on an actual field application. The Bussey Lake demonstration is intended to illustrate the application of incremental cost analysis for environmental planning in such a real world planning situation.

BUSSEY LAKE BACKGROUND

Bussey Lake is a 213-acre backwater lake located on the Upper Mississippi River. The lake was selected for habitat restoration under the Upper Mississippi River System - Environmental Management Program (UMRS-EMP), authorized under the Water Resources Development Act of 1986. Under this program, habitat restoration measures are implemented along the Upper Mississippi River from the head of navigation in Minneapolis, Minnesota, to the mouth of the Ohio River at Cairo, Illinois (Figure 1). Tributaries such as the Minnesota, St. Croix, and Illinois Rivers are also included to the respective head of navigation.

Under the UMRS-EMP, resource areas are selected for study through a collaborative effort between the Corps of Engineers, the U.S. Fish and Wildlife Service, and State natural resource agencies. Factors considered in the selection of an area include resource significance, potential benefits to be achieved, and opportunity for successful restoration.

Bussey Lake was selected for restoration because it is considered an important backwater habitat in lower pool 10, from both a habitat perspective and a public interest perspective. Bussey Lake has historically supported an excellent fishery for backwater fish species such as largemouth bass (Micropterus salmoides), bluegill (Lepomis macrochirus), crappie (Pomoxis annularis and P. nigromaculatus), and northern pike (Esox lucius).

An important characteristic of any backwater area on the UMRS, if it is to provide year-round habitat for a backwater fish community, is that it provide a refuge for fish in the winter from current and from near zero degrees Celsius main channel water

temperature. Bussey Lake is ideal in this respect, since it has no tributaries introducing current to the lake and it is totally protected from main channel flows.

Over the years, however, sedimentation has shallowed the lake to the point where fish habitat quality has begun to decline. It is projected that, if the degradation of habitat continues, the value of the lake as fish habitat will decline significantly. Selecting Bussey Lake for restoration at this time still allows the opportunity to delay or reverse the decline in habitat quality before it becomes irreversible.

HABITAT OBJECTIVES

The habitat objective for Bussey Lake was defined as improving the habitat quality for the riverine backwater fish community that would be expected to naturally occur in a lake such as Bussey Lake. The focus would be on improving habitat quality for the game fish and panfish that are of high interest to the resource agencies and to the public in the region.

Because the project would be a habitat restoration effort and not mitigation for habitat losses occurring elsewhere, there were no numerical goals per se as part of the objective. However, if conditions in the lake could be optimized (habitat suitability index (HSI) of 1.0), total outputs of 213 average annual habitat units (AAHU) would be expected (213 acres x 1.0).

EXISTING AND FUTURE WITHOUT PROJECT CONDITIONS

Bussey Lake is 213 acres in size and is shaped in the form of an embayment off the main channel of the Upper Mississippi River. The lake is bounded on three sides by land and is open to the river on its lower end (Figure 2). Bussey Lake was created with the construction of the locks and dams system on the Upper Mississippi River in the 1930's. Since that time, sedimentation has been gradually shallowing the lake.

Bussey Lake is shallow, with a maximum depth of 6 feet. Approximately 30 percent of the lake is less than 2 feet deep and 70 percent of the lake less than 4 feet deep. It is estimated that the lake has shallowed by an average of 2 feet since its creation. This shallowing of the lake has placed much of the lake within the photic zone, allowing the prolific growth of aquatic vegetation now present. Substrate type is predominantly silt and clay.

Aquatic vegetation is abundant in the lake, covering about 90 percent of the lake during peak summer growth. Arrowhead (*Sagittaria latifolia*) and water lilies (*Nymphaea* sp.) are predominant in the shallow upper portion of the lake, while

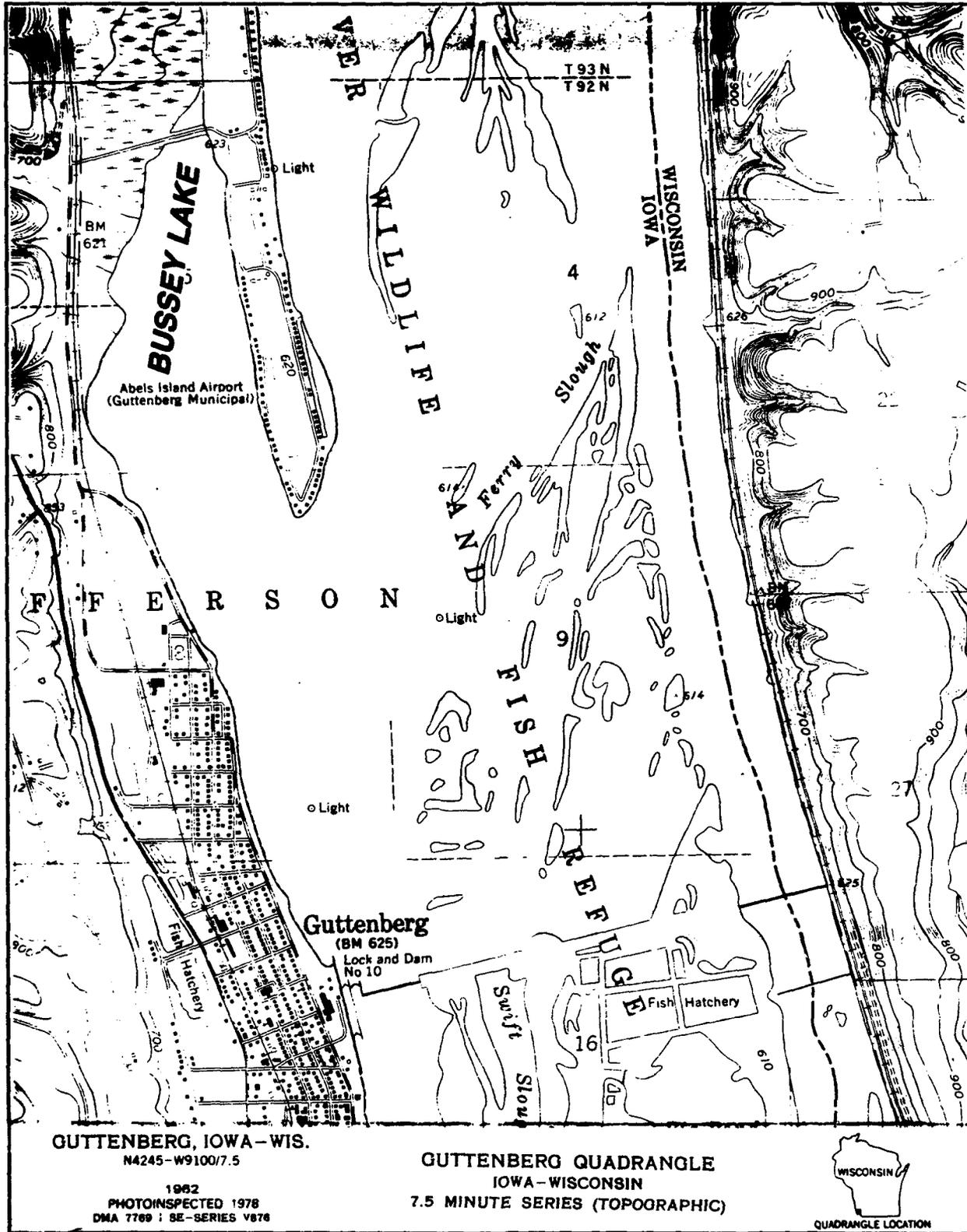


Figure 2 Bussey Lake Study Area

pondweeds (Potamogeton spp.) and coontail (Ceratophyllum demersum) are the most common submergents in the deeper portions of the lake.

Aside from the sport fish species noted earlier, other species of fish commonly found in Bussey Lake include bullheads (Ictalurus spp.) and more riverine species that frequent the lake from the adjacent river such as freshwater drum (Aplodinotus grunniens) and redhorse (Moxostoma spp.).

It is expected that, in the future, the lake will continue to shallow due to sedimentation. However, hydraulic analysis of current and sedimentation patterns indicates that the rate of shallowing is likely to be somewhat less than what has occurred in the past.

Summer dissolved oxygen sags have already been observed in the lake, and winter dissolved oxygen depletion problems are evident in the shallower portions of the lake. It is expected that these conditions will become more severe in the future as the lake continues to shallow and aquatic vegetation becomes even more prevalent.

MODEL SELECTION

Resource agencies and the public in the region were interested primarily in largemouth bass and bluegill in Bussey Lake. It was decided to use one of these species as the indicator species because U.S. Fish and Wildlife Service habitat models for these species were available; both species are common to Upper Mississippi River backwater lakes and are representative of those fish communities; and because of the interest in these species, it would be easier for the resource agencies and the public to identify with the outputs being provided.

Most fish species models, such as the U.S. Fish and Wildlife Service bluegill and largemouth bass models, do not consider ice cover winter conditions that commonly occur in northern climates. For this reason, the St. Paul District modified the bluegill model (Palesh and Anderson 1990) to incorporate winter habitat variables for use on habitat projects on the Upper Mississippi River. The U.S. Fish and Wildlife Service bluegill model (Stuber et al. 1982) was selected for use on the Bussey Lake project, because one of the concerns identified by local natural resource personnel was the declining quality of winter fish habitat at Bussey Lake.

The model identifies four primary life requisites for bluegills: food, cover, water quality, and reproduction. The model also includes an "other" category for miscellaneous factors. Tree diagrams showing the relationship of the life requisites to relevant habitat elements for both summer (upper) and winter (lower) are shown on Figure 3.

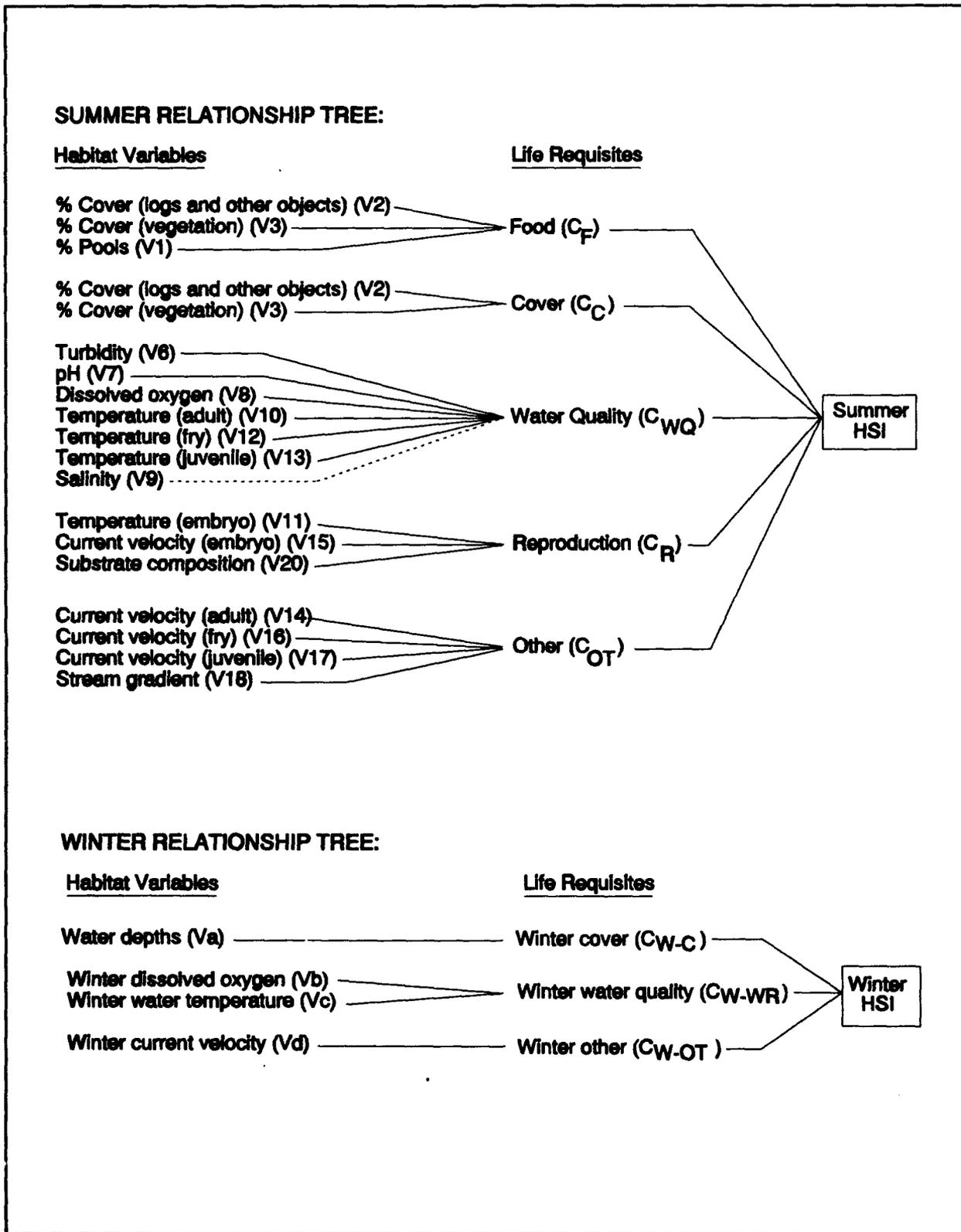


Figure 3 Relationship of the Life Requisites to Relevant Habitat Elements

The model incorporates nearly 20 habitat variables in determining the overall habitat suitability. Separate sub-totals are computed for summer and winter conditions, yielding an overall average annual suitability index. The habitat variables include type and extent of vegetative cover, turbidity, dissolved oxygen, pH, water temperature, substrate composition, and current velocity. Each variable has a unique relationship in determining the overall habitat suitability. These relationships have been represented by mathematical formulas that are not presented here, but are described in the manual for the bluegill model. Graphs depicting the functions of several "sub-optimal" variables at Bussey Lake are shown in the next section.

The bluegill model was modified for this project in that the variable for woody cover (V_2) was not used. In conditions such as exist at Bussey Lake where vegetative cover is so dominant, woody cover is an insignificant factor. In addition, the way the model is structured, incorporation of this variable in this type of situation results in a cover component value that does not reflect true habitat conditions.

ANALYSIS OF HABITAT CONDITIONS

The bluegill model was used to evaluate existing and future without habitat conditions to assist in identifying specific habitat deficiencies. Table 1 shows the *existing and future without habitat* values for the various model variables and the calculated habitat suitability index. Habitat variables that fall below the optimum level have been highlighted in Table 1. For the sub-optimal variables the graphs of the functions used to derive the habitat values are presented on Figures 4A through 4C, with the value for the existing condition marked with an "x".

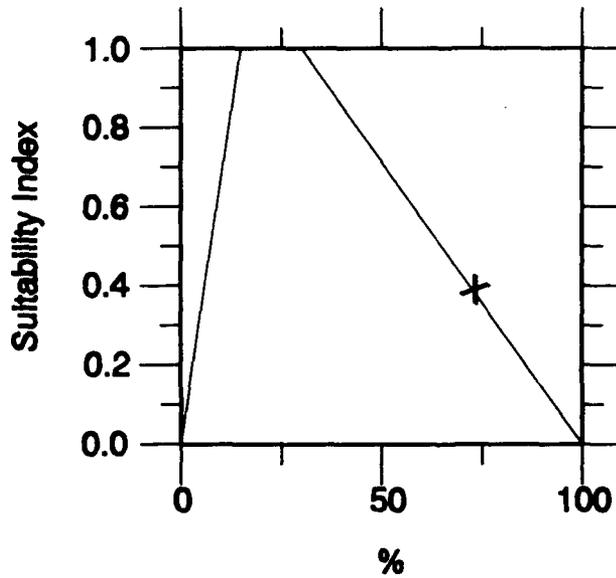
Existing conditions are represented in Table 1 in the "YR 1" column, and future without-project projections have been made for 25, 40, and 50 years into the future. These target years were selected because, after an analysis of past and estimated future habitat changes, it was projected that the decline in habitat quality over the next 25 years would likely be relatively linear. However, during the second 25 years of the planning period, it was projected that the decline would accelerate in the later years of this period due to the reaching of critical conditions in habitat quality, especially dissolved oxygen depletion and excessive shallowing. The total average annual habitat units for the without-project projection are 127 (see bottom right of table).

The model results reflect some of the same habitat problems identified by resource managers: excessive aquatic vegetation (summer V_3), dissolved oxygen depletion problems (summer V_6 and winter V_8), and shallow water depths (winter V_A). The use of the model also revealed other habitat deficiencies such as less than optimum water

SUMMER:		VARIABLE	FUTURE WITHOUT PROJECT			
			YR 1	YR 25	YR 40	YR 50
Pool Area % (summer)	V1	1.00	1.00	1.00	1.00	
Percent Cover (aquatic veg.)	V3	0.35	.25	0.20	0.15	
Turbidity	V6	1.00	1.00	1.00	1.00	
pH Range	V7	1.00	1.00	1.00	1.00	
Dissolved Oxygen	V8	0.70	0.40	0.40	0.40	
Temperature (adult)	V10	1.00	1.00	1.00	1.00	
Temperature (embryo)	V11	1.00	1.00	1.00	1.00	
Temperature (fry)	V12	1.00	1.00	1.00	1.00	
Temperature (juvenile)	V13	0.80	0.90	0.90	0.90	
Velocity (adult)	V14	1.00	1.00	1.00	1.00	
Velocity (embryo)	V15	1.00	1.00	1.00	1.00	
Velocity (fry)	V16	1.00	1.00	1.00	1.00	
Velocity (juvenile)	V17	1.00	1.00	1.00	1.00	
Stream Gradient	V18	1.00	1.00	1.00	1.00	
Substrate Composition	V20	0.70	0.70	0.70	0.70	
FOOD	C-F	0.59	0.50	0.45	0.39	
COVER	C-C	0.35	0.25	0.20	0.15	
WATER QUALITY	C-WQ	0.88	0.79	0.40	0.40	
REPRODUCTION	C-R	0.89	0.89	0.89	0.89	
OTHER	C-OT	1.00	1.00	1.00	1.00	
<i>SUMMER SUB-TOTAL</i>	<i>S-HSI</i>	<i>0.72</i>	<i>0.64</i>	<i>0.40</i>	<i>0.40</i>	
WINTER:						
Winter Cover (depth)	VA	0.75	0.55	0.45	0.40	
Winter Dissolved Oxygen	VB	0.70	0.40	0.40	0.40	
Winter Water Temperature	VC	1.00	1.00	1.00	1.00	
Winter Current Velocity	VD	1.00	1.00	1.00	1.00	
COVER	W-C	0.75	0.55	0.45	0.40	
WATER QUALITY	W-WQ	0.80	0.60	0.40	0.40	
OTHER	W-OT	1.00	1.00	1.00	1.00	
<i>WINTER SUB-TOTAL</i>	<i>W-HSI</i>	<i>0.83</i>	<i>0.67</i>	<i>0.40</i>	<i>0.40</i>	
SUITABILITY INDEX	HSI	0.77	0.65	0.40	0.40	
	HU		3804	1863	852	
	TOTAL HU				6339	
AVERAGE ANNUAL HU'S	AAHU				127	

Table 1 HEP Analysis of Future Without Project Conditions

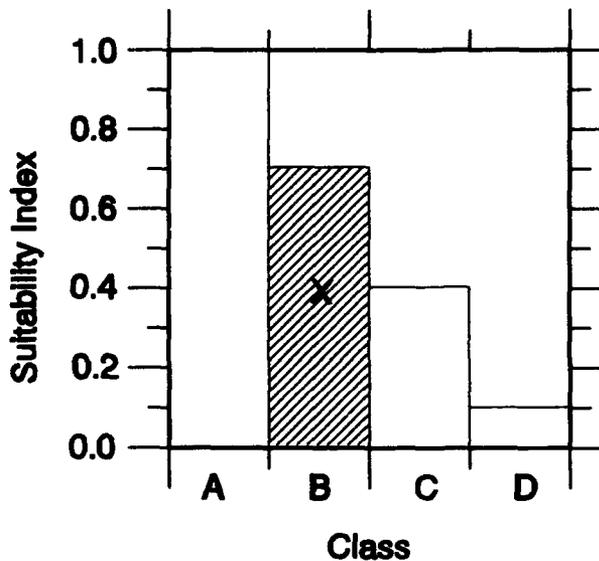
(V3) Percent Cover
 (aquatic vegetation,
 submersed, dense
 stands, finely divided
 leaves).



**(V8) Minimum Dissolved
 Oxygen Range During
 Summer**

- A) Seldom below 5.0 mg/l.
- B) Usually between 3.0 and 5.0 mg/l.
- C) Usually between 1.5 and 3.0 mg/l.
- D) Often below 1.5 mg/l.

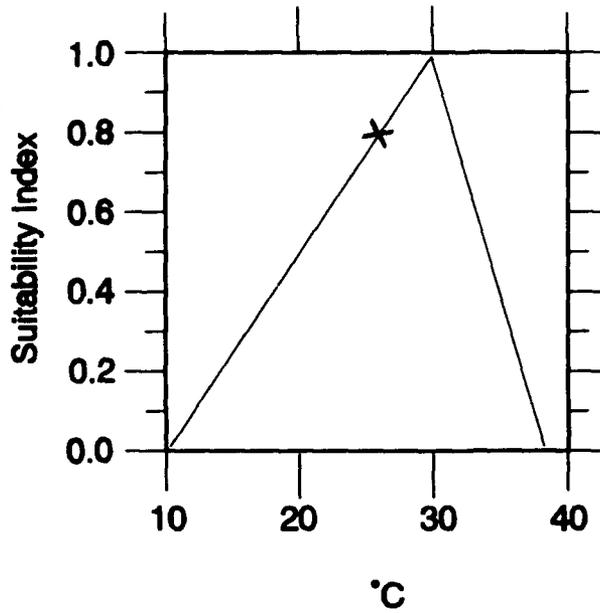
Note: Lacustrine D.O. levels refer to littoral areas; riverine, pools.



(Graphs taken from USFWS Bluegill HSI model, with UMRS winter modifications.)

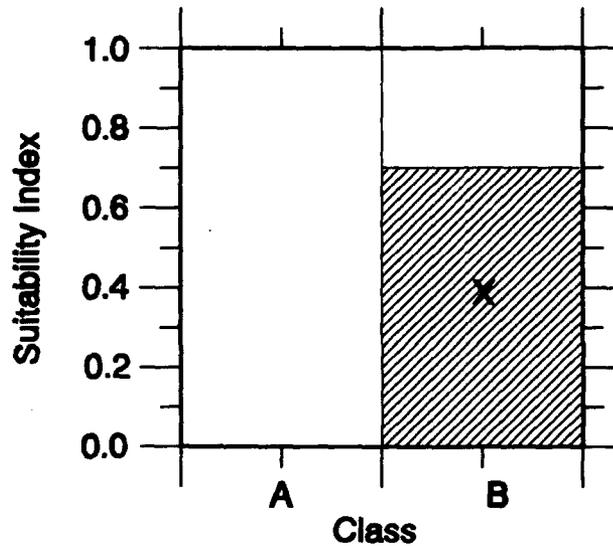
Figure 4A Graphs of Sub-Optimal Variables

(V13) Maximum Midsummer Temperature Within Pools or Littoral Areas (juvenile).



(V20) Substrate Composition within Pools or Littoral Areas During Spawning

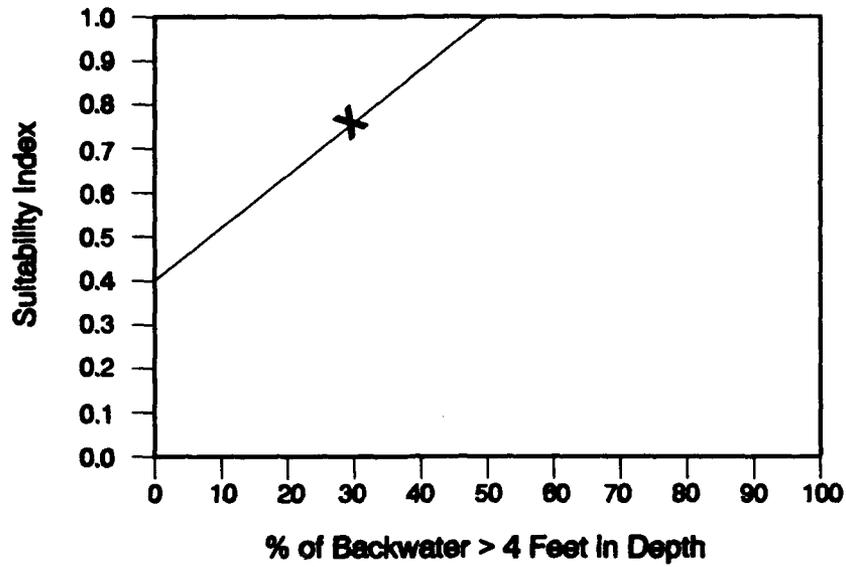
- A) Fines and gravel present.**
- B) Fines and gravel scarce.**



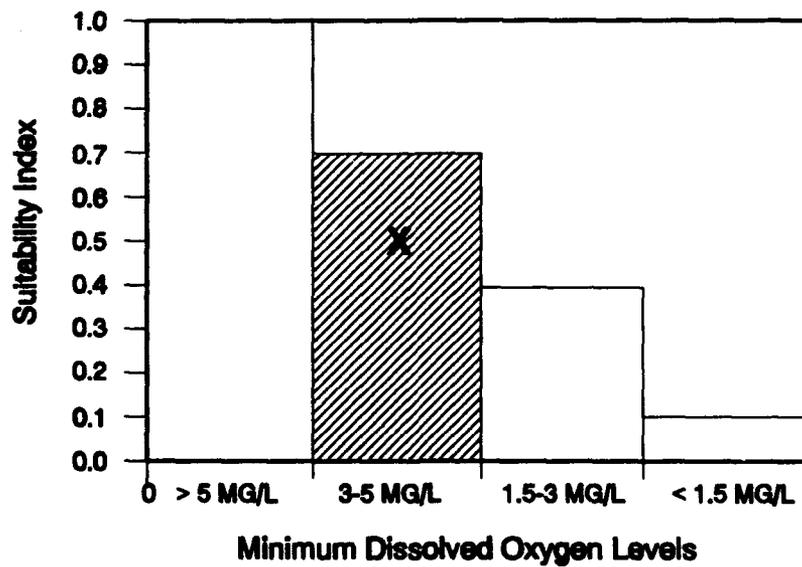
(Graphs taken from USFWS Bluegill HSI model, with UMRS winter modifications.)

Figure 4B Graphs of Sub-Optimal Variables

BACKWATER WATER DEPTHS



WINTER DISSOLVED OXYGEN



(Graphs taken from USFWS Bluegill HSI model, with UMRS winter modifications.)

Figure 4C Graphs of Sub-Optimal Variables

temperatures for juvenile bluegills (V_{13}) and less than optimum substrate conditions for spawning (V_{20}).

An analysis was conducted to identify the most critical factors in determining overall habitat suitability. These could also be considered "limiting factors." The critical variables were identified by independently optimizing each of the variables, isolating their relative effect on the HSI. The results of this analysis are summarized in Table 2.

Projected Variable*	TY1	TY25	TY40	TY50
Future Without (HSI)	0.77	0.65	0.40	0.40
If Vegetative Cover (V_3) Optimized	0.88	0.78	0.40	0.40
If Dissolved Oxygen (V_8 & V_B) Optimized	0.83	0.77	0.73	0.70
If Temperature (juvenile) (V_{13}) Optimized	0.78	0.66	0.40	0.40
If Substrate Composition (V_{20}) Optimized	0.78	0.66	0.40	0.40
If Backwater Depths (V_A) Optimized	0.80	0.70	0.40	0.40
*(Projected result if a single variable were optimized throughout the 50 year period.)				

Table 2 Analysis of Variable Criticality

This analysis indicates that in the near term (YR 1 - YR 25) overabundant aquatic vegetation (V_3) is the most significant problem, and the greatest habitat gains are likely to be made by addressing this problem. Optimizing this variable alone yields the highest overall HSI by year 25 (0.78).

In the long term, solving the dissolved oxygen depletion problem (variables V_8 and V_B) will become more significant, especially for winter conditions. In Table 2, the only HSI greater than 0.40 in year 50 is for the optimization of these two variables. Dissolved oxygen will be the long term limiting factor for bluegills in Bussey Lake.

Preserving the existing level of dissolved oxygen ($SI = 0.70$) would provide most of the benefits to be gained by an improvement project (HSI increases of 0.08 to 0.14). Improving dissolved oxygen levels to their optimum ($SI = 1.0$) would provide only minor additional gains in the overall habitat conditions (HSI increases of 0.01 to 0.03).

This analysis indicates that, if the overabundant aquatic vegetation and dissolved oxygen problems are not addressed, any habitat gains attempted through improving water temperature (V_{13}), spawning substrate (V_{20}), or depth (V_A) would be negligible. Specific results that could be expected from a variety of habitat improvement measures are discussed in the section below.

IDENTIFICATION OF HABITAT RESTORATION MEASURES

Habitat restoration measures were identified using the habitat deficiencies noted by resource managers and the habitat model. Table 3 lists those measures identified.

VARIABLE:	MANAGEMENT MEASURE:
PERCENT VEGETATIVE COVER	<ul style="list-style-type: none"> • Aquatic Plant Harvesting • Dredging • Water Level Increase • Herbicide Treatments
DISSOLVED OXYGEN (SUMMER & WINTER)	<ul style="list-style-type: none"> • Aeration • Dredging • Water Level Increase
SUBSTRATE TYPE/SPAWNING HABITAT	<ul style="list-style-type: none"> • Substrate Improvement
WINTER COVER	<ul style="list-style-type: none"> • Dredging • Water Level Increase
TEMPERATURE (JUVENILE)	<ul style="list-style-type: none"> • No Practical Alternatives Identified

Table 3 Measures Identified to Improve Habitat Conditions

It should be noted that two habitat improvement measures identified were not considered in the analysis. Increasing the water level in Bussey Lake to increase water depths was deemed infeasible. Water levels in the lake are regulated by a navigation dam, and there is some shoreline development present. To gain the depths necessary to significantly improve habitat quality in Bussey Lake, large expenditures would be required for increasing the dam height and for compensating property losses due to inundation. The use of herbicides was also not considered further. At Bussey Lake, employing herbicides on the massive scale necessary to control aquatic vegetation for habitat improvement would be institutionally and politically unacceptable.

The estimated change in each variable resulting from each measure has been run through the Habitat Evaluation Procedures (HEP) bluegill model to determine impacts. These projected impacts are displayed in Tables 4 through 6, described below. Since some impacts vary through time, all impacts are computed in average annual habitat units (AAHU). Future without-project conditions are included in each table for comparison (127 AAHUs); this figure is subtracted from proposed project conditions to determine the net improvement in AAHUs. Values for habitat variables affected by the various measures have been highlighted for ease in identification.

Aeration and substrate improvement impacts are presented in Table 4. Implementing

winter aeration would improve dissolved oxygen (V_B) and the winter water quality requisite (W-WQ) and would yield a net of 22 AAHUs. Substrate improvement (V_{20}) would improve the reproduction requisite (C-R) and would yield a net of 1 AAHU.

Impacts from various levels of aquatic plant harvesting are presented in Table 5. Harvesting options range from 21 to 106 acres per year. Improvement is evident in the aquatic vegetation cover variable (V_3), which increases with the level of harvesting in the range shown. With 106 acres of harvesting annually, an optimum value for this variable is reached for the full 50 years.

Improvement in aquatic vegetation cover improves both the food (C-F) and cover (C-C) requisites. Figures for both variables increase with the respective levels of harvesting considered. The net increases in habitat units from aquatic plant harvesting range from 4 to 16 AAHU's for the levels of harvesting presented.

Impacts from a number of dredging options are presented in Table 6. The dredging amounts range from 140,000 cubic yards to 310,000 cubic yards, and incorporate a number of disposal options. Dredging affects both summer (V_3) and winter (V_B) dissolved oxygen as well as winter depth (V_A). Improvement in these variables leads to increased suitability to the summer food (C-F) and cover (C-C) requisites and the winter cover (W-C) and water quality (W-WQ) requisites. Increases in net AAHU's range from 24 to 48 for the options displayed.

Var.	FWO				AERATION (WINTER) ABOVE 5 PPM				SUBSTRATE IMPROVEMENT			
	YR 1	YR 25	YR 40	YR 50	YR 1	YR 25	YR 40	YR 50	YR 1	YR 25	YR 40	YR 50
V1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
V3	0.35	0.25	0.20	0.15	0.35	0.25	0.20	0.15	0.35	0.25	0.20	0.15
V6	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
V7	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
V8	0.70	0.40	0.40	0.40	0.70	0.40	0.40	0.40	0.70	0.40	0.40	0.40
V10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
V11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
V12	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
V13	0.80	0.90	0.90	0.90	0.80	0.90	0.90	0.90	0.80	0.90	0.90	0.90
V14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
V15	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
V16	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
V17	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
V18	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
V20	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
C-F	0.59	0.50	0.45	0.39	0.59	0.50	0.45	0.39	0.59	0.50	0.45	0.39
C-C	0.35	0.25	0.20	0.15	0.35	0.25	0.20	0.15	0.35	0.25	0.20	0.15
C-WQ	0.88	0.79	0.40	0.40	0.88	0.79	0.40	0.40	0.88	0.79	0.40	0.40
C-R	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89
C-OT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
S-HSI	0.72	0.64	0.40	0.40	0.72	0.64	0.40	0.40	0.74	0.65	0.40	0.40
VA	0.75	0.55	0.45	0.40	0.75	0.55	0.45	0.40	0.75	0.55	0.45	0.40
VB	0.70	0.40	0.40	0.40	0.70	0.40	0.40	0.40	0.70	0.40	0.40	0.40
VC	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
VD	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
W-C	0.75	0.55	0.45	0.40	0.75	0.55	0.45	0.40	0.75	0.55	0.45	0.40
W-WQ	0.80	0.80	0.40	0.40	0.80	0.80	0.40	0.40	0.80	0.80	0.40	0.40
W-OT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
W-HSI	0.83	0.67	0.40	0.40	0.83	0.86	0.82	0.80	0.83	0.67	0.40	0.40
HSI	0.77	0.65	0.40	0.40	0.82	0.74	0.57	0.56	0.78	0.66	0.40	0.40
HU		3804	1683	852		4159	2101	1210		3841	1694	852
TOTAL HU				6339				7470				6387
AAHU				127				149				128

Table 4 HEP Analysis of Aeration and Substrate Improvement

Var.	FWO			HARVESTING 21 ACRES			HARVESTING 42 ACRES			HARVESTING 63 ACRES			HARVESTING 85 ACRES			HARVESTING 106 ACRES				
	YR 1	YR 25	YR 40	YR 50	YR 1	YR 25	YR 40	YR 50	YR 1	YR 25	YR 40	YR 50	YR 1	YR 25	YR 40	YR 50	YR 1	YR 25	YR 40	YR 50
V1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
V6	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
V7	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
V8	0.70	0.40	0.40	0.40	0.70	0.40	0.40	0.40	0.70	0.40	0.40	0.40	0.70	0.40	0.40	0.40	0.70	0.40	0.40	0.40
V10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
V11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
V12	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
V13	0.80	0.90	0.90	0.90	0.80	0.90	0.90	0.90	0.80	0.90	0.90	0.90	0.80	0.90	0.90	0.90	0.80	0.90	0.90	0.90
V14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
V15	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
V16	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
V17	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
V18	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
V20	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
C-WQ	0.88	0.79	0.40	0.40	0.88	0.79	0.40	0.40	0.88	0.79	0.40	0.40	0.88	0.79	0.40	0.40	0.88	0.79	0.40	0.40
C-R	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89
C-OT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
S-HSI	0.72	0.64	0.40	0.40	0.75	0.72	0.40	0.40	0.77	0.74	0.40	0.40	0.86	0.83	0.40	0.40	0.90	0.87	0.40	0.40
VA	0.75	0.55	0.45	0.40	0.75	0.55	0.45	0.40	0.75	0.55	0.45	0.40	0.75	0.55	0.45	0.40	0.75	0.55	0.45	0.40
VB	0.70	0.40	0.40	0.40	0.70	0.40	0.40	0.40	0.70	0.40	0.40	0.40	0.70	0.40	0.40	0.40	0.70	0.40	0.40	0.40
VC	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
VD	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
W-C	0.75	0.55	0.45	0.40	0.75	0.55	0.45	0.40	0.75	0.55	0.45	0.40	0.75	0.55	0.45	0.40	0.75	0.55	0.45	0.40
W-WQ	0.80	0.60	0.40	0.40	0.80	0.60	0.40	0.40	0.80	0.60	0.40	0.40	0.80	0.60	0.40	0.40	0.80	0.60	0.40	0.40
W-OT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
W-HSI	0.83	0.67	0.40	0.40	0.83	0.67	0.40	0.40	0.83	0.67	0.40	0.40	0.83	0.67	0.40	0.40	0.83	0.67	0.40	0.40
HSI	0.77	0.65	0.40	0.40	0.79	0.69	0.40	0.40	0.80	0.70	0.40	0.40	0.85	0.74	0.40	0.40	0.87	0.76	0.40	0.40
HU	3804	1683	852		3944	1746	852		4002	1763	852		4229	1827	852		4333	1856	852	
TOTAL HU																				
AAHU																				

ASSUME: LAKE IS 213 ACRES AND 70% (149 ACRES) IS VEGETATED.

Table 5 HEP Analysis of Aquatic Plant Harvesting

Vnr.	FWO				PLAN D1 140,000				PLAN D2 185,000				PLAN D3 220,000				PLAN D4 245,000				
	VR 1	VR 25	VR 40	VR 50	VR 1	VR 25	VR 40	VR 50	VR 1	VR 25	VR 40	VR 50	VR 1	VR 25	VR 40	VR 50	VR 1	VR 25	VR 40	VR 50	
V1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
V3	0.35	0.25	0.20	0.15	0.40	0.30	0.25	0.20	0.45	0.35	0.30	0.25	0.50	0.40	0.35	0.30	0.50	0.40	0.35	0.30	
V6	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
V7	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
V8	0.70	0.40	0.40	0.40	0.70	0.70	0.40	0.40	0.70	0.70	0.40	0.40	0.70	0.70	0.55	0.40	0.70	0.70	0.70	0.40	
V10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
V11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
V12	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
V13	0.80	0.90	0.90	0.90	0.80	0.90	0.90	0.90	0.80	0.90	0.90	0.90	0.80	0.90	0.90	0.90	0.80	0.90	0.90	0.90	
V14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
V15	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
V16	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
V17	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
V18	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
V20	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	
C-WQ	0.88	0.79	0.40	0.40	0.88	0.89	0.79	0.40	0.88	0.89	0.79	0.40	0.88	0.89	0.84	0.40	0.88	0.89	0.89	0.79	
C-R	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	
C-OT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
S-HSI	0.72	0.64	0.40	0.40	0.75	0.70	0.64	0.40	0.77	0.72	0.67	0.40	0.79	0.75	0.71	0.40	0.79	0.75	0.72	0.67	
VC	0.75	0.65	0.65	0.65	0.75	0.69	0.67	0.65	0.75	0.69	0.65	0.65	0.75	0.69	0.65	0.65	0.75	0.69	0.65	0.65	
VD	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
WC	0.75	0.65	0.65	0.65	0.75	0.69	0.67	0.65	0.75	0.69	0.65	0.65	0.75	0.69	0.65	0.65	0.75	0.69	0.65	0.65	
W-OT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
W-HSI	0.83	0.67	0.40	0.40	0.95	0.79	0.65	0.40	0.96	0.80	0.67	0.40	0.96	0.82	0.72	0.40	0.97	0.82	0.79	0.67	
HSI	0.77	0.65	0.40	0.40	0.84	0.74	0.65	0.40	0.86	0.76	0.67	0.40	0.87	0.78	0.72	0.40	0.88	0.78	0.76	0.67	
HU	3804	1683	852		4209	2216	1114		4318	2287	1138		4402	2384	1186		4419	2458	1517		
TOTAL HU			6339			7539				7744				7985				8393			
AAHU			127			151				155				160				168			

Table 6A HEP Analysis of Dredging Options

	FW/O					PLAN D5 255,000					PLAN D6 270,000					PLAN D7 310,000				
Var.	YR 1	YR 25	YR 40	YR 50		YR 1	YR 25	YR 40	YR 50		YR 1	YR 25	YR 40	YR 50		YR 1	YR 25	YR 40	YR 50	
V1	1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00	
V3	0.35	0.25	0.20	0.15		0.50	0.40	0.35	0.35		0.50	0.45	0.40	0.35		0.60	0.50	0.45	0.40	
V6	1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00	
V7	1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00	
V8	0.70	0.40	0.40	0.40		0.70	0.70	0.70	0.40		0.70	0.70	0.70	0.40		0.70	0.70	0.70	0.40	
V10	1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00	
V11	1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00	
V12	1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00	
V13	0.80	0.90	0.90	0.90		0.80	0.90	0.90	0.90		0.80	0.90	0.90	0.90		0.80	0.90	0.90	0.90	
V14	1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00	
V15	1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00	
V16	1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00	
V17	1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00	
V18	1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00	
V20	0.70	0.70	0.70	0.70		0.70	0.70	0.70	0.70		0.70	0.70	0.70	0.70		0.70	0.70	0.70	0.70	
C-F	0.50	0.50	0.45	0.35		0.71	0.65	0.65	0.50		0.71	0.67	0.63	0.50		0.77	0.71	0.67	0.63	
C-C	0.35	0.25	0.20	0.15		0.50	0.40	0.35	0.35		0.50	0.45	0.40	0.35		0.60	0.50	0.45	0.40	
C-WQ	0.89	0.79	0.40	0.40		0.88	0.89	0.89	0.79		0.88	0.89	0.89	0.89		0.88	0.89	0.89	0.79	
C-R	0.89	0.89	0.89	0.89		0.89	0.89	0.89	0.89		0.89	0.89	0.89	0.89		0.89	0.89	0.89	0.89	
C-OT	1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00	
S-HSI	0.72	0.64	0.40	0.40		0.79	0.75	0.72	0.70		0.79	0.77	0.75	0.70		0.83	0.79	0.77	0.72	
VA	0.75	0.55	0.45	0.40		0.90	0.75	0.65	0.55		0.90	0.75	0.65	0.55		0.95	0.80	0.70	0.60	
VB	0.70	0.40	0.40	0.40		1.00	0.70	0.70	0.40		1.00	0.70	0.70	0.40		1.00	0.70	0.70	0.40	
VC	1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00	
VD	1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00	
VE	0.75	0.55	0.45	0.40		0.90	0.75	0.65	0.55		0.90	0.75	0.65	0.55		0.95	0.80	0.70	0.60	
VF	0.70	0.40	0.40	0.40		1.00	0.70	0.70	0.40		1.00	0.70	0.70	0.40		1.00	0.70	0.70	0.40	
VG	1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00	
WH	1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00	
W-HSI	0.83	0.67	0.40	0.40		0.97	0.83	0.80	0.67		0.97	0.83	0.80	0.67		0.99	0.85	0.82	0.68	
HSI	0.77	0.65	0.40	0.40		0.88	0.79	0.76	0.68		0.88	0.80	0.78	0.68		0.90	0.82	0.79	0.70	
HU		3804	1683	852		4437	2481	1539	1552		4468	2520	1552	1593		4584	2578	1593	1593	
TOTAL HU								6339	8456				8456	8754				8754	8754	
AHU				127				169	171				171	175				175	175	

Table 6B HEP Analysis of Dredging Options

COST ESTIMATES FOR HABITAT IMPROVEMENT MEASURES

The following are the cost estimates for the various alternative habitat restoration features being used for this demonstration. Components of the estimates were rounded as deemed appropriate, given the sources of the estimates. All project costs have been computed in average annual terms for a 50-year project life for comparability.

Depending on project features, the estimates may contain anticipated expenditures for initial equipment (and/or labor), replacement equipment, annual labor, and annual operation and maintenance. These types of expenditures require different consideration when determining average annual costs.

Average annual costs for initial expenditures are determined by multiplying the expended amount by the interest and amortization (I & A) factor for the appropriate interest rate and period of time (in this case, 8 1/8 percent interest for a 50-year period: I & A factor equals 0.082919).

Costs for expenditures that take place in the future (replacement equipment, for example) must first be brought to "present worth" before being multiplied by the appropriate I & A factor to determine average annual costs. This is to account for the fact that money invested today will grow (at expected interest rates) to a larger amount by the time the replacement equipment expenditure is made. The present worth (PW) factor determines the amount of money required at the beginning of the project to pay for replacement equipment in the future.

Costs that occur consistently throughout the project life for either labor or operation and maintenance are already in average annual terms, and are simply added to other average annual costs to determine the total.

AERATION

The aeration cost estimate is based on a review of cost estimates for aeration equipment for other projects in the UMRS.

Initial Equipment

The initial equipment cost will be \$50,000. The life expectancy of the equipment is 25 years. Therefore, the aeration equipment will have to be replaced once during the 50-year life of the project, at year 25.

Operation and Maintenance

Annual operation and maintenance includes cost of electricity and routine inspection, maintenance, repair, and miscellaneous replacement costs. Annual operation and maintenance costs will be \$5,000.

SUMMARY OF AERATION COSTS:

Equipment purchases:

Year	Cost	PW Factor	Present Worth
0	\$50,000	1.0	\$50,000
25	\$50,000	0.141856	<u>\$7,093</u>
Total			\$57,093

I & A @ 50 YRS 0.082919
8 1/8 percent interest
Ave. Annual Cost \$4,734
Annual O & M \$5,000

Total Annual Cost \$9,734

AQUATIC PLANT HARVESTING

The estimated aquatic plant harvesting costs are based on experiences with the Sauk Lake and Lake Minnetonka projects.

Harvesting Equipment

The initial investment for aquatic plant harvesting equipment would be \$125,000. The equipment has a life expectancy of 10 years. Therefore, the equipment will have to be replaced four times during the 50-year life of the project; i.e., at year 10, year 20, year 30, and year 40.

Harvesting Costs

Harvesting costs vary by alternative. It is assumed that, as greater areas are harvested, the cost per acre decreases because of increased efficiencies. The total cost was rounded to the nearest \$1,000.

Maintenance Costs

Annual maintenance costs are also assumed to be related to acres harvested; e.g., the more the equipment is used, the greater the maintenance. These costs were rounded to the nearest \$500.

SUMMARY OF HARVESTING COSTS:

Acres	Cost/ Acre	Harvest Cost	Equip. O & M	Equip. Ann. Cost*	Total Ann. Cost
21	\$200	\$4,200	\$ 500	\$18,734	\$23,434
42	\$160	\$6,720	\$ 500	\$18,734	\$25,954
63	\$140	\$8,820	\$1,000	\$18,734	\$28,554
85	\$115	\$9,775	\$1,500	\$18,734	\$30,009
106	\$100	\$10,600	\$1,500	\$18,734	\$30,834

* Present Worth of Equipment Through Project Life:

Year	Cost	PW Factor	Present Worth
0	\$125,000	1.0	\$125,000
10	\$125,000	0.457866	\$57,233
20	\$125,000	0.209642	\$26,205
30	\$125,000	0.095988	\$11,998
40	\$125,000	0.043950	<u>\$5,494</u>
Total			\$225,930

I & A @ 50 YRS 0.082919
8 1/8 percent interest
Ave. Annual Cost \$18,734

SUBSTRATE IMPROVEMENT

Substrate improvement involves placing a 1-foot sand blanket over 20 acres of the lake bottom to improve spawning habitat. It is assumed that the life expectancy of the sand blanket would be 15 to 20 years. Therefore, the sand blanket would have to be replaced twice during the 50-year project life, at year 17 and at year 34.

Cost for placing the substrate is estimated to be \$15/cubic yard.

32,267 c.y. @ \$15 = \$500,000 (rounded to nearest \$25,000)

SUMMARY OF SUBSTRATE IMPROVEMENT COSTS:

Year	Cost	PW Factor	Present Worth
0	\$484,005	1.0	\$484,005
17	\$484,005	0.265006	\$128,264
34	\$484,005	0.070228	<u>\$33,991</u>
Total			\$646,260

I & A @ 50 YRS 0.082919
 8 1/8 percent interest
 Ave. Annual Cost \$53,587
 Annual O & M \$0

Total Annual Cost \$53,587

DREDGING

Dredging costs are based on actual bid estimates received for the Bussey Lake project, plus recent work done in evaluating additional placement sites for the project. The mobilization costs differ by alternative because some of the larger alternative placement sites require the use of additional equipment such as booster dredges.

Cost components used in preparing the estimates for dredging costs are presented in Table 7. A summary of the habitat affected by disposal of dredged material is included in Table 7.

PLAN	DREDGING (cubic yards)	MOBILIZATION	DISPOSAL SITE PREPARATION	DREDGING COST	SITE RESTORATION	TOTAL COST
D1	140,000	\$140,000	\$335,000	\$720,000	\$30,000	\$1,225,000
D2	185,000	\$140,000	\$350,000	\$950,000	\$40,000	\$1,480,000
D3	220,000	\$300,000	\$680,000	\$985,000	\$160,000	\$2,125,000
D4	245,000	\$300,000	\$735,000	\$1,110,000	\$170,000	\$2,315,000
D5	255,000	\$300,000	\$735,000	\$1,160,000	\$170,000	\$2,365,000
D6	270,000	\$300,000	\$760,000	\$1,240,000	\$175,000	\$2,475,000
D7	310,000	\$300,000	\$815,000	\$1,445,000	\$180,000	\$2,740,000

Table 7 Costs of Dredging Options

There would be no operation and maintenance costs associated with the dredging alternatives. Annualized costs are shown below.

SUMMARY OF DREDGING COSTS:

Item	Cubic yds	First Cost	Ave. Ann. Cost
D1	140,000	\$1,225,000	\$101,575
D2	185,000	\$1,480,000	\$122,719
D3	220,000	\$2,125,000	\$176,202
D4	245,000	\$2,315,000	\$191,957
D5	255,000	\$2,365,000	\$196,102
D6	270,000	\$2,475,000	\$205,223
D7	310,000	\$2,740,000	\$227,197

I & A @ 50 YRS 0.082919
 8 1/8 percent interest

FORMULATING ALTERNATIVES

Habitat improvement alternatives have been created by identifying all combinations of combinable measures. For Bussey Lake, all four habitat improvement measures are considered independent and combinable. Plans within measures (two dredging plans, for example) cannot be combined to form an alternative. A total of 192 combinations including the no action alternative, were formed.

aeration substrate improvement harvesting dredging
 2 X 2 X 6 X 8 =192

These combinations, along with their costs and output in AAHU's, are displayed in Tables 8A and 8B. A scattergram of the combinations, costs, and outputs is presented on Figure 5.

[Note: For simplification, the following tables identify all measures by their first letter (A=aeration, D=dredging, H=harvesting, and S=substrate improvement) and the respective options by a number (0=no action, 1=first identified option, etc.)]

<u>Combination</u>	<u>Output*</u>	<u>Cost*</u>	<u>Combination</u>	<u>Output*</u>	<u>Cost*</u>
D0 + H0 + A0 + S0	0	0.0	D0 + H0 + A1 + S0	22	9.7
D1 + H0 + A0 + S0	24	101.6	D1 + H0 + A1 + S0	46	111.3
D2 + H0 + A0 + S0	28	122.7	D2 + H0 + A1 + S0	50	132.4
D3 + H0 + A0 + S0	33	176.2	D3 + H0 + A1 + S0	55	185.9
D4 + H0 + A0 + S0	41	191.1	D4 + H0 + A1 + S0	63	200.8
D5 + H0 + A0 + S0	42	196.1	D5 + H0 + A1 + S0	64	205.8
D6 + H0 + A0 + S0	44	205.2	D6 + H0 + A1 + S0	66	214.9
D7 + H0 + A0 + S0	48	227.2	D7 + H0 + A1 + S0	70	236.9
D0 + H1 + A0 + S0	4	23.4	D0 + H1 + A1 + S0	26	33.1
D1 + H1 + A0 + S0	28	125.0	D1 + H1 + A1 + S0	50	134.7
D2 + H1 + A0 + S0	32	146.1	D2 + H1 + A1 + S0	54	155.8
D3 + H1 + A0 + S0	37	199.6	D3 + H1 + A1 + S0	59	209.3
D4 + H1 + A0 + S0	45	214.5	D4 + H1 + A1 + S0	67	224.2
D5 + H1 + A0 + S0	46	219.5	D5 + H1 + A1 + S0	68	229.2
D6 + H1 + A0 + S0	48	228.6	D6 + H1 + A1 + S0	70	238.3
D7 + H1 + A0 + S0	52	250.6	D7 + H1 + A1 + S0	74	260.3
D0 + H2 + A0 + S0	5	25.9	D0 + H2 + A1 + S0	27	35.6
D1 + H2 + A0 + S0	29	127.5	D1 + H2 + A1 + S0	51	137.2
D2 + H2 + A0 + S0	33	148.6	D2 + H2 + A1 + S0	55	158.3
D3 + H2 + A0 + S0	38	202.1	D3 + H2 + A1 + S0	60	211.8
D4 + H2 + A0 + S0	46	217.0	D4 + H2 + A1 + S0	68	226.7
D5 + H2 + A0 + S0	47	222.0	D5 + H2 + A1 + S0	69	231.7
D6 + H2 + A0 + S0	49	231.1	D6 + H2 + A1 + S0	71	240.8
D7 + H2 + A0 + S0	53	253.1	D7 + H2 + A1 + S0	75	262.8
D0 + H3 + A0 + S0	11	28.5	D0 + H3 + A1 + S0	33	38.2
D1 + H3 + A0 + S0	35	130.1	D1 + H3 + A1 + S0	57	139.8
D2 + H3 + A0 + S0	39	151.2	D2 + H3 + A1 + S0	61	160.9
D3 + H3 + A0 + S0	44	204.7	D3 + H3 + A1 + S0	66	214.4
D4 + H3 + A0 + S0	52	219.6	D4 + H3 + A1 + S0	74	229.3
D5 + H3 + A0 + S0	53	224.6	D5 + H3 + A1 + S0	75	234.3
D6 + H3 + A0 + S0	55	233.7	D6 + H3 + A1 + S0	77	243.4
D7 + H3 + A0 + S0	59	255.7	D7 + H3 + A1 + S0	81	265.4
D0 + H4 + A0 + S0	14	30.0	D0 + H4 + A1 + S0	36	39.7
D1 + H4 + A0 + S0	38	131.6	D1 + H4 + A1 + S0	60	141.3
D2 + H4 + A0 + S0	42	152.7	D2 + H4 + A1 + S0	64	162.4
D3 + H4 + A0 + S0	47	206.2	D3 + H4 + A1 + S0	69	215.9
D4 + H4 + A0 + S0	55	221.1	D4 + H4 + A1 + S0	77	230.8
D5 + H4 + A0 + S0	56	226.1	D5 + H4 + A1 + S0	78	235.8
D6 + H4 + A0 + S0	58	235.2	D6 + H4 + A1 + S0	80	244.9
D7 + H4 + A0 + S0	62	257.2	D7 + H4 + A1 + S0	84	266.9
D0 + H5 + A0 + S0	16	30.8	D0 + H5 + A1 + S0	38	40.5
D1 + H5 + A0 + S0	40	132.4	D1 + H5 + A1 + S0	62	142.1
D2 + H5 + A0 + S0	44	153.5	D2 + H5 + A1 + S0	66	163.2
D3 + H5 + A0 + S0	49	207.0	D3 + H5 + A1 + S0	71	216.7
D4 + H5 + A0 + S0	57	221.9	D4 + H5 + A1 + S0	79	231.6
D5 + H5 + A0 + S0	58	226.9	D5 + H5 + A1 + S0	80	236.6
D6 + H5 + A0 + S0	60	236.0	D6 + H5 + A1 + S0	82	245.7
D7 + H5 + A0 + S0	64	258.0	D7 + H5 + A1 + S0	86	267.7

(*Output is measured in habitat units; cost measured in \$1000)

Table 8A Outputs and Costs of Combinations (Reference "9 Easy Steps", Exhibit 3B)

<u>Combination</u>	<u>Output*</u>	<u>Cost*</u>	<u>Combination</u>	<u>Output*</u>	<u>Cost*</u>
D0 + H0 + A0 + S1	1	53.6	D0 + H0 + A1 + S1	23	63.3
D1 + H0 + A0 + S1	25	155.2	D1 + H0 + A1 + S1	47	164.9
D2 + H0 + A0 + S1	29	176.3	D2 + H0 + A1 + S1	51	186.0
D3 + H0 + A0 + S1	34	229.8	D3 + H0 + A1 + S1	56	239.5
D4 + H0 + A0 + S1	42	244.7	D4 + H0 + A1 + S1	64	254.4
D5 + H0 + A0 + S1	43	249.7	D5 + H0 + A1 + S1	65	259.4
D6 + H0 + A0 + S1	45	258.8	D6 + H0 + A1 + S1	67	268.5
D7 + H0 + A0 + S1	49	280.8	D7 + H0 + A1 + S1	71	290.5
D0 + H1 + A0 + S1	5	77.0	D0 + H1 + A1 + S1	27	86.7
D1 + H1 + A0 + S1	29	178.6	D1 + H1 + A1 + S1	51	188.3
D2 + H1 + A0 + S1	33	199.7	D2 + H1 + A1 + S1	55	209.4
D3 + H1 + A0 + S1	38	253.2	D3 + H1 + A1 + S1	60	262.9
D4 + H1 + A0 + S1	46	268.1	D4 + H1 + A1 + S1	68	277.8
D5 + H1 + A0 + S1	47	273.1	D5 + H1 + A1 + S1	69	282.8
D6 + H1 + A0 + S1	49	282.2	D6 + H1 + A1 + S1	71	291.9
D7 + H1 + A0 + S1	53	304.2	D7 + H1 + A1 + S1	75	313.9
D0 + H2 + A0 + S1	6	79.5	D0 + H2 + A1 + S1	28	89.2
D1 + H2 + A0 + S1	30	181.1	D1 + H2 + A1 + S1	52	190.8
D2 + H2 + A0 + S1	34	202.2	D2 + H2 + A1 + S1	56	211.9
D3 + H2 + A0 + S1	39	255.7	D3 + H2 + A1 + S1	61	265.4
D4 + H2 + A0 + S1	47	270.6	D4 + H2 + A1 + S1	69	280.3
D5 + H2 + A0 + S1	48	275.6	D5 + H2 + A1 + S1	70	285.3
D6 + H2 + A0 + S1	50	284.7	D6 + H2 + A1 + S1	72	294.4
D7 + H2 + A0 + S1	54	306.7	D7 + H2 + A1 + S1	76	316.4
D0 + H3 + A0 + S1	12	82.1	D0 + H3 + A1 + S1	34	91.8
D1 + H3 + A0 + S1	36	183.7	D1 + H3 + A1 + S1	58	193.4
D2 + H3 + A0 + S1	40	204.8	D2 + H3 + A1 + S1	62	214.5
D3 + H3 + A0 + S1	45	258.3	D3 + H3 + A1 + S1	67	268.0
D4 + H3 + A0 + S1	53	273.2	D4 + H3 + A1 + S1	75	282.9
D5 + H3 + A0 + S1	54	278.2	D5 + H3 + A1 + S1	76	287.9
D6 + H3 + A0 + S1	56	287.3	D6 + H3 + A1 + S1	78	297.0
D7 + H3 + A0 + S1	60	309.3	D7 + H3 + A1 + S1	82	319.0
D0 + H4 + A0 + S1	15	83.6	D0 + H4 + A1 + S1	37	93.3
D1 + H4 + A0 + S1	39	185.2	D1 + H4 + A1 + S1	61	194.9
D2 + H4 + A0 + S1	43	206.3	D2 + H4 + A1 + S1	65	216.0
D3 + H4 + A0 + S1	48	259.8	D3 + H4 + A1 + S1	70	269.5
D4 + H4 + A0 + S1	56	274.7	D4 + H4 + A1 + S1	78	284.4
D5 + H4 + A0 + S1	57	279.7	D5 + H4 + A1 + S1	79	289.4
D6 + H4 + A0 + S1	59	288.8	D6 + H4 + A1 + S1	81	298.5
D7 + H4 + A0 + S1	63	310.8	D7 + H4 + A1 + S1	85	320.5
D0 + H5 + A0 + S1	17	84.4	D0 + H5 + A1 + S1	39	94.1
D1 + H5 + A0 + S1	41	186.0	D1 + H5 + A1 + S1	63	195.7
D2 + H5 + A0 + S1	45	207.1	D2 + H5 + A1 + S1	67	216.8
D3 + H5 + A0 + S1	50	260.6	D3 + H5 + A1 + S1	72	270.3
D4 + H5 + A0 + S1	58	275.5	D4 + H5 + A1 + S1	80	285.2
D5 + H5 + A0 + S1	59	280.5	D5 + H5 + A1 + S1	81	290.2
D6 + H5 + A0 + S1	61	289.6	D6 + H5 + A1 + S1	83	299.3
D7 + H5 + A0 + S1	65	311.6	D7 + H5 + A1 + S1	87	321.3

(*Output is measured in habitat units; cost measured in \$1000)

Table 8B Outputs and Costs of Combinations (Reference "9 Easy Steps", Exhibit 3B)

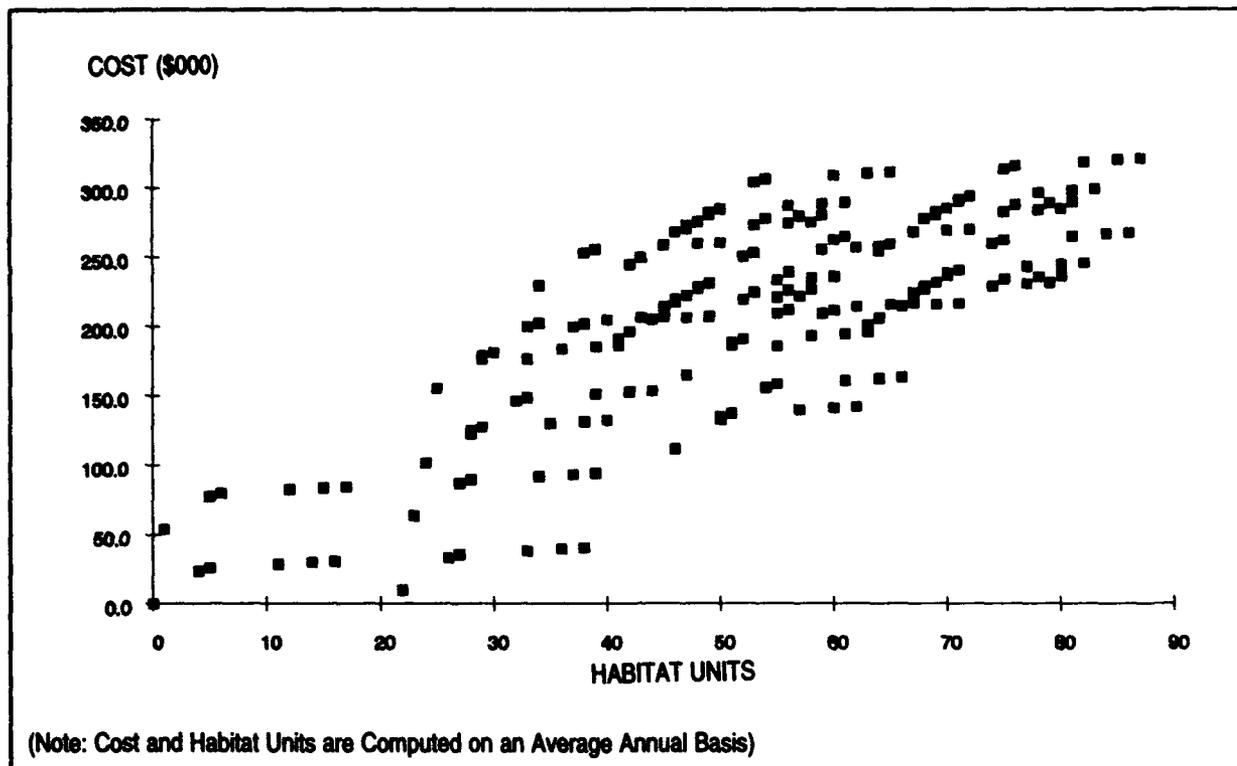


Figure 5 All Combinations of Combinable Measures (Reference "9 Easy Steps", Exhibit 3C)

ELIMINATING ECONOMICALLY INEFFICIENT COMBINATIONS

Economically inefficient combinations have been identified by following a series of steps described in the Corps' "Nine Easy Steps" (CEWRC-IWR-P; 17 April 1993 Draft; see Appendix A).

In the first step, all combinations have been sorted in ascending order by outputs and their respective costs. The sorted combinations are shown in Tables 9A and 9B. In cases where more than one combination yields a particular level of output, the more costly combinations have been shaded.

The shaded combinations are not economically efficient (that is, there is another alternative that will provide the same output for lower costs). These shaded combinations have been removed from further consideration. The remaining combinations are presented in Table 10. These combinations are the least costly alternative for each output level.

Combination	Output*	Cost*	Combination	Output*	Cost*
D0 + H0 + A0 + S0	0	0.0	D2 + H3 + A0 + S1	40	204.8
D0 + H0 + A0 + S1	1	53.6	D1 + H5 + A0 + S1	41	186.0
D0 + H1 + A0 + S0	4	23.4	D4 + H0 + A0 + S0	41	191.1
D0 + H2 + A0 + S0	5	25.9	D2 + H4 + A0 + S0	42	152.7
D0 + H1 + A0 + S1	5	77.0	D5 + H0 + A0 + S0	42	196.1
D0 + H2 + A0 + S1	6	79.5	D4 + H0 + A0 + S1	42	244.7
D0 + H3 + A0 + S0	11	28.5	D2 + H4 + A0 + S1	43	206.3
D0 + H3 + A0 + S1	12	82.1	D5 + H0 + A0 + S1	43	249.7
D0 + H4 + A0 + S0	14	30.0	D2 + H5 + A0 + S0	44	153.5
D0 + H4 + A0 + S1	15	83.6	D3 + H3 + A0 + S0	44	204.7
D0 + H5 + A0 + S0	16	30.8	D6 + H0 + A0 + S0	44	205.2
D0 + H5 + A0 + S1	17	84.4	D2 + H5 + A0 + S1	45	207.1
D0 + H0 + A1 + S0	22	9.7	D4 + H1 + A0 + S0	45	214.5
D0 + H0 + A1 + S1	23	63.3	D3 + H3 + A0 + S1	45	258.3
D1 + H0 + A0 + S0	24	101.6	D6 + H0 + A0 + S1	45	258.8
D1 + H0 + A0 + S1	25	155.2	D1 + H0 + A1 + S0	46	111.3
D0 + H1 + A1 + S0	26	33.1	D4 + H2 + A0 + S0	46	217.0
D0 + H2 + A1 + S0	27	35.6	D5 + H1 + A0 + S0	46	219.5
D0 + H1 + A1 + S1	27	86.7	D4 + H1 + A0 + S1	46	268.1
D0 + H2 + A1 + S1	28	89.2	D1 + H0 + A1 + S1	47	164.9
D2 + H0 + A0 + S0	28	122.7	D3 + H4 + A0 + S0	47	206.2
D1 + H1 + A0 + S0	28	125.0	D5 + H2 + A0 + S0	47	222.0
D1 + H2 + A0 + S0	29	127.5	D4 + H2 + A0 + S1	47	270.6
D2 + H0 + A0 + S1	29	176.3	D5 + H1 + A0 + S1	47	273.1
D1 + H1 + A0 + S1	29	178.6	D7 + H0 + A0 + S0	48	227.2
D1 + H2 + A0 + S1	30	181.1	D6 + H1 + A0 + S0	48	228.6
D2 + H1 + A0 + S0	32	146.1	D3 + H4 + A0 + S1	48	259.8
D0 + H3 + A1 + S0	33	38.2	D5 + H2 + A0 + S1	48	275.6
D2 + H2 + A0 + S0	33	148.6	D3 + H5 + A0 + S0	49	207.0
D3 + H0 + A0 + S0	33	176.2	D6 + H2 + A0 + S0	49	231.1
D2 + H1 + A0 + S1	33	199.7	D7 + H0 + A0 + S1	49	260.8
D0 + H3 + A1 + S1	34	91.8	D6 + H1 + A0 + S1	49	282.2
D2 + H2 + A0 + S1	34	202.2	D2 + H0 + A1 + S0	50	132.4
D3 + H0 + A0 + S1	34	229.8	D1 + H1 + A1 + S0	50	134.7
D1 + H3 + A0 + S0	35	130.1	D3 + H5 + A0 + S1	50	260.6
D0 + H4 + A1 + S0	36	39.7	D6 + H2 + A0 + S1	50	284.7
D1 + H3 + A0 + S1	36	183.7	D1 + H2 + A1 + S0	51	137.2
D0 + H4 + A1 + S1	37	93.3	D2 + H0 + A1 + S1	51	186.0
D3 + H1 + A0 + S0	37	199.6	D1 + H1 + A1 + S1	51	188.3
D0 + H5 + A1 + S0	38	40.5	D1 + H2 + A1 + S1	52	190.8
D1 + H4 + A0 + S0	38	131.6	D4 + H3 + A0 + S0	52	219.6
D3 + H2 + A0 + S0	38	202.1	D7 + H1 + A0 + S0	52	250.6
D3 + H1 + A0 + S1	38	253.2	D5 + H3 + A0 + S0	53	224.6
D0 + H5 + A1 + S1	39	94.1	D7 + H2 + A0 + S0	53	253.1
D2 + H3 + A0 + S0	39	151.2	D4 + H3 + A0 + S1	53	273.2
D1 + H4 + A0 + S1	39	185.2	D7 + H1 + A0 + S1	53	304.2
D3 + H2 + A0 + S1	39	255.7	D2 + H1 + A1 + S0	54	155.8
D1 + H5 + A0 + S0	40	132.4	D5 + H3 + A0 + S1	54	278.2

(*Output is measured in habitat units; cost measured in \$1000)

Table 9A Combinations (Sorted by Output and Cost) (Reference "9 Easy Steps", Exhibit 4B)

Combination	Output*	Cost*	Combination	Output*	Cost*
D7 + H2 + A0 + S1	54	306.7	D4 + H1 + A1 + S0	67	224.2
D2 + H2 + A1 + S0	55	158.3	D3 + H3 + A1 + S1	67	268.0
D3 + H0 + A1 + S0	55	185.9	D6 + H0 + A1 + S1	67	268.5
D2 + H1 + A1 + S1	55	209.4	D4 + H2 + A1 + S0	68	226.7
D4 + H4 + A0 + S0	55	221.1	D5 + H1 + A1 + S0	68	229.2
D6 + H3 + A0 + S0	55	233.7	D4 + H1 + A1 + S1	68	277.8
D2 + H2 + A1 + S1	56	211.9	D3 + H4 + A1 + S0	69	215.9
D5 + H4 + A0 + S0	56	226.1	D5 + H2 + A1 + S0	69	231.7
D3 + H0 + A1 + S1	56	239.5	D4 + H2 + A1 + S1	69	280.3
D4 + H4 + A0 + S1	56	274.7	D5 + H1 + A1 + S1	69	282.8
D6 + H3 + A0 + S1	56	287.3	D7 + H0 + A1 + S0	70	236.9
D1 + H3 + A1 + S0	57	139.8	D6 + H1 + A1 + S0	70	238.3
D4 + H5 + A0 + S0	57	221.9	D3 + H4 + A1 + S1	70	269.5
D5 + H4 + A0 + S1	57	279.7	D5 + H2 + A1 + S1	70	285.3
D1 + H3 + A1 + S1	58	193.4	D3 + H5 + A1 + S0	71	216.7
D5 + H5 + A0 + S0	58	226.9	D6 + H2 + A1 + S0	71	240.8
D6 + H4 + A0 + S0	58	235.2	D7 + H0 + A1 + S1	71	290.5
D4 + H5 + A0 + S1	58	275.5	D6 + H1 + A1 + S1	71	291.9
D3 + H1 + A1 + S0	59	209.3	D3 + H5 + A1 + S1	72	270.3
D7 + H3 + A0 + S0	59	255.7	D6 + H2 + A1 + S1	72	294.4
D6 + H5 + A0 + S1	59	280.5	D4 + H3 + A1 + S0	74	229.3
D6 + H4 + A0 + S1	59	288.8	D7 + H1 + A1 + S0	74	260.3
D1 + H4 + A1 + S0	60	141.3	D5 + H3 + A1 + S0	75	234.3
D3 + H2 + A1 + S0	60	211.8	D7 + H2 + A1 + S0	75	262.8
D6 + H5 + A0 + S0	60	236.0	D4 + H3 + A1 + S1	75	282.9
D3 + H1 + A1 + S1	60	262.9	D7 + H1 + A1 + S1	75	313.9
D7 + H3 + A0 + S1	60	309.3	D5 + H3 + A1 + S1	76	287.9
D2 + H3 + A1 + S0	61	160.9	D7 + H2 + A1 + S1	76	316.4
D1 + H4 + A1 + S1	61	194.9	D4 + H4 + A1 + S0	77	230.8
D3 + H2 + A1 + S1	61	265.4	D6 + H3 + A1 + S0	77	243.4
D6 + H5 + A0 + S1	61	289.6	D5 + H4 + A1 + S0	78	235.8
D1 + H5 + A1 + S0	62	142.1	D4 + H4 + A1 + S1	78	284.4
D2 + H3 + A1 + S1	62	214.5	D6 + H3 + A1 + S1	78	297.0
D7 + H4 + A0 + S0	62	257.2	D4 + H5 + A1 + S0	79	231.6
D1 + H5 + A1 + S1	63	195.7	D5 + H4 + A1 + S1	79	289.4
D4 + H0 + A1 + S0	63	200.8	D5 + H5 + A1 + S0	80	236.6
D7 + H4 + A0 + S1	63	310.8	D6 + H4 + A1 + S0	80	244.9
D2 + H4 + A1 + S0	64	162.4	D4 + H5 + A1 + S1	80	285.2
D5 + H0 + A1 + S0	64	205.8	D7 + H3 + A1 + S0	81	265.4
D4 + H0 + A1 + S1	64	254.4	D5 + H5 + A1 + S1	81	290.2
D7 + H5 + A0 + S0	64	268.0	D6 + H4 + A1 + S1	81	296.5
D2 + H4 + A1 + S1	65	216.0	D6 + H5 + A1 + S0	82	245.7
D5 + H0 + A1 + S1	65	259.4	D7 + H3 + A1 + S1	82	319.0
D7 + H5 + A0 + S1	65	311.6	D6 + H5 + A1 + S1	83	299.3
D2 + H5 + A1 + S0	66	163.2	D7 + H4 + A1 + S0	84	266.9
D6 + H3 + A1 + S0	66	214.4	D7 + H4 + A1 + S1	85	320.5
D5 + H0 + A1 + S0	68	214.9	D7 + H5 + A1 + S0	86	267.7
D2 + H5 + A1 + S1	67	216.8	D7 + H5 + A1 + S1	87	321.3

(*Output is measured in habitat units; cost measured in \$1000)

Table 9B Combinations (Sorted by Output and Cost) (Reference "9 Easy Steps", Exhibit 4B)

<u>Combination</u>	<u>Output*</u>	<u>Cost*</u>	<u>Combination</u>	<u>Output*</u>	<u>Cost*</u>
D0 + H0 + A0 + S0	0	0.0	D2 + H0 + A1 + S0	50	132.4
D0 + H0 + A0 + S1	1	53.6	D1 + H2 + A1 + S0	51	137.2
D0 + H1 + A0 + S0	4	23.4	D1 + H2 + A1 + S1	52	190.8
D0 + H2 + A0 + S0	5	25.9	D5 + H3 + A0 + S0	53	224.6
D0 + H2 + A0 + S1	6	79.5	D2 + H1 + A1 + S0	54	155.8
D0 + H3 + A0 + S0	11	28.5	D2 + H2 + A1 + S0	55	158.3
D0 + H3 + A0 + S1	12	82.1	D2 + H2 + A1 + S1	56	211.9
D0 + H4 + A0 + S0	14	30.0	D1 + H3 + A1 + S0	57	139.8
D0 + H4 + A0 + S1	15	83.6	D1 + H3 + A1 + S1	58	193.4
D0 + H5 + A0 + S0	16	30.8	D3 + H1 + A1 + S0	59	209.3
D0 + H5 + A0 + S1	17	84.4	D1 + H4 + A1 + S0	60	141.3
D0 + H0 + A1 + S0	22	9.7	D2 + H3 + A1 + S0	61	160.9
D0 + H0 + A1 + S1	23	63.3	D1 + H5 + A1 + S0	62	142.1
D1 + H0 + A0 + S0	24	101.6	D1 + H5 + A1 + S1	63	195.7
D1 + H0 + A0 + S1	25	155.2	D2 + H4 + A1 + S0	64	162.4
D0 + H1 + A1 + S0	26	33.1	D2 + H4 + A1 + S1	65	216.0
D0 + H2 + A1 + S0	27	35.6	D2 + H5 + A1 + S0	66	163.2
D0 + H2 + A1 + S1	28	89.2	D2 + H5 + A1 + S1	67	216.8
D1 + H2 + A0 + S0	29	127.5	D4 + H2 + A1 + S0	68	226.7
D1 + H2 + A0 + S1	30	181.1	D3 + H4 + A1 + S0	69	215.9
D2 + H1 + A0 + S0	32	146.1	D7 + H0 + A1 + S0	70	236.9
D0 + H3 + A1 + S0	33	38.2	D3 + H5 + A1 + S0	71	216.7
D0 + H3 + A1 + S1	34	91.8	D3 + H5 + A1 + S1	72	270.3
D1 + H3 + A0 + S0	35	130.1	D4 + H3 + A1 + S0	74	229.3
D0 + H4 + A1 + S0	36	39.7	D5 + H3 + A1 + S0	75	234.3
D0 + H4 + A1 + S1	37	93.3	D5 + H3 + A1 + S1	76	287.9
D0 + H5 + A1 + S0	38	40.5	D4 + H4 + A1 + S0	77	230.8
D0 + H5 + A1 + S1	39	94.1	D5 + H4 + A1 + S0	78	235.8
D1 + H5 + A0 + S0	40	132.4	D4 + H5 + A1 + S0	79	231.6
D1 + H5 + A0 + S1	41	186.0	D5 + H5 + A1 + S0	80	236.6
D2 + H4 + A0 + S0	42	152.7	D7 + H3 + A1 + S0	81	265.4
D2 + H4 + A0 + S1	43	206.3	D6 + H5 + A1 + S0	82	245.7
D2 + H5 + A0 + S0	44	153.5	D6 + H5 + A1 + S1	83	299.3
D2 + H5 + A0 + S1	45	207.1	D7 + H4 + A1 + S0	84	266.9
D1 + H0 + A1 + S0	46	111.3	D7 + H4 + A1 + S1	85	320.5
D1 + H0 + A1 + S1	47	164.9	D7 + H5 + A1 + S0	86	267.7
D7 + H0 + A0 + S0	48	227.2	D7 + H5 + A1 + S1	87	321.3
D3 + H5 + A0 + S0	49	207.0			

(*Output is measured in habitat units; cost measured in \$1000)

Table 10 Outputs and Costs of Least Cost Combinations for Each Level of Output (Reference "9 Easy Steps", Exhibit 4C)

Economically ineffective combinations were identified next. These combinations produce less output at equal or greater cost than subsequently ranked combinations. Such economically ineffective combinations have been shaded in Table 11. These combinations were removed from further consideration.

<u>Combination</u>	<u>Output*</u>	<u>Cost*</u>	<u>Combination</u>	<u>Output*</u>	<u>Cost*</u>
D0 + H0 + A0 + S0	0	0.0	D2 + H0 + A1 + S0	50	132.4
D0 + H0 + A0 + S1	1	53.6	D1 + H2 + A1 + S0	51	137.2
D0 + H1 + A0 + S0	4	23.4	D1 + H2 + A1 + S1	52	190.8
D0 + H2 + A0 + S0	5	25.9	D5 + H3 + A0 + S0	53	224.6
D0 + H2 + A0 + S1	6	79.5	D2 + H1 + A1 + S0	54	155.8
D0 + H3 + A0 + S0	11	28.5	D2 + H2 + A1 + S0	55	158.3
D0 + H3 + A0 + S1	12	82.1	D2 + H2 + A1 + S1	56	211.9
D0 + H4 + A0 + S0	14	30.0	D1 + H3 + A1 + S0	57	139.8
D0 + H4 + A0 + S1	15	83.6	D1 + H3 + A1 + S1	58	193.4
D0 + H5 + A0 + S0	16	30.8	D3 + H1 + A1 + S0	59	209.3
D0 + H5 + A0 + S1	17	84.4	D1 + H4 + A1 + S0	60	141.3
D0 + H0 + A1 + S0	22	9.7	D2 + H3 + A1 + S0	61	160.9
D0 + H0 + A1 + S1	23	63.3	D1 + H5 + A1 + S0	62	142.1
D1 + H0 + A0 + S0	24	101.6	D1 + H5 + A1 + S1	63	195.7
D1 + H0 + A0 + S1	25	155.2	D2 + H4 + A1 + S0	64	162.4
D0 + H1 + A1 + S0	26	33.1	D2 + H4 + A1 + S1	65	216.0
D0 + H2 + A1 + S0	27	35.6	D2 + H5 + A1 + S0	66	163.2
D0 + H2 + A1 + S1	28	89.2	D2 + H5 + A1 + S1	67	216.8
D1 + H2 + A0 + S0	29	127.5	D4 + H2 + A1 + S0	68	226.7
D1 + H2 + A0 + S1	30	181.1	D3 + H4 + A1 + S0	69	215.9
D2 + H1 + A0 + S0	32	146.1	D7 + H0 + A1 + S0	70	236.9
D0 + H3 + A1 + S0	33	38.2	D3 + H5 + A1 + S0	71	216.7
D0 + H3 + A1 + S1	34	91.8	D3 + H5 + A1 + S1	72	270.3
D1 + H3 + A0 + S0	35	130.1	D4 + H3 + A1 + S0	74	229.3
D0 + H4 + A1 + S0	36	39.7	D5 + H3 + A1 + S0	75	234.3
D0 + H4 + A1 + S1	37	93.3	D5 + H3 + A1 + S1	76	287.9
D0 + H5 + A1 + S0	38	40.5	D4 + H4 + A1 + S0	77	230.8
D0 + H5 + A1 + S1	39	94.1	D5 + H4 + A1 + S0	78	235.8
D1 + H5 + A0 + S0	40	132.4	D4 + H5 + A1 + S0	79	231.6
D1 + H5 + A0 + S1	41	186.0	D5 + H5 + A1 + S0	80	236.6
D2 + H4 + A0 + S0	42	152.7	D7 + H3 + A1 + S0	81	285.4
D2 + H4 + A0 + S1	43	206.3	D6 + H5 + A1 + S0	82	245.7
D2 + H5 + A0 + S0	44	153.5	D6 + H5 + A1 + S1	83	299.3
D2 + H5 + A0 + S1	45	207.1	D7 + H4 + A1 + S0	84	266.9
D1 + H0 + A1 + S0	46	111.3	D7 + H4 + A1 + S1	85	320.5
D1 + H0 + A1 + S1	47	164.9	D7 + H5 + A1 + S0	86	267.7
D7 + H0 + A0 + S0	48	227.2	D7 + H5 + A1 + S1	87	321.3
D3 + H5 + A0 + S0	49	207.0			

(*Output is measured in habitat units; cost measured in \$1000)

Table 11 Outputs and Costs of Least Cost Combinations for Each Level of Output, Shading Over Ineffective Combinations (Reference "9 Easy Steps", Exhibit 5A)

The remaining combinations are both cost effective and least-costly for the given levels of output. These combinations are shown in Table 12. The combinations are displayed graphically on Figure 6.

<u>Combination</u>	<u>Output*</u>	<u>Cost*</u>
D0 + H0 + A0 + S0	0	0.0
D0 + H0 + A1 + S0	22	9.7
D0 + H1 + A1 + S0	26	33.1
D0 + H2 + A1 + S0	27	35.6
D0 + H3 + A1 + S0	33	38.2
D0 + H4 + A1 + S0	36	39.7
D0 + H5 + A1 + S0	38	40.5
D0 + H5 + A1 + S1	39	94.1
D1 + H0 + A1 + S0	46	111.3
D2 + H0 + A1 + S0	50	132.4
D1 + H2 + A1 + S0	51	137.2
D1 + H3 + A1 + S0	57	139.8
D1 + H4 + A1 + S0	60	141.3
D1 + H5 + A1 + S0	62	142.1
D2 + H4 + A1 + S0	64	162.4
D2 + H5 + A1 + S0	66	163.2
D3 + H4 + A1 + S0	69	215.9
D3 + H5 + A1 + S0	71	216.7
D4 + H3 + A1 + S0	74	229.3
D4 + H4 + A1 + S0	77	230.8
D4 + H5 + A1 + S0	79	231.6
D5 + H5 + A1 + S0	80	236.6
D6 + H5 + A1 + S0	82	245.7
D7 + H4 + A1 + S0	84	266.9
D7 + H5 + A1 + S0	86	267.7
D7 + H5 + A1 + S1	87	321.3

(*Output is measured in habitat units;
cost measured in \$1000)

Table 12 Outputs and Costs of Cost Effective Least Cost Combinations for Each Level of Output (Reference "9 Easy Steps, Exhibit 5B)

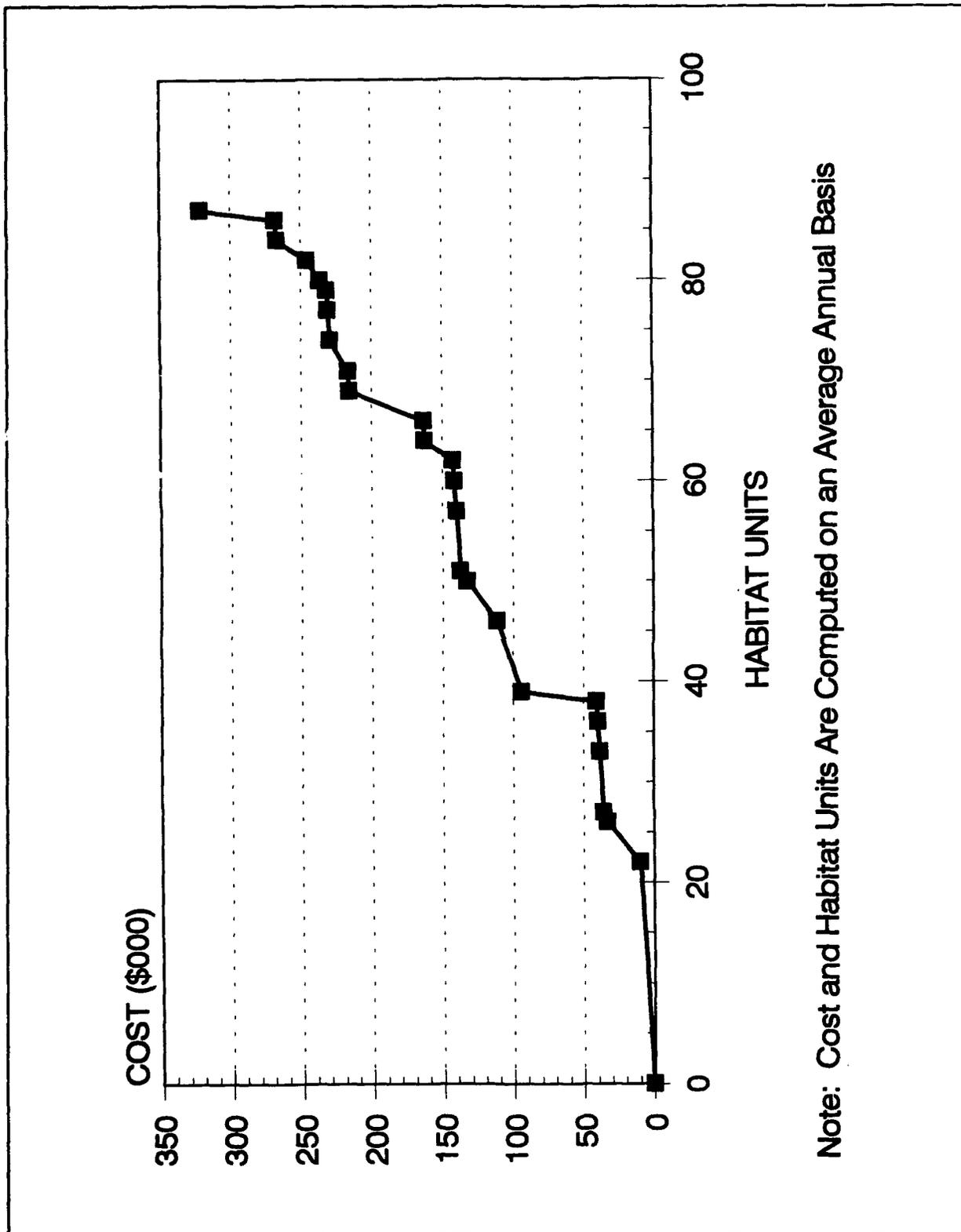
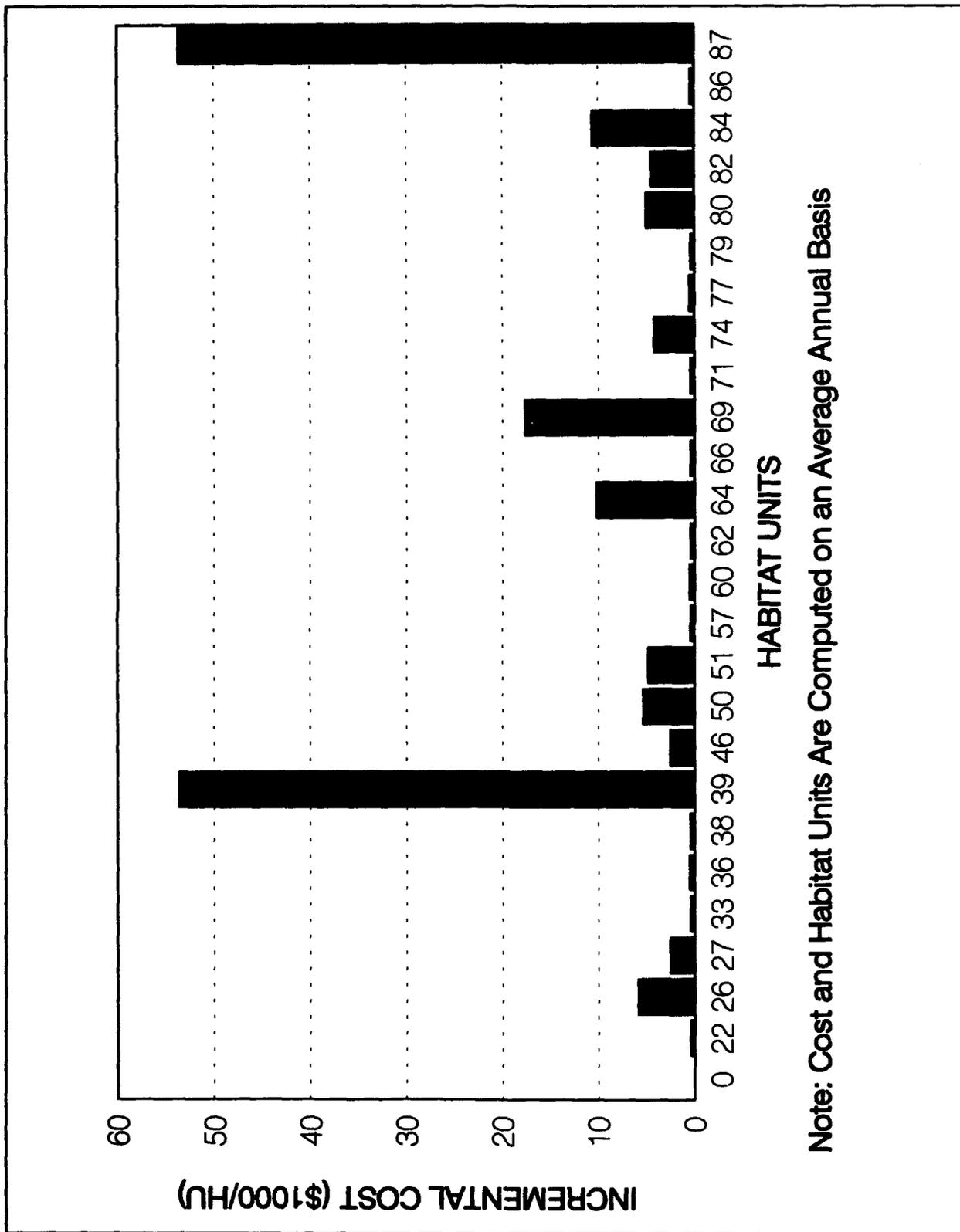


Figure 6 Cost Effective and Least Cost Combinations (Reference "9 Easy Steps", Exhibit 5D)

Per unit incremental costs for each remaining combination have been computed, and are presented in Table 13. Incremental costs for each combination have been computed by dividing the difference in outputs by the difference in costs between the current combination and the preceding combination. Incremental costs for each level of output are displayed on Figure 7.

<u>Combination</u>	<u>Output</u>	<u>Incremental Cost</u>	
		<u>Cost</u>	<u>(\$ per HU)</u>
D0+ H0+ A0+ S0	0	0.0	
D0+ H0+ A1+ S0	22	9.7	0.40
D0+ H1+ A1+ S0	26	33.1	5.80
D0+ H2+ A1+ S0	27	35.6	2.50
D0+ H3+ A1+ S0	33	38.2	0.40
D0+ H4+ A1+ S0	36	39.7	0.50
D0+ H5+ A1+ S0	38	40.5	0.40
D0+ H5+ A1+ S1	39	94.1	53.60
D1+ H0+ A1+ S0	46	111.3	2.50
D2+ H0+ A1+ S0	50	132.4	5.30
D1+ H2+ A1+ S0	51	137.2	4.80
D1+ H3+ A1+ S0	57	139.8	0.40
D1+ H4+ A1+ S0	60	141.3	0.50
D1+ H5+ A1+ S0	62	142.1	0.40
D2+ H4+ A1+ S0	64	162.4	10.20
D2+ H5+ A1+ S0	66	163.2	0.40
D3+ H4+ A1+ S0	69	215.9	17.60
D3+ H5+ A1+ S0	71	216.7	0.40
D4+ H3+ A1+ S0	74	229.3	4.20
D4+ H4+ A1+ S0	77	230.8	0.50
D4+ H5+ A1+ S0	79	231.6	0.40
D5+ H5+ A1+ S0	80	236.6	5.00
D6+ H5+ A1+ S0	82	245.7	4.50
D7+ H4+ A1+ S0	84	266.9	10.60
D7+ H5+ A1+ S0	86	267.7	0.40
D7+ H5+ A1+ S1	87	321.3	53.60

Table 13 Cost Effective and Least Cost Combinations, With Incremental Costs (Reference "9 Easy Steps", Exhibit 7B)



Note: Cost and Habitat Units Are Computed on an Average Annual Basis

Figure 7 Incremental Costs (Reference "9 Easy Steps", Exhibit 8)

INTERPRETATION OF RESULTS

The techniques undertaken to this point have identified cost effective alternatives for environmental restoration of Bussey Lake. For any desired level of habitat improvement, the least costly means of attaining it has been identified.

These techniques do not address the question of what level of improvement is most desired, however. In this section, several factors to consider when deciding "how much to buy" are explored, along with other factors that may play a role in determining the recommended plan.

CHOOSING THE DESIRED OUTPUT LEVEL

Choosing the desired amount of habitat improvement may depend on a number of factors, including significance of the resource, historical conditions of the resource, available budget, or mitigation targets.

For Bussey Lake, the available budget, efficiency of production, and consideration of the historical conditions proved to be most important in selecting the recommended level of output. Public, technical, and institutional considerations were important in the initial selection of Bussey Lake as a priority restoration area within the EMP. These factors of resource significance were less helpful in identifying the specific level of improvement desired. Similarly, there was no pre-existing target to assist in answering the question of "how much to buy" since the project was for restoration rather than for mitigation.

COMPARING SUCCESSIVE OUTPUTS AND INCREMENTAL COSTS

Figures 6 and 7 graphically depict the relationship between habitat outputs and associated costs for the cost effective alternatives. These figures are useful in considering "how much output to buy" since overall increases in cost per unit, as well as several dramatic "jumps" in cost, are evident as successive levels of output are considered.

These "jumps" in cost are often related to shifts in the types of measures necessary to produce additional outputs or the eventual diminishing returns of those measures due to physical or technological limitations.

It is important to note that greater levels of output do not necessarily rely on similar combinations of restoration measures. The measures in alternatives, in theory, are completely independent. Increased output does not imply increased scale in the measures used to create the output. Lower levels of harvesting, for example, appear

in alternatives producing higher outputs. Substrate improvement is a part of the alternative producing 39 AAHU's, but does not appear in subsequent alternatives until 87 AAHU's. The cost effectiveness analysis concentrates exclusively on the increments of environmental outputs.

Higher levels of output in Bussey Lake require substantial equipment purchases or mobilization, such as harvesters or dredges. Choosing to produce 26 AAHU's rather than 22 AAHU's would incur such a cost "jump" since average annual costs would increase by \$23,400 annually, more than tripling the total project costs.

Typically, such cost "jumps" will be associated with relatively low incremental costs for subsequent levels of output since a new level of efficient production has been employed. For Bussey Lake, this is true of output levels subsequent to 26 AAHU's. Output levels of 27, 33, 36, and 38 could all be produced with proportionally small total cost increases. In comparison to the tripling of total costs from producing 26 rather than 22 AAHU's, producing 38 rather than 26 AAHU's would increase total costs by only 20 percent. Presumably, if it is "worth it" to produce more than 22 AAHU's, the next output level to decide upon would be 38 AAHU's.

New cost "jumps" are encountered as the productivity of the new combinations of measures is "exhausted." Another large cost "jump" would be required if levels greater than 38 AAHU's were considered. Deciding whether to produce more than 38 AAHU's would follow a similar process of iterative choices. The most dramatic cost increases are at 39, 64, 69, and 87 AAHU's. In all cases, the additional costs for increases in AAHU's have to be considered "worth it" if the higher level of output is chosen.

OTHER CONSIDERATIONS IN SELECTING THE RECOMMENDED PLAN

Competing objectives emerged during the Bussey Lake planning process. One major issue that arose was whether to improve bluegill habitat by the cost effective means identified, or whether to try to restore the lake to its "modern historic condition." While the cost-effectiveness exercise in itself could not answer which objective should be sought, it could specifically identify the cost differences in pursuing the alternate goals.

All of the cost effective solutions for improving bluegill habitat in Bussey Lake include aeration and aquatic harvesting. These measures create greater gains in habitat for less cost than the other measures considered.

Neither of these measures affects the problem of lake shallowing, however, which is the most important factor in comparing the current state of Bussey Lake with its modern historic condition.

Alternatives including dredging, which are costlier, are the only ones to address the shallowing. While there are still cost-effective alternatives for restoring the "modern historic condition," this objective clearly differs from that of exclusively improving bluegill habitat.

Additional information became important in making the final decision. "External" consequences of employing various restoration measures were considered in the process.

As previously mentioned, two potential habitat improvement measures had been dismissed from consideration early in the planning process since the consequences of employing either measure were felt to be too great to be practical. These were raising water levels in pool 10 and using herbicides to control aquatic plants. Improvements in habitat using these measures were felt to be offset by the negative consequences of these potential solutions.

Other measures analyzed also had effects, both negative and positive, that were not fully considered in the cost effectiveness analysis. Use of aerators in Bussey Lake during the winter would leave open areas in the ice cover, creating potential safety hazards. Local operation and maintenance of harvesting equipment was considered burdensome by the potential cost-sharing partners. There were additional positive effects associated with several of the dredging options. The dredged material could be used to improve waterfowl habitat, resulting in larger overall habitat gains in pool 10.

THE RECOMMENDED PLAN

The selected alternative was to dredge 270,000 yards (option D6) from Bussey Lake, creating 29 acres of deeper water habitat with reduced vegetation growth. The material dredged from Bussey Lake was used at the Guttenberg waterfowl ponds to improve 35 acres of moist soil units and to create an additional 15 acres of moist soil units.

The average annual cost of the plan is approximately \$205,000. The project is expected to provide an additional 44 AAHU's in Bussey Lake and 24 AAHU's at the Guttenberg waterfowl ponds, for a total of 68 AAHU's.

If aeration and/or harvesting had been components of the selected plan, annual project costs would have been approximately \$60,000 to \$70,000 lower (based on alternatives that produce 50 or 60 AAHU's output without considering waterfowl ponds, see Table 12). These cost differences could be balanced against the safety and implementation concerns mentioned in the previous section.

If the harvesting and aeration options were considered alone, they would produce 38 AAHU's for \$40,500 annually. These options improve bluegill habitat, but do not restore the depth to the lake, restoring aspects of the "modern historical condition." The difference in cost (\$160,000 annually to provide an extra 30 AAHU's) can be considered the "price" of deciding to restore lake depth compared to simply improving bluegill habitat.

LESSONS LEARNED BY ST. PAUL DISTRICT IN THE BUSSEY LAKE DEMONSTRATION

- 1) Bluegill HEP model needed customization: The U.S. Fish and Wildlife Service HEP model "off the shelf" was not adequate, since it did not include winter conditions. Modifications made by members of the District during previous studies were used for Bussey Lake.
- 2) Firm up the scope of the study early on: The project manager points out that, for Bussey Lake, the objectives of the habitat improvement project shifted during the study based on changing interests of study stakeholders. This is evidenced by the desire for dredging, the interest in the waterfowl improvement areas, and the disinterest in harvesting by the local sponsors. Treating objectives as moving targets will typically result in inefficient, if not bad, planning. But this must be balanced with responsiveness to local interests and pragmatic planning.
- 3) Teamwork between economics/environmental: Teamwork is crucial to the process. While the benefits are calculated in non-monetary habitat units, making traditional cost/benefit analysis impossible, economists can still provide valuable assistance in the plan formulation process by identifying cost-effective alternatives.
- 4) Effective use of computers, part 1: Beware the spreadsheet error. Both the HEP bluegill model and the incremental analysis were performed with Lotus 123. Checking the accuracy of the spreadsheet calculations is always crucial. An error was discovered in the HEP formula converting total HU's to average annual HU's, requiring the incremental analysis to be redone. Another spreadsheet error in the computation of harvesting costs also required a complete reworking. Fortunately, once the process and formats were set, the incremental process could be completely reworked in a matter of hours, but the lesson to check all work in the early stages is still omnipresent.
- 5) Effective use of computers, part 2: Expanding beyond 2 X 2 matrices. The "Nine easy steps" example uses two measures with various levels of scaling. This makes for an easy example. Problems with more variables become harder to work rather quickly, since the number of alternatives increases geometrically. (Do many of us

really remember our matrix algebra?) For Bussey Lake, there were four measures, but two of the measures had one level of implementation only. That made the creation of alternatives fairly easy, since the 2 X 2 matrix of the multiple-level measures was treated as the base, and replicated three more times to add in the other two vectors alone and in combination. Even so, the Bussey Lake example relied on a short-cut method (merely adding outputs of alternatives, rather than running all of them through the model) to keep within a reasonable level of semi-manual effort. As discussed with members of the IWR technical staff, there is a clear need to develop an application that would create the alternatives. Hopefully it could incorporate the HEP model as well, to run the model with all factors included, rather than relying on externally added results as a simplified proxy.

6) Effective use of computers, part 3: Lotus "tricks". The spreadsheet effort would have been very tedious if sorting routines and custom macros were not used. Macros were developed to perform the "shading" and "eliminating" tasks in the "Nine easy steps," making them very simple. Lotus version 3 has multi-dimensional sheets, so the results of one step can be transferred to another layer for further manipulation. This proved to be very handy. One more tip: format all sheets in advance, once the general format is identified.

7) Simplifying assumptions in the incremental analysis: For this exercise, the HEP model was run separately for each habitat improvement measure at various project levels. Combinations of measures were created without returning to the model. The costs and associated outputs of the individual components were simply added to make the combinations. In some cases, this may differ from the result one would expect by running the combined alternative through the model. The resultant outputs could be higher or lower, depending on the component measures. Similarly, combining management measures' costs may not be simply additive. Running hundreds of alternatives through HEP models was deemed impractical.

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ADDENDUM

Subsequent to the completion of this report by the St. Paul District, the "9 Easy Steps" procedure was revised to eliminate non-monotonically increasing price jump perturbations that sometimes occur in the incremental cost curve. Such perturbations occurred in the Bussey Lake Demonstration as illustrated in Table 13 and Figure 7, and as described in the COMPARING SUCCESSIVE OUTPUTS AND INCREMENTS Section. These perturbations often result when major equipment, mobilization, or other such costs must be incurred to reach a higher level of output, followed by relatively low incremental costs for one or more subsequent levels of output which are taking advantage of a new level of efficient production. The revised "9 Easy Steps" procedure eliminates these perturbations by presuming that, within the set of least cost alternatives, a particular plan would not be selected if subsequent levels of output could be produced at lower costs per unit. That is, for various segments of the least cost curve, alternatives would be eliminated for consideration if higher levels of output could be incrementally provided at lower costs per unit. Following is a discussion of the revised steps beginning with the combinations of cost effective and least costly plans, previously identified in Table 12.

The first step requires calculating the average cost per unit of output for all of the previously identified cost effective and least costly plans. Table 14 is the same as Table 12 except an additional column has been added displaying the average cost per unit of output for each of the remaining plans. In this case, the (shaded) smallest plan ($D_0+H_0+A_1+S_0$) providing 22 habitat units has the lowest average cost and is the first to be included in the final incremental cost curve.

<u>Combination</u>	<u>Output</u>	<u>Cost</u>	<u>Avg. Cost</u>
D0+ H0+ A0+ S0	0	0.0	0.00
D0+ H0+ A1+ S0	22	9.7	0.44
D0+H1+ A1+ S0	26	33.1	1.27
D0+ H2+ A1+ S0	27	35.6	1.32
D0+ H3+ A1+ S0	33	38.2	1.16
D0+ H4+ A1+ S0	36	39.7	1.10
D0+ H5+ A1+ S0	38	40.5	1.07
D0+ H5+ A1+ S1	39	94.1	2.41
D1+ H0+ A1+ S0	46	111.3	2.42
D2+ H0+ A1+ S0	50	132.4	2.65
D1+ H2+ A1+ S0	51	137.2	2.69
D1+ H3+ A1+ S0	57	139.8	2.45
D1+ H4+ A1+ S0	60	141.3	2.36
D1+ H5+ A1+ S0	62	142.1	2.29
D2+ H4+ A1+ S0	64	162.4	2.54
D2+ H5+ A1+ S0	66	163.2	2.47
D3+ H4+ A1+ S0	69	215.9	3.13
D3+ H5+ A1+ S0	71	216.7	3.05
D4+ H3+ A1+ S0	74	229.3	3.10
D4+ H4+ A1+ S0	77	230.8	3.00
D4+ H5+ A1+ S0	79	231.6	2.93
D5+ H5+ A1+ S0	80	236.6	2.96
D6+ H5+ A1+ S0	82	245.7	3.00
D7+ H4+ A1+ S0	84	266.9	3.18
D7+ H5+ A1+ S0	86	267.7	3.11
D7+ H5+ A1+ S1	87	321.3	3.69

Table 14 Average Costs of Cost
Effective Least Cost Combinations for
Each Level of Output

An iterative process then begins, repeatedly asking the question, "Of the remaining levels of output, which level has the lowest average cost for additional output?" To initially answer this question, the output (22 habitat units) and cost (\$9,700) of the first plan are, respectively, subtracted from the outputs and costs of all remaining plans and a new average cost is calculated based on the additional cost and additional output that would be provided. The results of these computations are displayed in Table 15A. In this first round of recalculations the (shaded) plan ($D_0+H_5+A_1+S_0$) providing additional output of 16 habitat units (38 - 22) at an additional cost of \$30,800 ($\$40,500 - \$9,700$) has the lowest average cost (\$1,930 per habitat unit) for additional output and becomes the second plan to be included on the final incremental cost curve. Those four plans providing from 26 - 36 habitat units of total output (or 4 - 14 habitat units of additional output) are deleted from further analysis.

In the second recalculation (see Table 15B), the total outputs (38 habitat units) and total costs (\$40,500) of the shaded plan in Table 15A ($D_0+H_5+A_1+S_0$) are subtracted from the outputs and costs of all of the remaining plans and the average costs of the additional outputs are calculated. The shaded plan ($D_1+H_5+A_1+S_0$) providing 24 additional habitat units (62 - 38) at an additional cost of \$101,600 ($\$142,100 - \$40,500$) provides additional output at the lowest average cost (\$4,230) and becomes the third plan to be included in the final incremental cost curve. The recalculation process continues until no additional plans remain. In the Bussey Lake Demonstration, five recalculations were required (see Tables 15A - 15E).

<u>Combination</u>	<u>Output</u>	<u>Cost</u>	Additional		<u>Average Cost for Additional Output</u>
			<u>Output</u>	<u>Cost</u>	
D0+ H0+ A1+ S0	22	9.7	0	0.0	0.00
D0+ H1+ A1+ S0	26	33.1	4	23.4	5.85
D0+ H2+ A1+ S0	27	35.6	5	25.9	5.18
D0+ H3+ A1+ S0	33	38.2	11	28.5	2.59
D0+ H4+ A1+ S0	36	39.7	14	30.0	2.14
D0+ H5+ A1+ S0	38	40.5	16	30.8	1.93
D0+ H5+ A1+ S1	39	94.1	17	84.4	4.96
D1+ H0+ A1+ S0	46	111.3	24	101.6	4.23
D2+ H0+ A1+ S0	50	132.4	28	122.7	4.38
D1+ H2+ A1+ S0	51	137.2	29	127.5	4.40
D1+ H3+ A1+ S0	57	139.8	35	130.1	3.72
D1+ H4+ A1+ S0	60	141.3	38	131.6	3.46
D1+ H5+ A1+ S0	62	142.1	40	132.4	3.31
D2+ H4+ A1+ S0	64	162.4	42	152.7	3.63
D2+ H5+ A1+ S0	66	163.2	44	153.5	3.49
D3+ H4+ A1+ S0	69	215.9	47	206.2	4.39
D3+ H5+ A1+ S0	71	216.7	49	207.0	4.22
D4+ H3+ A1+ S0	74	229.3	52	219.6	4.22
D4+ H4+ A1+ S0	77	230.8	55	221.1	4.02
D4+ H5+ A1+ S0	79	231.6	57	221.9	3.89
D5+ H5+ A1+ S0	80	236.6	58	226.9	3.91
D6+ H5+ A1+ S0	82	245.7	60	236.0	3.93
D7+ H4+ A1+ S0	84	266.9	62	257.2	4.15
D7+ H5+ A1+ S0	86	267.7	64	258.0	4.03
D7+ H5+ A1+ S1	87	321.3	65	311.6	4.79

Table 15A Average Costs for Additional Output - First Recalculation

<u>Combination</u>	<u>Output</u>	<u>Cost</u>	<u>Additional Output</u>	<u>Additional Cost</u>	<u>Average Cost for Additional Output</u>
D0+ H5+ A1+ S0	38	40.5	0	0.0	
D0+ H5+ A1+ S1	39	94.1	1	53.6	53.60
D1+ H0+ A1+ S0	46	111.3	8	70.8	8.85
D2+ H0+ A1+ S0	50	132.4	12	91.9	7.66
D1+ H2+ A1+ S0	51	137.2	13	96.7	7.44
D1+ H3+ A1+ S0	57	139.8	19	99.3	5.23
D1+ H4+ A1+ S0	60	141.3	22	100.8	4.58
D1+ H5+ A1+ S0	62	142.1	24	101.6	4.23
D2+ H4+ A1+ S0	64	162.4	26	121.9	4.69
D2+ H5+ A1+ S0	66	163.2	28	122.7	4.38
D3+ H4+ A1+ S0	69	215.9	31	175.4	5.66
D3+ H5+ A1+ S0	71	216.7	33	176.2	5.34
D4+ H3+ A1+ S0	74	229.3	36	188.8	5.24
D4+ H4+ A1+ S0	77	230.8	39	190.3	4.88
D4+ H5+ A1+ S0	79	231.6	41	191.1	4.66
D5+ H5+ A1+ S0	80	236.6	42	1936.1	4.67
D6+ H5+ A1+ S0	82	245.7	44	205.2	4.66
D7+ H4+ A1+ S0	84	266.9	46	226.4	4.92
D7+ H5+ A1+ S0	86	267.7	48	272.2	4.73
D7+ H5+ A1+ S1	87	321.3	49	280.8	5.73

Table 15B Average Costs for Additional Output - Second Recalculation

<u>Combination</u>	<u>Output</u>	<u>Cost</u>	<u>Additional Output</u>	<u>Additional Cost</u>	<u>Average Cost for Additional Output</u>
D1+ H5+ A1+ S0	62	142.1	0	0.0	
D2+ H4+ A1+ S0	64	162.4	2	20.3	10.15
D2+ H5+ A1+ S0	66	163.2	4	21.1	5.28
D3+ H4+ A1+ S0	69	215.9	7	73.8	10.54
D3+ H5+ A1+ S0	71	216.7	9	74.6	8.29
D4+ H3+ A1+ S0	74	229.3	12	87.2	7.27
D4+ H4+ A1+ S0	77	230.8	15	88.7	5.91
D4+ H5+ A1+ S0	79	231.6	17	89.5	5.26
D5+ H5+ A1+ S0	80	236.6	18	94.5	5.25
D6+ H5+ A1+ S0	82	245.7	20	103.6	5.18
D7+ H4+ A1+ S0	84	266.9	22	124.8	5.67
D7+ H5+ A1+ S0	86	267.7	24	125.6	5.23
D7+ H5+ A1+ S1	87	321.3	25	179.2	7.17

Table 15C Average Costs for Additional Output - Third Recalculation

<u>Combination</u>	<u>Output</u>	<u>Cost</u>	<u>Additional Output</u>	<u>Additional Cost</u>	<u>Average Cost for Additional Output</u>
D6+ H5+ A1+ S0	82	245.7	0	0.0	
D7+ H4+ A1+ S0	84	266.9	2	21.2	10.60
D7+ H5+ A1+ S0	86	267.7	4	22.0	5.50
D7+ H5+ A1+ S1	87	321.3	5	75.6	15.12

Table 15D Average Costs for Additional Output - Fourth Recalculation

<u>Combination</u>	<u>Output</u>	<u>Cost</u>	<u>Additional Output</u>	<u>Additional Cost</u>	<u>Average Cost for Additional Output</u>
D7+ H5+ A1+ S0	86	267.7	0	0.0	
D7+ H5+ A1+ S1	87	321.3	1	53.6	53.60

Table 15E Average Costs for Additional Output - Fifth Recalculation

The plans identified in Table 14 and Tables 15A - 15E can now be used to derive a monotonically increasing incremental cost curve. The appropriate total output and cost, incremental output and cost, and incremental cost per unit of output from Table 14 and Tables 15A - 15E are summarized in Table 16. The monotonically increasing incremental cost curve is graphically illustrated in Figure 8.

<u>Combination</u>	<u>Output</u>	<u>Cost</u>	<u>Incremental Output</u>	<u>Incremental Cost</u>	<u>Incremental Cost/HU</u>
D0+ H0+ A0+ S0	0	0.0			
D0+ H0+ A1+ S0	22	9.7	22	9.7	0.44
D0+ H5+ A1+ S0	38	40.5	16	30.8	1.93
D1+ H5+ A1+ S0	62	142.1	24	101.6	4.23
D6+ H5+ A1+ S0	82	245.7	20	103.6	5.18
D7+ H5+ A1+ S0	86	267.7	4	22.0	5.50
D7+ H5+ A1+ S1	87	321.3	1	53.6	53.60

Table 16 Incremental Costs

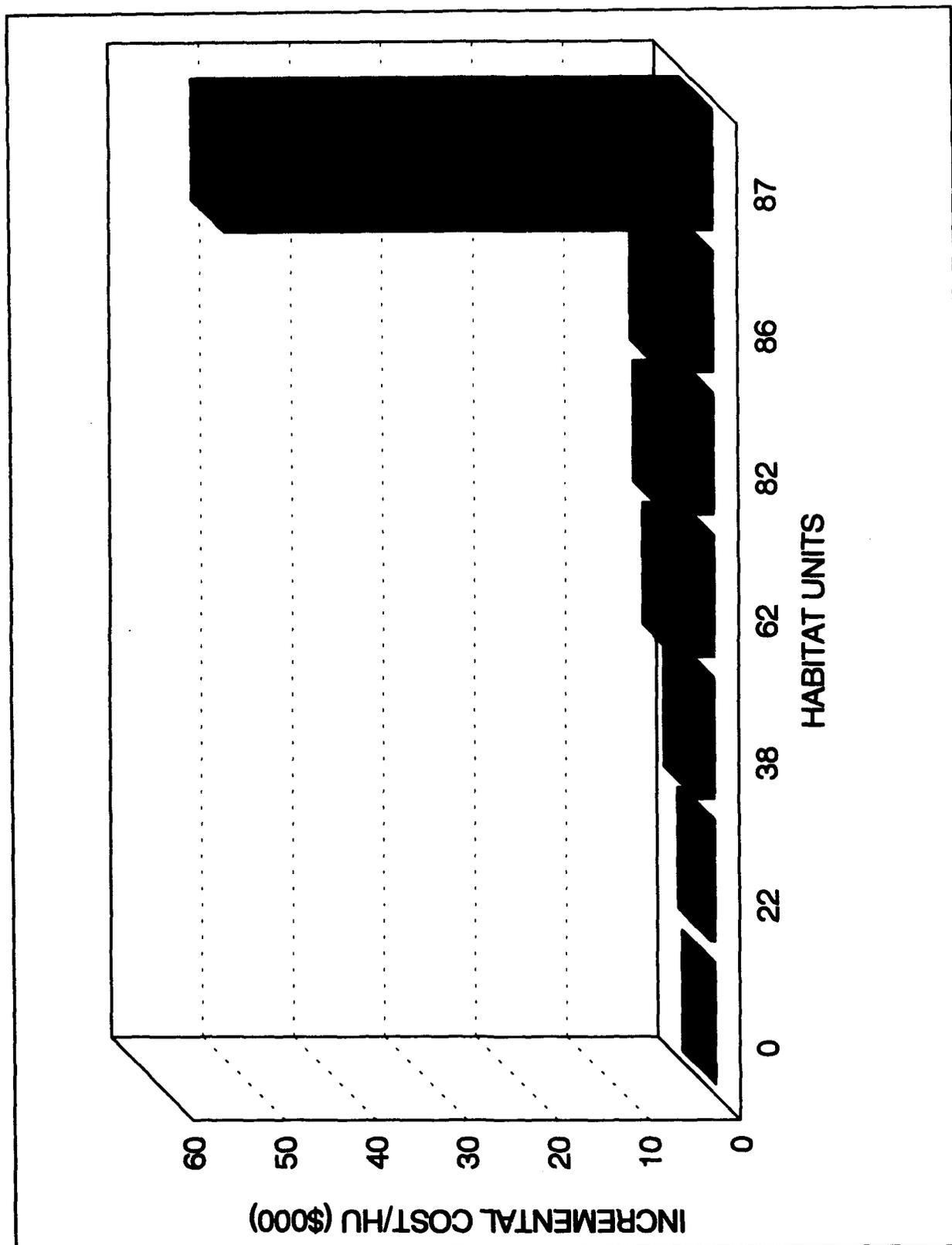
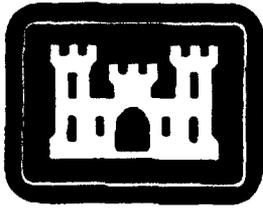


Figure 8 Incremental Costs

APPENDIX A



U.S. Army Corps of Engineers

Nine EASY Steps

Corps Incremental Cost Analysis for Fish and Wildlife Habitat

REVIEW DRAFT

**Policy and Special Studies Division
Institute for Water Resources
Water Resources Support Center
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17 April 1993

**Corps Incremental Cost Analysis for Fish and Wildlife Habitat
Nine EASY Steps**

The following draft paper was prepared to outline a procedure for conducting incremental cost analysis for fish and wildlife habitat evaluations for Corps of Engineers water resources studies. It was prepared by the staff of the Institute for Water Resources in conjunction with the staff of the Corps of Engineers Headquarters and the Washington Level Review Center.

This paper is a draft for review purposes only. It does not reflect official views or policies of the Department of the Army or the Corps of Engineers. Guidance on incremental cost analysis for fish and wildlife planning is in Corps regulation number ER 1105-2-100, *Guidance for Conducting Civil Works Planning Studies* (28 December 1990).

The procedure is continuing to be refined in response to comments and field experience. If you have any questions or comments, please contact:

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Corps Incremental Cost Analysis for Fish and Wildlife Habitat
Nine EASY Steps

Example. The following steps are illustrated through an example based on the management of habitat for a small songbird called a Veery. Three management measures have been identified for analysis:

A - Plant deciduous shrubs on a 20 acre site to increase shrub crown cover.

B - Construct berm to change an adjacent pond's water elevations as a means of increasing soil moisture.

C - Install a fence around selected areas to protect the natural increase in shrub development and herbaceous cover.

This example is for illustration purposes, and is not meant to be all inclusive of the variables or measures that could or should be considered.

Step 1 - Output Assessment and Cost Estimate. Display the environmental outputs (in this case, effects on habitat expressed in habitat units, HU) and the cost estimates (in dollars, \$) of plan increments of management measures. Exhibit 1 displays this information in a traditional and familiar table format.

Step 2 - Identify Combinable Management Measures. Analyze the management measures to separate those that can be implemented together from those that can't be implemented together. Exhibit 2 illustrates the analysis, which, for this example, concludes that management measures A and B are combinable; but doing any combination of A and B precludes doing C, and, therefore, management measure C cannot be combined with either A or B. The next Steps 3, 4 and 5 deal only with the combinable measures; measures that cannot be combined are put aside until Step 6.

Step 3 - Calculate Outputs and Costs of All Combinations. Identify all combinations of the combinable management measures' increments, and calculate each combination's output (HU) and cost (\$). Exhibit 3A presents the results of the calculations in a table format; Exhibit 3B presents the same information in a slightly different table that is easier to work with in the next step. Exhibit 3C graphically displays the relationships among all combinations of the measure A and B increments to illustrate the large number and range of choices possible.

Step 4 - Eliminate Economically Inefficient Combinations. Steps 4 and 5 identify economically irrational combinations. In this step, order the list of measure increment combinations so that they are listed in ascending order of their outputs (0 HU, 1 HU, 2 HU...), and, where two or more combinations produce the same output, in ascending order of their costs. Exhibit 4A presents the same information as Exhibit 3B in this reordered manner.

For each level of output, identify the least cost combination of measure increments. Exhibit 4B is the same as Exhibit 4A, except shading was added over the combinations that are economically inefficient - the not least cost - combinations. Exhibit 4C is the same as Exhibit 4B except that shaded (the not least cost) combinations are no longer listed and only the least cost combination for each level of output is displayed.

Step 5 - Eliminate Economically Ineffective Combinations. Conduct a pair-wise comparison of costs in Exhibit 4C, Column 3 to identify and delete those combinations that will produce less output at equal or greater cost than subsequently ranked combinations. Exhibit 5A is the same as Exhibit

4C, except that shading was added over the economically ineffective combinations. Exhibit 5B is the same as Exhibit 5A, except that the shaded (economically ineffective) combinations are no longer listed and only the efficient combinations are displayed. Exhibit 5C is the same as Exhibit 5B, except that shorthand names were given to each remaining combination of measure increments (P_1, P_2, \dots) in Column 1, and descriptions were added in Column 3 (from Exhibit 1, Column 2). Exhibit 5D graphically displays the relationships among the remaining combinations (compare with Exhibit 3C and note the reduction in combinations).

Step 6 - Compare the Combinations With the Measures That Cannot Be Combined. Exhibit 6 is the same as Exhibit 5D, with the addition of a graphic display of the measure that cannot be implemented in combination with any other measures - measure C in this example (recall Step 2).

Exhibit 6 shows that, in this case example, for any given level of output, an increment of the measure A and B combinations (points P_1 through P_{17}) is the least cost means to produce that level of output. Therefore, management measure C is eliminated from further consideration.

Step 7 - Calculate Per Unit Incremental Costs. In this procedure, incremental cost is defined as a change in cost divided by a change in output. Calculate incremental costs by dividing the difference between two combined measure increments' costs by the difference between the combined measure increments' outputs. Exhibit 7A is a supply schedule of the incremental costs for the combined measures. Exhibit 7B is the same as the more familiar Exhibit 5C table format, except that the incremental costs from the Exhibit 7A supply schedule have been added.

Step 8 - Graph Incremental Costs. Exhibit 8 is a bar graph of the incremental costs listed in Exhibit 7A.

Step 9 - Interpret Incremental Cost Graph. Study and analyze the incremental cost graph to identify any significant changes in incremental costs. Such changes suggest potential reasons for choosing one level of output over another - thereby selecting one alternative over another.

In the Exhibit 8 example, the comparatively large increases in incremental costs to produce 19, 28 and 37 HU (produced by measure combination increments $P_9, P_{12},$ and $P_{16},$ respectively) may provide reasons to select their preceding combination increments ($P_8, P_{11},$ and $P_{15},$ respectively).

Ideally, the incremental cost graph should display a smooth, increasing curve. In cases where results show peaks as in Exhibit 8, it may be useful to repeat the analysis, making the following types of changes:

- Where possible, add finer measure increments. For example, management measure A could be redefined in measure increments of 50 trees per acre between the original A_5 and A_7 measure increments.
- Add new management measures. For example, consider a ditch irrigation system (in increments of gallons/day delivery capability) as another measure to increase the soil moisture regime.
- Drop the combinations that cause relatively large peaks. In this example, the analysis could be rerun without $P_9, P_{12},$ and $P_{16}.$
- Reconsider basic assumptions. For example, are the cost estimates reasonable; are the outputs reasonable; has the right target-species (Veery, in this example) been selected?

Ken Orth/703-355-7250

Exhibit 1 - Outputs and Costs of Management Measure Increments

(1) Management Measures	(2) Management Measure Increments	(3) Outputs (HU)	(4) Costs (\$)
No Action	none	0	0
A - plant deciduous shrubs on 20 acre site (to increase shrub crown cover)	1 - plant 40 shrubs per acre	2	6,000
	2 - plant 75 shrubs per acre	4	8,000
	3 - plant 125 shrubs per acre	6	12,000
	4 - plant 175 shrubs per acre	8	17,000
	5 - plant 350 shrubs per acre	13	35,000
	6 - plant 550 shrubs per acre	17	56,000
	7 - plant 750 shrubs per acre	20	75,000
B - construct berm to change water elevations (to increase soil moisture)	1 - maintain water elevation at +120.0 feet	2	3,000
	2 - maintain water elevation at +120.4 feet	6	6,000
	3 - maintain water elevation at +120.8 feet	10	15,000
	4 - maintain water elevation at +121.2 feet	15	50,000
	5 - maintain water elevation at +121.6 feet	20	100,000
C - install fence around selected areas (to protect natural increase in shrub development and herbaceous cover)	1 - install 2,200 linear feet of fence	8	28,000
	2 - install 3,600 linear feet of fence	13	45,500
	3 - install 5,000 linear feet of fence	18	63,000
	4 - install 5,600 linear feet of fence	20	70,000

Exhibit 2 - Ability to Combine Management Measures

(1) Management Measures	Can be combined with:		
	(2) Management Measure A	(3) Management Measure B	(4) Management Measure C
A - plant deciduous shrubs on 20 acre site (to increase shrub crown cover)	---	Yes; A and B are located at adjoining sites; neither would preclude implementation of the other.	No; C would be located within the same site as A, and would employ natural processes and growth rather than managed growth; therefore, C and A are mutually exclusive.
B - construct berm to change water elevations (to increase soil moisture)		---	No; C would be located within the same site as B, and would employ natural processes and growth rather than managed growth; therefore, C and B are mutually exclusive.
C - install fence around selected areas (to protect natural increase in shrub development and herbaceous cover)			---

Exhibit 3A - Outputs and Costs of Combinations

(1) Management Measure A Increments	Management Measure B Increments											
	No B		B1		B2		B3		B4		B5	
	(2) Outputs (HU)	(3) Costs (\$)	(4) Outputs (HU)	(5) Costs (\$)	(6) Outputs (HU)	(7) Costs (\$)	(8) Outputs (HU)	(9) Costs (\$)	(10) Outputs (HU)	(11) Costs (\$)	(12) Outputs (HU)	(13) Costs (\$)
No A	0	0	2	3,000	6	6,000	10	15,000	15	50,000	20	100,000
A1	2	6,000	4	9,000	8	12,000	12	21,000	17	56,000	22	106,000
A2	4	8,000	6	11,000	10	14,000	14	23,000	19	58,000	24	108,000
A3	6	12,000	8	15,000	12	18,000	16	27,000	21	62,000	26	112,000
A4	8	17,000	10	20,000	14	23,000	18	32,000	23	67,000	28	117,000
A5	13	35,000	15	38,000	19	41,000	23	50,000	28	85,000	33	135,000
A6	17	56,000	19	59,000	23	62,000	27	71,000	32	106,000	37	156,000
A7	20	75,000	22	78,000	26	81,000	30	90,000	35	125,000	40	175,000

Exhibit 28 - Outputs and Costs of Combinations

(1) Management Measure Increase Combinations	(2) Outputs (HU)	(3) Costs (\$)
No A + No B	0	0
A ₁ + No B	2	8,000
A ₂ + No B	4	8,000
A ₃ + No B	6	12,000
A ₄ + No B	8	17,000
A ₅ + No B	13	35,000
A ₆ + No B	17	58,000
A ₇ + No B	20	75,000
No A + B ₁	2	3,000
A ₁ + B ₁	4	9,000
A ₂ + B ₁	6	11,000
A ₃ + B ₁	8	16,000
A ₄ + B ₁	10	20,000
A ₅ + B ₁	15	38,000
A ₆ + B ₁	19	59,000
A ₇ + B ₁	22	78,000
No A + B ₂	6	6,000
A ₁ + B ₂	8	12,000
A ₂ + B ₂	10	14,000
A ₃ + B ₂	12	18,000
A ₄ + B ₂	14	23,000
A ₅ + B ₂	19	41,000
A ₆ + B ₂	23	62,000
A ₇ + B ₂	26	81,000
No A + B ₃	10	15,000
A ₁ + B ₃	12	21,000
A ₂ + B ₃	14	23,000
A ₃ + B ₃	16	27,000
A ₄ + B ₃	18	32,000
A ₅ + B ₃	23	50,000
A ₆ + B ₃	27	71,000
A ₇ + B ₃	30	90,000
No A + B ₄	15	50,000
A ₁ + B ₄	17	58,000
A ₂ + B ₄	19	58,000
A ₃ + B ₄	21	62,000
A ₄ + B ₄	23	67,000
A ₅ + B ₄	28	85,000
A ₆ + B ₄	32	106,000
A ₇ + B ₄	35	126,000
No A + B ₅	20	100,000
A ₁ + B ₅	22	106,000
A ₂ + B ₅	24	108,000
A ₃ + B ₅	26	112,000
A ₄ + B ₅	28	117,000
A ₅ + B ₅	33	138,000
A ₆ + B ₅	37	166,000
A ₇ + B ₅	40	176,000

Exhibit 3C

All Combinations of Combinable Measures

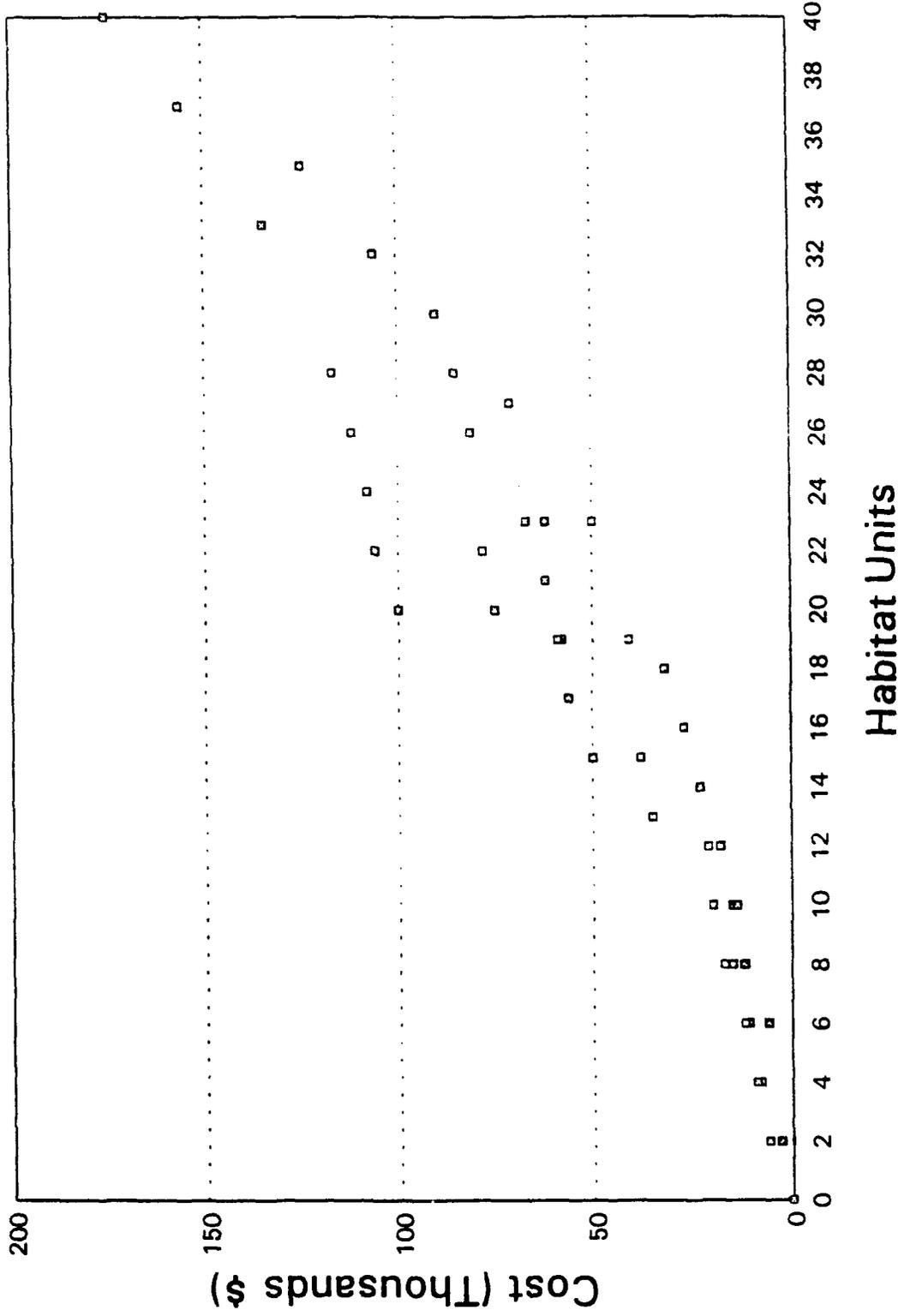


Exhibit 4A - Outputs and Costs of Combinations.
 Listed in Ascending Order of Outputs. Then in Ascending Order of Costs

(1) Management Methods Incremental Combinations	(2) Outputs (MUS)	(3) Costs (\$)
No A + No B	0	0
No A + B ₁	2	3,000
A ₁ + No B	2	6,000
A ₂ + No B	4	8,000
A ₁ + B ₁	4	9,000
No A + B ₂	6	6,000
A ₂ + B ₁	6	11,000
A ₃ + No B	6	12,000
A ₁ + B ₂	8	12,000
A ₄ + B ₁	8	15,000
A ₄ + No B	8	17,000
A ₂ + B ₂	10	14,000
No A + B ₃	10	15,000
A ₄ + B ₂	10	20,000
A ₃ + B ₂	12	18,000
A ₁ + B ₃	12	21,000
A ₅ + No B	13	35,000
A ₂ + B ₃	14	23,000
A ₄ + B ₃	14	23,000
A ₅ + B ₁	15	38,000
No A + B ₄	15	50,000
A ₃ + B ₃	16	27,000
A ₁ + B ₄	17	58,000
A ₆ + No B	17	56,000
A ₄ + B ₄	18	32,000
A ₅ + B ₂	19	41,000
A ₂ + B ₄	19	58,000
A ₆ + B ₁	19	69,000
A ₇ + No B	20	75,000
No A + B ₅	20	100,000
A ₃ + B ₄	21	62,000
A ₇ + B ₁	22	78,000
A ₁ + B ₅	22	106,000
A ₅ + B ₃	23	50,000
A ₆ + B ₂	23	62,000
A ₄ + B ₄	23	67,000
A ₂ + B ₅	24	106,000
A ₇ + B ₂	26	81,000
A ₃ + B ₅	26	112,000
A ₅ + B ₄	27	71,000
A ₆ + B ₄	28	85,000
A ₄ + B ₅	28	117,000
A ₇ + B ₃	30	90,000
A ₆ + B ₄	32	106,000
A ₆ + B ₅	33	135,000
A ₇ + B ₄	35	125,000
A ₈ + B ₅	37	166,000
A ₇ + B ₅	40	175,000

Exhibit 48 - Outputs and Costs of Combinations
 Shading Over Combinations That Are Not Least Cost Combinations for Each Level of Output

(1) Management Measure Increment Combinations	(2) Outputs (HU)	(3) Costs (\$)
No A + No B	0	0
No A + B ₁	2	3,000
A ₁ + No B	2	6,000
A ₂ + No B	4	8,000
A ₁ + B ₁	4	9,000
No A + B ₂	6	6,000
A ₂ + B ₁	6	11,000
A ₃ + No B	8	12,000
A ₁ + B ₂	8	12,000
A ₃ + B ₁	8	15,000
A ₄ + No B	8	17,000
A ₂ + B ₂	10	14,000
No A + B ₃	10	15,000
A ₄ + B ₁	10	20,000
A ₃ + B ₂	12	18,000
A ₁ + B ₃	12	21,000
A ₅ + No B	13	35,000
A ₂ + B ₃	14	23,000
A ₄ + B ₂	14	23,000
A ₅ + B ₁	15	38,000
No A + B ₄	16	50,000
A ₃ + B ₃	16	27,000
A ₁ + B ₄	17	58,000
A ₆ + No B	18	55,000
A ₄ + B ₃	18	32,000
A ₅ + B ₂	19	41,000
A ₁ + B ₅	19	68,000
A ₆ + B ₁	19	58,000
A ₇ + No B	20	75,000
No A + B ₅	20	100,000
A ₃ + B ₄	21	62,000
A ₁ + B ₆	22	78,000
A ₇ + B ₁	22	106,000
A ₅ + B ₃	23	50,000
A ₆ + B ₂	23	82,000
A ₇ + B ₂	23	97,000
A ₂ + B ₄	24	108,000
A ₁ + B ₇	26	81,000
A ₇ + B ₃	26	112,000
A ₈ + B ₁	27	71,000
A ₅ + B ₄	28	85,000
A ₆ + B ₃	28	117,000
A ₇ + B ₄	30	90,000
A ₈ + B ₂	32	106,000
A ₅ + B ₅	33	135,000
A ₇ + B ₅	35	125,000
A ₈ + B ₃	37	158,000
A ₇ + B ₆	40	175,000

**Exhibit 4C - Outputs and Costs of
Least Cost Combinations for Each Level of Output**

(1) Management Measure Increment Combinations	(2) Outputs (HU)	(3) Costs (\$)
No A + No B	0	0
No A + B ₁	2	3,000
A ₂ + No B	4	8,000
No A + B ₂	6	6,000
A ₁ + B ₂	8	12,000
A ₂ + B ₂	10	14,000
A ₃ + B ₂	12	18,000
A ₅ + No B	13	35,000
A ₂ + B ₃	14	23,000
A ₅ + B ₁	15	38,000
A ₃ + B ₃	16	27,000
A ₁ + B ₄	17	56,000
A ₄ + B ₃	18	32,000
A ₅ + B ₂	19	41,000
A ₇ + No B	20	75,000
A ₃ + B ₄	21	62,000
A ₇ + B ₁	22	78,000
A ₅ + B ₃	23	50,000
A ₂ + B ₅	24	108,000
A ₇ + B ₂	26	81,000
A ₈ + B ₃	27	71,000
A ₅ + B ₄	28	85,000
A ₇ + B ₃	30	90,000
A ₈ + B ₄	32	106,000
A ₅ + B ₅	33	135,000
A ₇ + B ₄	35	125,000
A ₈ + B ₅	37	156,000
A ₇ + B ₅	40	175,000

Exhibit 5A - Outputs and Costs of
Least Cost Combinations for Each Level of Output,
Shading Over Ineffective Combinations

(1) Management Measure Increment Combinations	(2) Outputs (HU)	(3) Costs (\$)
No A + No B	0	0
No A + B ₁	2	3,000
A ₂ + No B	4	8,000
No A + B ₂	6	6,000
A ₁ + B ₂	8	12,000
A ₂ + B ₂	10	14,000
A ₃ + B ₂	12	18,000
A ₅ + No B	13	35,000
A ₂ + B ₃	14	23,000
A ₅ + B ₁	15	38,000
A ₃ + B ₃	16	27,000
A ₁ + B ₄	17	59,000
A ₄ + B ₃	18	32,000
A ₅ + B ₂	19	41,000
A ₇ + No B	20	75,000
A ₃ + B ₄	21	62,000
A ₇ + B ₁	22	78,000
A ₅ + B ₃	23	50,000
A ₂ + B ₅	24	106,000
A ₇ + B ₂	26	81,000
A ₉ + B ₃	27	71,000
A ₅ + B ₄	28	85,000
A ₇ + B ₃	30	90,000
A ₉ + B ₄	32	106,000
A ₅ + B ₅	33	135,000
A ₇ + B ₄	35	125,000
A ₉ + B ₅	37	156,000
A ₇ + B ₅	40	175,000

**Exhibit 5B - Outputs and Costs of
Cost-Effective Least Cost Combinations for Each Level of Output**

(1) Management Measure Increment Combinations	(2) Outputs (HU)	(3) Costs (\$)
No A + No B	0	0
No A + B ₁	2	3,000
No A + B ₂	6	6,000
A ₁ + B ₂	8	12,000
A ₂ + B ₂	10	14,000
A ₃ + B ₂	12	18,000
A ₂ + B ₃	14	23,000
A ₃ + B ₃	16	27,000
A ₄ + B ₃	18	32,000
A ₅ + B ₂	19	41,000
A ₅ + B ₃	23	50,000
A ₆ + B ₃	27	71,000
A ₅ + B ₄	28	85,000
A ₇ + B ₃	30	90,000
A ₆ + B ₄	32	106,000
A ₇ + B ₄	35	125,000
A ₆ + B ₅	37	158,000
A ₇ + B ₅	40	175,000

Exhibit 5C - Cost Effective and Least Cost Combinations of Combinable Management Measures

(1) Name of Combination	(2) Component Management Measure Increments	(3) Description	(4) Outputs (HU)	(5) Costs (\$)
No Action	No A + No B	no action	0	0
P ₁	No A + B ₁	maintain water elevation at +120.0 feet	2	3,000
P ₂	No A + B ₂	maintain water elevation at +120.4 feet	6	6,000
P ₃	A ₁ + B ₂	plant 40 shrubs per acre, and, maintain water elevation at +120.4 feet	8	12,000
P ₄	A ₂ + B ₂	plant 75 shrubs per acre, and, maintain water elevation at +120.4 feet	10	14,000
P ₅	A ₃ + B ₂	plant 125 shrubs per acre, and, maintain water elevation at +120.4 feet	12	18,000
P ₆	A ₂ + B ₃	plant 75 shrubs per acre, and, maintain water elevation at +120.8 feet	14	23,000
P ₇	A ₃ + B ₃	plant 125 shrubs per acre, and, maintain water elevation at +120.8 feet	16	27,000
P ₈	A ₄ + B ₃	plant 175 shrubs per acre, and, maintain water elevation at +120.8 feet	18	32,000
P ₉	A ₅ + B ₂	plant 350 shrubs per acre, and, maintain water elevation at +120.4 feet	19	41,000
P ₁₀	A ₅ + B ₃	plant 350 shrubs per acre, and, maintain water elevation at +120.8 feet	23	50,000
P ₁₁	A ₆ + B ₃	plant 550 shrubs per acre, and, maintain water elevation at +120.8 feet	27	71,000
P ₁₂	A ₅ + B ₄	plant 350 shrubs per acre, and, maintain water elevation at +121.2 feet	28	85,000
P ₁₃	A ₇ + B ₃	plant 750 shrubs per acre, and, maintain water elevation at +120.8 feet	30	90,000
P ₁₄	A ₆ + B ₄	plant 550 shrubs per acre, and, maintain water elevation at +121.2 feet	32	106,000
P ₁₅	A ₇ + B ₄	plant 750 shrubs per acre, and, maintain water elevation at +121.2 feet	35	125,000
P ₁₆	A ₆ + B ₅	plant 550 shrubs per acre, and, maintain water elevation at +121.6 feet	37	156,000
P ₁₇	A ₇ + B ₅	plant 750 shrubs per acre, and, maintain water elevation at +121.6 feet	40	175,000

Exhibit 5D

Cost Effective and Least Cost Combinations of Combinable Management Measures

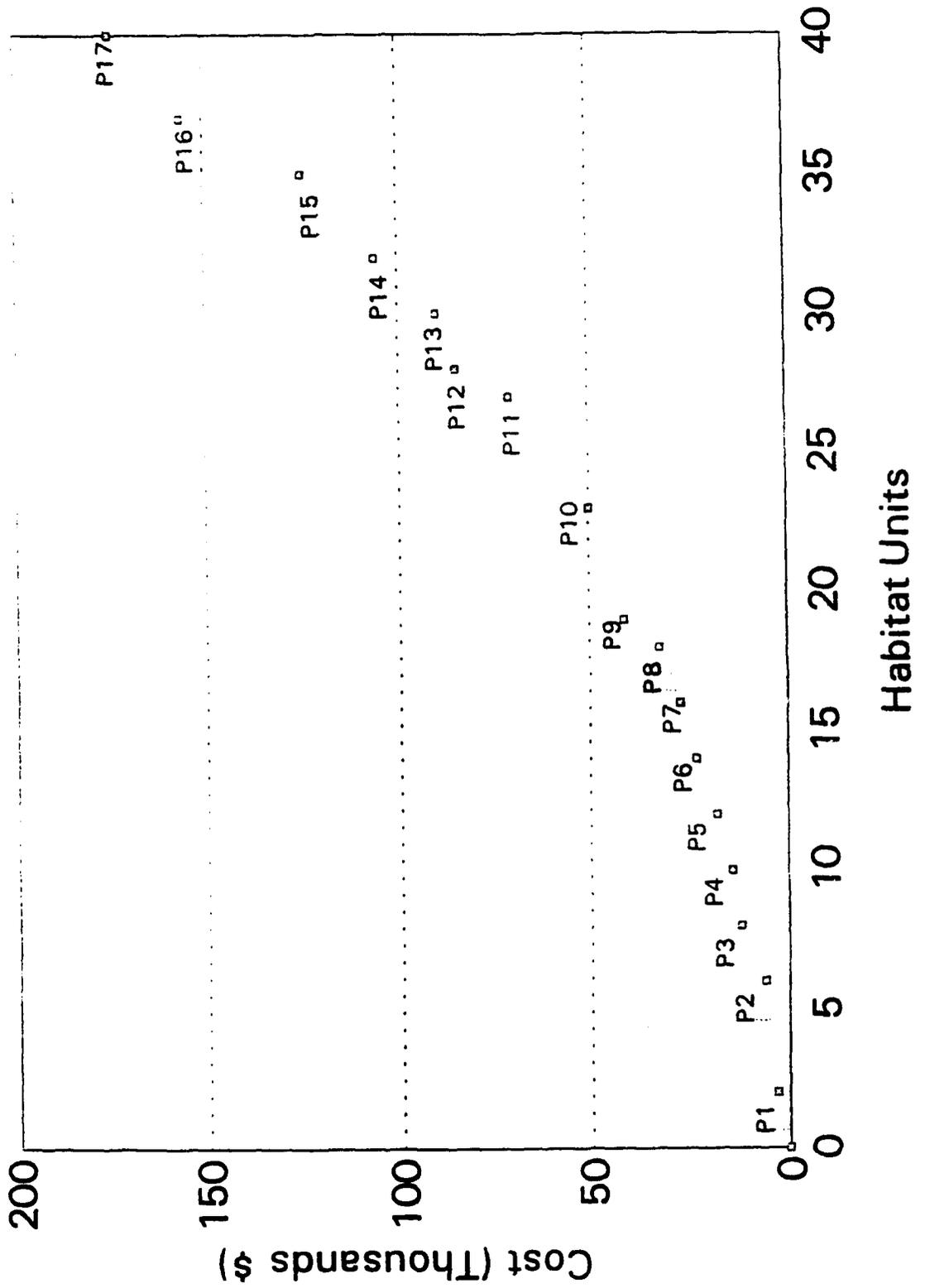


Exhibit 6
 Comparison of Measure Combinations With Measures That Cannot Be Combined

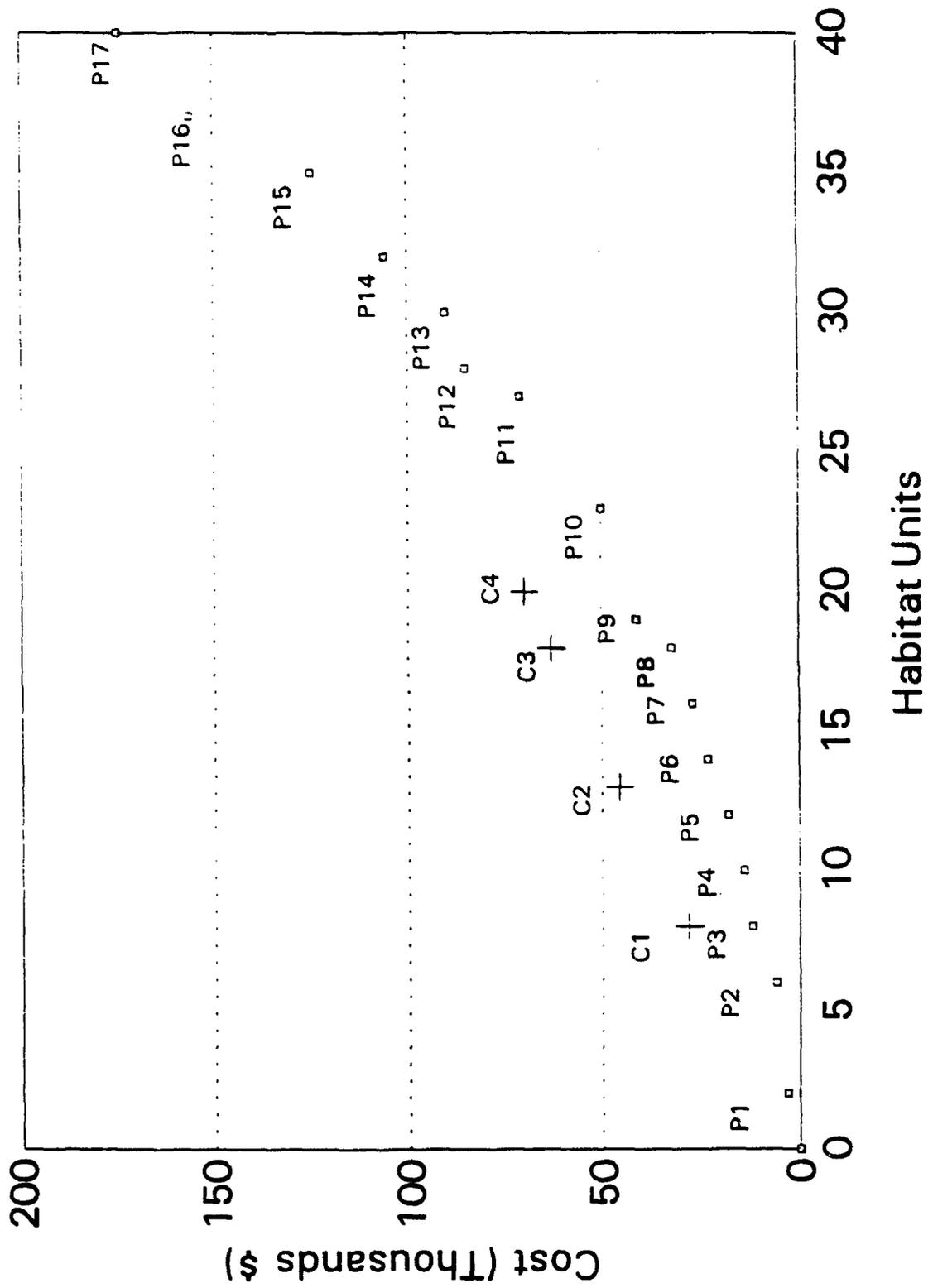


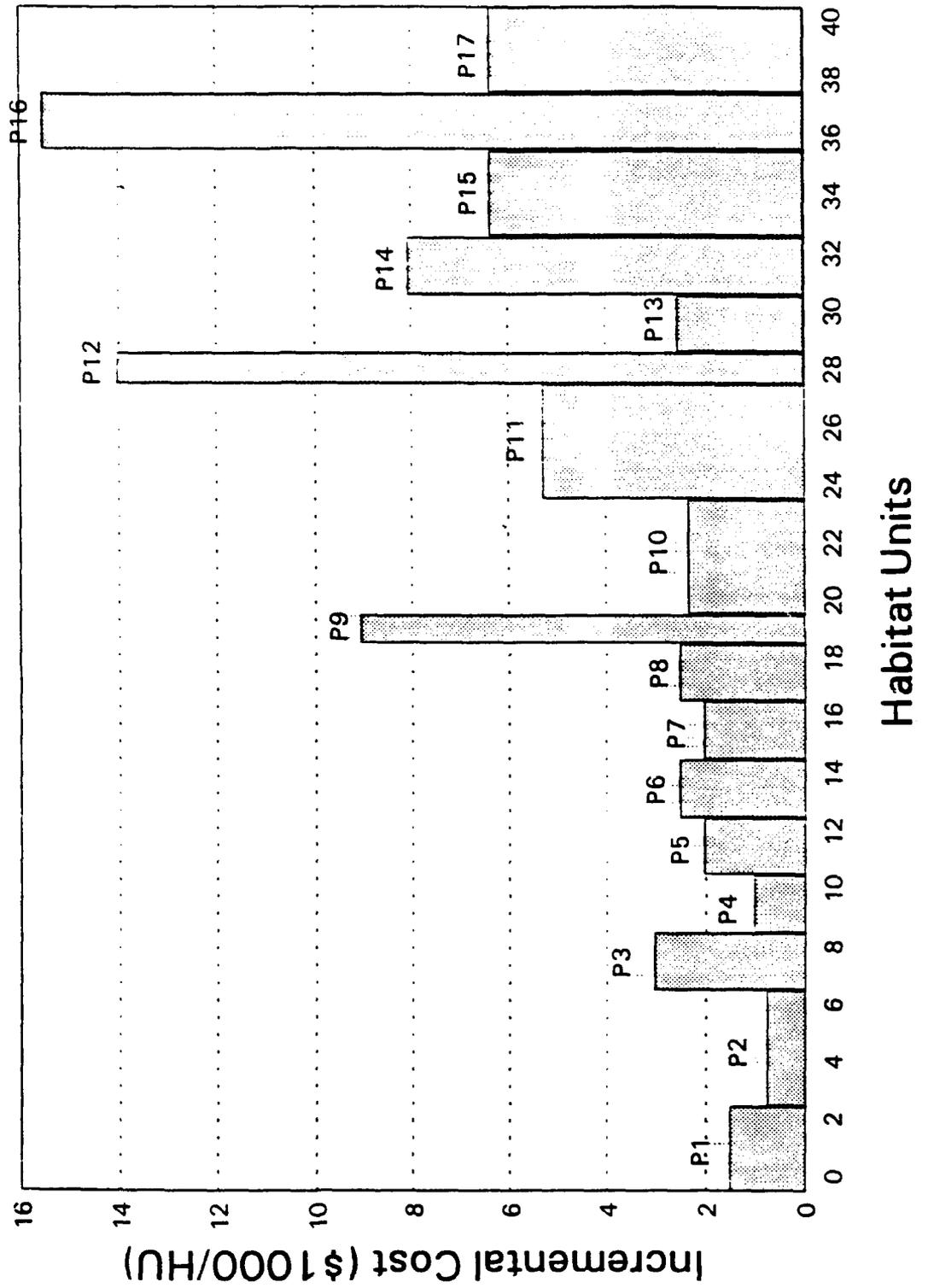
Exhibit 7A - Supply Schedule, Incremental Costs of Combinations

(1) Output (HU)	(2) Cost (\$)	(3) Incremental Cost (\$ per HU)
0	0	—
1		
2	3,000 (P ₁)	1,500
3		
4		
5		
6	6,000 (P ₂)	750
7		
8	12,000 (P ₃)	3,000
9		
10	14,000 (P ₄)	1,000
11		
12	18,000 (P ₅)	2,000
13		
14	23,000 (P ₆)	2,500
15		
16	27,000 (P ₇)	2,000
17		
18	32,000 (P ₈)	2,500
19	41,000 (P ₉)	9,000
20		
21		
22		
23	50,000 (P ₁₀)	2,250
24		
25		
26		
27	71,000 (P ₁₁)	5,250
28	85,000 (P ₁₂)	14,000
29		
30	90,000 (P ₁₃)	2,500
31		
32	106,000 (P ₁₄)	8,000
33		
34		
35	125,000 (P ₁₅)	6,333
36		
37	156,000 (P ₁₆)	15,500
38		
39		
40	175,000 (P ₁₇)	6,333

Exhibit 7B - Cost Effective and Least Cost Combinations of Combinable Management Measures

(1) Name of Combination	(2) Component Management Measure Increments	(3) Description	(4) Outputs (HU)	(5) Costs (\$)	(6) Incremental Costs (\$ per HU)
No Action	No A + No B	no action	0	0	---
P ₁	No A + B ₁	maintain water elevation at +120.0 feet	2	3,000	1,500
P ₂	No A + B ₂	maintain water elevation at +120.4 feet	6	6,000	750
P ₃	A ₁ + B ₂	plant 40 shrubs per acre, and, maintain water elevation at +120.4 feet	8	12,000	3,000
P ₄	A ₂ + B ₂	plant 75 shrubs per acre, and, maintain water elevation at +120.4 feet	10	14,000	1,000
P ₅	A ₃ + B ₂	plant 125 shrubs per acre, and, maintain water elevation at +120.4 feet	12	18,000	2,000
P ₆	A ₂ + B ₃	plant 75 shrubs per acre, and, maintain water elevation at +120.8 feet	14	23,000	2,500
P ₇	A ₃ + B ₃	plant 125 shrubs per acre, and, maintain water elevation at +120.8 feet	16	27,000	2,000
P ₈	A ₄ + B ₃	plant 175 shrubs per acre, and, maintain water elevation at +120.8 feet	18	32,000	2,500
P ₉	A ₅ + B ₂	plant 350 shrubs per acre, and, maintain water elevation at +120.4 feet	19	41,000	9,000
P ₁₀	A ₅ + B ₃	plant 350 shrubs per acre, and, maintain water elevation at +120.8 feet	23	50,000	2,250
P ₁₁	A ₆ + B ₃	plant 550 shrubs per acre, and, maintain water elevation at +120.8 feet	27	71,000	5,250
P ₁₂	A ₅ + B ₄	plant 350 shrubs per acre, and, maintain water elevation at +121.2 feet	28	85,000	14,000
P ₁₃	A ₇ + B ₃	plant 750 shrubs per acre, and, maintain water elevation at +120.8 feet	30	90,000	2,500
P ₁₄	A ₈ + B ₄	plant 550 shrubs per acre, and, maintain water elevation at +121.2 feet	32	106,000	8,000
P ₁₅	A ₇ + B ₄	plant 750 shrubs per acre, and, maintain water elevation at +121.2 feet	35	125,000	6,333
P ₁₆	A ₈ + B ₅	plant 550 shrubs per acre, and, maintain water elevation at +121.6 feet	37	156,000	15,500
P ₁₇	A ₇ + B ₅	plant 750 shrubs per acre, and, maintain water elevation at +121.6 feet	40	175,000	6,333

Exhibit 8 Incremental Costs



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For many years, U.S. Army Corps of Engineers field planners have been required to include an incremental cost analysis in their environmental mitigation, and now restoration, planning efforts. Although some general guidance has been provided, it has often been criticized as overly simplified and not responsive to real world planning applications. The Bussey Lake demonstration is intended to illustrate the application of incremental cost analysis for environmental planning in such a real world planning situation.

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