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UPPER MISSISSIPPI RIVER SYSTEM
ENVIRONMENTAL MANAGEMENT PROGRAM
POST-CONSTRUCTION PERFORMANCE EVALUATION REPORT
SUPPLEMENT (PERS2F)

BROWN'S LAKE REHABILITATION AND ENHANCEMENT

POOL 13, MISSISSIPPI RIVER MILE 545.8
JACKSON COUNTY, IOWA

APRIL 1997

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1. INTRODUCTION

The Brown's Lake Rehabilitation and Enhancement project, hereafter referred to as "the Brown's Lake project," is an ongoing part of the Upper Mississippi River System (UMRS) Environmental Management Program (EMP). The Brown's Lake project is located within the Upper Mississippi River National Wildlife and Fish Refuge.

a. Purpose. The purposes of this report are as follows:

(1) Supplement monitoring results and project operation and maintenance discussed in the May 1993 Post-Construction Evaluation Report;

(2) Summarize the performance of the Brown's Lake project, based on the project goals and objectives;

(3) Review the monitoring plan for possible revision;

(4) Update project operation and maintenance efforts to date; and

(5) Review engineering performance criteria to aid in the design of future projects.

b. Scope. This report summarizes available project monitoring data, inspection records, and observations made by the U.S. Army Corps of Engineers (Corps), the U.S. Fish and Wildlife Service (USFWS), and the Iowa Department of Natural Resources (IADNR) for the period from June 1987 through August 1996.

c. Project References. Published reports which relate to the Brown's Lake project which supplement those references in the May 1993 Post-Construction Evaluation Report are presented below.

(1) *Post Construction Performance Evaluation Report (PER2F), Brown's Lake Rehabilitation and Enhancement, Pool 13, River Mile 545.8, Upper Mississippi River, Jackson County, Iowa*, May 1993 (93PER). This document was prepared to summarize all

available monitoring data, project inspections, and project observations by the Corps, the USFWS, and the IADNR for the period June 1987 to October 1992.

(2) *Brown's Lake Habitat Rehabilitation and Enhancement Project, Great Flood of 1993 Damage Assessment*, February 1994. This document was prepared to summarize the Flood of 1993 damage, proposed corrective action, and estimated cost for repairs.

(3) *Report on the Revegetation of Fine-Grained Dredged Material with Mast-Producing Tree Species on the Upper Mississippi River in Jackson County, Iowa, December 1994.* This report summarizes the results of efforts to revegetate the fine-grained dredged material deposited in the containment area as a feature of the HREP project. The study was conducted for the Corps by Iowa State University researchers at the direction of the Iowa Cooperative Fish and Wildlife Unit. The objectives of the study were to determine optimal strategies for establishing mast-producing trees on fine-grained dredged material, and to establish a viable stand of mast-producing tree species at the Brown's Lake dredged material placement site.

(4) Letter from Mr. Robert Kelley, Corps, to Mr. William Hartwig, USFWS, June 19, 1995. This letter transmits the final report for the second phase of the project, revegetation of fine-grained dredged material with mast-producing tree species, and formally transfers the Brown's Lake project to the USFWS.

(5) Letter from Mr. William F. Hartwig, USFWS, to Colonel Cox, Corps, July 20, 1995, accepting the transfer of the Brown's Lake project from the Corps to the USFWS. This letter noted that revegetation of the dredged material placement site was not successful and that maintenance to ensure survival of the tree seedlings was not applicable.

(6) Letter from Mr. Robert Kelley, Corps, to Mr. William Hartwig, USFWS, August 10, 1995. This letter formally deletes the paragraph in the O&M Manual describing maintenance of the dredged material placement site.

(7) *Memorandum of Agreement between the USFWS and the Corps*, July 8, 1994, to allow the USFWS and the Corps to work together on a mutually beneficial project known as the Flood Damage Habitat Restoration Project. This project included several work orders funded by the USFWS, the first of which resulted in Plans and Specifications for the Brown's Lake Inlet Channel Excavation, River Mile 545.8, Pool 13, Upper Mississippi River System, Jackson County, Iowa, June 1995, Contract No. DACW25-95-C-0064. This document was prepared to provide sufficient detail of project features to allow clearing, stripping, and excavation of the inlet channel, and placement of the excavated material on the river bank and levee adjacent to the inlet channel by a contractor. This project was in response to flood damage caused by the Great Flood of 1993, an above design flood event (i.e., greater than 50-year event) for the Brown's Lake project, which resulted in large sediment accumulations in the inlet channel, on the water control structure apron, and complete burial of the riprap adjacent to the water control structure.

(8) *National Biological Service, Illinois Natural History Survey, Iowa Department of Natural Resources and Wisconsin Department of Natural Resources. Long-Term Resources Monitoring Program 1993 Flood Observations.* National Biological Service, Environmental Management Technical Center (EMTC), Onalaska, Wisconsin, December 1994 (LTRMP 94-SO11). This publication is a compilation of reports of observations made during the 1993 flood on the Upper Mississippi River. It includes observations of pre- and post-flood aquatic macrophyte abundance in the Brown's Lake complex, field observations of tree mortality in Pool 13 resulting from the 1993 flood, observations of sedimentation along two transects in Brown's Lake, and water quality sampling in Brown's Lake during peak flood levels in July 1993.

(9) *Largemouth Bass Response to Habitat and Water Quality Rehabilitation in a Backwater of the Upper Mississippi River,* by Russell Gent, John Pitlo, Jr., and Tom Boland. *North American Journal of Fisheries Management 15:784-793,* 1995. This study includes additional data on suspended sediments and creek statistics from the study and was identified as reference (4) in the May 1993 Performance Evaluation Report (PER2F).

(10) *Site Manager's Project Inspection and Monitoring Results - 6/19/95, 4/9/96.* These reports outline the results of USFWS inspections of the deflection levee, water control structures, inlet channel improvements, side channel excavation, lake dredging, and the dredged material placement site.

2. PROJECT GOALS, OBJECTIVES, AND MANAGEMENT PLAN

a. General. As stated in the 93PER, the Brown's Lake project was initiated primarily because of rapid accumulation of sediment and deterioration of water quality which resulted in significant winter fish kills in the lake. Although water quality within the lake was adequate to sustain native fisheries during the summer months, ice and snow cover produced periods when dissolved oxygen (DO) became depleted to the point where fish kills occurred.

b. Goals and Objectives. Goals and objectives were formulated during the project design phase and are summarized in Appendix A.

c. Management Plan. The 93PER recommended that a formal Management Plan be developed for the Brown's Lake project, as have been developed for more recently developed EMP projects, such as Potters Marsh, Illinois (RM 522.5 - 526.0). The Management Plan was developed by the USFWS and is shown in Table 2-1. The Brown's Lake project is operated as generally outlined in the O&M Manual.

TABLE 2-1

Annual Management Plan for Brown's Lake

Time Frame	Management Action	Purpose
Winter	Open one water control structure 10 inches after ice cover.	Increase DO concentrations for overwintering fish in backwaters.
Spring	Close water control structure when turbidity levels reach 40 turbidity (NTU) in the main channel or 100 NTU in the Maquoketa River. All gates will be closed prior to spring runoff.	Improve water quality in important backwater habitat by decreasing suspended sediment concentrations.

3. PROJECT DESCRIPTION

a. Project Features. Plate 1 shows a general plan and vicinity map, and plate 2 shows project features.

b. Construction and Operation. Following award of the levee/dredging construction contract on July 21, 1988, dredging began during late summer and was essentially completed in September 1990. Planting for the revegetation of the dredged material containment area was completed by May 1993. Excavation of the inlet channel to remove sediment deposited as a result of the Great Flood of 1993 (an above-design flood event, i.e., greater than the 50-year event) began in August 1995 and was completed in September 1996. The inlet channel excavation work was funded by the USFWS. Project operation and maintenance generally consists of: (1) operating the water control structure to ensure sufficient dissolved oxygen levels throughout the Brown's Lake complex during critical times of the year; (2) maintaining the inlet channel to ensure that it is kept free of silt and debris; (3) maintaining the water control structure gates; and (4) mowing and maintaining the sediment deflection levee and related revetment.

4. OPERATION, MAINTENANCE, AND PROJECT MONITORING

a. General. Appendix A presents the Post-Construction Evaluation Plan. This plan was developed during the design phase and serves as a guide to measure and document project performance. Appendix B contains the Monitoring and Performance Evaluation Matrix and Resource Monitoring and Data Collection Summary. This schedule presents the types and frequency of data that have been collected to meet the requirements of the Performance Evaluation Plan.

b. Corps of Engineers. The physical locations of the sampling stations referenced in the Performance Evaluation Plan and the Resource Monitoring and Data Collection Schedule are presented on plates 3, 4, 9A, 9C, and 9E. The Corps has collected data at 8 sedimentation transects and 10 deep hole transects and profiled the dredged channel. A ninth sedimentation transect, the Smith's Creek Thalweg, has been eliminated due to difficulties in replicating the 1987 transect. This transect has been designated as inactive on plate 3. The Corps sedimentation transect data are shown on plates 5 through 7. The deep hole transects are shown on plate 9F. The Upper Brown's Lake dredged channel profiles are shown on plate 9B. The Lower Brown's Lake dredged channel profiles are shown on plate 9D. The sediment transects, deep hole transects, and dredged channel profiles are surveyed every 5 years at various times during the year, depending on project access and workload. The Corps also has collected water quality data at six stations. Three stations are located within the dredged channel, two are off-channel, and one is in Lainsville Slough. The water quality monitoring stations are shown on plate 4. In addition, three staff gauges were installed during the summer of 1996 to assist in future monitoring efforts. Plates 3 and 4 show the staff gauge locations. The success of the project relative to original project objectives will be measured using this data along with other data, field observations, and project inspections performed by the USFWS and the IADNR. The Corps has overall responsibility to measure and document project performance.

c. U.S. Fish and Wildlife Service. The USFWS is responsible for operating and maintaining the Brown's Lake project. The USFWS has collected data at 4 sedimentation transects, 6 water quality stations (contracted to the IADNR), and 20 aquatic vegetation transects in Upper and Lower Brown's Lakes. The three sedimentation transects are surveyed annually during the winter, through the ice. Plate 8 shows USFWS sediment transect data. Data collection and monitoring by the USFWS is being performed under the Long-Term Resources Monitoring (LTRM) Program (Public Law 99-662). As part of the Corps Flood of 1993 Damage Assessment, LTRM representatives took soundings (sedimentation transects) at three of the USFWS Brown's Lake project dredged channel sedimentation transects. The USFWS Refuge Manager is required to conduct annual inspections of the project and participate in periodic joint inspections of the project with the Corps. As Refuge Manager, the USFWS is also in a position to make regular field observations which aid in determining the relative success or failure of the Brown's Lake project.

d. Iowa Department of Natural Resources. The IADNR has collected data at 4 sedimentation transects and 4 fish stations. The sedimentation transects are surveyed annually during the summer. Plate 9 shows IADNR sedimentation transect data. As manager of the adjacent Green Island Refuge, the IADNR is in a good position to make regular field observations of the Brown’s Lake project which aid in determining the relative success or failure of the project.

5. EVALUATION OF AQUATIC HABITAT OBJECTIVES

a. Retard the Loss of Fish and Wildlife Aquatic Habitat by Reducing Sedimentation in Upper and Lower Brown's Lakes.

(1) Monitoring Results. Sedimentation transects are shown on plates 5 through 9. The sediment data used to determine the average annual sediment volume consists of the USFWS and IADNR sediment transects and the undisturbed areas of the Corps transects. The undisturbed areas of the Corps transects were used because no as-built information is available for comparison of the dredge cut areas. Sediment transects used to determine sediment reduction are identified in Table A-2.

As shown in Appendix A, Table A-1, the Brown's Lake deflection levee was designed to provide an annual sediment reduction of 21.6 acre-feet at year 50. The without-project expected sediment volume was determined to be 30.8 acre-feet (reference DPR A-2, 3). The annual sediment deposition, based on all sediment transect information available to date, is 19.4 acre-feet (see Table 5-1 and Appendix E, Table E-1), resulting in an actual annual sediment reduction of 11.4 acre-feet.

TABLE 5-1

Brown's Lake Sediment Reduction

Without-Project Expected Annual Sediment Volume, Acre-Feet	30.8
With-Project Average Annual Sediment Volume, Acre-Feet [1/]	19.4
Actual Annual Sediment Reduction Due to Project, Acre-Feet	11.4
Designed Annual Sediment Reduction, Acre-Feet [2/]	21.6

[1/] Based on a weighted average annual sediment deposition rate of 0.3 in/yr
[2/] Based on a design annual sediment deposition rate of 0.1 in/yr

The average annual sediment deposition rates varied among the three groups of transects, as shown in Tables 5-2 and E-1. The weighted average annual sediment deposition rate of 0.3 inch/year is approximately three times the design sediment deposition rate of 0.1 inch/year.

TABLE 5-2

Brown's Lake Average Annual Sediment Deposition

Transects	Years of Transect Data	Average Annual Sediment Deposition Rate, Inch/Year
IADNR	10	0.2
Corps	65	0.4
USFWS	5	1.0
Weighted Average		0.3
Design Annual Sediment Deposition Rate		0.1

Individual sediment transect deposition rates are shown on plate 3. The Corps and IADNR transects have the lowest annual sediment deposition rate as they utilize or occur at undisturbed areas of the project. The USFWS transects include dredged channels and have a correspondingly higher sediment deposition rate due to the tendency of the dredge cuts to act as sediment traps.

The Corps transect with the highest annual sediment rate (545.8H) is in Upper Brown's Lake near the IADNR sediment transect with the highest annual sediment deposition rate (545.8E). These transects are close to the Smith's Creek outlet, the predominant watershed which directly contributes significant sediment to Upper Brown's Lake. Conversely, IADNR sediment transect 545.6B in Upper Brown's Lake has the lowest sediment deposition rate of all the transects and is also located close to the Smith's Creek outlet.

The remaining Corps transects in Upper Brown's Lake (545.7H, 545.3H) experienced similar, lesser sediment deposition than the transect closest to Smith's Creek. The similar sediment deposition rates of the Upper Brown's USFWS transects (545.4A, 545.5A) can be compared to the closest Corps transects (545.7H, 545.3H).

The Lower Brown's Lake USFWS transect (544.2C) has the highest annual sediment deposition rate. This may be due to its relatively short length (400 feet) and the inclusion of the dredge cut. Of the three Lower Brown's Lake Corps transects, two were not included in the analysis due to insufficient or questionable data (544.6H, 544.1E). The middle Lower Brown's Lake Corps transect (544.3H) experienced the lowest annual sediment deposition rate of all the Corps transects.

Measurements of current velocity and turbidity gradients along a transect through Upper Brown's Lake and Scarborough Lake taken by EMTC during the 1993 flood (reference 8) suggest that the deflection levee appears to have been effective in mitigating high turbidity and current velocity at sites along the study transect. Current velocities along the Brown's

Lake transect during the 1993 flood were strongly influenced by flooded islands with associated understory and mature tree cover.

The Corps Flood of 1993 Damage Assessment for the Brown's Lake project noted the Green Island levee was overtopped, resulting in the loss of the crushed stone road surface from the top of the levee (Appendix C). The Green Island levee forms the northern boundary of the Brown's Lake complex and serves as an access road to the water control structure and the sediment deflection levee. The sediment deflection levee was also overtopped in the northern end at the water control structure. Damage to the sediment deflection levee was limited to the loss of the crushed stone road surface from the top of the levee.

The 1996 USFWS Site Manager's project inspection report noted the deflection levee was in satisfactory condition, but needed mowing and had one small hole on the top due to a burrowing animal (Appendix C). The hole has been filled.

(2) Conclusions. The sediment reduction due to construction of the deflection levee is approximately half of the design reduction in sediment volume. Upper Brown's Lake appears to be experiencing a greater sedimentation rate than Lower Brown's Lake. This would suggest that the increase in sediment deposition in Upper Brown's Lake may be due to Smith's Creek.

Although reduced current velocities in Brown's Lake cannot be directly attributed to the diversion levee, it may exert some influence on flow dynamics, as was suggested by the presence of turbidity gradients on the Brown's Lake transect.

The Corps transects were difficult to recover, as they had not been monumented during the design phase. All of the recoverable Corps transects have been monumented for ease of recovery, and three staff gauges were installed during the summer of 1996 to assist in future monitoring efforts. Staff gauge locations are shown on plates 3 and 4. The next PERS will evaluate the Corps transects to include data from the dredge cuts for a better comparison with the USFWS transects. Continued monitoring will better determine long-term sedimentation rates and patterns.

b. Improve Water Quality for Upper and Lower Brown's Lakes by Decreasing Suspended Sediment Concentrations and Increasing Winter Dissolved Oxygen Concentrations.

(1) Monitoring Results. The primary water quality objectives of the Brown's Lake project are to decrease sediment input to the lake and to increase winter DO concentrations. As shown in Appendix A, Table A-1, the project was designed to keep suspended solids concentrations at or below 50 mg/l and to maintain DO concentrations at or above 5 mg/l by providing a water inflow of 350 cfs. Although no pre-project water quality data are available, it is presumed that fish kills observed during pre-project winters were likely due to low DO concentrations in conjunction with decreasing water depths due to

sedimentation. In an effort to avoid future winter kills, a water control structure was constructed in the inlet channel to Brown's Lake. The gated structure was designed to allow oxygen-rich Mississippi River water to flow into the lake during the critical winter months, while keeping sediment-laden waters from the lake the remainder of the year.

The first Brown's Lake performance evaluation report addressed the results from post-project water quality monitoring performed through early 1993. In this initial performance evaluation summary, DO concentrations during the winter months were reported to be more than sufficient to sustain aquatic life, ranging from 8.47 mg/l to 11.42 mg/l. Additionally, a study performed in 1990/1991 by the IADNR entitled *Largemouth Bass Use of Newly Dredged Channels and Response to Change in Water Quality During the Winter Period in Upper and Lower Brown's Lakes, Pool 13, Upper Mississippi River* showed that DO levels increased rapidly throughout the lake when the water control structure gates were opened. Water quality monitoring is ongoing at Brown's Lake, and the results from measurements taken during 1994, 1995, and 1996 are reported herein.

During the study period, water quality monitoring was performed year-round by the Corps at three Brown's Lake sites (W-M545.8F, W-M545.5C and W-M544.2C) and by the USFWS (contracted to the IADNR) at one site (W-M545.5B). Additional winter DO monitoring was performed by the Corps at the following three sites: W-M544.1D, W-M544.6F and W-M544.7F. Sites W-M545.8F, W-M544.2C, W-M545.5B, and W-M544.6F are located within dredged channels. Sites W-M545.5C and W-M544.7F are off-channel sites, while site W-M544.1D is located in Lainsville Slough. Site locations are identified on plate 4.

The results from water quality monitoring at all sites are found in Appendix D. Table D-1 gives the monitoring results for samples collected at site W-M545.8F. This site is located downstream of the water control structure in the inlet channel and is the site most representative of the inflow to the lake. DO concentrations here ranged from 2.58 mg/l - 18.72 mg/l. Eight DO measurements were below 5 mg/l, however, none of these occurred during the winter when the water control structure was open (see Table 5-3, Table D-1 and Figure D-1). One of the four water control structure gates was opened during the following periods to allow oxygen-rich water into the lake: December 27, 1993 - February 21, 1994 (10-inch opening) and December 16, 1994 - March 8, 1995 (8-inch opening). One gate also was opened 5 feet on four occasions during August through September 1994 in an attempt to flush out sediment which had accumulated in the vicinity of the water control structure. Most of the low DO values observed at this site were measured during the summer of 1995 (see Table 5-3). DO concentrations at sites W-M545.5C (see Table D-2 and Figure D-2) and W-M545.5B (see Table D-4 and Figure D-4) paralleled those observed at site W-M545.8F. Of particular interest is the drop in DO concentrations at all three sites following closure of the water control structure on February 21, 1994. Following ice-out, however, the DO concentrations quickly recovered. As shown in Table D-3 and Figure D-3, site W-M544.2C did not experience a drop in DO concentration following the February 21, 1994, closure. Also, the DO concentrations at this site fell below 5 mg/l on only one occasion during the summer of 1995 (4.94 mg/l on July 5, 1995 - see Table 5-3). These observations are likely due to this site's proximity to Lainsville Slough. Apparently, oxygenated Mississippi River water flowing down the slough is "backing up" the lower end of Brown's Lake and impacting water quality here. As shown in Tables D-5 through D-7, DO monitoring was performed only during the winter at sites W-M544.1D, W-M544.6F, and W-M544.7F. Except for a 4.03 mg/l DO concentration at W-M544.6F on January 24, 1995, all winter measurements exceeded 5 mg/l (see Table 5-3).

TABLE 5-3

DO Concentrations Below 5 mg/l

DO (mg/l)	Date	Location
4.78	3/1/94	W-M545.8F
4.75	6/20/95	W-M545.8F
4.79	7/5/95	W-M545.8F
3.96	7/18/95	W-M545.8F
2.58	8/22/95	W-M545.8F
3.63	9/5/95	W-M545.8F
3.87	9/19/95	W-M545.8F
4.20	8/20/96	W-M545.8F
2.89	7/31/95	W-M545.5C
3.06	9/5/95	W-M545.5C
4.12	9/19/95	W-M545.5C
1.08	8/20/96	W-M545.5C
4.97	9/10/96	W-M545.5C
4.94	7/5/95	W-M544.2C
4.10	8/20/96	W-M544.2C
4.03	1/24/95	W-M544.6F
3.0	6/26/95	W-M545.5B
3.0	8/10/95	W-M545.5B
4.9	9/8/95	W-M545.5B

Total suspended solids (TSS) samples were collected at sites W-M545.8F, W-M545.5B, W-M545.5C, and W-M544.2C. TSS concentrations were less than or equal to the 50 mg/l objective the majority of the time (see Tables D-1 through D-4). The TSS concentration exceeded 50 mg/l on nine occasions, as shown in Table 5-4. Many of the exceedences occurred on days when the wave height was significant, while others may have been related to algal biomass, as indicated by chlorophyll a concentrations. The average TSS concentrations at sites W-M545.8F, W-M545.5B, W-M545.5C, and W-M544.2C were 24.5 mg/l, 24.2 mg/l, 28.8 mg/l, and 31.2 mg/l, respectively.

TABLE 5-4

Total Suspended Solids Concentrations Exceeding 50 mg/l

Suspended Solids (mg/l)	Date	Location
57.0	7/5/95	W-M545.8F
68.6	2/21/94	W-M545.5B
92.5	11/29/94	W-M545.5B
50.2	7/10/95	W-M545.5B
57.0	7/5/95	W-M545.5C
58.0	9/19/95	W-M545.5C
100.0	11/21/95	W-M545.5C
69.0	7/5/95	W-M544.2C
83.0	7/18/95	W-M544.2C

Desired water inflow for the Brown's Lake project was determined during the design phase by performing an oxygen balance analysis. The results of the oxygen balance analysis indicated that approximately 350 cfs of river water would be required to ensure adequate DO throughout the winter in order to prevent winter kills. Design assumptions for the water control structure included a low-flow head of approximately 0.2 foot, which would generate a velocity of 3.5 ft/s, which would require an area of about 100 square feet. Consequently, the structure was designed with four 5-foot by 5-foot box culverts. Experience to date has shown that the size of the structure is more than adequate to supply oxygenated water throughout the lake. Typically, a single gate is opened 10 inches. At a velocity of 3.5 ft/s, this would result in a flow of only 14.6 cfs through the gate. No post-construction measurements of water inflow to Brown's Lake through the water control structure have been collected; however, it is apparent from DO measurements that a single gate opening of only 10 inches allows a sufficient amount of flow through the gates to oxygenate the lake.

A study was prepared for the USFWS by the IADNR entitled *Largemouth Bass Use of Newly Dredged Channels and Response to Change in Water Quality During Winter Period in Upper and Lower Brown's Lakes, Pool 13, Upper Mississippi River*. The results of this study conducted in the winter of 1990-1991 were recently published, with additional data on suspended sediments and creel statistics, in the *North American Journal of Fisheries Management* (reference 9). Water quality variables inside and outside the project area, movement of radio-tagged largemouth bass in response to changing oxygen concentrations, and creel statistics were used to evaluate the success of the improvements. Turbidity was significantly less in the Brown's Lake complex than in the main channel. An increase in DO concentrations at all sampling sites in the Brown's Lake complex was measured within 7 days after opening the inlet structure. Chemical and thermal stratification in the dredged channel water column resulted from colder (32 degrees F.), highly oxygenated water from the main channel moving over denser, warmer (36-38 degrees F.) water in the dredged channels. Stratification in the dredged channels persisted until ice-out, with colder, oxygenated water in the surface stratum; warmer, but anoxic, water in the bottom stratum; and a mixture in the middle stratum.

Movements of radio-tagged largemouth bass using the dredged channels coincided with DO concentrations. Bass exited the complex during oxygen declines and returned when the water control structure was opened and oxygen concentrations increased. Some radio-tagged bass moved as much as 4 miles under ice to return to the complex. Estimated angler effort and catch increased 58% and 117%, respectively, in the Lower Brown's Lake-Lainsville Slough complex following rehabilitation. A 10-fold increase in angler effort and catch was estimated for Upper Brown's Lake after the project was completed. Although angling statistics cannot be considered an absolute index of fish response, the creel surveys did provide information that was useful in assessing fish response to habitat and environmental changes produced by the project.

The 1996 USFWS Site Manager's project inspection report noted the water control structure was operating satisfactorily. The operating mechanisms were greased and flushed in October 1996. The report also noted that work continues on dredging the inlet channel (Appendix C).

(2) Conclusions. The Brown's Lake project continues to have a positive impact on water quality. During the critical winter months, DO concentrations have remained above the 5 mg/l objective throughout most of the lake. Only once during the study period did the DO concentration during the winter fall below 5 mg/l, and this occurred at a site located outside of the main basin of the lake. The project also has had a positive impact regarding TSS input to the lake. Only once during the study period did the TSS concentration in the inlet channel exceed the 50 mg/l objective.

To date, the Brown's Lake project has performed well in meeting its water quality objectives. Ongoing DO and TSS monitoring efforts are sufficient, and installation of a monitoring device to measure water inflow at the water control structure does not appear to be justified. Since monitoring efforts reveal oxygenated water can be provided to the Brown's Lake project by partially opening one of the four gates, the oxygen balance method used for design should reflect less conservative values. Consequently, this "lesson learned" was utilized in the design of the inlet structure at the Spring Lake, Illinois (RM 532-536) EMP project. Utilization of less conservative values for sediment oxygen demand (SOD) and biochemical oxygen demand in the Spring Lake design resulted in an optimum inflow (175 cfs), half of that determined to ensure an adequate inflow at the Brown's Lake project (350 cfs).

In addition, a potential for further improvement in water quality was seen. The low DO concentrations observed at several sites during the summer months could be alleviated by allowing Mississippi River water to enter the lake at times of relatively low flows when TSS concentrations are below 50 mg/l. This would require monitoring of TSS concentrations on the Mississippi River near the Brown's Lake inlet channel. The TSS monitoring could be performed by IADNR personnel as part of their biweekly sampling of LTRM sites. Another option would be to determine the relationship between TSS and turbidity at current LTRM sites. A regression analysis was performed in order to determine the turbidity level that corresponded to a TSS concentration of 50 mg/l for two sites: M556.4A (the closest upstream main channel site) and MQ02.1M (Maquoketa River site). The Maquoketa River site is important because it enters the Mississippi just upstream of Brown's Lake. The turbidity values corresponding to a TSS of 50 mg/l were determined to be 34 NTU and 27 NTU, respectively. Therefore, the gates to the inlet structure should only be opened during summer low DO periods if the turbidity levels at M556.4A and MQ02.1M are less than 34 NTU and 27 NTU, respectively.

Habitat rehabilitation in Brown's Lake was successful in creating wintering habitat for fish. The results of radio telemetry and creel studies summarized in reference 9 provide evidence that the project was successful in creating wintering habitat for largemouth bass. Oxygenation of the water column in the dredged channel system and by operation of the gated control structure, resulted in the return of radio-tagged largemouth bass to the dredged channel system. Inlet gate openings were reduced from 12 inches to 6 inches to ensure that current velocities would not be detrimental to wintering largemouth bass and other centrarchid species. Closure of the water control structure during high water also effectively protected the Brown's Lake complex from high suspended solid loads in the main channel.

The ability to introduce oxygenated water into the complex during periods of low DO concentrations is a key element in providing year-round habitat for native fisheries. The combination of increased water depths and higher DO levels has provided a viable over-wintering area for fish within Upper and Lower Brown's Lakes. Movement of radio-tagged largemouth bass in response to changing oxygen concentrations, and creel statistics all indicated increased use of the area following project construction.

c. Increase Fish Habitat in Upper and Lower Brown's Lakes and Increase Fish Diversity by Providing Varied Water Depths.

(1) <u>Monitoring Results</u>. Dredged channel sedimentation transects are shown on plates 5 through 8. Dredged channel plans and profiles are shown on plates 9A-9D. As shown in Appendix A, Table A-1, the Brown's Lake dredging was designed to increase fish habitat in Upper and Lower Brown's Lakes and increase fish diversity by providing varied water depths by 8 acre-feet at year 50. The assumed as-constructed lake volume was 240 acre-feet at year 0 (O&M Manual, Plate C-13, Details and Dredging Schedule). Based on sediment transect data, the additional lake volume at year 6 is 179 acre-feet (see Table 5-5 and Appendix E, Table E-2). The additional lake volume was determined using the dredge cut portions of the Corps and USFWS transects. Using dredged channel profile data, the additional lake volume at year 6 is 190 acre-feet. The transects and profiles used to determine the additional lake volume are identified in Table A-2.

The assumed as-built depth of the dredge cuts at flat pool was 9 feet. The average depth of the sediment transect dredge cuts at flat pool is 7.2 feet at year 6, as shown in Table 5-5 and Appendix E, Table E-2, which is comparable to the average dredged channel profile depth of 7.0 feet (see also Table E-5). The average dredged channel profile depths for both Upper and Lower Brown's Lake are less than the average sediment transect depth. This is to be expected, because the profiles include a great many more data points than the sediment transects.

TABLE 5-5

Acre-Feet of Additional Lake Volume

	Design Conditions	**Sediment Transect Dredge Cuts**	**Dredged Channel Profile**
Acre-Feet of Additional Lake Volume Due to Project at Year 6	238	179	190
Average Depth at Year 6, Ft	8.9	7.2	7.0
Upper Brown's Lake Average Depth at Year 6, Ft		6.9	6.6
Lower Brown's Lake Average Depth at Year 6, Ft		7.4	7.0
Sediment Deposition, in/yr	0.15	4.6	4.1
Upper Brown's Lake Sediment Deposition, in/yr		5.3	4.8
Lower Brown's Lake Sediment Deposition, in/yr		4.1	3.9

Annual sediment deposition used for design was 0.15 in/yr (reference DPR A-5). The dredge cuts have performed as sediment traps, however, and sediment deposition in the dredged channel sediment transects averages 4.6 in/year, as shown in Table 5-5 and Appendix E, Table E-2. In comparison, the dredged channel profile sediment deposition rate is 0.5 inch less at 4.1 in/year (see also Table E-5). The average dredged channel profile sediment deposition for Upper Brown's Lake is also 0.5 inch per year less than the average sediment transect sediment deposition, but the deposition rates for Lower Brown's Lake differ by only 0.2 inch. Sediment deposition rates in Upper Brown's Lake are higher than Lower Brown's Lake.

Deposition rates for each dredge cut sediment transect are shown on plate 3. Dredged channel plans and profiles are shown on plates 9A through 9D. When comparing sediment transect data, the dredge cuts in the southern part of Upper Brown's Lake experienced greater sedimentation than the dredge cuts in the northern part of Upper Brown's Lake and the access channel (see plate 3 and Table E-2). However, the channel profile shows greater sediment deposition in the mechanically excavated (north) portion of the channel than in the hydraulically dredged (south) portion of the channel. The greater sediment deposition in the mechanically excavated channel may be due to the water control structure (flows are low, so sediment would settle out early) and the narrower confines of the channel (sediment can settle out only in the channel in the mechanically excavated portion, but can settle out in the lake or channel in the hydraulically dredged portion).

Dredge cuts in the southern part of Lower Brown's Lake experienced greater sedimentation than the dredge cuts in the northern part of Lower Brown's Lake. This holds true for both the sediment transects and the channel profiles. This may be due to floodwaters backing up into the project from Lainsville Slough. For the two Lower Brown's Lake transects which included two dredge cuts each, the riverward dredge cut experienced greater sediment deposition than the landward dredge cut. This is also evident in the channel profiles, and may be due to overland flow during the Flood of 1993 or the riverward channel may be more susceptible to the backwater effects of Lainsville Slough. As noted previously, the Lower Brown's Lake USFWS transect (544.2A) has the highest annual sediment deposition rate.

The Corps Flood of 1993 Damage Assessment for the Brown's Lake project stated that LTRM representatives indicated sediment accumulations of generally less than 6 inches in the dredged channels. A study of sedimentation patterns in Upper Mississippi backwaters before and during the 1993 flood (report contained in reference 8) investigated changes in bed elevation as measured along an established transect in Brown's Lake that traversed one of the dredge cuts (USFWS transect S-M 545.4C). The dredge cut had accumulated an average of 7.4 inches of sediment/year prior to 1993 but had only 0.5 inch (1.2 cm) of accumulation in 1993. This compares favorably with the 1990 dredge cut area of 740.4 SF, the 1993 dredge cut area of 544.8 SF, and the 1994 dredge cut area of 539.5 SF (1994 data line because USFWS sediment transects are surveyed during the winter). (For additional dredge cut area comparisons, see Appendix E, Table E-2.)

The IADNR - Bellevue LTRMP field station took measurements of current velocity and turbidity gradients along a transect through Upper Brown's Lake and Scarborough Lake during the 1993 flood (reference 8). Turbidity measurements recorded on this transect during peak flows and turbidities on the Maquoketa River at its confluence with the Mississippi (just upstream of the project area) showed a marked decrease with lateral distance from the main channel. Current velocities along the Brown's Lake transect also generally declined with distance from the main channel.

Fish habitat is being monitored by observing changes in sedimentation transect depths over time, monitoring water quality, and monitoring aquatic (macrophytic) vegetation. Aquatic plant communities in backwater areas provide an important link to the productivity of Upper Mississippi River backwaters. Fisheries literature has recorded some 84 species of fish that utilize aquatic macrophytes in their life cycle, and 44 of these species utilize plants during spawning activity. Aquatic plants also provide benefits related to chemical balance, oxygen production, hydrology, and food sources.

Aquatic vegetation (submersed and floating-leafed) in backwater areas of Pool 13 is monitored by staff of the LTRMP Field Station at Bellevue, Iowa. A total of 20 transects were established in Upper and Lower Brown's Lakes (Appendix C). Transect sampling is conducted twice during the growing season (spring and summer periods). Historical datasets for the years 1991 through 1995 are available through the EMTC. Review of the monitoring data for the 1991-1995 period generally indicates an increase in submersed aquatic vegetation over time, with post-flood 1993 being an exception. A study that compared pre- and post-flood vegetation communities in Brown's Lake and two other backwater complexes in Pool 13 (reference 8) revealed that nearly all submersed aquatic macrophytes disappeared from monitored transects in Brown's Lake following the July 1993 flood. Increased water depths, turbidity, and current velocities associated with flood conditions were identified as contributing factors to plant mortality. Subsequent review of historical datasets for the 1994 and 1995 monitoring seasons appears to indicate a recovery of the aquatic plant community to levels comparable to pre-flood conditions.

Largemouth bass stock assessments of Lainsville Slough and Lower Brown's Lake, including Scarborough Lake, were conducted annually from 1984 through 1994 (high water levels during 1985 and 1986 prevented data collection during those years). Data collected during stock assessments were used to develop population estimates (Table 5-6).

TABLE 5-6

Largemouth Bass ($\geq$ 9 inch) Population Estimate
Lainsville Slough and Lower Brown's Lake
(Including Scarborough Lake)

		95% Confidence Interval	
Year	**Population Est.**	**Lower**	**Upper**
1984	1,665	1,283	3,609
1985*	-------	-------	-------
1986*	-------	-------	-------
1987	3,488	3,374	3,609
1988	1,645	1,390	2,015
1989	2,932	2,900	2,964
1990	3,465	3,293	3,655
1991	3,714	3,128	4,569
1992	1,577	932	2,848
1993	2,710	1,827	5,243
1994	5,908	5,207	6,827

* high water levels prevented data collection

(1984-1991 data contained in reference 12; 1992-1994 data obtained from IADNR files at Bellevue field station)

The 1996 USFWS Site Manager's project inspection report noted some bank erosion in the vicinity of the excavated side channel and two duck blinds which are scheduled to be removed.

(2) Conclusions. Based on the O&M Manual, the as-constructed lake volume at year 0 with project should be 240 acre-feet. At year 6, the as-constructed lake volume is

approximately 190 acre-feet. The present depths are within the range of depths for existing side channels (6 to 8 feet in depth). Sedimentation data collected to date indicates an average annual sediment deposition in the dredged channels of 4.6 inches/year for the sediment transects and 4.1 inches/year for the channel profile. Assuming a linear relationship, the dredged channels would be expected to fill in 23-26 years, as shown in Table 5-7 and Appendix E, Table E-4. Most of the Upper Brown's Lake sediment transects and the channel profile exhibited a higher annual sedimentation rate than Lower Brown's Lake, indicating the majority of the sediment deposition in Upper Brown's Lake may be due to Smith's Creek. However, the IADNR Mississippi River Monitoring Station (Gent) observed: "Site 545.6B on Plate 3 does not seem to verify that Smith Creek is a major contributor to the silt load in Upper Brown's. This site, which is adjacent to Smith Creek, has the lowest mean deposition of all sites listed in Table E-3 [transect sediment deposition versus dredge cut deposition comparisons]. Greater wind fetch, and associated silt resuspension, in Upper Brown's as compared to Lower Brown's may be a major factor in higher deposition of silt in dredge cuts in Upper Brown's. This would be similar to the 'leveling' observed in the impounded section of the pool where the old channels have disappeared." (Appendix C.) Continued monitoring will better define sedimentation rates and patterns.

TABLE 5-7

Brown's Lake Dredge Cut
Average Annual Sediment Accretion [1/]

Year	Additional Lake Volume, Acre-Feet [1/, 2/]		
	Design	Actual	
		Sediment Transects	Channel Profile
0	240	240	240
6	238	179	185
23	234	5	30
26	233		2
50	227		

[1/] Assumes an annual sedimentation rate
[2/] Design: S = 0.15 inches (0.01 foot)/year. Ref. DPR A-5.
Actual: Sediment Transects: S =4.6 inches (0.38 foot)/year. See Table 5-5.
Channel Profile: S=4.1 inches (0.34 foot)/year. See Table 5-5.

Results of post-project monitoring of aquatic habitat parameters indicate that the project has been successful in restoring aquatic habitat values and fulfilling the objectives outlined in Table 2-1. Deep holes and channels created by dredging in the Brown's Lake complex have restored variable water depths that had largely disappeared from the area prior to project construction, and this has increased the diversity of habitat available to fish species that utilize this backwater complex. Local bass fishermen reported that the project has had a positive effect on fisheries resources in the area.

The presence of aquatic vegetation in Upper and Lower Brown's Lakes since project construction, and its recovery in the years following the extreme conditions that prevailed during the summer of 1993, are indicators that may suggest an increase in the availability and diversity of fish habitat. While excessive growth of aquatic vegetation may actually be detrimental to fisheries habitat value under certain conditions, there is no indication that the current (post-project) levels of submersed aquatic macrophytes have limited the recovery of fish habitat in the Brown's Lake complex. The interspersion of the dredged channels and deep holes with shallow, vegetated areas appears to provide a variety of microhabitats that could meet the requirements of numerous fish species at various life cycle stages.

d. Increase Habitat Available for Wintering Fish by Providing Deeper Water Areas.

(1) Monitoring Results. As shown in Appendix A, Table A-1, the Brown's Lake project was designed to increase by 8 acre-feet habitat available for wintering fish by providing deeper water areas. The project includes 5 deep holes, 130 feet in diameter, dredged to an elevation of 566 (17 feet below Pool 13 flat pool). At year 6, the deep holes average 14.5 feet in depth, as shown in Table 5-8 and Appendix E, Table E-6. With the varying widths and side slopes shown on plate 9F, it is difficult to determine acre-feet available for wintering fish compared to an assumed increase in habitat based on as-built dimensions. The deep holes would be expected to assimilate side channel habitat characteristics when monitoring efforts reveal depths between 6-8 feet.

TABLE 5-8

Brown's Lake Deep Holes
Annual Sediment Deposition

Deep Holes	Depth at Year 6, Ft			Sediment Deposition Rate at Year 6	
	Transect 1	Transect 2	Average	Ft/Yr	In/Yr
Upper Brown's Lake					
A	13.6	13.5	13.6	0.57	6.9
Lower Brown's Lake					
B	15.5	15.3	15.4	0.27	3.2
C	15.0	15.2	15.1	0.32	3.8
D	13.4	13.8	13.6	0.57	6.8
E	15.0	14.4	14.7	0.38	4.6
Average			14.7	0.38	4.6
Brown's Lake Complex Average			14.5	0.42	5.1

Consistent with sediment transect and dredged channel profile sediment deposition rates, sediment deposition in deep hole A located in Upper Brown's was greater than sediment deposition measured in the Lower Brown's Lake deep holes (see Table 5-8 and Appendix

E, Table E-6). Deep hole B in Lower Brown's Lake experienced the least sediment deposition of the deep holes. This is supported by a corresponding lower sediment deposition rate measured at Corps sediment transect 545.6H, which is located near deep hole B (see plate 3 and Appendix E, Table E-3). Deep hole D experienced the greatest sediment deposition in Lower Brown's Lake. It is located just above the mouth of Scarborough Lake near the transect experiencing the greatest sediment deposition, USFWS 544.2C, located downstream of the mouth of Scarborough Lake.

During the study described in reference 9, water quality parameters inside and outside the project area, movement of radio-tagged largemouth bass in response to changing DO conditions, and creel statistics were used to evaluate operation of the water control structure and overwintering fish use of the dredged channels and deep holes. Water quality measurements performed during this study showed all deep hole sites were stratified with DO concentrations less than 1.0 ppm below the 10-foot depth, and less than 2.0 ppm below the 6-foot depth. Warmer water temperatures were measured with increasing depth (34-35 degrees F at the 6-foot depth and 36-38 degrees F at the 8-foot depth). No current velocity was detected at depths below 2 feet. Although overwintering largemouth bass prefer the warmer water and absence of current measured at these increased depths, the DO levels measured in the deep holes was insufficient, and no radio-tagged largemouth bass were found in association with the deep hole habitat.

(2) Conclusions. During the study described in reference 9, the deep hole habitat was anoxic and unsuitable for overwintering fish during most of the ice-over period, limiting fish use of the deep hole habitat to spring and fall when the water column was not stratified, questioning the benefits of deep hole overwintering habitat in lentic backwater areas. The stratified layer most beneficial for overwintering fish appears to occur below the 2-foot depth, and transitions to the anoxic deep hole habitat at depths approaching 6-8 feet. Consequently, this feature will be evaluated in subsequent performance evaluations by the number of deep holes with depths greater than 6-8 feet.

While the sediment deposition rate for the deep holes is greater than the dredged channels, assuming a linear rate of sediment deposition, the deep holes would be expected to maintain depths greater than 6-8 feet for a similar length of time, between 20-26 years, as shown in Table 5-9 and Appendix E, Table E-7.

TABLE 5-9

Brown's Lake Deep Holes
Average Annual Sediment Accretion

Year	Deep Hole Sediment Deposition Depth, Ft
0	17.0
6	14.5
20	8.6
21	8.2
22	7.8
23	7.3
24	6.9
25	6.5
26	6.1

6. EVALUATION OF WETLAND HABITAT OBJECTIVES

Increase Bottomland Hardwood Diversity by Increasing Selected Terrestrial Elevations and Reducing Frequency of Flooding for Such Hardwoods.

(1) Monitoring Results. The increased elevation of the dredged material containment area was expected to provide adequate growing conditions (in terms of water regime) for the establishment of mast-producing tree species. Planting of mast trees within and adjacent to the dredged material containment area was undertaken in two separate efforts. Both of the planting initiatives had experimental objectives in addition to the primary objective of increasing bottomland hardwood diversity in the project.

In May 1990, a 150-foot-wide strip immediately adjacent to the upstream dredged material containment levee was aerially seeded with pin oak acorns. The experimental objective of this effort was to determine the feasibility of this method of planting. Approximately 25,000 acorns were dropped by helicopter onto this 150-foot-wide strip. On May 20, 1991, a strip survey of this area was conducted by the Corps. Strips 3 feet wide and 15 feet apart were surveyed for pin oak seedlings. Based on this survey, it was estimated that 1,200 pin oak seedlings were growing on the site at that time. The Iowa State University (ISU) researchers reported that all of these remaining seedlings were lost due to extended inundation during 1992-1993.

The experimental objective of the ISU revegetation effort (reference 3) was to determine optimal strategies for establishing mast-producing trees on fine-grained dredged material placement sites along the Upper Mississippi River. Twelve species of mast-producing trees and shrubs, totaling 11,080 seedlings, were planted in the containment area during 1992 and 1993 (Table 6-1). Extreme wet weather and the 1993 flood hampered the effort and affected the experimental design of plot studies intended to compare species suitability and cultural treatments. All seedlings on more than half (12 of 23) of the original plots were lost due to flooding. The ISU researchers determined that 4,081 seedlings were alive in October 1994.

Corps and USFWS staff visited the area in May 1996. Standing water covered much of the west dredged material containment cell. The east cell had much less standing water than the west cell. The predominant woody vegetation observed in the containment area was willow, with some cottonwood. Silver maple seedlings were common throughout the east cell, along with lesser amounts of green ash. Of the planting done by ISU researchers, the only surviving trees observed were in the southeast quarter of the cell and the ridge that extends toward the middle of the cross dike separating the cells. Bur oak, red oak, cottonwood, *Populus spp.*, red-osier dogwood, sycamore, eastern red cedar, and black walnut trees were observed growing in this portion of the containment area.

Table 6-1: Species used in various studies on the Brown's Lake revegetation project listing wildlife food value, tolerance to flooding, tolerance to shade and tolerance to clay (heavy) soils.

	Type of Plot[a]			Food[b]	Tolerance to		
Species	**Suit.**	**Cult.**	**Oak**	**Value**	**Flooding**	**Shade**	**Clay**
American Sycamore (*Platanus occidentalis*)	X			low	high[d]	low[e]	high[d]
Black Cherry (*Prunus serotina*)	X			high	low[f]	mod.[d]	mod.[f]
N. Red Oak (*Quercus borealis maxima)*	X	X	X	high	mod.[e]	mod.[c]	mod.[g]
Wild Plum (*Prunus americana*)	X			med.	mod.[d]	mod.[d]	mod.[f]
Bur Oak (*Quercus macrocarpa*)	X		X	high	high[e]	mod.[d]	high[g]
Black Walnut (*Juglans nigra*)	X	X		high	low[d]	mod.[d]	mod.[d]
Shagbark Hickory (*Carya ovata*)	X			high	low[d]	high[c]	low[h]
Serviceberry (*Amelanchier alnifolia*)	X			high	mod.[e]	mod.[e]	NA
N. Pin Oak (*Quercus ellipsoidalis*)	X			high	high[c]	low[c]	high[g]
N. Pecan (*Carya illinoensis*)	X			high	low[d]	high[c]	mod.[c]
White Oak (*Quercus alba*)			X	high	low[d]	mod.[d]	mod.[c]
Swamp White Oak (*Quercus bicolor*)			X	high	high[d]	mod.[d]	high[g]
Red-Osier Dogwood (*Cornus alternifolia*)		X		high	high[e]	low[d]	high[e]
Hybrid Poplar (*Populus sp.*)		X		low	high	low[d]	high[e]

a= Suit.=species suitability study, Cult.=cultural treatment study, Oak=oak vs. oak study
b= food value for wildlife- (Source: Martin, 1951)
c= (Source: Barret, 1980)
d= (Source: Preston, 1980)
e= (Source: Sykes, 1993)
f= (Source: USDA Forest Service, 1971)
g= (Source: Ware, 1983)
h= (U.S.D.A. Forest Service, 1985)

Source: Reference 3

(2) Conclusions. The technique of aerial pin oak seeding immediately adjacent to the upstream containment levee was somewhat successful. Approximately 5% of the acorns dropped produced seedlings after the first year. These seedlings have since died from extended inundation in 1992-1993; however, this seeding effort was undertaken as an adjunct to, rather than a component of, the containment area replanting.

While creation of the dredged material containment area did succeed in raising the elevation of the placement site, much of this area remains too poorly drained to be suitable for regeneration of mast-producing tree species. Mast trees planted as part of the ISU revegetation study are growing on sites in the containment area that are relatively higher in elevation and better drained than the surrounding ground. This mast tree component currently occupies only a small percentage of the replanted area. Persistent poor drainage in much of the containment area limits the likelihood that further active mast tree revegetation efforts would be successful. Natural revegetation of the area by wet-soil adapted tree species such as willow and cottonwood appears to be under way. Over time, further consolidation of the dredged material may provide more favorable conditions for mast tree production. Although some mortality of the mast trees currently established on the site will continue to occur, those that survive to maturity could provide a future seed source for natural mast tree regeneration in the long term.

7. OPERATION AND MAINTENANCE SUMMARY

a. Operation. Project operations are detailed in the O&M Manual and generally consist of: (1) inspecting the sediment deflection levee during flood periods; (2) closing the water control structure during high water periods; (3) opening the water control structure during periods of low DO conditions in Brown's Lake; and (4) inspecting the inlet channel and side channel following each flood event for removal of flood carried debris, repair of sloughing banks, etc.

The project has been operated successfully in this manner since its completion in the fall of 1989. As described in the Annual Management Plan (Table 2-2), one gate of the water control structure should be opened approximately 10 inches after ice cover of Brown's Lake. This will allow water to thermally stratify under the ice when the colder main channel water enters the system later in the winter. This stratification is beneficial as it allows fish to select optimal zones of oxygen, temperature, and current by moving 4 to 6 feet vertically in the water column.

b. Maintenance.

(1) Inspections. Inspections of the Brown's Lake project are to be made by the USFWS Savanna District Manager of the Upper Mississippi River National Wildlife and Fish Refuge (Site Manager) at least annually and follow inspection guidance presented in the O&M Manual. A copy of the completed project inspection checklist should be furnished to the Corps, attention OD-S. Other project inspections should occur as necessary after high water events or as scheduled by the Site Manager. Joint inspections of the Brown's Lake project are to be conducted periodically by the USFWS and the Corps. These inspections are necessary to determine maintenance needs. The Site Manager's project inspection and monitoring results for 1995 and 1996 can be found at Appendix C.

(2) Maintenance Based on Inspections. In 1995, herbicide treatment was applied to vegetation on the deflection levee road, and the gate mechanism of the water control structure was greased and inspected. Excavation of the inlet channel began in August 1995, and was completed in September 1996. Inlet channel excavation was made possible by USFWS Flood Restoration funds and was in response to the Great Flood of 1993, which was an above-design flood event (i.e., greater than 50-year event) for the Brown's Lake project.

In 1996, the USFWS cut the woody vegetation at the end of the deflection levee and at the water control structure. Cutting was done in lieu of spraying because access to the levee was blocked by the contractor's equipment in the spring and because of high water during the summer. In the spring of 1997, the deflection levee will be subjected to a controlled burn to better manage woody vegetation growth.

In October 1996, the gate mechanism of the water control structure was greased, and the water control structure flushed. Three stop logs remain in place from the inlet channel excavation and are scheduled for removal in 1997.

8. CONCLUSIONS AND RECOMMENDATIONS

a. Project Goals, Objectives, and Management Plan. Based on data and observations collected since project completion, it appears that the stated goals and objectives are being met, increasing bottomland hardwood diversity excepted. Continued data collection will better define the degree of sedimentation rate reduction, water quality improvement, fish habitat and diversity improvement, and mast tree survival.

b. Post-Construction Evaluation and Monitoring Schedules. In general, project monitoring efforts have been performed according to the Post-Construction Performance Evaluation Plan in Appendix A and the Resource Monitoring and Data Collection Summary in Appendix B. The next Post-Construction Performance Evaluation will be completed in 2001 following collection of data for the second 5-year interval. A Performance Evaluation Supplement will be prepared annually.

(1) Post-Construction Evaluation.

(a) Retard the Loss of Fish and Wildlife Aquatic Habitat by Reducing Sedimentation in Upper And Lower Brown's Lakes. The annual sediment reduction due to the sediment deflection levee of 11.4 acre-feet is approximately half of the design reduction in sediment volume.

(b) Improve Water Quality for Upper and Lower Brown's Lake by Decreasing Suspended Sediment Concentrations and Increasing Winter Dissolved Oxygen Concentrations. To date, the Brown's Lake project has performed well in meeting its water quality objectives. Upon review of the data, a potential for further improvement in water quality was seen. The low DO concentrations observed at several sites during the summer months could be alleviated by allowing Mississippi River water to enter the lake at times of relatively low flows when TSS concentrations are below 50 mg/l. This would require monitoring of TSS concentrations on the Mississippi River near the Brown's Lake inlet channel. The TSS monitoring could be performed by IADNR personnel as part of their biweekly sampling of LTRM sites. Another option would be to determine the relationship between TSS and turbidity at current LTRM sites. A regression analysis was performed in order to determine the turbidity level that corresponded to a TSS concentration of 50 mg/l for two sites: M556.4A (the closest upstream main channel site) and MQ02.1M (Maquoketa River site). The Maquoketa River site is important because it enters the Mississippi just upstream of Brown's Lake. The turbidity values corresponding to a TSS of 50 mg/l were determined to be 34 NTU and 27 NTU, respectively. Therefore, the gates to the inlet structure should only be opened during summer low DO periods if the turbidity levels at M556.4A and MQ02.1M are less than 34 NTU and 27 NTU, respectively.

This objective also included measurement of cubic feet per second of desired water inflow based on the oxygen balance method used during the design phase. Since the water control structure is not operated to its full capacity, the year 50 target with alternative flow of 350 cfs is excessive. A monitoring device to collect data would cost approximately $10,000.

The positive impacts of the Brown's Lake project on water quality have been documented through measurement of DO and suspended solids. Consequently, measurement of cubic feet per second of desired water inflow will be deleted from the Post-Construction Evaluation Plan.

(c) Increase Fish Habitat in Upper and Lower Brown's Lakes. Of the 20 historic LTRM aquatic vegetation transects in Upper and Lower Brown's Lakes, 15 of these transects will continue to be sampled by LTRM Bellevue Field Station personnel twice yearly during the growing season.

(d) Increase Fish Diversity by Providing Varied Water Depths. Based on sedimentation data collected to date, the average annual sediment deposition in the dredged channels is greater than 4 inches/yr. Assuming a linear relationship and an as-built lake volume of 240 acre-feet, the dredged channels would be expected to fill in about 23-26 years. At year 6, the as-constructed lake volume is approximately 190 acre-feet. Although the present depths are within the range of depths for existing side channels (6 to 8 feet in depth), it appears a 50-year life for dredged channels may not be achievable. Continued monitoring will better define sedimentation rates and patterns and the expected life of dredged channels in backwater areas.

(e) Increase Habitat Available for Wintering Fish by Providing Deeper Water Areas. Based on sediment data collected to date, the average annual sediment deposition in the deep holes is about 5 inches/yr. Assuming a linear relationship, the deep holes would be expected to approach existing dredged channel depths of 6-8 feet in about 25 years. This feature will be evaluated in subsequent performance evaluations by the number of deep holes with depths greater than 6-8 feet.

(f) Increase Bottomland Hardwood Diversity by Increasing Selected Terrestrial Elevations and Reducing Frequency of Flooding for Such Hardwoods. The Corps vegetation transect V-M545.8H will not be included in future monitoring efforts. The persistence of standing water in the west cell of the containment area is expected to prevent regeneration of trees along this transect for the foreseeable future. The 1996 field observations along transect V-M545.3H revealed little presence of woody vegetation, with horsetail (*Equisetum spp*.) being the dominant species. As noted in Section 6a(1), some mast trees survive in the ISU study plots located in the southeast quarter of the containment area. Regeneration of bottomland hardwoods in the dredged material containment area will be monitored at 5-year intervals. The 50-year target with alternative of 35 acres of mast trees will be deleted.

(2) Resource Monitoring and Data Collection Schedules. The monitoring schedule will be revised to include deep hole monitoring at a 5-year interval. Coordinates for the Corps sediment transects and deep hole transects have been obtained for ease of recovery for continued post-construction monitoring.

c. Project Operation and Maintenance. Project operation and maintenance has been conducted in accordance with the O&M Manual. Annual site inspections by the Refuge Manager have resulted in proper corrective maintenance actions.

d. Project Design Enhancement. Discussions with USFWS and Corps personnel involved with operation, maintenance, and monitoring activities at the Brown's Lake project have resulted in the following general conclusions regarding project features which may affect future project design:

(1) Dredged Channels and Deep Holes. In general, the dredged channels and deep holes appear to be filling at a faster rate than the undisturbed areas. A 50-year life may not be an achievable goal. Continued monitoring will better define life expectancies for dredged channels and deep holes. Because deep hole habitat was anoxic and unsuitable for overwintering fish during most of the ice-over period, fish use of the deep hole habitat is limited to spring and fall when the water column is not stratified. The stratified layer most beneficial for overwintering fish appears to occur below the 2-foot depth, and transitions to the anoxic deep hole habitat at depths approaching 6-8 feet, questioning the benefits of deep hole overwintering habitat for fish in lentic backwater areas. Winter water quality monitoring of the deep holes at various depths in the water column should be considered in future monitoring efforts to supplement the data discussed in reference 9.

(2) Water Control Structure. During the 1993 performance evaluation review, it was recognized that the water control structure has more flow capacity than that required to re-oxygenate Brown's Lake. Oxygenated water can be provided to the Brown's Lake project by partially opening one of the four gates, which suggests the oxygen balance method used for design should reflect less conservative values. Consequently, this "lesson learned" was utilized in the design of the inlet structure at the Spring Lake, Illinois (RM 532-536) EMP project. Utilization of less conservative values for sediment oxygen demand (SOD) and biochemical oxygen demand resulted in an optimum inflow (175 cfs) half of that determined to ensure an adequate inflow at the Brown's Lake project (350 cfs), while oxygenating a greater area (720 acres at Spring Lake vs. 375 acres at Brown's Lake). As a result, the Spring Lake project water control structure consists of two gated box culverts.

(3) Entrance Channel. During initial project construction, the entrance channel into the Brown's Lake complex was re-oriented to reduce debris and sediment accumulation problems. Prior to the Great Flood of 1993, debris was still drifting into the entrance channel, requiring removal at least once per year, and sediment had deposited at the mouth of the entrance channel. During the Great Flood of 1993, the water control structure was inundated and overtopped, and large accumulations of sediment were deposited in the channel, completely burying the riprap located adjacent to the water control structure. The Great Flood of 1993 was an above-design flood event (i.e., greater than 50-year event) for the Brown's Lake project. USFWS Flood Restoration money was used to fund the contract to remove sediment deposited in the inlet channel as a result of the Great Flood of 1993. This contract has been completed; however, in order to keep the inlet channel open, periodic removal of accumulated sediment will be required. Operation of the water control

structure to provide oxygenated water during the winter months has not been affected by the sediment accumulation in the inlet channel.

Two wing dams upstream of the inlet channel are scheduled to be rebuilt during summer 1997. These wing dams may be contributing to sediment accumulation in the inlet channel. The Corps is investigating notching the rebuilt wing dams with the idea that flow will increase in the vicinity of the notch, resulting in a subsequent decrease in sediment accumulation in the vicinity of the inlet channel. Notching will be discussed with the project sponsor prior to finalizing design of the rebuilt wing dam elevations.

(4) Dredged Material Placement Site. An attempt was made to revegetate the dredged material placement site with mast-producing trees. The process of reforestation was severely hindered due to the lack of drainage in the dredged material placement site, which contributed to the minimal survival of the mast-producing trees. This problem was alleviated somewhat by construction of a relatively deep ditch through the site. Future projects which consider dredged material placement sites for reforestation should include remedial working of the material and/or a drainage system for the placement site, based on characteristics of the final in-place dredged materials, or consider alternative approaches such as planting the site with wet-soil adapted species, such as silver maple and cottonwood, to assist in dehydration and consolidation of the site prior to planting with mast trees (reference 6).

A P P E N D I X A

POST-CONSTRUCTION EVALUATION PLAN

TABLE A-1

Brown's Lake Rehabilitation and Enhancement Project
Post-Construction Evaluation Plan [1/]

Enhancement Potential

Goal	Objective	Alternative	Enhancement Feature	Unit	Year 0 (1991) Without Alternative	Year 0 With Alternative (As-Built)	Year 6 With Alternative	Year 50 Target With Alternative [2/]	Feature Measurement	Annual Field Observations by Sit Manager
Enhance Aquatic Habitat	Retard the Loss of Fish and Wildlife Aquatic Habitat by Reducing Sedimen-tation in Upper and Lower Brown's Lakes.	Basic development	Deflection levee	ac-ft of annual sediment reduction	0		11.4	20	Evaluate data per Note[5/.] Perform hydrographic soundings of transects	Observe by pole soundings or depth gauges.
	Improve Water Quality for Upper and Lower Brown's Lakes by Decreasing Suspended Sediment Concentrations and Increasing Winter DO Concentrations.	Basic development	Water control structure and inlet channel improvement	mg/l suspended solids	300		≤ 50	50	Evaluate Water Quality per Note [3/]	Observe water clarit differences between blocked river flows and lake water
				mg/l DO	≤5	≥ 5	≥ 5	5	Evaluate Water Quality per Note [3/]	Observe effects of low DO (fish kills)
				~~cubic feet (cfs) of desired water inflow~~				35~~0~~	Positive impacts of project on water quality have been documented through measurement of DO and suspended solids. Flow will not be monitored.	~~Observe effects of opening and closing gates~~

TABLE A-1 (Continued)

Brown's Lake Rehabilitation and Enhancement Project
Post-Construction Evaluation Plan [1/]

Enhancement Potential

Goal	Objective	Alternative	Enhancement Feature	Unit	Year 0 (1991) Without Alternative	Year 0 With Alternative (As-Built)	Year 6 With Alternative	Year 50 Target With Alternative [2/]	Feature Measurement	Annual Field Observations by Sit Manager
Enhance Aquatic Habitat (Continued)	Increase fish habitat in Upper and Lower Brown's Lakes and increase fish diversity by pro-viding varied water depths	Basic development	Dredging	ac-ft of additional lake volume	0	240	190	~~8~~ TBD	Evaluate data per Note [5/]	Observe/record fish changes and observe by pole soundings o depth gauges sedimentation in excavated channel
	Increase habitat available for wintering fish by providing deeper areas			number of deep holes (D>6'-8')	0	5	5	5	Evaluate data per Note [5/]	
Enhance Wetland Habitat	Increase bottomland hardwood diversity by increasing selected terrestrial elevations and reducing frequency of flooding for such hardwoods.	Basic development	Mast tree plantings on dredged material placement site	acres of mast trees	0			~~35~~	Evaluate data per Note [7/]	Observe/record planted mast tree survivability

TABLE A-1 (Cont'd)

Brown's Lake Rehabilitation and Enhancement Project

1/ See plate 3 of this report for active monitoring sites.

2/ Year 50 Target with Alternative are shown as underlined for revised targets and strike outs if deleted from the monitoring program.

3/ Corps/USFWS/LTRM Water Quality Stations	Remarks
W-M545.8 F	Corps site
W-M545.5 B	USFWS/LTRM site
W-M545.5 C	Corps site
W-M544.7 F	Corps winter only site
W-M544.6 F	Corps winter only site
W-M544.1 D	Corps winter only site
W-M544.2 C	Corps site
Corps Suspended Sediment Station	
W-M546.0A	Smith's Creek

4/ IADNR Fish Stations
F-M545.5 C
F-M545.4 B
F-M545.1 J
F-M544.3 C

5/ Sedimentation Transects (See Table A-2)

6/ USFWS/LTRM Vegetation Transect	
V-M545.0 B	Discontinued

7/ Corps Vegetation Transects	
V-M545.8 H	Discontinued
V-M545.5 H	

TABLE A-2

Brown's Lake Rehabilitation and Enhancement Project
Sedimentation Transect Project Objectives Evaluation

Transect	Project Objectives to Be Evaluated		
	Retard the Loss of Fish and Wildlife Aquatic Habitat by Reducing Sedimentation in Upper and Lower Brown's Lakes	Increase Fish Habitat in Upper and Lower Brown's Lakes and Increase Fish Diversity by Providing Varied Water Depths [3/]	Increase Habitat Available for Wintering Fish by Providing Deeper Areas [3/]
Corps			
S-M545.8H (Upper Brown's Lake)	X		
S-M545.7H (Upper Brown's Lake)	X [1/]	[4/]	
S-M545.3H (Upper Brown's Lake)	X [1/]	X	
Profile No. 1 (Upper Brown's Lake)		X	
Profile No. 2 (Upper Brown's Lake)		X	
Deep Hole A1 (Upper Brown's Lake)			X
Deep Hole A2 (Upper Brown's Lake)			X
S-M544.6H (Lower Brown's Lake)	[2/]	X	
S-M544.3H (Lower Brown's Lake)	X [1/]	X	
S-M544.1E (Lower Brown's Lake)	[2/]	X	
Profile No. 3 (Lower Brown's Lake)		X	
Profile No. 4 (Lower Brown's Lake)		X	
Profile No. 5 (Lower Brown's Lake)		X	
Profile No. 6 (Lower Brown's Lake)		X	
Profile No. 7 (Lower Brown's Lake)		X	
Profile No. 8 (Lower Brown's Lake)		X	
Deep Hole B1 (Lower Brown's Lake)			X
Deep Hole B2 (Lower Brown's Lake)			X
Deep Hole C1 (Lower Brown's Lake)			X
Deep Hole C2 (Lower Brown's Lake)			X
Deep Hole D1 (Lower Brown's Lake)			X
Deep Hole D2 (Lower Brown's Lake)			X
Deep Hole E1 (Lower Brown's Lake)			X
Deep Hole E2 (Lower Brown's Lake)			X
S-M545.9H (Access Channel)		[2/]	
S-M546.3H (Inlet Channel)		X	
USFWS			
S-M545.5A (Upper Brown's Lake)	X	X	
S-M545.4 C (Upper Brown's Lake)	X	X	
S-M544.2C (Lower Brown's Lake)	X	X	
S-M544.1D (Lainesville Slough)			
IADNR			
S-M545.8E (Upper Brown's Lake)	X		
S-M545.6B (Upper Brown's Lake)	X		
S-M544.9E (Lower Brown's Lake)	X		
S-M 545.0C (Upper Brown's Lake)	[2/]		

[1/] Does not include dredge cut.
[2/] Insufficient or questionable data.
[3/] Dredged channel only.
[4/] Because the area of the dredge cut in Corps transect S-M 545.7H was so much greater than the remaining transects (due to a wider bottom width), it was not used to determine the acre-feet of additional lake volume.

A P P E N D I X B

MONITORING AND PERFORMANCE EVALUATION MATRIX
AND
RESOURCE MONITORING AND DATA COLLECTION SUMMARY

TABLE B-1

Brown's Lake Rehabilitation & Enhancement Project
Monitoring and Performance Evaluation Matrix

Project Phase	Type of Activity	Purpose	Responsible Agency	Implementing Agency	Funding Source	Implementation Instructions
Pre-Project	Sedimentation Problem Analysis	System-wide problem definition. Evaluates planning assumptions.	USGS	USGS (EMTC)	LTRMP [1/]	--
	Pre-Project Monitoring	Identifies and defines problems at HREP site. Establishes need of proposed project features.	USFWS	USFWS	USFWS	--
	Baseline Monitoring	Establishes baselines for performance evaluation.	Corps	Corps	HREP [2/]	See Table B-2
Design	Data Collection for Design	Includes quantification of project objectives, design of project, and development of performance evaluation plan.	Corps	Corps	HREP	See Table B-2
Construction	Construction Monitoring	Assesses construction impacts; assures permit conditions are met.	Corps	Corps	HREP	See State Section 401 Stipulations
Post-Construction	Performance Evaluation Monitoring	Determines success of project as related to objectives.	Corps (quantitative) Sponsor (field observation)	Corps USFWS	HREP	See Table B-2
	Analysis of Biological Responses to Projects	Evaluates predictions and assumptions of habitat unit analysis. Studies beyond scope of performance evaluation, or if projects do not have desired biological results.	Corps	USGS (EMTC)	HREP	--

[1/] Long-Term Resource Monitoring Program is a component of the UMRS-EMP.
[2/] Habitat Rehabilitation and Enhancement Projects

TABLE B-2

Brown's Lake Rehabilitation & Enhancement Project
Resource Monitoring and Data Collection Summary [1/]

Type Measurement	Water Quality Data						Engineering Data			Natural Resource Data			Sampling Agency	Remark
	Pre-Project Phase		Design Phase		Post-Const. Phase		Pre-Project Phase	Design Phase	Post-Const. Phase	Pre-Project Phase	Design Phase	Post-Const. Phase		
	Apr-Sep	Oct-Mar	Apr-Sep	Oct-Mar	Apr-Sep	Oct-Mar								
NT MEASUREMENTS														
er Quality Stations [1/, 2/, 3/]													Corps/USFWS/ LTRM	
rbidity						*								
cchi Disk Transparency						*								
spended Solids					*	*								Corps o
ssolved Oxygen					*	*								
ecific Conductance					*	*								
ater Temperature					*	*								
					*	*								
tal Alkalinity					*	*M								Corps o
lorophyll					*	*								Corps o
locity					*	*								
ater Depth					*	*								
rcent Ice Cover						*								USFW LTRM o
Depth						*								
rcent Snow Cover						*								USFW LTRM o
ow Depth						*								
bstrate Hardness					*	*								USFW LTRM o
ind Direction					*	*								Corps o
ind Velocity					*	*								Corps o
ave Height					*	*								Corps o
r Temperature					*	*								Corps o
rcent Cloud Cover					*	*								Corps o

TABLE B-2 (Continued)

Type Measurement	Water Quality Data						Engineering Data			Natural Resource Data			Sampling Agency	Remarks
	Pre-Project Phase		Design Phase		Post-Const. Phase		Pre-Project Phase	Design Phase	Post-Const. Phase	Pre-Project Phase	Design Phase	Post-Const. Phase		
	Apr-Sep	Oct-Mar	Apr-Sep	Oct-Mar	Apr-Sep	Oct-Mar								
<u>NT MEASUREMENTS</u> nt'd)														
iment Test Stations [3/]													Corps	
pended Solids				1	D	D								
ter Depth					D	D								
charge Measurement					D	D								
ing Stations													Corps	
otechnical Borings - e Construction Drawings								1						
Stations [4/]														
eel Survey ectrofish/Netting dio Telemetry										1 1 -	1 1 1	6M 4M Y	IADNR	
<u>NSECT</u> <u>ASUREMENTS</u>														
imentation Transects [5/, 6/, 7/]													Corps	
drographic Soundings								1	**				Corps/USFWS/ LTRM/IADNR	
etation Transects [8/, 9/]													Corps	
ast Tree Survey												5Y	Corps	

TABLE B-2 (Continued)

Type Measurement	Water Quality Data						Engineering Data			Natural Resource Data			Sampling Agency	Remar
	Pre-Project Phase		Design Phase		Post-Const. Phase		Pre-Project Phase	Design Phase	Post-Const. Phase	Pre-Project Phase	Design Phase	Post-Const. Phase		
	Apr-Sep	Oct-Mar	Apr-Sep	Oct-Mar	Apr-Sep	Oct-Mar								
A MEASUREMENTS														
ping 10/														
rial Photography										1		5Y	Corps	

end

* = Sampling performed every other week at the USFWS/LTRM site. At the Corps sites, sampling was performed monthly from October through March, and every other week from April through September.
** = Every 5 years by the Corps, annually by USFWS/LTRM and IADNR
D = Daily
W = Weekly
M = Monthly
Y = Yearly
nW = n-Week interval
nY = n-Year Interval
3,.... = Number of times data was collected within designated project phase

TABLE B-2 (Continued)

Brown's Lake Rehabilitation and Enhancement Project

1/ See plate 3 of this report for locations of post-construction phase sampling points, transects, and area measurements. See DPR for locations of design phase sampling locations.

2/ Corps/USFWS/LTRM Water Quality Stations	Remarks
W-M545.8 F	Corps site
W-M545.5 B	USFWS/LTRM site
W-M545.5 C	Corps site
W-M544.7 F	Corps winter only site
W-M544.6 F	Corps winter only site
W-M544.1 D	Corps winter only site
W-M544.2 C	Corps site

3/ Corps Suspended Sediment Station	
W-M546.0A	Smith's Creek

4/ IADNR Fish Stations	
F-M545.5 C	
F-M545.4 B	
F-M545.1 J	
F-M544.3 C	

5/ USFWS/LTRM Sedimentation Transects	
S-M544.2 C	DPR Transect E
S-M545.5 A	DPR Transect B
S-M545.4 C	
S-M544.1 D	

6/ IADNR Sedimentation Transects	
S-M545.2 I	IADNR Number 11 - Discontinued
S-M544.9 E	IADNR Number 9
S-M545.0 C	IADNR Number 1
S-M545.6 B	IADNR Number 10
S-M545.8 E	IADNR Number 6

7/ Corps Sedimentation Transects	
S-M545.8 H	DPR Monitoring Range A
S-M545.7 H	DPR Monitoring Range B
S-M545.3 H	DPR Monitoring Range C
Profile No. 1	
Profile No. 2	
Deep Hole A1	
Deep Hole A2	
S-M544.6 H	DPR Monitoring Range N
S-M544.3 H	DPR Monitoring Range D
S-M544.1 E	DPR Monitoring Range E
Profile No. 3	
Profile No. 4	
Profile No. 5	
Profile No. 6	
Profile No. 7	
Profile No. 8	
Deep Hole B1	
Deep Hole B2	
Deep Hole C1	
Deep Hole C2	
Deep Hole D1	
Deep Hole D2	
Deep Hole E1	

S-M545.9 H	DPR Monitoring Range H
S-M546.3 H	DPR Monitoring Range I
S-M545.6 B	DPR Monitoring Range F (Smith's Creek Thalweg) - Discontinued

8/ USFWS/LTRM Vegetation Transect
V-M545.0 B

9/ Corps Vegetation Transects

V-M545.8 H	DPR Transect K
V-M545.5 H	DPR Transect L

10/ Mapping

September 2, 1989, Color Aerial Photography
July 12, 1993, Color Aerial Photography
November 20, 1995, Black and White Aerial Photography

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