APPENDIX 6

ENGINEERING SUMMARY

YAZOO BACKWATER AREA REFORMULATION

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ENGINEERING SUMMARY

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YAZOO BACKWATER AREA REFORMULATION

APPENDIX 6
ENGINEERING SUMMARY

SECTION 1 - GENERAL

AUTHORIZATION

PROJECT AUTHORIZATION

1. The Yazoo Basin Reformulation Study is an evaluation of a remaining unconstructed feature of the authorized Federal flood control project for the Yazoo Basin. The Reformulation Study is divided into four major features and includes a thorough analysis of engineering, economic, and environmental aspects of project alternatives. The Reformulation Study includes the following features: (1) Upper Steele Bayou Project, (2) Upper Yazoo Projects (UYP), (3) Yazoo Backwater Project, and (4) Headwater Tributaries Project. Reports for project features (1) and (2) were completed in 1993 and 1994, respectively. This Engineering Summary discusses and documents the findings of Feature 3--Yazoo Backwater Project. The Headwater Tributaries Project Study has not been completed.

REPORT AUTHORITY

2. The Flood Control Act (FCA) of 1941, dated 18 August 1941 (House Document (HD)/359/77/1), as amended by FCAs of 22 December 1944 and 27 October 1965 (HD/308/88/2), and the Water Resources Development Act of 1986 and 1996, authorized the Yazoo Backwater Project. The FCA of 1941 provided for the extension of a levee along the west bank of the Yazoo River from the Mississippi River levee to Yazoo City, Mississippi. Also included in the authorized plan of 1941 was a structure at Little Sunflower River and a combination structure and pump station at Big Sunflower River, Deer Creek, and Steele Bayou with a total pumping capacity of 14,000 cubic feet per second (cfs).

3. The FCAs of 1944 and 1965 extended the project to include approximately 38 miles of levee on the east bank of the Yazoo River and features for fish and wildlife.

PURPOSE OF REPORT

4. This Engineering Summary documents engineering studies performed on the design, operation, maintenance, and their associated costs for the structural and nonstructural features in the final array of alternatives.

PRIOR STUDIES, REPORTS, AND EXISTING WATER PROJECTS

MISSISSIPPI RIVER LEVEES

5. The Mississippi River Levees project was authorized by the FCA of 15 May 1928, as modified and amended in subsequent Acts of 23 April 1934, 15 June 1936, 18 August 1941, 24 July 1946, and 27 October 1965. The Mississippi River levees prevent inundation of the alluvial valley of the lower Mississippi River which begins at Cape Girardeau, Missouri, and gently slopes to the Gulf of Mexico. The main stem levees protect a number of major cities and towns as well as industrial areas, farmland, and wildlife habitats of woodlands and marshes. The Mississippi River levees protect the alluvial valley against the flooding from the Mississippi River by confining flow to the leveed channel except where it enters natural backwater areas or is diverted purposely into floodway areas.

6. A major Mississippi River flood in 1973 led to the development of the Refined 1973 Mississippi River and Tributaries (MR&T) Project Flood Flowline which enabled levee deficiencies along the main stem levees to be identified. An Environmental Impact Statement (EIS) was prepared in 1976 to address environmental impacts of the work needed to address the identified deficiencies. A reevaluation of the project was completed in 1998 on the remaining work along with a Supplement to the final EIS. This report documented that of the 460.4 miles of levee in the Vicksburg District, 216.8 miles need to be enlarged and raised to grade with placement of approximately 57.4 miles of seepage control measures. Of these amounts, 69.4 miles of levee enlargement and approximately 30 miles of associated seepage control are required in Mississippi generally in the area south of Greenville, Mississippi. This work is ongoing. During high stages on the Mississippi River, seepage enters into the Backwater Area from beneath the Mississippi River levee. Although the Corps cannot prevent the seepage, it is managing it by the construction of relief wells and seepage berms to protect the integrity of the Mississippi River levee.

PRIOR STUDIES AND REPORTS IN THE YAZOO BACKWATER AREA

7. Previous reports and studies that are pertinent to the Yazoo Backwater Project are listed below:

a. Big Sunflower, Little Sunflower, Hushpuckena, and Quiver Rivers, and their Tributaries, and Deer Creek, Steele Bayou, and Bogue Phalia, Mississippi, General Design Memorandum (GDM) No. 1, September 1955. This report proposed a system of channel improvement along these area rivers and tributaries.

b. Annex M to the Mississippi River and Tributaries, Comprehensive Review Report, Big Sunflower River Basin, 16 November 1959. This report recommended that the scope of the existing authorized project for the Big Sunflower River Basin be increased to provide greater channel capacity on Steele Bayou and its tributaries.

c. Big Sunflower, Little Sunflower, Hushpuckena, and Quiver Rivers, and their Tributaries, and Deer Creek, Steele Bayou, and Bogue Phalia, Mississippi, Supplement A (to GDM No. 1), April 1962. This report recommended modifications to project streams as proposed in GDM No. 1.

d. Supplement B (to GDM No. 1), October 1963. Prompted by local interests, this report modified GDM No. 1 to add channel improvement to a reach of Quiver River.

e. Steele Bayou, Main Canal - Riverside Drainage District (Canal No. 9) and Black Bayou, Supplement C (to GDM No. 1), February 1964. This supplement recommended more extensive improvement on Steele Bayou, Main Canal, and Black Bayou than those proposed in GDM No. 1 and modified in Annex M.

f. Muddy Bayou Report (Eagle Lake), December 1969, was prepared in response to requests by the Warren County Board of Supervisors, the Mississippi Game and Fish Commission, and other local interests. As a result of the report, the Yazoo Backwater Project was modified to include the Muddy Bayou Control Structure. The water control structure, approved and completed in 1970 and 1977, respectively, allows manipulation of lake levels between Eagle Lake and Steele Bayou for improvement of water quality and fishery resources in the lake. The structure also provides incidental flood protection for properties along Eagle Lake.

g. Yazoo Basin, Yazoo Backwater Area, Fish and Wildlife Mitigation Alternative Report, dated July 1976, and approved by the Chief of Engineers on 3 December 1976, authorized construction of nine greentree reservoirs and nine slough control structures in the Delta National Forest (DNF). These features as proposed would mitigate the fish and wildlife losses caused by the Yazoo Backwater Project. Five greentree reservoirs, five slough control structures, and one boat ramp have been completed. The others were eliminated due to unsuitable site conditions and problems with existing easement.

h. Steele Bayou Basin, Alternative Formulation, GDM No. 18, August 1976. This report recommended modifying the authorized project to provide additional channel improvements on Steele Bayou and Black Bayou.

i. Yazoo Basin, Yazoo Area Pump Project Report, July 1982, presented a reevaluation of the economic feasibility of the pump stations features of the Yazoo Backwater project. This report recommended installation of a 17,500-cfs pump station at Steele Bayou. In December 1985, the plan changed because budgetary guidance directed by the Work Allowance of 1986 did not provide funds for the 17,500-cfs pump station. Instead, the allowance provided funds for Engineering and Design for a 10,000-cfs capacity pump station to be located approximately 1 mile west of the existing Steele Bayou structure. Several design documents and Technical Reports have been prepared for the alternate pump station. These documents are listed in Table 6-1.

j. Fish and Wildlife Mitigation Report, July 1982, was prepared in conjunction with the reevaluation efforts of the Yazoo Area Pump Project, Yazoo Area, and the Satartia Area Backwater levee projects. This report was used as a basis for determining the modifications that should be made to achieve a balance in the use of the Yazoo Backwater Area's natural resources. The report included the mitigation analyses for the construction and operation of the Yazoo Area and Satartia Area Backwater Levee Projects, including the connection channel, structures, the recommended Yazoo Area Pump Project, and other appurtenances. The Fish and Wildlife Mitigation Report recommended the acquisition of 40,000 acres of woodlands through perpetual easements in the project area.

k. Yazoo Basin, Yazoo Backwater Area, Mississippi, Mississippi Mitigation Alternative Report, October 1989, presented a proposal for mitigation implementation to compensate for terrestrial wildlife losses incurred during construction and operation of the Yazoo Area and Satartia Area levees. This report recommended the purchase of 8,400 acres of frequently flooded cleared farmland to be reforested for terrestrial wildlife habitat through fee title acquisition. In 1990, the U.S. Army Corps of Engineers, Vicksburg District, purchased a tract of land containing 8,800 acres--this property is referred to as the Lake George Property. It is located in Yazoo County between the DNF and the Panther Swamp National Wildlife Refuge.

TABLE 6-1
STATUS OF REPORTS

Title	Completion Date
Vicksburg District	
Pump and Driver Feasibility Study	May 84
Design Memorandum No. 18, Site Selection	Jan 85
Channel Work Report	Feb 85
General Design Memorandum No. 20	Apr 85
Supplement No. 1 to General Design Memorandum No. 20	Jun 87
Design Memorandum No. 19, Pump and Prime Mover	Nov 88
U.S. Army Engineer Research and Development Center	
Steele Bayou Drainage Structure	17 Jan 69
Little Sunflower River Drainage Structure	28 Jul 75
Collins Creek Drainage Structure	16 Aug 76
Satartia Area Levee	22 Nov 76
Connecting Channel, Steele Bayou to Big Sunflower River	20 Jun 78
Yazoo Backwater Levee, Mississippi River Levee to LAC Levee	20 Jun 78
Muddy Bayou Control Structure	18 Jul 78
Technical Report HL-88-2, Pumping Station Inflow - Discharge Hydraulics, Generalized Pump Sump Research Study	Feb 88
Greentree Reservoirs	Dec 91
Technical Report 4-87-1, U.S. Army Corps Wetland Delineation Manual	

l. Upper Steele Bayou Reformulation Report, December 1992. Recommendations were made in this report for additional flood control improvements in the upper Steele Bayou Basin for Black Bayou, Main Canal, Ditch 6, and Robertshaw Ditch.

m. Memorandum for President, Mississippi River Commission, 2 December 1993, subject: FC/MR&T, Yazoo Basin, Mississippi, Big Sunflower, Bogue Phalia, Little Sunflower, Holly Bluff Cutoff, Bogue Phalia Cutoff, and Dowling Bayou Channel Maintenance Project. This memorandum outlined the plan for preparing the Supplement D (to GDM No. 1) report.

n. Flood Control, Mississippi River and Tributaries, Yazoo Basin, Big Sunflower River Basin Channel Maintenance, November 1994, Supplement D to GDM No. 1. Supplement D was approved by Mississippi River Commission 1st endorsement, 1 February 1995, subject to resolution of comments.

o. Flood Control, Mississippi River and Tributaries, Mississippi River Mainline Levees Enlargement and Seepage Control, July 1998

p. Flood Control, Mississippi River and Tributaries, Yazoo Basin, Yazoo Backwater Area, Draft Reformulation Report and SEIS, September 2000.

EXISTING WATER PROJECTS

8. There are five existing projects within the subarea of the Yazoo Backwater—Yazoo area, Satartia area, Satartia Extension area, Rocky Bayou, and Carter area (see Plate 6-1). Although these projects are separate elements of the Yazoo Basin Backwater Project, they are part of the flood control measures authorized in 1941, 1944, 1965, and 1986. A brief description of the authorized improvements for these existing projects follows:

a. <u>Yazoo Area (926,000 acres)</u>. This project area is located between the east bank Mississippi River levee and the Will M. Whittington Auxiliary Channel. The area extends north from Vicksburg, Mississippi--a distance of approximately 60 miles to Belzoni, Mississippi. Authorized work in the Yazoo Area consists of a levee system 27.0 miles long, extending from the end of the east bank Mississippi River levee, generally along the west bank of the Yazoo River to a connection with the west levee of the Will M. Whittington Auxiliary Channel. This levee system includes two structures, one at Steele Bayou with a design capacity of 19,000 cfs and one at Little Sunflower River with a design capacity of 8,000 cfs, and a channel between the Sunflower River and Steele Bayou to connect the upper and lower ponding areas within the Yazoo Area. The levee system is completed to an interim grade of 107.0 feet, National Geodetic Vertical Datum (NGVD). The work also includes 15.2 miles of channel work, two major structures, and two river closures. This work is complete and now operational. A list on the status of reports located in the vicinity of the Yazoo Backwater Area can be found in Table 6-1.

b. Satartia Area (28,800 acres). The Satartia area is located south of Satartia, Mississippi, between the Yazoo River on the west and the hill line on the east. Authorized work in the area consists of 20 miles of levee and one major structure. Protection of this area was completed in November 1976.

c. Satartia Extension Area (3,200 acres). This area is located south of the Satartia area, and protection includes 8.2 miles of levee and floodgate for drainage. Currently, no flood control features are authorized for the Satartia Extension Project.

d. Rocky Bayou (14,080 acres). The Rocky Bayou area is located south of the city of Yazoo City, Mississippi, between the Yazoo River on the west and the hill line on the east. Authorized improvements consist of about 19 miles of levee and one major structure. Levee Item 1, which is the reach along O'Neal Creek, was separated into two construction contracts--Items 1A and 1B. Item 1A, a 3.0-mile levee item, was awarded 25 March 1985 and Item 1B, a 0.7-mile reach and a small structure, was awarded on 12 November 1986 and both are complete.

e. Carter Area (102,400 acres). The Carter Area is bounded by the Yazoo River on the east and the Will M. Whittington Auxiliary Channel on the west. The area begins upstream of the confluence of the Big Sunflower and Yazoo Rivers and extends northward to the latitude of Yazoo City. Improvements authorized for the Carter area consist of approximately 29 miles of levee and one major structure. No work has been initiated on this project.

PROJECT LOCATION

9. This appendix is concerned specifically with the Yazoo Area of the Yazoo Backwater Project. The area, as depicted on Plate 6-1, lies in west-central Mississippi between the Mississippi River east bank levee and the west bank levee of the Will M. Whittington channel on the east. The triangular-shape area extends northward approximately 60 miles to the latitude of Hollandale and Belzoni, Mississippi, and comprises approximately 926,000 acres. Big Sunflower and Little Sunflower Rivers, Deer Creek, and Steele Bayou flow through the project area. Interior drainage of the area is provided by structures at Little Sunflower River (upper ponding area) and Steele Bayou (lower ponding area).

ALTERNATIVES

GENERAL

10. There were many alternative plans considered during the evaluation of the Yazoo Backwater Reformulation Study. The array of alternatives are discussed in detail in the Main Report to this appendix. A brief synopsis is given in the following paragraphs.

PAST ALTERNATIVES

11. The Yazoo Backwater Reformulation Study began by analyzing structural flood control features consisting of five pump size alternatives, a levee alternative, and local protection projects for five communities. The five pump alternatives that were originally analyzed in the 1982 Reevaluation Report were reanalyzed. The 10,500-, 14,000-, 17,500-, 21,000-, and 24,500-cfs pump stations were reanalyzed, and their location was to be adjacent to the Steele Bayou structure.

12. A levee alternative was developed to basically open the Big Sunflower River Basin back to Mississippi River Backwater flooding. The Yazoo Backwater levee would be realigned along the Big Sunflower and Little Sunflower Rivers to a point near Highway 49 West, where it would tie back into natural ground as shown on Plate 6-5. The levee alignment was designed to skirt the wildlife management forested areas along the Big and Little Sunflower Rivers such that minimal damage to the environment would occur. Approximately 61 structures would be required to protect the landside areas of the levee and some lengthy landside drainage ditches would also be required. The connecting channel between the Big Sunflower Basin and the Steele Bayou Basin would be closed off, thereby establishing a drainage divide between the two basins and the closure at Big Sunflower River opened to pass flows and protected to serve as a way to maintain low water levels. The Little Sunflower structure would be modified to maintain a minimum ponding area for waterfowl and aquatic habitat.

13. The economic analysis performed on the initial array of alternatives showed the 14,000-cfs pump to be the National Economic Development plan. This plan had a year-round pump-on/pump-off elevation of 80.0 feet, NGVD. Shortly after reviewing the initial array economic analysis, the Vicksburg District decided to seek additional input from outside agencies and groups. The District conducted several public involvement workshops to gather input on additional plans that needed to be evaluated, which led to a second array of alternatives. After evaluating the second array of alternatives, the Mississippi Levee Board organized a consensus group which was comprised of interested Federal agencies, state agencies, wildlife interests, environmental agencies, and other groups. After the workshops and consensus group meetings, a large array of alternatives was considered. Alternatives resulting from these meetings (Plate 6-6) included not only structural flood control measures, but also the combination of structural and nonstructural flood control. Nonstructural flood control measures include reforestation by buying easements on open lands, nontraditional operation of the pump station to include various ponding levels and pump-on/off operation, and the purchasing of lands below the 100-year frequency flood level.

FINAL ARRAY

14. The alternatives carried into the final array are described below, and all elevations are based on the elevation at the Steele Bayou structure. The operation of the Little Sunflower structure will not change with any of the alternatives.

[NOTE: Blocking Out. The reforestation/conservation features easement acquisition limits for the Yazoo Backwater Reformulation Study were established based upon flood frequency stage elevations. However, based upon sound real estate practices and guidance as found in USACE real estate regulations, blocking out will be utilized to address such items as access, the extent of severance damages, and avoidance of an uneconomic remainder. The blocking out will result in the acquisition of some lands outside a given flood event or elevation. The Vicksburg District Real Estate Division has vast experience in the acquisition of lands based upon elevation and typically uses a blocking factor of 30 percent. This figure was utilized for calculating the acreage to be acquired for the reforestation/conservation features easement in connection with the Yazoo Backwater Reformulation Study. The symbol "(b)" indicates a blocked acreage in the alternative descriptions listed below. Acreages are rounded to the nearest 100 acres and are based on 2005 land use.

Slope. Throughout the descriptions of the alternatives, the elevation at the Steele Bayou structure will be referenced regarding the acquisition of perpetual/flowage easements. These references do not imply an absolute elevation, but imply an elevation that rises as you move upstream from the structure. The rate of the rise or the slope of the surface can be found in Appendix 6 (Engineering), and it is based upon a hydrologic event, such as the 1-year frequency flood. The use of the elevation at the Steele Bayou structure establishes a standard point of reference for comparison of the alternatives.]

a. No Action.

Alternative 1. This is the no-action alternative. This action would not eliminate potential flood damages. Residential and nonresidential structures would continue to be affected by flooding, which economically impacts the area. Local, state, and Federal governments would continue to pay for flood-fighting efforts and repair of urban and rural roads, bridges, and other infrastructure. There will be no project impacts with the no-action alternative.

b. Nonstructural alternatives. The flowage easements and income assurance features of the nonstructural alternatives would require additional authorization from Congress to implement

(1) Alternative 2. This alternative contains nonstructural and operational features which influence land-use patterns and activities. There is a no-pump station feature in Alternative 2. To be consistent with alternatives that include a pump station (i.e., some level of benefit across the study area), the nonstructural easements would provide flood damage reduction through reforestation or some degree of compensation across the entire study area. Reforestation of the 2-year flood plain (elevation 91.0 feet, NGVD, at the Steele Bayou structure) would provide flood damage reduction and remove impacts of agricultural practices on these lands. Compensation would be provided above elevation 91.0 feet, NGVD, at the Steele Bayou structure. Features include:

(a) Nonstructural.

1. Acquisition and reforestation/conservation features on up to 124,400 (b) acres of agricultural lands through perpetual easements from willing sellers only. Approximately 95,700 acres of cleared land are potentially available below elevation 91.0 feet, NGVD (2-year flood plain at the Steele Bayou structure), and the remaining acreage needed to reach up to the 124,400 acres would be acquired above elevation 91.0 feet, NGVD (2-year flood plain at the Steele Bayou structure). Up to10 percent of an acquired property could be in conservation features other than reforestation. Conservation features are practices implemented and maintained solely for wildlife management purposes. Conservation features include, but are not necessarily limited to, (a) water management impoundments for waterfowl, wading birds, or other wildlife purposes; (b) food plots; (c) permanent openings maintained in early successional stages; (d) access trails, roads, and firebreaks; or (e) facilities and buildings necessary for property management (constructed above the 100-year flood plain elevation). While the Vicksburg District will provide the pipe for the waterfowl impoundment, landowners would be responsible for the cost of implementing and maintaining the waterfowl impoundment and any other conservation practices. Landowners also would be responsible for maintaining ditches used for agricultural operations on remaining portions of their properties or for agricultural operations on other properties dependent on those ditches. The Vicksburg District will have the right to enforce the terms of the recorded conservation easements.

2. Acquisition of up to 197,600 acres of agricultural lands between elevations 91.0 and 100.3 feet, NGVD, at the Steele Bayou structure, through flowage easements. No agricultural intensification or other development would be allowed under the easement. Easements would be perpetual and from willing sellers only.

(b) Operational. Operation of the Steele Bayou structure to maintain water elevations between 70.0 and 73.0 feet, NGVD, during low-water periods. No additional real estate is required for this feature.

(2) Alternative 2A. This alternative contains nonstructural features which influence land-use patterns and activities. There is a no-pump station feature in this alternative. Features include:

(a) Nonstructural.

1. Acquisition and reforestation/conservation features on up to 81,400 (b) acres of agricultural lands through perpetual easements from willing sellers only. Approximately 62,600 acres of cleared land are potentially available below elevation 88.5 feet, NGVD, at the Steele Bayou structure, and the remaining acreage needed to reach up to the 81,400 acres would be acquired between elevations 88.5 and 91.0 feet, NGVD (2-year flood plain at the Steele Bayou structure). Up to 10 percent of an acquired property could be in conservation features other than reforestation. Conservation features are practices implemented and maintained solely for wildlife management purposes. Conservation features include, but are not necessarily limited to, (1) water management impoundments for waterfowl, wading birds, or other wildlife purposes; (2) food plots; (3) permanent openings maintained in early successional stages; (4) access trails, roads, and firebreaks; or (5) facilities and buildings necessary for property management (constructed above the 100-year flood plain elevation). While the Vicksburg District will provide the pipe for the waterfowl impoundment, landowners would be responsible for the cost of implementing and maintaining the waterfowl impoundment and any other conservation practices. Landowners also would be responsible for maintaining ditches used for agricultural operations on remaining portions of their properties or for agricultural operations on other properties dependent on those ditches. The Vicksburg District will have the right to enforce the terms of the recorded conservation easements.

2. Flood proofing 1,363 structures in the 100-year flood plain.

3. Implementing an income assurance program that would be established for 235,000 acres of cropland above elevation 88.5 feet, NGVD.

(3) Alternative 2B. This alternative is a nonstructural alternative with a structural component. There is a no-pump station with this alternative. Features include:

(a) Nonstructural.

1. Acquisition and reforestation/conservation features on up to 26,400 (b) acres of agricultural lands through perpetual easements from willing sellers only. As a result of design and alignment of the 14 ring levees (see below), approximately 20,300 acres of cleared land are

potentially available below elevation 91.0 feet, NGVD (2-year flood plain at the Steele Bayou structure), and outside the ring-leveed areas. Up to 10 percent of an acquired property could be in conservation features other than reforestation. Conservation features are practices implemented and maintained solely for wildlife management purposes. Conservation features include, but are not necessarily limited to, (1) water management impoundments for waterfowl, wading birds, or other wildlife purposes; (2) food plots; (3) permanent openings maintained in early successional stages; (4) access trails, roads, and firebreaks; or (5) facilities and buildings necessary for property management (constructed above the 100-year flood plain elevation). While the Vicksburg District will provide the pipe for the waterfowl impoundment, landowners would be responsible for the cost of implementing and maintaining the waterfowl impoundment and any other conservation practices. Landowners also would be responsible for maintaining ditches used for agricultural operations on remaining portions of their properties or for agricultural operations on other properties dependent on those ditches.

2. Relocate the remaining 194 structures not protected by the ring levees.

(b) Structural. Fourteen ring levees would be required with this alternative to provide 100-year protection to 88 percent of the structures in the Yazoo Backwater Study Area. Ring levees would require an accompanying infrastructure to evacuate precipitation from inside the ringed area and provide for operation of septic systems in saturated grounds. This would require water control structures, interior channels, road crossings, wastewater facilities, pumps, etc., in addition to the levees.

(4) Alternative 2C. This alternative is a nonstructural alternative that influences land-use patterns and activities. This alternative is based on the Shabman Report. There is a no-pump station feature in this alternative. Features include:

Nonstructural.

1. Acquisition and reforestation/conservation features on up to 114,400 (b) acres of agricultural lands through perpetual easements from willing sellers only. Approximately 95,700 acres of cleared land are potentially available below elevation 91.0 feet, NGVD (2-year flood plain at the Steele Bayou structure), and the remaining acreage needed to reach up to the 114,400 acres would be acquired above elevation 91.0 feet, NGVD (2-year flood plain at the Steele Bayou structure). Up to 10 percent of an acquired property could be in conservation features other than reforestation. Conservation features are practices implemented and maintained solely for wildlife management purposes. Conservation features include, but are not necessarily limited to, (1) water management impoundments for waterfowl, wading birds, or other wildlife purposes; (2) food plots; (3) permanent openings maintained in early successional stages; (4) access trails, roads, and firebreaks; or (5) facilities and buildings necessary for property management (constructed above the 100-year flood plain elevation). While the Vicksburg District will provide the pipe for the waterfowl impoundment, landowners would be

responsible for the cost of implementing and maintaining the waterfowl impoundment and any other conservation practices. Landowners also would be responsible for maintaining ditches used for agricultural operations on remaining portions of their properties or for agricultural operations on other properties dependent on those ditches.

2. Implementing an income assurance program on 201,900 acres of cropland, which is all remaining cropland in the 100-year flood plain.

3. Relocation of all 1,576 structures damaged by a 100-year flood event.

c. Structural alternative. As part of the structural feature, pump-on elevations were selected to meet project purpose.

(1) Alternative 3. Features include:

(a) Structural. A 14,000-cfs pump station with a pumping elevation of 80.0 feet, NGVD, between 1 March and 31 October. Pumping elevation of 85.0 feet, NGVD, between 1 November and 28 February. This would allow retention of more water during the winter waterfowl season.

(b) Operational. Operation of the Steele Bayou structure to maintain water elevations between 70.0 and 73.0 feet, NGVD, during low-water periods. No additional real estate is required for this feature.

d. Combined structural and nonstructural alternatives. As part of the structural feature, pump-on elevations were selected to meet project purpose.

(1) Alternative 4. Features include:

(a) Nonstructural. Acquisition and reforestation/conservation features on up to 37,200 (b) acres of agricultural lands through perpetual easements from willing sellers only. Approximately 28,600 acres of cleared land are potentially available below elevation 85.0 feet, NGVD, at the Steele Bayou structure, and the remaining acreage needed to reach up to the 37,200 acres would be acquired between elevations 85.0 and 91.0 feet, NGVD (2-year flood plain at the Steele Bayou structure). Up to 10 percent of an acquired property could be in conservation features other than reforestation. Conservation features are practices implemented and maintained solely for wildlife management purposes. Conservation features include, but are not necessarily limited to (1) water management impoundments for waterfowl, wading birds, or other wildlife purposes; (2) food plots; (3) permanent openings maintained in early successional stages; (4) access trails, roads, and firebreaks; or (5) facilities and buildings necessary for property management (constructed above the 100-year flood plain elevation). While the

Vicksburg District will provide the pipe for the waterfowl impoundment, landowners would be responsible for the cost of implementing and maintaining the waterfowl impoundment and any other conservation practices. Landowners also would be responsible for maintaining ditches used for agricultural operations on remaining portions of their properties or for agricultural operations on other properties dependent on those ditches.

(b) Structural. A 14,000-cfs pump station with a year-round pumping elevation of 85.0 feet, NGVD.

(c) Operational. Operation of the Steele Bayou structure to maintain water elevations between 70.0 and 73.0 feet, NGVD, during low-water periods. No additional real estate is required for this feature.

(2) Alternative 5. Features include:

(a) Nonstructural. Acquisition and reforestation/conservation features on up to 55,600 (b) acres of agricultural lands through perpetual easements from willing sellers only. Approximately 42,800 acres of cleared land are potentially available below elevation 87.0 feet, NGVD (1-year flood plain at the Steele Bayou structure), and the remaining acreage needed to reach up to the 55,600 acres would be acquired between elevations 87.0 and 91.0 feet, NGVD (2-year flood plain at the Steele Bayou structure). Up to 10 percent of an acquired property could be in conservation features other than reforestation. Conservation features are practices implemented and maintained solely for wildlife management purposes. Conservation features include, but are not necessarily limited to (1) water management impoundments for waterfowl, wading birds, or other wildlife purposes; (2) food plots; (3) permanent openings maintained in early successional stages; (4) access trails, roads, and firebreaks; or (5) facilities and buildings necessary for property management (constructed above the 100-year flood plain elevation). While the Vicksburg District will provide the pipe for the waterfowl impoundment, landowners would be responsible for the cost of implementing and maintaining the waterfowl impoundment and any other conservation practices. Landowners also would be responsible for maintaining ditches used for agricultural operations on remaining portions of their properties or for agricultural operations on other properties dependent on those ditches.

(b) Structural. A 14,000-cfs pump station with a year-round pumping elevation of 87.0 feet, NGVD.

(c) Operational. Operation of the Steele Bayou structure to maintain water elevations between 70.0 and 73.0 feet, NGVD, during low-water periods. No additional real estate is required for this feature.

(3) Alternative 6. Features include:

(a) Nonstructural. Acquisition and reforestation/conservation features on up to 81,400 (b) acres of agricultural lands through perpetual easements from willing sellers only. Approximately 62,600 acres of cleared land are potentially available below elevation 88.5 feet, NGVD, at the Steele Bayou structure, and the remaining acreage needed to reach up to the 81,400 acres would be acquired between elevations 88.5 and 91.0 feet, NGVD (2-year flood plain at the Steele Bayou structure). Up to 10 percent of an acquired property could be in conservation features other than reforestation. Conservation features are practices implemented and maintained solely for wildlife management purposes. Conservation features include, but are not necessarily limited to (1) water management impoundments for waterfowl, wading birds, or other wildlife purposes; (2) food plots; (3) permanent openings maintained in early successional stages; (4) access trails, roads, and firebreaks; or (5) facilities and buildings necessary for property management (constructed above the 100-year flood plain elevation). While the Vicksburg District will provide the pipe for the waterfowl impoundment, landowners would be responsible for the cost of implementing and maintaining the waterfowl impoundment and any other conservation practices. Landowners also would be responsible for maintaining ditches used for agricultural operations on remaining portions of their properties or for agricultural operations on other properties dependent on those ditches.

(b) Structural. A 14,000-cfs pump station with a year-round pumping elevation of 88.5 feet, NGVD.

(c) Operational.

1. Operation of the Steele Bayou structure to maintain water elevations between 70.0 and 73.0 feet, NGVD, during low-water periods. No additional real estate is required for this feature.

2. Reintroduce flows from the Mississippi River up to a maximum elevation of 87.0 feet, NGVD (1-year frequency annual flood event), by leaving the Steele Bayou structure open.

(4) Alternative 7. Features include:

(a) Nonstructural.

1. Acquisition and reforestation/conservation features on up to 124,400 (b) acres of agricultural lands through perpetual easements from willing sellers only. Approximately 95,700 acres of cleared land are potentially available below elevation 91.0 feet, NGVD (2-year flood plain at the Steele Bayou structure), and the remaining acreage needed to reach up to the

124,400 acres would be acquired above elevation 91.0 feet, NGVD (2-year flood plain at the Steele Bayou structure). Up to 10 percent of an acquired property could be in conservation features other than reforestation. Conservation features are practices implemented and maintained solely for wildlife management purposes. Conservation features include, but are not necessarily limited to, (a) water management impoundments for waterfowl, wading birds, or other wildlife purposes; (b) food plots; (c) permanent openings maintained in early successional stages; (d) access trails, roads, and firebreaks; or (e) facilities and buildings necessary for property management (constructed above the 100-year flood plain elevation). While the Vicksburg District will provide the pipe for the waterfowl impoundment, landowners would be responsible for the cost of implementing and maintaining the waterfowl impoundment and any other conservation practices. Landowners also would be responsible for maintaining ditches used for agricultural operations on remaining portions of their properties or for agricultural operations on other properties dependent on those ditches.

2. Conservation easements on 81,800 acres of forested lands below elevation 91.0 feet, NGVD. Easements would be perpetual and from willing sellers only.

(b) Structural. A 14,000-cfs pump station with a year-round pumping elevation of 91.0 feet, NGVD.

(c) Operational.

1. Operation of the Steele Bayou structure to maintain water elevations between 70.0 and 73.0 feet, NGVD, during low-water periods. No additional real estate is required for this feature.

2. Reintroduce flows from the Mississippi River up to a maximum elevation of 87.0 feet, NGVD (1-year frequency annual flood event), by leaving the Steele Bayou structure open.

SECTION 2 - HYDROLOGY AND HYDRAULICS

PURPOSE OF HYDROLOGIC ANALYSIS

15. The purpose of these hydrologic analyses is to identify the base hydrologic conditions in the Yazoo Backwater Study Area and estimate the changes to those conditions resulting from various flood control alternatives. Hydrologic information summarized in this appendix has been used in other analyses, including the economic and environmental analyses.

16. This section presents the methodology used in the hydrologic analyses and explains the types of data used in the analysis which support the formulation of the various plans. Engineer Manual (EM) 1110-2-1413 was used as guidance and criteria for the hydrologic analyses.

DESCRIPTION OF YAZOO BACKWATER AREA

17. The Mississippi River Mainline Levees are designed to protect the alluvial valley from extreme flood events by confining flow to the leveed floodway, except where it enters the natural backwater areas or is diverted intentionally into floodway areas. When major floods occur and the carrying capacity of the Mississippi River leveed channel is threatened, additional conveyance through the Birds Point-New Madrid Floodway and relief outlets through the Atchafalaya Basin Floodway, Morganza Floodway, and Bonnet Carre Floodways are utilized as well as the storage capacity of flat lowlands at the junctions of tributaries with the Mississippi River. These tributary areas are commonly referred to as backwater areas. The Yazoo River tributary area is commonly known as the Yazoo Backwater Area. The Yazoo Backwater levees were built to protect a major portion of the Mississippi Delta from major Mississippi River floods and are primarily designed to overtop prior to the MR&T Project Design Flood (PDF) peak such that storage is made available in order to reduce the level of the PDF, thus resulting in a lesser levee grade along the mainline levees.

DRAINAGE AREAS

18. The Yazoo Area has a drainage area comprised of the Little Sunflower River, Big Sunflower River, Deer Creek, and Steele Bayou Basins as shown on Plate 6-2. These streams have a total drainage area of 4,093 square miles of the alluvial valley of the Mississippi River commonly called the Mississippi Delta. The area extends from the confluence of Steele Bayou

with the Yazoo River north to the vicinity of Clarksdale, Mississippi, and has an average width of approximately 30 miles. The Mississippi Delta alluvial plain is generally flat with slopes averaging 0.3 to 0.9 foot per mile. Drainage areas of the four basins can be seen in Table 6-2.

TABLE 6-2
YAZOO AREA DRAINAGE BASIN AREA

Stream	Drainage Area (sq mi)
Big Sunflower River	2,832
Little Sunflower River	309
Deer Creek	200
Steele Bayou	752
Total	4,093

CLIMATE

19. The climate of the Yazoo Area is primarily humid, subtropical with abundant precipitation. The summers are long and hot; the winters are short and mild. The average annual temperature is about 64 degrees F. Average monthly temperatures range from 44 degrees F in January to 82 degrees F in July and extremes range from approximately -10 degrees F to 110 degrees F.

PRECIPITATION

20. The average annual rainfall over the Yazoo Backwater Area is approximately 51 inches. Normal monthly rainfall varies from 5.81 inches in March to 2.58 inches in October. Snowfall occurs about once a year with an average of approximately 2 inches.

INFILTRATION AND RUNOFF

21. When precipitation falls, some is stored as infiltration and some leaves as runoff. The runoff coefficient is the percentage of precipitation that leaves. Runoff coefficients vary from 10 percent in the summer months to 70 percent in the spring and winter months, depending on antecedent conditions, rainfall distribution, and rainfall intensity. Observed data on the Big Sunflower River at Sunflower, Mississippi, show that annual runoffs vary from about 6 to 41 inches and average about 24.5 inches over the drainage area. The runoff coefficients are average values that reflect conditions in the basin. Seasonal variations in runoff coefficients are shown by the monthly generalized values in Table 6-3.

TABLE 6-3
AVERAGE MONTHLY PERCENT RUNOFF

Month	Runoff Coefficients (%)
January	60
February	60
March	70
April	70
May	60
June	40
July	25
August	10
September	10
October	25
November	25
December	60

HISTORY OF FLOOD PROBLEMS

22. Efforts to prevent flood damage were generally organized on a local level. Most of the Mississippi River Alluvial Valley received some level of protection from local levees. In 1927, the basin experienced a flood which overwhelmed the local protections and flooded 4,000 square miles (4 million acres). The flood started in January and continued until July. Over 1 million residents were displaced, and damages exceeded $1 billion. In response to this flood, Congress passed the FCA of 1928 which created the Mississippi River and Tributaries Project (MR&T). The MR&T uses a combination of levees, reservoirs, floodways, and bendway cutoffs to reduce flood damages. The levees prevent overbank flooding, while the reservoir and floodway features reduce flood stages by storing or diverting floodwaters, respectively. The bendway cutoffs shorten the river channel and lower stages all of the time. The bendway cutoffs feature was initiated in 1933 and completed in the 1950s. Initially, the bendway cutoffs lowered flood elevations by approximately 10 feet in Vicksburg, but the Mississippi River bed has aggraded, and much of the benefits have been lost. Plate 6-87 shows the annual peak water surface elevations at Vicksburg from 1872 to 2003, which illustrates how the peak flood elevations dropped during the 1940s and 1950s, but has climbed back up since then. Plate 6-88 shows the annual minimum stage of the Mississippi River at Vicksburg during the same period. Again, the effect of the bendway cutoffs is very evident during the 1940s and 1950s, but the minimum stages have been slowly climbing upward as the Mississippi River bed has aggraded at Vicksburg.

YAZOO BACKWATER AREA
BASE CONDITIONS FLOODING

23. When the Little Sunflower River and Steele Bayou structures are closed because of high stages on the Mississippi River, flooding from ponding of interior drainage is the principal problem in the project study area. However, the interior stages of floodwater is less than it would be if the Yazoo Backwater levees were not in place. Major problems that have resulted from frequent flooding include flood damage to agricultural crops, rural residential property, commercial fisheries, timber management, and public roads and bridges. Major floods have caused undue hardships and economic losses to residents of the area due to flooding of homes, disruption of sanitation facilities, lines of communications, and transportation.

24. Three important factors which affect flood losses in the Yazoo Area are time of year, duration, and frequency of flooding. These factors are important for the agricultural lands, but are just as important to the forested areas, lakes, streams, commercial fisheries, wildlife management areas (WMA), wetland areas, and rural residential areas. Frequent or intermittent floods can occur any time of the year. However, flood records indicate that the majority of floods occur during the months of March through June, which is typically the time land preparation and spring crop planting occurs.

MAJOR BACKWATER FLOOD EVENTS

25. The alluvial lands of the Yazoo Backwater Area have always been subject to flooding by the Mississippi River. From 1897 through 1937, massive floods inundated the region regularly. Then for a 35-year period less severe flooding occurred, causing many to dismiss massive floods as a thing of the past. In 1973, a severe flood again devastated the area. Other destructive floods followed in rapid succession in 1974, 1975, 1979, 1983, 1984, 1991, 1993, and 1997. Hundreds of persons were forced from their homes; crops and buildings were damaged or lost; and wildlife was destroyed.

Flood of 1973

26. Beginning in late September 1972 and continuing through the spring of 1973, unusual meteorological and hydrological events persisted with a relentless variety of phenomena over areas and basins in the Vicksburg District. Severe weather in the form of intense thunderstorms, tornadoes, high winds, and rain was observed at frequent and recurring intervals, inflicting widespread flooding and extensive property damage. Storm cells pelted some areas with measured precipitation which exceeded amounts expected to occur on an average of only once in 100 years. Flooding in the Yazoo Backwater Area was the worst recorded since the 1937 flood. The resulting damage to Delta farmlands and properties was the highest ever experienced because of extensive developments over the past years. The 1973 flood created a body of water 60 miles long (almost as large as the Great Salt Lake), flooded 672,000 acres, and the flood stage lasted almost 9 months. Although the Steele Bayou structure was completed at this time, the Yazoo Backwater levees, Little Sunflower River structure, and connecting channel were not complete during this flood event.

Flood of 1974

27. The 1974 high water season began in November 1973 and continued through May 1974. Continuing rains kept streams above damage levels. The situation was worsened when backwater from the rising Mississippi River was added to headwater runoff. Families in portions of Sharkey, Issaquena, and Warren Counties, many of whom had only recently returned to their homes from the 1973 flood, were once again forced to evacuate. Although the Steele Bayou structure was completed at this time, the Yazoo Backwater levees, Little Sunflower River structure, and connecting channel were not complete during this flood event.

Flood of 1975

28. The third consecutive year of significant flooding throughout the Yazoo Backwater Area began during December 1974. About 90 percent of Sharkey and Issaquena Counties was inundated, and between 700 and 800 families were evacuated from the flooded area. Although the Steele Bayou structure was completed at this time, the Yazoo Backwater levees, Little Sunflower River structure, and connecting channel were not complete during this flood event.

Flood of 1979

29. This flood occurred after the Yazoo Backwater levee, Little Sunflower River structure, and connecting channel were completed and began as the Mississippi River started to rise early in 1979. By 1 March, due to a combination of rainfall in the Yazoo Area and high Mississippi River stages, Steele Bayou began to rise above elevation 80 feet, NGVD. On 4 March, as water reached elevation 82.5 feet, NGVD, the Steele Bayou structure was closed to prevent the Mississippi and Yazoo Rivers from flowing into the Yazoo Area. The Little Sunflower River structure was closed on 5 March as water reached 85.05 feet, NGVD. On both the river and landsides of the Yazoo Backwater levees, the water continued to rise, with the riverside reaching peak elevations of 97.2 and 97.6 feet, NGVD, on 28 April at the Steele Bayou and Little Sunflower River structures, respectively. Due to the large amount of rainfall in the Yazoo area, the land side did not reach its peak of 96.6 feet, NGVD, at the Little Sunflower River structure until 5 May. The Mississippi and Yazoo Rivers, which had begun their fall several days before, fell low enough for the floodgates to be opened at Steele Bayou on 4 May at elevation 96.3 feet, NGVD, and Little Sunflower River on 5 May at elevation 96.6 feet, NGVD. This decline continued until water fell below elevation 80.0 feet, NGVD, at the Steele Bayou structure on 14 June and the Little Sunflower area on 15 June 1979 ending a flood which lasted 104 days and flooded a maximum of 350,400 acres. Without the Yazoo Backwater levees and structures, approximately 400,000 acres would have been flooded. Many homes in the Eagle Lake area were threatened with major flooding as water levels were within inches of the natural ridge protecting the area adjacent to the Muddy Bayou structure. Emergency efforts to raise the ridge by the Corps were successful during this event; however, lake water levels were raised to elevation 90.0 feet, NGVD, with flow through the Muddy Bayou structure in preparations to lessen catastrophic damage which would have occurred had Steele Bayou stages risen another inch or two.

Flood of 1983

30. Flooding in the Yazoo area actually began in December 1982 and peaked at 92.0 feet, NGVD, on 11 January 1983 and fell to below elevation of 80.0 feet, NGVD, on 19 February 1983. The Mississippi River began to rise again due to three storms occurring from late April until May, producing rainfall totals up to 16 inches in the lower Ohio and Mississippi River Basins. The Mississippi River peaked on 7 June at 95.8 feet, NGVD. The flood receded below elevation of 80 feet, NGVD, at the Steele Bayou structure on 30 June 1983.

Flood of 1984

31. The 1984 Yazoo Backwater flood began on 26 March due to a rising Mississippi River and peaked on 29 May at 92.0 feet, NGVD, at the Steele Bayou structure. The flood receded below elevation of 80.0 feet, NGVD, on 16 June. The riverside elevation peaked at 94.5 feet, NGVD, on 25 May at the Steele Bayou structure.

Flood of 1991

32. The 1991 Yazoo Area flood was a headwater flood that caused tremendous flooding in the Upper Yazoo Area. The flooding in the Yazoo Area peaked at elevation 92.46 feet, NGVD, on 6 May at the Steele Bayou structure. The Steele Bayou and Little Sunflower River floodgates never closed during this flood event because the riverside elevation reached a peak of 90.8 feet, NGVD, on 4 May at the Steele Bayou structure.

Flood of 1993

33. The flood of 1993 primarily affected the Upper Mississippi River and its tributaries. High antecedent soil moisture followed by persistent, heavy rainfall from April through September produced extensive flooding in the Upper Mississippi Basin. The effect on the Lower Mississippi River was passed without major flooding. The flood of 1993 demonstrated that during high Upper Mississippi River discharges, flooding on the Upper Mississippi River alone would not produce a major flood event on the Lower Mississippi River. The Yazoo Area began flooding on 13 March and reached an elevation of 91.5 feet, NGVD, on 19 May at the Steele Bayou structure. The flood receded below elevation of 80 feet, NGVD, on 7 June. The Mississippi River rose again on 16 July due to the Upper Mississippi River flooding and reached an elevation of 86.5 feet, NGVD, on 12 August. The flood receded on 2 September.

Flood of 1997

34. The Flood of 1997 began with the Mississippi River reaching the highest flood levels experienced at Arkansas City, Arkansas, and Natchez, Mississippi, since 1973 and the highest at Greenville and Vicksburg, Mississippi, since 1983. The 1997 Mississippi River flood was the fourth highest of record at Natchez and Cairo following close behind 1927, 1937, and 1973. The flooding in the Yazoo Area reached a peak elevation of 93.3 feet, NGVD, on 8 April at the Steele Bayou structure. The riverside reached a peak elevation of 98.2 feet, NGVD, on 23 March at the Steele Bayou structure.

PROJECT FEATURES

35. Completed flood control projects in the Yazoo Area are shown on Plate 6-3. These features include the following:

a. Yazoo Backwater Levee connects to the end of the east bank Mississippi River levee just north of Vicksburg and extends north eastward to the downstream end of the west bank Will M. Whittington Lower Auxiliary Channel Levee. The Yazoo Backwater levee has a net levee grade of elevation 107.0 feet, NGVD. The Yazoo Backwater levee is considered an overtopping section to the mainline levee of the Mississippi River, except for 1,000 feet on each side of the Steele Bayou and Little Sunflower structures. These 27.0 miles of overtopping levee ensure that in case of the MR&T Project Design Flood (PDF), the storage in the Yazoo Backwater Area will be utilized to reduce the risk of overtopping the main stem levee. Construction of the Yazoo Backwater levee was completed 20 June 1978.

b. Steele Bayou structure is located 3,200 feet upstream of the confluence of Steele Bayou and the Yazoo River. The structure consists of four vertical lift gates 30 by 22.5 feet, concrete-paved approach channel, and a stilling basin. The Steele Bayou ponding area is connected by a 200-foot bottom width channel to the Little Sunflower ponding area. Construction of the Steele Bayou structure was begun on 22 July 1965 and completed 17 January 1969.

c. Two connecting channels play a vital part in the operation of the Yazoo Backwater Project. One is a 200-foot bottom width channel between the Big and Little Sunflower Rivers. The Little Sunflower River is enlarged between this connecting channel and the Little Sunflower Structure. The other connecting channel is a 200-foot bottom width channel between the Little Sunflower River and Steele Bayou, which also intercepts Deer Creek flow. The purpose of the channel connecting the Sunflower ponding area with the lower and larger Steele Bayou ponding area is to make the most efficient and economical use of the pumping capacity. Construction of the connecting channel was completed 20 June 1978.

d. Little Sunflower structure is located opposite Yazoo River RM 32.6, approximately 21 miles northeast of Vicksburg. The structure consists of two vertical lift gates 25.0 by 22.5 feet, concrete-paved approach channel, and a stilling basin. Construction of the structure was completed 28 July 1975.

e. Muddy Bayou control structure is located 13 miles northwest of Vicksburg in the Yazoo Backwater Area on Muddy Bayou--a tributary of Steele Bayou--approximately 1,300 feet from its mouth at RM 11.4 of Steele Bayou. The control structure consists of two 20- by 12-foot vertical lift gates--the Muddy Bayou Channel (a cutoff dam adjacent to the structure) and an access road from Mississippi Highway 465. The control structure was completed 18 July 1978, controls all water flowing in or out of Eagle Lake through Muddy Bayou, provides flood protection to the Eagle Lake area during periods of moderately high stages (elevation 95.0 feet, NGVD) on Steele Bayou, and provides the means of regulating pool stages in Eagle Lake.

EXISTING PROJECT OPERATION

36. The primary purpose of the Yazoo Backwater Project is to provide flood protection from the Mississippi and Yazoo Rivers to areas in the Lower Mississippi Delta. During periods of high water stages on the Mississippi and Yazoo Rivers, the Steele Bayou and Little Sunflower structures are closed, necessitating storage of interior drainage within the ponding areas. The interior areas will pond until the riverside tailwater subsides and the interior water can be released through the floodgates. The water that ponds behind the structures comes from the 4,093-square-mile drainage area that includes most of the Mississippi Delta.

37. The Steele Bayou structure is the principal structure for the Yazoo Backwater Project. Anytime the stage on the landside of the Steele Bayou and Little Sunflower structures is higher than the riverside and above 70 feet, NGVD, the gates are opened. With a rising river, the interior ponding areas are allowed to rise to an elevation of 75.0 feet, NGVD. The structures are closed when the river elevation is higher than the interior ponding levels.

38. The Steele Bayou structure is operated to control minimum water levels in the Steele Bayou and Little Sunflower ponding areas during periods of low water. The present criterion calls for holding minimum water levels in the ponding areas between 68.5 and 70.0 feet, NGVD. Managing the Steele Bayou structure in this manner allows the system to have a minimum discharge during low-water periods and prevents extended periods of stagnation and stratification. The Little Sunflower structure generally remains closed. It is opened during flood events when the riverside water surface elevation is less than the landside elevation and the Steele Bayou structure is closed. Its operation will not change with any of the alternatives.

39. The interior ponding areas are primarily agricultural and forested lands. Several developed areas exist in the Yazoo Backwater Area. Although the interior area is protected from the high stages of the Mississippi and Yazoo Rivers, it is subject to flooding resulting from inflow into the ponding areas from Steele Bayou, Deer Creek, Little Sunflower River, and Big Sunflower River.

INTERIOR HYDROLOGIC AND HYDRAULIC ANALYSES

ECONOMIC AND HYDROLOGIC REACHES

40. Economic reaches were developed for this study as shown on Plate 6-4. For clarification of the economic reaches, the descriptions of the reaches are as follows:

a. <u>Lower reach (lower ponding area)</u>: The Steele Bayou and Deer Creek drainage areas.

b. <u>Upper reach (upper ponding area)</u>: The Little and Big Sunflower River Basins.

INTERIOR ROUTING

41. A period-of-record routing analysis was used and involves analysis of continuous historic records of hydrologic events. Analyses are performed for "with" and "without" conditions. The routing procedure consists of performing sequential hydrologic simulations of interior water surface elevations given exterior river stages, interior stage-area curve, interior stage-volume curve, seepage curve, channel and floodgate rating curves, and computed runoff for the entire period-of-record. The base conditions and final array of alternatives and their structural flood control component were analyzed using two interior routing models to simulate the interior hydrology and hydraulics of the Yazoo Backwater study area. The U.S. Army Corps of Engineers Hydrologic Engineering Center-Interior Flood Hydrology (HEC-IFH) computer model was used as an interior rainfall-runoff model to compute daily streamflows for the period 1943-1997 by using daily rainfall, runoff coefficients, and unit hydrographs. These will be described later in this Engineering Summary. Although the HEC-IFH model has the capability to be used as a period-of-record routing model, its capabilities were limited to a single ponding area. The Vicksburg District hydrologic engineers developed a complex period-of-record routing model to be used in the hydrologic and hydraulic analysis for the Yazoo Backwater study area. This period-of-record routing model uses the computed daily inflow hydrographs from the

HEC-IFH model as input. Stage-area curves, storage curves, seepage curve, and tailwater rating curves for Steele Bayou and Little Sunflower structures, connecting channel rating curve, stage-relation data, and pump-head curves are also used as input into the model. This period-of-record routing model is able to simulate a daily stage routing of the Yazoo Backwater Area which takes into account the inflows from the upper and lower ponding areas (i.e., Big Sunflower and Steele Bayou Basins), stages for riverside and landside conditions at both Steele Bayou and Little Sunflower structures, riverside flow conditions, and a pump operation for any number of pump on and off elevations. The output from the period-of-record routing model is the computed daily stages for the period 1943-1997 for base conditions and alternatives at Steele Bayou and Little Sunflower structures. A schematic derived from EM 1110-2-1413 (Figure 4-2) is provided on Plate 6-8 to illustrate the models used in the Yazoo Basin period-of-record routing analysis and how the data were used to support the economic, environmental, and wetland analyses.

RAINFALL-RUNOFF DESCRIPTIVE RELATIONSHIPS

PRECIPITATION DATA

42. Precipitation data were obtained from as many as 12 contributing National Weather Service rainfall gage stations in developing the inflow hydrographs. Table 6-4 shows the gages used. Plate 6-11 shows the gage locations. The HEC-IFH computer model was used to develop the inflow hydrographs using the daily precipitation data. Station weights were assigned by the Thiessen Polygon technique and were recomputed as new stations were added and old ones were discontinued.

TABLE 6-4
NATIONAL WEATHER SERVICE (N.W.S.) RAINFALL GAGES

N.W.S. Rainfall Gage	Period-of-Record
Clarksdale	1943-1997
Swan Lake	1950-1997
Moorehead	1950-1997
Cleveland	1948-1988
Rosedale	1948-1982
Arkansas City	1948-1997
Greenville	1943-1997
Belzoni	1948-1997
Rolling Fork	1948-1997
Onward	1954-1990
Yazoo City	1943-1997
Vicksburg	1943-1997

UNIT HYDROGRAPHS

43. The Unit Hydrograph of a drainage basin is defined as a hydrograph of direct runoff resulting from 1 inch of effective rainfall generated uniformly over the basin area at a uniform rate during a specified period of time or duration. Unit hydrographs developed from rainfall and stage-discharge hydrographs on the Big Sunflower River at Harvey Chapel and Little Callao Landing were used as the basis for developing the synthetic unit hydrograph for the Upper Ponding Area. The unit hydrograph for the Lower Ponding Area was developed by using observed data on Steele Bayou at Onward, Mississippi, gage. Inflow unit hydrographs are shown on Plates 6-9 and 6-10. These unit hydrographs, originally developed in the 1982 reevaluation report, reflect current conditions in the watershed and are also applicable to conditions assuming all currently approved Corps channel works in the watershed are completed.

PERIOD-OF-RECORD ROUTING DESCRIPTIVE RELATIONSHIPS

STAGE GAGE DATA

44. Daily stage data for the 1-day (24-hour) routing periods used in the period-of-record routing model consisted of using the Mississippi River gage at Vicksburg and stage relating it to the tailwater of the Steele Bayou and Little Sunflower structures. The Mississippi River gage at Vicksburg discharge-rating curve was used to reflect expected conditions at the Steele Bayou and Little Sunflower gages for the period-of-record 1943 to 1997. Actual observed interior and exterior gage stage data (1978 to 1997) for the Steele Bayou and Little Sunflower structures were used to verify the accuracy of the period-of-record routings. Plate 6-12 shows the locations of the gages used in the period-of-record routing analysis.

ELEVATION-AREA AND LAND USE DEVELOPMENT

45. The development of the elevation-area curves and land use data for this study has evolved as newer technology advances come along. Described in the following paragraphs are the methodologies used in previous studies and to where we are today. These technology advances have allowed for very accurate determinations of area and land use classifications, along with the aerial extent mapping capability of these lands in the study area which was not possible in the 2000 draft report.

a. Contour method. This method was used to develop the elevation-area curves in the 1982 Reevaluation Report. The area between the elevation contours of 1:24000 scale U.S. Geological Survey (USGS) quadrangle maps was determined by digitizing each contour using a planimeter. This method develops an elevation-area relationship that assumes the water surface during a flood event is flat within the reach.

b. Satellite flood scene method.

(1) This method utilized in the draft 2000 reformulation study involved the application of a remote-sensing method coupled with the Geographic Information System (GIS). This method allows the natural slope, which is present in a flood event to be taken in account, thus providing a more accurate representation of the elevation-area relationship. The method utilizes digital satellite images as input data to determine the aerial extent of flood events. Each satellite scene is a synoptic view of an actual flood event. The slope that is found is that which was present during that flood event. Ten satellite scenes were selected to determine the elevation-area curves. These ten scenes covered a range of 34.1 feet at the Steele Bayou gage. The ten events and their respective water surface elevations at the two principle gages in the study area are presented in Table 6-5. By coupling the remote-sensing output with a GIS, the land use of the flooded areas could easily be determined.

TABLE 6-5
FLOOD SCENE STREAM GAGE ELEVATIONS

Flood Scene	Steele Bayou Gage Elevation Lower Ponding Area	Little Sunflower Gage Elevation Upper Ponding Area
	(feet, NGVD)	
December 2, 1987	66.2	70.8
February 17, 1984	76.1	81.4
March 12, 1973	77.2	82.2
March 5, 1987	79.5	82.4
February 1, 1993	83.0	83.2
April 30, 1991	N/A	91.7
March 10, 1989	89.7	90.0
January 13, 1983	91.9	93.1
January 30, 1974	90.6	93.4
May 5, 1973	100.3	100.3

(2) After the flood scenes are selected, they are classified, then the accuracy is verified, finally the resultant data points are plotted and the curves drawn. Digital imagery is composed of pixels (picture elements). Each pixel represents a small area on the earth's surface. This project used two types of satellite imagery, Multi-Spectral Scanner (MSS) imagery, and

Thematic Mapper (TM) imagery. Both types were collected by the LANDSAT satellites. MSS imagery became available in 1972, while TM imagery became available in 1983. MSS imagery was used for the majority of the flood scenes. Raw MSS imagery represents a 57- by 79-meter (m) area. That data were resampled into 50- by 50-m pixels. Each of these pixels represents 0.25 hectare (ha) or 0.62 acre. This resolution was deemed adequate for a planning study of this scale. Some of the later satellite scenes were TM imagery. TM imagery has a raw pixel size of 28.5 by 28.5 m. This imagery was resampled to 25.0- by 25.0-m pixels, which is 0.0625 ha or 0.15 acre per pixel. TM imagery was used for the land-use determinations and some of the flood scenes. The raw satellite imagery was classified with an unsupervised classifier (MAPIX, Canonical Classifier, Delta Data Systems). Classification is a term which describes the process that sorts multibanded digital imagery into groups or clusters which are statistically similar. If the selection of training clusters is performed manually using a *priori* information, the classification is considered supervised. If the clustering is performed by a computer based on a statistically derived relationship, the classification is termed unsupervised. The raw classified scenes contained between 65 and 70 classes. A color table was constructed for the image, based on the reflectance values from three of the four bands of data. The raw classes are then manually sorted into groups of like data. A schema containing ten classes was utilized. These ten classes were subgrouped into four categories. The four categories were wet (water), saturated, dry, and clouds. The wet category contained three classes: ponds, flooded cleared, and flooded forest. The saturated and dry categories had three classes--cleared, forested, and herbaceous. The GIS system converted all pixels classified as wet into land use, based on the 1988 land-use classification used in the 2000 draft report. The flood scene classifications were verified by plotting a scene on vellum, sandwiching the scene with a quadrangle sheet, and examining the scene on a light table. The observed flood scene elevation would then be compared to the recorded elevation for the date of the scene. Variations were noted, based on whether the river stages were rising, falling, or steady. Steady stages represent the best condition, for the flooded area will likely correspond well to the recorded river stages. Flood scenes obtained when the river stages were falling generally overestimated the flooded area, while flood scenes obtained when the stages are rising generally underestimated flooded area.

(3) In addition to the flood scenes, two other satellite images were utilized to classify the land use/land cover in the project area. Two satellite scenes from 1988 were used to prepare a multitemporal classification for land use in the 2000 draft report. A classifier classed the scenes into 60 classes. Land use information was used to determine the correct land use of each class. Crop data were obtained from the U.S. Department of Agriculture. Other classes were determined by field verification. The land use/land cover scenes were broken down into the following classes-- cotton, soybeans, corn, rice, herbaceous, pasture, ponds, bottom-land hardwoods, swamp, rivers, lakes, and sandbar/clouds. The classes were divided in three categories--cleared, forested, and water. Later, the managed lands in the study area were digitized and the following classes were added--National Wildlife Refuges, WMAs, Wetland Reserve Program (WRP), and Conservation Reserve Program lands. The land use and flood scenes were sandwiched to create a new coverage for each flood scene, which was the land use

of the flooded area. In this way, a common year's land use was used for all flood scenes. The elevation-area curves were developed for the cleared, forested, and total categories. The elevation-area curves were developed by plotting the GIS flood scene elevations versus the area flooded on that date. A best fit curve routine was used to plot the curves. These stage-area curves were used in the draft 2000 report economic analysis and environmental analyses for waterfowl, fish, and terrestrial.

c. Flood Event Simulation Model (FESM) method.

(1) The elevation-area curve and land use data were updated to 1999 conditions for this study, along with delineation of pre- and postproject conditions, which were originally accomplished by using the Flood Event Assessment Tool (FEAT) model (J. R. Ballard, Jr., and M. R. Kress, 1999), "Flood Event Assessment Tool (FEAT) User's Manual and Technical Documentation," Instruction Report EL-99-X, U.S. Army Engineer Research and Development Center (ERDC) (formerly the U.S. Army Engineer Waterways Experiment Station), Vicksburg, Mississippi. This model which runs in the Arc-View 3.x GIS environment was developed solely for the Vicksburg District. The FEAT model was used to map the aerial extent of frequency flood events in the 2000 Draft Report.

(2) During the fall of 2003, the Vicksburg District moved from using the FEAT model to the FESM model. The model uses the exact same input files, but it is a stand-alone model instead of an Arc-View extension. The output is a Geo-TIFF file that can readily be used in either the 3.x or 9.x versions of Arc-View. The major difference is that the FESM provides either a 2- or 3-dimensional output file. The FESM model was used to simulate the frequency flood events and map wetland extent in the Final Report and FSEIS.

(3) There are five steps in applying the FESM model to develop the elevation-area curves for the Yazoo Backwater study area--acquire or create input data layers, calibrate the model output to a satellite image, verify the model output versus a second satellite scene, run the base and with-project conditions, and determine the land use of the flooded areas.

(4) FESM input data.

(a) The first step in applying the FESM model is building the required input datasets. The model uses five data layers. Three are required input while two are optional. All five were used in this modeling effort. The required input layers are an elevation model of the Basin, point coverage with water surface elevations, and line coverage of the Basin's major streams. The optional layers are a line file with secondary channels and grid coverage of land cover to provide the land use of flooded areas. The quality of the model output is dependent mainly on the quality and accuracy of the elevation data. The elevation data used in this study were developed from USGS 1:24000-scale digital elevation model (DEM) files. These are grid files with elevations posted every 30 m and are based on the hypsography layer (elevation contours) from 1:24000-scale quadrangle sheets. A map scale of 1:24,000 means that each inch on the map represents 24,000 inches or 2,000 feet. According to the National Map Standards, the minimum resolution between two objects on a map is 1/50th of an inch or 40 feet on a 1:24,000 scale map. For instance, the minimum distance between two elevation contour lines would be 40 feet. Thus obtaining an elevation every 30 m (98.43 feet), as for the DEMs, is within the resolution of the maps. For most of the United States, the elevation contour interval on 1:24,000 scale maps is 20 feet, but because the Mississippi Delta is so flat, the contour interval is 5 feet. Although the minimum distance between contour lines is 40 feet, the average distance is much greater. Thus, most of the posting on a DEM were determined by interpolation of the elevation between adjacent contour lines. The elevations are interpolated to the nearest tenth of a foot. The accuracy of the elevations on a 1:24,000 quad map are plus or minus one-half a contour interval or 2.5 feet. The accuracy of elevations on the DEMs is also plus or minus 2.5 feet. The channel file was digitized from 1:24000-scale digital line graph (DLG, hydrography) files or from digital raster graphics (DRG) data files. The water surface elevation file was digitized from the 1:24000-scale DRG files of the quadrangle sheets.

(b) Water surface elevations of a flood event are provided to the model as point data at nodes along the streams and rivers. The node locations are located primarily at gages such that the delineation accurately covers the entire Basin. There are six continuous recording gages located in the Yazoo Backwater Area—Steele Bayou structure landside gage; Steele Bayou at Grace, Mississippi, gage; the Little Sunflower structure landside gage; Big Sunflower River at Holly Bluff, Mississippi, gage; Big Sunflower River at Anguilla, Mississippi, gage; and Big Sunflower River at Little Callao. These gages cover the major streams—Steele Bayou and Big Sunflower River. The Onward gage on Steele Bayou does not have a continuous period-of-record and was only used to check stages when data were available. Other node locations were developed by linear interpolation between the gages. The node locations and major and minor streams used for the FESM model runs in the Backwater area are displayed on Plate 6-13.

(5) <u>FESM calibration</u>.

(a) After the input data layers were developed, the next process was to calibrate the FESM. Calibration is accomplished by simulating one or more flood scenes. The 10 March 1989 flood scene was the first calibration scene used in this study. Before running the model, the areal extent of the flood scene is checked for reasonableness. The areal extent of flooding does not track the changes in gage elevation perfectly. When stages are rising, the areal extent will be less than expected, but will be greater than expected when stages are falling. This scene has falling stages in the upper part of the basin and nearly constant stages in the lower part of the basin (Table 6-6). The second calibration scene was 21 March 1987. The 21 March 1987 scene was acquired one day past the peak at most gages, and the flood scene may underestimate flooding. Plate 6-67 shows the March 1989 and 1987 floods in the vicinity of Holly Bluff. Both floods have gage readings of 90.5 feet at Holly Bluff, and the areal extent of flooding is nearly identical. Plate 6-68 shows the same two floods near the Little Sunflower structure. The March 1989 flood has a water surface of 90.0 feet, and the March 1987 flood has a water surface of 86.3 feet at that gage. The 3.7-foot difference in the water surface elevations creates greatly different flood extents. The FESM model accurately reflected this difference in the water surface slope between the two gages. Once the appropriate stages that match the extent of a flood scene are determined, the model simulations can begin. The model output is then compared to the TM flood scene. Intermediate nodes and secondary channels are added to calibrate the model output to the observed flood. This is an iterative process of running the model, comparing the model to the flood scene, and recalibrating the model until a satisfactory fit is obtained. When the DEM indicates depressions that are flooded in the satellite image, but not flooded by the model, the DLG hydrology layer is checked to see if stream channels exist that would connect these depressions. If streams existed, then secondary channels are added to connect these depressions. Off-channel flooded areas, with no corresponding depressions in the DEM or no stream connection, are considered detached, and it is unlikely that these areas will be impacted by the project. In some cases, the addition of secondary channels is not enough to achieve a good fit to a flood scene, then additional main channels are added. Main channels differ from secondary channels in that they require additional water surface nodes. The water surface at these nodes may be unknown and must be estimated by examination of the satellite image or extrapolated from existing stage data and stream profiles. Examples of major tributaries that were added to the gaged (main channels) streams are Silver Creek, Straight Bayou, Dowling Bayou, and Panther Creek. These are illustrated on Plate 6-14. (Added main channels are highlighted in yellow.) More sites were selected in areas where the gradient was poorly defined.

TABLE 6-6
SATELLITE SCENE GAGE ELEVATIONS
(feet, NGVD)

Date	Steele Bayou	Onward	Grace	Little Sunflower	Holly Bluff	Anguilla	L. Callao
20 March 1987	82.40	NA	81.68	86.20	91.58	95.24	98.72
21 March 1987	81.90	NA	82.58	86.30	91.48	95.14	98.32
8 March 1989	89.60	89.51	89.49	89.90	91.88	93.48	95.42
9 March 1989	89.70	89.71	89.59	90.00	91.68	93.08	94.72
10 March 1989	89.70	89.71	89.69	90.00	91.48	92.66	93.97

(b) In general, when using the FESM model to simulate backwater flooding, tributaries with ungaged nodes should not be added because flooding along these tributaries is due to headwater flooding, resulting from a rising water surface in the tributary. However, calibration to flood scenes often requires the addition of these streams and their upper water surfaces because the flood scene may not represent backwater flooding only. The calibration was considered complete when the model output matched the flood scene for flooded areas contiguous to the river as illustrated in Plates 6-15 and 6-17. (Main channels contiguous to flooding are highlighted in yellow.) The areas contiguous to the streams are given priority because these are the areas affected by backwater flooding. A perfect fit between the FESM model flood and the satellite image of the flood is not possible due to discrepancies in the two GIS data layers. The major sources of error are the DEM, the flood scene, and whether stages are rising or falling on the date of acquisition. Table 6-7 gives the areal extent of the flood scene by land-use category and the same information for the FESM model, both with and without side channels. Once the area of catfish ponds is removed from the flood scene, the areal extent of the model output is 97 percent of the satellite scene. Plate 6-16 displays FESM simulation versus the 21 March 1987 flood scene. Plate 6-17 displays the FESM simulation versus the 10 March 1989 flood scene.

TABLE 6-7
LAND USE OF 10 MARCH 1989 FLOOD SCENE AND FESM SIMULATION
MARCH 1989

Land Use	Flood Scene (Acres)	FESM Simulation (Acres)	FESM Acres/Flood Acres
Crop	29,987.3	24,963.7	0.83
Noncrop	9,576.5	9,475.8	0.99
Bottom-land Hardwoods	105,169.3	106,295.9	1.01
Reforest	44,012.2	43,443.8	0.99
Catfish	28,281.8	1,490.3	0.05
Water	16,315.2	14,522.1	0.89
Cloud	68.6	25.1	0.37
Miscellaneous	203.1	220.0	1.08
Total	233,614.2	200,436.6	0.86
Total Excluding Catfish	205,332.3	198,946.3	0.97

(6) FESM model validation. Once the model is calibrated, it is verified using additional satellite scenes. Table 6-8 lists the water surface elevations at the basin gages for the period of, and before the date of, the 13 January 1983 satellite image used for validation. Table 6-9 includes the land-use percentages of the satellite scene and FESM model runs for 12-13 January 1983. Because stages were falling during the period, the 12 January stages fit the areal extent of flooding better than those of 13 January. It can take several days for floodwaters to recede from flooded areas, and the areal extent of flooding often matches the gage readings from 1 or more days earlier. The FESM model return of 94 percent of the areal extent of the satellite flooding shows the FESM model accurately depicts flooding. Plate 6-18 displays the FESM model output of the 12 January 1983 simulation versus the 13 January 1983 satellite image. In general, the FESM model overestimates flooding in the vicinity of the two ponding areas, which results in a conservative estimate of flood extent.

TABLE 6-8
13 JANUARY 1983
GAGE ELEVATIONS
(feet, NGVD)

Date	Steele Bayou	Onward	Grace	Little Sunflower	Holly Bluff	Anguilla	L. Callao
9 January 1983	91.80	92.87	95.99	92.90	95.68	99.04	102.52
10 January 1983	91.90	93.07	95.59	93.10	95.68	98.94	102.02
11 January 1983	92.00	93.07	95.19	93.20	95.58	98.64	101.72
12 January 1983	92.00	92.97	94.99	93.20	95.58	98.44	101.32
13 January 1983	91.90	92.87	94.59	93.10	95.48	98.14	100.82

TABLE 6-9
LAND USE OF 13 JANUARY 1983
FLOOD SCENE AND FESM SIMULATION

Land Use	Flood Scene (acres)	FESM 13 January 1983 (acres)	FESM Acres/Flood Acres	FESM 12 January 1983 (acres)	FESM Acres/Flood Acres
Crop	133,306.5	105,199.5	0.79	121,277.4	0.91
Noncrop	22,229.6	21,441.0	0.96	22,943.1	1.03
Bottom-land Hardwoods	168,792.6	157,479.9	0.93	162,546.9	0.96
Reforest	85,662.0	77,227.5	0.90	80,138.0	0.94
Catfish	27,776.2	15,306.5	0.55	16,486.2	0.59
Water	18,089.5	15,933.5	0.88	16,264.7	0.90
Cloud	255.7	116.8	0.46	130.3	0.51
Miscellaneous	381.2	407.3	1.07	419.5	1.10
Total	456,493.3	393,111.9	0.86	420,206.1	0.92
Total Excluding CF	428,717.1	377,805.4	0.88	403,719.9	0.94

(7) FESM model output. With the FESM calibrated and verified, the stage-area and land-use data could be determined. Plates 6-19 and 6-20 show the total stage-area curves for the upper and lower ponding areas. Stage-storage curves were developed by numerical integration of the computed total stage-area curves. Stage-storage curves are shown on Plate 6-21. The land use acreages in the Yazoo Backwater Area are shown in Tables 6-10 through 6-13. The FESM model results were used to support the economic, environmental, reforestation, and wetland analyses. While the satellite flood scene method produced very similar results with the FESM method, the FESM model allows the simulation of pre- and postproject frequency and duration flood events. The total stage-area curves did not change significantly from the 2000 draft report and were used in the period-of-record analysis.

TABLE 6-10
TOTAL 2005 LAND USE WITHIN THE YAZOO BACKWATER PROJECT AREA a/

2005 Land Use Category	Unadjusted Acres	Adjusted Acres b/
Cotton	195,400	192,600
Soybeans	233,500	219,400
Corn	47,000	46,100
Rice	26,300	25,600
Total Crop	502,200	483,700
Herbaceous	60,500	54,300
Reforest	29,700	0
Total Noncrop	90,200	54,300
Bare Soil	1,200	1,200
Bottom-land Hardwoods	264,800	144,100
Cypress	10,100	5,500
Total Forest	274,900	149,600
River	16,600	13,400
Lake	9,800	9,500
Total Water	26,400	22,900
Ponds	31,100	30,600
Total Ponds	31,100	30,600
WMA		27,000
NWR		90,900
WRP		36,800
CRP		23,500
FmHome		5,500
Total Managed		183,700
Total 2005 Landuse	926,000	926,000

a/ Acres developed from FESM Model using 2005 Landuse Data

b/ Adjusted Acres - the landuse acres were adjusted by removing all lands managed by state and Federal agencies or under Federal farm programs.

NOTE: WMA - Wildlife Management Area
NWR - National Wildlife Area
WRP - Wetland Reserve Program
CRP - Conservation Reserve Program
FmHome - Farmer Home Administration Lands

TABLE 6-11
2005 LAND USE WITHIN THE 100-YEAR FLOOD OF THE YAZOO BACKWATER STUDY AREA a/

2005 Land Use Category	Unadjusted Acres	Adjusted Acres b/
Cotton	74,800	73,200
Soybeans	160,800	149,200
Corn	21,200	20,800
Rice	16,300	15,800
Total Crop	273,100	259,000
Herbaceous	39,400	34,000
Reforest	27,900	0
Total Noncrop	67,300	34,000
Bare Soil	300	300
Bottom-land Hardwoods	233,000	119,400
Cypress	8,800	4,500
Total Forest	241,800	123,900
River	15,000	12,300
Lake	9,100	8,800
Total Water	24,100	21,100
Ponds	23,400	23,000
Total Ponds	23,400	23,000
WMA		18,400
NWR		88,200
WRP		35,100
CRP		21,700
FmHome		5,300
Total Managed		168,700
100-year 2005 Land Use	630,000	630,000

a/ Acres developed from FESM Model using 2005 Land Use Data

b/ Adjusted Acres - the land use acres were adjusted by removing all lands managed by state and Federal agencies or under Federal farm programs.

NOTE: WMA - Wildlife Management Area
NWR - National Wildlife Area
WRP - Wetland Reserve Program
CRP - Conservation Reserve Program
FmHome - Farmer Home Administration Lands

TABLE 6-12
TOTAL 2005 LAND USE WITHIN THE YAZOO BACKWATER PROJECT AREA BY REACH a/

2005 Land Use	Unadjusted Acres			Adjusted Acres b/		
Category	Lower Ponding Area	Upper Ponding Area	Total	Lower Ponding Area	Upper Ponding Area	Total
Cotton	75,100	120,300	195,400	73,900	118,700	192,600
Soybeans	112,300	121,200	233,500	105,600	113,800	219,400
Corn	25,100	21,900	47,000	24,600	21,500	46,100
Rice	14,000	12,300	26,300	13,600	12,000	25,600
Total Crop	226,500	275,700	502,200	217,700	266,000	483,700
Herbaceous	36,000	24,500	60,500	32,900	21,400	54,300
Reforest	9,800	19,900	29,700	0	0	0
Total Non-Crop	45,800	44,400	90,200	32,900	21,400	54,300
Bare Soil	500	700	1,200	500	700	1,200
Bottom-land Hardwoods	112,700	152,100	264,800	84,000	60,100	144,100
Cypress	6,600	3,500	10,100	3,800	1,700	5,500
Total Forest	119,300	155,600	274,900	87,800	61,800	149,600
River	8,300	8,300	16,600	6,800	6,600	13,400
Lake	8,700	1,100	9,800	8,500	1,000	9,500
Total Water	17,000	9,400	26,400	15,300	7,600	22,900
Ponds	3,300	27,800	31,100	3,100	27,500	30,600
WMA				13,000	14,000	27,000
NWR				20,100	70,800	90,900
WRP				15,500	21,300	36,800
CRP				6,000	17,500	23,500
FmHome				500	5,000	5,500
Total Managed				55,100	128,600	183,700
Total	412,400	513,600	926,000	412,400	513,600	926,000

NOTE: WMA - Wildlife Management Area
NWR - National Wildlife Area
WRP - Wetland Reserve Program
CRP - Conservation Reserve Program
FmHome - Farmer Home Administration Lands

a/ Acres developed from FESM Model using 2005 Landuse Data

b/ Adjusted Acres - the landuse acres were adjusted by removing all lands managed by state and federal agencies or under Federal farm programs.

TABLE 6-13

LAND USE WITHIN THE 100-YEAR FLOOD OF YAZOO BACKWATER STUDY AREA BY REACH a/

2005 Land Use Category	Unadjusted Acres			Adjusted Acres b/		
	Lower Ponding Area	Upper Ponding Area	Total	Lower Ponding Area	Upper Ponding Area	Total
Cotton	19,400	55,400	74,800	19,100	54,100	73,200
Soybeans	57,400	103,400	160,800	52,900	96,300	149,200
Corn	8,400	12,800	21,200	8,300	12,500	20,800
Rice	5,000	11,300	16,300	4,700	11,100	15,800
Total Crop	90,200	182,900	273,100	85,000	174,000	259,000
Herbaceous	19,100	20,300	39,400	16,800	17,200	34,000
Reforest	8,400	19,500	27,900	0	0	0
Total Non-Crop	27,500	39,800	67,300	16,800	17,200	34,000
Bare Soil	100	200	300	100	200	300
Bottom-land Hardwoods	87,200	145,800	233,000	64,900	54,500	119,400
Cypress	5,400	3,400	8,800	2,900	1,600	4,500
Total Forest	92,600	149,200	241,800	67,800	56,100	123,900
River	6,000	9,000	15,000	4,900	7,400	12,300
Lake	8,200	900	9,100	8,000	800	8,800
Total Water	14,200	9,900	24,100	12,900	8,200	21,100
Ponds	2,000	21,400	23,400	1,900	21,100	23,000
WMA				5,000	13,400	18,400
NWR				17,600	70,600	88,200
WRP				14,800	20,300	35,100
CRP				4,300	17,400	21,700
FmHome				400	4,900	5,300
Total Managed				42,100	126,600	168,700
Total	226,600	403,400	630,000	226,600	403,400	630,000

NOTE: WMA - Wildlife Management Area
NWR - National Wildlife Area
WRP - Wetland Reserve Program
CRP - Conservation Reserve Program
FmHome - Farmer Home Administration Lands

a/ Acres developed from FESM Model using 2005 Landuse Data

b/ Adjusted Acres - the landuse acres were adjusted by removing all lands managed by state and federal agencies or under Federal farm programs.

INTERIOR PONDING AREA INFLOWS

46. The inflow hydrographs used in the period-of-record routing model were developed by using the HEC-IFH model. Input to the model consisted of daily precipitation data, unit hydrographs, and runoff coefficients. The computed inflow hydrographs were used as input to the period-of-record routing model. Observed inflow data were not available to replicate a long period-of-record that could be used in the hydrologic, economic, and environmental impact analysis of the project.

DISCHARGE RATING CURVES

47. Tailwater discharge rating curves for the Steele Bayou and Little Sunflower structures and connecting channel were developed from observed stages and measured discharges. These rating curves are shown on Plates 6-22 through 6-26.

YAZOO RIVER FLOWS

48. Daily Yazoo River discharges were developed above the Little Sunflower River by using discharge-rating curves developed at the Yazoo City and Belzoni gages on the Yazoo River. These discharges were adjusted for headwater improvements and reservoir regulation.

SEEPAGE

49. The Yazoo Backwater Study Area is bounded by the mainline Mississippi River levees on the west, the Yazoo Backwater levees on the south, and the Yazoo River and Will M. Whittington levees on the east. These levees total approximately 260 miles in length. They generally are not completely impervious and seepage may pass through or beneath the levees. In fact, a large number of relief wells have been built along the Mississippi River levees to control seepage and sand boils, which occur when river stages exceed stages on the landside in major floods. The Yazoo Backwater period-of-record routing model used in this study uses the same criteria and seepage curve data as most other interior routing models such as the HEC-IFH model which also assumes that seepage can occur as inflow from the exterior to the interior only. Seepage can occur along an extensive reach of the Mississippi River even when stages at the Steele Bayou structure may be higher than the river. The levees were divided into reaches according to soil type, and curves relating seepage to head were developed for each type. The head for each reach was then correlated to the appropriate river gage, and a composite seepage

curve for relating seepage inflow to the appropriate river gage was derived. The seepage curve developed assumes average flood conditions in the Yazoo Backwater Area. The seepage curve used in the period-of-record routings is shown on Plate 6-27.

PERIOD-OF-RECORD ROUTING MODEL ASSUMPTIONS

50. The following conditions were assumed in the recommended plan routing procedure:

a. The period-of-record used in the interior routing model analysis was 1943 to 1997. The EM 1110-2-1413 requires a period-of-record sufficient to satisfactorily analyze all major flood events in the drainage area. This period-of-record has 55 years of daily data and complies with the EM's requirements. Some may question why the period-of-record was not extended to 2005. Prior to the 2000 draft report, the period-of-record was extended from 1993 to 1997. The results showed very little difference in the results. Adding another 8 years of stage data would not alter the results since there were no significant flood events that occurred from 1998 to 2005. Peak stages at the Steele Bayou structure from 1998 to 2005 ranged from 79.6 to 90.3, which are below the 2-year flood event.

b. Flooding in the Upper and Lower Reaches was determined by using the Little Sunflower and Steele Bayou structures landside gage locations. The total elevation-area curves used in the period-of-record routing model take into account the effects of actual flooding in the ponding areas and adjacent areas since the FESM model accurately accounts for slope in each reach. Land use data were updated to 2005 conditions since land use changes in the area have occurred since the 1988 land use data used in the 2000 draft report.

c. The minimum ponding elevation was set at 73.0 feet, NGVD, at the Steele Bayou structure year-round and used throughout the entire period-of-record such that additional water would be available during extreme low-water periods.

d. Twelve pumps were operated at 1,167 cfs each. The actual head-discharge pump curve for the recommended pump station was used to simulate the pump operation (Plate 6-28). The number of pumps operated in any routing period was determined by the available storage above the minimum ponding elevation. In real time operational mode, flood forecasts of incoming flood hydrographs will be utilized in determining the actual number of pumps, which would need to be brought on-line to provide required flood protection.

e. The pump-on elevation used for the recommended plan, Alternative 5, was 87.0 feet, NGVD, and the pump-off elevation was 87.0 feet, NGVD, for 1 January through 31 December for the entire period-of-record.

f. The floodgates and the pump station were not operated simultaneously due to the fact that the floodgates in a real time operation can pass significantly more flow when the interior ponding elevation is higher than the exterior river elevation and based on the fact that damages to the pump could occur if operated against a negative head. The discharge from the Steele Bayou structure with only 1 foot of head is 19,000 cfs, which is greater than the maximum discharge from the pump station.

PERIOD-OF-RECORD ROUTING MODEL VERIFICATION

51. As a standard procedure, the Corps compares the period-of-record routing model computed under existing condition stages with observed stages to ensure that the model was properly calibrated and verified. In the 1982 reevaluation report, the period-of-record routing looked only at the peak flood event. Hydrographs for each year were performed mostly by hand computations. This did not allow for a continuous period-of-record for each day of the year. With the latest version of the Yazoo Backwater period-of-record routing model, it allows for computation of daily routings for each day of the year. With such a large and complex drainage system in the Yazoo Backwater Area, the model produces stages at the Steele Bayou and Little Sunflower structure gages and compares very well with observed stages.

52. An analysis was performed using the observed stage data from 1978 to 1997 at the Steele Bayou structure landside gage comparing the differences between the period-of-record routing model output stages for existing conditions would have on average an accuracy level of -0.5 foot based on each of the 7,300 days from 1978 to 1997. The year 1978 was chosen as the start date since the Yazoo Backwater levee, connecting channel, Steele Bayou structure, and Little Sunflower River structure were complete and in operation. This average is considered very good since period-of-record daily inflows were computed using average monthly runoff coefficients, average daily observed rainfall, and unit hydrographs. With this level of accuracy, it shows that the period-of-record routing model can be used to reasonably calibrate and verify existing conditions for an area as complicated as the Yazoo Backwater Area. Plates 6-29 through 6-34 show the observed stages versus computed stages for flood events in 1978, 1984, 1990, 1991, 1993, and 1997. While the period-of-record routing model verified very well, the same period-of-record inflows computed for 1943-1997 were used in the base conditions and with-project conditions. Any discrepancy in the stage data would be used across the entire analysis which would give the same difference between pre- and postproject conditions and would not result in a significant difference in the overall answer.

PERIOD-OF-RECORD ROUTING MODEL OUTPUT RESULTS

STAGE-FREQUENCY ANALYSIS

53. Stage-frequency curves were computed according to procedures outlined in "Statistical Methods in Hydrology," by Leo R. Beard. The period-of-record used was from 1943 to 1997. Annual and partial stage-frequency curves were computed for Base Condition and for all the array of alternatives using the computed daily stage output data from the period-of-record routing model for both Steele Bayou gage (lower ponding area) and the Little Sunflower structure gage (upper ponding area). The computer program, FREQ32.EXE, was used to compute the annual and partial stage-frequency curves using the median plotting position method which is historically the method the Corps uses. The frequency data points were plotted in Microsoft Excel, and the best fit stage-frequency curves were developed. Table 6-14 depicts the stage-frequency data for base conditions and the final array of alternatives and the corresponding acres.

54. The period-of-record routing analysis used only the gages at the Steele Bayou and Little Sunflower structures to develop pre- and postproject condition daily stage data. The gages at Holly Bluff, Anguilla, Little Callao, and Steele Bayou at Grace had to be modeled to take into account the postproject conditions. An analysis was performed to determine the postproject conditions at these gages using a HEC-RAS model to determine the impacts of the alternatives at these gages. Stage-frequency data for postproject conditions were developed at these gages for the final array alternatives as shown in Table 6-15. These with-project stage-frequency curves were applied to the existing period-of-record stages at each gage to develop daily stages for with-project conditions. These postproject daily stages were used in the wetlands, waterfowl, aquatics, terrestrial, and economics appendixes described later in this report.

55. Water surface profiles were developed from the six gages for Steele Bayou and the Big Sunflower River for the various flood frequencies used in the study. These profiles were the basis for the linear interpolation for the FESM model. These profiles are shown on Plates 6-60 through 6-63.

RISK AND UNCERTAINTY

56. A risk-based analysis was performed on the computed stage-frequency curves developed at the Steele Bayou and the Little Sunflower structures as outlined in EC 1105-2-205. These two gages were used in period-of-record routing analysis from which stage-frequency curves were developed and utilized in the Economic Analysis.

TABLE 6-14
STAGE-FREQUENCY AND STAGE AREA DATA

Frequency Event	Base Conditions		Alternative (Final Array)									
			Plan 3		Plan 4		Plan 5		Plan 6		Plan 7	
Year	Elevation	Acres	Elevation	Acres	Elevation	Acres	Elevation	Acres	Elevation	Acres	Elevation	Acres
Lower Ponding Area a/												
1	87.0	75,882	81.5	47,845	85.0	65,236	87.0	75,882	87.0	75,882	87.0	75,882
2	91.0	109,491	84.7	63,630	86.0	70,583	87.8	81,192	89.5	93,723	91.2	112,057
3	92.9	135,108	86.6	73,762	87.2	76,942	88.5	86,341	89.9	97,425	91.5	115,893
5	94.6	162,306	88.4	85,606	89.1	90,775	89.6	94,648	90.5	103,046	91.8	119,729
10	96.3	187,780	90.3	101,126	91.0	109,491	91.2	112,057	91.8	119,729	92.5	128,937
20	97.6	209,356	92.0	122,358	92.2	124,989	92.7	131,984	93.2	139,774	93.4	142,865
25	98.0	217,205	92.5	128,937	92.6	130,423	93.0	136,669	93.5	144,411	93.7	147,502
50	99.2	236,988	94.0	152,471	94.0	152,471	94.4	159,086	94.6	162,306	94.6	162,306
100	100.3	226,574	95.4	174,089	95.4	174,089	95.7	178,673	96.0	183,358	96.0	183,358
Upper Ponding Area b/												
1	87.8	140,317	83.2	73,747	85.9	109,140	87.8	140,317	87.8	140,317	87.8	140,317
2	91.6	208,044	86.8	123,543	87.3	131,856	88.9	162,872	90.0	181,981	91.8	211,543
3	93.4	240,407	88.3	150,092	89.0	165,002	89.7	176,887	90.8	194,435	92.0	215,041
5	95.0	268,727	89.9	180,283	90.2	185,095	90.7	192,879	91.5	206,295	92.7	227,624
10	96.8	300,369	91.5	206,295	91.8	211,543	92.0	215,041	92.9	231,219	93.8	247,796
20	98.1	325,661	92.8	229,422	93.2	236,712	93.5	242,254	94.0	251,491	94.6	261,833
25	98.5	334,125	93.3	238,559	93.5	242,254	93.8	247,796	94.4	258,385	94.8	265,280
50	99.5	355,946	94.3	256,662	94.8	265,280	95.1	270,481	95.3	273,989	95.5	277,497
100	100.3	403,413	95.6	279,251	96.0	286,267	96.4	293,318	96.5	295,081	96.7	298,606

NOTE: Elevation - feet, NGVD.
a/ Steele Bayou Structure landside gage location
b/ Little Sunflower Structure landside gage location

TABLE 6-15

STAGE-FREQUENCY DATA FOR FESM MODEL OBSERVED GAGES WITHIN THE YAZOO BACKWATER STUDY AREA

BASE CONDITIONS								
GAGE LOCATION	.5-YEAR	1-YEAR	2-YEAR	5-YEAR	10-YEAR	25-YEAR	50-YEAR	100-YEAR
LITTLE SUNFLOWER STRUCTURE	78.8	87.8	91.6	95.0	96.8	98.5	99.5	100.3
BIG SUNFLOWER AT HOLLY BLUFF	88.0	90.7	93.0	95.3	96.8	98.5	99.5	100.5
BIG SUNFLOWER AT ANGUILLA	92.4	95.5	97.1	98.4	99.4	100.4	101.2	101.8
BIG SUNFLOWER AT LITTLE CALLAO	97.6	100.4	101.8	103.4	104.2	104.9	105.5	105.8
STEELE BAYOU STRUCTURE	78.0	87.0	91.0	94.6	96.3	98.0	99.2	100.3
STEELE BAYOU AT GRACE	94.0	95.4	96.5	97.9	99.0	99.7	100.1	100.5
PLAN 3								
GAGE LOCATION	.5-YEAR	1-YEAR	2-YEAR	5-YEAR	10-YEAR	25-YEAR	50-YEAR	100-YEAR
LITTLE SUNFLOWER STRUCTURE	78.8	83.2	86.8	89.9	91.5	93.3	94.3	95.6
BIG SUNFLOWER AT HOLLY BLUFF	88.0	88.4	89.4	91.7	92.6	93.8	94.7	95.6
BIG SUNFLOWER AT ANGUILLA	92.4	94.5	95.6	96.2	96.5	97.0	97.3	97.7
BIG SUNFLOWER AT LITTLE CALLAO	97.6	99.7	100.8	101.7	102.3	102.9	103.4	103.8
STEELE BAYOU STRUCTURE	78.0	81.5	84.7	88.4	90.3	92.5	94.0	95.4
STEELE BAYOU AT GRACE	94.0	94.6	95.3	96.4	96.8	97.6	98.1	98.6
PLAN 4								
GAGE LOCATION	.5-YEAR	1-YEAR	2-YEAR	5-YEAR	10-YEAR	25-YEAR	50-YEAR	100-YEAR
LITTLE SUNFLOWER STRUCTURE	78.8	85.9	87.3	90.2	91.8	93.5	94.1	96.0
BIG SUNFLOWER AT HOLLY BLUFF	88.0	89.0	89.7	91.9	92.9	94.2	95.1	96.0
BIG SUNFLOWER AT ANGUILLA	92.4	95.2	96.1	96.7	97.3	97.7	97.9	98.1
BIG SUNFLOWER AT LITTLE CALLAO	97.6	100.0	101.2	102.0	102.6	103.1	103.6	104.0
STEELE BAYOU STRUCTURE	78.0	85.0	86.0	89.1	91.0	92.6	94.0	95.4
STEELE BAYOU AT GRACE	94.0	94.8	95.7	96.5	97.2	97.8	98.3	98.8
PLAN 5								
GAGE LOCATION	.5-YEAR	1-YEAR	2-YEAR	5-YEAR	10-YEAR	25-YEAR	50-YEAR	100-YEAR
LITTLE SUNFLOWER STRUCTURE	78.8	87.8	88.9	90.7	92.0	93.8	95.1	96.4
BIG SUNFLOWER AT HOLLY BLUFF	88.0	90.6	91.6	93.0	94.0	95.2	95.9	96.4
BIG SUNFLOWER AT ANGUILLA	92.4	95.4	96.4	97.1	97.5	97.9	98.2	98.4
BIG SUNFLOWER AT LITTLE CALLAO	97.6	100.3	101.3	102.3	102.8	103.4	103.9	104.3
STEELE BAYOU STRUCTURE	78.0	87.0	87.8	89.6	91.2	93.0	94.4	95.7
STEELE BAYOU AT GRACE	94.0	95.4	96.0	96.8	97.5	98.1	98.6	98.9

TABLE 6-15 (Cont)

PLAN 6								
GAGE LOCATION	.5-YEAR	1-YEAR	2-YEAR	5-YEAR	10-YEAR	25-YEAR	50-YEAR	100-YEAR
LITTLE SUNFLOWER STRUCTURE	78.8	87.8	91.8	92.7	93.8	94.8	95.5	96.7
BIG SUNFLOWER AT HOLLY BLUFF	88.0	90.6	92.7	94.0	95.0	95.7	96.0	96.7
BIG SUNFLOWER AT ANGUILLA	92.4	95.4	96.8	97.5	97.9	98.4	98.8	99.0
BIG SUNFLOWER AT LITTLE CALLAO	97.6	100.3	101.7	102.7	103.2	103.8	104.3	104.7
STEELE BAYOU STRUCTURE	78.0	87.0	91.2	91.8	92.5	93.7	94.6	96.0
STEELE BAYOU AT GRACE	94.0	95.4	96.3	97.5	98.0	98.6	99.2	99.5

PLAN 7								
GAGE LOCATION	.5-YEAR	1-YEAR	2-YEAR	5-YEAR	10-YEAR	25-YEAR	50-YEAR	100-YEAR
LITTLE SUNFLOWER STRUCTURE	78.8	87.8	90.0	91.5	92.9	94.4	95.3	96.5
BIG SUNFLOWER AT HOLLY BLUFF	88.0	90.6	91.7	93.5	94.4	95.3	96.3	96.5
BIG SUNFLOWER AT ANGUILLA	92.4	95.4	96.2	97.3	97.7	98.2	98.5	98.6
BIG SUNFLOWER AT LITTLE CALLAO	97.6	100.3	101.4	102.4	103.0	103.6	104.1	104.5
STEELE BAYOU STRUCTURE	78.0	87.0	89.5	90.5	91.8	93.5	94.6	96.0
STEELE BAYOU AT GRACE	94.0	95.4	96.1	97.3	97.7	98.3	98.9	99.2

57. Stage-frequency curves cannot be described by an analytic distribution. Analysis of these curves is usually performed graphically or nonanalytically. The uncertainty in a nonanalytical frequency curve that is estimated from a graphical fit of ordered observations (e.g., peak annual stages) may be calculated from order statistics. No assumption has to be made concerning the analytic form of the frequency curve. The statistic derived to estimate uncertainty is termed "nonparametric" or "distribution free." The order statistic approach is limited to calculating uncertainty in the estimated frequency curve for the range of observed data or, alternatively, the equivalent length of record. Extrapolating the estimates beyond the range of data is performed by using asymptotic approximations of uncertainty distributions. The order statistic and asymptotic estimates of uncertainty is matched at the limits of the observed data. The estimates of uncertainty are computed using the asymptotic approximation beyond the range of data.

58. The computer program LIMIT.exe developed by HEC was used in the computation of confidence limits for the stage-frequency curves developed at the Steele Bayou and Little Sunflower gages for base and alternative conditions. The program can be used when a frequency curve has been developed based on systematic observations, hypothetical events, or both. Input data consist of systematic observations, equivalent years of record, and the systematic and equivalent record. Output consists of lengthy computation results from the LIMIT.exe program for the 55-year period-of-record in an ASCII data file that are used in the economics model to run the RISK program and an HEC-DSS output file. The ASCII output data were utilized in the economics models and used in the risk analysis as described in Appendix 7.

ALTERNATIVE 2B

59. Alternative 2B, as described earlier in this appendix, is a combination of nonstructural and structural features designed to provide 100-year frequency flood protection to most of the structures (homes, businesses, shops, etc.) located in the Yazoo Backwater study area (Plate 6-7). The structural component of this alternative consists of 14 ring levees which have a total drainage area of 807 square miles and protects 1,382 structures out of a total of 2,281 structures in the 100-year flood plain within the ring levees. Each ring levee was designed to provide 100-year frequency flood protection from the major tributaries, Steele Bayou and Big Sunflower River, within the study area. A total of 439 miles of levee was determined, with a total levee footprint area of 3,686 acres and a total volume of 39,849,850 cubic yards. The total levee area, plus construction area, was determined to be 7,677 acres. The number of streams, highways, and roads crossed by the ring levees were 226, 32, and 127, respectively. Levee crossings were estimated using the total number of highway and street crossings. A slope of 1:10 and side slopes of 1:3 were used to estimate length and quantities for the crossings. The total length and volume for the highway and street crossings were determined to be 0.55 mile and 84,893 cubic yards, respectively.

60. The interior areas of the ring levees were provided flood protection utilizing drainage structures and pumps sized to remove 3.5 inches of runoff per day. The 14 ring levee areas will require 75,989 cfs total pumping capacity, 80 miles of channels, and 226 drainage structures to provide internal drainage. The 226 drainage structures are required for the streams crossed by the ring levees were of three types (A, B, or C). Type A structures consist of a round concrete flap-gate culvert with diameters ranging from 1 to 4 feet. Type B structures consist of round concrete screw-gate culverts with diameters ranging from 4 to 6 feet. Type C structures consist of a 7 inch by 7 inch concrete box screw-gate culvert. The total number of structures for each type is Type A = 68, Type B = 113, and Type C = 45.

61. In addition to the ring levees and drainage structures required, it was estimated that a wastewater treatment facility will be required for each structure (home, business, etc.), which is typical for ring levees since the ground around the structures gets saturated, and septic systems used in these areas will be rendered ineffective (Table 6-16).

RECOMMENDED PLAN

62. The recommended plan from the final array of alternatives is Alternative 5. Table 6-17 shows the reduction in stages for the recommended plan for the various flood frequency events. Table 6-18 shows the departures for the various frequency flood events for the current Yazoo Backwater study recommended plan versus the revised 1982 Yazoo Backwater report recommended plan (17,500-cfs pump, Alternative 28, Array 3). While the recommended plan reduces the 100-year frequency flood from elevation 100.3 to 95.7 feet, NGVD, it also reduces the volume of water by 43 percent which is significant in a backwater area. The stage-frequency curves for the upper and lower ponding area stage-frequency curves for base conditions and the recommended plan are shown on Plates 6-35, 6-35a, 6-36, and 6-36a. The FESM model was used to delineate the 1-, 2-, 10-, and 100-year frequency floods for base conditions and with-project conditions as shown on Plates 6-37 through 6-40. Plates 6-41 through 6-44, respectively, show the base condition 1-, 2-, 10-, and 100-year frequency land-use classifications. Plates 6-45 through 6-48, respectively, show the recommended plan 1-, 2-, 10-, and 100-year frequency land use classifications.

TABLE 6-16
ALTERNATIVE 2B RING LEVEE STRUCTURES

Ring Levee Area	Total Number of Structures within Ring Levee	Total Number within 100-Year Flood plain and Ring Levee	Total Number of Structures Protected
1	28	22	22
2	69	48	48
3	227	187	187
4	175	136	136
5	507	147	147
6	72	63	63
7	202	90	90
8	256	202	202
9	366	266	266
10	54	25	25
11	37	25	25
12	106	47	47
13	169	113	113
14	13	11	11
Total	2,281	1,382	1,382

Note: Total number of structures within the YBW study area is 2,813.
Therefore, there are 532 structures not within the ring levees.
Of the 1,576 structures within the 100-year flood plain, there are
194 structures not protected by the ring levees.

TABLE 6-17
RECOMMENDED PLAN ON LOWER PONDING AREA REDUCTIONS

Flood Frequency	Reduction in Stage	Reduction in Area	Reduction in Volume	Days to lower flood to 87 feet	Change in Water Surface per day
1-Year	0.0	0.0	0.0	N/A	N/A
2-Year	3.2	31.1%	38.6%	25.2	0.16
5-Year	5.0	30.3%	46.5%	58.3	0.11
10-Year	5.1	31.6%	47.9%	82.7	0.07
25-Year	5.0	28.4%	47.0%	110.5	0.06
50-Year	4.8	27.3%	45.4%	129.0	0.06
100-Year	4.6	25.0%	42.6%	145.3	0.07

TABLE 6-18
2007 YAZOO BACKWATER REFORMULATION REPORT VERSUS
1982 YAZOO BACKWATER REPORT
RECOMMENDED PLANS
STAGE-FREQUENCY DEPARTURES

Frequency Years	2007 Report Recommended Alternative 14,000-cfs Pump Elevation (ft)	1982 Report a/ Recommended Alternative 17,500-cfs Pump Elevation (ft)	Difference (ft)
Lower Ponding Area			
1	87.0	81.3	5.7
2	87.8	82.7	5.1
3	88.5	84.9	3.6
5	89.6	86.5	3.1
10	91.2	88.7	2.5
20	92.7	90.3	2.4
25	93.0	90.8	2.2
50	94.4	92.5	1.9
100	95.7	94.0	1.7
Upper Ponding Area			
1	87.8	83.0	4.8
2	88.9	85.7	3.2
3	89.7	86.9	2.8
5	90.7	88.4	2.3
10	92.0	90.1	1.9
20	93.5	91.6	1.9
25	93.8	92.1	1.7
50	95.1	93.3	1.8
100	96.4	94.3	2.1

a/ Updated to 1943-1997 period-of-record (Alternative 28, Array 3).

PUMP STATION AND FLOODGATE OPERATION DATA

63. The period-of-record routing results were used to develop the data required to determine the pump station energy requirements. The data used to calculate the energy requirements included average head, average annual number of days of pump operation, and discharge duration. Table 6-19 shows the average number of days of pumping per year for each of the final array of alternatives. The recommended plan yearly pumping data which show the periods of continuous flood event, number of days pumped per year, and some pumping statistics are found in Table 6-20. Plate 6-49 shows the number of days pumped per year. Plate 6-50 shows the number of days pumped by month. Plate 6-51 shows the recommended plan pump and Steele Bayou structure operation by month for days the gates are closed and opened and pump operation (pump station does not operate when gates are open). Using the data to calculate energy requirements and costs for both electric- and diesel-driven pumps, it was determined the diesel-driven pumps to be the most cost effective.

TABLE 6-19
AVERAGE ANNUAL DAYS OF PUMPING FOR THE FINAL
ARRAY OF ALTERNATIVES

Alternative	Average Number of Days Pumped Per Year
Alternative 3	63
Alternative 4	44
Alternative 5 (Recommended Alternative)	31
Alternative 6	24
Alternative 7	12

TABLE 6-20
RECOMMENDED PLAN YEARLY PUMPING DATA
YAZOO BACKWATER AREA REFORMULATION

YEAR	TOTAL DAYS PUMPED	CONTINUOUS FLOOD EVENTS PUMPED												DAYS ABOVE 87.0 FEET NGVD W/O PUMPING	YEAR
		PERIOD PUMPED	PUMP ON	PUMP OFF	PERIOD PUMPED	PUMP ON	PUMP OFF	PERIOD PUMPED	PUMP ON	PUMP OFF	PERIOD PUMPED	PUMP ON	PUMP OFF		
1943	21	4/3-4/14	87.3	87.5	6/15-6/23	87.1	87.1							1	1943
1944	43	3/30-4/6	87.3	89.4	4/21-5/24	90.7	91.8							21	1944
1945	87	3/7-5/13	87.3	91.4	5/29-6/5	88.8	87.4	6/29-7/9	87.1	87.3				18	1945
1946	26	1/18-2/1	87.7	90.3	2/22-3/4									4	1946
1947	23	4/22-5/14	87.3	87.3										1	1947
1948	59	3/1-3/19	87.4	89.1	3/30-5/8	87.6	87.5							4	1948
1949	76	1/23-3/23	87.3	87.3	4/2-4/17	87.7	88.1							4	1949
1950	72	1/17-3/17	87.4	90.4	4/12-4/23	87.5	87.3							13	1950
1951	55	3/7-3/30	87.1	87.4	4/8-5/8	87.4	87.4							2	1951
1952	51	2/14-2/26	87.2	87.4	4/2-5/9	87.2	87.4							4	1952
1953	0													0	1953
1954	0													0	1954
1955	15	3/28-4/11	87.5	89.2										6	1955
1956	0													4	1956
1957	8	4/28-5/5	87.3	87.4										1	1957
1958	12	5/13-5/24	87.9	89.4										7	1958
1959	0													0	1959
1960	0													0	1960
1961	51	3/17-4/13	87.5	89.1	5/16-6/7	87.2	87.3							15	1961
1962	50	3/16-5/4	87.2	87.4										1	1962
1963	10	4/5-4/14	87.1	87.2										1	1963
1964	12	3/27-4/7	87.3	87.3										2	1964
1965	6	4/27-5/2	87.1	87.2										1	1965
1966	0													0	1966
1967	0													0	1967
1968	10	4/10-4/19	87.3	87.9										2	1968
1969	19	2/14-2/26	87.3	87.4	5/1-5/6	87.3	87.3							2	1969
1970	21	5/4-5/24	87.4	87.4										1	1970
1971	13	3/8-3/20	87.2	87.5										2	1971
1972	16	5/9-5/15	87.2	87.4	12/23-12/31	87.3								2	1972
1973	116	1/1-1/17		88.7	2/2-2/26	87.5	87.7	3/20-6/1	87.8	95.6				31	1973
1974	66	1/10-2/21	87.3	91.3	3/31-4/4	87.2	87.3	6/10-6/27	87.5	88.7				22	1974
1975	87	2/12-2/22	87.3	87.6	3/2-4/25	87.5	89.3	5/5-5/25	87.4	87.8				8	1975
1976	0													0	1976
1977	0													0	1977
1978	0													0	1978
1979	70	3/14-5/22	87.2	90.3										7	1979
1980	29	3/29-4/26	87.7	91.0										9	1980
1981	0													0	1981
1982	19	4/11	87.2	87.2	12/14-12/31	87.3								2	1982
1983	78	1/1-1/14		90.6	4/18-6/16	87.2	89.8	12/14-12/17	87.6	87.9				10	1983
1984	65	4/7-6/10	87.2	87.2										1	1984
1985	18	3/22-4/2	87.1	87.3	4/13-4/18	87.2	87.2							7	1985
1986	0													0	1986
1987	5	3/13-3/17	87.3	87.5										2	1987
1988	1	1/8	87.3	87.3										2	1988
1989	28	3/3-3/24	87.3	87.3	4/16-4/21	87.2	87.2							2	1989
1990	56	2/12-3/9	87.4	88.7	3/24-4/2	87.6	87.5	5/30-6/17	87.2	87.3	12/31	87.3		7	1990
1991	44	1/1-2/1		88.9	2/27-2/28	88.2	88.6	3/5-3/7	89.8	90.2	4/16-4/22	87.4	89.2	48	1991
1992	0													0	1992
1993	53	4/8-5/30	87.3	90.5										6	1993
1994	101	2/12-5/23	87.4	87.4										1	1994
1995	27	6/4-6/30	87.1	87.0										1	1995
1996	26	6/3-6/28	87.1	87.1										1	1996
1997	37	3/9-4/14	87.4	88.9										4	1997
55 YRS	1682													290	55 YRS

AVERAGE # DAYS PUMPED PER YEAR= 31 DAYS
TOTAL # DAYS PUMPED = 1682 DAYS
TOTAL # CONTINUOUS PERIODS PUMPED = 68 PERIODS
AVERAGE PUMP ON ELEVATION = 87.5 feet NGVD
AVERAGE PUMP OFF ELEVATION = 88.4 feet NGVD
MINIMUM PUMP ON ELEVATION = 87.1 feet NGVD
MAXIMUM PUMP ON ELEVATION = 90.7 feet NGVD
MINIMUM PUMP OFF ELEVATION = 87.0 feet NGVD
MAXIMUM PUMP OFF ELEVATION = 95.6 feet NGVD

RECOMMENDED PLAN PUMP OPERATION

64. For the recommended plan, Alternative 5, the period-of-record routing models pump station operation included 12 pumps at 1,167 cfs each with a pump on/off elevation of 87.0 feet, NGVD. The model operated the number of pumps based on the available storage above elevation 87.0 feet, NGVD; e.g., if the inflow was such that it required ten pumps, the model would turn ten pumps on automatically. The real time pump operation would use a forecast of Mississippi River stages, forecasts of inflows from the Steele Bayou and Sunflower River, and consideration of interior runoff conditions to determine requirements for pump operation. Since the diesel-driven pumps cannot be instantaneously turned on at the same time, a pump operation scheme will be developed to achieve a pumping capability and flood control benefits commensurate with the benefits projected in the flood routings and benefit analysis. Specific refinements to the pump operation sequence will be developed as part of the water control plan for the project. The recommended plan pumping units and pump station layout are designed for a nominal pump-on elevation of 87.0 feet, NGVD. To provide for a margin of safety, the discharge pipe maximum elevation was set at 106.0 feet, NGVD, as shown on Plate 6-79. This design allows for the pumps to operate efficiently and without damage down to elevation 86.0 feet, NGVD. Operation below 86.0 feet, NGVD, is outside of the design requirements for the pumping units and could damage the diesel engines and/or pumps.

STANDARD PROJECT FLOOD

65. The Standard Project Flood (SPF) represents the flood that can be expected from the most severe combination of meteorologic and hydrologic conditions that are considered reasonably characteristic of the geographic region involved, excluding extremely rare combinations. Procedures for estimating the SPF involve a single storm event--the Standard Project Storm (SPS). However, with base conditions, flooding in the Yazoo Backwater Area generally results from a number of storm events occurring over a period of several months.

66. Assuming a condition when the floodgates are closed and the SPF event occurs over the drainage basin. The inflows are of such magnitude that the 14,000-cfs pump station capacity is greatly exceeded and the interior ponding area would rise significantly with the floodgates operated for an extended period of time to evacuate the interior ponding for this headwater-type event. A similar but smaller event by comparison was the 1991 flood event, which was a headwater-type event with a low tailwater condition on the Mississippi River.

67. Should this condition occur with a high Mississippi River tailwater and an SPF event over the Yazoo Area, the pump station would slightly reduce the peak stage. The extent and magnitude of flooding with the SPF would not be greatly affected by the 14,000-cfs pump station because the storm is a very intense, short duration event with inflow rates much in excess of the pump station capacity.

HYDRAULIC DESIGN

INLET AND OUTLET CHANNELS

68. A portion of the inlet and outlet channels was completed by contract in 1987 prior to the cancellation of the project. The inlet and outlet channels were constructed with the exception of the portion that crosses Highway 465. Upon approval of this project, the portion of the inlet and outlet channels that has not been constructed will be reevaluated for stone protection and approach discharge apron for the 14,000-cfs recommended pump station. The cost required to finish construction of the inlet and outlet channels has been included in the cost estimate.

PUMP DESIGN

69. The pump station was designed and modeled prior to the cancellation of the project in 1987. Reference Technical Report HL-88-2, "Pump station Inflow-Discharge Hydraulics, Generalized Pump Sump Research Study," ERDC, February 1988.

ENVIRONMENTAL ANALYSES

70. Data were developed from the period-of-record routing output to support the environmental analyses assessing the impact of the recommended plan on the environmental resources. Plate 6-52 shows the environmental reaches developed to analyze the Yazoo Backwater study area. Since over 75 percent of the Big Sunflower River Maintenance Project Area is included within the Yazoo Backwater Study Area, the environmental reaches were developed so environmental effects could be measured for both projects. This allowed the environmental appendixes to evaluate two scenarios: B1 (Yazoo Backwater study without Big Sunflower maintenance) and B2 (Yazoo Backwater study with Big Sunflower maintenance). Habitat Evaluation Procedures team agreed to use the 2-year frequency flood area to evaluate impacts to the fisheries and terrestrial habitats. Stage-frequency, stage-duration, and stage-area data were used to compute the impacts to the waterfowl, fisheries, and terrestrial habitats. Plates 6-53 through 6-57 show the base conditions stage-duration and the Recommended Alternative stage-duration curves, respectively, using gage data from Steele Bayou, Little Sunflower, Holly Bluff, Anguilla, and Little Callao.

WATERFOWL

71. The ENVIRODUCK program was developed by the Vicksburg District with assistance from wildlife biologists from FWS and has been utilized on numerous previous studies. The program was developed to provide the hydrology data required to run the FWS caloric model for ducks. The model uses daily stages, stage-area curves, beginning and ending dates for the annual waterfowl season, maximum feeding depth, percent land use of available forage foods, and caloric value of the available forage foods. With this information, it calculates the daily acres flooded and the daily kilocalories of forage food available. The FWS model provides the kilocalories required per day for ducks. The model then calculates the duck-use-days (DUD) of available habitat (the number of ducks that can be supported each day by the available habitat). The daily DUDs are summed for the period-of-record and divided by the total days in the waterfowl seasons for the period-of-record to determine the average DUD provided in the study area. The procedure is repeated for each project alternative to determine the change in habitat available due to the various project alternatives. The conditions that were used to analyze the waterfowl habitat in this area were a timeframe from 1 November to 29 February and a maximum depth of 1.5 feet for feeding habitat. The period-of-record used was from 1943 to 1997. The average daily duck acres (acres with depths less than 1.5 feet) computed for Base Conditions and the Final Array can be seen in Table 6-21. These acres and land use were provided to ERDC for their waterfowl analysis. Detailed information can be found in Appendix 12.

TABLE 6-21
COMPUTED DUCK ACRES

CONDITION	LOWER PONDING AREA	UPPER PONDING AREA
Base (min. 70.0)	4,748	11,450
Base (min. 73.0) a/	6,102	11,896
Alternative 3	4,782	11,271
Alternative 4	4,923	11,650
Alternative 5	4,970	11,913
Alternative 6 b/	6,417	12,184
Alternative 7 b/	6,418	12,344

a/ Alternatives 3 through 7 have a minimum ponding elevation of 73.0 feet, NGVD.
b/ Alternatives 6 and 7 allow water to back in up to elevation 87.0 feet, NGVD.

FISHERIES

72. The ENVIROFISH program was developed by the Vicksburg District with assistance from fishery biologists from ERDC; FWS; and the Mississippi Department of Wildlife, Fisheries and Parks (MDWFP). The program was developed and refined over a 10-year period. Adjustments were made throughout that period based on input from the cooperating agencies. The purpose of the program is to provide the average spawning and rearing acres which are used for the calculation of aquatic habitat units. The ENVIROFISH program calculates two statistics--the average rearing acres and the average spawning acres. The rearing acres are computed by summing the daily acres flooded during the 122-day fishery season (1 March to 30 June) and then determining the daily average for each year. The spawning acres are calculated by summing the daily acres flooded which are greater than 1 foot in depth and for more than 8 consecutive days during the fishery season then determining the daily average. The annual fish acres for each year in the period-of-record are then averaged to determine the average seasonal rearing and spawning acres. The conditions that were used to analyze the fisheries habitat in this area was to determine acres within a timeframe from 1 March to 30 June, maximum depth of 10 feet, a minimum depth of 1.0 foot, and an 8-day minimum continuous duration. The period-of-record was from 1943 to 1997. The average seasonal fish acres (acres which fit all of the above criteria) computed for Base Conditions and the Final Array are shown in Table 6-22. These data were provided to ERDC who analyzed the fisheries habitat. Detailed information regarding the fisheries analysis can be found in Appendix 11.

TERRESTRIAL

73. The Habitat Evaluation Team selected six species for the terrestrial evaluation. Two of the species were water dependant. The wood duck required 90 days of continuous flood duration between March and May, and the mink required 90 days cumulative flood duration per year. These hydrologic requirements were determined by FWS and are published in the habitat models for these species. The computed terrestrial acres for Base Conditions and the Final Array are in Table 6-23. These data were provided to ERDC who analyzed the terrestrial habitat. Detailed information regarding the terrestrial analysis can be found in Appendix 13.

TABLE 6-22
COMPUTED FISH ACRES

Condition	Type Acres	Lower Ponding Area	Upper Ponding Area
Base (Min. 70.0)	Rearing	48,044	87,248
	Spawning	11,637	22,485
Base (Min. 73.0	Rearing	49,990	87,655
	Spawning	11,637	22,485
Plan 3	Rearing	37,313	72,450
	Spawning	4,956	12,881
Plan 4	Rearing	41,800	78,128
	Spawning	8,530	17,129
Plan 5	Rearing	44,016	82,955
	Spawning	10,182	20,637
Plan 6	Rearing	47,957	85,749
	Spawning	11,571	22,549
Plan 7	Rearing	49,861	87,873
	Spawning	12,610	24,340

NOTE: Rearing Acres - total average daily acres
Spawning Acres - acres with a duration of flooding greater than or equal to 8 days

TABLE 6-23
TERRESTRIAL COMPUTED ACRES

CONDITION	CATAGORY	WOOD DUCK	
		LOWE R PONDING AREA	UPPER PONDING AREA
Base Conditions (Min. Sump 70.0)	Min. Elev.	70	70
Base Conditions (Min. Sump 70.0)	Total Acres	9,743	21,012
Base Conditions (Min. Sump 70.0)	Tot. Forested	6,220	16,861
Base Conditions (Min. Sump 70.0)	BLH	2,191	9,050
Base Conditions (Min. Sump 70.0)	Cypress	3,523	7,811
Base Conditions (Min. Sump 70.0)	Cleared	4,029	4,151
Base Conditions (Min. Sump 73.0)	Min. Elev.	73	73
Base Conditions (Min. Sump 73.0)	Total Acres	16,658	23,472
Base Conditions (Min. Sump 73.0)	Tot. Forested	9,600	19,139
Base Conditions (Min. Sump 73.0)	BLH	3,682	10,647
Base Conditions (Min. Sump 73.0)	Cypress	5,918	8,492
Base Conditions (Min. Sump 73.0)	Cleared	7,058	4,333
Plan 3	Min. Elev.	70	70
Plan 3	Total Acres	9,743	21,012
Plan 3	Tot. Forested	5,714	16,861
Plan 3	BLH	2,191	9,050
Plan 3	Cypress	3,523	7,811
Plan 4	Min. Elev.	70	70
Plan 4	Total Acres	9,743	21,012
Plan 4	Tot. Forested	5,714	16,861
Plan 4	BLH	2,191	9,050
Plan 4	Cypress	3,523	7,811
Plan 5	Min. Elev.	73	73
Plan 5	Total Acres	16,658	23,472
Plan 5	Tot. Forested	9,600	19,338
Plan 5	BLH	3,682	10,758
Plan 5	Cypress	5,918	8,580
Plan 6	Min. Elev.	73	73
Plan 6	Total Acres	16,658	23,472
Plan 6	Tot. Forested	9,600	19,338
Plan 6	BLH	3,682	10,758
Plan 6	Cypress	5,918	8,580
Plan 7	Min. Elev.	73	73
Plan 7	Total Acres	16,658	23,472
Plan 7	Tot. Forested	9,600	19,338
Plan 7	BLH	3,682	10,758
Plan 7	Cypress	5,918	8,580

CONDITION	CATAGORY	MINK	
		LOWE R PONDING AREA	UPPER PONDING AREA
Base Conditions (Min. Sump 70.0)	Total Acres	8,021	24,072
Base Conditions (Min. Sump 70.0)	BLH	3,076	12,492
Base Conditions (Min. Sump 70.0)	Cypress	4,945	11,580
Base Conditions (Min. Sump 70.0)	No. of Days	111	113
Base Conditions (Min. Sump 70.0)	% of Year	30.4	31.075
Base Conditions (Min. Sump 73.0)	Total Acres	11,517	26,108
Base Conditions (Min. Sump 73.0)	BLH	4,417	13,360
Base Conditions (Min. Sump 73.0)	Cypress	7,100	12,748
Base Conditions (Min. Sump 73.0)	No. of Days	110	112
Base Conditions (Min. Sump 73.0)	% of Year	30	31
Plan 3	Total Acres	8,036	23,998
Plan 3	BLH	3,082	12,469
Plan 3	Cypress	4,954	11,529
Plan 3	No. of Days	111	113
Plan 3	% of Year	30.4	31.075
Plan 4	Total Acres	8,087	24,122
Plan 4	BLH	3,101	12,507
Plan 4	Cypress	4,986	11,615
Plan 4	No. of Days	111	113
Plan 4	% of Year	30.4	31.075
Plan 5	Total Acres	8,098	24,153
Plan 5	BLH	3,106	12,516
Plan 5	Cypress	4,992	11,637
Plan 5	No. of Days	111	113
Plan 5	% of Year	30.4	31.075
Plan 6	Total Acres	11,624	25,494
Plan 6	BLH	4,458	12,922
Plan 6	Cypress	7,166	12,572
Plan 6	No. of Days	110	113
Plan 6	% of Year	30.2	31.025
Plan 7	Total Acres	11,615	25,510
Plan 7	BLH	4,454	12,927
Plan 7	Cypress	7,160	12,583
Plan 7	No. of Days	110	113
Plan 7	% of Year	30.2	31.025

REFORESTATION/CONSERVATION FEATURES

74. The reforestation/conservation features on private developed lands in the Yazoo Backwater Study Area below the 1-year frequency flood elevation is the nonstructural feature of the recommended plan. The FESM model was used to determine and delineate the privately owned cleared lands within the 1-year frequency flood event. Using the updated 2005 land-use maps, the FESM model determined that in Alternative 5, 42,800 privately owned cleared acres were flooded by this event as shown on Plate 6-58. These acres include all cleared acres and catfish ponds without CRP, WRP, and WMAs. Plate 6-59 shows the delineation for the nonstructural unprotected areas below the 1-year event and the structurally protected areas above the 1-year event. More detailed information regarding reforestation can be found in the Mitigation Appendix 1.

WETLAND HYDROLOGY

75. The Corps Wetland Delineation Manual defines wetland hydrology as: “An area may have wetland hydrology if it is inundated or saturated to the surface for at least 5 percent of the growing season in most years.” The Corps interprets the “in most years” to mean the median annual 5 percent duration for a period-of-record. Hydrologists recommend using the longest period-of-record possible. A longer period-of-record contains more data and is more likely to include significant hydrologic events. The Yazoo Backwater levee and the associated outlet structures were completed in 1978, thus using 1978 to present would be one logical choice for the period-of-record. However, this would eliminate the 1973 flood, which is the flood of record. Corps guidance (Engineer Manual (EM) 1110-2-1413) for selecting the appropriate period-of-record requires that all significant hydrologic events be incorporated into the interior analysis. In 1994, the Vicksburg District determined that 1943-1992 would be utilized. This would provide a 50-year period. The period-of-record was expanded to 1943 to 1997 in 1998. That is the period-of-record that was utilized for the wetland study. Because no stage data were available for the period prior to completion of the Steele Bayou and Little Sunflower structures, the data were modeled with a runoff model (HEC-IFH) using observed rainfall data and calibrated to the existing data using the period-of-record routing model. The simulation of missing gage data with a routing model is standard engineering practice and is described in the aforementioned EM. The base simulated stage data were modeled to account for the base condition of the Backwater levee being in place. For example, the observed peak of the 1973 flood was 101.5 feet, NGVD, but the modeled peak was 100.3 feet, NGVD, which was the predicted peak with the Backwater levee in place.

76. The annual 5 percent duration elevation varies considerably from year to year, and this discussion constitutes a sensitivity analysis of the period-of-record stage data. The median 5 percent duration elevation at Steele Bayou is 88.6 feet, NGVD, with a standard deviation of 5.86 feet and a 90 percent confidence interval of 87.3 to 89.9 feet, NGVD. The 10-year median has a range of 5.8 feet about the median value, while the 25-year median, 5 percent duration elevation, has a range of 3.8 feet over the period-of-record. Lengthening the period-of-record over which the median is calculated reduces the observed modulation of the median 5 percent duration elevation. The Yazoo Backwater wetlands experience significantly different amounts of inundation from one year to the next. The annual stage hydrograph is generally represented as a sine curve. The amplitude of the sine curve (annual hydrograph) varies from one year to the next. The 5 percent duration elevation also appears to plot sinusoidally, but it has a varying period of 3 to 9 years. This results in periods of several years with above average water levels followed by several years of below average water levels. From this analysis of the variation of the median 5 percent duration elevation, it must be understood that the wetland hydrology within the Yazoo Backwater Area varies considerably from year to year and that the annual 5 percent duration elevation is a dynamic value, not a static value. In order to capture a median value that is representative of the wetland hydrology available in most years and to avoid the problems created by using a short period-of-record, the Vicksburg District chose to use the entire 55-year period-of-record to calculate the median 5 percent duration.

77. As stated above, this wetland delineation was based on a median 5 percent duration for the period 1943 to 1997. The period-of-record at the Little Callao gage begins in 1948, and the period-of-record for the Anguilla gage begins in 1949. These represent the initial years of data collection at these gages. Gage data for the period of 1943 to 1948 or 1949 at these two gages were interpolated from gage data from the Big Sunflower gages at Sunflower and Holly Bluff. This wetland analysis is the only analysis which utilized other gages. The additional gages were used in order to account for slope in the 5 percent duration elevation within the Backwater Study Area.

78. The wetland definition in paragraph 20 states that the sites must be inundated or saturated to the surface continuously for 5 percent of the growing season (14 days). This method accounts for the inundated areas, but the saturated areas are more difficult to determine. In order to compensate for areas saturated, but not inundated, the Corps interpreted the wetland definition in the following manner. The definition states that areas inundated for 12.5 percent of the growing season (34 days) are definitely wetlands and areas inundated for less than 5 percent of the growing season are not wetlands. The areas inundated for less than 12.5 percent, but more than 5 percent, may or may not be wetlands. This wetland delineation has interpreted all of these lands to be wetlands.

WETLAND ELEVATION DEVELOPMENT

79. The 5 percent wetland elevation data for the wetland delineation were developed from the six recording gage locations throughout the study area (Plate 6-12). These gages, along with other pertinent data, are listed in Table 6-24. The period-of-record for most gages was approximately 50 years. Observed stage data were utilized at four of the gages while computed stage data were used for the Steele Bayou and Little Sunflower gages. This computed period-of-record stage data are the same data that were utilized in the economic, terrestrial, waterfowl, and aquatic analyses. The computed stages were calibrated to the observed data.

TABLE 6-24
GAGES PERIOD-OF-RECORD DATA

Gage	Period-of-Record Available	Period-of-Record Used
Steele Bayou Landside at the Steele Bayou Structure	21 October 1968 to Present	1943 to 1997, computed
Steele Bayou at Grace	22 September 1955 to Present	1956 to 1997, observed 1943 to 1955, computed
Little Sunflower Landside at the Little Sunflower Structure	April 1978 to Present	1943 to 1997, computed
Big Sunflower at Holly Bluff	28 August 1910 to Present	1943 to 1997, observed
Big Sunflower at Anguilla	18 February 1949 to Present	1949 to 1997, observed 1943 to 1948, computed
Big Sunflower at Little Callao	3 February 1948 to Present	1948 to 1997, observed 1943 to 1947, computed

80. The wetland elevations were developed using the Corps WETSORT computer program. This program computes the annual stages for the 2.5, 5, 7.5, 10, and 12.5 percent duration events during the growing season; sorts the data by stage; and calculates the median elevation for each duration event. Required input data are the beginning and ending dates of the growing season and period-of-record stage data. An example of the output for the 5 percent duration event is provided in Table 6-25.

TABLE 6-25
STEELE BAYOU STRUCTURE
MONTH/DAY GROWING SEASON BEGINS 1 MARCH
MONTH/DAY GROWING SEASON ENDS 27 NOVEMBER
NUMBER OF DAYS IN 5 PERCENT DURATION=14

Rank	Stage	Elevation	Starting Date	Ending Date
1	99.69	99.69	5/14/1973	5/27/1973
2	96.38	96.38	4/27/1945	5/10/1945
3	95.43	95.43	3/2/1950	3/15/1950
4	95.08	95.08	4/29/1979	5/12/1979
5	95.01	95.01	6/1/1983	6/14/1983
6	94.48	94.48	4/11/1975	4/24/1975
7	94.45	94.45	5/10/1944	5/23/1944
8	92.96	92.96	5/12/1993	5/25/1993
9	92.9	92.9	5/23/1984	6/5/1984
10	92.85	92.85	3/1/1949	3/14/1949
11	92.8	92.8	5/4/1994	5/17/1994
12	92.78	92.78	3/29/1997	4/11/1997
13	91.99	91.99	4/12/1980	4/25/1980
14	91.78	91.78	4/19/1948	5/2/1948
15	91.2	91.2	3/30/1961	4/12/1961
16	91.06	91.06	4/19/1962	5/2/1962
17	90.58	90.58	4/30/1991	5/13/1991
18	90.19	90.19	6/15/1974	6/28/1974
19	90.01	90.01	4/29/1947	5/12/1947
20	90	90	5/9/1970	5/22/1970
21	89.8	89.8	4/1/1955	4/14/1955
22	89.56	89.56	3/9/1989	3/22/1989
23	89.26	89.26	4/13/1952	4/26/1952
24	89.25	89.25	6/16/1995	6/29/1995
25	89.19	89.19	6/14/1996	6/27/1996
26	89.04	89.04	5/15/1958	5/28/1958
27	88.78	88.78	4/12/1951	4/25/1951
28	88.64	88.64	3/1/1990	3/14/1990
29	87.65	87.65	4/3/1943	4/16/1943
30	87.58	87.58	3/9/1971	3/22/1971
31	87.43	87.43	3/27/1964	4/9/1964
32	87.09	87.09	3/22/1985	4/4/1985
33	86.93	86.93	4/9/1968	4/22/1968
34	86.83	86.83	4/2/1963	4/15/1963
35	86.68	86.68	4/25/1957	5/8/1957
36	86.51	86.51	4/22/1965	5/5/1965
37	86.4	86.4	5/6/1972	5/19/1972
38	86.19	86.19	4/27/1969	5/10/1969
39	85.82	85.82	5/19/1978	6/1/1978
40	85.62	85.62	3/9/1987	3/22/1987
41	85.39	85.39	4/3/1982	4/16/1982
42	84.2	84.2	5/9/1966	5/22/1966

TABLE 6-25 (Cont)

Rank	Stage	Elevation	Starting Date	Ending Date
43	83.91	83.91	2/29/1956	3/13/1956
44	83.82	83.82	3/30/1946	4/12/1946
45	83.28	83.28	3/4/1976	3/17/1976
46	82.36	82.36	5/20/1953	6/2/1953
47	82.09	82.09	5/22/1967	6/4/1967
48	80.33	80.33	4/19/1960	5/2/1960
49	79.77	79.77	6/11/1981	6/24/1981
50	79.7	79.7	4/11/1988	4/24/1988
51	79.06	79.06	3/20/1992	4/2/1992
52	78.79	78.79	3/12/1977	3/25/1977
53	77.88	77.88	11/10/1986	11/23/1986
54	76.38	76.38	3/2/1959	3/15/1959
55	72.6	72.6	5/6/1954	5/19/1954

NOTE: The median value is shaded.

81. The period-of-record stages for the five pump alternatives (Alternatives 3-7) were developed by the routing model. These stages were also analyzed by the Wetsort Program to determine the post-project wetland elevations for each gage. The program sorts the annual duration periods from highest to lowest and determines the median elevation. The Wetlands Delineation Manual states that areas inundated or saturated to the surface continuously for 5 percent of the growing season in most years may be wetlands. As the median value is the 50th percentile value, it guarantees that the requirement "in most years" is met in a period-of-record analysis for exactly 50 percent of the years. The median value is greater than or equal to the mean at most stations (five of six) for the base 5 percent duration condition. (NOTE: Steele Bayou at Grace was the only station with the mean 5 percent duration elevation greater than the median. This station is more than 40 miles upstream of the Steele Bayou structure and it is upstream of a weir. The use of the mean at this gage would have had little impact on the wetlands delineation.) The decision to use the median wetland elevation instead of the mean elevation provides a conservative estimate of base wetland extent. An Arc-view model (FESM) was used to model both the mean and the median 5 percent duration extents for comparison. The median 5 percent duration area is 189,600 acres, while the mean 5 percent duration area is 174,600 acres. The areal difference between the two is 15,000 acres which represents 7.5 percent of the total wetland extent. The larger areal extent based on the median values was used as the base for this study because it is more protective of wetlands.

82. For example, based on the 55-year period-of-record, flood elevations indicated that the pump station would have been utilized in 42 years with Alternative 5. Similar calculations were conducted for each of the alternatives in the Final Array, but were not reported here. In 40 of those years, the pump station would have operated during the growing season (1 March through 27 November) and could have affected the 5 percent duration elevation. In 27 of the 40 years with pumping during the growing season, the number of consecutive days of pumping exceeds 14 and the 5 percent duration elevation was affected. Table 6-26 contains the annual pumping information for Alternative 5 alternative. (Column 1 is the year. Columns 2-5 provide the number of days of pumping for the first through the fourth pumping periods. Column 6 provides the number of days of pumping during the growing season, and column 7 provides the longest continuous period of pumping during the growing season. Columns 8-13 are yes/no indicating with 1=yes. Columns 8-11 are pumping days during the growing season equal or exceeding 14, 20, 27, and 34 days, respectively. Column 12 indicates whether pumping occurred during that year, and column 13 indicates whether there was pumping during the growing season.) The sum of these years for each duration will indicate whether the with-project median durations will change. When the number of effected years is less than 25, there will be no change in the median duration. For instance, at Holly Bluff the Wetsort results show there was no change in the annual 5 percent duration elevation in the 14 years with no pumping during the growing

TABLE 6-26
PLAN 5 ANNUAL PUMPING REQUIREMENTS

Year	Period1 Days	Period2 Days	Period3 Days	Period4 Days	Days in Growing Season	Longest Pumping Period In Growing Season	>14 Days	>20 Days	>27 Days	>34 Days	Years Pumping	Pump in Grows
1943	12	9			21	12	0	0	0	0	1	1
1944	8	34			43	34	1	1	1	1	1	1
1945	68	8	11		87	68	1	1	1	1	1	1
1946	15	11			0	0	0	0	0	0	1	0
1947	23				23	23	1	1	0	0	1	1
1948	19	40			59	40	1	1	1	1	1	1
1949	60	16			39	16	1	0	0	0	1	1
1950	60	12			29	17	1	0	0	0	1	1
1951	24	31			55	31	1	1	1	0	1	1
1952	15	36			36	36	1	1	1	1	1	1
1953	0				0	0	0	0	0	0		0
1954	0				0	0	0	0	0	0		0
1955	15				15	15	1	0	0	0	1	1
1956	0				0	0	0	0	0	0		0
1957	8				8	8	0	0	0	0	1	1
1958	12				12	12	0	0	0	0	1	1
1959	0				0	0	0	0	0	0	0	0
1960	0				0	0	0	0	0	0	0	0
1961	27	24			51	27	1	1	1	0	1	1
1962	50				50	50	1	1	1	1	1	1
1963	10				10	10	0	0	0	0	1	1
1964	12				12	12	0	0	0	0	1	1
1965	6				6	6	0	0	0	0	1	1
1966	0				0	0	0	0	0	0	0	0
1967	0				0	0	0	0	0	0	0	0
1968	10				10	10	0	0	0	0	1	1
1969	15	4			4	15	1	0	0	0	1	1
1970	21				21	21	1	1	0	0	1	1
1971	13				13	13	0	0	0	0	1	1
1972	7	9			7	7	0	0	0	0	1	1
1973	17	25	74		74	74	1	1	1	1	1	1
1974	43	5	18		23	18	1	0	0	0	1	1
1975	11	57	19		76	57	1	1	1	1	1	1
1976	0				0	0	0	0	0	0	0	0
1977	0				0	0	0	0	0	0	0	0
1978	0				0	0	0	0	0	0	0	0
1979	70				70	70	1	1	1	1	1	1
1980	29				29	29	1	1	1	0	1	1
1981	0				0	0	0	0	0	0	0	0
1982	1	18			1	1	0	0	0	0	1	1
1983	14	60	4		60	60	1	1	1	1	1	1
1984	65				65	65	1	1	1	1	1	1

TABLE 6-26 (Cont)

Year	Period1 Days	Period2 Days	Period3 Days	Period4 Days	Days in Growing Season	Longest Pumping Period In Growing Season	>14 Days	>20 Days	>27 Days	>34 Days	Years Pumping	Pump in Grows
1985	12	6			18	12	0	0	0	0	1	1
1986	0				0	0	0	0	0	0	0	0
1987	5				5	5	0	0	0	0	1	1
1988	1				0	0	0	0	0	0	1	0
1989	22	6			28	22	1	1	0	0	1	1
1990	26	10	19	1	38	19	1	0	0	0	1	1
1991	32	2	3	7	10	7	0	0	0	0	1	1
1992	0				0	0	0	0	0	0	0	0
1993	53				53	53	1	1	1	1	1	1
1994	101				84	84	1	1	1	1	1	1
1995	27				27	27	1	1	1	0	1	1
1996	26				26	26	1	1	0	0	1	1
1997	37				37	37	1	1	1	1	1	1
55 YRS					1335	1149	27	21	17	13	42	40

season and in 10 of 12 years where the longest pumping period was less than 14 days. The differences between the base and with-project median 5 percent duration elevation as you move up the basin are: Steele Bayou, 1.5 feet; Little Sunflower, 1.3 feet; Holly Bluff, 0.8 foot; Anguilla, 0.3 foot; and Little Callao, 0.1 foot. Thus, the greatest impact to wetland hydrology will be to areas closest to the pump station and diminish as you move upstream in the basin.

SATELLITE IMAGERY

83. The second step in the wetland delineation is the selection and classification of the selected flood scene. There are two basic types of classifications, supervised and unsupervised. For a supervised classification, a trained individual makes the decisions about classes. This is generally done by selecting areas from the satellite scene that represent a known land-cover class of pixels. These sites are generally called training sites. Computer software then determines the reflectance characteristics of these training pixels and finds all other pixels in the image which share these characteristics. For an unsupervised classification, a computer program analyzes the reflectance data from the satellite image, creates classes based on the statistical analysis of the reflectance data, and sorts the image into the classes. Basically, the difference is that a human makes the decisions in a supervised classification based on their knowledge and experience, while a computer makes the decisions in an unsupervised classification based entirely on the statistical analysis of the satellite images reflectance of light. Classification is the systematic clustering of the image pixels into classes based on their similar reflectance characteristics within the separate bands of the image. After the raw classification is performed, the identified classes must be labeled based on ground-truth information. Thematic Mapper (TM) satellite imagery was utilized for this step. A TM image contains seven separate bands of data and has a pixel size of 28.5 m squared. Each TM scene has three visible bands and four infrared bands. The observed stages on the dates of the flood scenes used to make the elevation-area curves were compared to the 5 percent duration elevation. After examining the stage data from ten dates, the 10 March 1989 flood scene was selected as most representative of the 5 percent elevation for this study. Table 6-27 shows the 5 and 12.5 percent duration elevations, the elevation of the 10 March 1989 flood scene, and the 1- and 2-year frequency flood elevations at the gage locations within the Yazoo Backwater Area. The 1- and 2-year frequency elevations are presented in Table 6-27 for comparison. Plate 6-64 shows the Big Sunflower River 5 percent duration profiles for both base and the final array of with-project conditions. Plate 6-65 shows the Steele Bayou 5 percent duration profiles for both base and with-project conditions. These profiles were developed in the same fashion as the stage-frequency profiles using the gages listed in Table 6-27.

TABLE 6-27
WETSORT ELEVATIONS
BASE CONDITIONS

Gage Location	12.5 percent Duration	5 percent Duration	10 March 1989	1-Year	2-Year
Steele Bayou Landside Gage	84.0	88.6	89.7	87.0	91.0
Steele Bayou at Grace	89.4	91.9	89.7	91.5	94.0
Little Sunflower Landside Gage	86.0	89.3	90.0	87.8	91.6
Big Sunflower at Holly Bluff	88.4	91.0	91.5	90.7	93.0
Big Sunflower at Anguilla	89.3	93.3	93.1	95.5	97.1
Big Sunflower at Little Callao	89.8	94.4	94.0	100.4	101.8

84. The raw satellite image was classified as described earlier. All pixels in the wet category were compared to the 2005 land-use classification to determine the land use of the flooded acres. Because the satellite sensors cannot distinguish between floodwater, lakes, and intentionally ponded water such as catfish ponds, the classification returns all areas covered by water. Therefore, all pixels from the resultant map, except the intentionally ponded water classes of the land use classification, were considered wetlands. Plate 6-66 shows the land use of the 10 March 1989 flooded areas.

85. Verification of the flood stages on 10 March 1989 was determined in the same fashion as for the elevation-area curves. The classified flood scene was printed at 1:24000 on transparent vellum and sandwiched with a 1:24000-scale quadrangle map. The extent of flooding was compared to the flood elevations for that date and the elevation contours by visual comparison on a light table. The 10 March 1989 flood scene has falling stages and generally overestimates the areal extent of flooding for the river stages on that date. For example, the river stages at Holly Bluff and Little Sunflower Structure were 91.5 and 90.0 feet, NGVD, respectively, but the areal extent of flooding indicates the water surface was higher. Thus, the selected flood scene conservatively estimates the areal extent of wetlands. This is illustrated on Plates 6-67 and 6-68. Plates 6-67 and 6-68 each depict two flood scenes, 10 March 1989 and 21 March 1987. The 21 March 1987 scene is depicted in dark blue. The areal extent of the 10 March 1989 flood is represented by the combined areas in dark and light blue. The water surface at points along the river between gages was determined by linear interpolation. Plate 6-67 shows that the water surface elevation at Holly Bluff is above the 90-foot contour and less than the 95-foot contour.

Plate 6-68 shows that the flooded area is very close to the 90-foot contour, which is the water surface elevation at the Little Sunflower gage. This type of analysis was performed for each flood scene at each gage to insure that the observed gage elevations matched the flood elevations on these dates.

LAND-USE CLASSIFICATION

86. Two new LULC classifications were developed after the 2000 Draft Report and SEIS as part of the wetland study. The first new LULC classification was performed in 2001 and was based on four satellite scenes acquired in 1999. All four were acquired by the LANDSAT-7 satellite. Images from 5 August, 22 September, 24 October, and 27 December 1999 were utilized. One or more bands from each of the scenes were composited into a single file, and a multitemporal classification was performed on the composite satellite scene. The use of imagery from several dates aided in the determination of crop type, due to the differences in planting and harvesting dates for the crops in the project area. For instance, corn is generally planted in March and harvested in late August or early September. Cotton is planted in May and harvested in October or November. The raw classified scene contained 70 to 75 classes which were clustered into seven land-use classes. The seven classes are crop, noncrop, forest, water, pond, cloud, and miscellaneous. Noncrop represents cleared lands not in row crops such as pasture, fallow fields, catfish pond levees, and reforested lands. The reforested subclass represented cleared lands which were replanted in trees. These include almost all of the Conservation Reserve Program (CRP) and Wetland Restoration Program (WRP) lands. The water class includes permanent water bodies and some marginal land adjacent to the water body. The actual water surface elevations differ between the satellite images. The land use was based on the highest water surface of the scenes, which means some adjacent wetlands are included in the water land-use class. The second new LULC was developed using 2005 imagery and was done in May 2006. Again, four scenes were utilized, and they were 25 May, 12 July, 16 October, and 17 November 2005. All four were LANDSAT-5 images. The raw classified scene contained 70 to 75 classes which were clustered into 16 and 7 classes for the full and simplified LULC, respectively.

VERIFICATION OF WETLAND DELINEATION

87. Verification was performed by the Vicksburg District's Regulatory Branch using the 1987 Manual during the summer of 2001. Onsite techniques or visual verification was performed utilizing Digital Raster Graphics (DRG) maps with the flood scene superimposed on the quadrangle map. Fifty-four sites were checked using these techniques. The sites were not randomly selected. Instead, the sites were selected along the gradient separating the wet areas from nonwet. More sites were selected in areas where the gradient was poorly defined.

Agreement was found in 52 of the 54 sites. The sampling sites are shown on Plate 6-69. An additional field verification exercise was performed jointly with EPA, FWS, and NRCS in 2003. Results of the additional field verification are presented in the Wetlands Appendix (Appendix 10).

WETLAND IMPACTS DETERMINATION

88. Wetland impacts are evaluated in Appendix 10.

EFFECTS OF RECOMMENDED PLAN

MISSISSIPPI RIVER AND YAZOO BACKWATER FLOOD STAGES

89. In the 1982 analysis and subsequent design analysis, the impact of a large pump station (25,000 cfs) on Mississippi River stages was evaluated by use of the Mississippi Basin Model, which was calibrated to 1973 conditions. Flood hydrographs for the 1973 and 1975 floods were introduced and stage hydrographs were recorded at stations on the Lower Yazoo and Mississippi Rivers for various conditions including preproject (no backwater levees), existing (levees and floodgates only), and the recommended 17,500-cfs pumping plan. The tests indicated a maximum increase of about 0.4 foot in riverside stages with the 25,000-cfs station in continuous operation. With the recommended 14,000-cfs pump station, the increase would be much smaller than with the 17,500-cfs station as tested.

90. From the routing results and rating curves, it is estimated that the maximum increase in peak stages with the 14,000-cfs pump station would be approximately 0.25 foot for riverside conditions near the initial pump startup elevation of 87.0 feet, NGVD. At 87.0 feet, NGVD, the water levels are below major damage levels for developed areas downstream of the pump station along the Yazoo and Mississippi Rivers. For example, for the start pump elevation of 87.0 feet, NGVD, on the riverside of the pump station and a comparable stage of 40.77 feet, NGVD, on the Mississippi River at Vicksburg gage (gage zero = 46.23 feet, NGVD), the flow is approximately 1.1 million cfs. The maximum discharge of 14,000 cfs from the pump station is approximately 1 percent of the total flow in the Mississippi River at the pump start elevation of 87.0 feet, NGVD.

NAVIGATION

91. The Recommended Alternative will not impact any stages on the Yazoo River for river stages below 87.0 feet, NGVD. Therefore, the navigation depth under low-flow conditions would not be impacted. The pump station outlet channel was designed to minimize crosscurrents in the navigation channel when the pump station would be operating. Reference Technical Report HL-90-4, "Yazoo Backwater Pump Station Discharge Outlet," ERDC, May 1990.

SEDIMENTATION

92. During certain prolonged periods when the pump station is not in operation and river stages are at moderate levels (80 to 87 feet), some minor sedimentation is expected to occur in the approach to the inlet channel and in the outlet channel near the confluence with the Yazoo River. While sedimentation is not expected to be of any major concern, the control of vegetation in the deposited areas will need to be pursued possibly on an annual basis. It is likely after the project is complete, that removal of sediment accumulations (averaging about 1 foot in depth over the extent of the channels which is approximately 80,000 cubic yards) once or twice in the life of the project may be necessary depending upon the sequence of hydrologic events which could result in deposition in the channels as described above. Material deposited in the outlet channel by the secondary currents of the Yazoo River may be returned to the Yazoo River without any significant impacts. That material deposited in the inlet channel will likely be disposed in upland areas available near the pump station. The Water Quality Appendix 16 also addresses sedimentation issues.

CHANNEL STABILITY

93. With the Recommended Alternative, the water surface slope in the existing connecting channel will be slightly steeper than base conditions. However, during the most severe conditions indicated by the period-of-record routings, the channel velocity would be less than 4 feet per second, and no channel stability problems are anticipated.

ENDANGERED SPECIES

94. Potential project effects to the endangered plant pondberry and the threatened Louisiana black bear were analyzed using period-of-record hydrologic data and the FESM model.

PONDBERRY

95. Since the 2000 Draft Report, additional hydrologic analyses were performed to support the Endangered Species Analysis which is found in Appendix 14, a reevaluation of field surveys for the 62 pondberry colonies sampled in May-June 2000 by Gulf South Research Corporation (GSRC), a contractor for the Vicksburg District, was undertaken in February-March 2001 by the Vicksburg District. Fifty colonies are located in the DNF, and 12 colonies are in Bolivar and Sunflower Counties, Mississippi. Each of these colonies were visited in February-March 2001 by Corps and GSRC personnel to locate each colony by GPS, get elevations of each colony, take pictures of each colony, measure the distance to the nearest water body, and obtain a soil sample to determine soil moisture content for each colony. The location of each pondberry colony was plotted on a map, and each colony was hydraulically tied to the river or stream that would flood it naturally. Based on the average elevation for each colony site, the stage frequency for each colony site was determined from the frequency profiles as shown on Plates 6-62 and 6-63. Existing and with-project flood frequency data for each of the 62 pondberry sites were developed and are displayed in the following report. The data were coordinated with GSRC and incorporated into the 24 August 2001 Revised Final Report, "Survey Report Reevaluation of Pondberry in Mississippi, Gulf South Research Corporation."

96. The DNF personnel provided the Vicksburg District with maps showing compartments that known pondberry sites were located in the DNF from a database compiled from pondberry surveys from 1988 to 2005. In a combined effort with the DNF, Vicksburg District, and other researchers, an analysis was performed to determine the relation of the pondberry sites located in the DNF to the 1-year frequency flood event. The Vicksburg District developed the 1-year frequency flood mapping to determine the number of pondberry sites in relation to the 1-year frequency flood event. The data are summarized and displayed in Appendix 14.

97. An overbank flooding analysis was performed to determine the potential for overbank flooding of pondberry colonies using observed stage-gage data from 1984 to 2003 on DNF to examine the pattern of overbank flooding. This period-of-record was selected because it best represented current conditions. The analysis used actual stage-gage data and the surveyed colony elevations of 49 sites in DNF included in the 2001 report (one site was located in a greentree reservoir and was not included). The stage frequency of the colony sites ranged from 0.17 to 17 years. Each colony was associated with the stage reading at one of three gages (Little Sunflower structure landside, Big Sunflower at Holly Bluff, and Big Sunflower at Anguilla) or interpolated points between the three gages in a spreadsheet analysis. It was assumed that if the stage reading was above the colony elevation, the colony was receiving overbank flooding. This is a conservative evaluation because in some cases, although the stage is higher than the colony

elevation, the water from the river may not be able to reach the site. A period-of record rainfall analysis was performed on observed rainfall gage data for the period 1984-2003. The Yazoo City, Mississippi, NWS gage was utilized due to its close proximity of the DNF, and the average rainfall over this 20-year period was approximately 56 inches (Plate 6-82). For the period 1984-2003, the annual precipitation has been 50 inches or greater in 16 of 19 years during this period (2003 is only a partial data set and not included). During this same time period, the average monthly precipitation was greater than 5 inches for November through April (Plate 6-83). The summary of this analysis is displayed and discussed in Appendix 14.

98. A pondberry wetland and geomorphology assessment was performed on the known pondberry colonies on DNF, and the 49 colonies from the 2001 reevaluation report were compared to the underlying geomorphology and the 5 percent duration backwater flooding (Plates 6-84 and 6-85). The 5 percent duration was selected because it meets the hydrology criterion for the jurisdictional definition of wetlands. The definition states that lands flooded for less than 5 percent of the growing season are definitely not wetlands. The growing season was defined as March to November and the dormant season December to February. This analysis assumed that backwater flooding was the only source of saturation. Most of the pondberry colonies occur on point bar and abandoned channel/courses. Eighty-nine percent of known colonies and 96 percent of the 2001 reevaluation report colonies occur on sites above the 5 percent duration backwater flood event. There is good agreement between geomorphology and the 5 percent backwater flooding duration, with most of the 5 percent duration occurring on backswamp areas. The with- and without-project distribution of pondberry colonies on the DNF by duration zone are shown on Plate 6-86. The summary of this analysis is displayed and discussed in Appendix 14.

99. Additional pondberry sites outside of the Yazoo Backwater Study Area were visited by Vicksburg District personnel in April and September of 2004. These pondberry sites were located along the St. Francis River in the St. Francis Sunken Lands WMA near Black Oak, Arkansas. These pondberry sites were documented and photographed.

100. A resampling of the 62 pondberry colonies was performed by GSRC in June-July 2005. The purpose of this study was to update the existing pondberry profile relative to the previously surveyed colonies. Additional soil samples were taken to determine soil moisture content and the general soil type. The results of this study are in the September 2005 Final Survey Report, “Reevaluation of Pondberry (*Lindera melissifolia*) in the Big Sunflower River and Yazoo River Backwater Areas, GSRC.”

101. Additional sampling of the 50 pondberry colonies on the DNF was performed by Vicksburg District personnel in January-February 2007 to obtain soil density readings using the Troxler Nuclear Density Machine Model 3411-B. Field notes were taken at each colony, and pictures were also taken.

LOUISIANA BLACK BEAR

102. The locations of the threatened Louisiana black bear were obtained from MDWFP Louisiana black bear database dated August 2004. There are four known den trees located in or near the DNF. Elevations of these four sites were determined using a professional survey crew. From this survey data, the flood frequency for each site was determined. Elevations of the four den trees ranged from 86.23 to 92.13 feet, NGVD. Three of the trees occur in the 1-year or less flood frequency, and one occurs in the 1- to 2-year flood frequency. Pump operation would have no effect on lands at or below the 1-year frequency.

EFFECTS OF PUMP ON FISH

103. The Vicksburg District provided information on pump design, as well as channel and pump velocities as summarized in Table 6-28, for use in evaluating impacts to fish. The possible impact of the project on fish, including impingement at the pumps and entrainment at the pump screens, is addressed in the Aquatics Appendix 11. Reference Technical Report HL-90-8 Yazoo Backwater Pump station Sump, Hydraulic Model Investigation, dated August 1990 and Technical Report HL-90-4 Yazoo Backwater Pump station Discharge Outlet Model Study, dated May 1990.

MINIMUM PONDING LEVELS AT THE STEELE BAYOU STRUCTURE

104. The current minimum ponding area elevation at the Steele Bayou Structure during periods of low water ranges from 68.5 to 70.0 feet, NGVD. With this operation plan, the structure was either closed or operated to maintain minimum ponding levels 3,475 out of 7,300 days (48 percent) for the period-of-record 1978 to 1997. Out of the 3,475 days, the structure was closed; 71 percent of the time (2,452 days), the structure was operated for environmental purposes (maintaining water in the river channels) and 29 percent of the time, the structure was closed for flood damage reduction purposes. A revision in this operation plan to raise this minimum ponding level to 70.0 to 73.0 feet, NGVD, was considered in the final array of alternatives. For base conditions with this operation plan, the structure would have been either closed or operated to maintain minimum ponding levels 5,017 out of 7,300 days (69 percent). Out of the 5,017 days, the structure would have been operated to maintain minimum ponding levels 80 percent of the time (3,994 days) for environmental purposes and would have been closed 20 percent of the time (1,023 days) for flood damage reduction purposes. Table 6-29 shows the number of days the Steele Bayou structure would be either closed or operated for maintaining minimum ponding levels for the period 1978 to 1997 for base conditions and the recommended alternative. Plate 6-51 shows the pumping and floodgate operation for the recommended alternative. The FESM model determined that 1,200 additional in-channel acres

TABLE 6-28

YAZOO BACKWATER PUMP STATION VELOCITIES a/

Location	Width (ft)	Height (ft)	Diameter (ft)	Pump (rpm)	Area (sq ft)	Velocity (ft/second)
Inlet Channel	300 b/	invert@65'	N/A	N/A	N/A	1.7
Trash Rack	23	22	N/A	N/A	506.0	2.3
Formed Suction Intake, FSI	22.92	8.833	N/A	N/A	202.5	5.8
Pump Prop	n/a	N/A	20	120-130	78.5	14.9
Discharge Outlet	11.5	8.25	N/A	N/A	94.9	12.3
Outlet Channel	150-346 b/	invert@76'	N/A	N/A	n/a	2.5

a/ Velocities were developed from detailed pump design and Technical Report HL-90-4 Yazoo Backwater Pump Station Discharge Outlet Model Study - May 1990.

b/ Inlet and Outlet Channel bottom width with 1 on 4 side slopes.

NOTE: Maximum flow rate for each pump is 1,167 cfs.

Average velocities measured for the 1973, 1991, and 1997 flood events at the Steele Bayou sttructure outlet varied from 1.27 to 3.65 feet per second with flows ranging from 27,800 to 48,500 cfs.

TABLE 6-29
NUMBER OF DAYS THE STEELE BAYOU STRUCTURE WAS
OPERATED FOR PERIOD OF RECORD 1978-1997

	Base Days	% Time Structure Operated	Rec. Alt. Days	% Time Structure Operated
Total Days (20 x 365)	7,300		7,300	
Total Days (With Min. Pond at 68.5-70.0)	3,475	48	4,865	67
Days > 70.0 (Flood Control)	1,023	29	1,203	25
Days < 70.0 (Environmental)	2,452	71	3,662	75
Total Days (With Min. Pond at 70.0-73.0)	5,017	69	5,352	73
Days > 73.0 (Flood Control)	1,023	20	1,203	22
Days < 73.0 (Environmental)	3,994	80	4,149	78

would be available during low-water periods with the revised Steele Bayou structure operation from 70.0 to 73.0 feet, NGVD. Assuming a flat slope on Steele Bayou and the Big Sunflower River, the FESM model determined the extent of minimum ponding level of elevation 73.0 feet, NGVD, would extend upstream approximately 30 and 63 miles, respectively. The impact of this increase in minimum ponding levels provided a cumulative increase of 1,384 acres of waterfowl foraging habitat and 2,353 acres of rearing habitat, without implementation of the structural measures (Appendixes 11 and 12).

FEDERAL EMERGENCY MANAGEMENT AGENCY (FEMA) FLOOD INSURANCE MAPPING

105. The base flood mapping for the entire study area was compared to the FESM model 100-year frequency base conditions flood delineation. The FESM model delineation produced very similar results. Coordination meetings with FEMA and the Mississippi Emergency Management Agency were held to address issues pertaining to flood insurance issues. The Corps is required by law to update any FEMA Flood Insurance Study mapping impacted by a project. The project will require updating of the current FEMA Flood Insurance mapping through the Letter of Map Amendment Revision (LOMAR) process. The LOMAR study typically will be performed when construction is over 50 percent complete.

CUMULATIVE IMPACTS

106. Cumulative impacts are the sum of all changes to an area by all of the projects. This discussion will be limited to impacts due to the Vicksburg District flood control projects in the Yazoo Backwater Study Area. These cumulative impacts were not addressed in the 2000 Draft Report.

BIG SUNFLOWER RIVER MAINTENANCE PROJECT

107. The Big Sunflower River Maintenance Project shares much of the Yazoo Backwater Study Area. The Yazoo Backwater Study Area is 926,000 acres, and the Big Sunflower River Maintenance Project area is 723,980 acres. The two studies share a project area of 513,565 acres or 55 percent of the Yazoo Backwater Study Area and 71 percent of the Big Sunflower River Maintenance Project area (Plate 10-51). While flood control channel modifications have occurred in the Yazoo Backwater Study Area, the primary control is the outflow from the basin area, which is affected by backwater effects from the Mississippi River, the capacity of the gravity outlets, and the proposed with-project conditions utilizing a pump. The channel modifications primarily impact the timing and magnitude of peak inflows. The rate at which

flows from the Steele Bayou and Sunflower River Watersheds enter the lower Delta's ponding area may be changed slightly if the conveyance capacity of the channels are modified, but the same volume of flow from the storm will reach the lower Delta. For example, analysis of the impacts of the Big Sunflower River Maintenance Project indicated that the maintained channel would shorten the travel time of major floods (having durations above flood levels of approximately 10 to 14 days) by approximately 12 hours. This is not a significant impact on the lower Delta because, if gates are open, the flood passes through the system; if gates are closed due to high Mississippi River stages, the water ponds in the lower Delta at a slightly faster rate initially. In an event of 10- to 14-day duration, getting the peak rate of flow into the system 12 hours sooner and then storing the flow for another extended period, which could extend to possibly several months until Mississippi River stages recede, is not considered of any significant impact. With a potential pump station in place, increased channel conveyance in the upstream watershed would shorten travel times, thereby resulting in a requirement for storage (and potential flooding) until the pumps could evacuate the flow. However, this storage requirement will occur in almost all instances where major flows are experienced as the pump capacities investigated are below the peak inflow rates for all storms in excess of an approximate 1-year frequency. Cumulative impacts to wetlands that are shared by both projects are addressed in the Wetlands Appendix 10.

MISSISSIPPI RIVER AND
TRIBUTARIES PROJECT (MR&T)

108. The cumulative impacts to the wetlands as a result of overall MR&T project was initiated in response to a request for data from FWS as part of the formal consultation on the endangered plant pondberry. This is additional information developed after the 2000 Draft Report. This analysis is explained in detail in the Wetland Appendix 10.

SECTION 3 - GEOTECHNICAL

GENERAL

109. The 2007 Yazoo Backwater Reformulation Study provides a detailed evaluation of geotechnical conditions at the project and reevaluation of the selected plan. The two main alternative plans evaluated geotechnically include a pump station alternative (with various sizes to be evaluated) and the initial array levee plan along the Big Sunflower and Little Sunflower Rivers. The purpose of this geotechnical portion of the study is to give a preview of the geology and soil types to be encountered and to provide sufficient geotechnical design input so as to properly evaluate each alternative and for cost estimating purposes.

SCOPE OF WORK

110. Geotechnical evaluations, including review of available soils information, geologic maps, previous reports, and field investigations, were performed to evaluate the geotechnical concerns for the different alternatives. Evaluation of the initial array levee alternative required extensive field investigations, as very little soils information was available. Field investigations along the proposed levee alignment and at each of the proposed structure sites (approximately 75) were performed utilizing the cone penetration test (CPT). The CPT is a method of obtaining in situ soils information including soil type, stratigraphy, and soil strength. Approximately 87 CPT tests were performed to obtain the required soils information and stratification of the levee foundation. Design analyses included slope stability to evaluate the stability of the recommended levee section and seepage analyses to determine the need for and location of seepage berms. Soils information concerning the levee alternative will not be presented in this report. Soils information and design of the pump station were performed previously and published in various Design Memorandums (DM) in the 1970s and 1980s. Since the recommended plan (Alternative 5) is a pump station, the remainder of this report will deal exclusively with the geotechnical considerations for the pump station. The information presented is based on published geologic reports, borings made for site selection and presented in DM No. 18, borings made for the general design and presented in DM No. 20, borings drilled subsequent to the GDM and presented in Supplement No. 1 to GDM No. 20, additional field investigations subsequent to GDM No. 20, and detailed design completed in 2005.

FOUNDATION EXPLORATION

SITE SELECTION

111. The initial field explorations for this project consisted of 79 borings taken for and presented in DM No. 18, Site Selection. The borings were taken during the period September 1983 to February 1984; however, these borings are considered good since no major deposition has occurred at the pump site. An analysis of the borings is discussed later in this report. Five piezometers were installed during this phase of field exploration to monitor ground-water fluctuations in the alluvial aquifer.

GENERAL DESIGN

112. Foundation explorations during the general design phases, and published in GDM No. 20, consisted of 22 borings taken during the months of June, August, and September 1984.

SUPPLEMENT NO. 1 TO DM NO. 20

113. Geotechnical explorations presented in Supplement No. 1 to DM No. 20 consisted of 61 borings taken at the site during the period November 1984 to June 1986. These borings were drilled to serve as the basis for the detailed geotechnical design and are prefixed YPS. Additional field investigations, which include undisturbed borings and cone penetration tests, were taken in 2003 during final detailed design.

FIELD METHODS

114. All borings were obtained using the rotary drilling method with drilling mud. Undisturbed samples in clays and silts were secured using a 5-inch I.D. vacuum type Shelby tube sampler or a Hvorslev (fixed piston) sampler. General samples were obtained in sands using a 2.5-inch-diameter drive tube or 2.5-inch-diameter split spoon sampler. Standard Penetration Test blow counts, or N-values, were recorded during the advancement of the split spoon sampler. Graphic logs of the borings taken during the Site Selection and General Design phases are shown in DM Nos. 18 and 20. Graphic logs of the borings taken for the geotechnical design (prefixed YPS), as well as six previously published borings which fall within the protected area, are shown on Plates III-2 through III-15 of Supplement No. 1 to DM No. 20. Selected electric logs for borings made during the site selection and General Design phases are published in DM Nos. 18 and 20. Cone penetration tests were performed in 2003 during final design and will be presented in design documentation and in the plans and specifications.

LABORATORY INVESTIGATIONS

115. Laboratory tests consisting of visual classification, water content determination, Atterberg Limits, grain-size analyses, and unconfined compression (UC) tests were performed by the Vicksburg District Soils Laboratory. The Mississippi Valley Division Soils Laboratory performed unconsolidated-undrained (Q) triaxial and consolidated-drained (S) direct shear tests and one-dimensional consolidation test. The consolidation, UC, Q, and S tests were performed on representative clay samples only. Test data summaries and individual test data sheets are presented on Plates III-17 through III-52 of Supplement No. 1 to DM No. 20.

REGIONAL GEOLOGY

PHYSIOGRAPHY-TOPOGRAPHY

116. The Yazoo Backwater Pump Station site is located near the southern limits of the Yazoo Basin, a subprovince of the Mississippi Alluvial Valley. The Yazoo Basin is bounded on the west by the Mississippi River and on the east by the Bluff Hills. The surface of the Yazoo Basin consists mainly of an intricate network of meander belt (point bar, abandoned channel, and natural levee) deposits. The point bar deposits, which form the ground surface at the pump station site, exhibit an undulating surface of ridges and swales partially covered by remnant natural levees. Natural ground surface elevations in the vicinity of the pump station range from approximately 55 feet, NGVD, at Centennial Lake, to more than 100 feet, NGVD, along the base of the Bluff Hills where elevations increase abruptly to 300 feet, NGVD, on the top of the Bluff Hills.

STRATIGRAPHY

117. The geologic formations present at the project site consist of the Quaternary alluvium, underlain by the Eocene Yazoo Formation. The alluvium is divisible into topstratum deposits, which overlay substratum deposits. The topstratum consists of fine-grained silts, clays, sandy silts, and silty sands deposited by vertical accretion. The substratum is comprised of a thick deposit of fine sands that grade downward to coarse sands and sandy gravel. Lenses of silty sands and clays are occasionally encountered in the substratum. The contact between the

topstratum and substratum is highly irregular and reveals channels of topstratum incised into the substratum. The substratum overlies the eroded surface of Tertiary formations within the Mississippi Alluvial Valley. In the study area, the substratum overlies the Yazoo Formation of the Jackson Group. The Yazoo Formation consists of highly plastic, impervious montmorillonitic clay. This formation is a regional aqualude.

STRUCTURE

118. The study area is situated about 25 miles west of the structural axis of the Mississippi Embayment. Much of the Mississippi Embayment is underlain by extensions of the Ouachita Mountain fold belt of Paleozoic age. Numerous major structures; i.e., fault systems, basins, uplifts, etc., of various ages lie, or partially lie, within the Mississippi Embayment, however, not within the project area. The established trace of the Pickens-Gilbertown Fault System extends from Gilbertown, Alabama, through Pickens, Mississippi, and terminates near the axis of the Mississippi Embayment approximately 30 miles northeast of the study area. The study area is situated a few miles southwest of the Monroe Uplift-Sharkey Platform, along the west limb of the structural embayment, where the formational dip is to the southeast. Surficial evidence of a northwesterly trending fault exists along Bluff Creek, in the Bluff Hills, approximately 4 miles north of Vicksburg and is referred to as the Bliss Creek Fault. The Bliss Creek Fault is reportedly Tertiary in age; i.e., only the Tertiary deposits have been disturbed, whereas the overlying Plio-Pleistocene deposits have not been disturbed. This observation indicates that movement along the fault has not occurred since Tertiary time. The northwesterly extent of the Bliss Creek fault is not known because the Tertiary surface is covered by more than 100 feet of alluvium. A straight line northwesterly projection of the fault from Bliss Creek places the fault trace about 1 mile northeast of the project site. The questionable extent of the fault, the apparent inactivity of the fault since Tertiary time, and the fact that the Tertiary surface is covered by more than 100 feet of alluvium in the area of the site, are considered sufficient reasons for dismissing the Bliss Creek Fault as a threat to the project.

TECTONICS AND SEISMOLOGY

119. The New Madrid earthquakes of 1811-1812 are generally considered to be the most powerful earthquakes in United States history and were rated approximately XI on the Modified Mercalli (MM) scale, and had a body-wave magnitude of approximately 7.2. Subsequent record keeping and more recent seismic monitoring show that the New Madrid area continues to be an active earthquake area. During the 1950s, more than ten earthquakes were recorded in the New Madrid area, with intensities of MM of V or VI. The numbers and intensities were similar during the 1960s and 1970s. Record keeping and seismic monitoring led to the development of earthquake zones across the United States, relative to occurrences and intensities of the earthquakes. The generally accepted southern limit of the New Madrid earthquake zone lies near

Marked Tree, Arkansas, northwest of Memphis, Tennessee (about 225 miles from the project site). In the area of the project site, earthquakes should be infrequent and of low intensity if they occur. It is recommended that 0.025g seismic coefficient be used for design purposes involving pseudo static analysis (Engineer Regulation (ER) 1110-2-1805, 30 April 1977 or EM 1110-2-1902, 27 December 1960, Change 1).

HYDROGEOLOGY

120. The entire study area is ultimately drained into the Mississippi River, which also bounds the region on the west and south. The Yazoo River, locally occupying an abandoned course, traverses the area from the northeast to the southwest and enters the Mississippi River at Vicksburg. The Steele Bayou, Big Sunflower, and Yazoo River drains most of the study area and forms the southern boundary of the project site. The fine-grained topstratum overlies the more permeable sands and gravels of the substratum. The hydraulic connectivity of the topstratum and substratum is dependent on the thickness, lenticularity, and permeability of the topstratum material. Permeable sandy lenses that are overlain and underlain by clay should be considered as hydraulically connected to the substratum during high water, and may develop perched water table conditions at low water stages. Piezometers indicate that the water table, as measured by the pressure head in the alluvial aquifer, fluctuates considerably and is primarily controlled by the stages on Steele Bayou and the Yazoo River. It is anticipated that a water table elevation above 100 feet, NGVD, will exist when the Mississippi River stage is at the Project Design Flowline.

SITE GEOLOGY

GENERAL

121. The Yazoo Backwater Pump station site is located in the alluvial valley of the Mississippi River approximately 8 miles north of Vicksburg. Ground surface elevations vary from 79 to 91 feet, NGVD, and average 85 feet, NGVD. An interpretation of the local geology is presented in ERDC Technical Report 3-480, "Geological Investigations of the Yazoo Basin" (Vicksburg Quadrangle) by F. L. Smith, 1979 (Plate 6-70). Alluvial sediments are generally divisible into a fine-grained upper unit called the topstratum and a coarse-grained lower unit called the substratum. Technical Report 3-480 further classifies topstratum sediments based on their environment of deposits. Each category of sediments contains a suite of material types whose engineering properties vary within known limits. The topstratum deposits present at the pump station site are point bar in origin. Point bar topstratum is deposited on the inside of

river bends as a result of meandering of the stream. Point bar deposits consist of an alternating series of ridges and swales. Ridges are elongated silty sandy bars deposited during high river stages. Swales are fine-grained deposits which accumulate between ridges during falling river stages.

TOPSTRATUM

122. Investigative borings revealed the following subsurface conditions. Point bar topstratum thickness ranges from 13 to 63 feet and averages 37 feet. The topstratum is composed primarily of silt (ML) and silty sand (SM, SP-SM) with subordinate amounts of clay (CH-CL). The silt (ML) is generally gray with sand, silty sand, and clay strata. The silty sands (SM, SP-SM) are brown, fine-grained and contain occasional clay strata. The clays are gray and brown, range from medium to hard in consistency, and contain silt strata, sand strata, and roots. Excavation for the pump station structure will extend through the topstratum materials to approximately elevation 50 feet, NGVD. Plates 6-71 and 6-72 show the relationship between the geology and the structural excavation along the pump station and approach channel centerlines.

SUBSTRATUM

123. Four of the exploratory borings penetrated through the quaternary alluvium and into the underlying Yazoo Formation. These borings show that the substratum extends to an average elevation of -57 feet, NGVD, and has an average thickness of 103 feet. The substratum is composed of gray sand (SP) with subordinate amounts of silty sand (SM) and silty fine sand (SP-SM). The sand is fine to medium and contains occasional silt strata, lignite, silty sand strata, and a trace of gravel. This unit will form the foundation for the structure and will require dewatering prior to excavation. Dewatering is the temporary drawdown of ground-water levels for construction purposes. The ground-water levels will only be affected during construction of the pump station. After construction, the ground-water levels will return to their natural levels.

TERTIARY

124. The alluvial sediments are underlain by the Yazoo Formation of the Jackson Group. This formation consists of greenish-gray plastic clay (CH) with silt strata or lenses and scattered shell fragments. This formation is a barrier to ground-water migration (aqualude) and underlies the entire site.

ENGINEERING CONSIDERATIONS

GENERAL

125. Detailed design is beyond the scope of this report; however, design of the Yazoo Backwater pump was previously performed and results presented in DM No. 20 (April 1985) and in Supplement No. 1 to DM No. 20 (June 1987). A detailed review of the borings and the design analysis of DM No. 20 and Supplement No. 1 were performed. Additional field investigations and detailed design were performed and completed in 2005. These files can be found in the design documentation files on the Vicksburg District website. The following observations from that review are presented below as engineering considerations.

CHANNEL SLOPES, EXCAVATION SLOPES, COFFERDAM, AND STRUCTURE SLOPES

126. Borings indicate there are no thick clay swales present at the site. Areas that have no clay in the topstratum are present in the inlet channel and structure area. Excavation of the inlet channel, structure area, and some of the outlet channel will expose substratum sands which are highly erodible. Any erodible soils on the channel slopes will be protected by filter fabric and riprap which will reduce the potential for erosion. Slope stability analyses presented in DM No. 20 indicate all slopes are safe with greater than 1.3 factors of safety against sliding along deep-seated failure planes. Additional stability analyses during final design verified adequate factors of safety.

FOUNDATION SETTLEMENT

127. The foundation for the pump station will be located in point bar deposits. Settlement analyses of all pertinent structures, including the pump station, wingwall monoliths, intake structures, pump bay, and service bay, indicated differential settlement between the pertinent structures would possibly be unacceptable. Preloading of the foundation will be necessary to develop all immediate settlement prior to construction which will then limit settlement of the foundation to acceptable levels. Preloading is the temporary loading of a foundation site with suitable fill material to induce consolidation and settlement prior to construction. Preloading of the pump station site will be one of the first items of work in the construction sequence for the project.

DEWATERING

128. Dewatering is the temporary drawdown of ground-water levels for construction purposes. The thickness and permeability of the substratum sands indicate the need of an extensive dewatering system during construction of the pump station. DM No. 20 contains a comprehensive dewatering analysis that includes both a deep well design and a slurry trench design. A field pumping test was completed at the site in 1984. Water quality impacts due to dewatering will be addressed in the Water Quality Appendix.

UNDERSEEPAGE AND GROUND-WATER CONTROL

129. Detailed underseepage analyses were performed and the results presented in DM No. 20. Steele Bayou and Little Sunflower structures also required underseepage analyses due to the increased differential heads which will occur after completion of the pump station as the water level will be reduced by the pump of the ponding area. Seepage analyses of the two structures included examination of the piezometer data at both sites. The piezometer data indicate filters in the inlet channel(s) may have become clogged during their operation. This condition has a significant impact on the results of the analyses. Review of soils data at the pump station site indicates that piping could develop in the inlet channel due to concentrated underseepage into the inlet channel. Analyses indicate inadequate factors of safety against piping for all three structures when relief of the underseepage heads in the inlet channel areas of these structures is impaired. This condition results from excess heads created by the pump station and the resulting drawdown of the interior stages during high river conditions. At Steele Bayou and Little Sunflower structures, inlet channel relief appears to be impaired. This impairment is best attributed to siltation of the riprap and filters. It is suggested that relief wells be installed at the structures. Relief wells also provide the added benefit of hydrostatic uplift relief which improves the structures safety against overturning and uplift. The structure length of the proposed pump station provides adequate safety factors against piping in the inlet channel when underseepage relief is not impaired. However, the possibility exists that impaired seepage relief could result from siltation in the future as it has at other sites. Therefore, it is recommended that relief wells be included at this site to provide a positive means of pressure relief. The dewatering wells required for construction will be designed such that they function as relief wells after construction is complete. In addition, an under slab drain system will be required.

CONSTRUCTION MATERIALS

130. Materials that will be required during construction of the project are (1) clays for compacted impervious backfills, (2) silts and clays for random fills, (3) sands and gravels for concrete aggregate, (4) crushed stone for coarse concrete aggregate, and (5) riprap for paving of inlet and outlet channel slopes. Clays, silts, and sands can be obtained from excavated materials and nearby borrow sources. Sources for gravels, aggregates, and riprap will be presented in future design documentation and the construction plans and specifications. Quantities and volumes of construction materials were estimated and are provided in the Cost Estimate Section 7, Attachment 1 of this Appendix.

SECTION 4 - DESCRIPTION OF PROPOSED PROJECT DESIGN

GENERAL

131. The structural flood control alternatives investigated for the project included several pump station alternatives and the initial array levee alternative. The pump station alternatives included a pump station with pumping capacities ranging from 10,500 to 24,000 cfs and various pump operational stages and water management elevations and with electric motors and diesel engines as the pump prime mover. The energy analysis for the pump station is presented later in this section. The initial array levee alternative included numerous structures ranging in size from a single pipe conduit to a multicell box culvert with a reinforced concrete inlet structure and gated outlet structure. The structural, mechanical, and electrical quantities for all alternatives were developed and are reflected in the cost estimates.

132. The recommended plan presented in this report (see Plate 6-73) provides for the construction of an inlet channel, an outlet channel, a pump station with all appurtenant structures, and site work. The pump station will be located approximately 3,000 feet west of Steele Bayou structure and approximately 1,200 feet north of Highway No. 465. The pump station will be constructed of reinforced concrete and will consist of wingwalls, flood walls, retaining walls, intake structures, pump bay monoliths, control room monolith, and a service bay monolith.

133. The pump station will tie in with the existing backwater levee by means of new levee construction and floodwalls. In order to retain the backfill and maintain stable slopes, wingwalls will be required at the inlet and outlet abutments of the pump station. Preliminary structural designs for an electric-operated pump station were performed to develop a conceptual plan and were presented in a separate design memorandum, "FC/MR&T, Yazoo Basin, Yazoo Backwater Pump Station, Design Memorandum No. 20," April 1985, and "Supplement No. 1 to Design Memorandum No. 20," June 1987. The quantities from these reports were utilized to develop the cost estimate for the electric operated pump station. Following approval of the above supplement, North Pacific Division initiated design on a Feature Design Memorandum. Even though work on the Feature Design Memorandum was terminated, sufficient work was completed to substantiate the GDM level designs. The quantities for the electric operated pump station were adjusted to accommodate the diesel operated pump station including fuel storage and distribution. The final designs of the pump station will be developed to account for the intake elevation of the selected plan and any other cost-saving features. The designs will be presented in the Design Documentation Report which will be developed concurrently with the plans and specifications. The design criteria for the channels were prepared as a separate report,

"Yazoo Backwater Project, Yazoo Backwater Pump station, Channel Work Report," February 1985, and approved in a design conference held 5 March 1985 and completed in 1987. Based on this report, plans and specifications were prepared, and a channel work contract was awarded on 25 March 1986. This contract allowed for the construction of a portion of the inlet and outlet channels, the cofferdam, an interim levee, and a storage area as shown on Plate 6-74. There was approximately 885,500 cubic yards of material excavated from the inlet and outlet channels under the channel work contract. Approximately 995,500 cubic yards of material remains to complete the inlet and outlet channels which does not include excavation of any silt that has accumulated in the channels since the completion of the channel work contract. Even though the channel contract was designed for a 17,500-cfs station, it is sufficiently flexible to accommodate a smaller pump station. A description of the revised 14,000-cfs pump station, appurtenant structures, channels, and site work is furnished in the following paragraphs. Detailed design for the recommended plan 14,000-cfs pump station is currently being performed for the development of the construction plans and specifications.

DESCRIPTION OF CHANNELS AND SITE WORK

INLET CHANNEL

134. The inlet channel will connect the pump station to Steele Bayou and the connecting channel as shown on Plate 6-73. The inlet channel will be 3,065 feet long with an bottom width of 300 feet from Steele Bayou to Station 0+00 and then transition to a width of approximately 346 feet at Station 29+63.83. The inlet channel will have a bottom elevation of 65 feet, NGVD, and side slopes of 1 on 4. The inlet channel will be protected by 18 inches of riprap for the first 100 feet upstream of the intake structure. During construction, the inlet channel will be unwatered to allow for final channel construction and placement of bank stabilization measures. Unwatering is the temporary removal of surface water for construction purposes. The Water Quality Appendix addresses unwatering issues.

OUTLET CHANNEL

135. The outlet channel will connect the pump station to the Yazoo River as shown on Plate 6-73. The outlet channel will be 4,048 feet long with a bottom width of approximately 346 feet until Station 34+11.92 and then transition to a width of 150 feet at Station 40+00 and remain at 150 feet wide to Station 49+49.98 to pass under Highway 465 bridge/culvert. Then the outlet channel will transition to a bottom width of 300 feet at Station 53+99.98 until it enters the Yazoo River at Station 72+59.26. The outlet channel will have a bottom elevation of 76 feet, NGVD, and side slopes of 1 on 4 from the pump station to Station 49+49.98 and then transition to elevation 68.0 feet, NGVD, and side slopes of 1 and 4 at Station 53+99.98. The outlet channel will be protected by 24 inches of riprap for the first 200 feet downstream of the pump discharge

(stilling basin) and by 18 inches of riprap for 1,400 feet providing protection for the Highway 465 bridge/culvert. During construction, the outlet channel will be unwatered to allow for final channel construction and placement of bank stabilization measures. Unwatering is the temporary removal of surface water for construction purposes. The Water Quality Appendix addresses unwatering issues.

SITE WORK

136. All impervious material taken from the channel and structural excavation will be used in the cofferdam, new levee construction, and structural backfill. Due to a shortage of impervious material in the channels, it will be necessary to borrow impervious material from the borrow areas shown on Plate 6-73. Any excavated materials not required for construction will be placed within the borrow areas or stockpiled for future use. A storage area was constructed to provide sufficient room to store maintenance equipment, and any other storage facilities. The new levee will tie into the existing Yazoo Backwater levee approximately 1,400 feet west of Steele Bayou structure. From this point, the new levee will extend approximately 1,400 feet parallel to the centerline of the channel before turning 90 degrees and extending approximately 500 feet to tie into the east abutment of the pump station. The new levee will then extend from the west abutment of the pump station and tie back into the Yazoo Backwater levee approximately 3,800 feet west of Steele Bayou structure. There will be 50-foot berms between the toes of the new levee sections and the ends of the pump station. Two access roads will provide access from Highway No. 465 to the pump station as shown on Plate 6-73. See paragraph entitled "Access Roads" for further discussion of the access roads. Parking for visitors and pump station employees is provided.

STEELE BAYOU AND LITTLE SUNFLOWER STRUCTURES

137. The Steele Bayou and Little Sunflower structures were evaluated for a range of water management elevations from 70.0 to 90.0 feet, NGVD, with a tailwater elevation of 60 feet, NGVD, and were found structurally adequate. No structural or mechanical modifications of either of these structures will be required for the proposed 70 to 73 feet, NGVD, water management elevations.

DESCRIPTION OF STRUCTURES

FLOODWALLS

138. The pump station will tie into the new levee segments by means of floodwalls as shown on Plate 6-77. The floodwalls will consist of an inverted T-type reinforced concrete floodwall. The floodwalls will have an overall length of approximately 136 feet with a top elevation of 119.0 feet, NGVD. The T-type floodwalls will be soil founded and will have steel sheet pile cutoffs. The floodwalls will be founded on compacted clay fill.

INLET AND OUTLET WINGWALLS

139. The inlet wingwalls will retain backfill to elevation 95.0 feet, NGVD, as shown on Plate 6-77. The inlet wingwalls will consist of inverted T-type retaining wall monoliths which extend 50 feet parallel to flow before turning 45 degrees and extending approximately 200 feet. The top of the inlet wingwall will be elevation 95.5 feet, NGVD. The outlet walls are essentially the same except they retain backfill to elevation 104.0 feet, NGVD, and the top of the retaining wall will be elevation 104.5 feet, NGVD. A backfill drainage system consisting of a 12-inch perforated stainless steel collector pipe surrounded by select sand backfill will be provided for both the inlet and outlet retaining walls.

INTAKE STRUCTURE MONOLITHS

140. The four intake structures will consist of slabs and piers as shown on Plates 6-75 and 6-76. The approach monoliths will be 89 feet wide by 55 feet long. In addition to preventing cross currents, the piers will provide support for the trashracks, trash rakes, and service bridge.

141. The service bridge will consist of a concrete deck and concrete girders. Slots will be provided in the upstream portion of the approach monolith piers to accommodate stoplog closure.

PUMP BAY MONOLITH

142. The four pump bay monoliths will consist primarily of a substructure and a superstructure as shown on Plates 6-77 through 6-80. The monoliths will be 89 feet wide by 93 feet long. The substructure extends from the operating floor at elevation 112.8 feet, NGVD, down to the bottom of the monolith at approximate elevation 58.0 feet, NGVD. The substructure consists of a massive concrete pour with block-outs for the pump intake, pump impeller, discharge elbow, discharge conduit, and pump maintenance area.

143. The substructure also includes the intake gate operator support area at elevation 112.8 feet, NGVD, and the discharge gate at elevation 78.0 feet, NGVD. The superstructure will extend upward to the roof from elevation 112.8 feet, NGVD. It will consist primarily of a framework of columns and girders supporting a bridge crane and the roof. The roof will be supported by long span bar joists.

HIGHWAY 465

144. The roadway alignment for Highway 465 will be retained and raised to elevation 112.8 feet, NGVD, as shown on Plate 6-73. The new Highway 465 bridge/culvert will be designed so that it will be utilized to route traffic around the pump station on the Yazoo Backwater levees during major flood events which naturally overtop Highway 465. The embankment material for the new bridge/culvert will be obtained from the excavated material deposited from the pump station construction and moved to the road approachment location by the bridge/culvert contractor.

FUEL TRANSFER DOCK

145. A structural steel fuel transfer dock will be constructed 2,500 feet downstream of the pump station, as shown on Plate 6-73, to allow for the offloading of diesel fuel from barges. Dolphins will be provided to protect the dock and secure the barges during offloading of the fuel. Fuel will be transferred from barges via a piping system to storage tanks approximately 400 feet upstream of the pump station. Details of the fuel transfer dock are shown on Plate 6-81.

STOPLOGS

146. Two different sets of stoplogs, which are temporary gate closures, will be required--one for the landside and another for the riverside. The stoplogs will be fabricated from structural steel with rubber J-bulb seals. A lifting beam will be required for each size stoplog. The stoplogs will be stored in the maintenance area.

PUMP STATION FACILITIES AND APPURTENANCES

SUPERSTRUCTURE

147. Exterior walls will be of cast in place with brick façade concrete recessed into the framework. The pump station roof will be modified bituminous. The roof structure will be a rigid insulating roof deck over steel joists. Penetrations in the roof; i.e., vent stacks, skylights, exhaust fans, etc., will be avoided in order to preserve a clean, uncluttered appearance and enhance the integrity of the roof against potential leaks. Natural lighting will be provided by insulating fixed glass mounted in aluminum frames along the upstream face and downstream of the superstructure. Aluminum louvers and supply fans also installed in the upstream and downstream wall will provide ventilation.

CONTROL ROOM

148. An in-plant, climate-controlled control room will be elevated at elevation 129.0 feet, NGVD, and glassed with acoustical glass to provide increased observation of and isolation from the pump station operating floor. The control room will house the plant monitoring and remote control equipment and related peripherals. The office, lounge, and kitchen will be incorporated into the control room. The men's and women's restrooms and mechanical room will be located below the control room at elevation 112.8 feet, NGVD. The mechanical room will house the hydraulic pumps and reservoir for the gate operators.

NOISE CONSIDERATIONS

149. Sound levels inside the pump station have been evaluated. It is estimated that the sound pressure level inside the structure will be about 111 decibels (dB) with all 12 pumps operating. Acoustical glass will be required between the pumps and the operator's station in order to achieve a typical office sound pressure level environment. Because the structure will be constructed of concrete cast in place, it is anticipated that the exterior sound pressure level at the structure will be about 60 dB (the same level as average speech). Such a low sound level outside the building is considered quiet when compared to the nearby highway (about 85 dB).

SERVICE BAY

150. The Service Bay area, serviced by the bridge crane and a flatbed truck, having enough room to completely disassemble one pump, will be provided inside the pump station. There will be only one service bay area for the entire pump station. The air compressors will be located outside the building.

MAINTENANCE AREA

151. A fenced outside area will be provided for the mobile equipment storage building; paint, oil, and lubrication storage building; well house; intake stoplog storage; miscellaneous storage; and general maintenance. Wastewater will be treated with an approved onsite wastewater treatment plant.

MOBILE EQUIPMENT STORAGE BUILDING

152. A building located in the outside maintenance area will be required for the storage of the mobile crane, front-end loader, forklift, and tractors and to provide a sheltered area for miscellaneous storage and maintenance. The building will be a pre-engineered single span metal building of approximately 3,600 square feet, roofed, enclosed on four sides, and with a concrete floor. Garage doors will be provided on one side for equipment entrance.

PAINT, OIL, AND LUBRICATION STORAGE

153. A concrete block building of about 600 square feet will be located in the outside maintenance area for the storage of makeup oil, grease, and paint required for normal maintenance.

WELL HOUSE

154. A building of approximately 150 square feet will be located in the maintenance area to house the potable water pump, water treatment facilities, and storage tank.

FUEL OIL STORAGE AREA

155. A fenced fuel oil storage area will be provided. Two 250,000-gallon fuel storage tanks, clean lube oil storage tanks, and dirty lube oil storage tanks will be located within this area.

LUBE OIL STORAGE AREA

156. Clean and dirty lube oil will be stored on the lower level tunnel inside the pump station. Dirty lube oil supplemented with diesel fuel will be used to heat the plant.

PUMPS

General

157. The pumps presented in this appendix reflect previous pump selection presented in DM No. 19 Pump and Prime Mover.

Pump Design Criteria

158. The pump station will include 12 identical pumps rated at 1,167 cfs each, for a total plant design capacity of 14,000 cfs. The rated capacity will be discharged against a static (pool-to-pool) head of 3.7 feet. The maximum design static head is 20.0 feet, against which a capacity of 667 cfs per pump is required. Furthermore, each pump will be required to discharge not less than 1,167 cfs against a static head of -1.0 foot (the expected typical condition at startup). These requirements are presented in Table 6-30.

TABLE 6-30
DESIGN CONDITIONS FOR EACH PUMP

Static Head (feet)	Minimum Capacity (cfs)
20.0	667
3.7	1,167 (rated)
-1.0	1,167

159. The average annual operating time of the pump station will be approximately 31 days. The target landside elevation is 87.0 feet, NGVD, year-round. The maximum design pumping head of 20 feet (static) is reached with the river rising. Landside stages will be allowed to rise such that the design pump head limit is not exceeded.

Formed Suction Intake

160. The pumps will utilize a formed suction intake (FSI). Model testing has proven that this design minimizes submerged vortexing and prerotation at the pump intake, resulting in smoother pump operation. The elbow and conical section of the FSI will be fabricated from steel plate, which will form an embedded liner for pouring the concrete. Removable concrete forms will be used for the portion of the FSI upstream of the elbow.

ENGINES

General

161. The engines selected as the prime movers for the pump units will be diesel-fueled engines.

Engine Design Criteria

162. The power requirements for the engines are based on the pump horsepower requirements. During normal operation, the greatest power demand will occur at the design maximum head of 20.0 feet or when priming the siphon during pump startup. Given the constraints of the plant structure, siphon priming will require about 20.0 feet total dynamic head from the pump.

Therefore, normally the greatest power demand will be about 2,500 horsepower (hp). DM No. 19 explained that if the pumps are started when the river is high (above the siphon invert), either a variable speed drive or shutter gates must be used. The diesel engines act as a variable speed drive; therefore, the shutter gates are not required and the power requirement will not exceed 2,500 hp.

Engine Selection

163. The continuous duty horsepower rating of the engine should be 2,500 hp plus an anticipated 3 percent loss through the speed reducer for a rating of 2,575 hp. It is anticipated that a number of engine suppliers will be able to supply engines to meet these requirements.

SPEED REDUCERS

164. The speed reducers will be right-angle single reduction units designed for flood control pump drive service. The rating of the speed reducer should be 2,575 hp with a service factor of 1.5. It is anticipated that a number of gear suppliers will be able to supply gears to meet these requirements.

COOLING SYSTEM

165. The cooling system will provide the cooling requirements for the engines and speed reducers. The cooling water system will consist of four cooling water pumps. Under full load conditions, three cooling water pumps will be required--the additional pump serves as a standby. The cooling system intake will be located on the landside of the pump station inlet channel, and the water will be discharged into the pump station discharge outlet channel. At maximum engine load, the cooling system will only increase the temperature of the pump station discharge 0.05 degree F. The cooling system will not discharge any pollutants into the waters of the United States.

GATES AND GATE OPERATORS

166. The intake gates will be located on the intake to each pump. The intake gates serve the dual purposes of allowing the pump impellers to be dry during nonpumping periods and as the emergency backflow gates. The discharge gates on the riverside provide backflow protection and allow the pumps to come up to speed when a discharge head is present. Both gates will be roller type.

167. The gate operators will be hydraulic cylinders with dogs for open position. A centrally located hydraulic reservoir with dual pumps will supply the cylinders.

CRANES

168. A 40-ton bridge crane with 10-ton auxiliary hoist will be located inside the superstructure. The bridge crane will service the diesel engines, speed reducers, and the discharge gates.

TRASH RAKES

169. Two electric motor operated trash raking systems will remove trash to the service bridge.

MONITORING AND CONTROL SYSTEM

170. The pump station will be equipped with a controller for monitoring and control. Alternative operation will be by an operator located in the control room.

171. The system will monitor pumping unit operating parameters such as bearing temperature, bearing cooling water flow rate, engine oil level, reducer oil temperature, and engine cooling water temperature. Also, the system will monitor water levels, day tank fuel level, main fuel storage tank level, fuel and lube oil piping leakage, clean lube oil tank level, dirty lube oil tank level, contaminated water tank level and all support pumps, critical valve positions, flow rates, and system parameters. The system will notify the operator when any monitored function is outside of accepted operating parameters.

172. The controller will make decisions about some critical functions such as fuel system supply rate and cooling water supply. The pumping unit controllers will supply alarm and make critical decisions about individual pump units, stopping the unit – if the unit is operating outside critical parameters.

173. The control functions will allow the operator to perform functions such as start and stop or open and close pumping units, siphon breaker valves, intake and discharge gates, cooling water pumps, lube oil pumps, fuel transfer, lube oil transfer, and contaminated water transfer.

POWER

174. A 15-kilovolt (kV) class distribution feeder of approximately 10 miles in length will be supplied from Yazoo Valley Electric Power Association's Redwood substation. The overhead distribution lines will dip below grade and continue underground to the service entrance equipment.

STANDBY GENERATOR SET

175. A single emergency generator set will be located onsite with the capacity to feed all electrical during emergency power outages.

LIGHTING

176. High intensity discharge lighting is provided throughout the site, as well as on the pump station itself, providing a safe and energy-efficient installation.

SECURITY

177. The pump station site will provide the required security measures as dictated by Homeland Security. No public access will be allowed at the pump station site. Card access control and closed-circuit television cameras provide theft and vandalism detection and deterrent, as well as the means for the plant operator to monitor outside plant operations.

FIRE

178. The fire alarm and detection system will be a complete, addressable fire alarm reporting system. Notification appliances will be provided throughout the facility to alert personnel of a fire and take proper action for life safety and protection of property.

LIGHTNING PROTECTION

179. The pump station and outlying structures will include an Underwriters Laboratory listed master label lightning protection system to protect electrical systems during severe weather events.

COMMUNICATIONS

180. A telephone system that will provide paging, mass notification, and intercom capabilities will be provided.

ADDITIONAL EQUIPMENT

181. Additional equipment consists of the following:

a. Fuel oil system.

b. Clean lubrication oil system.

c. Dirty lubrication oil system.

d. Heating, ventilating, and air conditioning.

e. Unwatering system.

f. Waste water system.

g. Washdown water system.

h. Compressed air system.

i. Vacuum breaker system.

j. Fire extinguishers.

ESTIMATED AVERAGE ANNUAL OPERATION AND MAINTENANCE (O&M) COSTS AND MAJOR REPLACEMENT

Estimated Average Annual O&M Costs

182. The O&M costs presented in this paragraph include the cost of having personnel on duty at the pump station, cost of routine maintenance for the diesel engines, and diesel fuel cost. For the 14,000-cfs pump station capacity (12 pumps), the personnel cost is estimated at $978,000, and the estimated cost of routine maintenance on the diesel engines is $78,000. The personnel cost and routine maintenance cost is expected to be constant, regardless of the ponding area elevation. Fuel consumption for the recommended 14,000-cfs pump station was evaluated using a comprehensive analysis method. The analysis utilized the daily period-of-record routing of the plant, computed pumping system friction and discharge losses, a probable pump performance curve, gear reducer efficiency, parasitic losses, and diesel engine manufacturer's fuel consumption rates. The average daily diesel fuel rate was determined by dividing the sum of the entire period by the number of records indicating pumping was required. The average yearly fuel consumption of 286,883 gallons was then determined by multiplying the daily rate by the average number of pumping days, which is 31 days.

183. The best value procurement contract for the pumps, gears, and engines will require evaluation of energy usage as a major part of the pump selection procedure. Systems that utilize less energy while achieving the required performance will be given added value. This method will achieve the required capacity while utilizing the least energy possible, thus achieving the best environmental and economic balance. Further, any engine utilized in this station will comply with EPA standards.

184. The cost per unit volume of $1.94 per gallon for fuel used for annual cost computations was the value paid by the Government in July 2006 for bulk fuel delivered within 5 miles of the Vicksburg Harbor under the current DLA contract. This results in an annual fuel cost of $556,553.00. The operation and maintenance costs for the Final Array pump alternatives are shown in Table 6-31.

TABLE 6-31
O&M COSTS FOR THE FINAL ARRAY OF PUMP ALTERNATIVES

PUMP STATION CAPACITY	ALTERNATIVE	PUMP-ON ELEVATION (FEET, NGVD)	PERSONNEL COSTS ($)	MAINTENANCE COSTS ($)	FUEL ($)	TOTAL AVERAGE ANNUAL O&M COSTS ($)
14,000-cfs	3	80.0	978,000	78,000	1,155,013	2,211,013
14,000-cfs	4	85.0	978,000	78,000	770,598	1,826,598
14,000-cfs	5	87.0	978,000	78,000	556,553	1,612,553
14,000-cfs	6	88.5	978,000	78,000	432,960	1,488,960
14,000-cfs	7	91.0	978,000	78,000	232,156	1,288,156

NOTES: Based on fuel costs of $1.94 per gallon.

Estimated Major Replacement Cost

185. Major replacement cost is expected to incur at 35 years into the 50-year project life. The major replacement items and their present estimated costs are presented in Table 6-32. The present value of the major replacement items for the 14,000-cfs capacity pump station (12 pumps) is estimated to be $40,691,848.

TABLE 6-32
ESTIMATED MAJOR REPLACEMENT COST

Major Replacement Item Description	Estimated Cost Per Three Pumps (one monolith) ($)
2,700-hp Diesel Engine	1,905,202
Axial Flow Pump	7,166,880
Speed Reducer	943,980
High Speed Coupling	56,283
Low Speed Coupling	55,614
Total per Three Pumps	10,172,962

DEVIATIONS FROM PREVIOUS DESIGN MEMORANDUM

186. There are several features of the design presented here which deviate from the design presented in DM No. 19, “Pump and Prime Mover,” dated November 1988. The most significant deviation is the use of diesel engines to power the pumps rather than electric motors. Other deviations are hydraulic gate hoists and right angle speed reducers.

ACCESS ROADS

187. Construction and permanent access to the Yazoo Backwater pump station will be by Highway Nos. 61 and 465 from Vicksburg. From Highway No. 465, approximately 0.5 mile of access road will be constructed providing access to the pump station and joining the plant to the service road on the Yazoo Backwater levee. This access road will have a roadway width of 24 feet and an asphalt surface. During flood conditions when Highway No. 465 becomes inundated, levee roads will only provide access to local residents and emergency personnel.

PERIODIC INSPECTION AND CONTINUING EVALUATION

188. The periodic inspection and continuing evaluation portion of the supplement is the same as GDM No. 20.

ENERGY ANALYSIS

GENERAL

189. An energy analysis was performed to determine the pump operating costs so that the most cost-effective pump station configuration is selected. Electric motors and diesel engines as pump prime movers were compared. The first six documents listed in Table 6-1 describe the electric-motor drive alternatives. This paragraph focuses on the motors and engines as energy using devices.

ASSUMPTIONS

190. Certain assumptions were made for the energy analysis:

a. Standby Power. The differences in the costs of the standby power systems of all alternatives could be neglected. Diesel-electric generators would provide plant service power during utility power outages. The ratings of these systems, increasing as plant size increases with the alternative, are small when compared to the main pump power required. For alternatives of equal plant size, the differences in engine-generator set size could be neglected. The size would be similar because of fewer auxiliaries on the pump diesel-engine would require electric power. The diesel engines used to drive the pumps would power many of the auxiliaries on the engines, much like the alternator and water pump are powered on a car or truck.

b. Alternative Auxiliary Systems. Differences in plant auxiliary systems, such as lighting and receptacles and other miscellaneous electrical systems, could be neglected. The differences in the number of pumps in a particular type of alternative had little effect because the costs of the auxiliary systems are so small compared to the total electrical construction cost.

c. Engineering Considerations.

(1) Pump station structure. At the onset of the consideration of diesel engines as prime movers, it was determined that diesel engines would fit into the pump station structure that was designed for electric motors. Not having to enlarge the operating floor would provide large savings.

(2) Permanent power. Permanent power would be available for all pump station alternatives. For the diesel-engine alternatives, a 15-kV Class distribution feeder of approximately 10 miles in length would be run from Yazoo Valley Electric Power Association's Redwood Substation. For the electric-motor alternatives, a 115-kV Class subtransmission line would be run from Entergy's North Vicksburg Substation.

(3) Auxiliary power. The power drawn by auxiliary equipment contributes little to the average power-factor because the auxiliary load (mostly lighting and heating) is relatively small and of high power-factor. Therefore, the auxiliary load can be neglected for the purposes of the energy analysis.

d. Pump Operating Costs. The process to forecast the annual cost for operating the various alternative pump drives, namely, electric motors and diesel engines, begins with the output from the Period-of-record Program.

(1) General. The Period-of-Record Program is the source of pumping data needed to compute the pump station operating costs. Those pumping data are generated during a Continuous Simulation Analysis (CSA) of pump station operation over the period-of-record. Pumping data are extracted from the database output file generated. Postprocessing of these pumping data using pump and driver models results in month-by-month electrical meter and diesel fuel consumption histories that give the best predictions of pump station operation costs available. Applying electric and fuel rates on a monthly basis over the period-of-record result in electrical and diesel billing histories, from which the average annual cost of operating the pump station naturally follows.

(2) Extending period-of-record routing data.

(a) CSAs of pump station operation over the period-of-record compute and summarize monthly, annual, and total pump station operation data, such as energy usage and pump operating time. However, the period-of-record model does not estimate demand and power factor. Although pump station operation data can be utilized to give a rough estimate of maximum demand during the period-of-record, such data cannot be used to account for the effects of the monthly demands on the electric bill over the period-of-record. Such data are also not amenable to evaluating power-factor correction.

(b) Given an average value of engine efficiency, fuel quantities can be very roughly estimated by converting the resulting megawatts per hour to British Thermal Units (BTU), then applying the high-heat value to convert BTU to volume of fuel, and finally dividing by the average engine and speed reducer efficiencies.

(c) The pumping data generated by the period-of-record model only while the pump station was operating are extracted from the model output database. Each extracted record has fields for the date, time, flow, ponding area elevation, and static (differential) head computed during each time step while pumping; a 24-hour time step was used in this study. The file is then processed in an Excel workbook to produce the electrical metering and fuel usage histories. The output data generated using data from the model are energy usage; real, reactive, and apparent motor input power (demands); average power factor; and fuel usage.

(d) To properly configure the pump characteristics in the period-of-record model, the system loss curve is built into the pump H-Q (head-capacity) and η-Q (efficiency-capacity) curves and the drive efficiency is included in the η-Q curve. These may be called a "static (pool-to-pool) pump performance curves," in which all losses are taken into account, modeling the entire pumping system from intake to discharge.

(e) Electric power demand charges, power-factor penalties, and minimum monthly charges can add significantly to pump station operation costs. Because of the way demand is measured and used to calculate various charges for monthly electric bills, it can cause a dramatic increase in the annual electrical operation cost. Thus, it should be no surprise that concerns are frequently expressed over demand charges. The billing demand charge usually penalizes the seasonal consumer, like pump stations. Also, energy charges, power-factor penalties, and minimum monthly charges are sometimes linked to the billing demand. An electrical metering and billing history can account for these charges.

(3) Histories. Applying the applicable rate schedule from YVEPA to the electrical metering history results in an electrical billing history, which is a month-by-month cost history of electric bills over the period-of-record. Unit fuel costs are similarly applied to the fuel usage history. Average annual electric bill and fuel usage cost are calculated from all the months in the period-of-record. Computation of the electrical metering and billing histories gives an accurate prediction of electrical operation costs. The process is much simpler than computing electrical energy usage where internal combustion engines are being considered. Only the average annual volume of diesel fuel need be computed before applying unit costs for fuel.

(4) Benefits. The main benefit of this method is that demand and power factor can now be adequately estimated. Another benefit is that power-factor correction, drive efficiency, and different electric utility rate schedules can be readily evaluated. The last benefit is that the electric utility and fuel supplier need to have an understanding of the amount of energy to be supplied and when.

(5) Pump station operation and maintenance costs. These are the costs for operating and maintaining the pump station, less the costs for operating the pump units. These costs are shown in the MCACES attachment (Attachment 1).

RESULTS

191. Diesel fuel cost (excluding engine maintenance) was significantly lower than electrical cost, approximately 8 to 10 times lower. Even when the higher cost of maintaining the diesel engines (over electric motors) is taken into account, the total cost for operation and maintenance of the engines is still significantly lower than that associated with electric motors. The high electric rates proposed by YVEPA and relatively lower diesel fuel cost priced the electric motor option out of reach. The diesel engine alternative was further supported by the use of the same floor space as was used with electric motor.

192. Table 6-33 is a sample of the calculation period data generated from the 14,000-cfs (400 cubic meters per second), 12-pump alternative for the 55-year period-of-record. Table 6-34 is a partial listing of the electrical metering and fuel usage histories with the billing history for consecutive years and period-of-record statistics for the same alternative. Table 6-35 is given as an example of how much demand charges, power-factor penalties, and the minimum monthly charge can affect the electrical operation costs.

TABLE 6-33

POWER, ENERGY, AND FUEL USAGE--TOTAL, MIN, AVERAGE, AND MAX PERIOD-OF-RECORD VALUES

Date	Q	h_sump	h_static	h_river	h_total	N	Pump_eff	Bhp	E_Load	M_Load	Motor_eff	Motor_pf	P_Input	S_Input	W_e	Fuel_use
Apr 73	12998	89.57	(7.74)	97.31	10.07	4	78.0%	4755.5	64.4%	64.0%	95.5%	82.9%	15,044.7	18,098.3	360,112	7,870.8
Apr 73	12969	89.73	(7.83)	97.56	10.15	4	78.2%	4773.9	64.7%	64.3%	95.5%	83.0%	15,061.8	18,152.9	361,484	7,896.3
Apr 73	12946	89.86	(7.90)	97.76	10.22	4	78.3%	4787.6	64.8%	64.5%	95.5%	83.0%	15,104.6	18,193.7	362,511	7,915.3
Apr 73	12901	89.95	(8.05)	98.00	10.35	4	78.5%	4820.2	65.3%	64.9%	95.5%	83.1%	15,205.9	18,290.3	364,942	7,960.5
Apr 73	12881	90.02	(8.11)	98.13	10.40	4	78.6%	4831.3	65.4%	65.1%	95.5%	83.2%	15,240.7	18,323.3	365,776	7,976.1
Apr 73	12856	90.06	(8.19)	98.25	10.48	4	78.7%	4847.5	65.7%	65.3%	95.5%	83.2%	15,290.9	18,371.0	366,981	7,998.5
Apr 73	12809	90.08	(8.34)	98.42	10.61	4	79.0%	4877.1	66.1%	65.7%	95.5%	83.3%	15,383.1	18,458.5	369,195	8,039.6
Apr 73	12746	90.09	(8.54)	98.63	10.79	4	79.3%	4915.4	66.6%	66.2%	95.5%	83.5%	15,502.2	18,571.0	372,053	8,092.8
Apr 73	12693	90.10	(8.71)	98.81	10.94	4	79.5%	4947.5	67.0%	66.6%	95.5%	83.6%	15,602.1	18,665.2	374,451	8,137.4
Apr 73	12710	90.12	(8.65)	98.77	10.89	4	79.5%	4934.8	66.8%	66.5%	95.5%	83.5%	15,562.6	18,628.0	373,503	8,119.8
Apr 73	12718	90.13	(8.62)	98.75	10.86	4	79.4%	4928.0	66.7%	66.4%	95.5%	83.5%	15,541.5	18,608.0	372,995	8,110.3
Apr 73	12719	90.13	(8.62)	98.75	10.86	4	79.4%	4928.9	66.8%	66.4%	95.5%	83.5%	15,544.1	18,610.5	373,058	8,111.5
Apr 73	12708	90.11	(8.66)	98.77	10.90	4	79.5%	4937.7	66.9%	66.5%	95.5%	83.6%	15,571.4	18,636.3	373,715	8,123.7
Apr 73	12684	90.08	(8.74)	98.82	10.97	4	79.6%	4953.4	67.1%	66.7%	95.5%	83.6%	15,620.4	18,682.4	374,891	8,145.6
Apr 73	12640	90.04	(8.87)	98.91	11.08	4	79.8%	4974.4	67.4%	67.0%	95.5%	83.7%	15,685.7	18,743.7	376,456	8,174.7
Apr 73	12598	89.98	(9.01)	98.99	11.21	4	80.0%	5001.3	67.7%	67.4%	95.5%	83.8%	15,769.2	18,822.1	378,461	8,212.0
Apr 73	12576	89.94	(9.07)	99.01	11.26	4	80.1%	5011.4	67.9%	67.5%	95.5%	83.8%	15,800.7	18,851.5	379,217	8,226.1
Apr 73	12559	89.91	(9.13)	99.04	11.32	4	80.1%	5025.2	68.1%	67.7%	95.6%	83.9%	15,843.7	18,891.7	380,248	8,245.3
Apr 73	12590	89.92	(9.03)	98.95	11.23	4	80.0%	5004.2	67.8%	67.4%	95.5%	83.8%	15,778.2	18,830.4	378,677	8,216.0
Apr 73	12623	89.95	(8.93)	98.88	11.14	4	79.9%	4986.8	67.5%	67.2%	95.5%	83.7%	15,724.1	18,779.7	377,377	8,191.9
Apr 73	12663	90.01	(8.80)	98.81	11.02	4	79.7%	4962.6	67.2%	66.8%	95.5%	83.6%	15,648.9	18,709.1	375,573	8,158.3
Apr 73	12783	90.07	(8.42)	98.49	10.68	4	79.1%	4891.9	66.3%	65.9%	95.5%	83.4%	15,429.1	18,501.9	370,298	8,060.1
Apr 73	12867	90.13	(8.16)	98.29	10.45	4	78.7%	4842.8	65.6%	65.2%	95.5%	83.2%	15,276.4	18,357.2	366,632	7,992.0
Apr 73	12831	90.22	(8.27)	98.49	10.55	4	78.8%	4863.4	65.9%	65.5%	95.5%	83.3%	15,340.5	18,418.1	368,172	8,020.6
Apr 73	12735	90.37	(8.57)	98.94	10.82	4	79.3%	4919.7	66.6%	66.3%	95.5%	83.5%	15,515.7	18,583.7	372,376	8,098.8
Apr 73	12728	90.60	(8.59)	99.19	10.83	4	79.4%	4922.9	66.7%	66.3%	95.5%	83.5%	15,525.5	18,593.0	372,611	8,103.2
Apr 73	12767	90.89	(8.47)	99.36	10.73	4	79.2%	4901.2	66.4%	66.0%	95.5%	83.4%	15,458.2	18,529.4	370,996	8,073.1
Apr 73	12819	91.21	(8.31)	99.52	10.58	4	78.9%	4871.8	66.0%	65.6%	95.5%	83.3%	15,366.4	18,442.6	368,794	8,032.2
Apr 73	12899	91.54	(8.05)	99.59	10.35	4	78.5%	4818.5	65.3%	64.9%	95.5%	83.1%	15,200.7	18,285.3	364,817	7,958.2
Apr 73	12964	91.84	(7.85)	99.69	10.17	4	78.2%	4779.1	64.7%	64.4%	95.5%	83.0%	15,078.2	18,168.5	361,876	7,903.5
May 73	12987	92.13	(7.77)	99.90	10.10	4	78.1%	4760.6	64.5%	64.1%	95.5%	82.9%	15,020,4	18,113.3	360,489	7,877.8
May 73	12997	92.40	(7.74)	100.14	10.07	4	78.0%	4754.7	64.4%	64.0%	95.5%	82.9%	15,002.1	18,095.8	360,051	7,869.6
May 73	13063	92.66	(7.53)	100.19	9.88	4	77.7%	4709.6	63.8%	63.4%	95.5%	82.7%	14,861.6	17,961.1	356,678	7,806.9
May 73	13120	92.91	(7.35)	100.26	9.72	4	77.4%	4670.2	63.3%	62.9%	95.5%	82.6%	14,739.0	17,843.1	353,737	7,752.3
May 73	13170	93.14	(7.20)	100.34	9.59	4	77.2%	4638.7	62.8%	62.5%	95.4%	82.5%	14,640.9	17,748.4	351,382	7,708.5
May 73	13237	93.37	(6.94)	100.31	9.35	4	76.6%	4577.6	62.0%	61.6%	95.4%	82.3%	14,450.6	17,563.9	346,814	7,623.7
May 73	13291	93.57	(6.72)	100.29	9.15	4	76.1%	4528.9	61.3%	61.0%	95.4%	82.1%	14,298.8	17,416,1	343,172	7,556.1
May 73	13314	93.77	(6.62)	100.39	9.06	4	75.9%	4504.6	61.0%	60.7%	95.4%	82.0%	14,223.0	17,342.0	341,352	7,522.3
May 73	13321	93.95	(6.60)	100.55	9.04	4	75.8%	4502.3	61.0%	60.6%	95.4%	82.0%	14,215.9	17,335.1	341,183	7,519.2
May 73	13333	94.13	(6.55)	100.68	8.99	4	75.7%	4490.6	60.8%	60.5%	95.4%	82.0%	14,179.3	17,299.2	340,303	7,502.8

TABLE 6-33 (Cont)

Date	Q	h_sump	h_static	h_river	h_total	N	Pump_eff	Bhp	E_Load	M_Load	Motor_eff	Motor_pf	P_Input	S_Input	W_e	Fuel_use
May 73	13336	94.30	(6.53)	100.83	8.98	4	75.6%	4483.9	60.7%	60.4%	95.4%	81.9%	14,158.4	17,278.8	339,801	7,493.5
May 73	13341	94.45	(6.51)	100.96	8.96	4	75.6%	4479.3	60.7%	60.3%	95.4%	81.9%	14,144.3	17,264.9	339,463	7,487.2
May 73	13440	94.58	(6.10)	100.68	8.58	4	74.6%	4380.0	59.3%	59.0%	95.4%	81.6%	13,834.5	16,959.9	332,028	7,349.3
May 73	13506	94.69	(5.83)	100.52	8.33	4	73.9%	4312.4	58.4%	58.1%	95.4%	81.3%	13,623.7	16,750.8	326,969	7,255.5
May 73	13522	94.79	(5.76)	100.55	8.27	4	73.8%	4293.3	58.1%	57.8%	95.4%	81.3%	13,564.1	16,691.4	325,538	7,229.0
May 73	13528	94.87	(5.73)	100.60	8.24	4	73.7%	4284.2	58.0%	57.7%	95.4%	81.2%	13,535.5	16,663.0	324,852	7,216.2
May 73	13550	94.93	(5.64)	100.57	8.16	4	73.5%	4260.8	57.7%	57.4%	95.3%	81.1%	13,462.5	16,590.1	323,101	7,183.8
May 73	13611	94.97	(5.39)	100.36	7.93	4	72.9%	4194.3	56.8%	56.5%	95.3%	80.9%	13,254.9	16,381.9	318,117	7,091.4
May 73	13652	95.00	(5.22)	100.22	7.77	4	72.5%	4147.3	56.2%	55.9%	95.3%	80.7%	13,108.1	16,234.0	314,593	7,026.2
May 73	13716	95.02	(4.95)	99.97	7.52	4	71.8%	4069.3	55.1%	54.8%	95.3%	80.5%	12,864.5	15,987.2	308,747	6,917.9
May 73	13799	95.03	(4.60)	99.63	7.20	4	71.0%	3964.3	53.7%	53.4%	95.3%	80.1%	12,536.2	15,651.9	300,870	6,772.2
May 73	13797	95.03	(4.61)	99.64	7.21	4	71.0%	3967.8	53.7%	53.4%	95.3%	80.1%	12,547.0	15,663.0	301,128	6,776.9
May 73	13773	95.02	(4.71)	99.73	7.30	4	71.3%	3997.9	54.1%	53.8%	95.3%	80.2%	12,641.2	15,759.5	303,390	6,818.7
May 73	13858	95.00	(4.33)	99.33	6.95	4	70.1%	3893.8	52.7%	52.4%	95.2%	79.8%	12,315.6	15,424.7	295,574	6,674.1
May 73	13959	94.97	(3.87)	98.84	6.54	4	68.6%	3767.8	51.0%	50.7%	95.2%	79.4%	11,921.5	15,015.4	286,116	6,499.2
May 73	14053	94.94	(3.44)	98.38	6.15	4	67.2%	3641.2	49.3%	49.0%	95.1%	78.4%	11,535.8	14,710.2	276,859	6,323.4
May 73	14233	94.91	(2.61)	97.52	5.39	4	64.5%	3370.2	45.6%	45.4%	94.7%	75.5%	10,723.2	14,208.4	257,357	5,947.1
May 73	14383	94.88	(1.93)	96.81	4.77	4	62.3%	3124.5	42.3%	42.1%	94.3%	72.8%	9,980.7	13,710.1	239,537	5,606.0
May 73	14452	94.87	(1.53)	96.40	4.40	4	61.0%	2949.7	40.0%	39.7%	94.0%	70.9%	9,448.7	13,327.6	226,770	5,363.2
May 73	14527	94.86	(1.08)	95.64	3.97	4	59.7%	2740.2	37.1%	36.9%	93.7%	68.6%	8,807.1	12,835.3	211,371	5,072.3
May 73	14660	94.86	(0.27)	95.13	3.21	4	57.2%	2327.4	31.5%	31.3%	93.1%	64.1%	7,530.3	11,743.3	180,728	4,499.0

TABLE 6-34

DEMAND, ENERGY, AND FUEL USAGES AND COSTS FOR THE 12-PUMP, 14,000-CFS ALTERNATIVE

MONTH	YEAR	Motor pf	P Input	S Input	W e	Fuel Use	Billing kW	Demand ($)	Energy ($)	FCA ($)	Total Bill ($)	Diesel ($)
1	1972	100.00%	0	0	0	0	0	0.00	0.00	0.00	45,000.00	0.00
2	1972	100.00%	0	0	0	0	0	0.00	0.00	0.00	45,000.00	0.00
3	1972	65.00%	8,287	12,409	1,119,131	27,645	8,287	45,991.00	75,206.00	8,393.00	129,691.00	19,351.00
4	1972	71.70%	10,671	14,175	1,158,761	27,303	10,671	59,226.00	77,869.00	8,691.00	145,885.00	19,112.00
5	1972	76.20%	12,292	15,401	5,816,552	133,846	12,292	68,223.00	390,872.00	43,624.00	502,820.00	93,692.00
6	1972	100.00%	0	0	0	0	0	0.00	0.00	0.00	45,000.00	0.00
7	1972	100.00%	0	0	0	0	0	0.00	0.00	0.00	45,000.00	0.00
8	1972	100.00%	0	0	0	0	0	0.00	0.00	0.00	45,000.00	0.00
9	1972	100.00%	0	0	0	0	0	0.00	0.00	0.00	45,000.00	0.00
10	1972	100.00%	0	0	0	0	0	0.00	0.00	0.00	45,000.00	0.00
11	1972	75.10%	12,067	15,167	2,143,851	49,485	12,067	66,969.00	144,067.00	16,079.00	227,215.00	34,639.00
12	1972	66.90%	8,908	12,915	2,797,302	67,975	8,908	49,442.00	187,979.00	20,980.00	258,500.00	47,583.00
1	1973	66.40%	9,069	13,040	3,338,711	81,464	9,069	50,332.00	224,361.00	25,040.00	299,834.00	57,025.00
2	1973	69.10%	9,977	13,707	4,876,248	116,691	9,977	55,372.00	327,684.00	36,572.00	419,728.00	81,684.00
3	1973	79.60%	14,963	18,058	5,390,591	121,387	14,963	83,043.00	362,248.00	40,429.00	485,820.00	84,971.00
4	1973	83.40%	15,844	18,892	11,128,246	242,164	15,844	87,932.00	747,818.00	83,462.00	919,312.00	169,515.00
5	1973	79.60%	15,020	18,113	9,628,068	215,341	15,020	83,363.00	647,006.00	72,211.00	802,680.00	150,739.00
6	1973	100.00%	0	0	0	0	0	0.00	0.00	0.00	45,000.00	0.00
7	1973	100.00%	0	0	0	0	0	0.00	0.00	0.00	45,000.00	0.00
8	1973	100.00%	0	0	0	0	0	0.00	0.00	0.00	45,000.00	0.00
9	1973	100.00%	0	0	0	0	0	0.00	0.00	0.00	45,000.00	0.00
10	1973	100.00%	0	0	0	0	0	0.00	0.00	0.00	45,000.00	0.00
11	1973	100.00%	0	0	0	0	0	0.00	0.00	0.00	45,000.00	0.00
12	1973	78.50%	12,920	16,044	2,122,930	47,996	12,920	71,706.00	142,661.00	15,922.00	230,389.00	33,597.00
1	1974	66.60%	8,652	12,711	5,040,746	122,789	8,652	48,020.00	338,738.00	37,806.00	424,664.00	85,952.00
2	1974	69.80%	10,200	13,862	3,947,198	94,014	10,200	56,611.00	265,252.00	29,604.00	351,566.00	65,810.00
3	1974	79.40%	15,439	18,511	3,783,690	84,386	15,439	85,687.00	254,264.00	28,378.00	368,429.00	59,070.00
4	1974	78.00%	14,979	18,074	7,081,199	160,969	14,979	83,135.00	475,857.00	53,109.00	612,201.00	112,678.00
5	1974	100.00%	0	0	0	0	0	0.00	0.00	0.00	45,000.00	0.00
6	1974	100.00%	0	0	0	0	0	0.00	0.00	0.00	45,000.00	0.00
7	1974	100.00%	0	0	0	0	0	0.00	0.00	0.00	45,000.00	0.00
8	1974	100.00%	0	0	0	0	0	0.00	0.00	0.00	45,000.00	0.00
9	1974	100.00%	0	0	0	0	0	0.00	0.00	0.00	45,000.00	0.00
10	1974	100.00%	0	0	0	0	0	0.00	0.00	0.00	45,000.00	0.00
11	1974	100.00%	0	0	0	0	0	0.00	0.00	0.00	45,000.00	0.00
12	1974	100.00%	0	0	0	0	0	0.00	0.00	0.00	45,000.00	0.00

TABLE 6-35
SUMMARY OF DEMAND, ENERGY, AND FUEL USAGES AND COSTS FOR THE 12-PUMP, 14,000-CFS ALTERNATIVE

MONTH	YEAR	Motor pf	P Input	S Input	W e	Fuel Use	Billing kW	Demand	Energy	FCA	Total Bill	Diesel
400-cms	MO	Motor_pf	P_Input	S_Input	W_e	Fuel_use	Billing kW	Demand	Energy	FCA	Total Bill	Diesel
SUM	612	#N/A	#N/A	#N/A	595,622,700	13,458,747	#N/A	$10,518,640	$40,025,845	$4,467,170	$75,762,528	$9,421,123
MIN	#N/A	62.6%	0	0	0	0	0	$0	$0	$0	$45,000	$0
AVG	51	79.2%	3,097	3,911	973,240	21,991	3,097	$17,187	$65,402	$7,299	$123,795	$15,394
MAX	#N/A	100.0%	20,343	23,395	11,758,000	255,061	20,343	$112,901	$790,138	$88,185	$973,387	$178,543

SECTION 5 - RELOCATIONS

193. Construction of the Yazoo Backwater Pump Station will require MDOT to build a new State Highway 465 bridge/culvert across the outlet channel of the pump station. The bridge deck or culvert will be constructed to elevation 112.8 feet, NGVD. It will be built to current State of Mississippi standards. The embankment material will be obtained from the excavated material deposited from the pump station construction and moved to the road approachment location by MDOT contractors.

194. The relocation of one 2-wire, 7.6 kV power line, one 3-inch waterline, and a buried fiber optic telephone cable will be necessary to build the pump station.

195. Any clearing of right-of-way for the construction of the bridge/culvert and embankment has been included in the analysis for the recommended plan.

SECTION 6 - HAZARDOUS, TOXIC, AND RADIOACTIVE WASTE (HTRW) ASSESSMENT

196. The HTRW assessment was conducted following guidelines and procedures outlined in the regulation, "Hazardous, Toxic, and Radioactive Waste Guidance for Civil Works Projects," Engineer Regulation 1165-2-132 (U.S. Army Corps of Engineers, 1992), Lower Mississippi Valley Regulation 1165-2-132, "Water Resources and Authorities for Hazardous, Toxic and Radioactive Waste for Civil Works Projects" (14 June 1996), and the American Society for Testing and Materials, E1527-97, "Standard Practice for Environmental Site Assessments: Phase 1 Environmental Site Assessment Process" (ASTM, 1997). Engineer Regulation 1165-2-132 states that Civil Works project funds are not to be employed for HTRW-related activities except when specifically provided by law or where HTRW-contaminated areas or impacts cannot be avoided. The objective for conducting HTRW assessments is to identify HTRW problems early in a project design to ensure appropriate consideration of HTRW problems that can be addressed in the reconnaissance, feasibility, preconstruction engineering and design, land acquisition, construction, operations, maintenance, repair, replacement, and rehabilitation phases of Civil Works projects.

197. The Vicksburg District conducted an HTRW assessment of the proposed pump station construction area, located near the Steele Bayou control structure in Issaquena County, Mississippi. Vicksburg District personnel conducted an onsite assessment of the site on the 31 July 1998. HTRW assessments on the perpetual conservation easements properties within the study area/Mississippi alluvial valley will be conducted after they have been identified and prior to any real estate transactions.

198. The land use of this area is primarily rural and forested. Illegal dumping of household garbage and appliances was scattered along the service road to the Steele Bayou control structure. An abandoned refrigerator, television, and stove were observed scattered along the edge of the service road. No indicators of hazardous wastes were observed during the onsite assessment.

199. In addition to an onsite assessment, a record search of the Mississippi Office of Pollution Control environmental records for known hazardous or potential hazardous waste sites, landfills, leaking underground storage tanks, and national priorities list sites was conducted for this site. No known or potential sites were identified within a 1-mile radius of the proposed pump station construction area.

200. Based on this assessment, the risk of encountering HTRW at the construction site of the pump station is determined to be low. All construction contracts will require the proper removal and disposal of abandoned appliances, household garbage, and nonhazardous debris encountered during construction of this project.

SECTION 7 - COST ESTIMATE

201. The baseline estimate for the recommended plan was developed with a price level date of 1 October 2006. This estimate has been prepared in accordance with appropriate regulations. A detailed MCACES cost estimate can be found in Attachment 1.

SECTION 8 - OPERATION AND MAINTENANCE

GENERAL

202. The operation, maintenance, repair, replacement, and rehabilitation of all completed works after construction are the responsibility of the Corps, except for vegetation control in the inlet and outlet channels. They will be maintained by the local sponsor.

PROPOSED FACILITY

203. The operation and maintenance requirement for the Yazoo Backwater Pump station should be accomplished in accordance with the water control manual and the operation and maintenance manual.

STORMWATER PROTECTION PLAN

204. Construction activities associated with the pump station will conform to MDEQ Stormwater Construction General Permit. A Stormwater Pollution Prevention Alternative (SWPPP) will be developed during final engineering design according to USACE guidance (USACE, 1997). Both temporary and permanent stormwater management practices and controls will be incorporated into SWPPP to manage stormwater discharges from the project area as outlined in the “Mississippi Stormwater Pollution Prevention Alternative Guidance Manual for Construction Activities” (MDEQ, 2005) and the “Planning and Design Manual for the Control of Erosion, Sediment, and Stormwater” (NRCS, 1994). Continued maintenance and inspection of the stormwater management controls will be conducted throughout construction to ensure compliance with the general permit.

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