US Army Corps
of Engineers
Memphis District

Mississippi River Commission

REELFOOT LAKE
TENNESSEE AND KENTUCKY

VOLUME 2

APPENDIX A

ENVIRONMENTAL ANALYSIS

SEPTEMBER 1999

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REELFOOT LAKE
TENNESSEE AND KENTUCKY

APPENDIX A - ENVIRONMENTAL

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SECTION I

HABITAT EVALUATION SYSTEM ANALYSIS

Habitat Evaluation System (HES) Analysis

The Habitat Evaluation System (HES), U.S. Army Corps of Engineers (1980), was used to determine existing habitat quality, project future habitat quality, quantify future with-project impacts, and calculate net habitat gains. The HES is based on the fundamental assumption that the diversity and abundance of animal populations are determined by basic biotic and abiotic factors that can be readily quantified. The HES field data collection methodology rates key biotic and abiotic factors of habitat types on a scale of 0 to 1, with 1 representing the maximum value. These habitat ratings are called habitat quality index (HQI) scores.

In order to quantify values for each significant habitat type, habitat evaluations were conducted at potential impact sites (a total of 75 terrestrial plots were sampled). Field data collection was conducted by Memphis District biologists and with help from U.S. Fish and Wildlife Service biologists for portions of the sampling process. Plot sizes were as prescribed in the standard HES methodology. A description of the habitat types sampled are as follows:

Bottomland Hardwood – This palustrine wetland (i.e. wetland dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens) is a broad-leaved deciduous forest that is temporarily or seasonally flooded. These forests of the sample area are comprised of various bottomland hardwood associations (excluding baldcypress and tupelo) and total approximately 1,270 acres.

Cutover Bottomland Hardwoods – This palustrine wetland is a broad-leaved deciduous forest that is temporarily or seasonally flooded. These timber stands have been logged in the recent past (less than 10 years), and remaining stems are primarily young trees and of poor quality species composition (willow, ash, elder, etc.). These stands within the sample area total approximately 61 acres.

Wooded Swamp – This palustrine forest is found on semipermanently and permanently flooded sites within the project area. It is comprised of broad-leaved deciduous and/or needle-leaved deciduous trees. Baldcypress, water tupelo, swamp tupelo and black willow are dominant tree species. Presently, wooded swamps occupy approximately 423 acres of the area sampled. Note: Although this forest is often considered a bottomland hardwood forest type, it was placed into this separate wetland habitat category because of its tolerance for wetter site conditions.

In addition to existing habitat types which were actually sampled by HES plots, projections were also made for habitat quality expected to exist in some of the habitats to be created as a result of project construction. These "to be created" habitats include: Regenerating Bottomland Hardwoods to be created as part of the New Spillway Outlet Channel, Shelby Lake and Reelfoot Creek project features, Riparian Habitat to be created along the New Spillway Outlet Channel, Waterfowl Management Units to be created as part of the Shelby Lake and Reelfoot Creek project features, and Freshwater Marsh Habitat to be created as a result of the Shelby Lake and Reelfoot Creek project features. A description of these "to be created" habitat types is as follows:

Regenerating Bottomland Hardwoods – Upon maturity, this palustrine wetland will consist of a broad-leaved deciduous forest that is temporarily or seasonally flooded. These timber stands consist of previously cleared agricultural lands which will be planted during project construction with a mixture of bottomland hardwood seedlings and will mature over Project Life into a high quality wildlife habitat. These stands within the sample area total approximately 625 acres.

Riparian Habitat – Upon maturity, this palustrine forest will consist of a broad-leaved deciduous forest that is temporarily or seasonally flooded. These timber stands consist of channel banks along the New Spillway Outlet Channel which will naturally revegetate following construction with riverbank species, such as willow, birch, maple, and ash, as well as other bottomland hardwood species. This habitat type accounts for approximately 15 acres within the "to be created" project area.

Waterfowl Management Units – This habitat will consist of leveed agricultural fields which will be flooded during winter months to provide feeding and resting areas for resident and migratory waterfowl. Since these areas will be planted in annual crops, an HQI value was assigned which would remain constant over Project Life. Approximately 483 acres of Waterfowl Management Units will be constructed at the Shelby Lake site, and approximately 318 acres will be constructed as part of the Reelfoot Creek project feature.

Freshwater Marsh - This habitat will consist of freshwater marsh which will be created as a result of project construction at the Shelby Lake site and within the Reelfoot Creek sediment dam borrow pit. Approximately 122 acres will be created as part of the Shelby Lake site and approximately 51 acres will be created as part of the Reelfoot Creek project feature.

The four major areas in which HES sample plots were taken during the Habitat Evaluation Survey were Grassy Island, Lake Isom NWR, the location of the New Spillway, and the Reelfoot Creek area. HQI values for all sample plots are presented in Tables 1A through 1D.

TABLES 1A,1B,1C,and 1D - Habitat Quality Index Values for Grassy Island, Lake Isom NWR, the New Spillway, and Reelfoot Creek

TABLE 1A – Grassy Island HQI Values

Habitat Type	Plot Number	HQI Value
BLH	1-1	0.62
BLH	1-2	0.53
BLH	1-3	0.52
BLH	1-4	0.62
BLH	2-2	0.61
BLH	2-3	0.67
BLH	2-4	0.62
BLH	3-1	0.54
BLH	3-2	0.50
BLH	3-3	0.65
BLH	3-4	0.61
BLH	4-1	0.69
BLH	4-2	0.71
BLH	4-3	0.60
BLH	4-4	0.55

BLH = Bottomland Hardwoods

TABLE 1B – Lake Isom NWR HQI Values

Habitat Type	Plot Number	HQI Value
BLH	3-1W	0.61
BLH	3-2W	0.57
BLH	4-1W	0.55
BLH	4-2W	0.41
BLH	4-1E	0.62
BLH	4-2E	0.54
BLH	4-3E	0.51
BLH	5-1E	0.63
BLH	5-2E	0.51
BLH	6-1W	0.57
BLH	6-1E	0.60
BLH	6-2E	0.78
BLH	8-1W	0.76
BLH	8-2W	0.49

BLH	9-1W	0.58
BLH	10-1W	0.56
BLH	10-2W	0.45
BLH	10-3W	0.57
BLH	11-1W	0.72
BLH	11-2W	0.64
BLH	11-3W	0.70
BLH	12-1	0.61
BLH	12-2	0.53
BLH	13-1E	0.65
BLH	13-2E	0.48
BLH	13-3	0.57
WS	1-1	0.54
WS	1-2	0.71
WS	1-3	0.72
WS	1E	0.70
WS	2-1W	0.71
WS	2-2W	0.72
WS	2-1E	0.63
WS	2-2E	0.73
WS	3E	0.60
WS	3-3W	0.76
WS	5-1W	0.73
WS	5-2W	0.79
WS	6-2W	0.78
WS	7-1W	0.78
WS	7-2W	0.73
WS	8-3W	0.78
WS	9-2W	0.70
WS	9-3W	0.62

WS = Wooded Swamps

TABLE 1C – New Spillway HQI Values

Habitat Type	Plot Number	HQI Value
BLH	1S	0.41
BLH	2S	0.47
BLH	3S	0.44
WS	1W	0.55
WS	2W	0.79
WS	3W	0.78

TABLE 1D – Reelfoot Creek HQI Values

Habitat Type	Plot Number	HQI Value
BLH	1	0.43
BLH	2	0.78
BLH	3	0.74
BLH	4	0.69
BLH	5	0.53
BLH	6	0.50
BLH	7	0.43
BLH	8	0.63
BLH	9	0.75
BLH	10	0.61

In the HES analysis, average HQI values taken from individual sample plots were used in determining average habitat values. (In project features where habitats would be created by project construction, HQI values were taken from other studies where comparable habitats had been measured for HQI values.) These average HQI values were then projected for each habitat type, over Project Life, based on natural succession, expected project impacts such as increases in flooding or sedimentation, or other factors. In addition, expected changes in habitat type quantity (acres) were then projected over the 50-year project life for both future-without project and future-with project conditions. Both of these factors are explained in the "Assumptions" which follow each HES Analysis table.

A habitat unit value (HUV) was then derived, as a product of the HQI times acres, for each habitat type for future-without project and future-with project conditions. These HUVs were then annualized, and annualized HUV comparisons were made between future-without project and future-with project conditions to measure project-induced gains or losses in habitat quality.

Tables 2A through 2H include HES analyses of the existing areas where HES plots were taken, as well as the HES projections for the "to be created" habitats.

Grassy Island HES Analysis: In the Grassy Island portion of Reelfoot Lake, bottomland hardwoods are currently being impacted by significant sediment deposition from Reelfoot Creek. HES plots were sampled downstream of the new sediment dam to be constructed on Reelfoot Creek. "Future-without project" values reflect the projected continued deterioration of this stand due to continued sediment deposition. "Future-with project" values reflect a gradual improvement of this stand with the sediment dam in place.

Table 2A - Grassy Island HES Analysis

		Without Project			With Project		
Habitat Type	Year	Acres	HQI	HUV	Acres	HQI	HUV
Bottomland	0	600	0.6	360	600	0.6	360
Hardwoods	10	600	0.57	342	600	0.63	378
	20	600	0.54	324	600	0.66	396
	30	600	0.51	306	600	0.69	414
	40	600	0.48	288	600	0.72	432
	50	600	0.45	270	600	0.75	450
		Total HUV		15750	Total HUV		20250
		Annualized HUV		315	Annualized HUV		405

NET AHUV with project: +72

Assumptions:

1. Without construction of the sediment retention dam, the existing blh stands would continue to decline due to ongoing sediment deposition from Reelfoot Creek.
2. With construction of the sediment retention dam, excessive sediment deposition would be stopped the existing blh stands would be expected to gradually improve over project life.

Lake Isom HES Analysis: At Lake Isom NWR, HES plots were sampled along a series of transects, which ran perpendicular to the perimeter of the lake. "Future-without project" values for Lake Isom NWR reflect projected continued stand deterioration due to long-term drying. Lack of hydrology is occurring in the area due to channelization, the Reelfoot dam, and construction of Highway 21. The area is also silting in as a result of sedimentation from adjacent agricultural lands. "Future-without project" values assume continued drying of the area with ongoing conversion to more upland species associations. "Future-with project" values reflect restoration of wetland communities as a result of new dam construction and installation of new water wells/pumps that will provide higher water levels by as much as 2 feet.

Table 2B – Lake Isom NWR HES Analysis

Habitat Type	Year	Without Project Acres	HQI	HUV	With Project Acres	HQI	HUV
Bottomland	0	760	0.59	448.4	760	0.59	448.4
Hardwoods	10	760	0.56	425.6	760	0.62	471.2
	20	760	0.53	402.8	760	0.65	494
	30	760	0.5	380	760	0.68	516.8
	40	760	0.47	357.2	760	0.71	539.6
	50	760	0.44	334.4	760	0.74	562.4
		Total HUV		19570	Total HUV		25270
		Annualized HUV		391.4	Annualized HUV		505.4

			Without Project				With Project		
		Year	Acres	HQI	HUV		Acres	HQI	HUV
Wooded		0	417	0.71	296.07		417	0.71	296.07
Swamp		10	417	0.68	283.56		417	0.74	308.58
		20	417	0.65	271.05		417	0.77	321.09
		30	417	0.62	258.54		417	0.81	337.77
		40	417	0.59	246.03		417	0.84	350.28
		50	417	0.56	233.52		417	0.87	362.79
			Total HUV		13239.75		Total HUV		16471.5
			Annualized HUV		264.795		Annualized HUV		329.43

AHUV TOTALS: BLH +114
WS + 65

NET AHUV with project: +179

Assumptions:

1. Without project construction, the existing blh stands would be expected to decline in quality as a result of long term drying and conversion to drier site species.
2. With project construction, the existing blh stands would be expected to improve in quality over project life, as hydrology is restored.
3. Without project construction, the existing wooded swamp stands would be expected to decline in quality as a result of long term drying and conversion to drier site species.
4. With project construction, the existing wooded swamp stands would be expected to improve in quality over project life as hydrology is restored.

<u>New Spillway HES Analysis:</u> At the location of the New Spillway, HES plots were sampled north and south of Highway 21, where construction of the New Spillway would result in clearing 30 acres of bottomland hardwood non-wetlands and approximately 3.5 acres of wooded swamp and marsh. "Future-without project" values reflect a gradual improvement of the bottomland hardwoods south of the highway and a constant value of the wooded swamps north of the highway. "Future-with project" values show a total loss of both of these areas as a result of spillway and inlet channel construction.

Table 2C - New Spillway HES Analysis

		Without Project			With Project		
Habitat Type	Year	Acres	HQI	HUV	Acres	HQI	HUV
Bottomland	0	30	0.44	13.2	30	0.44	13.2
Hardwoods	10	30	0.47	14.1	0	0	0
	20	30	0.5	15	0	0	0
	30	30	0.53	15.9	0	0	0
	40	30	0.56	16.8	0	0	0
	50	30	0.59	17.7	0	0	0
		Total HUV		772.5	Total HUV		66
		Annualized HUV		15.45	Annualized HUV		1.32

		Without Project			With Project		
Habitat Type	Year	Acres	HQI	HUV	Acres	HQI	HUV
Wooded	0	3.5	0.71	2.485	3.5	0.71	2.485
Swamps	10	3.5	0.71	2.485	0	0	0
	20	3.5	0.71	2.485	0	0	0
	30	3.5	0.71	2.485	0	0	0
	40	3.5	0.71	2.485	0	0	0
	50	3.5	0.71	2.485	0	0	0
		Total HUV		124.25	Total HUV		12.425
		Annualized HUV		2.485	Annualized HUV		0.2485

AHUV TOTALS: BLH -14
WS - 4

NET AHUV with project: -18

Assumptions:

1. Without project construction, the existing stands of blh and wooded swamp would continue to increase in quality.
2. With project construction, the stands of both blh and wooded swamp would be cleared as a result of project construction.

New Spillway Outlet Channel HES Analysis: Construction of the Outlet Channel below the New Spillway would result in the creation of approximately 115 acres of planted bottomland hardwoods along top bank and approximately 15 acres of riparian habitat along the Channel banks. "Future-without project" values for both areas reflect a constant, low HQI value, as these areas would continue to produce row crops. "Future-with project" conditions would indicate HQI values steadily increasing in value. Along the top bank, regenerating blh would continue to mature and produce a high quality stand of timber over Project Life. The Channel banks would regenerate naturally and the stand of riverbank tree species would increase in habitat value over Project Life.

Table 2D - Outlet Channel HES Analysis

		Without Project			With Project		
Habitat Type	Year	Acres	HQI	HUV	Acres	HQI	HUV
Regenerating	0	115	0.2	23	115	0.2	23
Bottomland	10	115	0.2	23	115	0.4	46
Hardwoods	20	115	0.2	23	115	0.52	59.8
	30	115	0.2	23	115	0.64	73.6
	40	115	0.2	23	115	0.76	87.4
	50	115	0.2	23	115	0.88	101.2
		Total HUV		1150	Total HUV		3289
		Annualized HUV		23	Annualized HUV		65.78

		Without Project			With Project		
Habitat Type	Year	Acres	HQI	HUV	Acres	HQI	HUV
Regenerating	0	15	0.2	3	15	0.2	3
Riparian	10	15	0.2	3	15	0.4	6
Forest	20	15	0.2	3	15	0.46	6.9
	30	15	0.2	3	15	0.52	7.8
	40	15	0.2	3	15	0.58	8.7
	50	15	0.2	3	15	0.64	9.6
		Total HUV		150	Total HUV		357
		Annualized HUV		3	Annualized HUV		7.14

AHUV Regen BLH: +43
AHUV Regen Riparian +4

Total AHUV +47

Assumptions:

1. Under "Future-without" project conditions, it is assumed that this area would continue to be farmed and so no blh would be present.
2. Under "Future-with" project conditions, mixed blh would be planted along both sides of the outlet channel and would be expected to increase in quality over the 50 year Project Life.
3. Under "Future-with" project conditions, riparian habitat would develop along approximately 15 acres of channel bank, and would continue to increase in value over the 50 year Project Life.

<u>Reelfoot Creek HES Analysis:</u> In the Reelfoot Creek vicinity, HES plots were sampled upstream of the proposed sediment dam, where bottomland hardwoods would be impacted under future-with project conditions by slight increases in flooding durations, and increased sedimentation rates. "Future-without project" values reflect the projected gradual increases in the quality of these stands. "Future-with project" values reflect a slight, gradual deterioration occurring after Project Year 30, when increased sedimentation is projected to approach detrimental levels within these timber stands.

Table 2E - Reelfoot Creek HES Analysis

		Without Project			With Project		
Habitat Type	**Year**	**Acres**	**HQI**	**HUV**	**Acres**	**HQI**	**HUV**
Existing	0	261	0.61	159.21	261	0.61	159.21
Bottomland	10	261	0.64	167.04	261	0.64	167.04
Hardwoods/	20	261	0.67	174.87	261	0.67	174.87
Sediment	30	261	0.7	182.7	261	0.7	182.7
Deposition	40	261	0.73	190.53	261	0.67	174.87
Area	50	261	0.76	198.36	261	0.64	167.04
		Total HUV		8939.25	Total HUV		8626.05
		Annualized HUV		178.785	Annualized HUV		172.521

		Without Project			With Project		
Habitat Type	**Year**	**Acres**	**HQI**	**HUV**	**Acres**	**HQI**	**HUV**
Existing	0	61	0.4	24.4	61	0.4	24.4
Cutover	10	61	0.43	26.23	61	0.43	26.23
Bottomland	20	61	0.46	28.06	61	0.46	28.06
Hardwoods/	30	61	0.49	29.89	61	0.49	29.89
Sediment	40	61	0.52	31.72	61	0.46	28.06
Deposition	50	61	0.55	33.55	61	0.43	26.23
Area							
		Total HUV		1448.75	Total HUV		1375.55
		Annualized HUV		28.975	Annualized HUV		27.511

		Without Project			With Project		
Habitat Type	**Year**	**Acres**	**HQI**	**HUV**	**Acres**	**HQI**	**HUV**
Regenerating	0	168	0.2	33.6	168	0.2	33.6
Bottomland	10	168	0.2	33.6	168	0.4	67.2
Hardwoods/	20	168	0.2	33.6	168	0.52	87.36
Sediment	30	168	0.2	33.6	168	0.64	107.52
Deposition	40	168	0.2	33.6	168	0.61	102.48
Area	50	168	0.2	33.6	168	0.58	97.44
		Total HUV		1680	**Total HUV**		4300.8
		Annualized HUV		33.6	**Annualized HUV**		86.016

Habitat Type	Year	Without Project Acres	HQI	HUV	With Project Acres	HQI	HUV
Regenerating	0	60	0.2	12	60	0.2	12
Bottomland	10	60	0.2	12	60	0.4	24
Hardwoods/	20	60	0.2	12	60	0.52	31.2
No	30	60	0.2	12	60	0.64	38.4
Sediment	40	60	0.2	12	60	0.76	45.6
Deposition	50	60	0.2	12	60	0.88	52.8
			Total HUV	600		Total HUV	1716
			Annualized HUV	12		Annualized HUV	34.32

AHUV TOTALS:	**Existing BLH**	**+13**
	Cutover BLH	**-1**
	Regen BLH/Sediment	**+53**
	Regen BLH/No Sediment	**+22**

NET AHUV with project: + 87

Assumptions:

1. Without project construction, the existing stands of blh and cutover blh would be expected to continue to increase in quality.
2. With project construction, the existing stands of blh and cutover blh would be expected to continue to increase in quality for the first 30 years of Project Life, and would then be expected to begin a gradual decline in quality as a result of sedimentation impacts.
3. Without project conctruction, the approximately 228 acres of regenerating blh would never be planted.
4. With project construction, approximately 228 acres of blh seedlings would be planted.
5. The 168 acres of regenerating blh within the sediment deposition area would be expected to increase in quality for the first 30 years of Project Life, and would then be expected to begin a gradual decline in quality as a result of sedimentation impacts.
6. The 60 acres of regenerating blh outside the sediment deposition area would be expected to increase in quality over the entire 50 year Project Life

Shelby Lake HES Analysis: Project construction at Shelby Lake would include the planting of approximately 282 acres of bottomland hardwood seedlings in stands adjacent to Shelby Lake and the project Waterfowl Management Units. "Future-without project" conditions reflect a constant, low HQI value, as these areas would continue to produce row crops. "Future-with project" conditions would indicate HQI values staedily increasing in value, as planted blh seedlings would mature and produce valuable wildlife habitat over Project Life.

Table 2F - Shelby Lake HES Analysis

		Without Project			With Project		
Habitat Type	Year	Acres	HQI	HUV	Acres	HQI	HUV
Existing	0	282	0.2	56.4	282	0.2	56.4
Bottomland	10	282	0.2	56.4	282	0.4	112.8
Hardwoods/	20	282	0.2	56.4	282	0.52	146.64
Sediment	30	282	0.2	56.4	282	0.64	180.48
Deposition	40	282	0.2	56.4	282	0.76	214.32
Area	50	282	0.2	56.4	282	0.88	248.16
		Total HUV		2820	Total HUV		8065.2
		Annualized HUV		56.4	Annualized HUV		161.304

NET AHUV with project: +105

Assumptions:

1. Under "Future-without" project conditions, it is assumed that this area would continue to be farmed and so no blh would be present.
2. Under "Future-with" project conditions, mixed blh seedlings would be planted on approximately 282 acres of the Shelby Lake area and these stands would be expected to increase in quality over the 50 year Project Life.

Waterfowl Management Units HES Analysis: Project implementation at Shelby Lake would include the construction of 483 acres of terraced, seasonally flooded waterfowl management units. At the Reelfoot Creek site, project implementation would include the construction of 310 acres of terraced, seasonally flooded waterfowl management units. "Future-without project" conditions reflect a constant, low HQI value as these areas would continue to be planted in row crops. "Future-with project" conditions would indicate HQI values increasing initially, then remaining relatively constant over Project Life.

TABLE 2G – Waterfowl Management Units HES Analysis

Habitat Type	Year	Without Project Acres	Without Project HQI	Without Project HUV	With Project Acres	With Project HQI	With Project HUV
Waterfowl	0	483	0.2	96.6	483	0.2	96.6
Management	10	483	0.2	96.6	483	0.56	270.48
Units/	20	483	0.2	96.6	483	0.56	270.48
Shelby	30	483	0.2	96.6	483	0.56	270.48
Lake	40	483	0.2	96.6	483	0.56	270.48
	50	483	0.2	96.6	483	0.56	270.48
		Total HUV		4830	Total HUV		12654.6
		Annualized HUV		96.6	Annualized HUV		253.092

Habitat Type	Year	Without Project Acres	Without Project HQI	Without Project HUV	With Project Acres	With Project HQI	With Project HUV
Waterfowl	0	310	0.2	62	310	0.2	62
Management	10	310	0.2	62	310	0.56	173.6
Units/	20	310	0.2	62	310	0.56	173.6
Reelfoot	30	310	0.2	62	310	0.56	173.6
Creek	40	310	0.2	62	310	0.56	173.6
Sed. Dam	50	310	0.2	62	310	0.56	173.6
Borrow Pit							
		Total HUV		3100	Total HUV		8122
		Annualized HUV		62	Annualized HUV		162.44

AHUV Totals:

Shelby Lake +156
Reelfoot Creek +100

NET AHUV with project: +256

Assumptions:

1. Under "Future-without" project conditions, it is assumed that both the Shelby Lake area and the site of the Reelfoot Creek sediment dam would continue to be farmed, and so the HQI value would remain constant at approximately 0.2.
2. Under "Future-with" project conditions, it is assumed that both sites would be developed into terraced, seasonally-flooded waterfowl management units. These units would be planted in crops for waterfowl and seasonally flooded, so HQI values would increase initially, then remain consistent over Project Life.

Created Marsh HES Analysis: Project implementation at Shelby Lake would include the shallow excavation of 122 acres of freshwater marsh adjacent to Shelby Lake. At the Reelfoot Creek site, project implementation would include the shallow excavation of 51 acres of freshwater marsh adjacent to the sediment dam borrow pit. "Future-without project" conditions reflect a constant, low HQI value as these areas would continue to be planted in row crops. "Future-with project" conditions would indicate HQI values increasing initially, then remaining relatively constant over Project Life.

Table 2H – Created Marsh HES Analysis

		Without Project			With Project		
Habitat Type	**Year**	**Acres**	**HQI**	**HUV**	**Acres**	**HQI**	**HUV**
Freshwater	0	122	0.2	24.4	122	0.2	24.4
Marsh/	10	122	0.2	24.4	122	0.52	63.44
Shelby	20	122	0.2	24.4	122	0.52	63.44
Lake	30	122	0.2	24.4	122	0.52	63.44
	40	122	0.2	24.4	122	0.52	63.44
	50	122	0.2	24.4	122	0.52	63.44
		Total HUV		1220	Total HUV		2976.8
		Annualized HUV		24.4	Annualized HUV		59.536

		Without Project			With Project		
Habitat Type	**Year**	**Acres**	**HQI**	**HUV**	**Acres**	**HQI**	**HUV**
Freshwater	0	51	0.2	10.2	51	0.2	10.2
Marsh/	10	51	0.2	10.2	51	0.52	26.52
Reelfoot	20	51	0.2	10.2	51	0.52	26.52
Creek	30	51	0.2	10.2	51	0.52	26.52
Sed. Dam	40	51	0.2	10.2	51	0.52	26.52
Borrow Pit	50	51	0.2	10.2	51	0.52	26.52
		Total HUV		510	Total HUV		1244.4
		Annualized HUV		10.2	Annualized HUV		24.888

AHUV Totals

Marsh/Shelby Lake +35
Marsh/Reelfoot Creek +15

NET AHUV +50

Assumptions:

1. Under "Future-without" project conditions, it is assumed that both the Shelby Lake area and the site of the Reelfoot Creek sediment dam would continue to be farmed, and so the HQI value would remain constant at approximately 0.2.
2. Under "Future-with" project conditions, it is assumed that both sites would be subject to shallow excavation and allowed to exist as freshwater marsh. The HQI values would increase initially, then remain relatively consistent over Project Life.

Water Level Management Impacts

During the study process, the interagency study team decided that execution of an aquatic HEP or HES on Reelfoot Lake as a means of evaluating impacts and water level management options was not necessary because management options had been thoroughly examined by an interdisciplinary panel of experts who participated in a workshop August 24-29, 1986. Proceeds of the workshop were published in a report entitled *Water Management Alternatives at Reelfoot Lake: Results of a Workshop* (December, 1986). This report is included as Appendix B, in the approved *Reelfoot Lake Water Level Management Draft Environmental Impact Statement.* This DEIS was prepared by the U.S. Fish and Wildlife Service and the Record of Decision (ROD) is dated September 25, 1989. The Corps draft Feasibility Report and DEIS recommended Plan 5b for implementation. However, during the public review period, strong opposition to the Reelfoot Lake water level management aspect of Plan 5b was presented. After subsequent meetings and discussions, Alternative 3 Water Level Management Practice (Interim Plan Combined with Periodic Major Drawdown) is now recommended as the "preferred plan".

The following tables (21 and 22) now reflect the total and annualized habitat unit values associated with Alternative 3 Water Level Management Plan, Interim Plan + Drawdown.

Table 2I – Reelfoot Lake Aquatic Habitat HES Analysis

		Without Project				With Project		
Habitat Type	**Year**	**Acres**	**HQI**	**HUV**		**Acres**	**HQI**	**HUV**
Aquatic	0	8300	0.56	4648		8300	0.56	4648
Habitat/	10	7720	0.48	3705.6		8300	0.59	4897
Reelfoot Lake	20	7140	0.4	2856		8300	0.62	5146
	30	6560	0.32	2099.2		8300	0.64	5312
	40	5980	0.24	1435.2		8300	0.65	5395
	50	5400	0.16	864		8300	0.68	5644
		Total HUV		128520		**Total HUV**		250600
		Annualized HUV		2570.4		**Annualized HUV**		5012

NET AHUV **+2442**

Assumptions:

1. Under future without project conditions, the size of the aquatic habitat is expected to diminish from a present acreage of 8300 acres, to approximately 5,400 acres at the end of Project Life. At the same time, HQI values would be expected to decrease from an existing value of 0.56 to a value of 0.16 at the end of Project Life.

2. Under future-with project conditions, \the size of the aquatic habitat would be expected to remain approximately the same, while the HQI value would be expected to increase from its present value of 0.56 to a value of 0.7.

Table 2J – Buck Basin Aquatic Habitat HES Analysis

		Without Project			With Project		
Habitat Type	**Year**	**Acres**	**HQI**	**HUV**	**Acres**	**HQI**	**HUV**
Aquatic	0	1900	0.5	950	1900	0.5	950
Habitat/	10	1700	0.43	731	1900	0.54	1026
Buck Basin	20	1500	0.36	540	1900	0.58	1102
	30	1300	0.3	390	1900	0.62	1178
	40	1100	0.23	253	1900	0.66	1254
	50	900	0.16	144	1900	0.7	1330
		Total HUV		24610	**Total HUV**		57000
		Annualized HUV		492.2	**Annualized HUV**		1140

NET AHUVs **+648**

Assumptions:

1. Under future-without project conditions, aquatic habitat would be reduced from 1900 acres to approximately 900 acres over Project Life, due to ongoing sedimentation. HQI values would be reduced over this period as well from a value of 0.50 to a value of 0.16 at the end of Project Life.
2. Under future-with project conditions, aquatic habitat would remain consistent over Project Life, with an increase in HQI value from 0.50 to 0.70, as a result of the positive impacts water level management.

Additional impacts from water level management would be expected to accrue with bottomland hardwoods adjacent to the Lake, which would be positively impacted by the dynamic fluctuation of the lake's surface elevation from 283.0 NGVD to approximately 284.0 NGVD with the "preferred plan". Table 2J below shows the results of this water level fluctuation upon these BLH stands.

Table 2K – BLH Adjacent to the Lake, HES Analysis

			Without Project					With Project		
Habitat Type		Year	Acres	HQI	HUV			Acres	HQI	HUV
BLH adjacent		0	800	0.62	496			800	0.62	496
to Lake		10	800	0.65	520			800	0.68	544
		20	800	0.68	544			800	0.74	592
		30	800	0.72	576			800	0.8	640
		40	800	0.75	600			800	0.86	688
		50	800	0.78	624			800	0.92	736
			Total HUV		28000			Total HUV		30800
			Annualized HUV		560			Annualized HUV		616

NET AHUV **+56**

Assumptions:

1. Under future-without project conditions, approximately 800 acres of bottomland hardwoods immediately adjacent to the Lake would gradually increase in HQI value from 0.62 to approximately 0.78.
2. Under future-with project conditions, raising of the dynamic water elevation from 283.0 to 284.0 NGVD would result in additional seasonal inundation of approximately 800 acres of BLH, resulting in increased HQI values, from 0.62 to 0.92.

AHUV Totals with project

Grassy Island	+72
Lake Isom	+179
New Spillway	-18
Spillway Outlet Channel	+47
Reelfoot Creek Sediment Dam	+ 87
Shelby Lake	+105
Waterfowl Management Units	+256
Freshwater Marsh	+50
Aquatic Habitat - Reelfoot Lake	+2659
Aquatic Habitat – Buck Basin	+648
BLH Adjacent to Reelfoot Lake	+56
NET AHUV Gain with project:	+4141

SECTION II

HABITAT GAINS AND LOSSES

Habitat Gains and Losses

This section summarizes individual habitat gains and losses, as well as a summary of net habitat gains, which would result from the implementation of the recommended features for restoration. Probable impacts are of two categories: 1) Direct impacts of project construction; and 2) Impacts resulting from changes in water level management techniques following project construction.

1. Project Construction Impacts

A. Impacts by Constructed Items

(1)Dredged Circulation Channels. Project impacts associated with dredging of approximately 3 miles of circulation channels would consist of excavation of approximately 62,555 cubic yards of material, most of which will be under water, and the deposition of this material in bottomland hardwood/wooded swamp/marsh wetlands adjacent to the channels. Clearing of bottomland hardwoods or wooded swamp would be minimal and limited to cutting of occasional trees for equipment operation. Approximately 2 acres of wetlands will be filled as a result of these deposition activities and specific impacts to wetlands will be addressed in the Section 404 (b)(1) Evaluation (See Appendix C).

(2) New Lake Isom Dam/Spillway/Water Wells. Project impacts at the Lake Isom NWR consist of renovation of an existing dam and spillway, and installation of new water wells and pumps which will raise water levels within Lake Isom by as much as 2 feet. Seasonal raising of the Lake water level for waterfowl would raise the surface area of the normal pool from approximately 1100 acres to approximately 1350 acres. Direct project construction impacts will be minimal and will be limited to removal of occasional trees as necessary for renovation of the dam and spillway. Borrow material for the dam renovation (approximately 5,056 cubic yards) will be excavated from cleared, farmed wetlands within the Lake Isom refuge. .

(3) New Spillway/Inlet & Outlet Channels. Construction of the New Spillway and Inlet & Outlet Channels will create both aquatic and terrestrial impacts. Construction of the Inlet Channel will require the clearing of approximately 6 acres of wooded swamp, and excavation of approximately 51,600 cubic yards of excavated material, most of which will be under water. This excavated material will be deposited in prior converted farmland. Construction of the New Spillway will result in the clearing of 30 acres of bottomland hardwoods. The new Outlet Channel will be excavated on lands that are presently being farmed, and approximately 115 acres of new bottomland hardwoods will be planted along the sides of the channel. Approximately 25 acres of new aquatic habitat will be created by excavation associated with construction of the New Spillway and the Outlet Channel and 1 acre of existing aquatic habitat will be filled in at the location of the Old Spillway.

(4) Reelfoot Creek Sediment Retention Dam. Project impacts resulting from construction of the Reelfoot Creek Sediment Retention Dam would consist of: increased sediment deposition on 61 acres of existing bottomland hardwoods upstream of the dam, reduced sediment deposition on 600 acres of existing bottomland hardwoods downstream of the dam (Grassy Island area), and planting of 228 acres of bottomland hardwoods on lands upstream and downstream of the dam. Construction of the dam would require excavation of approximately 424,833 cubic yards of fill material from existing farmland and deposition of this material on approximately 35 acres of existing farmland as a sediment retention dam. Excavation of this fill material would result in the creation of an approximately 57 acre borrow pit which would be designed to function as a wetland/waterfowl area for approximately 30 years, then over the remainder of Project Life as a sediment retention reservoir.

(5) Shelby Lake. Project construction impacts at Shelby Lake would consist of: excavation of approximately 482,000 cubic yards of excavated material from the old Shelby Lake location and deposition/spreading of this material over approximately 220 acres of adjacent farmland; use of 69,000 cubic yards of excavated material for construction of a series of low levees/terraces to form approximately 483 acres of waterfowl management units on existing farmlands; and planting of approximately 282 acres of bottomland hardwoods on existing farmlands adjacent to Shelby Lake. Excavation of the old lake would result in creating of approximately 50 acres of new aquatic habitat. The new Shelby Lake control structure (stoplog) will be capable of inundating an additional 122 acres of lowland for waterfowl, shorebirds, and furbearers. Deposition/spreading of the excavated material would take place on existing farmlands (prior converted) and so would result in no wetland impacts.

B. Accounting of Project Construction Impacts

	BLH	WETLANDS	AQUATIC HABITAT	AHUV
Circulation Channels	NI	-2 ac	NI	NC
Lake Isom	NI	NI	NI	+179
Spillway/ Inlet & Outlet Channel	+79 ac	NI	+24 ac	+29
Reelfoot Creek/ Sediment Dam 1/	+228 ac	+57 ac	NI	+209
Shelby Lake 2/	+282 ac	+605 ac	+50 ac	+361
TOTALS	+589 ac	+660 ac	+74 ac	+778

1/ Includes benefits resulting from sediment dam, creation of freshwater marsh, and impacts to Grassy Lake
2/ Includes benefits resulting from impacts to Shelby Lake, as well as creation of waterfowl units

- NI – No Impacts
- NC - No Calculations

2. Water Level Management Impacts.

A. Impacts to Aquatic Habitat in Reelfoot Lake

As a result of water level management, the size of the aquatic habitat within Reelfoot Lake would remain constant at 8300 acres, rather than losing approximately 2900 acres due to sedimentation over 50 years under without-project conditions.

B. Impacts to Bottomland Hardwoods Adjacent to Reelfoot Lake

As a product of water level management, raising of Reelfoot Lake's high water elevation from 283.0 to 284.0 NGVD would result in seasonal inundation of approximately 800 acres of bottomland hardwoods adjacent to the Lake. This seasonal inundation would result in increases in quality of these timber stands over Project Life.

C. Impacts to Aquatic Habitat in Buck Basin

As a result of water level management, the size of the aquatic habitat within Buck Basin would remain constant at 1900 acres, rather than losing approximately 900 acres due to sedimentation over 50 years under future-without project conditions.

D. Accounting of Water Level Management Impacts

	BLH	WETLANDS	AQUATIC HABITAT	AHUV
Reelfoot Lake	NI	NI	2900 ac	+2659
Buck Basin	NI	NI	900 ac	+648
BLH adjacent to Reelfoot Lake	Quality increase	NI	NI	+56
TOTALS			3800 ac	+3363

3. Habitat Impact Totals

BLH	WETLANDS	AQUATIC HABITAT	AHUV
+589 ac	+660 ac	+3874 ac	+4141

SECTION III

AQUATIC PLANT CONTROL

CESAJ-CO-OR-A 22 June 1993

MEMORANDUM FOR Commander, Memphis District, U.S. Army Corps of Engineers, (ATTN: CELMM-PD-R), B-202 Clifford Davis Federal Building, 167 North Mid-America Mall, Memphis, TN 38103-1894

SUBJECT: APCOSC Site-Visit to Reelfoot Lake, Tennessee

1. Enclosed please find the Jacksonville District, Aquatic Plant Control Operations Support Center (APCOSC) follow-up report on the subject site-visit. Providing information exchange and assistance to the various Corps offices with aquatic plant issues is an important function of the APCOSC.

2. I would like to thank you and your staff for the assistance and hospitality provided the APCOSC representative during his recent site visit.

3. If you have further questions or if we can be of additional assistance please contact Bill Zattau at 904-232-2218.

FOR THE COMMANDER:

Encl

GIRLAMO DiCHIARA
Chief, Construction-Operations Division

CESAJ-CO-OR-A

21 June 1993

MEMORANDUM FOR RECORD

SUBJECT: APCOSC Site-visit to Reelfoot Lake, Tennessee

1. Upon request of Richard Hite, CELMM-PD-R, the undersigned conducted a site visit to Reelfoot Lake, TN, to provide options for the management of nuisance aquatic plants impacting the Reelfoot Lake ecosystem.

2. Reelfoot Lake is located in extreme northwest Tennessee with a small portion extending into Kentucky. At normal pool elevation (282.2 feet m.s.l.) the aquatic habitat covers approximately 15,500 acres with an estimated 10,000 acres being open water. The lake's origin was a Mississippi River floodplain oxbow lake/forested wetland which was significantly deepened by the massive New Madrid earthquakes of 1811 and 1812.

3. Reelfoot Lake is classified as hypereutrophic, the most advanced eutrophic stage which is characterized by excessive plant growth (algae and macrophytes) and poor water quality. The lake receives major influxes of sediments and nutrients via erosion of surrounding agricultural and woodland areas causing inorganic sediment deposition and water quality degradation. Several siltation basins have been constructed on tributaries and are effectively trapping some silt and nutrients. Lake turbidity due to phytoplankton remains a problem. Sedimentation also occurs due to the annual decomposition of thousands of acres of aquatic plants.

4. On 7 June, 1993, the undersigned, accompanied by Richard Hite, Edward Lambert, and Rodger Funderburk (all CELMM); Paul Brown, Wildlife Manager, Reelfoot Lake Wildlife Management Area, Tennessee Wildlife Resources Agency (TWRA); and Randy Cook, Refuge Manager, Reelfoot National Wildlife Refuge, U.S. Fish and Wildlife Service (FWS) surveyed the Buck Basin area of Reelfoot Lake by boat. The purpose of the survey was to observe the aquatic vegetation and its impacts on the lake. Major emergent species observed along the shoreline were Leersia hexandra (cutgrass), Nuphar luteum (spatterdock) and Nelumbo lutea (American lotus). Upon entering Buck Basin from Kirby Pocket several scattered populations of Ceratophyllum demersum (coontail) were observed; travelling across the basin, populations of Potamogeton crispus (curlyleaf pondweed) mixed with coontail were seen. Herbicide test plots (4 gallons endothall/acre applied 15 April 1993) appeared to be void of both coontail and curlyleaf. In going north through the cypress trees, large populations of senescing curlyleaf were observed extending to the western shoreline. Many of these submersed plant beds were covered with duckweed and/or watermeal.

5. According to survey participants, curlyleaf usually reaches maximum biomass during the fishing season (March - June); quickly drops out and is rapidly replaced with coontail. Curlyleaf asexually reproduces by turions and spreads by rhizomes. Reproduction by seed is thought to be insignificant. The life history of curlyleaf (a rooted winter annual) in Reelfoot begins as turions in the sediment germinate in the fall producing plants which usually remain

low-lying through most of the winter, then growing rapidly to the lake surface by early spring forming a thick canopy. (Outboard motor boats cannot navigate through these plant beds). Turions are produced in early summer followed by plant senescence and fragmentation. The turions drop to the lake bottom and germinate in the fall renewing the cycle. Curlyleaf's competitive success is due to the fact that it grows efficiently early in the year at low water temperatures when few, if any, other aquatics are growing; then forming a dense canopy which shades out any lower plants. The plant grows generally in depths to 5 feet. Coontail, a rootless submersed species, then assumes dominance through the summer and fall. Coontail is not regarded as a major nuisance by the survey participants.

6. On 8 June a meeting was held at the TWRA office at Reelfoot Lake. Participants included the lake survey party plus Jim Johnson, Wildlife Manager, TWRA, and Dr. Wesley Henson, University of Tennessee at Martin. The overall Reelfoot ecosystem was discussed as was past ecosystem management. Agency concerns and objectives for the lake were explored. Reelfoot Lake is utilized for recreational boating, hunting and fishing, eagle tours, and birdwatching. A FWS National Wildlife Refuge, Tennessee State Park and Tennessee State Wildlife Management Area are located in and around the lake as are several lodges and marinas.

7. Aquatic plant management operations have been conducted for over 50 years in the lake. All four of the technology areas (chemical, biological, mechanical and environmental manipulation technology) are available and an integrated management program is attainable. Beginning in the 1940's, the FWS initiated herbicide treatments to manage curlyleaf. These efforts continued through the 1960's but were discontinued. The TWRA resumed herbicide operations in 1992 and treated five 10-acre plots in April 1993 with excellent results.

8. Biological control technology has been employed for the last ten years with varying success. In 1983, 30,000 grass carp were released by the TWRA with a resultant 3-year plant decline followed by target vegetation expansion for several years which prompted additional stocking. In 1992, TWRA stocked 100,000 grass carp in Reelfoot. Agency plans call for radio-tagged grass carp to be released in the lake for monitoring movement and feeding patterns.

9. Mechanical control is utilized by the FWS which owns and operates a "Cookie-Cutter" for annual maintenance operations of approximately 35 miles of navigation trails and circulatory channels. Environmental manipulation has also been employed for aquatic vegetation management. The last drawdown was in the spring and summer of 1985 when the lake was lowered approximately 2 1/2 feet before the drawdown was discontinued by court order in July 1985.

10. The 1985 court order resulted in the production of an Environmental Impact Statement by the FWS. The 1989 EIS presented a number of options aimed at ecosystem restoration/ enhancement ranging from no action to extreme drawdown. Circumstances have dictated re-

initiation of the NEPA process and at this time a new Reconnaissance Report is being prepared. Possible options under consideration include construction of a new water control structure/spillway which would allow up to an 8-foot drawdown. In addition, a large sediment trap at Grass Island (on Reelfoot Creek) is being considered.

11. Agency objectives for Reelfoot Lake include: 1) prevention/reduction of sedimentation due to inorganic influx; 2) improvement of recreational opportunities; 3) enhancement of the lake fisheries; 4) increased management opportunities for waterfowl overwintering; 5) enhanced accessibility; 6) enhanced ability to manipulate water level fluctuation; and 7) increased discharge rate during drawdown. As emphasized during the discussion, the Reelfoot Lake problem is broad-based requiring a total ecosystem management approach. The aquatic plant problem is one part of the problem.

12. The following actions and management options are offered in light of agency objectives and priorities:

a) The first step in addressing the aquatic plant problem is to develop a written, comprehensive management plan for Reelfoot Lake. From discussions with agency personnel, it is apparent that an integrated aquatic plant management program is feasible for the lake. In fact, an integrated program is essentially in place but I am not aware that a written plan exists. The plan should identify the problems caused by excessive aquatic plants, both by season and plant type; the available management technologies; and clearly state program goals and objectives. It is obvious from the survey and meeting I attended that the participants are well versed on exotic aquatic plant problems and identification, so development of this plan should not be difficult.

b) Obtain accurate, seasonal baseline surveys of the vegetation to be managed. This will be necessary to document program successes both for in-house funding purposes and for use at public meetings.

c) I suggest that an interagency Aquatic Plant Management Task Force be established with regularly scheduled meetings focused on this subject alone be held. I realize that another group of scheduled meetings might appear to be a burden and redundant, but I have found that such focused meetings can be very helpful, especially when developing a management plan. Invite select members of the public and those with commercial interests.

d) Next spring begin herbicide treatment(s) earlier in the year before the curlyleaf tops out. Survey and mark plots in early February if possible and treat as soon after as practical. This option is already under consideration by TWRA.

e) Instead of using contact herbicides next spring, consider using fluridone (a systemic herbicide, trade name Sonar) in Buck Basin. Fluridone is effective on both curlyleaf and coontail at low rates and will not harm the cypress or beneficial native aquatics if the treatment is made late winter when the curlyleaf is the only plant actively growing. Use the liquid formulation in checkerboard plots which are effective in open water treatments. I have talked to the fluridone manufacturer technical representative (David Tarver, 904/668-2352) who has offered to visit the lake to discuss fluridone treatment options. Cost per acre of control would be comparable (maybe less) to that of contact herbicides. Since contact time is critical (suggest 5 weeks minimum), use the existing structure to lower the waterlevel prior to treatment and close the spillway at time of treatment. This action will minimize flow through the treatment area and increase contact time; and with the water level down already down, discharge may not be necessary if heavy rainfall occurs. Fluridone will move into the rhizomes which will be killed; this does not happen with contacts. Follow up with a subsequent fluridone treatment at the same time the following year to kill plants from turions which germinated late. The life expectancy of these turions are one year (according to Henson) so these two treatments would definitely disrupt and possibly eliminate the curlyleaf seedbank.

f) Spot-treat nursery areas including small tributaries and canals with contact herbicides in the spring before turions are formed and again in late fall as previously formed turions are germinating. Do this for a couple of years to eliminate the seed bank and limit reinfestation.

g) Initiate a Myriophyllum spicatum (Eurasian watermilfoil) education and prevention program. Milfoil is present in several waterbodies in close proximity to Reelfoot and Reelfoot appears to be a prime candidate for future expansion. Recommend warning signs with pictures of milfoil at all Reelfoot boat ramps and handouts or posters for bait shops and marinas. In the Management Plan recommended at 12 (a), anticipate invasion and treatment of Eurasian watermilfoil.

h) Expand the use of the FWS Cookie-cutter for cutting navigation trails during the fishing season before coontail becomes dominant as the rootless coontail would rapidly move into the open trails.

13) Integration of major drawdowns with the above technologies will be of great benefit for Reelfoot. If a new structure can be constructed which allows a 6 to 8 feet drawdown, then major benefits would be realized when adequate drying time (120 days) is allowed. It is recommended that once the structure is complete, two sequential annual drawdowns be completed either in the fall after turion germination or in early spring before turions are produced. The two drawdowns in a row should disrupt or eliminate the curlyleaf seedbank if adequate drying time is allowed. These initial drawdowns should be followed by a major drawdown every 4 or 5 years.

William C. Zattau

WILLIAM C. ZATTAU, PH.D.
Chief, APCOSC

CELMM-PD-F (1105)　　　　　　　　　　　　9 June 1993

MEMORANDUM FOR THE RECORD

SUBJECT: Trip Report, Reelfoot Lake, TN & KY, 7-8 June 1993

1. This memorandum serves as a record of discussions held concerning aquatic vegetation at Reelfoot Lake. The following persons were in attendance:

Rodger Funderburk	CELMM-PD-F
Richard Hite	CELMM-PD-R
Ed Lambert	CELMM-PD-R
Dr. Bill Zattau	CESAJ (Aquatic Plant Control Center)
Paul Brown	TWRA
Jim Johnson	TWRA (Present only on 6/8/93)
Randy Cook	USFWS
Dr. Wesley Henson	UT Martin (Present only on 6/8/93)

2. On 7 June 1993, attendees met at the WMA office at Reelfoot Lake and drove to the boat ramp at Kirby Pocket. At Kirby Pocket, an outboard-motor boat and an air-boat were used to reach areas in Kirby Pocket and Buck Basin which were having aquatic vegetation problems at that time. Paul Brown and Randy Cook stated that three weeks prior, the vegetation almost encompassed the entire Kirby Pocket and Buck Basin area. They stated that the vegetation comes in cycles with curlyleaf pondweed coming out in the spring and dying off when the water temperature rises. Then, coontail replaces the curlyleaf pondweed. The remainder of 7 June 1993 was spent viewing the different aquatic vegetation types at the lake and discussing chemical and mechanical treatment results as well as the proposed drawdown.

3. On 8 June 1993, attendees met at the WMA office at Reelfoot Lake and discussed the types of aquatic vegetation at Reelfoot Lake as well as potential methods for treatment. During the meeting, TWRA and USFWS representatives stated that Reelfoot Lake had been stocked with 100,000 diploid grass carp in 1992 (10" - 12" length). The initial stocking of the lake with grass carp was in 1983-1984. Dr. Zattau stated that Florida stocks grass carp at the rate of about 5 per vegetated acre and a 10" grass carp would be productive for about 5 years (after 5 years the lakes need to be restocked). It was also stated that grass carp prefer hydrilla (which is not present at Reelfoot Lake) but they will eat curlyleaf pondweed.

4. Dr. Henson stated that Reelfoot Lake froze in December 1989, and the freeze killed the southern smartweed except in the deep water. He also stated that the plants are now coming back from those which survived the freeze.

5. When asked by Dr. Zattau what their agency objectives were at Reelfoot Lake, Jim Johnson stated the TWRA wanted to (1) prevent further deterioration (filling up with sediment) of the lake, (2) improve the aquatic ecosystem (through water level fluctuation), and (3) provide wintering areas for waterfowl. Randy Cook of the

USFWS stated their objectives as being (1) waterfowl habitat, (2) avoiding the use of herbicides (environmental and effectiveness concerns), (3) control of vegetation for fishing, and (4) move towards implementation of periodic drawdowns and higher lake fluctuation levels as stated in the 1989 EIS.

6. Other items surfaced at the meeting are as follows:

a. Most of the sediment from Reelfoot Creek is going into Grassy Island. (The sediment pathway has turned north.)

b. There are no aquatic vegetation problems in Blue Basin due to high turbidity levels (caused by plankton and algae).

c. The USFWS cuts approximately 35 miles of trails through the lake each year using the "cookie cutter". The trails are cut in the spring with a follow-up in the fall where needed. The "cookie cutter" is not effective in deep water.

d. Mr. Bill Hickman is circulating a petition to pump water from the Mississippi River into Reelfoot Lake.

e. At a meeting held a few weeks ago (called by the owner of Little Daddy's Resort) the Senators committed the TWRA to spraying 500 acres with herbicide next year (50 acres were sprayed this year). The locals appear to be in favor of spraying herbicide to combat aquatic vegetation. However, TWRA and the USFWS believe the locals are not fully aware that the problem also involves sediment and other factors.

f. Both Randy Cook and Jim Johnson stated that they did not want to lose sight of the objective of implementing a periodic drawdown with higher water level fluctuations. They do not want herbicide applications to be seen as a "cure all".

7. Dr. Zattau will provide the Memphis District with a summary of his trip notes and discussions as well as additional research and potential solutions for addressing the aquatic vegetation problems at Reelfoot Lake. Preliminary discussions indicate that a combination of herbicide application, mechanical control ("cookie cutter"), grass carp, and/or a drawdown may be the best solution.

Rodger Funderburk
Study Manager

SECTION IV

SECTION 404(B)(1) EVALUATION

Reelfoot Lake, Tennessee and Kentucky
SECTION 404(b)(1) DOCUMENT

I. Project Description

a. Location. Reelfoot Lake is located within the Mississippi Alluvial Plain in portions of Lake and Obion counties in northwest Tennessee and a section of Fulton County in southwest Kentucky. The lake is situated between the Mississippi River to the west and north and loess bluffs and upland hills to the east and is located about 120 miles north of Memphis and 6 miles east of Tiptonville, Tennessee

The areas to be directly affected by the proposed actions are located within and adjacent to Reelfoot Lake, and consist of: approximately 3.5 acres of aquatic habitat and associated wetlands adjacent to the alternative spillway and along approximately 700 feet of inlet channel ; approximately 15 acres of aquatic habitat and associated wetlands within and adjacent to approximately 3 miles of dredged circulation channels within Reelfoot Lake; approximately 63 acres of bottomland hardwood wetlands, approximately 2 acres of farmed wetlands, and approximately 1.25 miles of Reelfoot Creek within a 2,197 acre sediment retention basin in the Reelfoot Creek basin; approximately 4 acres of forested wetlands and 2 acres of farmed wetlands to be impacted by the restoration of Shelby Lake and construction of a 483-acre waterfowl management unit in the area; and approximately 2 acres of aquatic habitat and associated wetlands to be impacted by modification of the dam embankment, spillway, and outlet structure on the lower end of Lake Isom.

b. General Description. Reelfoot Lake was formed by the New Madrid earthquake of 1811-1812 and now covers approximately 15,500 acres at normal pool, of which 10,200 acres are open water and the remaining are marsh and swamp. Reelfoot Lake is a nationally significant and unique natural resource. It is the largest natural freshwater lake in Tennessee and one of the largest in the country.

The primary purpose of the project is to provide sediment control, water quality, recreation, regional development, and fish and wildlife preservation and enhancement to Reelfoot Lake and the surrounding area. The project involves five major features of work. A new spillway for Reelfoot Lake would be constructed to allow for water level control. Cleanout of existing circulation channels within Reelfoot Lake which connect the three major basins of the lake (Blue, Buck, and Upper Blue basin) to each other and the new spillway channel to aid in lake water level management would take place. A sediment retention basin designed to attenuate deposition of sediment into the lake from Reelfoot Creek would be constructed. Also proposed is the restoration of Shelby Lake to approximate historic conditions and the construction of waterfowl management units to provide feeding and resting habitat for waterfowl. Lastly, modification of the dam embankment, spillway, and outfall structure on Lake Isom would take place in order to increase water level management capabilities and help restore historic water levels in the wetland complex within this area.

c. Authority and Purpose. The U.S. Senate and House of Representatives passed resolutions on August 2 and 8, 1984, requesting the Chief of Engineers "to review the report on the Mississippi River and Tributaries Project ... and other pertinent reports with a view to determining whether any modifications of the recommendations contained therein are advisable, with particular reference to the need and feasibility of improvements in the vicinity of Reelfoot Lake, Tennessee, in the interest of flood control, sediment control, water quality, water supply, fish and wildlife preservation and enhancement, recreation, regional development, and allied purposes". Funds were provided to the U.S. Army Corps of Engineers, Memphis District, in December, 1985, to conduct the reconnaissance portion of the investigation. The reconnaissance report was completed in May 1988 but was not certified at that time.

Recent Corps of Engineers budget guidance elevated the restoration of fish and wildlife habitat as a priority output of the Corps of Engineers. Specifically, "fish and wildlife restoration activities may be recommended if justified and: (1) a Civil Works project has contributed to the degradation ... or (2) restoration can be most cost effectively accomplished through modification of an existing Civil Works project ..." (Policy Guidance Letter No. 24). By letter dated April 9, 1992, the State of Tennessee, acting through the Tennessee Wildlife Resources Agency, requested that the U.S. Army Corps of Engineers, Memphis District, update the May 1988 reconnaissance report to include fish and wildlife habitat restoration in addition to other Corps outputs.

d. General Description of Dredged and/or Fill Material.

(1) General Characteristics of Fill Material. Earthen fill material would be required for all of the major features of the project. Activities requiring excavation and filling with earthen material include construction of the inlet and outlet channel for the alternative spillway, cleanout of the circulation channels, construction of a levee for the sediment retention basin and also low level terraces for waterfowl impoundments, restoration of Lake Shelby and the construction of terraces for waterfowl management units in and around Lake Shelby, and the modification of the existing levee embankment at Lake Isom. In addition, gravel, riprap, concrete, and steel would be used to construct the alternative spillway for Reelfoot Lake as well as waterway inlets and outlets for other project features.

(2) Quantity of Material. Approximately 506,300 cubic yards of earthen material would be excavated for the construction of the new inlet and outlet channel and alternative spillway, of which approximately 68,000 cubic yards would occur in Waters of the U.S. The closure of the old spillway would require the deposition of 34,200 cubic yards of earthen material into Waters of the U.S. In addition, 4,340 cubic yards of concrete, 15,400 cubic yards of gravel, 4,250 cubic yards of riprap, and 29,300 pounds of steel would be used in the construction of the alternative spillway.

Approximately 63,000 cubic yards of material would be excavated for the cleanout of the circulation channels within Reelfoot Lake. The cleanout would result in approximately two acres of forested wetlands being filled by the resulting disposal pile.

The construction of the dam for the sediment retention basin would require approximately 1,500,000 cubic yards of earthen material and 7,000 tons of riprap. Approximately two acres of forested wetlands and two acres of farmed wetlands would be impacted by construction of the dam. In addition, roughly 127,000 cubic yards of earthen material would be required in the construction of low level terraces for wintering waterfowl impoundments. The annual removal of approximately 8,600 cubic yards of sediment from 1.25 miles Reelfoot Creek would be required to ensure adequate flow under the Highway 22 bridge. This material would be placed on prior converted (PC) cropland and stabilized to prevent reentry into the creek.

The restoration of Shelby Lake and construction of an adjacent waterfowl management unit would entail the excavation of approximately 482,000 cubic yards of earthen material to restore the historic dimensions of the lake. Approximately two acres of farmed wetlands, and four acres of forested wetlands would be impacted by the excavation work. Excess material would be placed on PC cropland, seeded in grass, and planted in bottomland hardwood seedlings.

The modification of the levee embankment, spillway and new outlet structure for Lake Isom would require the deposition of approximately 5,500 cubic yards of earthen material, 140 cubic yards of concrete, and 600 cubic yards of riprap. Wetland impacts would occur as a result of levee enlargement (approximately 0.50 acre of forested wetland) and excavation from adjacent farmed wetlands for borrow material (approximately 1.25 acres).

(3) Source of Material. Fill material for the various features described above would be obtained from onsite locations and would be free from contamination. Borrow areas, where possible, would be designed to promote wildlife usage.

e. Description of Proposed Discharge Sites.

(1) Location. The location of the discharge sites for all described features would be in nonwetland areas wherever practicable.

At the alternative spillway feature, materials needed for the construction of the spillway would be placed in the newly constructed inlet/outlet channel. The area is currently a nonwetland forest. Excess material from the inlet/outlet channel construction would be placed on adjacent PC cropland, spread, and planted in bottomland hardwood seedlings. In addition, earthen material would be placed in the old spillway area for closure.

At the circulation channels feature, excavated material would be placed on and adjacent to existing disposal piles located near the channels..

At the sediment retention basin feature, materials necessary for the construction of the levee and outlet structures would be placed primarily on PC cropland with a small portion impacting forested areas. Terraces for the waterfowl impoundments and excavated materials from maintenance dredging to occur on Reelfoot Creek would be placed on PC cropland.

At the Shelby Lake waterfowl management unit feature, approximately four miles of low level terraces would be constructed on PC cropland to hold water for waterfowl. Excess material excavated from the Shelby Lake restoration work would be placed on adjacent (PC) croplands and planted with bottomland hardwood seedlings.

At the Lake Isom feature, materials necessary for the modification of the dam embankment, spillway, and outlet structure, would be placed on the existing dam embankment and adjacent wooded wetlands after site preparation is complete.

(2) Size. The smallest practicable area for deposition of materials would be utilized for all described features. Areas temporarily cleared for construction would be allowed to revegetate following project construction.

At the alternative spillway feature, approximately 1.3 acres of primarily open water area would be filled as part of the closure of the old spillway. It would be necessary to clear approximately 3.5 acres of wetlands and also excavate approximately 2.5 acres of this area for the construction of the inlet channel.

At the circulation channels feature, it is estimated that two acres of wetlands would be filled as additional disposal areas for the excavated material from the channel. The remainder of the excavated material would be placed on existing disposal piles.

At the sediment retention basin feature, approximately two acres of wetlands would be directly impacted by filling from construction of the levee. Indirect impacts to approximately 61 acres of wetlands would occur through large quantities of sediment flowing into the area. Annual maintenance dredging of Reelfoot Creek would also be necessary to remove trapped sediment. The dredged material would be placed on adjacent PC cropland.

At the Shelby Lake waterfowl management unit feature, all deposition would occur in PC cropland. Excavation of material to restore historic dimensions of the lake would impact approximately 6 acres of wetlands.

At the Lake Isom feature, approximately 0.5 acre of wetland located directly adjacent to the existing dam embankment would be cleared and filled as a result of modifications to the existing dam, spillway, and outlet structure. It is estimated that 1.25 acres of wetlands would be converted to open water in order to obtain the required earthen material.

(3) Approximately 3.8 acres of forested swamp and open water would occur through filling and excavation. In addition, 1.5 acres of forested swamp would be temporarily impacted due to clearing for construction.

At the circulation channels feature, direct impacts would occur to approximately two acres of forested, scrub-shrub, and bottomland hardwood wetlands for the placement of dredged material.

At the sediment retention basin feature, a total of approximately 63 acres of low quality, recently timbered bottomland hardwood wetlands would be impacted through either filling for levee construction or as a result of deposition of sediment. In addition, approximately two acres of farmed wetlands would be impacted by sediment deposition as well.

At the Shelby Lake feature, roughly four acres of wetlands consisting of young willows and two acres of farmed wetlands would be impacted through either excavation or inundation.

At the Lake Isom feature, approximately 0.5 acre of bottomland hardwood wetland and 1.25 acres of farmed wetlands would be impacted by the work. In addition, roughly three acres of bottomland hardwood wetlands would be temporarily impacted for construction purposes.

(4) Timing and Duration of Discharge. Project construction is assumed to begin in 2002 and take roughly 4 years to complete. All work would be accomplished during dry or low water periods where practicable. Tentative construction dates are as follows:
Alternative spillway feature – May 2002 – June 2004
Circulation channels feature – June 2002 – August 2002
Sediment retention basin feature – September 2004 – September 2005
Shelby Lake feature – April 2004 – September 2004
Lake Isom feature – January 2003 – April 2003

It should be noted that the purpose of the sediment retention basin feature is to capture sediment before entering Reelfoot Lake, and as such, discharges of sediment into this area would occur on a regular basis following rain events.

f. Description of Disposal Method. All features would require the use of conventional heavy equipment such as draglines, excavators, and bulldozers. Work on the inlet channel of the alternative spillway feature would occur using a dredge to pump material out of the new channel. The cleanout of circulation channels may require the use of an amphibious excavator to accomplish this feature.

II. FACTUAL DETERMINATION

a. Physical Substrate Determinations.

(1) Substrate Elevation and Slope. At the alternative spillway feature, substrate elevation would be lowered by inlet channel construction by approximately 15 feet and convert the habitat from forested swamp to open water. Due to the abundance of similar habitat located adjacent to this area, impacts are not considered significant. The deposition of fill material into the area of the old spillway closure would convert this area from open water/shrub-scrub habitat to dry ground. Impacts would be offset by the construction of approximately 6,000 feet of new outlet channel.

At the circulation channels feature, substrate elevations would be lowered in the channels and raised on the adjacent top banks an average of two feet. It is expected that species occurring within the existing channels would likely recolonize the area shortly after work is complete. The abundance of like habitat adjacent to the channels would minimize impacts to species impacted by dredge disposal. In addition, the creation of higher elevations within these areas would create additional nonwetland habitat and would be utilized by many species found there.

At the sediment retention basin feature, a levee would be constructed that would range in height from 0 to 13 feet above existing ground elevations. Due to the abundance of similar habitat located adjacent to the wetlands impacted by levee construction, the impact is not considered significant. All other deposition would occur within PC cropland.

At the Shelby Lake feature, four acres of wetlands would be converted to open water by excavating roughly six feet of soil from the area. Most species occupying this area would be able to relocate to adjacent similar habitat. All other deposition would occur in PC cropland.
At the Lake Isom feature, the modification of the existing dam embankment would raise the height of the dam by roughly 2.5 feet and would be approximately 5 feet above the existing ground surface of adjacent wetlands. Most species occupying this area would be able to relocate to adjacent similar habitat

(2) Sediment Type. Sediment found within the project area is composed primarily of silt, sand, loess, and various clays.

(3) Dredged and Fill Material Movement. At all work sites, embankments and disposal piles would be seeded and stabilized. Riprap and concrete would be placed in order to prevent scouring and movement along the banks, channel bottoms, water control structures, and inlets and outlets.

(4) Physical Effects on Benthos. At each of the work sites, where deposition and excavation takes place, the physical destruction of the benthic community is expected. However, the project would create new habitat for benthics and recolonization is expected to occur in areas where destruction of habitat is not permanent.

(5) Other Effects. No other effects are expected to occur.

(6) Action Taken to Minimize Impacts. At all work sites, the smallest practical area would be used for deposition of material. Excavated material would be stabilized, and seeded to minimize soil erosion. Levees, and channel side slopes would be designed and stabilized with riprap where necessary to prevent erosion and increase long term stability .

b. Water Circulation, Fluctuation, and Salinity Determination.

(1) Water Quality. As a result of point and primarily nonpoint pollution, poor water quality is a significant problem in Reelfoot Lake. A study completed by the Tennessee Department of Health and Environment concluded that Reelfoot Lake has been severely impacted by nonpoint pollution. The alternative spillway, circulation channels, and sediment retention basin features are designed to reduce sedimentation, and turbidity, and thus improve water quality. Implementation of the project would compact and solidify loose sediment and organic matter, increase dissolved oxygen concentrations, improve water quality and nutrient availability, and increase biodiversity among plants and animals. Completion of the project should result in an improvement in water quality in Reelfoot Lake.

At all work sites, excavated material should, for the most part, contain the same contaminants as at the disposal sites. While there may be increased silt loads and turbidity during and immediately after project construction at each site, these impacts should decrease markedly upon completion of the project.

(a) Salinity. NA.

(b) Water Chemistry. The water chemistry of the project-affected areas should not change as a result of the project.

(c) Clarity. Increased sediment deposition into Reelfoot Lake has resulted in increased turbidity and lowered water quality. It has been estimated by the Tennessee Department of Health and Environment that the lake has an average sedimentation rate of 2.8 feet per year. Completion of the alternative spillway, circulation channels, and sediment retention basin features should provide improvements in water clarity. However, there would be a temporary increase in turbidity during project construction at each site.

(d) Color. No expected change.

(e) Odor. No expected change.

(f) Taste. No expected change.

(g) Dissolved Gas Levels. No expected change.

(h) Nutrients. Agricultural and silvicultural activities have increased erosion on lands adjacent to the lake and, thus, increased sediment deposition into the lake. Since most of this sediment is eroded from agricultural fields, large amounts of agriculture related nutrients enter the lake. It has been estimated that average nutrient loads of 64,370 kg of total phosphorus/year and 344,760 kg of total nitrogen/year enter the lake. Implementation of the project should reduce nutrient loads entering the lake, and improve water quality and nutrient availability.

(i) Eutrophication. Hypereutrophic conditions is considered one of the primary reasons for the deterioration of Reelfoot Lake. The accumulation of undecomposed organic material, high nutrient inflow, inadequate circulation, and limited water level fluctuation all continue to contribute to the Hypereutrophic condition. Implementation of the alternative spillway, circulation channels, and sediment retention basin features should improve conditions presently existing on the lake.

(2) Current Patterns and Circulation.

(a) Current Patterns and Circulation. At the alternative spillway feature, a new inlet/outlet channel and spillway would be constructed and the old spillway would be closed. The new spillway structure would allow fluctuations in water levels in Reelfoot Lake which currently are not possible.

At the circulation channels feature, the cleanout of approximately 17,000 feet of channels an average depth of two feet would improve circulation within the lake, allow more efficient lake drawdowns, and improve boat access within the lake.

At the sediment retention basin feature, construction of this feature would impede, but not prevent, flow in Reelfoot Creek to trap sediment traveling in the creek prior to entering the lake. The outlet structures would be designed such that water exiting the basin would enter existing drains.

In addition, the construction of roughly 38,000 feet of low level terraces within this area would hold shallow water during the winter for waterfowl on approximately 310 acres of PC cropland. During periods of inadequate rainfall, wells installed in the area would pump water into the site and artificially create current and circulation.

At the Shelby Lake feature, presently this area has very little flow other than runoff from adjacent fields. Completion of this project would hold shallow water during the winter on approximately 500 acres of PC cropland. During periods of inadequate rainfall, wells installed in the area would pump water into the site and artificially create current and circulation. In addition, roughly 170 acres of primarily PC cropland would be semi- permanently/permanently inundated at depths varying from one to six feet. A water control structure would be constructed which would connect Reelfoot Lake to this area (as was historically the case) and provide water on a as needed basis.

At the Lake Isom feature, modification of the dam embankment, spillway and outlet structure would increase water level management capabilities and allow flooding of an additional 510 acres of land. Current patterns and flows would be altered only during periods of inadequate rainfall where wells installed in the area would pump water into the site and artificially create current and circulation.

(b) Velocity. The construction of the alternative spillway would create velocities in the new outlet channel and Running Reelfoot Bayou during drawdown periods which do not presently occur. However, velocity changes would be within acceptable limits. Velocities would also be effected within the sediment retention basin feature as water would be slowed in order to trap sediments before being released into the lake.

(c) Stratification. No expected significant change.

(d) Hydrologic Regime. Significant changes in the hydrologic regime are expected to occur with the implementation of the alternative spillway and circulation channels features. A new spillway with a broader range of water management capabilities would restore natural seasonal water level fluctuations to the lake and would enable effective management of aquatic vegetation, better attenuation of flood peaks, and would result in long term habitat improvements and increased lake longevity.

Implementation of the sediment retention basin feature would alter the present hydrologic regime of Reelfoot Creek by retaining flows and allowing sediment to fall out of the water column before moving into the lake. In addition, shallow water would be retained during the winter on approximately 310 acres of PC cropland by the construction of low level terraces.

Implementation of the Shelby Lake and Lake Isom features would alter the hydrologic regime on these areas by holding water at greater depths and for longer duration in some areas, and seasonally inundating additional areas not presently effected.

(3) Normal Water Level Fluctuations. Normal water level fluctuations would not change beyond that previously discussed.

(4) Salinity Gradients. NA

(5) Action Taken to Minimize Impacts. At all work sites, excavation and placement of earthen material, placement of riprap, concrete, steel, etc., would be performed during low flow periods to avoid disruption of normal flow patterns and to reduce the levels of sediment introduced into the system.

c. Suspended Particulate/Turbidity Determinations.

(1) Expected Changes in Suspended Particulates and Turbidity Levels in Vicinity of Disposal Sites. At all work sites, discharge activities would increase turbidity during construction but should return to pre-construction levels following project completion. Long term decreases in turbidity in the lake are expected to occur with implementation of the project. No significant increase in suspended particulate levels or extended periods of turbidity are expected with deposition of fill or excavated material at any of the sites. Excavated material which is placed in embankments would be deposited during drier months to reduce suspended solids and turbidity levels in the lake and surrounding wetlands. Seeding of the embankments would significantly reduce particulate runoff once the grasses become established.

(2) Effects on Chemical and Physical Properties of the Water Column.

(a) Light Penetration. At all work sites, deposition of riprap, concrete, gravel, and excavated material may produce an increase in turbidity and a corresponding decrease in light penetration. This should return to near existing levels after construction.

(b) Dissolved Oxygen. Implementation of the alternative spillway feature would be expected to produce short term extremely low dissolved oxygen concentrations during major drawdown events. These low dissolved oxygen conditions could be expected to result in fish kills. However, following drawdown, and with normal water level fluctuation, increases in dissolved oxygen concentrations is expected to occur. At other work sites, temporary minor reductions in dissolved oxygen levels may occur, but normal levels should return upon completion of project construction.

(c) Toxic Metals and Organics. A reconnaissance of the project area revealed no known hazardous, toxic, or radioactive waste located within the project site or surrounding vicinity. Therefore, it is not anticipated that significant levels of contaminated sediment, if any, are present. However, when sediment is disturbed during project construction, the possibility exists that some of the pesticide materials may be transferred to the water column either through resuspension of the sediment solids, disposal of the interstitial water, or desorption from the resuspended solids. A feature of primary concern in this area is the cleanout of the circulation channels. To reduce the potential for reintroduction of toxic metals and organics, testing for these substances would occur in these areas prior to commencement of work.

(d) Pathogens. Implementation of this project is not expected to impact pathogen levels at any of the work sites.

(e) Aesthetics. Short term impacts to aesthetics may occur during construction. However, increases in the aesthetic value of the project area is expected to occur over the long term due to a reduction in sediment loads entering the lake, providing normal water level fluctuations, as well as benefits derived from the creation of additional wintering waterfowl habitat.

(f) Others as Appropriate. None noted.

(3) Effects on Biota.

(a) Primary Production. At present, as water depths continue to decline along with readily available nutrients and an abundant seed source, conditions are favorable for a massive invasion of aquatic macrophytes into areas of the lake which are currently free from excessive macrophyte populations. However, with implementation of the project, aquatic vegetation in Reelfoot lake should be significantly impacted. During a major drawdown, die back of aquatic vegetation is expected to occur. Submerged vegetation would begin to recolonize to more suitable habitat fairly quickly. In addition, existing vegetation zones would be reestablished shoreward. The inclusion of a dynamic water level fluctuation plan is expected to compliment the beneficial impacts that the drawdown would have on macrophyte problems.

The conversion of approximately 800 acres of PC cropland into winter habitat for waterfowl would provide an increase in aquatic vegetation and macrophytes in these areas. It is expected that the new and improved water level management capabilities at the Shelby Lake and Lake Isom features would improve aquatic vegetation and macrophyte populations within newly created permanent wetlands and existing wetlands as well.

(b) Suspension/Filter Feeders. Any adverse impacts to suspension and filter feeders will be of short duration, and these organisms should repopulate impacted areas after project completion.

(c) Sight Feeders. Construction of the project would have varying impacts on Reelfoot Lake's fishery. During a major drawdown, some fish kill is expected. As the lake refills, the surviving fishery should realize habitat conditions more favorable than those existing prior to the drawdown. In addition to the expected habitat changes, the project also would significantly change the population dynamics of the fishery. The expected creation of more acceptable spawning habitat and decreased competition would result in conditions favorable for game species.

Work proposed on the Shelby Lake feature would create an additional 50 acres of fishery habitat. In addition, the use of pumps during periods of low water would produce a water source to downstream fisheries.

(5) Actions Taken to Minimize Impacts. At all work sites, construction would be conducted during low-water periods, and vegetation would be cleared only to the extent necessary to allow adequate construction of project features. Excavated material embankments and disposal piles would be designed and seeded so as to reduce erosion and re-entry into the watercourse. All construction activities would comply with the Best Management Practices for Construction Activities (BMPs).

d. Contaminant Determinations. It is not expected that any contaminants would be introduced or increased due to deposition of excavated material or fill material at any of the work sites.

e. Aquatic Ecosystems and Organism Determination.

(1) Effects on Plankton. With the implementation of the project, it is expected that phytoplankton populations would continue to be extremely high in the lake. However, distribution of the populations may be effected by changes in circulation patterns and probable movement of aquatic vegetation zones shoreward. The creation of 50 acres of lake habitat in the Shelby Lake feature would create additional plankton habitat as would the new outlet channel.

(2) Effects on Benthos. It is expected that aquatic invertebrates would respond to the habitat changes induced by the project. During a major drawdown, the drying action would destroy a significant portion of Reelfoot's benthic populations. However, recolonization should occur rapidly after refilling. The reduction in biological oxygen demand near the bottom of the lake should help establish a population more indicative of improved water quality and habitat conditions. In addition, the reduced influx of sediment entering the lake should enhance benthic populations. The creation of 50 acres of lake habitat in the Shelby Lake feature would create additional benthic habitat as would the new outlet channel also. The placement of gravel, riprap, concrete, or excavated material at the work sites would destroy benthic communities but these areas would be recolonized within one year.

(3) Effects on Nekton. Construction of the project would have varying impacts on Reelfoot Lake's free-swimming aquatic animals. During major drawdowns, some fish and other nekton kill is expected. As the lake refills, the surviving populations should realize habitat conditions more favorable than those existing prior to the drawdown. In addition to the expected habitat changes, the project also would significantly change the nektonic population dynamics. The expected creation of more acceptable spawning habitat and decreased competition would result in conditions favorable for game species.

Work proposed on the Shelby Lake feature would create an additional 50 acres of habitat for fish or other nekton. In addition, the use of pumps during periods of low water would produce a water source to downstream populations.

(4) Effects on Aquatic Food Web. The project would have both short-term and long-term impacts on the aquatic environment. On Reelfoot Lake, during low water periods, water quality conditions would be temporarily stressed as well as those aquatic organisms which depend on these conditions. Conversely, periodic high water conditions would enhance water quality and beneficially impact the aquatic environment. The reduction of sediment entering the lake by roughly 35 percent due to the sediment retention basin feature would augment the benefits derived from increased water level management capabilities provided by the alternative spillway and circulation channels features. These long-term impacts are all recognized as beneficial towards the goal of preserving Reelfoot Lake in its current condition.

(5) Effects on Special Aquatic Sites.

(a) Sanctuaries and Refuges. During construction of the Lake Isom and sediment retention basin features BMPs would be utilized to prevent excessive sedimentation from impacting the Reelfoot and Lake Isom National Wildlife Refuges located around and adjacent to these two features.

(b) Wetlands. At the alternative spillway feature, approximately 1.3 acres of primarily open water area would be filled as part of the closure of the old spillway. To construct the inlet channel it would be necessary to clear and excavate approximately 2.5 acres of forested swamp and also clear and additional 1.0 acre for right-of-way. It is estimated that approximately 15 acres of aquatic habitat would be created as a result of construction of the new outlet channel and spillway.

At the circulation channels feature, approximately 2.0 acres of forested, shrub-scrub, and bottomland hardwood wetlands would be directly impacted as a result of disposal of excavated material. Removal of sediment from roughly 17, 000 feet of channels would occur.

At the sediment retention basin feature, approximately two acres of forested wetlands would be directly impacted by filling from construction of the levee. In addition, roughly 1.25 miles of Reelfoot Creek would be impacted as a result of levee construction and sediment deposition. Indirect impacts to approximately 61 acres of low quality bottomland hardwood wetlands and 2.0 acres of farmed wetlands would occur as a result of sediment deposition into the area. Annual maintenance dredging of Reelfoot Creek would also be necessary to remove the trapped sediment and the material would be placed on adjacent PC cropland. Also planned on this feature is the planting of 228 acres of PC cropland with bottomland hardwood seedlings. In addition, approximately 57 acres of wetlands would be created from the excavation of borrow material for levee construction. Due to sediment deposition, these areas are expected to exhibit wetland hydrology for roughly 30 years. In addition, approximately 310 acres of winter waterfowl impoundments would be created on PC cropland within this feature.

At the Shelby Lake waterfowl management unit feature, all deposition would occur in PC cropland. Excavation of material to restore historic water elevations in the lake would impact approximately four acres of wetlands consisting primarily of young willows and two acres of farmed wetlands. Project construction would result in the creation of a 50 acre lake where Shelby Lake was historically located. This construction would also seasonally inundate an additional 120 acres of PC cropland. In addition, roughly 483 acres of PC cropland would be converted into shallow water impoundments for wintering waterfowl.

At the Lake Isom feature, approximately 0.5 acre of forested wetland located directly adjacent to the existing dam embankment would be cleared and filled as a result of modifications to the existing dam, spillway, and outlet structure. It is estimated that 1.25 acres of farmed wetlands would be converted to open water in order to obtain the required earthen material for embankment construction. The resulting construction would seasonally flood and additional 510 acres of a mixture of bottomland hardwoods, forested swamp, scrub-shrub swamp, open water, and open fields.

(c) Mud Flats. The water level manipulations proposed for Reelfoot Lake would, during drawdowns, expose bottom areas and temporarily create large expanses of mud flats. This is expected to be a generally positive feature for species which utilize this type habitat.

(d) Vegetated Shallows. Implementation of the project is expected to have a generally positive effect on vegetated shallows. It is felt that implementation would reduce aquatic vegetation problems which currently exist within the lake without adversely effecting the positive impacts which occur from their presence. In addition, the construction of approximately 800 acres of winter waterfowl impoundments and a 120-acre seasonally to permanently inundated shallow water area should create extensive vegetated shallows near Reelfoot Lake.

(e) Riffle and Pool Complexes. Impacts to riffle and pool complexes is not expected to occur. Some riffle areas would be created on the outlet end of outfall structures and spillways.

(6) Threatened and Endangered Species. This project was coordinated with the United States Fish and Wildlife Service and they determined that no significant impacts to species listed or proposed for listing as a Federally threatened or endangered species would be affected by this project. Requirements of Section 7(c) of the Endangered Species Act have been fulfilled.

(7) Other Wildlife. Implementation of the project would have both short-term and long-term impacts to wildlife populations within and adjacent to Reelfoot Lake. Temporary displacement of some species would occur during project construction. Much of the project would be constructed in nonwetland cropland where the habitat would be converted to either, open water, shallow water, seasonally inundated shallow water, or forest. Many of the small mammal populations which occupy these areas would be displaced by species more appropriate for the new habitat.

In order to evaluate the impacts associated with the project on the wildlife populations found within wooded tracts located within construction areas, a study was initiated using the Habitat Evaluation System (HES). Impacts were then converted into Habitat Unit Values (HUVs). Results of the study revealed an increase in HUV's with implementation of the project (see Appendix ? for the study results). Therefore, it is expected that the project would have a net long-term benefit to wildlife.

(8) Actions Taken to Minimize Impacts. At all work sites, project construction would be conducted during low-flow periods, and vegetative clearing would be limited to the extent necessary for construction of project features. Disposal areas would be seeded in grass or planted in bottomland hardwood seedlings to assist stabilization of the material.

f. Proposed Disposal Site Determinations.

(1) Mixing Zone Determination. Excavation of sediment from the circulation channels and inlet channel would increase turbidity for several hundred yards within the area while work is ongoing. Excavated material would be placed in nonwetlands where possible and seeded in grass or bottomland hardwood seedlings to assist in stabilization. Slight increases in turbidity is expected at all project features during construction, however these increases are expected to be short-term.

(2) Determination of Compliance with Applicable Water Quality Standards. All applicable Federal, State, and local water quality standards, including issuance of water quality certification from the Tennessee Department of Environment and Conservation, would be met prior to commencement of work.

(3) Potential Effects on Human Use Characteristics.

(a) Municipal and Private Water Supply. NA.

(b) Recreational and Commercial Fishing. As a result of continued siltation and deteriorating water quality, the future recreational demand for Reelfoot Lake is expected to continue to decline. Implementation of the project is expected to increase the sport fish populations within Reelfoot Lake. Consequently, as the sport fish population increases, so should recreational and commercial fishing.

(c) Water Related Recreation. Sport and commercial fishing, hunting, birdwatching, and tourists are very important to the economics of both Lake and Obion Counties. As the recreational demand declines, several businesses around the lake would eventually fail. With project implementation it is estimated that water related recreation would increase on the lake, and consequently so would income derived from these activities.

(d) Aesthetics. Short term adverse impacts to aesthetics may occur during construction. However, increases in the aesthetic value of Reelfoot lake is expected to occur over the long term due to water quality increases, as well as benefits derived from activities related to fish and wildlife habitat restoration, enhancement, and preservation.

(e) Parks, National Historical Monuments, National Seashores, Wilderness Areas, Research Sites and Similar Preserves. Reelfoot Lake State Park, Reelfoot Wildlife Management Area, Reelfoot National Wildlife Refuge, and Lake Isom National Wildlife Refuge occur within, or are adjacent to the project area. Temporary impacts are expected to occur during project construction, however completion of the project should result in long-term benefits to these properties.

g. Determination of Cumulative Effects on the Aquatic Ecosystem. The proposed construction of the alternative spillway feature is designed to provide a safe and more versatile structure for water level control at Reelfoot Lake in the interest of water quality, and fish and wildlife habitat restoration. This would be accomplished by construction of a structure consisting of six 12 foot by 20 foot retainer gates and approximately 6,000 feet of outlet channel to connect the spillway to Running Reelfoot Bayou.

The proposed cleanout of circulation channels within Reelfoot Lake is designed to connect the three major basins of the Lake (Blue, Buck, and Upper Blue Basin) to each other and the alternative spillway channel to aid in lake water level management. The channels would provide improved circulation between major pools during normal lake stages and minimize isolation of major pools in extremely low stages. The channels would also aid in the periodic drawdown of the Lake using the new spillway. This will be accomplished by dredging approximately 13 miles of 30-foot average bottom width channel, at an elevation of 276 NGVD.

The proposed construction of a sediment retention basin within the Reelfoot Creek basin is designed to prevent deposition of sediment into the lake from Reelfoot Creek. This would be accomplished by the construction of approximately 3.2 miles of levee, a 1,200 foot wide emergency spillway, a 175 foot wide primary spillway, and three outlets consisting of two 72 inch culverts.

The proposed construction of approximately 500 acres of waterfowl management units in the Shelby Lake area is designed so that areas of open land would be terraced and flooded in order to provide feeding and resting habitat for waterfowl. This would be accomplished by construction of approximately 19 miles of levees, nine 1,000 gpm wells, and fifteen water control structures, consisting of stop-log structures, riser pipes, and culverts.

The proposed construction of a new spillway and stoplog structure on Lake Isom is designed to increase water level management capabilities by providing the ability to drawdown water levels within Lake Isom to 274 NGVD, and to raise water levels to elevation to 282 NGVD, which is approximately 1.5 feet above the existing maximum water elevation. This will be accomplished by replacement of the existing stop log structure, modification of the existing emergency spillway, modification of the dam embankment, and installation of ten 1,000 gpm wells to facilitate raising water surface elevations above existing levels.

In summary, the proposed project should have no cumulative adverse impacts on the aquatic ecosystem.

h. Determination of Secondary Effects on the Aquatic Ecosystem. No adverse secondary impacts to the aquatic ecosystems should occur as a result of construction of the proposed project.

III. FINDING OF COMPLIANCE FOR REELFOOT LAKE PROJECT.

a. No significant adaptations of the Section 404(b)(1) guidelines were made relative to this evaluation.

b. Alternative sites and methods of excavation, disposal, and construction have been considered throughout the project design process. The current proposal is considered the least damaging practicable alternative considering cost, existing technology, and logistics in light of overall project purposes.

c. The proposed action will not violate any applicable State water quality standards.

d. No federally listed, or proposed, threatened or endangered species or their critical habitats will be adversely impacted by the proposed project.

e. The proposed project will not result in significant adverse effects on human health and welfare, the municipal water supply, or commercial or sport fishing. No long-term adverse impacts on plankton communities; breeding, spawning, or nursery habitats; or shellfish areas are expected.

f. No significant adverse impacts to aquatic life or terrestrial wildlife, dependent on aquatic ecosystems, are expected. The proposed project should not cause significant adverse impacts on ecosystem diversity, productivity, or stability.

g. No adverse impacts on recreational, aesthetic, or economic values are anticipated.

h. In order to minimize potential environmental impacts, construction will be conducted during periods of low rainfall. Additionally, vegetative clearing will be limited to the extent necessary for construction of project features.

i. On the basis of the guidelines, the proposed project, as discussed, is specified as complying with the requirement of these guidelines with the inclusion of appropriate and practical conditions to minimize pollution or adverse effects to the aquatic ecosystem.

j. The criteria for Section 404 R Exemption has been met.

REPORT NUMBER
99-158-0208 PAGE 1

ACCOUNT NUMBER
07686

A&L Analytical Laboratories, Inc.
411 North Third Street • Memphis, TN 38105 • (901) 527-2780 • FAX (901) 526-1031

SEND TO:

U.S. CORPS OF ENGINEERS
ATTN: CELMM-ED-HW/TRACY JAMES
167 N. MAIN RM B202
MEMPHIS, TN 38103-1894

P.O.# 99153

REPORT DATE: 07/02/99
DATE RECEIVED: 06/07/99

REPORT OF ANALYSIS

LAB NUMBER: 59055
SAMPLE ID : LOVELLS #7 6/5/99 1100

Analysis	Result	Detection Limit	Method	Date and Time Test Started	Analyst
Digestion For Total Metals	METAL PREP	N/A	SW-6010	06/08/99 04:00PM	ADG
Total Arsenic, mg/Kg	0.30	0.001	SW-6010	06/10/99 11:04AM	ADG
Total Chromium, mg/Kg	3.95	0.02	SW-6010	06/10/99 11:04AM	ADG
Total Mercury, mg/Kg	0.033	0.02	SW-7471	06/22/99 10:00AM	ANA
Total Zinc, mg/Kg	17.6	0.01	SW-6010	06/10/99 11:04AM	ADG

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Carlton Gibson, Environmental Lab Manager

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REPORT DATE: 07/02/99
DATE RECEIVED: 06/07/99

REPORT OF ANALYSIS

LAB NUMBER: 59056
SAMPLE ID : DONALDSON DITCH #1 6/5/99 1200

Analysis	Result	Detection Limit	Method	Date and Time Test Started	Analyst
Digestion For Total Metals	METAL PREP	N/A	SW-6010	06/08/99 04:00PM	JRF
Total Arsenic, mg/Kg	2.31	0.001	SW-6010	06/10/99 11:04AM	ADG
Total Chromium, mg/Kg	3.49	0.02	SW-6010	06/10/99 11:04AM	ADG
Total Mercury, mg/Kg	0.038	0.020	SW-7471	06/22/99 10:00AM	ANA
Total Zinc, mg/Kg	14.4	0.01	SW-6010	06/10/99 11:04AM	ADG

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REPORT DATE: 07/02/99
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REPORT OF ANALYSIS

LAB NUMBER: 59057
SAMPLE ID : DONALDSON DITCH #2 6/5/99 1230

Analysis	Result	Detection Limit	Method	Date and Time Test Started	Analyst
Digestion For Total Metals	METAL PREP	N/A	EPA-4.3.1	06/08/99 04:00PM	ADG
Total Arsenic, mg/Kg	0.32	0.001	SW-6010	06/10/99 11:05AM	ADG
Total Chromium, mg/Kg	3.37	0.02	SW-6010	06/10/99 11:05AM	ADG
Total Mercury, mg/Kg	0.033	0.020	SW-7471	06/22/99 10:00AM	ANA
Total Zinc, mg/Kg	12.8	0.01	SW-6010	06/10/99 11:05AM	KJW

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REPORT DATE: 07/02/99
DATE RECEIVED: 06/07/99

REPORT OF ANALYSIS

LAB NUMBER: 59058
SAMPLE ID : HORSE ISLAND DITCH #3 6/5/99 1330

Analysis	Result	Detection Limit	Method	Date and Time Test Started	Analyst
Digestion For Total Metals	METAL PREP	N/A	EPA-4.1.3	06/08/99 04:00PM	JRF
Total Arsenic, mg/Kg	1.11	0.001	SW-6010	06/10/99 11:06AM	ADG
Total Chromium, mg/Kg	5.09	0.02	SW-6010	06/10/99 11:06AM	ADG
Total Mercury, mg/Kg	ND	0.020	SW-7471	06/22/99 10:00AM	ANA
Total Zinc, mg/Kg	18.8	0.01	SW-6010	06/10/99 11:06AM	ADG

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REPORT DATE: 07/02/99
DATE RECEIVED: 06/07/99

REPORT OF ANALYSIS

LAB NUMBER: 59059
SAMPLE ID : HORSE ISLAND DITCH #4 6/5/99 1400

Analysis	Result	Detection Limit	Method	Date and Time Test Started	Analyst
Digestion For Total Metals	METAL PREP	N/A	EPA-4.1.3	06/08/99 04:00PM	JRF
Total Arsenic, mg/Kg	1.38	0.001	SW-6010	06/10/99 11:07AM	ADG
Total Chromium, mg/Kg	7.55	0.02	SW-6010	06/10/99 11:07AM	ADG
Total Mercury, mg/Kg	0.023	0.020	SW-7471	06/22/99 10:00AM	ANA
Total Zinc, mg/Kg	27.7	0.01	SW-6010	06/10/99 11:07AM	ADG

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CONTINUATION ON NEXT PAGE

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P.O.# 99153

REPORT DATE: 07/02/99
DATE RECEIVED: 06/07/99

REPORT OF ANALYSIS

LAB NUMBER: 59060
SAMPLE ID : NIX TOWHEAD DITCH #5 6/5/99 1500

Analysis	Result	Detection Limit	Method	Date and Time Test Started		Analyst
Digestion For Total Metals	METAL PREP	N/A	EPA-4.1.3	06/08/99	04:00PM	JRF
Total Arsenic, mg/Kg	2.38	0.001	SW-6010	06/10/99	11:07AM	ADG
Total Chromium, mg/Kg	4.54	0.02	SW-6010	06/10/99	11:07AM	ADG
Total Mercury, mg/Kg	ND	0.020	SW-7471	06/22/99	10:00AM	ANA
Total Zinc, mg/Kg	17.7	0.01	SW-6010	06/10/99	11:07AM	ADG

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REPORT NUMBER
99-158-0208 PAGE 7

ACCOUNT NUMBER
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P.O.# 99153

REPORT DATE: 07/02/99
DATE RECEIVED: 06/07/99

REPORT OF ANALYSIS

LAB NUMBER: 59061
SAMPLE ID : SUNSET #6 6/5/99 1545

Analysis	Result	Detection Limit	Method	Date and Time Test Started	Analyst
Digestion For Total Metals	METAL PREP	N/A	EPA-4.1.3	06/08/99 04:00PM	JRF
Total Arsenic, mg/Kg	0.80	0.001	SW-6010	06/10/99 11:08AM	ADG
Total Chromium, mg/Kg	4.15	0.02	SW-6010	06/10/99 11:08AM	ADG
Total Mercury, mg/Kg	ND	0.020	SW-7471	06/22/99 10:00AM	ANA
Total Zinc, mg/Kg	16.4	0.01	SW-6010	06/10/99 11:08AM	ADG

Comments:

EPA = "METHODS FOR CHEMICAL ANALYSIS OF WATER AND WASTES",EPA 600/4-79-020,REVISED MARCH 1983
SW = "TEST METHODS FOR EVALUATING SOLID WASTE,PHYSICAL/CHEMICAL METHODS,SW-846 3rd EDITION

A & L Analytical Laboratories, Inc.

Carlton Gibson, Environmental Lab Manager

SECTION V

VEGETATION IMPACT ANALYSIS

PART A. REELFOOT LAKE

Final Draft

Project Title: **Vegetation Impact Analysis of Reelfoot Lake**

The University of Memphis Project No. : **5-36298**

Principal Investigator: **Dr. S. Reza Pezeshki**
Department of Biology
The University of Memphis
Memphis, TN 38152

Submitted to: **U.S. Army Corps of Engineers, Memphis District**

August 2, 1998

1.0 INTRODUCTION

1.1 Physical Description and History

Historically, the Mississippi River had a floodplain that spanned several miles in width and was responsible for the creation and ecological maintenance of various types of freshwater habitats. Included in this list of habitats are oxbow lakes, sloughs, riparian forests, marshes, swamps and shallow lakes (Messina and Conner 1998). One such shallow lake influenced by the periodic cycle of flooding of the Mississippi River is Reelfoot Lake, located primarily in Lake and Obion counties in Northwestern Tennessee and Fulton county in Southwestern Kentucky (TWRA 1986). It is Tennessee's largest natural lake and is widely known as an outstanding recreational resource (USACE 1993). Reelfoot Lake has endured tremendous change since it was last a tributary of the Mississippi River, most of which has been a direct result from human manipulation of the natural processes which helped create and maintain its diversity and function.

In 1811 and 1812, modern Reelfoot Lake was created when the New Madrid earthquakes heaved portions of the earth out of place, and conversely allowed other portions to sink (Smith and Pitts 1982). Positioned approximately three miles east of the Mississippi River, the lake was probably a wetland at the time and functioned as part of the drainage basin for the area (Steenis and Cottam 1945, Smith and Pitts 1982). However, the sudden elevation change and the drainage of Indian Creek, Reelfoot Creek and Bayou Du Chien into this area subsequently created a permanent shallow lake. For the next one hundred years the lake was governed by the natural fluctuations in water level associated with the Mississippi River. According to Smith and

Pitts (1982), it was not uncommon for the lake to rise up to 10-12 feet above its normal water elevation when the river experienced serious flooding.

In the late 19th century, the bottomland hardwood forests, which occur throughout the Mississippi River floodplain, began to be harvested for commercial timber, and the land was converted for agricultural use (USFWS 1989). Similarly, timber production and commercial fishing began at Reelfoot Lake. As a result, the trend for large-scale use and manipulation of the lake was established. In 1913 the Tennessee State Supreme Court deemed Reelfoot Lake a navigable water, opening the door for the construction of a highway along the southern border of the lake in 1919 (USFWS 1989). The highway was built on an elevated levee, thus effectively and permanently severing it from the natural hydrological fluctuations produced by the Mississippi River (USFWS 1989). The levee was constructed with a single spillway approximately eighty feet in length, which drained the lake into Running Reelfoot Bayou. Design flaws in the spillway led to the subsequent construction of a second spillway in 1931, which has remained in use until the present time (Smith and Pitts 1982). Various water level management plans have been exercised in attempt to appease local agricultural and commercial fishing demands, however for the past 30-40 years the standard practice has been to maintain the lake water level as close to 282.2 feet mean sea level (m.s.l.) as possible.

Presently, the State of Tennessee owns 26,826 acres of land within the Reelfoot Lake area. The majority of which is managed by the Tennessee Wildlife Resources Agency (TWRA) as The Reelfoot Lake State Park. In 1941 the United States Fish and Wildlife Service (USFWS) signed a 75-year lease with the State of Tennessee for 7,847 acres that they manage as the Reelfoot National Wildlife Refuge. The Tennessee Department of Conservation manages an additional 279 acres of land. In addition to the land owned by the State of Tennessee, the USFWS owns 2,580 acres in fee title in both Tennessee and Kentucky (USFWS 1989).

The lake consists of four major regions, all of which are at least narrowly connected to each other, except for the Upper Blue Basin (Figure 1). Ditches have been constructed in several areas, which aid in the flow of water from one basin to the next. The Upper Blue Basin is the northern most basin and consists primarily of open water. The Bayou Du Chien, one of the three inlets to the lake, connects it to Buck Basin to the south; this is the only natural connection between Upper Blue Basin and the rest of the lake. Buck Basin is directly south of the Upper Blue Basin and is connected to the Middle Basin via Horse Island Ditch, Rag Point Ditch, and Nation's Ditch. Indian Creek, another of the lake's three inlets, drains into the Middle Basin from the east. This area flows naturally into the final portion of the lake, Blue Basin. Donaldson Ditch also connects these last two basins on the northwestern end of the Blue Basin. The lakes' only outlet occurs at the southern banks of the Blue Basin, through the spillway running under Highway 21. This area is known as Running Reelfoot Bayou, and has historically been dredged to maintain adequate drainage of excess water during the high precipitation periods of the year (USFWS 1989). The four basins located within the Reelfoot Lake area are characteristically shallow maintaining a mean depth of approximately 5.2 feet at the normal pool elevation of 282.2 feet m.s.l. Approximately 43 percent of the total lake area has a depth of 3.0 feet or less at this

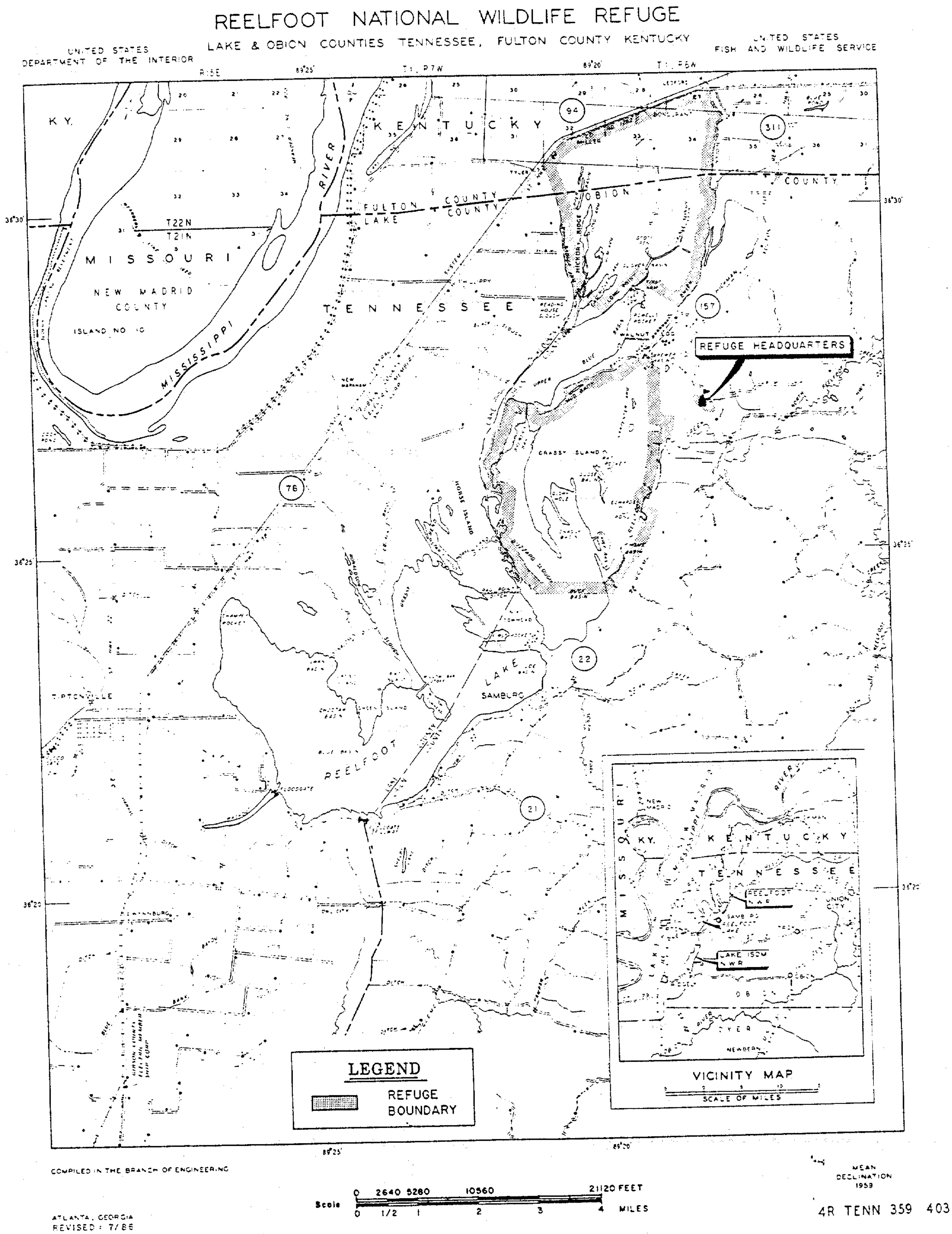

Figure 1. Map of Reelfoot Lake and vicinity.
(USFWS)

stage (TWRA 1985). The relative homogeneity of the physical features of the lake makes it particularly vulnerable to environmental modifications because any changes can potentially impact the entire system.

1.20 Objectives

The purpose of this work was to scour the scientific literature and, considering the uniqueness of Reelfoot Lake's ecology and location as well as its current condition and ecological health, speculate upon the potential effects several water level manipulation proposals would have on its flora. This work includes an in-depth analysis of the problems facing Reelfoot Lake as well as the actions that have been proposed to counteract them. Finally, the effects of the proposed dynamic water level fluctuation on the system responsible for the unique vegetative structure, and the effects of consequential modifications of this structure on the surrounding wildlife communities, will also be examined.

2.00 Problems Associated with Reelfoot Lake

2.10 Past Remedial Actions

The present condition of the lake is declining and has been over the past several decades. Sedimentation and eutrophication have both been continual problems for the governing agencies of Reelfoot Lake for nearly half of a century. Ecological and economical concerns have arisen due to the synergistic effect that sedimentation and eutrophication have on the lake ecosystem. Virtually every agency involved has made attempts to eliminate the problems using a number of potential solutions. Herbicides have proven to be relatively ineffective and, in light of current water quality standards, may pose environmental hazards. Cutting of aquatic macrophytes has also proven ineffective and is very costly. In 1960, a project was approved to construct a series of fifteen sediment retention impoundments on Reelfoot and Indian Creeks. As of 1989, only eight of those impoundments had been completed. Again in 1979 a program was adopted to attempt to improve water quality and decrease agricultural soil erosion. The Rural Clean Water Program gave incentives to farmers whom implemented erosion controls and conservation programs within the area. Despite these efforts, sedimentation and eutrophication at Reelfoot Lake have continued. Finally, in 1985 the TWRA proposed a major drawdown at the lake as a viable solution to both problems. The drawdown was quickly recognized and accepted by the USFWS and was begun in May of the same year. However, shortly after the drawdown was initiated, a concerned group of citizens halted any further action by filing a court injunction. This injunction required the preparation of an Environmental Impact Statement (EIS) and a detailed investigation into the ecological and economical impacts that a major drawdown would have on Reelfoot Lake and its surrounding communities (USFWS 1989). Presently, the EIS has been completed and implementation of the drawdown is drawing near.

2.20 Sedimentation

Reelfoot Lake serves as a drainage basin for an agricultural area of approximately 240 mi^2 (USFWS 1957). As a result, it is the catch basin for the large amount of pollutants produced by modern agricultural practices. Conversion of this area to agricultural use in the early 1900's has resulted in a massive increase in the sediment and nutrient load introduced to the lake. It has been proposed that 75 percent of the sedimentation at the lake has occurred since 1900, and 75 percent of that amount since 1925 (Tennessee Game and Fish Commission 1951). Modifications to the lake as a result of these artificial inputs include physical and chemical changes of the lake itself as well as species composition, abundance, and productivity in both vegetative and wildlife communities.

Traditionally, natural sediment accretion would have been partially flushed and replaced each year with the periodic flooding of the Mississippi River. However, the natural hydrological regime has been virtually eliminated, therefore sediment entering the lake remains in place. As a result, the lake is filling in at an alarming rate. Denton (1986) stated that sedimentation from the Reelfoot Creek, Indian Creek and Bayou du Chien watersheds have the greatest negative impacts at Reelfoot Lake, delivering 93.4 percent of the calculated 293,000-ton annual sediment load to the lake. Studies using Cesium 137 and probing data from Reelfoot have calculated the sedimentation rate for the Blue, Buck and Upper Blue Basins to be .89, 1.09, and 1.88 cm (.35, .43, and .74 inches) per year, respectively (Tennessee Dept. of Health and Environment 1984). Based on these sedimentation rates, the Blue Basin would be filled to a depth of two feet in approximately 210 years, the Buck in 110, and the Upper Blue in just 60 years; and would be completely filled in 275, 165, and 90 years (Denton 1986). Channelization of many of the tributaries has also become a widespread problem throughout the watershed. This agricultural practice is used to remove standing water from surrounding agricultural fields as quickly as possible, and results in increased flow velocities entering the lake (USFWS 1989). An increase in the deposition of larger sized soil particles, such as sands, has been documented since sections of Reelfoot Creek were channelized (McIntyre and McHenry, 1984, Denton 1986). Similarly, channelization of streams can yield large amounts of sediment from erosion of their earthen banks, especially during unusually wet years which would increase the magnitude and frequency of its peak flow (Trimble 1997). Denton (1986) reports maximum soft sediment depths of 150, 175, and 200 cm (59, 69, and 79 inches) at the Upper Blue, Buck, and Blue Basins, respectively. Two sample locations at Blue Basin indicated no deposition at those sites during the past one hundred years. Thus, sedimentation appears to have impacted virtually the entire lake bottom, and is a major contributor to the decrease in mean lake depth. However, sedimentation also plays a major role in the definition of aquatic community dynamics by influencing water quality and its associated chemical properties. Agricultural erosion often carries with it byproducts of the industry, the most important of which is nitrogen and phosphorous from fertilizer (Talley et al. 1984).

2.30 Eutrophication

After sediment, fertilizer is the second major pollutant produced by the agricultural industry surrounding the lake. Storm water runoff and excess irrigation have increased the amount of nitrogen and phosphorous in the Reelfoot system (McIntyre and McHenry, 1984). Soil particles adsorb these chemicals onto their surface and carry them into the system as erosion takes place (Messina and Conner, 1998). In 1975 it was estimated that application of nitrogen fertilizers to croplands in Lake and Obion counties, TN, exceeded recommended high level application limits by 22% and 5%, respectively (Henderson and Free 1975). Introduction of excess nutrient loads to a lake is called eutrophication. Reelfoot Lake has recently been classified as a hypereutrophic lake (USFWS 1989) meaning that the amount of nutrients in the lake has become excessive (Mitch and Gosselink 1993). Normally, nutrients such as nitrogen and phosphorous are limited in aquatic systems, this acts to control the production of aquatic algae and plants. However, in a hypereutrophic system, such as Reelfoot Lake, these nutrients are abundant and result in massive production of vegetative biomass. Consequently, the lake has been overrun by aquatic macrophytes to the point that boat navigation in some areas is becoming difficult if not impossible.

The maintenance of a constant water level at Reelfoot Lake has also had a detrimental effect on the lake. Long-term constant water levels promote a detritus build up on the lake bottom that contributes to low dissolved oxygen contents in the lake substrate and water column (TWRA 1988). At very low soil redox potentials, decay slows markedly due to the shortage of oxygen. Lack of oxygen (anoxia) slows the decay of organic matter. Anaerobic decomposition processes have been shown to be less efficient than aerobic ones (Messina and Conner 1998). These reductions in oxygen concentrations and soil redox potential may lead to significant changes in the nutrient cycling patterns within the system, affecting transformations of nitrogen, iron, manganese, sulfur, carbon, and phosphorus and have consequent detrimental effects on plants and other organisms. Low oxygen levels at Reelfoot Lake have been reported (Baine and Yonts 1937, Baker 1940, Shore 1952, USFWS 1989). Such low oxygen levels are known to adversely affect biological systems including aquatic, emergent and forested species (Conner et al 1981, Conner and Day 1991, Mitsch and Gosselink 1993). At present, the lake's water level is maintained at 282.2 feet m.s.l. with slight fluctuation due to local precipitation trends and short-term wildlife management objectives (USFWS 1989). Such conditions have created an anaerobic condition in the lake's water and sediment.

In the following sections, we will examine the effects of the anaerobic conditions on the Lake's biological systems in general and plants in detail.

2.40 Effects of Oxygen Deficiency on Nutrient Cycling

Oxygen is necessary for root respiration to occur and for aerobic soil microorganisms to survive, and is therefore critical for normal root functioning. Flooding reduces soil oxygen as the air pore spaces within the soil are replaced with water. Gas exchange is then restricted at the soil-air interface and this restriction along with the subsequent depletion of oxygen results in a series of chemical changes within the soil including accumulation of such gases as CO_2, methane, N_2 and H_2 (Ponnamperuma 1984). Once the soil has been waterlogged, the short supply of oxygen found in floodwater is rapidly depleted by roots and soil microbes (Ponnamperuma 1972, Reddy et al. 1980), and aerobic microorganisms are soon replaced by anaerobes. The anaerobic communities that become established are predominantly characterized by bacteria (Yoshida 1978). This process is followed by denitrification, then reduction of iron and manganese, and finally by sulfate reduction, resulting in a change in soil pH and Eh (Gambrell et al. 1991). In a typical series of reductions, NO_3^- is reduced to NO_2^-, followed by reductions of Mn^{+4} to Mn^{+2}, Fe^{+3} to Fe^{+2}, SO_4^{2-} to S^{2-}, ultimately acetic and butyric acid accumulations are produced by microbial metabolism (Gambrell and Patrick 1978, Ponnamperuma 1984). Each of these transformations play an integral part in the biogeochemistry of wetland systems, thus, a brief discussion of each process is warranted, and is presented in the following sections.

2.41 Nitrogen Transformations

Nitrogen is the most limiting nutrient in flooded soils (Gambrell and Patrick 1978). Transformation of nitrogen requires many microbial pathways. The ammonium ion (NH_4^+) is the most available form of nitrogen found in flooded soils. Once formed, it may undergo several processes, some which make it less available for plant uptake. The ammonium ion may be taken up by plants or microorganisms and converted back into organic nitrogen or it may be bound by negatively charged soil particles (Mitsch and Gosselink 1993). The available ammonium-nitrogen may be oxidized when oxygen is present converting nitrate to nitrogen in a process known as nitrification. The nitrate form of nitrogen (NO_3^-) is not easily immobilized by negatively charged soil particles, due to its negative charge, thus it is more mobile in solution. If sufficient oxygen is not available, and the existing nitrates are not taken up by plants and microbes, the nitrogen may be reduced further by denitrification, which produces molecular nitrogen (N_2) and nitrous oxide gas (N_2O) (Wiebe et al. 1981). It is well known that denitrification results in a significant loss of nitrogen in wetland systems (e.g., Kaplan et al. 1979, Whitney et al 1981, Mohanty and Dash 1982).

2.42 Iron and Manganese Transformations

In permanently flooded soils, both iron and manganese are found in the reduced forms and may build up to toxic levels within the soil. These reduced forms of iron and manganese (ferrous and manganous, respectively) are more soluble and may easily be used by microorganisms (Mitsch and Gosselink 1993). Both reduced metals may be oxidized within the rhizosphere by oxygen leaking from plant roots, coating the roots with metal oxides which inhibits nutrient uptake (Pezeshki 1994a). Although harmful in the reduced state, both iron and manganese are vital to plant life. Iron is necessary for chlorophyll synthesis, a key factor in photosynthesis. Deficiencies in iron cause decreased photosynthesis and leaf chlorosis. Manganese is required for the release of oxygen from the plant during photosynthesis, and may decrease photosynthetic activity if found in inadequate levels.

2.43 Sulfur Transformations

Although sulfur is usually not considered a limiting nutrient in plant growth, reduced forms found in soils of low redox potential may be toxic to plant roots. Organic and elemental sulfur (S) enter the system from plant material and from the sloughing off of parent material in the soil, while sulfates (SO_4) enter from the atmosphere. Once organic sulfur is oxidized, it is readily available for uptake by plants and microbes or for chemical transformations. Sulfate reduction occurs when certain anaerobic bacteria, such as *Desulfovibrio*, use sulfate as the terminal electron acceptor in aerobic respiration which produces hydrogen sulfide gas (H_2S) (Mitsch and Gosselink 1993). Sulfur may also be released from the system in the form of methyl and dimethyl sulfides (Faulkner and Richardson 1989). Sulfides can be highly toxic to both plants and microbes and have been attributed to the direct toxicity to plant roots, lower availability to plants due to precipitation with trace minerals, and the immobility of copper and zinc due to sulfide precipitation (Ponnamperuma, 1972). Oxidation of sulfides is provided by both chemoautotrophic and photosynthetic microbes which transform the sulfides into elemental sulfur and sulfates (Mitsch and Gosselink 1993).

2.44 Phosphorus Transformations

Another important nutrient transformation is that of phosphorus. Phosphorus is one of the most important nutrients in ecosystems and is one of the most limiting factors affecting productivity (Mitsch and Gosselink 1993). Inorganic phosphorus is released from its organic form through a process known as mineralization. The inorganic form of phosphorus, generally in the form of orthophophate, is the most useful form as a plant nutrient. It is sedimentary in nature as opposed to the gaseous nature of nitrogen, and large proportions can usually be found in organic litter and inorganic sediments. Phosphorus is not generally altered by low soil redox potential, instead it is affected by elements, such as iron and manganese, whose chemistry is dependent upon its state of reduction (Mohanty and Dash 1982). Phosphorus is rendered relatively unavailable to plants and microconsumers when insoluble phosphates precipitate with ferric iron, calcium, and aluminum under aerobic conditions. Similarly, phosphorus be immobilized by the adsorption of phosphate onto clay particles, or by the binding of phosphorus in organic matter as a result of its incorporation into the living biomass of bacteria, algae, and vascular macrophytes (Mitsch and Gosselink, 1993).

2.50 Effect of Sediment pH

One of the most important factors influencing phosphorus mineralization along with other nutrients is soil pH (Atlas and Bartha 1981). Soil pH is important because of its effects on soil bacteria, soil toxicity, soil structure, and nutrient leaching, all of which affect plant growth. Most affected by pH are the soil microbes. These microbes are necessary to convert the organic forms of nutrients to forms readily available for plant uptake and consumption. Many of these microbes such as *Nitrosomas*, *Desulfovibrio*, and certain species of *Thiobacillus* have optimum pH ranges from slightly acidic to neutral. Soil pH has also been shown to have a direct connection to soil redox potential (Eh). Soil Eh at which chemical stability, whether reduced or oxidized, is directly correlated to soil pH.

2.60 Effect of Low Soil Redox Conditions on Plants

Low soil and sediment redox potential (Eh) conditions create high oxygen demands within the soil that may adversely affect internal plant tissue oxygen concentrations. Another consequence of low soil Eh is that changes may occur in the availability and/or concentrations of various essential nutrients. In addition, soil reduction may also result in the production of certain chemicals that are toxic to plant roots and systems (Patrick and DeLaune 1977, DeLaune et al. 1983a,b, Gambrell et al. 1991). These compounds include ethanol, lactic acid, acetaldehyde, acetic acid, and others (DeLaune et al. 1978, Ponnamperuma 1972, 1984). Other phytotoxic compounds such as reduced forms of Fe and Mn may accumulate in the flooded soils and cause further injury to plants (Gambrell and Patrick 1978, Drew and Lynch 1980). The presence of these compounds, in addition to oxygen depletion, creates a stressful environment for plant roots. For example, low soil Eh and excess soil sulfide has been shown to inhibit the growth of numerous marsh macrophytes (King et al. 1982, Ingold and Havill 1984, Havill et al. 1985, Armstrong et al. 1996). The presence of soluble sulfide species such as H_2S have been shown to be toxic to plant roots (Tanaka et al. 1968, Allam and Hollis 1972). For example, the effect of H_2S on cytochrome oxidase is disruptive to aerobic respiration while excess cytosolic Fe and Mn are harmful to enzymatic structures (Drew 1990). However, flood-tolerant plants have adapted a transport system that facilitates the diffusion of oxygen from the aerial parts of the plant to the root system. This allows a plant to oxidize not only sulfide but also Fe and Mn within the rhizosphere, thereby allowing the plant to minimize the level of toxicity (Teal and Kanwisher 1966). The inhibitory effects of low soil redox potential, along with high sulfide concentrations, on leaf photosynthetic capacity have been confirmed in several wetland species (Pezeshki et al. 1988, 1991). This decrease in photosynthetic capacity has been associated with the disruption of light reactions (Shimazaki and Sugahara 1980) and/or photophosphorylation (Wellburn et al. 1981). Furthermore, changes in the activity of photosynthetic enzymes have also been shown to be a direct cause of decreased photosynthetic capability (Garsed 1981, Khan and Malhotra 1982, Dropff 1987).

Tree species that occur naturally in forested wetlands use various mechanisms to cope with the soil oxygen-deficiency and low soil Eh conditions. These mechanisms include morphological and anatomical adaptations such as adventitious root development, lenticel formation, changes in root metabolism, acceleration of anaerobic fermentation, and the development of aerenchyma tissue which allows for oxygen diffusion to the roots from aerial parts of the plant. Among the mechanisms developed to cope with low soil oxygen conditions is the morphological and anatomical adaptations of roots that facilitate root oxygenation and that have been attributed to flood-tolerance in tree species (Hook and Brown 1972, Kozlowski 1982, Topa and McLeod 1986a,b). Adventitious roots and lenticel formation are important characteristics of many bottomland tree species (Hook et al. 1971, Hook and Brown 1972, 1973, Topa and McLeod 1986a,b, Angeles et al. 1986). Stem and root lenticels are among the means by which oxygen is supplied to the flooded roots (Hook et al. 1971, Philipson and Coutts 1978; Topa and McLeod 1986a). Development of adventitious roots and stem lenticels have been reported for woody species when subjected to flooded conditions (Topa and McLeod 1986b, Yamamoto et al. 1995a, b). Although root anatomy studies have shown moderate aerenchyma development in *T. distichum* and *Q. lyrata* roots, the former species is capable of developing an extensive adventitious root system in response to flooded conditions (Pezeshki et al. 1987). The ability to produce adventitious roots appears to be critical to the survival of bottomland species by allowing them to withstand long-term flooding and the associated reduced soil conditions (Pezeshki 1991).

The growth of flood-tolerant species in oxygen-deficient environments requires the development of an extensive internal aeration system that allows for the transport of atmospheric oxygen to the roots (Yamasaki 1952, Jackson and Drew 1984, Armstrong et al. 1994). Aerenchyma tissue development is important not only because it allows aerobic respiration by facilitating oxygen diffusion to the roots (Armstrong 1972, Keeley 1979, Fisher and Stone 1991, Pezeshki 1996) but also by aiding in the detoxification of the reduced rhizosphere (Williams and Barber 1961, Armstrong 1972).

In addition to the anatomical and morphological adaptations, the tolerance of oxygen deficiency is also achieved through the maintenance of anaerobic metabolism (Jackson and Drew 1984, Saglio et al. 1988, Drew 1997). Plants tolerate oxygen deficiencies by utilizing accelerated ethanol fermentation in the roots. Wetland plants use ethanolic fermentation in order to avoid high ethanol concentrations (Armstrong et al. 1994). It has been shown that many species rely on anaerobic metabolism as a means of surviving root hypoxia.

Alcohol dehydrogenase (ADH), the enzyme involved in catalyzing the reaction that produces ethanol, is found at high concentrations in roots of flood-tolerant plants under flooded conditions (Smith and ap Rees 1979, Keeley 1979, Jackson and Drew 1984). It has been suggested that an increase in ADH activity within flooded roots of *Betula nigra* (Tripepi and Mitchell 1984), *Nyssa sylvatica* var. *biflora* (Keeley 1979) and *Fraxinus pennsylvanica* (Good 1985) is evidence that flood-tolerant species are capable of increasing anaerobic respiration to compensate for oxygen depletion. In response to low soil Eh conditions in the reduced range of 0 to +300 mV, root ADH activity increased in *T. distichum* seedlings (Pezeshki et al. 1991). The observed increase in ADH activity in roots suggests that oxygen deficiency develops immediately following reduced soil conditions and likewise stimulates alcoholic fermentation. Comparable responses have been reported in *Betula nigra* (Tripepi and Michell 1984), *Nyssa sylvatica* var. *biflora* (Keeley 1979), *F. pennsylvanica* (Good 1985) and *N. sylvatica* (Hook et al. 1971, Keeley 1979).

In some species, increased ADH activity is accompanied by an increase in ethylene concentration which thereby enhances aerenchyma tissue formation (Drew et al. 1979, Jackson et al. 1985b). Elevated tissue ethylene concentration has been found under flooded conditions (Kawase 1972, Jackson 1988, Yamamoto et al. 1995, Visser et al. 1996b). Ethylene is also known to inhibit root elongation in certain species (Robbins et al. 1985, Riov and Yang 1989) as well as promoting rapid stem elongation in others (Metraux and Kende 1984). Such growth promotion is due to enhanced cell growth, increase in cell numbers and increased cell wall acidification (Metraux and Kende 1984). In many woody species, ethylene concentrations in both root and shoot increase in response to soil flooding (Topa and McLeod 1988, Vossenek et al. 1993). Furthermore, ethylene has been implicated in several responses of woody species to flooding including growth reduction, leaf senescence (Kozlowski 1984 a,b), hypertrophy of lenticels (Angeles et al. 1986, Topa and McLeod 1988, Kludze et al. 1994), formation of aerenchyma tissues (Hook 1984, Topa and McLeod 1988, Visser et al. 1996b) and adventitious root formation on submerged stems (Tsukahara and Kozlowski 1985). In addition to ethylene, other plant growth regulator levels change in response to flooding due to changes in the synthesis and translocation patterns for such various growth regulators. Generally, flooding results in increases in ethylene, auxins (IAA) and abscisic acid (ABA), whereas cytokinins (CK) and gibberellins (GA) show marked decreases (Reid and Bradford 1984). It has been demonstrated (Reid and Bradford 1984, Jackson, 1988, Visser et al. 1996a, Kozlowski 1997, Vartapetian and Jackson 1997) that many growth regulators are affected by root oxygen deficiency to some degree, therefore the resulting ACC synthesis may depend on complex interactions among such compounds in the stressed tissue.

Plant water relations are impacted by flooding and by subsequent low soil Eh conditions. It is well documented that flooded roots have slower water flux when compared to roots under aerated soil conditions (Kramer and Jackson 1954, Everard and Drew 1989). Development of plant internal water stress and leaf dehydration resulting from a decrease in root permeability under flooded conditions have also been documented in some species (Kramer 1940, Hiron and Wright 1973). The development of plant tissue water stress reported for some species (Zaerr 1983) appears to be species-specific, yet in most cases initial stomatal closure occurs without significant changes in plant water status (Pereira and Kozlowski 1977, Sena Gomes and Kozlowski 1980b, Tang and Kozlowski 1982a, Pezeshki and Chambers 1985a, b). In addition, the initial stomatal closure due to a root oxygen deficiency suggests a transfer of compounds as one of the likely factors affecting leaves (Bradford 1983, Reid and Crozier 1971, Hiron and Wright 1973, Shaybany and Martin 1977, Pallas and Kays 1982, Tang and Kozlowski 1982c, Zhang and Davies 1990, Else et al. 1996). Furthermore, fluctuations in the level of growth regulators transported from roots through the transpiration stream may also play a role in the initial rapid leaf response. For example, stomatal closure was attributed to ABA accumulation in leaves following flooding (Zhang et al. 1987).

For a majority of plant species, flooding and the associated reducing soil conditions stimulate stomatal closure (Kozlowski 1982, 1984a, b, Pezeshki 1994a). Stomatal closure in response to flooding has been reported for several species including *Ulmus americana* (Newsome et al. 1982), *F. pennsylvanica* (Kozlowski and Pallardy 1979, Sena Gomes and Kozlowski 1980a), and *Q. macrocarpa* (Tang and Kozlowski 1982a). However, stomatal reopening may occur under long-term reducing soil Eh conditions (Pezeshki 1993). The degree to which reopening will occur appears to be dependent on species, duration of reducing conditions, and the intensity of soil reduction. Stomatal reopening under flooded conditions has been reported in some woody species (Regehr et al. 1975, Kozlowski and Pallardy 1979, Pezeshki 1994a) and has been correlated with certain flood-tolerance criteria such as production of adventitious roots (Sena Gomes and Kozlowski 1980a). The trend of stomatal reopening and gas exchange recovery in *T. distichum* under continuous low soil Eh conditions suggests that stomatal reopening in this species may in part reflect an important flood-tolerance characteristic allowing resumption of gas exchange. In contrast, flood-sensitive species such as *Q. falcata* var. *pagodaefolia* apparently lacks the necessary mechanisms to resume stomatal functioning; therefore, continuous low soil Eh conditions would result in persistent stomatal closure with no apparent recovery (Pezeshki 1993). If stomatal reopening occurs under flooded conditions and in the absence of adventitious roots, then any reduction in root water uptake capacity may become an important factor affecting plant functioning through increasing the potential for development of internal water deficits.

Decreased photosynthetic rates have also been reported for numerous species due to low soil Eh conditions (Pezeshki 1994a). Similarly, many woody species show a reduction in net photosynthesis in response to low soil Eh conditions (Pezeshki and Chambers 1985a, b, Pezeshki 1993, Pezeshki et al. 1997). In addition, substantial differences are found in subsequent photosynthetic responses among bottomland tree species. The most flood-tolerant species are capable of improving and regaining their leaf photosynthetic capacity within two or three weeks following the initiation of low soil Eh conditions (Figure 3). Such recovery is initiated despite the continuation of low soil Eh conditions (Pezeshki 1993, Pezeshki and Anderson 1997). In contrast, little or no recovery is found in flood-sensitive species under the same conditions (Pezeshki 1993, 1994a). As mentioned previously, the reduction in photosynthetic activity has been associated with diffusional limitations on gas exchange due to stomatal closure and metabolic inhibition. Non-stomatal, or metabolic, inhibition of photosynthetic capacity has been reported in *Q. falcata* var. *pagodaefolia* and *Q. lyrata* (Pezeshki 1993). Even if a substantial recovery occurs later, the impact of the apparent delayed and/or slow recovery on plant survival and growth may be substantial due to the potential disruption of carbon fixation and the subsequent decrease in photosynthate production (Pezeshki and Anderson 1997).

Plant nutrition under soil flooding and the associated low soil Eh conditions is affected by many factors including the soil physicochemical characteristics, soil nutrient pools, plant developmental and physiological status and flood-tolerance capabilities (Kozlowski 1984b, 1997, Pezeshki 1994a). Such conditions result in the inhibition of nutrient uptake and transport in flood-sensitive species due to root dysfunction and/or death. It is also well documented that adequate energy is required for roots to uptake nutrients. However, anaerobic metabolism is inefficient in providing adequate energy for active ion uptake in many species (Trought and Drew 1980a, b, c, Jackson and Drew 1984) and oxygen stress may change the permeability of cell membranes in the roots allowing for nutrient leaching (Rosen and Carlson 1984). For many species, root oxygen-deficiency results in low foliage concentrations of N, P and K (Letey et al. 1965, Drew and Sisworo 1979, Trought and Drew 1980a, Osundina and Osonubi 1989, Dreyer et al. 1991, Larson et al. 1992). Tissue nitrogen concentration and total nitrogen content decreases in flood-sensitive species in response to flooding (Kozlowski and Pallardy 1997). The decrease in tissue nitrogen content has been attributed to the rapid volatilization and subsequent loss through denitrification occurring in reduced soils (Ponnamperuma 1972). Phosphorus is another important essential element that is influenced by soil reduction processes. Plant tissue phosphorus content decreases in response to low soil Eh conditions presumably due to the suppressed capability for uptake in roots (Leyson and Sheard 1974, Kozlowski 1997). Depending on the conditions of the soil prior to flooding, phosphorus availability may even increase under flooding conditions (Ponnamperuma 1972). This increase may be reflected by a rise in plant tissue phosphorus content during a short-term flooding. Nonetheless, phosphorus concentrations and total phosphorus content decrease during long-term flooding episodes (Kozlowski and Pallardy 1984). Even flood-tolerant species such as *T. distichum* and *Nyssa aquatica* sustain decreased tissue nitrogen content when grown under flooded yet aerated conditions. In contrast, higher tissue concentrations of P, Ca, K, and Mg were found compared to plants under non-flooded conditions (Dickson et al 1972). Soil iron (Fe) and manganese (Mn) availability increases under reducing soil conditions due to the reduction processes as previously mentioned (Ponnamperuma 1972). High iron concentration may interfere with phosphorus uptake (Armstrong 1968). In flood-sensitive plants, potassium uptake is reduced in response to flooding (Lawton 1945).

In wetland species ion uptake may continue partly because of the internal O_2 supply system (John et al. 1974). These species develop adventitious roots and internal aerenchyma cells that allow for oxygen transport from aerial tissues to the roots and root-soil interface (Armstrong 1968, Coutts and Armstrong 1976). Despite these adaptations, various nutritional deficiencies and toxicity may still occur (Tanaka and Yoshida 1970). Toxic levels of nutrient concentrations may be accumulated in tissues under reduced conditions due to higher availability of certain nutrients as well as root dysfunction (Hook et al. 1983). During prolonged waterlogging, pH decreases and zinc availability increases leading to increased tissue zinc concentration (Pavanasasivam and Axley 1980). Under such conditions, ferric and manganic forms are reduced to soluble ferrous and manganous forms (Ponnamperuma 1972). Thus tissue Mn and Fe concentrations are greater than in plants under aerated conditions. Sulfide toxicity may also occur due to soil chemical changes. The decline in Eh begins a chain of reactions that includes the reduction of sulfate to sulfide by anaerobic microorganisms (Armstrong 1975). Sulfide is considered to be phytotoxic. In most cases, however, flood-tolerant species possess the capability of oxidizing sulfide in the rhizosphere and are therefore able to minimize or avoid injury (Tanaka and Yoshida 1970). However, Fe, Mn, and S content in plant tissue may reach toxic levels under low soil Eh conditions (Good and Patrick 1987, McKevlin et al. 1987, Gries et al. 1990), although some flood-tolerant species, such as *N. aquatica* and *N. sylvatica* var. *biflora* (swamp tupelo), are capable of immobilizing Fe (Hook et al. 1983, McKevlin et al. 1995). It is obvious that reducing soil conditions can dramatically influence tree nutrition; however, relatively little data is available on the effects of low soil Eh conditions on plant uptake of Cu, Zn, Mo and Bo (Kozlowski and Pallardy 1984, Pezeshki 1994a).

2.70 Effects of Low Soil Redox Conditions on Emergent Plant Regeneration, Survival and Growth

The impacts of reduced soil Eh conditions on regeneration, survival, and growth of wetland species are dependent on several factors: the species' physiological adaptation to reducing soil conditions, the duration of soil reduction (i.e. how long the reduction period lasts), the intensity of soil reduction (i.e. how low the Eh level reaches in the soil), the time during which such conditions may occur (i.e. during the growing season or during dormancy), and the stage of plant development at the time of stress initiation. For example, plants are more susceptible to low soil Eh during the growing season as compared to dormancy season (Pezeshki 1994a). Young seedlings are more susceptible than saplings or mature trees of the same species. Nevertheless, reducing soil conditions that accompany flooding events influence numerous aspects of root and shoot physiology (Cannel and Jackson 1981). Such conditions may lead to reduction in leaf area (Smit et al.1989, Smit and Stachowiak 1990, Bishroi and Krishnamoorthy 1992), foliage and root injury, foliage and root death, and threaten survival and growth of plants (Kozlowski 1982, 1984 a,b, 1997). For example, many wetland species develop roots in sediments that are not highly reduced (Pezeshki and DeLaune 1990, DeLaune and Pezeshki 1991). Root growth is adversely affected by highly reduced soil conditions and root penetration into reduced zones is unlikely as long as reducing conditions persists (Aomine 1962, Armstrong and Boatman 1967, Pezeshki and DeLaune 1990, Pezeshki 1991).

2.80 Response of Plants to Low Oxygen Concentrations

For forested wetland species that occur naturally in periodically flooded soils, it appears as though root growth is dramatically affected during the period immediately following the initiation of soil reducing conditions. Root growth is an energy dependent process that requires oxygen and is therefore affected greatly under flooded conditions because molecular oxygen is required as an electron acceptor for oxidative phosphorylation (Bertani and Brambilla 1982, Drew 1990). Root growth is also a function of cell division and elongation. Cessation of root growth is found under oxygen deficiency in many species (Huck 1970, Sachs et al. 1980). Root penetration depth is also adversely affected under low soil Eh treatment and results in the development of shallow root systems different in architecture than those of plants growing in aerated (high Eh) conditions (Pezeshki 1991). However, once such conditions have been terminated and root aeration restored, root growth may resume root aeration (Kordan 1976). The threshold oxygen concentration at which root elongation is adversely affected is around 50% of the concentration in the air (Hopkins et al. 1950, Kordan 1976, Turner et al. 1981). Nonetheless, oxygen may be transported from shoots and may change the threshold. If the supply of oxygen from the shoot is eliminated, cessation of root growth occurs at an oxygen pressure of 0.01-0.03 atm at 20°C (Jackson and Drew 1984). However, cell expansion and division may continue under low oxygen concentrations in some species (Kordan 1976, Vartapetian et al. 1978, Atwell et al. 1982).

In addition to the dramatic effects of soil reduction on root growth, height growth in seedlings of many wetland species also decreases in response to low soil Eh conditions. For instance, under soil Eh treatment ranging between -200 to +100 mV, both height and diameter growth in *Q. nuttallii* continued but were significantly lower than control plants (Pezeshki and Anderson 1997). Height growth in *T. distichum* has also been shown to decrease when exposed to continuous flooding (Shanklin and Kozlowski 1985, Yamamoto 1992, Conner 1994). Field studies have reported enhanced diameter growth in 18 year-old *T. distichum* trees subjected to a deep flooding regime as compared to trees exposed to shallow flooding treatment (Yamamoto 1992). Furthermore, stimulated stem growth in response to flooding has been reported in *Alnus japonica* and *F. mandshurica* (Yamamoto et al. 1995a, b). Stem growth for some species was greatest under moderately wet conditions in the field (Mitsch and Ewel 1979).

As mentioned previously, decrease in biomass production under low soil Eh conditions is a common response in numerous species that include both flood-sensitive and flood-tolerant species. (Pezeshki 1994a, Will et al. 1995, Pezeshki and Anderson, 1997). Since the effects of soil reduction are usually more drastic on root systems than shoots, significant changes have also been reported in root to shoot ratio (DeLaune et al. 1983, Pezeshki 1991). While a range of responses to low soil Eh conditions may occur in a given species, these changes occur within the context of an overall reduction in biomass (Jackson and Drew 1984, Kozlowski 1984a,b, Pezeshki 1994b). In a comparative study, the growth of seedlings of three bottomland species was compared under various soil Eh treatments. The low soil Eh treatment of -200 to +100 mV resulted in a decrease of total plant biomass and various biomass components (Pezeshki and Anderson 1997). In *T. distichum*, the treatment resulted in decreased leaf and root dry weights but had no significant effect on stem dry weight. Total plant biomass and various biomass components decreased significantly for *Q. nuttallii* and *Q. falcata var. pagodaefolia* under low soil Eh treatment. Despite the high flood-tolerance capability of *T. distichum*, initial adverse reactions to flooding on biomass production have been reported. Flooded baldcypress seedlings had decreased root and shoot biomass after 12 weeks (McLeod et al. 1986). Shanklin and Kozlowski (1985) found lower biomass accumulation in flooded *T. distichum* seedlings compared to non-flooded control plants after 14 weeks of flooding. Flynn (1986) noted that *T. distichum* seedlings under non-flooded condition had significantly greater biomass than seedlings flooded to the depth of 15-20 cm for 18 weeks. In the field, above ground biomass production in *T. distichum* was adversely affected by continuous flooding but not periodic flooding (Mitsch and Ewel 1979, Dicke and Toliver 1990). Megonigal and Day (1992) studied *T. distichum* seedlings and saplings in large outdoor rhizotrons under continuous and periodical flooding conditions over three growing seasons. They reported that total biomass (both above and below ground) was highest in the periodically flooded treatment. However, after three growing seasons, no significant difference in total biomass was observed among the treatments yet differences in root to shoot ratios were evident. Oaks with comparable flood-tolerance capabilities have been shown to have similar biomass responses to low soil Eh conditions in laboratory studies (Pezeshki et al 1996).

Based on the literature synthesized above, it is obvious that permanently flooded, non-flowing water management creates an environment that is hostile to many organisms including aquatic plants, emergent species and forested wetlands. Literature also suggests that moving and/or fluctuating water provides a better environment for plant functioning (Mitsch and Gosselink 1993). Such bodies of evidence provide the basis for the argument that alternative management practices appear to be necessary at Reelfoot Lake in order to restore a water level regime which mimics natural water level fluctuations. The goal of potential alternative management practices should be to restore an environment conducive to naturally occurring plant and animal communities, with similar natural water quality standards and rates of production, and which provides similar environmental functions.

3.0 PROPOSED COURSES OF ACTION

The original plan proposed by the TWRA, which was adopted and begun in 1985, decreased Reelfoot Lake's water level 5.8 feet. At this level, 50 percent of the lake bottom would be exposed to the drying effects of the sun. This process has been used in other states to improve soil consolidation, control dense aquatic vegetation, and enhance production of plant species native to the area which have evolved with the ability to survive frequent and sometimes dramatic water level fluctuations (USFWS 1989). Under the new proposal, however, six options were offered, each with varying amounts of remedial action, ranging from no action at all to large-scale recurring manipulation of water levels. These alternatives are outlined in the United States Fish and Wildlife Service's EIS (1989) and are outlines as follows:

3.1 Alternative 1 – No Action

This alternative provides no remedial action for past degradation of the lake and provides no course of action to attempt to control continued degradation in the future. The lake would be managed as it currently is with water levels maintained at 282.2 feet m.s.l. throughout the year. This alternative is the least favored because it will lead to the premature killing and filling of the lake.

3.2 Alternative 2 – Dynamic Water Level

This alternative would manage the water level at seasonal and yearly fluctuations ranging from as high as 284.0 feet m.s.l. to as low as 280.0 feet m.s.l. (figure 1). The objective of this management practice would be to maintain a yearly fluctuation of at least two feet per year, in order to duplicate natural water level fluctuations in an alluvial lake. High water would be maintained in the winter and spring at an elevation between

283.0 and 283.5 feet m.s.l., unless environmental factors such as excess precipitation or seepage from the Mississippi dictated otherwise. Low water levels would occur in the summer and fall and would be dependent upon climatic conditions. Fluctuations of 1 to 2 feet below 282.2 feet m.s.l. would be expected yearly and would be prescribed based on the need to improve fish and wildlife habitat, vegetative control, or other such management objectives.

3.3 Alternative 3 – Major Drawdown

This alternative proposes a major drawdown of the lake, the degree of which is dependent upon the construction of a new spillway. If the existing spillway is not replaced then the lake would be allowed to drop four feet to 278.2 feet m.s.l., if a new spillway is constructed the lake would be dropped six to eight feet (as low as 274.2 feet m.s.l.). A drawdown of four feet would expose approximately 5300 acres, or roughly 53%, of the lake bottom to aeration (see Table 1).

The drawdown would begin on June 1 and be complete by at least July 15, and the lake would be maintained at its lowest levels for at least 120 days to allow complete drying and aeration of the exposed soils. Refilling of the lake would begin in mid-November and, based on current hydrologic data, typically be completed by mid winter. Water levels would be maintained at 283.2 feet m.s.l. until June 1, the following year, at which time current water level management practices would resume. Subsequent drawdowns would be expected every 5 to 10 years based on the biological needs of the lake.

Elevation	Reelfoot Lower Basin Area (ac)	Upper Blue and Buck Basins Area (ac)	TOTAL	SUMMARY
264-265	35.16		35.16	35.16
265-266	108.18		108.18	143.34
266-267	134.76		134.76	278.10
267-268	316.13		316.13	594.23
268-269	279.02		279.02	873.25
269-270	167.23		167.23	1040.48
270-271	176.67		176.67	1217.15
271-272	201.35		201.35	1418.50
272-273	196.83	9.29	206.12	1624.62
273-274	223.23	80.00	303.23	1927.85
274-275	254.31	142.78	397.09	2324.94
275-276	320.37	168.20	488.57	2813.51
276-277	567.95	266.18	834.13	3647.64
277-278	896.26	292.03	1188.29	4835.93
278-279	981.34	423.17	1404.51	6240.44
279-280	679.50	354.16	1033.66	7274.10
280-281	633.98	431.07	1065.05	8339.15
281-282	445.03	1016.16	1461.19	9800.34
282-283	328.23	13.48	341.71	10142.05
TOTAL:	6945.53	3196.52	10142.05	

Table 1. Reelfoot Lake Area by Elevation. (Groundwater Institute)

3.4 Alternative 4 – State Law

Under this option the same basic management practices would be continued using the existing spillway structures, however, the gates of the spillway would not be opened until the lake reached an elevation of 283.6 feet m.s.l. At that point, the lake would be allowed to drain over the existing structure until the lake reached the normal elevation (282.2 feet m.s.l.). The net result of this plan would be the continued maintenance of standard water levels; however, standard elevations would tend to be greater than normal and the lows would be for shorter periods of time.

3.5 Alternative 5 – Raise Permanent Pool One Foot

This alternative is similar to the previous alternative, the major exception being the construction of a new spillway. The new structure would be constructed with adequate gates to control excessive flood waters during the wetter seasons and would set the water level one foot higher than existing levels (283.2 feet m.s.l.).

3.6 Alternative 6 – Water Level Fluctuation and Periodic Major Drawdown

This proposal is a combination of alternatives 2 and 3. It is the preferred alternative because it includes the quick modification of habitat structure necessary to restore natural flora to the lake through a major drawdown. Plus, this plan includes yearly fluctuations in the water table, which should provide the variable water levels to which native species have adapted, resulting in the potential for long term maintenance of natural communities. The drawdown would decrease the lake either four, or six to eight feet depending upon whether or not a new spillway was constructed (alternative three), and yearly fluctuations in water level would range over a four foot interval depending upon seasonal climatic conditions (alternative two).

Each of these six alternatives has a set of associated ramifications, some of which are political, some are social, and others are environmental. Regardless of these controversies, each proposed action will have a reaction upon the system as a whole. The success of each action will be based on its ability to accomplish the goals of restoring Reelfoot Lake to a naturally productive system supporting native floral and faunal communities in such a way as to accommodate the environmental and recreational functions and demands placed upon it. The potential for reaching this goal using the preferred alternative is discussed in detail in the following sections.

4.0 Effects of Drawdown

4.1 Effect of Drawdown on Sedimentation

Sedimentation and silt deposition have been recognized as substantial problems of Reelfoot Lake for many years. Although sediment retention ponds and lakes have been constructed on both Reelfoot and Indian creeks, sedimentation still continues to present a problems for the lake system including decreasing lake depth, decreased water clarity, and decreased dissolved oxygen concentration. The sediment load has also been shown to be a contributing factor to the creation of the current "muck" lake bottom. This "muck" bottom has many effects on the lake system such as decreasing the rates of organic material decomposition and the loss of suitable spawning grounds of those species of fish that lay their eggs on the lake bottom. The primary desired effects that a major drawdown would have on sedimentation would be to increase oxygen to the decomposing substrates and to allow drying to compress and solidify the current "muck" bottom.

A 1977 study was conducted by the Corvallis Laboratory on the possible effects of a major drawdown on Lake Apopka in central Florida. This study, performed in conjunction with the Environmental Protection Agency, revealed the effects of drawdown on sediment within a laboratory environment (Fox et al. 1977). Sediment was collected by dredging the lake bottom and then transplanting the sediment samples into aquaria, columns, tanks, and pools. These sediments were then dried under various drying regimes and once cracking had occurred, the sediments were refilled to previous water levels. The results were as expected. Obviously, the rate of drying was dependent on the depth of sediment as well as sediment composition. The sediments of shallow depth dried much faster than those that were considerably deeper.

Once refilling had occurred, minimal swelling of the sediment was noticed along with a visible increase in water clarity. Sediment consolidation was also found to be caused primarily by water loss with little or no loss in volatile solids. The new sediment structure appeared to prevent rapid reabsorption and there was no apparent loss in organic material through the drawdown mechanism.

In applying the results of this study to Reelfoot Lake, it is to be assumed that the effects on sediment would be similar and that the area of lake bottom exposed would be improved to support both organic material decomposition and increased available fish spawning ground.

4.2 Effect of Drawdown on Macroinvertebrate Populations

Aquatic invertebrates are known to process organic matter and serve as food for higher trophic levels (Leslie, 1997). Benthic organisms exist within the substrate and feed on dead or dying plant and animal parts that have settled to the bottom. In turn they secrete nutrients that facilitate plant growth and function as food for other organisms (USFWS 1989). Under normal conditions benthic organisms provide a biological control mechanism that regulates algal populations and decomposes settling organic material. However, in hypereutrophic conditions, such as seen in Reelfoot Lake, these invertebrates cannot sustain such control with the increased production of material. Furthermore, the increasing amount of organic sediments and declining oxygen levels reduce the numbers and species diversity of aquatic invertebrates (USFWS 1989).

Much of Reelfoot Lake is not considered suitable for a diverse assemblage of invertebrates. One of few studies on aquatic invertebrates at Reelfoot Lake was conducted by Slugger and Henson in 1984. This study documented populations of Chiromidae, Chaobridae, Ceratopogonidae, Pelecypoda, Oligochaeta, and Hirudinea at Reelfoot Lake. The study suggests that the invertebrate distribution is directly correlated to bottom substrate. Locations that had clean sandy bottoms had higher values for both species diversity and biomass as opposed to those sites with high sediment (TWRA 1988). Other benthic sampling at Reelfoot has determined populations of midge larvae, Oligocheates, leeches, beetle larvae, and Isopods (USFWS 1989).

While Reelfoot Lake is a unique system, a possible invertebrate response to drawdown may be estimated by examining studies in other aquatic ecosystems. One example was reported in Florida Pondcypress Swamps. These ponds undergo seasonal fluctuations in water levels with occasional dry down periods. In one study, pondcypress swamps experienced a drying down for at least one month during the summer and for at least one week in September (Leslie et al., 1997). In these swamps, Diptera, Coleoptera, Chironomidae, Hytiscidae, Dytiscidae and Hydrophilidae populations were documented. A total of eighty-five total taxa were found with Diptera and Coleoptera being the dominant populations, making up 35% of the total species richness. Annual mean density of benthic macroinvertebrates was approximately 4,229 individuals/m^2. Total mean density peaked in April and August. During dry periods, 90 percent of the individuals identified during the dry months had been sampled previously in wet months. Total density during the month of June was not significantly lower than that of April and was also similar to the other months. There was no loss of taxon richness from April to

June. Of 40 taxa found in June, 12 were exclusive to that sampling period; an average of 3 taxa were exclusive to each wet sampling period. Among the taxa unique to June were many semi-aquatic taxa including beetles and Dipteran larvae. The study showed that densities of benthic macroinvertebrates in ponds that had been dry for over one month were similar to those of wet months. Furthermore, many of the taxa found in the ponds during dry months were also present during wet months. These taxa are therefore able to survive *in situ*, since aquatic invertebrates of shallow or temporary water bodies have evolved various tactics to avoid desiccation, including the ability to fly, burrow, and exhibit drought resistance in the larval or egg stage (Leslie et al., 1997). Such a trend could be speculated for Reelfoot Lake. It can be assumed that there will be some loss of the taxa that are present during the wetter periods, however there should be an increase in semi-aquatic taxa during drawdown. This shift in taxa may increase the total invertebrate diversity and/or biomass in Reelfoot Lake in response to a drawdown.

Another example of change in benthic type occurs in limesink wetlands typically found in southeast Georgia. These wetlands are seasonally inundated, with wet and dry periods. As seen in the Florida pondcypress swamps, invertebrate dominance changes with the inundation of these ecosystems. In one study of limesink wetlands, 33 total taxa of invertebrates were found consisting mainly of Amphipods, Oligochaetes, Cladocerans, Copepods, Chironomids, and Isopods. During wet periods, the dominant organisms were Copepods, while during dry periods the dominant taxa was larval Chironomids (Golladay, 1997). Again, a similar pattern could be seen at Reelfoot Lake. During the drawdown a shift in dominance may occur to species that are better adapted to handle shallow water levels. Once reflooding occurs, it is to be expected that there would be a shift back to favoring types of invertebrates such as Isopods, Copepods, and Cladocerns.

Another strong factor that may possibly affect invertebrate populations in response to drawdown is a change in the abundance of aquatic vegetation. During the drawdown, a decrease in open water and an increase in littoral area is expected. A study on contrasts in benthic invertebrate densities between macrophyte beds and open littoral patches was conducted on Eau Galle Lake, Wisconsin (Beckett, Aartila, and Miller). Eau Galle Lake is a small, eutrophic reservoir that was constructed mainly for flood control purposes. It has a surface area of 0.6 km^2 and a mean depth of 3.6m. The majority of the lake inflow is from agricultural runoff. The littoral zone, as defined by the presence of aquatic macrophytes, makes up approximately 17% of the lake's surface. The study found that the mean invertebrate density of open water littoral zones was far less than that of the mean invertebrate density in vegetated littoral zones. The difference between the two benthic habitat densities was demonstrated by the distribution of the most common taxa found. The most common Oligocheate found was seven to nine times more abundant under vegetated littoral areas than in open littoral areas. Tubificids were eight times more abundant beneath littoral vegetation than they were in open littoral areas. In fact, significant density differences among habitats were detected for all ten of the taxa measured. In each case benthic densities in the open littoral zones were significantly lower than benthic densities in vegetated littoral zones. Sediments below vegetated littoral zones were also shown to support more taxa than the nonvegetated littoral zones did (Beckett, 1992). Samples from vegetated littoral sites found a total of 44 to 45 taxa, while samples from open littoral sites contained only 18. It has also been speculated that the increase in invertebrate densities within the vegetated littoral zone could possibly be a function of the dead organic matter accumulated beneath the plants.

Another factor that may have an impact on the response of invertebrate densities to drawdown is the trophic status of the lake. Benthic invertebrates show a structural change in response to trophic level changes of the lake. While small bodied taxa (<30 *m*m) dominate the ciliate assemblages of all lakes, larger bodied (40 –50 *m*m) forms are favored with increasing eutrophy. Even within Oligotrichida, this size replacement trend is seen. Rotifer abundance is seen to reach a maximum in eutrophic Florida lakes, likewise a similar increase is also seen in ciliated Protozoans. Zooplankton are grouped according to body size into microzooplankton (Ciliates, Rotifers, Nauplii) and macrozooplankton (Copepodite, adult Copepods, and Cladocerans). Microzooplankton biomass shows a positive correlation to lake trophic status, yet no trend is noted for macrozooplankton. In addition, the abundance of total crustacean zooplankton declines with increasing eutrophy (Hackney, 1992). Total ciliate biomass reveals obvious seasonal differences according to a lake's trophic state. Oligotrophic lakes peak in the fall and late winter, mesotrophic lakes peak in the fall, and eutrophic lakes peak during the summer. Large bodied Oligotrichida are thought to be largely responsible for the peak in abundance in oligotrophic lakes, while the small-bodied Scuticociliatida were the major contributors in higher trophic levels. Unlike ciliates, the two remaining contributors to the microzooplankton, rotifers and copepod Nauplii, display seasonal patterns that appear independent of trophic state. Both show peak in biomass during midsummer and abundance remains high throughout the fall. (Hackney, 1992).

In addition, the vertical penetration of organisms into the sediments has been shown to be a contributing factor in the vertical extent of the oxidized layer. A study of Lake Michigan documented the vertical distribution of zoobenthos in the lake. The zoobenthos can be divided into two categories : 1) the majority of the population (>50 %) occurring in the 0-1 cm interval and 2) the majority occurring deeper than 1 cm. The first category of zoobenthos included Oligochaetes, Chironomids, Cyclopoids, Harpacticoids, Cladocerns, Turbellarians, Ostracods, Rotifers, Sphaeriids, and Harpacticoids. Of all of these species only Harpacticoids were consistently found deeper than 2 cm. However, feeding patterns, aerobic requirements, methods of locomotion, and body shape were found to restrict the majority of taxa to the upper few centimeters regardless of sediment type. The next deepest occurring group included immature Tubificids, Claparede, Enchytraeid Oligochaetes, Nematodes, and Tardigrades. Seasonal variation was seen in distribution and more taxa were found in the higher sediment horizons during spring when the detrital layer was thickest. However, some taxa moved to the deeper sediments when detrital layer was thin in the autumn (Nalepa, 1981). An increase in Reelfoot Lake's oxidized layer by implementing a drawdown may increase the depth of sediment at which benthic invertebrates are able to penetrate. Since the relative abundance of invertebrates is already considered to be low within Reelfoot Lake due to low oxygen, poor water quality, and hypereutrophic conditions, a drawdown in water level may increase invertebrate biomass and diversity. The dry conditions of a drawdown would allow for an introduction or shift in dominance to Chironomids and more semi-aquatic taxa while most of the wet environment taxa should recover once reflooding occurs. The increase in littoral zones and littoral vegetation may also increase the invertebrate diversity and biomass within these zones. Likewise, increased oxygen levels should allow for more abundant and deeper penetration of benthic invertebrates.

4.3 Effect of Drawdown on Fish Populations

One of the major concerns with a possible drawdown at Reelfoot Lake is the effect it would have on fish. Sportfishing along with commercial crappie fishing are major economic forces within the Reelfoot community. Reduction in lake size by approximately fifty percent would have a tremendous effect on dissolved oxygen concentration, fish habitat, and fish food sources. However, of all the concerns associated with the Reelfoot drawdown, the effect on fish populations has the largest amount of research and published data. The Florida Game and Fresh Water Fish Commission has been conducting drawdowns for the past three decades in order to improve fishing resources. The published results show that these drawdowns have been very successful. The largest portion of research regarding drawdowns comes from Lake Tohopekaliga.

Consisting of 22,700 acres, Lake Tohopekaliga is located in western Osceola county in southern Florida, and is one of the larger lakes within the Kissimmee lake chain. It provides a prolific and potent sport fishing resource as well as being a major source of water for Lake Okeechobee, a world renowned sport fishery. In January of 1964, the Central and Southern Florida Flood Control District completed the construction of a concrete lock and spillway, thereby stabilizing the lake water levels.

The immediate outcome of the water level stabilization was the eradication of a large portion of the natural floodplain, which quickly promoted the invasion of agricultural and urban developments. This encroachment was quickly followed by the tell-tale signs of hypereutrophication: rapid accumulation of organic matter, increased numbers of algal blooms from nutrient laden runoff, and loss of important rooted aquatic vegetation. All of these factors were soon responsible for the loss of desirable sport fisheries. Therefore an extreme drawdown was proposed in 1968 in order to remedy the unwanted effects of hypereutrophication. The actual drawdown occurred in February of 1971, decreasing the lake level by approximately four feet by June of the same year. The lake level gradually returned to normal pool through reflooding by February of 1972. Fish populations were sampled prior to drawdown, during the drawdown, and post drawdown. The major problem reported by sportfisherman was that of limited boat access. Although the standing crop of fish was reduced compared to predrawdown statistics, standing crops quickly became reestablished once reflooding occurred. Both largemouth bass and sunfish species showed marked decreases during low water phases but survival and growth following the reflooding event were much higher than the predrawdown statistics (see Table 2). Black crappie and chain pickerel, however, showed a decline in numbers with little to no recovery. The drawdown seemed to have a direct detrimental effect on crappie populations at that time. However, in the next few years following the drawdown, crappie populations returned to surpass predrawdown numbers with a fall season record calculated success estimate of 2.30 fish/man hour in 1973. When later compared to the Lake Kissimmee drawdown, it became apparent that the sharp decline in crappie population in 1971 was more than likely of a normal cyclic nature exhibited by the species (State of Florida 1979).

4.4 Effect of Drawdown on Aquatic Macrophytes

Under the current eutrophic state at Reelfoot Lake, there is a high rate of ecological succession. A natural succession of vegetation is expected, such as the appearance of aquatics in previously open water and the invasion of woody species into the shallow confines of the lake, but the rate at which it is occurring at Reelfoot Lake is

Table 2. Summary of Harvest and Success Estimates Lake Tohopekaliga for 1970-1978
(State of Florida Game and Freshwater Fish Commission, 1979)

*No data available

Year	1970	1971	1972	1973	1974	1975 *	1977	1978
Bass	2405	5898	5859	8504	18054	15240	6149	8370
Crappie	58526	1011	2788	30181	74284	39646	65238	54278
Panfish	35414	46944	29476	52528	52035	18306	69611	55254
Misc	2284	416	130	493	671	307	556	201
Total	98629	54269	38253	91706	145044	73499	141554	118103

Year	1970	1971	1972	1973	1974	1975 *	1977	1978
Bass	0.23	0.35	0.39	0.58	0.45	0.30	0.20	0.26
Crappie	1.39	0.73	1.15	2.30	1.77	1.28	1.67	1.47
Panfish	2.24	2.96	2.25	4.27	2.37	1.67	3.74	2.35

indicative of a detrimental hypereutrophic condition. This hypereutrophic condition is characterized by excessive plant growth and deteriorating water quality (USFWS 1989). The increased aquatic vegetation

hinders navigation on the lake and thereby interferes with recreational pursuits such as boating and fishing. Furthermore, the excessive vegetation decreases dissolved oxygen concentrations within the lake. Aquatic vegetation has been shown to alter dissolved O_2 dynamics within the water column (Rose and Crumpton, 1996). Decreased dissolved oxygen levels have harmful effects on both plants and organisms, especially fish, as mentioned previously.

Spatterdock (*Nuphar advena*) and giant lotus (*Nelumbo* spp.) are the two most common non-persistent emergent macrophytes, while coontail (*Ceratophyllum demersum*) and curlyleaf pondweed (*Potamogeton* spp.) are the most common submerged macrophytes in the lake (USFWS 1989). Purple loosestrife (*Lythrum Salicaria*), southern smartweed (*Polygonum* spp.), and giant cutgrass (*Zizaniopsis miliacea*) are the most common persistent emergent species. All are typically found in the shallows of the lake where, except during the driest years, they are flooded or saturated. However, the TWRA has concluded that coontail and giant cutgrass are the major aquatic problem plants at Reelfoot Lake (TWRA 1985).

The response of these and other aquatic macrophytes to drawdown is not well researched. What information there is primarily deals with vegetation specific to a particular region which does not necessarily carry over to Reelfoot Lake. However, Johnson (1998), reported data regarding similar problem vegetation at nearby Crockett

Lake. The lower portion of Gooch Unit E Wildlife Management Area, also known as Crockett Lake, suffered conditions similar to those seen at Reelfoot Lake such as sedimentation, hypereutrophication, and increased aquatic vegetation. In 1987 an unexpected drawdown occurred as a result of structural problems in the lake's spillway. Although deep drying was not seen, some drying did occur. Unfortunately, however, no quantitative data was collected. TWRA management observed some relief from the problematic conditions and local fishermen reported noticeable improvement in fishing success to the Agency. However, by the early 1990's, the positive effects of the drawdown had diminished. After soliciting public comments and supporting an aquatic plant assessment by the University of Tennessee at Martin, the Agency proposed an extreme lake water level drawdown for April of 1994.

In April of 1994, the project was initiated and complete drainage was attained by early July. Complete drying occurred throughout the summer and into November. Although rainfall was normal, the impoundment was allowed to dry effectively for 107 days. In mid November, refilling began after a 3.0 inch rainfall and continued to fill until it reached maximum pool in December of 1995. During the dry period, yellow-nut sedge and smartweed covered approximately 100% of the dried impoundment. Oak seedlings and other vegetation were also noted. By October of 1994, it appeared as though coontail had been destroyed by the drying process, and that lotus and spatterdock were in decline. Once refilling occurred, unwanted submergent vegetation appeared to be under control, despite a slight resurgence in spatterdock. According to TWRA officials and photographic evidence, Crockett Lake appears to be in much more favorable condition than before the drawdown (Johnson 1998).

4.5 Effect of Water Fluctuation on Emergent Vegetation and Plant Communities

In addition to the aquatic macrophytes discussed in the previous section, other macrophytes such as emergent species, marsh and forest species, species associated with transition zones, and woody species, surrounding Reelfoot Lake are expected to respond to the drawdown. In the dynamic environments of wetland ecosystems, flooding is usually characterized by moving water and/or a frequently shifting water table creating an alternation of high and low soil Eh conditions through various depths in the soil horizon. Consequently, regeneration could be susceptible to low soil Eh conditions. However, short-term periods of soil saturation during the growing season, encountered by seedlings of forested wetland species, are likely to have little or no long-term effects on growth and survival if the species is at least moderately flood-tolerant. For instance, the effect of low soil redox on highly flood tolerant tree species such as *T. distichum* and *N. aquatica* may be minimal whereas such conditions may have substantial adverse effects on seedlings of flood intolerant species such as *Q. falcata var. pagodaefolia*. Therefore, it is apparent that seedlings of forested wetland species, including the most flood-tolerant species, require periods of drainage characterized by high soil Eh conditions during the growing season in order to allow for both root growth and root establishment. Once the roots are established, adaptations such as anaerobic root metabolism, internal oxygen transport systems, adventitious roots, and root anatomical changes would allow seedlings to survive periodic low soil Eh conditions that result from flooding.

Studies have been conducted focusing on the species composition, recruitment, growth and productivity of three swamp sites in Louisiana with three different water regimes (Conner et al. 1981 and Conner and Day 1992). The first site was a naturally flooded baldcypress/water tupelo (*Taxodium distichum, Nyssa aquatica)* swamp. The second site was an area that had been permanently flooded 20 years prior to the study due to construction of several levees and roads. The final site was an area that was flooded in the fall for use as a crawfish farm and then drained from June through August. The authors argued that all three of these sites were baldcypress/water tupelo swamps prior to alteration of their hydrological regimes. The results of these studies showed that the crawfish farm, which experienced frequent cycles of flooding and drying each year, had the highest densities of trees (1,564 trees/ha) and saplings (5,854 stems/ha), and had the greatest primary production (1,779.9 $g/m^2/yr$). Conversely, the area under permanent flooding scored the lowest (943 trees/ha and 2,146 stems/ha, and 886.7 $g/m^2/yr$ respectively)(figures 2 and 3, Table 3). Interestingly, the authors noted that the crawfish farm did not produce any aquatic vegetation due to the intense shading produced by the large number of trees, and to the duration of dry conditions produced each year. The permanently flooded area, on the other hand, produced nearly four times the amount of aquatic vegetation as the naturally flooded area did (78.8 ± 7.9g dry weight/m^2 vs. 20.3 ± 1.8g dry weight/m^2). Nearly all of the hardwood tree species have died or were dying in this area because of the permanent flooding, allowing light to reach the surface of the water promoting optimal conditions for aquatic vegetation growth. Not only do these areas show significant differences in vegetation densities, but the species composition has also changed. The authors concluded that each of the three areas studied have resulted in different plant communities. First, in the naturally flooded area, the continuation of frequent flooding has allowed the area to

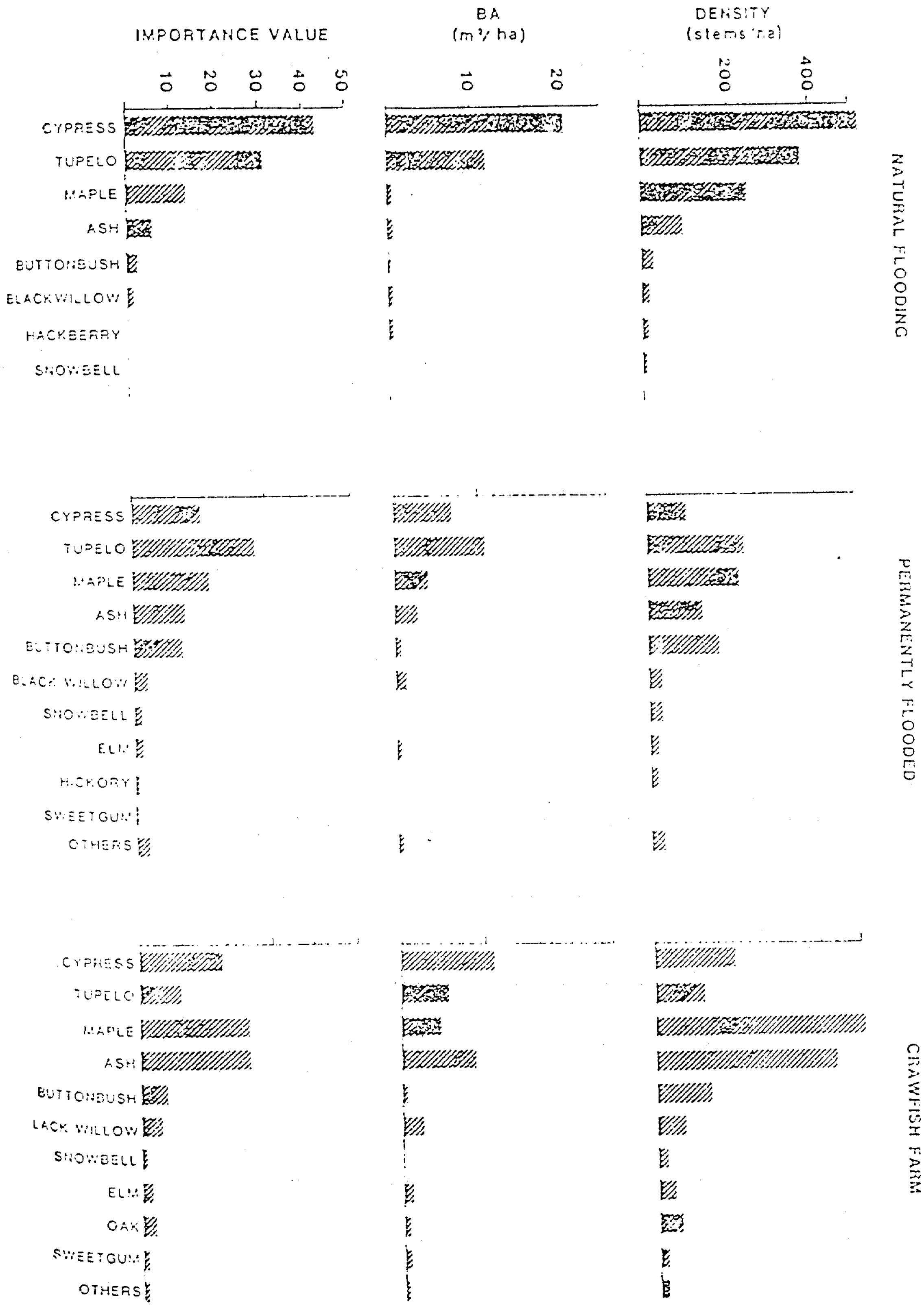

Figure 2. Tree composition in the three swamp sites (tree > 2.5 cm DBH). Importance value is the sum of the relaitive frequency, relative density, and relative dominance. (Conner et al. 1981)

Figure 3. Shrub dinsity and importance values for each species (individuals < 2.5 cm DBH). Importance value is the sum of the relative frequency and relative density. (taken (Conner et al. 1981)

Table 3. Stem productivity and litterfall in the three study areas. (Conner et al, 1981)

Species or Component	Net primary production ($g/m^2/yr$)
Natural Flooding	
Stem production	
Baldcypress *Taxodium distichum*	646.0
Water tupelo *Nyssa aquatica*	57.9
Other trees	44.9
Litterfall	417.4
Total	1,166.2
Permanently Flooded	
Stem production	
Baldcypress *Taxodium distichum*	209.9
Water tupelo *Nyssa aquatica*	149.1
Ash *Fraxinus* spp.	48.6
Other trees	150.8
Litterfall	328.3
Total	886.7
Controlled Flooding	
Stem production	
Baldcypress *Taxodium distichum*	387.8
Water tupelo *Nyssa aquatica*	57.8
Ash *Fraxinus* spp.	453.1
Other trees	332.4
Litterfall	548.8
Total	1,779.9

maintain its dominance by water tupelo and baldcypress, however, the authors did note the lack of recruitment by each species but could not offer a reason for the phenomenon. In the permanently flooded area, the flood intolerant species such as ash (*Fraxinus* sp.) have died and been blown over into the lake. In effect, this has opened the forest canopy allowing dense aquatic vegetative growth as well as providing stumps and decaying logs for the invasion of flood tolerant saplings and shrubs such as buttonbush (*Cephalanthus occidentalis*). Finally, the authors conclude that the hydroperiod at the crawfish farm is very similar to that produced by the Mississippi River. As a result, the area has maintained its large number of baldcypress and water tupelo; however, it has also allowed the invasion of hardwood species such as ash and red maple (*Acer rubrum* var. *drummondii*). Under this water regime, the baldcypress/water tupelo community would eventually develop into a maple-ash community more typical of bottomland hardwoods.

The flora at Reelfoot Lake is similar to the flora found in the permanently flooded area described above. Sparsely spaced baldcypress and water tupelo providing an open canopy, and allowing aquatic vegetation to take over the lake dominate the tree community. There is very little recruitment of either of the dominant species because of the permanently flooded conditions. Based on the studies above, it can be assumed that the species composition and community structure differs significantly from a natural system. Thus, the maintenance of a constant water level in the lake has potentially changed its community structure as well as decreased its primary productivity.

4.6 Effect of Drawdown on Wildlife Communities

Each community discussed above has evolved its own suite of adaptations that allow it to survive the harsh and often dynamic environment presented as wetland habitats. Similarly, wildlife communities take advantage of their own adaptations in order to utilize this highly productive system to their advantage. Clearly, the mobility of upland wildlife allows most species to fluctuate their use of particular habitats as the physical structure and condition of those habitats change. In fact, the life histories of many wetland animals, most notably amphibians and reptiles have evolved to take advantage of the fluctuations in these environmental conditions (Messina and Conner 1998). In order to maintain natural species diversity, therefore, it is obvious that restoration and maintenance of a natural water regime is critical (Drayton and Hook 1989). The preferred course of action proposed for Reelfoot Lake will mimic natural water level fluctuations normally produced by the Mississippi River, except during the years of extreme drawdown. Wildlife will be subjected to the most stressful conditions during these times, due to changes in habitat structure. It is important to note, however, that while a large number of species will be negatively impacted, some species will be able to take advantage of the dry conditions and increase their abundance.

Wetlands have been described as very productive habitats (Mitsch and Gosselink 1993), with detrital-based food webs receiving nutrition and energy inputs from surrounding upland areas (Messina and Conner 1998). The transition zone between aquatic and terrestrial habitat is often a product of frequent flooding and drying. This zone is often characterized by wildlife species that can survive in either habitat type, thus potentially forming a link in the food chain between upland and wetland habitats (Messina and Conner 1998). In 1995, deMaynadier and Hunter showed that amphibians are often very abundant in wetland habitats, and proposed that they act as the link between aquatic and terrestrial systems through their predation on invertebrate detrivores. Reelfoot Lake has 28 species of amphibians including salamanders, frogs and toads (Table 4) (USFWS 1989). Disruption of this community of organisms may, therefore, have cascading negative impacts on the rest of the wetland wildlife. The major impact drawdown would have on the amphibian population would probably be due to potential changes in invertebrate density and species composition. However, major changes in the invertebrate population are not expected.

Flora changes within any system tend to increase habitat for some species and decrease habitat for others. For example, vertical and horizontal diversity of a forested wetland's vegetation often increases the wildlife diversity and abundance (Messina and Conner 1998). Vertical diversity can be altered when prolonged flooding of a forest inhibits the development of a midstory or understory (Messina and Conner 1998). In this case, wildlife species commonly found within these structures such as the hooded warbler (*Wilsonia citrina*) and the wood thrush (*Hylocichla mustelina*) are not found (Howard and Allen 1989). Similarly, prolonged flooding often causes tree mortality which produces snags which are often used by other species like the prothonotary warbler (*Protonotaria citrea*) (Messina and Conner 1998). Horizontal habitat diversity is also very important for varying wildlife species. For example, dead and decaying logs are often utilized by ground skinks (*Scincella lateralis*) for shelter and as refuge from predators (Conant and Collins 1991), whereas black bears (*Ursus americanus*) often use hollow snags as den sites (Weaver and Pelton 1994). The proposed water

Table 4. Amphibians and Reptiles of Reelfoot Lake. (USFWS 1989)

AMPHIBIANS (Amphibia)

SIRENIDAE	
Lesser Siren	*Siren intermedia*
SALAMANDRIDAE	
Eastern Newt	*Notophthalmus viridescens*
PROTEIDEA	
Mudpuppy	*Necturus maculosus*
AMPHIUMIDAE	
Three-toed Amphiuma	*Amphiuma tridactylum*
AMBYSTOMATIDAE	
Mole Salamander	*Ambystoma talpoideum*
Marbled Salamander	*Ambystoma opacum*
Small-mounted Salamander	*Ambystoma texanum*
Spotted Salamander	*Ambystoma maculatum*
Tiger Salamander	*Ambystoma tigrinum*
PLETHODONTIDAE	
Dusky Salamander	*Desmognathus fuscus*
Long-tailed Salamander	*Eurycea longicauda*
Eastern Red-backed Salamander	*Plethodon cinereus*
Slimy Salamander	*Plethodon glutinosus*
Zig Zag Salamander	*Plethodon dorsalis*
PELOBATIDAE	
Eastern Spadefoot	*Scaphiopus holbrookii*
BUFONIDAE	
American Toad	*Bufo americanus*
Woodhouse's Toad	*Bufo woodhousii*

Table 4. cont.

HYLIDAE	
Northern Cricket Frog	*Acris crepitans*
Bird-voiced Treefrog	*Hyla avivoca*
Green Treefrog	*Hyla cinerea*
Gray Treefrog	*Hyla versicolor*
Spring Peeper	*Hyla crucifer*
Striped Chorus Frog	*Pseudacris triseriata*
RAINDAE	
Bullfrog	*Rana catesbeiana*
Crawfish Frog	*Rana areolata*
Green Frog	*Rana clamitans*
Southern Leapord Frog	*Rana sphenocephala*
Pickerel Frog	*Rana palustris*

REPTILES (Reptilia)

KINOSTERNIDAE	
Common Mud Turtle	*Kinosternon subrubrum*
Common Musk Turtle	*Sternotherus odoratus*
CHELYDRIDAE	
Alligator Snapping Turtle	*Macroclemys temminckii*
Snapping Turtle	*Chelydra serpentina*
EMYDIDAE	
Painted Turtle	*Chrysemys picta*
Common Slider	*Trachemys scripta*
Mississippi Map Turtle	*Graptemys kohnii*
False Map Turtle	*Graptemys pseudogeographica*
Common Box Turtle	*Terrapene carolina*
TRIONYCHIDAE	
Smooth Softshell Turtle	*Trionyx muticus*
Spiny Softshell Turtle	*Trionyx spiniferus*
IGUANIDAE	
Eastern Fence Lizard	*Sceloporus undulatus*

Table 4. cont.

TEIIDAE	
Six-lined Racerunner	*Cnemidophorus sexlineatus*
SCINCIDAE	
Five-lined Skink	*Eumeces fasciatus*
Broad-headed Skink	*Eumeces laticeps*
Ground Skink	*Scincella lateralis*
ANGUIDEA	
Slender Glass Lizard	*Ophisaurus attenuatus*
COLUBRIDAE	
Worm Snake	*Carphophis amoenus*
Racer	*Coluber constrictor*
Ring-necked Snake	*Diadophis punctatus*
Rat Snake	*Elaphe obsoleta*
Mud Snake	*Farancia abacura*
Eastern Hog-nosed Snake	*Heterodon platyrhinos*
Common King Snake	*Lampropeltis getulus*
Prairie King Snake	*Lampropeltis calligaster*
Milk Snake	*Lampropeltis triangulum*
Green Water Snake	*Nerodia cyclopio*
Plain-bellied Water Snake	*Nerodia erythrogaster*
Diamondback Water Snake	*Nerodia rhombifera*
Southern Water Snake	*Nerodia fasciata*
Northern Water Snake	*Nerodia sipedon*
Rough Green Snake	*Opheodrys aestivus*
Eastern Ribbon Snake	*Thamnophis sauritus*
Western Ribbon Snake	*Thamnophis proximus*
Common Garter Snake	*Thamnophis sirtalis*
DeKay's Brown Snake	*Storeria dekayi*
Red-bellied Snake	*Storeria occipitomaculata*
Smooth Earth Snake	*Virginia valeriae*
VIPRIDAE	
Copperhead	*Agkistrodon contortrix*
Cottonmouth	*Agkistrodon piscivorus*
Timber Rattlesnake	*Crotalus horridus*

management plan for Reelfoot Lake should increase the vertical and horizontal diversity of vegetation, and therefore increase the amount of habitat for wildlife.

Weller (1978) proposed a set of management recommendations for prairie pothole marshes in the north-central United States and south-central Canada which are similar to the proposed water level management plans for Reelfoot Lake. In these recommendations the marsh should be drawn down in the spring when the marsh has become an open water pond to stimulate the germination of seedlings. Water depth should slowly be increased following the drawdown to stimulate the growth of flood tolerant marsh species. The shallow areas produced by slowly increasing water depth are particularly attractive to dabbling ducks in the winter. In this plan, Weller (1978) suggests that the drawdown should occur again the next year to maximize the amount of emergent vegetation produced. Following this, shallow water should be maintained for several years to encourage the growth of emergent perennials such as cattails. Stable water elevations should then be maintained for several years to promote the growth of rooted submergent aquatic plants and the associated benthic organisms, which provide an excellent food source for waterfowl. During this time, the emergent vegetation will die out and the pothole will revert back to an open water marsh, at which time the process would be repeated. The author points out that maximum species diversity is maintained under this type of management strategy because all stages of the marsh cycle are maintained at once at different areas within the wetland. Wetlands typically flourish under cycles of flooding, and as a result any management practices that restrain these cycles often reduce wildlife productivity. Therefore, there is a general agreement that maintaining stable water levels in not a good management practice (Mitsch and Gosselink 1993).

5.0 Naturally Occurring and Other Known Drawdowns

There is a large void of information regarding both the short and long-term effects of drawdown on lake soils and vegetation. This may be due primarily to the lack of pre-drawdown data, few permanent sampling plots, and a deficit of data obtained after re-flooding has occurred. Most drawdowns that have occurred were either accidental (i.e. a levee broke) or were initiated to improve water quality and/or fish and waterfowl habitat as seen in the Florida lake systems. Therefore, most reported data overlooks many important aspects including plant communities and soils. However, much research has been done on the effects of flooding on wetland systems with hydrologic regimes that are very similar to that of a lake drawdown. One example of a naturally occurring dry down or "drawdown" is prairie potholes. These wetland systems undergo seasonal dry downs that are almost solely dependent upon the rates of precipitation and evapotranspiration. Although during a drawdown period these wetland systems may appear not to be true wetlands, the plant species found within the system reflect the predominant hydric conditions that exist during the majority of the year (Mitsch and Gosselink, 1993). Another example of naturally occurring drawdowns can be seen in pondcypress swamps which are characteristic of the southeastern Coastal Plain of the United States. Also known as sinkhole ponds, cypress ponds, and cypress domes, these systems also undergo yearly fluctuations in water level that range from flooded (eight to nine months out of the year) to very dry periods (for varying amounts of time). The major source of water is usually rainfall since low elevational gradients allow for very little groundwater movement. The major source of outflow is evapotranspiration, and is almost equal to nearby upland forests. This water level fluctuation is very important in the regeneration of cypress since its seeds are unable to germinate underwater. The higher water levels are required to allow young cypress seedlings to compete against faster growing competitors. Although dissolved oxygen levels are typically below saturation, the water fluctuation and dry periods promotes greater soil redox potential within the oxidized range and higher oxygen concentrations than in stagnant ponded water.

In addition to naturally occurring drawdowns, there have been a few drawdowns recorded in the southeast. These drawdowns, as mentioned earlier, include Crockett Lake, Lake Apopka, and Lake Tohopekaliga. Table 5 represents known effects of drawdown on these lake systems. However, much of the data is incomplete or may be site specific.

Table 5. Effects of known drawdowns.

Effect on:	Crockett Lake, TN	Lake Apopka, FL	Lake Tohopekaliga, FL
Sedimentation	Increased solidification	Lab study showed increased solidification	Increased solidification
Navigation	Improved	NOT MEASURED	Improved
Dissolved O_2	NOT MEASURED	Increased O2 level	Increased O2 level
Water Quality	NOT MEASURED	Improved	Improved
Fish Populations	* Restocked higher success	NOT MEASURED	Higher calculated success estimates
Fish Size	Improved quality	NOT MEASURED	Increase size & quality
Macro-invertebrates	NOT MEASURED	NOT MEASURED	Increased biodiversity and relative abundance
Aquatic Macrophytes	Reduced unwanted aquatic weeds	NOT MEASURED	Shift from undesirable species toward desired species

6.0 Conclusions

There is more than sufficient literature to support the hypothesis that various plant physiological functions are influenced by low soil redox potential conditions that result from stagnant and stable water levels. The extent of the impact is dependent on many factors including the species, timing, duration of soil reduction, and intensity of soil reduction. Low soil redox potential is a major factor in wetland ecosystems that influences not only plant survival and growth but also community development. In addition, plant response to low soil redox potential conditions also reflects a species' ability to respond to such conditions by utilizing a variety of internal defense mechanisms. Nevertheless, many bottomland species, including those that are considered to be "highly flood-tolerant", are impacted by reduced soil conditions. Such responses are indicative of the fact that the reducing soil conditions encompass not only soil oxygen deprivation but also the production of various phytotoxins. The impact of such conditions on plant species varies from temporary disruption of physiological processes and growth to serious damage to plant tissue and death. The reduced soil conditions substantially influence various critical plant processes including water relations, gas exchange, photosynthate partitioning, hormone balance, growth, nutrition, and biomass production. The impact is more likely to affect seedlings and young saplings than mature trees. Saplings and trees with well-developed root systems are better equipped to endure reduced soil conditions than are young seedlings. Reelfoot Lake's current stable water level promotes reducing sediment conditions. Thus if no action is taken to remedy the reduced soil conditions at Reelfoot Lake, individual plants as well as plant communities may suffer both detrimental and irreversible effects.

From the literature it may be ascertained that lake water level drawdowns and manipulation are not only useful management techniques but may also be necessary in order to slow the effects of hypereutrophication on impounded lake systems. Drawdowns have been shown to compact and solidify loose sediment and organic matter, increase dissolved oxygen concentrations, improve water quality and nutrient availability, and increase biodiversity among plants and animals. Restoring the lake's hydrologic cycle by manipulating water level fluctuations has also been documented as to improving plant and animal communities. Such manipulation may even cause a shift in macrophytic vegetation communities from unwanted species to more desirable ones, thereby protecting navigation and recreation by controlling the invasion of certain pest species into open water.

Reelfoot Lake is a unique resource within the region and is of great economic and environmental importance. It provides commercial fishing (as well as superb sportfishing), multiple habitats for numerous species of which some are endangered, and an unlimited wealth of natural and cultural history. Reelfoot Lake is unique in itself, luring many tourists from across the nation to come and view its natural beauty. Such a resource should be preserved for the benefit of future generations. Preservation of the lake as a natural resource can only be accomplished through biologically sound management practices. The preferred management practice proposed by the USFWS includes a periodic major drawdown followed by yearly fluctuations in water elevation. Based on the limited amount of published scientific information on this practice, the proposed drawdown appears to be a viable solution to the known biological problems at Reelfoot Lake.

7.0 Disclaimer

Due to the unique, modern nature of the proposed management practices, little scientific literature was available that compared pre-practice and post-practice environmental conditions. Conclusions drawn from this report must be considered in light of this lack of data. An effort was made to limit the case studies used within this report to areas located in the southeastern United States when possible. However, it is imperative to note that most case studies cited are not located within the vicinity of Reelfoot Lake, and thus may respond differently to the variable environmental conditions presented at each site. Consequently, it cannot be guaranteed that flora responses to the proposed management practices will be the same for Reelfoot Lake as those found elsewhere. Furthermore, there is no guarantee of success or failure that the water level management plan will control weed populations and production, provide an increase in wildlife and fisheries population and production, or increase water quality.

8.0 Acknowledgments

Funding for this project was provided by the United States Corps of Engineers, Memphis District Office. Graduate Students Mitch Elcan, Jason Farmer, Emily Fisher, Crystall Spence, and Shamsul Kutty participated in the literature search. Graduate Research Assistants, Chris Brown and Steve Schaff assisted with literature synthesis and report writing.

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SECTION V

VEGETATION IMPACT ANALYSIS

PART B. LAKE ISOM

Final Draft

Project Title: Vegetation Impact Analysis of Lake Isom

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Memphis District

August 2, 1998

Lake Isom

1.10 Introduction

Lake Isom National Wildlife Refuge is located approximately 15 miles south of Reelfoot National Wildlife Refuge and is an important wintering area for migratory waterfowl using the Mississippi Flyway (Figure 1). The refuge was established by Presidential Proclamation in 1938 and is composed of 1,850 acres in northwest Tennessee including the 700 acre reservoir named Lake Isom (USFWS 1997). Besides open water, the area consists predominantly of croplands and woodlands and offers excellent opportunities for game hunting, bird watching, photography, and other wildlife-oriented recreation. The lake itself offers great sportfishing opportunities for bass, bream, and crappie and is used primarily by local fishermen who are familiar with the lake's waters. The refuge is also home to numerous wood ducks as well as large numbers of geese, ducks, and bald eagles during the winter months. Along with the waterfowl, other wildlife species such as songbirds, mammals, reptiles, and amphibians thrive on this small, but important refuge (USFWS 1997).

1.20 Objectives

The purpose of this work was to scour the scientific literature and, considering the uniqueness of Lake Isom's ecology and location as well as its current condition and ecological health, and to speculate upon the potential effects of water level manipulation on its flora. This work includes an in-depth analysis of the problems facing Lake Isom as well as the action that has been proposed to counteract such problems. Finally, the effects of the proposed dynamic water level fluctuation on the system responsible for the

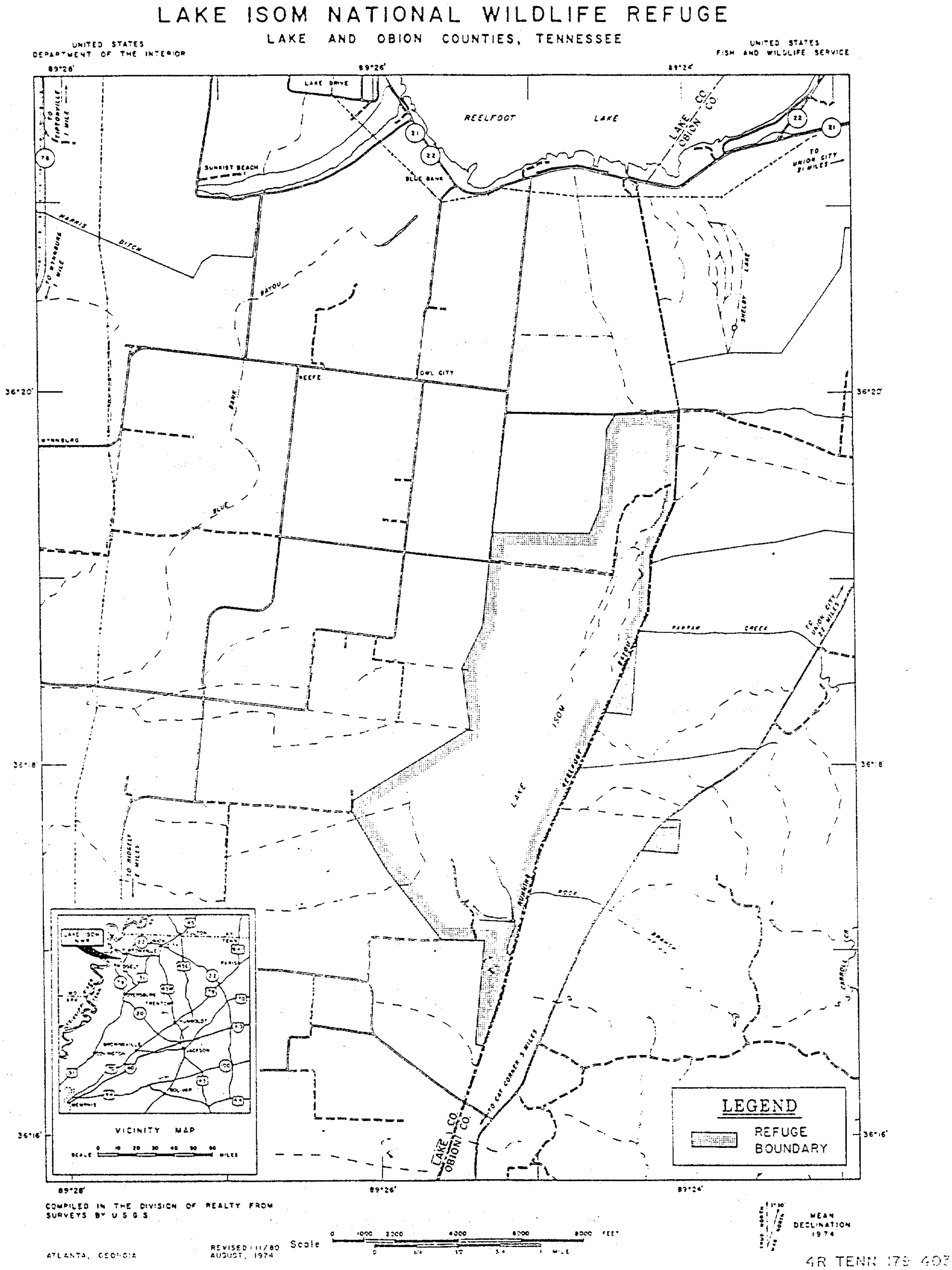

FIGURE 1. Area Map of Lake Isom National Wildlife Refuge. (USFWS)

unique vegetative structure, and the effects of consequential modifications of this structure on the surrounding wildlife communities, will also be examined.

2.00 PROBLEMS ASSOCIATED WITH LAKE ISOM

2.10 CURRENT WATER LEVEL MANAGEMENT PRACTICE

Steps are being taken at Lake Isom to increase migratory waterfowl habitat and to control current problems such as sedimentation and eutrophication. Water level management plans in 1997 imposed a target water elevation of 278.0 feet mean sea level (m.s.l.) beginning April 1, 1997. This spring drawdown from normal pool elevation of 282.0 feet m.s.l. enhanced refuge cropland operations on the lower moist soil management areas and allowed for mechanical methods of control of woody and other undesirable vegetation (USFWS 1997). The spillway stoplog structure was then closed on October 1 in order to allow for the flooding of natural and agricultural foods produced during the summer and to inundate timbered areas around the lake's edge for waterfowl use (USFWS 1997).

The present condition of the lake is declining and has been over the past several decades. Having once been a part of Reelfoot's drainage basin, Lake Isom no longer receives natural floodwater from Reelfoot since the construction of the highway and dam structure. Therefore, natural hydrologic regimes are virtually nonexistent. Sedimentation and eutrophication have both been continual problems for the governing agencies of both Reelfoot and Lake Isom National Wildlife Refuge (NWR) for nearly half of a century. Ecological and economical concerns have arisen due to the synergistic effect that sedimentation and eutrophication have on the lake ecosystem. Virtually every agency involved has made attempts to eliminate the problems using a number of potential solutions. In 1979, a program was initiated to attempt to improve water quality and decrease agricultural soil erosion. The Rural Clean Water Program gave incentives to farmers whom implemented erosion controls and conservation programs within the area. Despite these efforts, sedimentation and eutrophication of Lake Isom has continued. Clearly, the root of these problems is linked to the historical manipulation, use, and management of the area surrounding Lake Isom.

2.20 SEDIMENTATION

Much of the land around Lake Isom has been converted from bottomland hardwood forest to agricultural property. As a result, the lake has become a catch basin for the large amount of pollutants produced by modern agricultural practices. Conversion of this area to agricultural use in the early 1900's has resulted in a massive increase in the sediment and nutrient load introduced to the lake. Modifications to the lake as a result of these artificial inputs include physical and chemical changes of the lake itself as well as species composition, abundance, and productivity in both vegetative and wildlife communities.

Traditionally, natural sediment accretion would have been partially flushed and replaced each year with the periodic flooding of the Mississippi River and consequently Lake Isom. However, the natural hydrological regime has been virtually eliminated, therefore sediment entering the lake remains in place. Channelization has been used as an agricultural practice throughout the region to remove standing water from surrounding agricultural fields as quickly as possible, and results in increased flow velocities entering the lake (USFWS 1989). Similarly, channelization of streams can yield large amounts of sediment from erosion of their earthen banks, especially during unusually wet years which would increase the magnitude and frequency of its peak flow (Trimble, 1997). Thus, sedimentation may have already affected the entire lake bottom as well as played a role in the mean decrease in lake depth. However, sedimentation also plays a major role in the definition of aquatic community dynamics by influencing water quality and its associated chemical properties. Agricultural erosion often carries with it byproducts of the industry, the most important of which is nitrogen and phosphorous from fertilizer (Talley et al. 1984).

2.30 EUTROPHICATION

After sediment, fertilizer is the second major pollutant produced by the agricultural industry surrounding the lake. Storm water runoff and excess irrigation have been shown to increase the amount of nitrogen and phosphorous in lake systems (McIntyre and McHenry, 1984). Soil particles adsorb these chemicals onto their surface and carry them into the system as erosion takes place (Messina and Conner, 1998). In 1975 it was estimated that application of nitrogen fertilizers to croplands in Lake and Obion counties, TN, exceeded recommended high level application limits by 22% and 5%, respectively (Henderson and Free 1975). Introduction of excess nutrient loads to a lake is called eutrophication. Normally, nutrients such as nitrogen and phosphorous are limited in aquatic systems, this acts to control the production of aquatic algae and plants. However, in a hypereutrophic system, such as Lake Isom, these nutrients are abundant and result in massive production of vegetative biomass that may negatively affect boat navigation.

The maintenance of a constant water level at Lake Isom has also had a detrimental effect on the lake. Long-term constant water levels promote a detritus build up on the lake bottom that contributes to low dissolved oxygen contents in the lake substrate and water column (TWRA 1988). At very low soil redox potentials, decay slows markedly due to the shortage of oxygen. Lack of oxygen (anoxia) slows the decay of organic matter. Anaerobic decomposition processes have been shown to be less efficient than aerobic ones (Messina and Conner 1998). These reductions in oxygen concentrations and soil redox potential may lead to significant changes in the nutrient cycling patterns within the system, affecting transformations of nitrogen, iron, manganese, sulfur, carbon, and phosphorus and have consequent detrimental effects on plants and other organisms. Such low oxygen levels are known to adversely affect biological systems including aquatic, emergent and forested species (Conner et al 1981, Conner and Day 1991, Mitsch and Gosselink 1993). At present, the lake's water level is maintained at 280.5 feet m.s.l. with a slight drawdown (1.5 feet) occurring in the spring due to short-term wildlife management objectives (USFWS 1997). Such conditions have created an anaerobic condition in the lake's water and sediment.

In the following sections, we will examine the effects of the anaerobic conditions on the Lake's biological systems in general and plants in detail.

2.40 EFFECTS OF OXYGEN DEFICIENCY ON NUTRIENT CYCLING

Oxygen is necessary for root respiration to occur and for aerobic soil microorganisms to survive, and is therefore critical for normal root functioning. Flooding reduces soil oxygen as the air pore spaces within the soil are replaced with water. Gas exchange is then restricted at the soil-air interface and this restriction along with the subsequent depletion of oxygen results in a series of chemical changes within the soil including accumulation of such gases as CO_2, methane, N_2 and H_2 (Ponnamperuma 1984). Once the soil has been waterlogged, the short supply of oxygen found in floodwater is rapidly depleted by roots and soil microbes (Ponnamperuma 1972, Reddy et al. 1980), and aerobic microorganisms are soon replaced by anaerobes. The anaerobic communities that become established are predominantly characterized by bacteria (Yoshida 1978). This process is followed by denitrification, then reduction of iron and manganese, and finally by sulfate reduction, resulting in a change in soil pH and Eh (Gambrell et al. 1991). In a typical series of reductions, NO_3^- is reduced to NO_2^-, followed by reductions of Mn^{+4} to Mn^{+2}, Fe^{+3} to Fe^{+2}, SO_4^{2-} to S^{2-}, ultimately acetic and butyric acid accumulations are produced by microbial metabolism (Gambrell and Patrick 1978, Ponnamperuma 1984). Each of these transformations play an integral part in the biogeochemistry of wetland systems, thus, a brief discussion of each process is warranted, and is presented in the following sections.

2.41 NITROGEN TRANSFORMATIONS

Nitrogen is the most limiting nutrient in flooded soils (Gambrell and Patrick 1978). Transformation of nitrogen requires many microbial pathways. The ammonium ion (NH_4^+) is the most available form of nitrogen found in flooded soils. Once formed, it may undergo several processes, some which make it less available for plant uptake. The ammonium ion may be taken up by plants or microorganisms and converted back into organic nitrogen or it may be bound by negatively charged soil particles (Mitsch and Gosselink 1993). The available ammonium-nitrogen may be oxidized when oxygen is present converting nitrate to nitrogen in a process known as nitrification. The nitrate form of nitrogen (NO_3^-) is not easily immobilized by negatively charged soil particles, due to its negative charge, thus it is more mobile in solution. If sufficient oxygen is not available, and the existing nitrates are not taken up by plants and microbes, the nitrogen may be reduced further by denitrification, which produces molecular nitrogen (N_2) and nitrous oxide gas (N_2O) (Wiebe et al. 1981). It is well known that denitrification results in a significant loss of nitrogen in wetland systems (e.g., Kaplan et al. 1979, Whitney et al 1981, Mohanty and Dash 1982).

2.42 IRON AND MANGANESE TRANSFORMATIONS

In permanently flooded soils, both iron and manganese are found in the reduced forms and may build up to toxic levels within the soil. These reduced forms of iron and manganese (ferrous and manganous, respectively) are more soluble and may easily be used by microorganisms (Mitsch and Gosselink 1993). Both reduced metals may be oxidized within the rhizosphere by oxygen leaking from plant roots, coating the roots with metal oxides which inhibits nutrient uptake (Pezeshki 1994a). Although harmful in the reduced state, both iron and manganese are vital to plant life. Iron is necessary for chlorophyll synthesis, a key factor in photosynthesis. Deficiencies in iron cause decreased photosynthesis and leaf chlorosis. Manganese is required for the release of oxygen from the plant during photosynthesis, and may decrease photosynthetic activity if found in inadequate levels.

2.43 SULFUR TRANSFORMATIONS

Although sulfur is usually not considered a limiting nutrient in plant growth, reduced forms found in soils of low redox potential may be toxic to plant roots. Organic and elemental sulfur (S) enter the system from plant material and from the sloughing off of parent material in the soil, while sulfates (SO_4) enter from the atmosphere. Once organic sulfur is oxidized, it is readily available for uptake by plants and microbes or for chemical transformations. Sulfate reduction occurs when certain anaerobic bacteria, such as *Desulfovibrio*, use sulfate as the terminal electron acceptor in aerobic respiration which produces hydrogen sulfide gas (H_2S) (Mitsch and Gosselink 1993). Sulfur may also be released from the system in the form of methyl and dimethyl sulfides (Faulkner and Richardson 1989). Sulfides can be highly toxic to both plants and microbes and have been attributed to the direct toxicity to plant roots, lower availability to plants due to precipitation with trace minerals, and the immobility of copper and zinc due to sulfide precipitation (Ponnamperuma, 1972). Oxidation of sulfides is provided by both chemoautotrophic and photosynthetic microbes which transform the sulfides into elemental sulfur and sulfates (Mitsch and Gosselink 1993).

2.44 PHOSPHORUS TRANSFORMATIONS

Another important nutrient transformation is that of phosphorus. Phosphorus is one of the most important nutrients in ecosystems and is one of the most limiting factors affecting productivity (Rubio et al.). Inorganic phosphorus is released from its organic form through a process known as mineralization. The inorganic form of phosphorus, generally in the form of orthophophate, is the most useful form as a plant nutrient. It is sedimentary in nature as opposed to the gaseous nature of nitrogen, and large proportions can usually be found in organic litter and inorganic sediments. Phosphorus is not generally altered by low soil redox potential, instead it is affected by elements, such as iron and manganese, whose chemistry is dependent upon its state of reduction (Mohanty and Dash 1982). Phosphorus is rendered relatively unavailable to plants and microconsumers when insoluble phosphates precipitate with ferric iron, calcium, and aluminum under aerobic conditions. Similarly, phosphorus may be immobilized by the adsorption of phosphate onto clay particles, or by the binding of phosphorus in organic matter as a result of its incorporation into the living biomass of bacteria, algae, and vascular macrophytes (Mitsch and Gosselink, 1993).

2.50 EFFECT OF SEDIMENT pH

One of the most important factors influencing phosphorus mineralization along with other nutrients is soil pH (Harrison 1982). Soil pH is important because of its effects on soil bacteria, soil toxicity, soil structure, and nutrient leaching, all of which affect plant growth. Most affected by pH are the soil microbes. These microbes are necessary to convert the organic forms of nutrients to forms readily available for plant uptake and consumption. Many of these microbes such as *Nitrosomas*, *Desulfovibrio*, and certain species of *Thiobacillus* have optimum pH ranges from slightly acidic to neutral. Soil pH has also been shown to have a direct connection to soil redox potential (Eh). Soil Eh at which chemical stability, whether reduced or oxidized, is directly correlated to soil pH.

2.60 EFFECT OF LOW SOIL REDOX CONDITIONS ON PLANTS

Low soil and sediment redox potential conditions create high oxygen demands within the soil that may adversely affect internal plant tissue oxygen concentrations. Another consequence of low soil Eh is that changes may occur in the availability and/or concentrations of various essential nutrients. In addition, soil reduction may also result in the production of certain chemicals that are toxic to plant roots and systems (Patrick and DeLaune 1977, DeLaune et al. 1983a,b, Gambrell et al. 1991). These compounds include ethanol, lactic acid, acetaldehyde, acetic acid, and others (DeLaune et al. 1978, Ponnamperuma 1972, 1984). Other phytotoxic compounds such as reduced forms of Fe and Mn may accumulate in the flooded soils and cause further injury to plants (Gambrell and Patrick 1978, Drew and Lynch 1980). The presence of these compounds, in addition to oxygen depletion, creates a stressful environment for plant roots. For example, low soil Eh and excess soil sulfide has been shown to inhibit the growth of numerous marsh macrophytes (King et al. 1982, Ingold and Havill 1984, Havill et al. 1985, Armstrong et al. 1996). The presence of soluble sulfide species such as H_2S have been shown to be toxic to plant roots (Tanaka et al. 1968, Allam and Hollis 1972). For example, the effect of H_2S on cytochrome oxidase is disruptive to aerobic respiration while excess cytosolic Fe and Mn are harmful to enzymatic structures (Drew 1990). However, flood-tolerant plants have adapted a transport system that facilitates the diffusion of oxygen from the aerial parts of the plant to the root system. This allows a plant to oxidize not only sulfide but also Fe and Mn within the rhizosphere, thereby allowing the plant to minimize the level of toxicity (Teal and Kanwisher 1966). The inhibitory effects of low soil redox potential, along with high sulfide concentrations, on leaf photosynthetic capacity have been confirmed in several wetland species (Pezeshki et al. 1988, 1991). This decrease in photosynthetic capacity has been associated with the disruption of light reactions (Shimazaki and Sugahara 1980) and/or photophosphorylation (Wellburn et al. 1981). Furthermore, changes in the activity of photosynthetic enzymes have also been shown to be a direct cause of decreased photosynthetic capability (Garsed 1981, Khan and Malhotra 1982, Dropff 1987).

Plant species that occur naturally in forested wetlands use various mechanisms to cope with the soil oxygen-deficiency and low soil Eh conditions. These mechanisms include morphological and anatomical adaptations such as adventitious root development, lenticel formation, changes in root metabolism, acceleration of anaerobic fermentation, and the development of aerenchyma tissue which allows for oxygen diffusion to the roots from aerial parts of the plant. Among the mechanisms developed to cope with low soil oxygen conditions is the morphological and anatomical adaptations of roots that facilitate root oxygenation and that have been attributed to flood-tolerance in tree species (Hook and Brown 1972, Kozlowski 1982, Topa and McLeod 1986a,b). Adventitious roots and lenticel formation are important characteristics of many bottomland tree species (Hook et al. 1971, Hook and Brown 1972, 1973, Topa and McLeod 1986a,b, Angeles et al. 1986). Stem and root lenticels are among the means by which oxygen is supplied to the flooded roots (Hook et al. 1971, Philipson and Coutts 1978; Topa and McLeod 1986a). Development of adventitious roots and stem lenticels have been reported for woody species when subjected to flooded conditions (Topa and McLeod 1986b, Yamamoto et al. 1995a, b). Although root anatomy studies have shown moderate aerenchyma development in *T. distichum* and *Q. lyrata* roots, the former species is capable of developing an extensive adventitious root system in response to flooded conditions (Pezeshki et al. 1987). The ability to produce adventitious roots appears to be critical to the survival of bottomland species by allowing them to withstand long-term flooding and the associated reduced soil conditions (Pezeshki 1991).

In addition to the anatomical and morphological adaptations, the tolerance of oxygen deficiency is also achieved through the maintenance of anaerobic metabolism (Jackson and Drew 1984, Saglio et al. 1988, Drew 1997). Plants tolerate oxygen deficiencies by utilizing accelerated ethanol fermentation in the roots. Wetland plants use ethanolic fermentation in order to avoid high ethanol concentrations (Armstrong et al. 1994). It has been shown that many species rely on anaerobic metabolism as a means of surviving root hypoxia.

Plant water relations are impacted by flooding and by subsequent low soil Eh conditions. It is well documented that flooded roots have slower water flux when compared to roots under aerated soil conditions (Kramer and Jackson 1954, Everard and Drew 1989). Development of plant internal water stress and leaf dehydration resulting from a decrease in root permeability under flooded conditions have also been documented in some species (Kramer 1940, Hiron and Wright 1973). The development of plant tissue water stress reported for some species (Zaerr 1983) appears to be species-specific, yet in most cases initial stomatal closure occurs without significant changes in plant water status (Pereira and Kozlowski 1977, Sena Gomes and Kozlowski 1980b, Tang and Kozlowski 1982a, Pezeshki and Chambers 1985a, b). In addition, the initial stomatal closure due to a root oxygen deficiency suggests a transfer of compounds as one of the likely factors affecting leaves (Bradford 1983, Reid and Crozier 1971, Hiron and Wright 1973, Shaybany and Martin 1977, Pallas and Kays 1982, Tang and Kozlowski 1982c, Zhang and Davies 1990, Else et al. 1996). Furthermore, fluctuations in the level of growth regulators transported from roots through the transpiration stream may also play a role in the initial rapid leaf response. For example, stomatal closure was attributed to ABA accumulation in leaves following flooding (Zhang et al. 1987).

Plant nutrition under soil flooding and the associated low soil Eh conditions is affected by many factors including the soil physicochemical characteristics, soil nutrient pools, plant developmental and physiological status and flood-tolerance capabilities (Kozlowski 1984b, 1997, Pezeshki 1994a). Such conditions result in the inhibition of nutrient uptake and transport in flood-sensitive species due to root dysfunction and/or death. It is also well documented that adequate energy is required for roots to uptake nutrients. However, anaerobic metabolism is inefficient in providing adequate energy for active ion uptake in many species (Trought and Drew 1980a, b, c, Jackson and Drew 1984) and oxygen stress may change the permeability of cell membranes in the roots allowing for nutrient leaching (Rosen and Carlson 1984). For many species, root oxygen-deficiency results in low foliage concentrations of N, P and K (Letey et al. 1965, Drew and Sisworo 1979, Trought and Drew 1980a, Osundina and Osonubi 1989, Dreyer et al. 1991, Larson et al. 1992). Tissue nitrogen concentration and total nitrogen content decreases in flood-sensitive species in response to flooding (Kozlowski and Pallardy 1997). The decrease in tissue nitrogen content has been attributed to the rapid volatilization and subsequent loss through denitrification occurring in reduced soils (Ponnamperuma 1972). Phosphorus is another important essential element that is influenced by soil reduction processes. Plant tissue phosphorus content decreases in response to low soil Eh conditions presumably due to the suppressed capability for uptake in roots (Leyson and Sheard 1974, Kozlowski 1997). Depending on the conditions of the soil prior to flooding, phosphorus availability may even increase under flooding conditions (Ponnamperuma 1972). This increase may be reflected by a rise in plant tissue phosphorus content during a short-term flooding. Nonetheless, phosphorus concentrations and total phosphorus content decrease during long-term flooding episodes (Kozlowski and Pallardy 1984). Even flood-tolerant species such as *T. distichum* and *Nyssa aquatica* sustain decreased tissue nitrogen content when grown under flooded yet aerated conditions. In contrast, higher tissue concentrations of P, Ca, K, and Mg were found compared to plants under non-flooded conditions (Dickson et al 1972). Soil iron (Fe) and manganese (Mn) availability increases under reducing soil conditions due to the reduction processes as previously mentioned (Ponnamperuma 1972). High iron concentration may interfere with phosphorus uptake (Armstrong 1968). In flood-sensitive plants, potassium uptake is reduced in response to flooding (Lawton 1945).

In wetland species ion uptake may continue partly because of the internal O_2 supply system (John et al. 1974). These species develop adventitious roots and internal aerenchyma cells that allow for oxygen transport from aerial tissues to the roots and root-soil interface (Armstrong 1968, Coutts and Armstrong 1976). Despite these adaptations, various nutritional deficiencies and toxicity may still occur (Tanaka and Yoshida 1970). Toxic levels of nutrient concentrations may be accumulated in tissues under reduced conditions due to higher availability of certain nutrients as well as root dysfunction (Hook et al. 1983). During prolonged waterlogging, pH decreases and zinc availability increases leading to increased tissue zinc concentration (Pavanasasivam and Axley 1980). Under such conditions, ferric and manganic forms are reduced to soluble ferrous and manganous forms (Ponnamperuma 1972). Thus tissue Mn and Fe concentrations are greater than in plants under aerated conditions. Sulfide toxicity may also occur due to soil chemical changes. The decline in Eh begins a chain of reactions that includes the reduction of sulfate to sulfide by anaerobic microorganisms (Armstrong 1975). Sulfide is considered to be phytotoxic. In most cases, however, flood-tolerant species possess the capability of oxidizing sulfide in the rhizosphere and are therefore able to minimize or avoid injury (Tanaka and Yoshida 1970). However, Fe, Mn, and S content in plant tissue may reach toxic levels under low soil Eh conditions (Good and Patrick 1987, McKevlin et al. 1987, Gries et al. 1990), although some flood-tolerant species are capable of immobilizing Fe (Hook et al. 1983, McKevlin et al. 1995). It is obvious that reducing soil conditions can dramatically influence tree nutrition.

2.70 EFFECTS OF LOW SOIL REDOX CONDITIONS ON EMERGENT PLANT REGENERATION, SURVIVAL AND GROWTH

The impacts of reduced soil Eh conditions on regeneration, survival, and growth of wetland species are dependent on several factors: the species' physiological adaptation to reducing soil conditions, the duration of soil reduction (i.e. how long the reduction period lasts), the intensity of soil reduction (i.e. how low the Eh level reaches in the soil), the time during which such conditions may occur (i.e. during the growing season or during dormancy), and the stage of plant development at the time of stress initiation. For example, plants are more susceptible to low soil Eh during the growing season as compared to dormancy season (Pezeshki 1994a). Young seedlings are more susceptible than saplings or mature trees of the same species. Nevertheless, reducing soil conditions that accompany flooding events influence numerous aspects of root and shoot physiology (Cannel and Jackson 1981). Such conditions may lead to reduction in leaf area (Smit et al.1989, Smit and Stachowiak 1990, Bishroi and Krishnamoorthy 1992), foliage and root injury, foliage and root death, and threaten survival and growth of plants (Kozlowski 1982, 1984 a,b, 1997). For example, many wetland species develop roots in sediments that are not highly reduced (Pezeshki and DeLaune 1990, DeLaune and Pezeshki 1991). Root growth is adversely affected by highly reduced soil conditions and root penetration into reduced zones is unlikely as long as reducing conditions persists (Aomine 1962, Armstrong and Boatman 1967, Pezeshki and DeLaune 1990, Pezeshki 1991).

2.80 RESPONSE OF PLANTS TO LOW OXYGEN CONCENTRATIONS

Decreased biomass production under low soil Eh conditions is a common response in numerous species that include both flood-sensitive and flood-tolerant species. (Pezeshki 1994a, Will et al. 1995, Pezeshki and Anderson, 1997). Since the effects of soil reduction are usually more drastic on root systems than shoots, significant changes have also been reported in root to shoot ratio (DeLaune et al. 1983, Pezeshki 1991). While a range of responses to low soil Eh conditions may occur in a given species, these changes occur within the context of an overall reduction in biomass (Jackson and Drew 1984, Kozlowski 1984a,b, Pezeshki 1994b).

Based on the literature synthesized, it is obvious that permanently flooded, non-flowing water management creates an environment that is hostile to many organisms including emergent and forested plants. Literature also suggests that moving and/or fluctuating water provides a better environment for plant functioning (Mitsch and Gosselink 1993). Such bodies of evidence provide the basis for the argument that alternative management practices appear to be necessary at Lake Isom in order to restore a water level regime which mimics natural water level fluctuations. The goal of potential alternative management practices should be to restore an environment conducive to naturally occurring plant and animal communities, with similar natural water quality standards and rates of production, and which provides similar environmental functions.

3.00 PROPOSED COURSES OF ACTION

The current plan proposed by the TWRA involves the construction of a new stoplog structure that would allow for maximum pool elevation to be 282.0 feet m.s.l., while the current structure allows for only a 280.4 feet m.s.l. maximum pool elevation. Furthermore, the proposed water level management plan allows for a 3.0 foot elevational change between 279.0 feet and 282.0 feet as opposed to the current 1.5 foot change between 279.0 feet and 280.5 feet. Such dynamics would allow for an increase in acreage of migratory waterfowl habitat during those months of winter flooding. Water levels are proposed to be lowered each March 1 to 279.0 feet, before the vegetational growing season begins. Refilling is to occur beginning October 15, just as plants are supposed to become dormant. Such water level management plans are similar to other water level management practices often referred to as greentree reservoirs.

4.00 GREENTREE RESERVOIRS

Greentree Reservoirs (GTRs) are a common waterfowl habitat management technique used throughout much of the United States. This technique has been used since the early 1930's and consists of winter flooding of bottomland areas followed by a spring drawdown before the trees come out of dormancy (Rudolph and Hunter 1964). However, GTRs are a controversial management technique because they may cause shifts in plant community structure as well as changes in species composition to more flood-tolerant species (King 1994). Changes may stem from increased standing water at the beginning of the growing season due to delayed spring drawdowns or from years of extended flooding (Wigley and Filer 1989). Such changes in vegetation may negatively affect waterfowl habitat and food sources (Fredrickson and Batema 1993). Yet there is still insufficient data, perhaps due to a lack of pre-impoundment data as well as a lack of established long-term plots, in order to fully recognize and understand all of the potential effects that greentree reservoir techniques may have on forest communities.

4.10 Effect of Water Fluctuation on Emergent Vegetation and Plant Communities

As seen at the community level in greentree reservoirs, macrophytes such as emergent species, marsh and woody species, species associated with transition zones, and forest species, surrounding Lake Isom are expected to respond to the proposed water level management plans. In the dynamic environments of wetland ecosystems, flooding is usually characterized by moving water and/or a frequently shifting water table creating an alternation of high and low soil Eh conditions through various depths in the soil horizon. Consequently, regeneration could be susceptible to low soil Eh conditions. However, short-term periods of soil saturation during the growing season, encountered by seedlings of forested wetland species, are likely to have little or no long-term effects on growth and survival if the species is at least moderately flood-tolerant.

Studies have been conducted focusing on the species composition, recruitment, growth and productivity of three swamp sites in Louisiana with three different water regimes (Conner et al. 1981 and Conner and Day 1992). The first site was a naturally flooded baldcypress/water tupelo (*Taxodium distichum, Nyssa aquatica)* swamp. The second site was an area that had been permanently flooded 20 years prior to the study due to construction of several levees and roads. The third site was an area that was flooded in the fall for use as a crawfish farm and then drained from June through August. The authors argued that all three of these sites were baldcypress/water tupelo swamps prior to alteration of their hydrological regimes. The results of these studies showed that the crawfish farm, which experienced frequent cycles of flooding and drying each year, had the highest densities of trees (1,564 trees/ha) and saplings (5,854 stems/ha), and had the greatest primary production (1,779.9 $g/m^2/yr$). Conversely, the area under permanent flooding scored the lowest (943 trees/ha and 2,146 stems/ha, and 886.7 $g/m^2/yr$ respectively)(figures 2 and 3, Table 2). Interestingly, the authors noted that the crawfish farm did not produce any aquatic vegetation due to the intense shading that resulted from the large number of trees, and to the duration of dry conditions imposed each year. The permanently flooded area, on the other hand, produced nearly four times the amount of aquatic vegetation as the naturally flooded area did (78.8 ± 7.9g dry weight/m^2 vs. 20.3 ± 1.8g dry weight/m^2). Nearly all of the hardwood tree species have died or were dying in this area because of the permanent flooding, allowing light to reach the surface of the water promoting optimal conditions for aquatic vegetation growth. Not only do these areas show significant differences in vegetation densities, but the species composition has also changed. The authors concluded that each of the three areas studied have resulted in different plant communities. First, in the naturally flooded area, the continuation of frequent flooding has allowed the area to maintain its dominance by water tupelo and baldcypress, however, the authors did note the lack of recruitment by each species but could not offer a reason for the phenomenon. In the permanently flooded area, the flood intolerant species such as ash (*Fraxinus* sp.) have died and been blown over into the lake. In effect, this has opened the forest canopy allowing dense aquatic vegetative growth as well as providing stumps and decaying logs for the invasion of flood tolerant saplings and shrubs such as buttonbush (*Cephalanthus occidentalis*). Finally, the authors concluded that the hydroperiod at the crawfish farm is very similar to that produced by the Mississippi River. As a result, the area has maintained its large number of baldcypress and water tupelo; however, it has also allowed the invasion of hardwood species such as ash and red maple (*Acer rubrum* var. *drummondii*). Under this water regime, the baldcypress/water tupelo community would eventually develop into a maple-ash community more typical of bottomland hardwoods.

The flora at Lake Isom is similar to the flora found in the permanently flooded area described above. The tree community is dominated by sparsely spaced baldcypress and water tupelo providing an open canopy, and allowing aquatic vegetation to take over the lake. There is very little recruitment of either of the dominant species because of the permanently flooded conditions. Based on the studies above, it can be assumed that the species composition and community structure differs significantly from a natural system. Thus, the maintenance of a constant water level in the lake has potentially changed its community structure as well as decreased its primary productivity.

4.20 Effect of Water Management on Wildlife Communities

Each community discussed above has evolved its own suite of adaptations that allow it to survive the harsh and often dynamic environment presented as wetland habitats. Similarly, wildlife communities take advantage of their own adaptations in order to utilize this highly productive system to their advantage. Clearly, the mobility of upland wildlife allows most species to fluctuate their use of particular habitats as the physical structure and condition of those habitats change. In fact, the life histories of many wetland animals, most notably amphibians and reptiles have evolved to take advantage of the fluctuations in these environmental conditions (Messina and Conner 1998). In order to maintain natural species diversity, therefore, it is obvious that restoration and maintenance of a natural water regime is critical (Drayton and Hook 1989). The preferred course of action proposed for Lake Isom will, to some degree, mimic natural water level fluctuations normally produced by the Mississippi River,

Wetlands have been described as very productive habitats (Mitsch and Gosselink 1993), with detrital-based food webs receiving nutrition and energy inputs from surrounding upland areas (Messina and Conner 1998). The transition zone between aquatic and terrestrial habitat is often a product of frequent flooding and drying. This zone is often characterized by wildlife species that can survive in either habitat type, thus potentially forming a link in the food chain between upland and wetland habitats (Messina and Conner 1998). In 1995, deMaynadier and Hunter showed that amphibians are often very abundant in wetland habitats, and proposed that they act as the link between aquatic and terrestrial systems through their predation on invertebrate detrivores. Both Reelfoot Lake and Lake Isom have 28 species of amphibians including salamanders, frogs and toads (Table 3) (USFWS 1989). Disruption of this community of organisms may, therefore, have cascading negative impacts on the rest of the wetland wildlife. The major impact water level fluctuation would have on the amphibian population would probably be due to potential changes in invertebrate density and species composition. However, major changes in the invertebrate population are not expected. Floral changes within any system tend to increase habitat for some species and decrease habitat for others. For example, vertical and horizontal diversity of a forested wetland's vegetation often increases the wildlife diversity and abundance (Messina and Conner 1998). Vertical diversity can be altered when prolonged flooding of a forest inhibits the development of a midstory or understory (Messina and Conner 1998). In this case, wildlife species commonly found within these structures such as the hooded warbler (*Wilsonia citrina*) and the wood thrush (*Hylocichla mustelina*) are not found (Howard and Allen 1989). Similarly, prolonged flooding often causes tree mortality which produces snags which are often used by other species like the prothonotary warbler (*Protonotaria citrea*) (Messina and Conner 1998). Horizontal habitat diversity is also very important for varying wildlife species. For example, dead and decaying logs are often utilized by ground skinks (*Scincella lateralis*) for shelter and as refuge from predators (Conant and Collins 1991), whereas black bears (*Ursus americanus*) often use hollow snags as den sites (Weaver and Pelton 1994). The proposed water management plan for Lake Isom should increase the vertical and horizontal diversity of vegetation, and therefore increase the amount of habitat for wildlife.

Weller (1978) proposed a set of management recommendations for prairie pothole marshes in the north-central United States and south-central Canada which are similar to the proposed water level management plans for Lake Isom. In these recommendations the marsh should be drawn down in the spring when the marsh has become an open water pond to stimulate the germination of seedlings. Water depth should slowly be increased following the drawdown to stimulate the growth of flood tolerant marsh species. The shallow areas produced by slowly increasing water depth are particularly attractive to dabbling ducks in the winter. In this plan, Weller (1978) suggests that the drawdown should occur again the next year to maximize the amount of emergent vegetation produced. Following this, shallow water should be maintained for several years to encourage the growth of emergent perennials such as cattails. Stable water elevations should then be maintained for several years to promote the growth of rooted submergent aquatic plants and the associated benthic organisms, which provide an excellent food source for waterfowl. During this time, the emergent vegetation will die out and the pothole will revert back to an open water marsh, at which time the process would be repeated. The author points out that maximum species diversity is maintained under this type of management strategy because all stages of the marsh cycle are maintained at once at different areas within the wetland. Wetlands typically flourish under cycles of flooding, and as a result any management practices that restrain these cycles often reduce wildlife productivity. Therefore, there is a general agreement that maintaining stable water levels in not a good management practice (Mitsch and Gosselink 1993).

5.0 Conclusions

There is more than sufficient literature to support the hypothesis that various plant functions are influenced by low soil Eh conditions. The extent of the impact is dependent on many factors including the species, timing, duration of soil reduction, and intensity of soil reduction. Low soil Eh is a major factor in wetland ecosystems that influences not only plant survival and growth but also community development. In addition, plant response to low soil Eh conditions also reflects a species' ability to respond to such conditions by utilizing a variety of internal defense mechanisms. Nevertheless, many wetland species, including those that are considered to be "highly flood-tolerant", are impacted by reduced soil conditions. Such responses are indicative of the fact that the reducing soil conditions encompass not only soil oxygen deprivation but also the production of various phytotoxins. The impact of such conditions on plant species varies from temporary disruption of normal processes and growth to serious damage to plant tissue. The reduced soil conditions substantially influence various critical plant processes including water relations, gas exchange, photosynthate partitioning, hormone balance, growth, nutrition, and biomass production. The impact is more likely to affect seedlings and young saplings than mature trees. Saplings and trees with well-developed root systems are better equipped to endure reduced soil conditions than are young seedlings. Yet if no action is taken to remedy the reduced soil conditions at Lake Isom, individual plants as well as plant communities may suffer both detrimental and irreversible effects.

Restoring the lake's hydrologic cycle by manipulating water level fluctuations has been documented as to improving plant and animal communities. Such manipulation may even create a shift in macrophytic vegetation communities from unwanted species to more desirable ones, thereby protecting navigation and recreation by controlling the invasion of certain pest species into open water. It has also been shown that greentree reservoir techniques have increased and improved waterfowl habitat, yet such practices are still controversial since shifts in plant communities may occur due to prolonged flooding. Any changes in plant community structure would also affect wildlife communities living in that environment. Preservation of the lake as a natural resource can only be accomplished through biologically sound management practices which may include the proposed water level management. Due to the unique, modern nature of the proposed management practices, little scientific literature was available that compared the response of plants to pre-practice and post-practice environmental conditions. Conclusions drawn from this report must be considered in light of this lack of data. An effort was made to limit the case studies used within this report to areas located in the southeastern United States when possible. However, it is imperative to note that most case studies cited are not located within the vicinity of Lake Isom, and thus may respond differently to the variable environmental conditions presented at each site.

6.0 Acknowledgments

Funding for this project was provided by the United States Corps of Engineers, Memphis District Office. Graduate Research Assistants Christopher Brown and Steve

Schaff assisted with literature synthesis and report writing. Graduate Students Mitch Elcan and Jason Farmer participated in the literature search.

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SECTION VI

COORDINATION

PART A. FISH AND WILDLIFE

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Draft
Fish and Wildlife Coordination Act Report on the Reelfoot Lake Project Lake and Obion Counties, Tennessee and Fulton County, Kentucky

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July 1999

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INTRODUCTION

In accordance with the National Transfer Funding Agreement and the Scope of Work agreed to by our agencies, the U.S. Fish and Wildlife Service (Service) is providing this draft Fish and Wildlife Coordination Act Report. In November 1993, the U.S. Army Corps of Engineers, Memphis District, conducted a reconnaissance study for water and related land resources problems in the Reelfoot Lake drainage basin. The reconnaissance study was authorized by the U.S. Senate and House of Representatives resolutions dated August 2 and 8, 1984, respectively. The Service issued a "Planning Aid Report on the Reelfoot Lake Study Lake and Obion Counties, Tennessee and Kentucky" on August 16, 1996. This report presented a general description of fish and wildlife resources in the study area and contained a cursory description of fish and wildlife-associated problems and needs.

Numerous other studies have been conducted and reports prepared on the many problems (sedimentation, hypereutrophication, etc.) of Reelfoot Lake, located along the westernmost border of Tennessee and Kentucky. The majority of site-specific studies and reports have focused heavily on the issue of sedimentation. Such reports have been prepared by agencies including the Tennessee Department of Health and Environment (currently known as the Tennessee Department of Environment and Conservation), Region IV of the Environmental Protection Agency (EPA), the U.S. Department of Agriculture, and the U.S. Geological Survey.

Due to the conflicting demands of a wide variety of user groups, management of Reelfoot Lake (Reelfoot) has resulted in significant public debate. As the result of a dispute over manipulation of water levels in Reelfoot and subsequent legal actions, decisions were issued by the U.S. District Court (June 9, 1985) and the Sixth U.S. Circuit Court of Appeals (June 17, 1986). These decisions led to production of the Reelfoot Lake Water Level Management Final Environmental Impact Statement (EIS)(U.S. Fish and Wildlife Service [USFWS], 1989).

The recommended course of action outlined in the EIS is an "integrated program of dynamic water level fluctuation combined with a periodic major drawdown." Normal pool elevation at Reelfoot is 282.2' above mean sea level (m.s.l.). Under the recommended course of action, water levels at Reelfoot would be allowed to fluctuate on an annual basis at least two feet between 280.0' and 284.0' m.s.l., depending on rainfall and other climatic conditions. In addition to the annual water level fluctuations, a major drawdown of four to eight feet (from 282.2' to 274.2' m.s.l.) would be attempted approximately every five to ten years. A new water control structure would have to be constructed to accomplish the recommended drawdown. The drawdown would start on or about June 1 and would be completed no later than July 15. A minimum of 120 days would be allowed for drying, with refilling to begin no later than November 15. The lake would be refilled to at least 283.2' m.s.l. and then allowed to fluctuate between 280.0' to 284.0' m.s.l. (USFWS, 1989).

Existing problems at Reelfoot addressed by the Corps during this Feasibility Study include reduced flood attenuation capacity, sediment detention and accretion, poor water quality, and degraded fish and wildlife habitat. As a result of land-use conversion to agriculture, sedimentation, and hydrological modifications, the Shelby Lake and Lake Isom areas have also experienced degradation of fish and wildlife habitats.

This draft Fish and Wildlife Coordination Act report describes probable benefits and/or impacts to fish and wildlife resources as a result of implementation of the project features proposed by the Corps. These features include construction of a new spillway, circulation channels within Reelfoot Lake, and a sediment retention basin on Reelfoot Creek (downstream of the confluence of North and South Reelfoot Creeks), as well as restoration and enhancement of Lake Isom, Shelby Lake, and their associated palustrine forested wetlands.

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STUDY AREA

The study area boundary is the Reelfoot Lake drainage basin, located within portions of Lake and Obion counties in northwest Tennessee and Fulton County in southwest Kentucky. The drainage basin occupies an area of approximately 240 square miles (153,600 acres) within the Mississippi Embayment portion of the Coastal Plain physiographic province. Topography in the area is generally flat and associated with the alluvial floodplain of the Mississippi River.

Reelfoot Lake has a water surface area of approximately 15,500 acres at a normal pool elevation of 282.2' m.s.l. Approximately 9,300 acres are open water habitat and 5,800 acres are emergent/forested wetlands. At normal pool elevation, approximately 68% of the lake has a depth of 3.0 feet or less. Reelfoot Lake is generally divided into three distinguishable sub-basins -- Blue Basin, Buck Basin, and Upper Blue Basin (Figure 1). Major tributaries to Reelfoot include Bayou du Chien, North and South Reelfoot Creeks, and Indian Creek. The existing spillway segregates Running Reelfoot Bayou from the southern end of the lake (Figure 2). Running Reelfoot Bayou occasionally receives backwater flooding from the Obion River during high flow periods.

There are approximately 31,300 acres of publicly owned land within the study area. The Tennessee Department of Environment and Conservation owns and manages the 279-acre Reelfoot State Park, and the Tennessee Wildlife Resources Agency (TWRA) owns and manages the 18,700-acre Reelfoot Wildlife Management Area (WMA). In addition, the USFWS leases 7,847 acres from the State of Tennessee and owns 2,580 acres which, managed together, comprise the 10,427-acre Reelfoot National Wildlife Refuge (NWR). The USFWS also manages, and owns in its entirety, the 1,850-acre Lake Isom NWR located approximately five miles south of Reelfoot (Figure 3).

Construction (1915-1919) of State Highway 22 along the southern shore of Reelfoot effectively restricted the natural drainage of the lake. The existing spillway, completed in 1931, was built at an elevation of 282.2' m.s.l. In 1941, the State of Tennessee granted control of lake levels to the USFWS under the terms of a 75-year lease (USFWS, 1989). The majority of the area surrounding Reelfoot has undergone considerable alteration over time, causing significant cumulative impacts throughout its watershed. Runoff from highly erodible soils and subsequent sedimentation and nutrient loading to Reelfoot Lake are generally attributed to three primary causes -- agriculture, residential development, and recreation-related enterprises.

Lake Isom has a surface water area of approximately 158 acres at a normal pool elevation of 280.0' m.s.l. Approximately 931 acres of scrub-shrub and forested wetlands are adjacent to the lake at an elevation below 284.0' m.s.l.. The Lake Isom wetland complex is no longer recharged by flood waters from Reelfoot and the Mississippi River. Hydrologic replenishment of the Lake Isom complex (by means of surface flooding) decreased even further when Running Reelfoot

Figure 1. Reelfoot Lake and Vicinity.

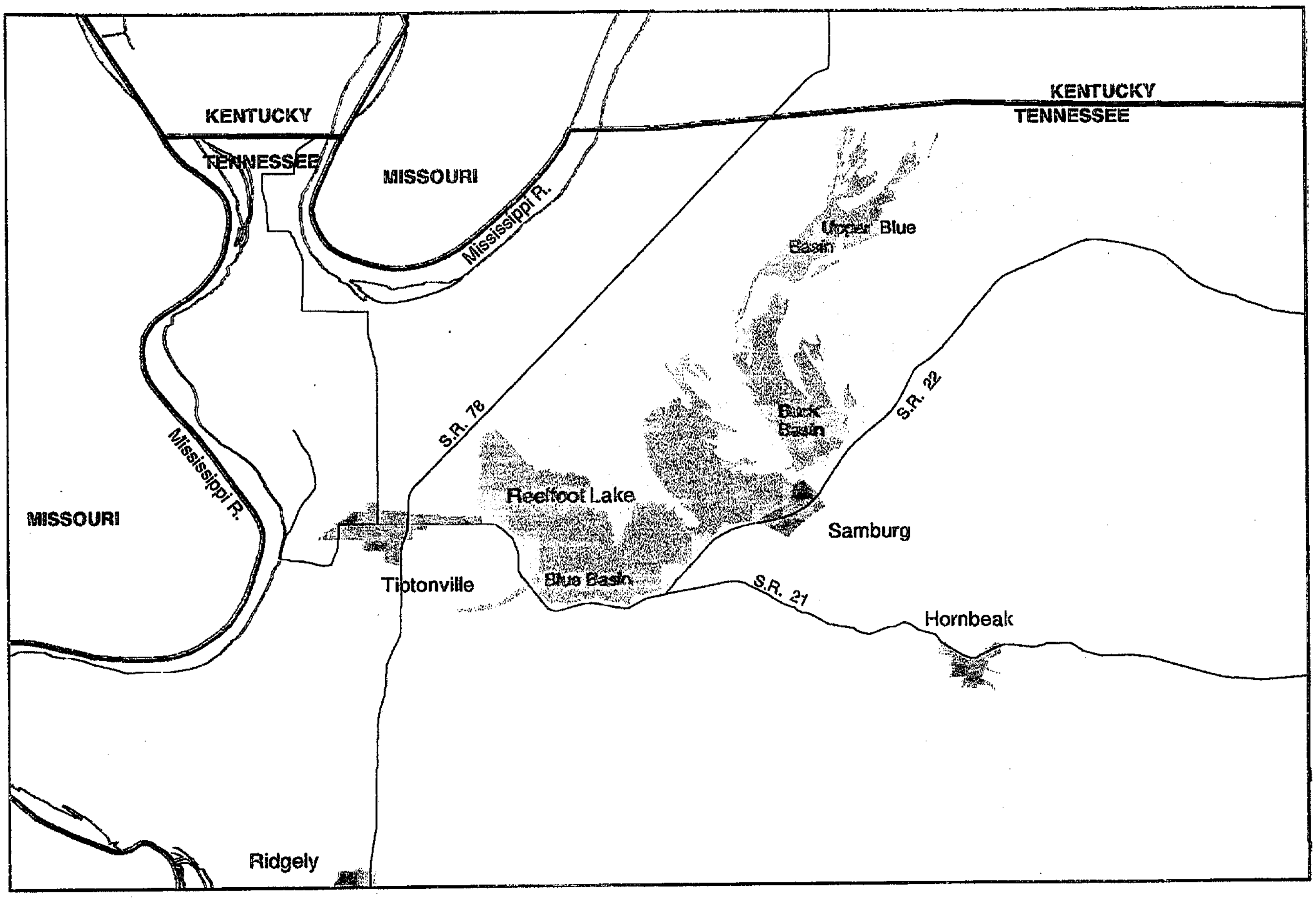


Figure 2. Basins and Tributaries of Concern

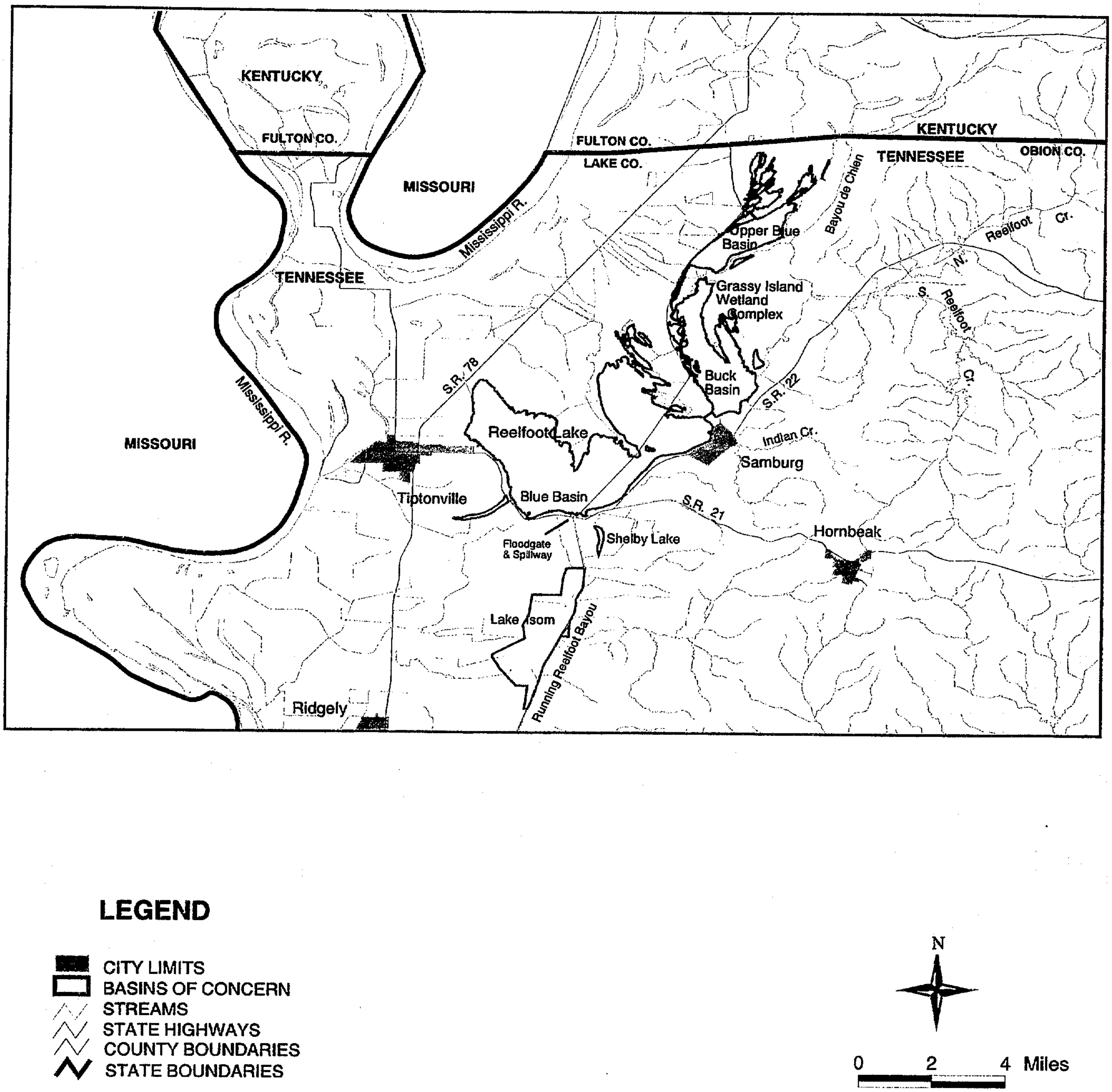
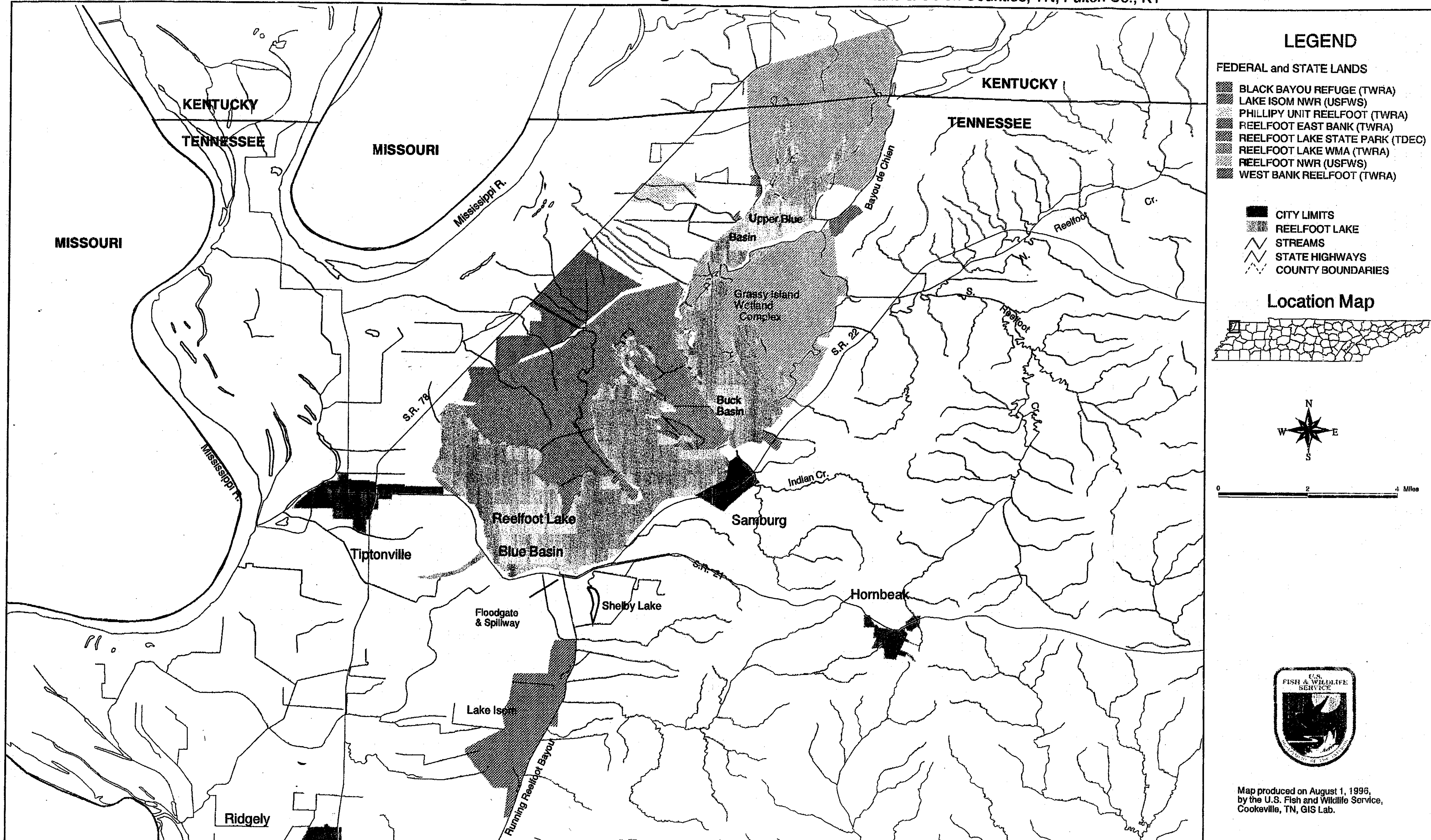


Figure 3. Reelfoot National Wildlife Refuge and State Management Areas

Lake & Obion Counties, TN, Fulton Co., KY



Bayou was channelized in 1959 (USACE, 1993). Sediment accretion in Lake Isom stimulates submerged, non-persistent and persistent emergent vegetation establishment in the lacustrine open water areas.

Shelby Lake was once a natural, 40-acre oxbow lake surrounded by cypress. Prior to construction of the Mississippi River levees, the current Reelfoot spillway, and State Highway 21, it was regularly replenished by flood waters from Reelfoot Lake and the Mississippi River. However, with the loss of frequent flooding, Shelby Lake filled and was subsequently cleared for agriculture. Approximately 25 acres have remained too wet for crop production and has now grown up in willows.

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EXISTING HABITAT CONDITIONS and FISH AND WILDLIFE RESOURCES

Upland Habitats

Upland habitats adjacent to Reelfoot include mature to early successional forested habitats, old fields, and various agricultural habitats including cropland and pasture. Upland forested habitats consist primarily of hardwood or mixed hardwood/softwood stands. These areas provide habitat for a variety of neotropical migratory and resident birds, as well as game bird species like the eastern wild turkey (*Meleagris gallopavo*), northern bobwhite (*Colinus virginianus*), and mourning dove (*Zenaida macroura*). The gray squirrel (*Sciurus carolinensis*) is also common in these upland forested habitats.

Early successional forested habitats, such as old fields and second growth timber areas, provide habitat for a number of species including the white-tailed deer (*Odocoileus virginianus*) and fox squirrel (*Sciurus niger*). Agricultural lands provide additional habitat where waste grain is heavily utilized by waterfowl and other avian species. Developed areas in close proximity or adjacent to Reelfoot include the communities of Tiptonville and Samburg, and numerous resorts which have been built on the lake shoreline. Wildlife resources in these developed areas are generally limited to those species tolerant of human disturbance.

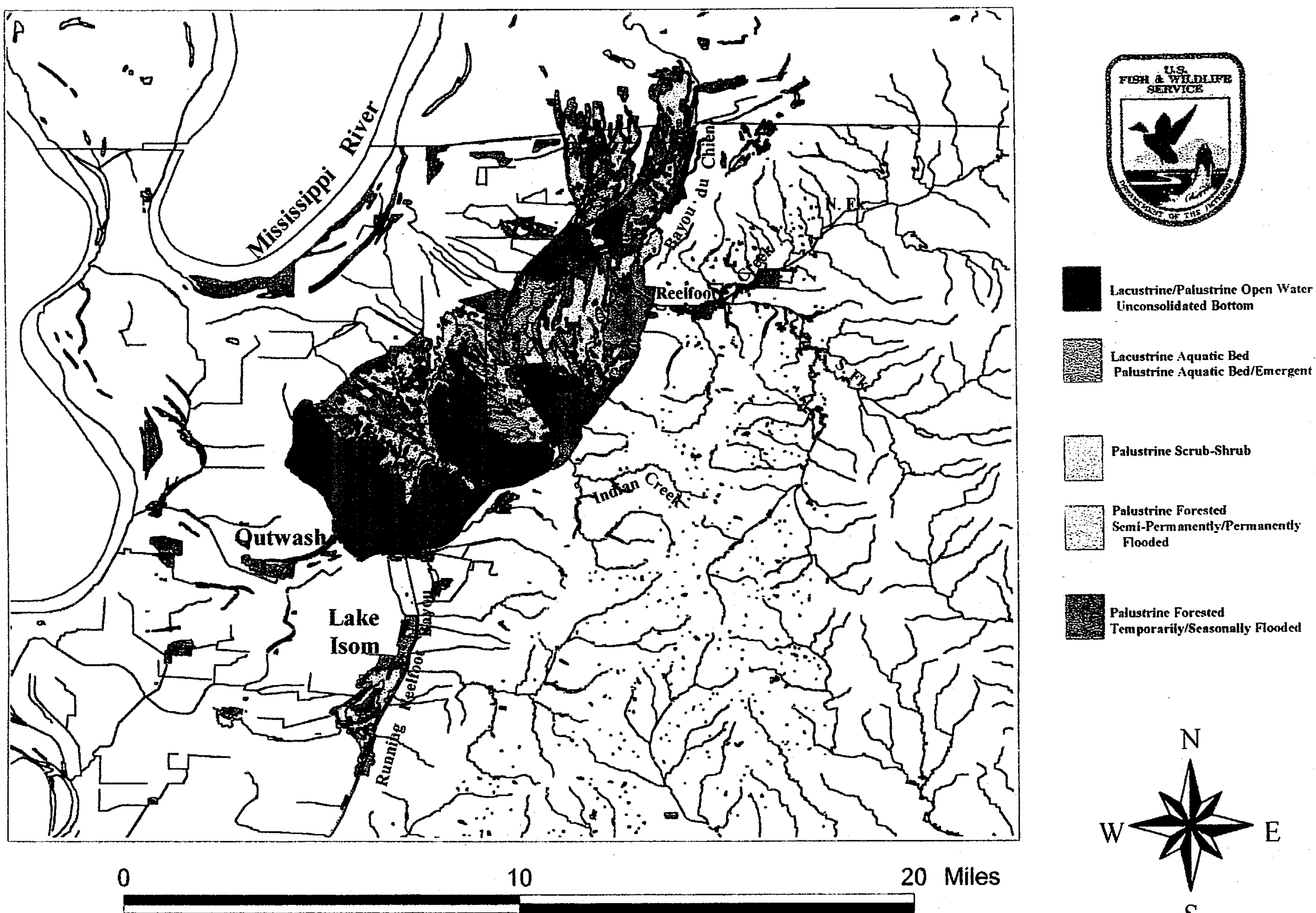
Reelfoot is well known for its winter abundance of the federally threatened bald eagle (*Haliaeetus leucocephalus*). Other raptor species occurring in the Reelfoot vicinity include ospreys (*Pandion haliaetus*) and several species of owls and hawks.

Wetland Habitats

The varied and numerous wetlands in the Reelfoot project area provide extremely valuable fish and wildlife habitat. These wetland areas can be placed into three primary categories -- lacustrine, palustrine, and riverine (Cowardin et al., 1979). Based on an analysis by the Corps and the University of Memphis, Reelfoot contains approximately 9,358 acres of lacustrine/palustrine open water/unconsolidated bottom; 3,236 acres of lacustrine aquatic bed/palustrine aquatic bed and emergent; 186 acres of palustrine scrub-shrub; and 7,750 acres of palustrine forested wetlands between the 266.0' and 288.0' m.s.l. contour intervals (Figure 4). These estimates do not include those wetlands associated with the Reelfoot outwash area. Lake Isom has approximately 158 acres of lacustrine open water and 140 acres of palustrine scrub-shrub wetlands below 281.0' m.s.l.

Lacustrine wetlands comprise the majority of the open water areas of Reelfoot. Reelfoot Lake lies directly within the Mississippi Flyway and is a key migratory stopover point for waterfowl. Ducks and geese use the lacustrine open water areas extensively both as a food source and as an important roosting area. Peak fall and winter waterfowl populations normally reach or exceed 400,000 ducks and 95,000 Canada geese (Johnson et al., 1988).

Figure 4. Reelfoot Wetlands



The lacustrine open water wetlands of Reelfoot provide spawning habitat for many species of fishes, as well as valuable habitat for amphibians and reptiles. These areas are extremely important for recreational fishing and non-consumptive recreational activities such as eagle observation tours and boating. Outdoor recreation, both consumptive and non-consumptive, is an integral component of the study area economy. An estimated $3,832,000 are expended annually on all study area recreation activities, and approximately 322,800 man-days are annually spent fishing (USACE, 1993).

Common submerged and emergent aquatic vegetation in these lacustrine areas include American lotus (*Nelumbo lutea*), coontail (*Ceratophyllum demersum*), duckweed (*Lemna minor*), watermeal (*Wolffia* sp.), white water-lily (*Nymphae* sp.), spatterdock (*Nuphar advena*), creeping water primrose (*Ludwigia repens*), curly-leaf pondweed (*Potamogeton crispus*), water-velvet (*Azolla cardiniana*), frog's-bit (*Limnobium spongia*), arrow-head (*Sagittaria* sp.), bladderwort (*Utricularia* sp.), and fanwort (*Cabomba caroliniana*). Bald cypress (*Taxodium distichum*) is also scattered throughout these lacustrine areas (Smith and Pitts, 1982; Broadbent, 1996).

Palustrine wetlands in and around Reelfoot include permanent and non-permanent emergent marsh and scrub-shrub areas, and forested wetlands. They also include shallow-water or mudflat-dominated areas. Common palustrine emergent species include cattail (*Typha* sp.), smartweed (*Polygonum* sp.), giant cutgrass (*Zizaniopsis milliacea*), and various sedges (*Carex* sp.) and rushes (*Cyperus* or *Sciurpus* sp.). Buttonbush (*Cephalanthus occidentalis*), water willow (*Decodon verticillatus*), and swamp rose (*Rosa carolina*) are common species in the scrub-shrub areas. These areas are heavily utilized by a variety of waterfowl and shorebird species as brood and foraging habitat. Many of the lacustrine non-persistent emergent species are also found in areas classified as palustrine aquatic bed.

Typical hardwood tree species in the palustrine forested areas of Reelfoot include bald cypress, tupelo (*Nyssa aquatica*), black willow (*Salix nigra*), green ash (*Fraxinus pennsylvanica*), red maple (*Acer rubrum*), sweet gum (*Liquidambar styraciflua*), cottonwood (*Populus deltoides*), sycamore (*Platanus occidentalis*), American elm (*Ulmus americana*), boxelder (*Acer negundo*), sugarberry or hackberry (*Celtis laevigata*), red oak (*Quercus falcata*), and water hickory(*Carya aquatica*). When flooded, these forested wetlands are used extensively by waterfowl, especially mallards (*Anas platyrhyncos*) and wood ducks (*Aix sponsa*) for feeding, as well as by wood ducks for nesting and brood habitat (USACE, 1993).

Temporary and seasonally flooded areas comprise approximately 3,413 acres of the palustrine forested wetlands of Reelfoot. Regeneration of desirable wetland tree species such as cypress, black gum (*Nyssa sylvatica*), shellbark hickory (*Carya laciniosa*), and various oaks (*Quercus* sp.) has seriously decreased as older trees die off due to "suffocation" by sediment (USACE, 1993). Hydrologic replenishment to these palustrine forested wetlands is insufficient to flush accumulated sediment and to suppress regeneration of water-intolerant species. The 480-acre Grassy Island wetland is indicative of this problem. Species composition consists primarily of green ash, sycamore, American elm, cottonwood, boxelder, black willow, red maple, and hackberry. Cypress are also scattered throughout the area. This area is exhibiting declines associated with sediment deposition from Reelfoot Creek, and regeneration is limited primarily to red maple and hackberry. Green ash appears to be the most susceptible to stress from sedimentation.

The palustrine forested wetlands of Lake Isom encompass approximately 798 acres below 285.0' m.s.l. Temporarily and seasonally flooded areas comprise approximately 381 acres of the total. Dominant tree species include black willow, sycamore, green ash, red maple, and hackberry. Sourwood (*Oxydendrum arboreum*) and alder (*Alnus serrulata*) are also present. The area is scattered with individual large cypress, black willow, and sycamore specimens, however, very little regeneration of these species is occurring. The existing water level of 280.0' m.s.l. does not provide the extent or duration of water necessary to induce desirable species regeneration. Early successional species consist primarily of red maple and hackberry.

Riverine wetlands in the vicinity of Reelfoot Lake primarily consist of the Mississippi River adjacent to the western extent of the project area. Riverine wetlands historically occurred in Reelfoot Creek, Indian Creek, Bayou du Chien, and Running Reelfoot Bayou. Most of these riverine systems have been altered by channelization, levee construction, and impoundment. In some years, the interior population of the least tern (*Sterna antillarum*), a federally listed endangered species, nests on sand bars associated with the Mississippi River and uses Reelfoot for feeding throughout the summer.

Water and Sediment Quality

Hydrologic replenishment of Reelfoot results from tributary discharges, overland flow, and direct precipitation. Water circulation between the lacustrine open water wetlands of Upper Blue Basin, Blue Basin, and Buck Basin is limited due to sedimentation and vegetative obstruction. Water quality in Reelfoot is characterized as hypereutrophic and observed nutrient levels (nitrogen and phosphorus) are associated primarily with nonpoint source pollution (siltation and sedimentation) from the upland areas on the eastern side of the lake. Based on a review of historical water quality data, nonpoint nutrient loads from tributary streams discharging to Reelfoot contribute 55,720 kilograms (kg) of phosphorus and 305,750 kg of nitrogen per year (USFWS, 1989). Reelfoot Creek and Bayou du Chien convey the majority of these nutrients. The erosional sources are associated with agricultural activities and instability of the stream channels as a result of channelization.

In addition to the high nutrient loading to Reelfoot, other water quality parameters exhibit spatial and temporal variations. The Tennessee Department of Environment and Conservation (TDEC) has established ambient water quality monitoring stations at seven locations in the basin (Walnut Log, Bayou du Chien, Black Slough, Buck Basin, Kirby Pocket, Keystone Pocket, and the spillway)(Figure 5). Water quality data have also been collected in Reelfoot Creek and Indian Creek. Dissolved oxygen (DO) concentrations are particularly problematic, with the lowest levels observed below 1 mg/l. Low DO levels are most prevalent in May, June, and July. Factors affecting DO levels in the lake include temperature, water circulation, degree of stratification, sediment oxygen demand, algal photosynthesis and respiration, submerged and emergent vascular plant photosynthesis and respiration, and detrital oxygen demand (USFWS, 1989). The data collected by TDEC have also indicated that levels of suspended solids and select metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc) have occasionally exceeded existing state water quality criteria. Factors affecting metal concentrations in water are similar to those which control DO levels, and also result from elevated temperatures, occasional low pH values, and disturbance of sediments.

Recent sediment analyses within Reelfoot Lake indicated elevated levels of arsenic, chromium, mercury, and zinc (USFWS, 1998). Arsenic concentrations (mg/kg, dry weight) were 5.8 at Donaldson Ditch, 8.4 at Samburg, 11.0 at Horse Island Ditch, 12.0 at Upper Blue Basin, and 18.0 at Buck Basin. Chromium levels ranged from 62.0 to 91.0 mg/kg at the five stations, with the highest concentration at Buck Basin. Mercury and zinc levels ranged from 0.06 to 0.16 mg/kg and 83 to 160 mg/kg, respectively, with the highest concentrations at Buck Basin. Sediment analyses conducted by TDEC at the spillway have generally produced lower results, indicating that metal concentrations of concern are most likely associated with tributary discharges to Reelfoot.

Fisheries

Creel surveys, electrofishing, seine hauls, and rotenone surveys performed by the Tennessee Wildlife Resources Agency (TWRA) have indicated that the game fish population of Reelfoot consists primarily of largemouth bass (*Micropterus salmoides*), white crappie (*Pomoxis annularis*), black crappie (*Pomoxis nigromaculatus*), bluegill (*Lepomis macrochirus*), longear sunfish (*Lepomis megalotis*), warmouth (*Lepomis gulosus*), green sunfish (*Lepomis cyanellus*), and yellow bass (*Morone mississippiensis*).

Major prey or forage species for the game fish population include gizzard shad (*Dorosoma cepedianum*), threadfin shad (*Dorosoma petenense*), golden shiner (*Notemigonus chrysoleucas*), brook silverside (*Labidesthes sicculus*), inland silverside (*Menidia beryllina*), bullhead minnow (*Pimephales vigilax*), and various young-of-year and juvenile sunfish species. Inland silverside was the most abundant forage fish in Reelfoot.

Channel catfish (*Ictalurus punctatus*), common carp (*Cyprinus carpio*), freshwater drum (*Aplodinotus grunniens*), spotted gar (*Lepisosteus oculatus*), bowfin (*Amia calva*), and yellow bullhead (*Ictalurus natalis*) comprise the majority of non-game species collected. TWRA has stocked approximately 175,000 grass carp (*Ctenopharyngodon idella*) in the Kirby Pocket area of Reelfoot from 1983-1996 for the control of aquatic vegetation.

Largemouth bass experienced poor recruitment in 1989, 1991, 1994, and 1995. These recruitment problems have been attributed to survival of young-of-year fish during summer months. Crappie and bluegill densities also declined slightly, however, there was increased recruitment and reproductive success noted for bluegill. It is theorized that abbreviated drawdowns in 1984 and 1985 may have contributed to the improved bluegill success. Increases in the densities of gizzard shad have also been observed since 1991 (Broadbent, 1996).

Specific goals addressed by this study included: restoration and protection of aquatic habitat, restoration of palustrine forested wetlands, maintenance of the lake's flood attenuation capability, and waterfowl habitat restoration. The objectives developed to meet these goals were:

- decrease sediment deposition in the lake,
- restore water level management capabilities,
- prevent isolation of the lake's basins, and
- provide additional habitat for waterfowl and other wildlife.

The preferred alternative selected by the Corps is the same integrated program of dynamic water level fluctuation combined with periodic major drawdown that was described in the EIS. A list of features was evaluated against the goals and objectives, and features best addressing the objectives were evaluated in greater detail. Specific project features recommended by the Corps to accomplish the preferred alternative and project objectives are described below.

Proposed Features

Spillway

The spillway design was developed to accommodate the Corps' preferred alternative and in accordance with the following operational criteria:

- capability for a two-foot seasonal fluctuation between 280' and 284' m.s.l.,
- capability for a four-foot drawdown to 278.2' m.s.l. between June 1 and July 15, with 120 days of drying time following the drawdown (every five to ten years), and
- gradual refilling of the lake following a drawdown and holding at 283.2' m.s.l. until June 1 of the following year (USFWS, 1989).

The construction of the spillway will require the clearing and grubbing of approximately 25 acres south of the existing alignment of State Route 21 (Figure 5). Approximately 3.5 acres will be cleared on the north side of the highway. Excavation of approximately 506,300 cubic yards of material will be required for construction of the spillway and the relocation of State Route 21. Under a Federal Court decision and an existing lease agreement, the USFWS operates the current spillway and is responsible for water level management at Reelfoot Lake.

Figure 5. Proposed Spillway, Circulation Channels and TDEC Monitoring Sites.

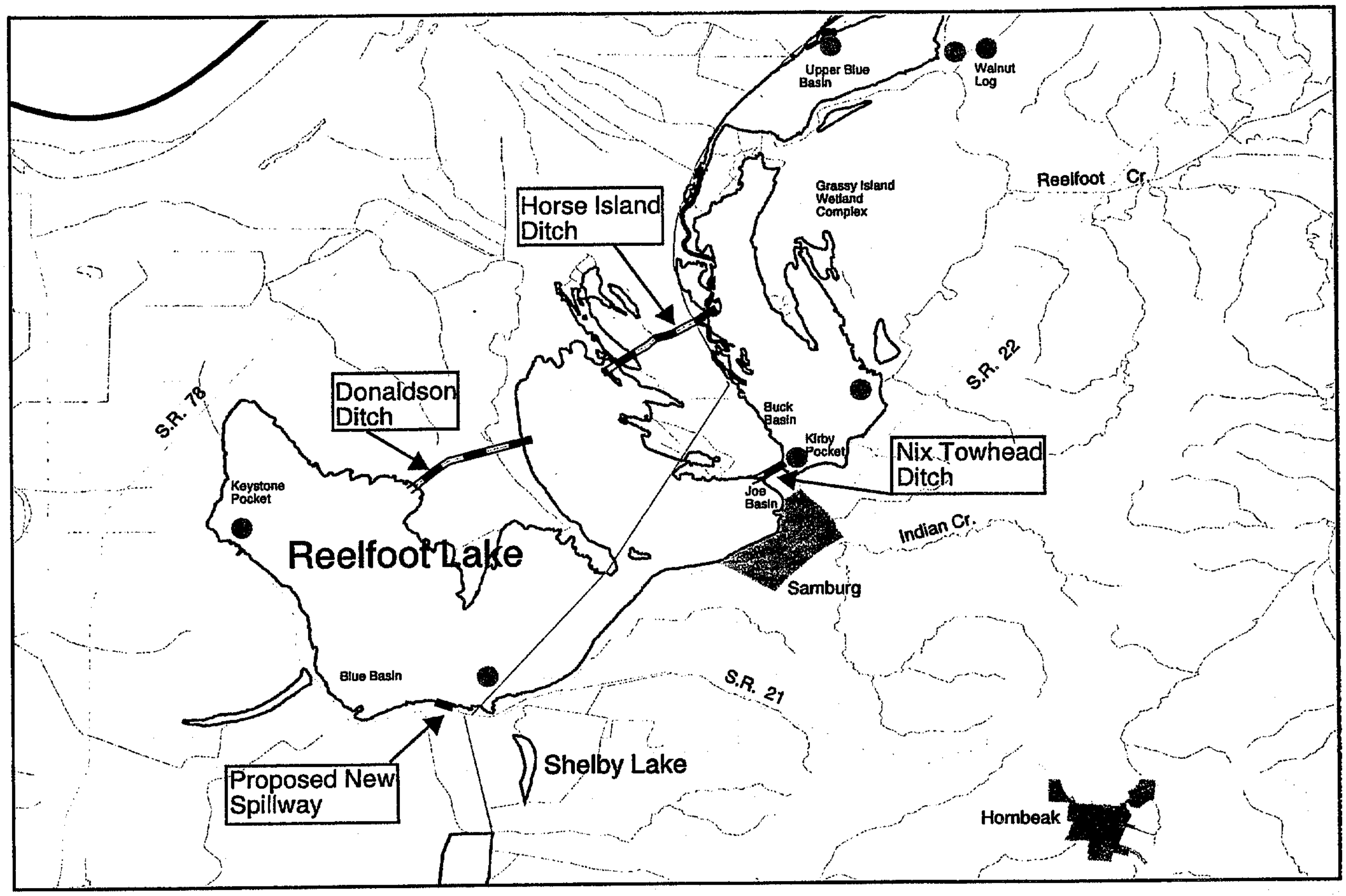
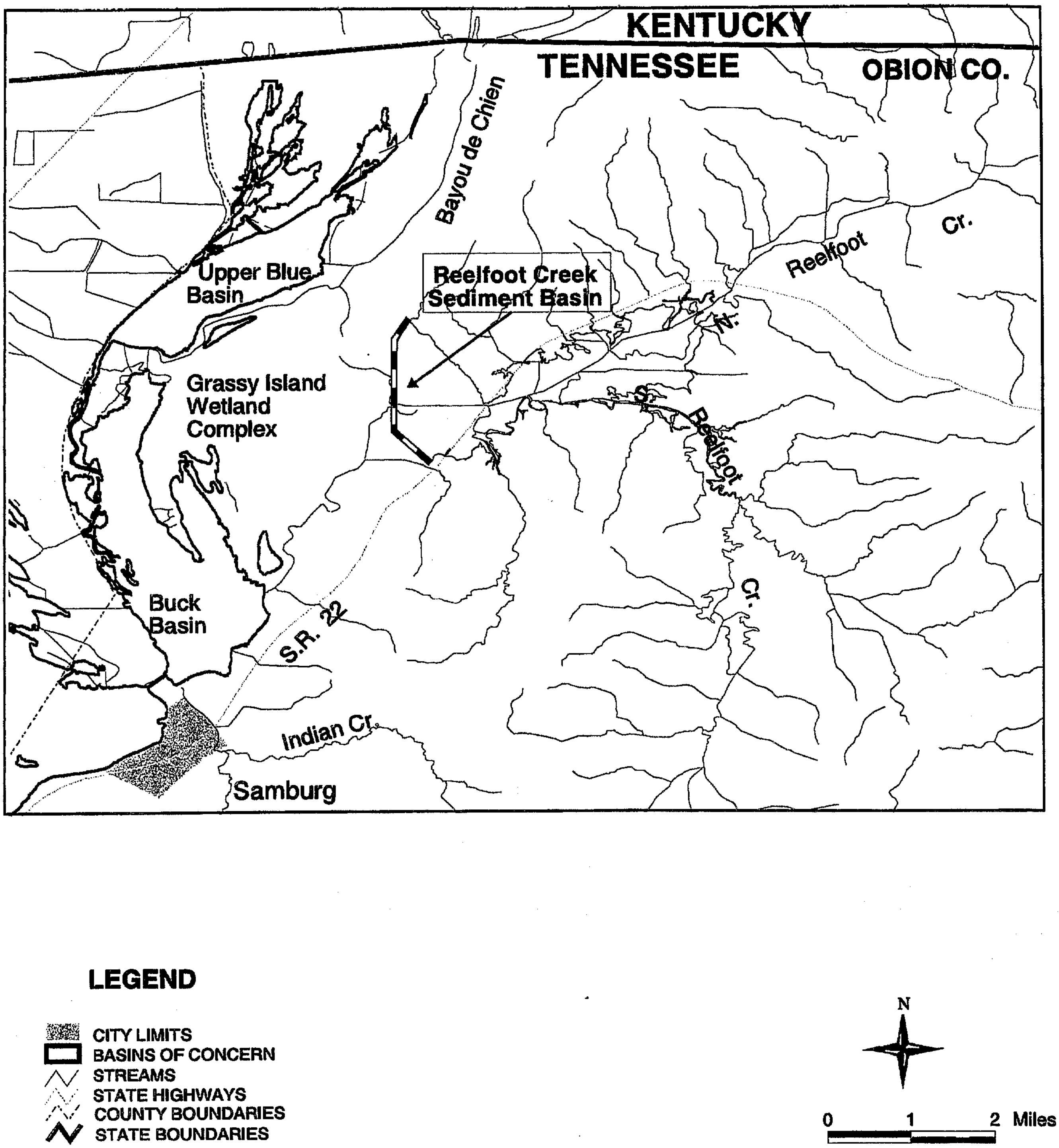


Figure 6. Reelfoot Creek Sediment Basin



basin. The existing channel of Reelfoot Creek will be routed through the borrow pit, with three low flow outlets, a primary spillway, and emergency spillway.

Enhancement features proposed for the basin include 250 acres of palustrine forested wetland restoration, 360 acres of moist soil (waterfowl) management units (WMUs), and 676 acres of agricultural leases. Hydrology for the moist soil management units will be provided by stoplog control structures and pumps/wells. TWRA will be responsible for operation and maintenance of the basin.

Lake Isom Restoration

Lake Isom only receives hydrologic replenishment from direct precipitation and overland flow from adjacent agricultural areas. The proposed plan is to modify the existing water control structure at the southern end of Lake Isom by raising the current earthen levee approximately two feet. Groundwater wells and a pump system will be utilized to enhance hydrologic replenishment of the area. The modified levee will enhance water holding capacity, allowing an increase in winter water level from 280.0' to 282.0' m.s.l. This increase will inundate 314 acres of adjacent agricultural land. Water levels on 175 acres of palustrine forested and 6 acres of palustrine scrub-shrub wetlands would also be increased. During a 100-year storm event, Lake Isom water levels may reach 283.0' m.s.l. to 285.0' m.s.l.

The material needed to raise the earthen levee will be taken from cropland northwest of the existing floodgate structure. The 4-acre borrow area is within the influence of the existing levee. It will be designed with varying depths and an irregular shape. The borrow area will be connected to Lake Isom and will impact an as yet undetermined acreage of palustrine forested wetlands. This borrow area should provide additional feeding and resting habitat for migratory waterfowl and shorebirds. The USFWS will continue to be responsible for operation and maintenance of the spillway.

Shelby Lake Restoration

Restoration of Shelby Lake will provide water management capability on approximately 965 acres of cleared agricultural land. Shelby Lake will be enlarged to approximately 170 surface acres. Excavation will create a bottom configuration with depths varying from one to six feet. There will be 19,700 feet of shoreline at elevation 280' m.s.l. Hydrology will primarily be provided by a connection to the new spillway outlet channel.

The additional surface area proposed for Shelby Lake is required to provide adequate fill material for terrace (low-level levees) construction. Six WMUs totaling approximately 483 acres will be constructed on existing agricultural ground. Water used to flood the WMUs will also periodically be allowed to flow through the existing 25-acre stand of palustrine forested wetlands (willows) north of Shelby Lake. Stop-log structures and a well/pump system will also be used to maintain hydrology in the WMUs when water is not diverted from the spillway outlet. Shallow flooding of the WMUs should provide resting and feeding habitat for waterfowl. Upon project completion, ownership of the WMUs and Shelby Lake will be transferred from the Corps to TWRA. At that time, TWRA will assume the responsibility of ongoing operation and maintenance.

Fish and Wildlife Resource Conditions

Future Without the Project

Hydrologic Restoration, Water Management Capability, and Sediment Retention

The current spillway operation plan allows lake levels to reach 282.7' m.s.l. between April 16 and November 14 before the spillway gates are opened to achieve normal pool elevation. Lake levels are allowed to reach 283.2' m.s.l. between November 15 and April 15. These levels are not sufficient to restore a more natural pattern of water level fluctuations or to increase flood attenuation capacity. Due to the age of the existing spillway, continuous maintenance will be required to ensure its structural integrity.

As a result of continued sediment accretion, the open water surface area of Reelfoot is estimated to decrease to 6,300 acres by the year 2025 (USACE, 1993). Storage, depth, and circulation patterns of Reelfoot will continue to be diminished as sediment accretion and organic matter decomposition rates increase. Inorganic sediment accretion rates have been estimated at 0.35 to 0.75 inches per year (USFWS, 1989). Denton (1986) estimated that Blue Basin, Buck Basin, and Upper Blue Basin would be filled completely in 275, 165, and 90 years, respectively.

Open Water Habitat and Aquatic Bed/Emergent/Scrub-Shrub Wetlands

As Reelfoot continues to become shallower due to cumulatively increasing sediment loads, deposition of additional materials will have a proportionately greater effect on vegetation and aquatic-dependent organisms. Through the course of natural succession, lacustrine aquatic bed and palustrine aquatic bed/emergent wetlands will likely be the first to progress toward exhibiting upland characteristics. General vegetative communities in Reelfoot have been described (Smith and Pitts 1982) and succession of open water to upland is thought to occur in the following stages: 1) submerged stage (coontail, elodea, fanwort, and pondweed); 2) floating stage (Lotus, spatterdock, duckweed, and water-velvet); 3) sawgrass stage (cutgrass, sawgrass, cattail, Lizard's tail); 4) shrub stage (buttonbush, swamp rose, and water willow); and 5) pioneer tree stage (black willow, bald cypress, green ash, and cottonwood). Conversion of these wetlands will cause a detrimental loss of foraging capacity to the diverse shorebird and waterfowl populations of Reelfoot.

Forested Wetlands

Because of reduced water levels and sedimentation, early successional tree species (e.g., red maple, willow, and hackberry) are expanding throughout the palustrine forested areas. These species are generally of lower value to wildlife, especially in comparison to oak and hickory species. The loss of desirable tree species is serious not only due to the wildlife breeding, nesting, and brood-rearing habitat provided therein, but also because these hardwoods yield hard mast as a high-protein, high-energy food source for turkey, deer, waterfowl, and numerous other species.

Water and Sediment Quality

Reelfoot Lake will continue to be in an increasingly hypereutrophic state characterized by poor water quality and excessive plant growth. Major influxes of sediments and nutrients will continue to be received by way of erosion from the surrounding watershed, causing ongoing severe water quality degradation. During a 1978 sampling of nutrient inflow to southeastern United States lakes, Reelfoot had both the highest total nitrogen (2.17 mg/L) and the second highest total phosphorus (0.233 mg/L), with these nutrient levels being respectively 20% and almost 40% higher than the next highest ranked lake (USEPA, 1978).

Smith and Pitts (1982) described the relationship between DO concentrations and the occurrence of aquatic macrophytes in Reelfoot. These data indicated that the presence of duckweed, an emergent species, with no submerged vegetation correlated with a mean DO concentration of 1.6 mg/l. When duckweed was present with coontail, mean DO concentrations were 0.4 mg/l. The absence of emergent vegetation in conjunction with the presence of submerged vegetation produced DO levels of greater than 12.0 mg/l. The presence of submerged and emergent vegetation, the accumulation of sediment and decaying organic material, and the existing nutrient loading to Reelfoot will continue to negatively influence DO, biological oxygen demand, and sediment oxygen demand.

The dense submerged and emergent aquatic vegetation also trap sediment from upland areas in the near shore littoral areas and shallow open water of Reelfoot. The metals associated with these sediments are generally tightly bound and are only released to the water column as a result of changes in water chemistry or remobilization. The levels of metals in Reelfoot sediments exceed those found in the surficial Memphis series (Karathanasis and Seta, 1993), the predominate upland soil in the eastern portion of the project area (Brown et al., 1969). Legacy point source discharges and atmospheric deposition in the basin may have also contributed to metal enrichment of Reelfoot sediments. These metal concentrations would not be expected to degrade to any extent over time.

Fisheries

The increasing accumulations of inorganic and organic sediment in Reelfoot will continue to produce shallower lake levels. Suitable spawning substrates for the desirable game fish species will decline proportionately. Where spawning does occur, demersal eggs may be buried and suffocated by silt/sediment loads associated with storm events and resuspension. The water quality degradation in Reelfoot places continual stress on larval, young-of-year, and juvenile fish populations. Angling pressure also contributes to declines in the population of desired species, necessitating active management (stocking) of these species. Year-class failures, such as those noted for the largemouth bass, cannot be attributed solely to Reelfoot's water quality degradation or normal predator-prey relationships. Increased competition between Centrarchids for limited spawning habitat may also be a contributing factor in year-class failures of specific species. Since water quality parameters are not consistently uniform throughout Reelfoot and predator-prey relationships are not fully understood, population trends for desirable game fish species are difficult to interpret or predict.

Management strategies, including harvest regulations, limited water-level management, and supplemental stocking, have been unsuccessful in producing a desirable number, distribution, and diversity of fishes (Johnson et al., 1988; USFWS, 1989). Recent fishery surveys of Reelfoot have reflected a shift in species composition from game fish toward rough fish, as well as an attendant decline in sport fish biomass and abundance (Johnson et al., 1988). Carp, catfish, and buffalo do not depend on light for foraging and generally have a higher tolerance for low DO levels. Bowfin and gar are also better adapted to periodic anoxia through their ability to utilize atmospheric oxygen. The increasing nutrient and sediment levels, coupled with the continued stocking of grass carp for aquatic vegetation control, will result in an increased assemblage of these species. Since carp, buffalo, gar, and bowfin typically spawn in shallow vegetated areas, their reproductive success will continue to increase as Reelfoot water levels decrease and lacustrine aquatic bed/palustrine aquatic bed/emergent habitats increase. Periodic thermal stratification and low DO levels will also influence movement of these rough fish to the near-shore littoral areas for foraging, increasing turbidity and the potential of disturbance to available game fish spawning habitat.

Future With the Project

Hydrologic Restoration, Water Management Capability, and Sediment Retention

The construction of a new spillway and circulation channels for Reelfoot (Figure 5) would, **concomitant with** execution of an integrated program of dynamic water level fluctuation combined with periodic major drawdown (USFWS 1989), restore a more natural pattern of water level fluctuation to the lake. Sediment compaction will occur during drawdown periods and enhance the ability of Reelfoot to sustain additional sediment accretion.

Construction of the inlet channel, spillway, and outlet channel will impact approximately 3.5 acres of temporarily and seasonally flooded palustrine wetlands north of State Route 21 and approximately 30 acres of palustrine forested wetlands on the south side of State Route 21. Five channels within the lake will also require dredging to improve water circulation and provide boat access through the lake. Our GIS analyses of the National Wetlands Inventory data (Tiptonville and Samburg quadrangles) indicate that the Donaldson Ditch excavation will impact approximately 0.7 acre of lacustrine and palustrine open water/unconsolidated bottom, 0.9 acre of lacustrine aquatic bed/palustrine aquatic bed and emergent, and 4.1 acres of palustrine forested wetlands. The Horse Island Ditch excavation will impact approximately 1.3 acre of lacustrine and palustrine open water/unconsolidated bottom, 1.8 acre of lacustrine aquatic bed/palustrine aquatic bed and emergent, and 2.4 acres of palustrine forested wetlands. The Nix Towhead excavation will impact approximately 0.5 acre of lacustrine and palustrine open water/unconsolidated bottom and 1.0 acre of lacustrine aquatic bed/palustrine aquatic bed and emergent wetlands. Excavation of the boat channels will impact approximately 0.5 acre of lacustrine and palustrine open water/unconsolidated bottom wetlands. The precise location for the additional 2 acres of dredged material disposal has not been determined.

Construction and operation of the proposed sediment basin on Reelfoot Creek (Figure 6) will intercept approximately 70 percent of sediment being carried down the North and South Forks of Reelfoot Creek, removing 60 percent of the total sediment currently entering Reelfoot. Projections by the Corps indicate that the majority of sediments conveyed by Reelfoot Creek will be deposited within the levee borrow pit downstream of the State Route 22 bridge. Periodic sediment removal from Reelfoot Creek and its tributaries will be required. The frequency of sediment removal and exact locations of properly confined upland disposal areas have not been determined.

Open Water Areas and Aquatic Bed/Emergent/Scrub-Shrub Wetlands

The proposed four-foot temporary drawdown to 278.2' m.s.l. will expose approximately 51% of Reelfoot sediments to drying and compaction, reduce the lake volume by 59%, and reduce the mean depth by 17% (USFWS, 1989). The drawdown would affect approximately 2,376 acres of lacustrine/palustrine aquatic bed and emergent and 101 acres of palustrine scrub-shrub wetlands between 278.0' m.s.l. and 285.0' m.s.l. Submerged and non-persistent emergent vegetation will be adversely affected by a drawdown, however, some rootstock would remain for recolonization. Definitive data regarding aquatic macrophyte response to drawdowns is limited, however, the TWRA has accumulated data obtained during a major drawdown of Crockett Lake in 1994. After approximately 107 days of drying, coontail had been eradicated and lotus and spatterdock were in decline. A two-foot seasonal fluctuation between 280.0' and 284.0' m.s.l. would delay recolonization of shallow water areas by emergent non-persistent species.

GIS analyses indicates that approximately 30.2 acres of palustrine emergent and 2.4 acres of palustrine scrub-shrub wetlands are within and below the 305' m.s.l. contour of the proposed sediment basin in the Reelfoot Creek watershed. Temporary increases in water levels associated with a 100-year storm event would not be expected to affect these wetlands. Sediment accretion in these wetlands may gradually induce succession to species more indicative of a palustrine forested wetland or upland community.

The Lake Isom area contains approximately 140 acres of palustrine scrub-shrub wetlands below the 281' m.s.l. contour interval. Water levels at 282.0 m.s.l. during winter and early spring, or an increase to a higher level during a 100-year storm event, would not significantly affect these wetlands. If sediment accretion in Lake Isom is controlled, reduced expansion of palustrine scrub-shrub species, such as buttonbush, into the lacustrine open water/unconsolidated bottom wetlands would be expected.

Forested Wetlands

The palustrine forested wetlands of Reelfoot encompass approximately 3,220 acres between 278.0' m.s.l and 285.0' m.s.l. Temporarily and seasonally flooded palustrine forested wetlands comprise approximately 1,225 acres of this total. A four-foot drawdown to 278.2 m.s.l. would not be expected to significantly affect these wetlands. The 1,995 acres of semi-permanently and permanently flooded palustrine wetlands would, however, be susceptible to prolonged drying.

With a major drawdown occurring no more often than once every 5-10 years, significant negative impacts to hydrophytic tree species such as cypress and black willow would not be expected (USFWS, 1989). Since seeds require moist but not flooded conditions for germination and early seedling growth, temporary reductions in inundation would benefit regeneration of hydrophytic and water-tolerant tree species. A two-foot seasonal fluctuation in water levels between 280.0' and 284.0' m.s.l. would also be beneficial for the temporarily and seasonally flooded palustrine forested wetlands. Depending on the frequency and duration of water level increases, regeneration of undesirable pioneer species such as red maple may be suppressed.

Approximately 175 of the 791 acres of palustrine forested wetlands at Lake Isom below 284.0' m.s.l. would be expected to benefit from an increase in water level to 282.0' m.s.l. Benefits would be more pronounced on the 151 acres of temporary and seasonally flooded palustrine forested wetlands between 280.0' and 282.0' m.s.l. Suppressed regeneration of species such as red maple would be expected with a significant duration of increased water levels. Hydrologic replenishment at Shelby Lake would also provide benefits to the existing 25 acres of palustrine forested wetlands.

Of the approximately 362.4 acres of palustrine forested wetlands within the 305' m.s.l contour of the proposed sediment retention basin, approximately 298.9 acres are temporarily or seasonally flooded. Species composition in these forested wetlands consists primarily of green ash, sweetgum, willow, red oak, red maple, and sugarberry. As a result of channelization in Reelfoot Creek, these areas exhibit signs of reduced flooding. Pioneer species such as red maple are regenerating, while preferred hard mast species are not. The increased frequency of flood waters associated with a 100-year storm event may help reduce vegetative stress. With a continuous discharge from the proposed sediment basin, it is unlikely that the duration of floodwaters associated with a 100-year storm event would be sufficient to totally suppress undesirable pioneer species regeneration within the 305' m.s.l. contour interval.

Water and Sediment Quality

As previously noted by the Service in the Reelfoot Lake Water Level Management Final EIS (USFWS, 1989), temporary environmental consequences associated with drawdown years will include reduced water quality and temporary nutrient surges. Over the long term, however, these drawdowns should decelerate the eutrophication of Reelfoot, increase dissolved oxygen levels, reduce turbidity, and improve biological and sediment oxygen demand.

Fisheries

As submerged and emergent aquatic macrophytes are directly impacted by the drying associated with a four-foot drawdown, there will be a corresponding decrease in aquatic invertebrate abundance and densities. Significant numbers of benthic and pelagic aquatic invertebrates will be directly affected in those areas of the lake which completely dry, however, recolonization should rapidly occur after the lake is refilled. A 50% reduction of water levels in Great Lakes marshes increased aquatic invertebrate biomass substantially after these areas were reflooded (Bookhout et al., 1989). Both the species richness and abundance of littoral zooplankton and benthic macroinvertebrates are positively related to DO concentrations at the sediment-water interface (Elmore et al., 1984). After the lake is refilled, the reduction in the biological oxygen demand near the lake bottom should also help in the establishment of an aquatic invertebrate population more indicative of improved water quality and habitat conditions (USFWS, 1989).

The proposed drawdown will directly affect existing fish populations, due to stress as water temperatures increase and DO levels decrease. Demersal and adhesive eggs would also be exposed in some areas. During the summer months, isolated fish kills may result from lowered DO concentrations. Unaffected individuals will be concentrated in isolated pools. A similar drawdown at Wapanocca Lake (on Wapanocca National Wildlife Refuge, Arkansas) in 1986 demonstrated that even severe fish kills during very low water and unusually hot temperatures will not eliminate the fishery of a large lake like Reelfoot (USFWS, 1989).

While most game fish prefer shallow vegetated littoral zones for foraging, significant variability has been observed in the response of various species to a progressive dominance of the water column by submerged vegetation. Largemouth bass biomass quadrupled and recruitment increased following complete removal of submergent macrophytes at Lake Baldwin, Florida (Shireman et al. 1984). Food availability and the trophic state of this lake also influenced biomass and recruitment. Although Florida lakes would not be completely representative of Reelfoot, game fish biomass and abundance would be expected to decrease when lakes are hypereutrophic. Improvements in water quality and maintenance of submerged and emergent macrophytes in Reelfoot would be expected to benefit the game fish population.

As the lake is refilled, habitat conditions will be favorable to produce population levels of desirable game species that equal or surpass pre-drawdown levels (USFWS, 1989). Readily available breeding habitat for those species requiring spawning beds will be created as a result of sediment consolidation and compaction. Seasonal fluctuations in water levels to 284.0' m.s.l. will also provide critical access to palustrine forested wetlands, which provide optimal sites for reproduction, food, and cover.

DRAFT

CONCLUSIONS AND RECOMMENDATIONS

The study area includes fish and wildlife resources of local, regional, and national significance, including large wintering populations of waterfowl and the federally listed threatened bald eagle as well as Reelfoot's status as the largest remaining natural lake in Tennessee. Over time, the entire watershed of Reelfoot Lake has undergone significant changes as a result of agricultural activity, residential development, and recreation-related enterprises. Area fish and wildlife resources and their habitats exhibit numerous indications of both localized and basin-wide, prolonged stresses. As a result of hydrological modification and sedimentation, the palustrine forested wetlands of Reelfoot, Lake Isom, and Shelby Lake are exhibiting characteristics of succession to upland plant communities.

The Corps' preferred alternative is designed to enhance water level fluctuation capabilities, which to some limited extent should simulate natural, long-term hydrological conditions. Without project implementation, storage, depth, circulation patterns, and water quality within Reelfoot Lake will continue to be diminished due to sediment accretion, submerged and emergent aquatic vegetation expansion in lacustrine open-water areas, and the subsequent organic decomposition of aquatic macrophytes. The establishment of a sediment basin in Reelfoot Creek should help reduce the sediment load which over the past 50 years has substantially impacted the hydrological, physico-chemical, and biological characteristics of Reelfoot Lake. Without project implementation and active management (direct seeding) of the palustrine forested wetlands, less desirable species, such as red maple, willow, and hackberry, will continue to be the primary successional species, providing limited benefits to Reelfoot's wildlife resources.

Fish and wildlife impacts of the proposed project will center around the construction of the new spillway and circulation channels, implementation of the water level management program, construction and operation of the sediment retention basin on Reelfoot Creek, and the development and enhancement of waterfowl management capabilities at Lake Isom and Shelby Lake. Benefits accrued from implementation of the Corps' preferred alternative would compensate for the projected construction-related impacts to wetlands. These benefits include:

1. enhanced flood storage capability[1];

2. improved water quality;

3. partial deceleration and/or reversal of lake eutrophication[1] ;

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[1]If the preferred water level management scheme (as recommended in the EIS) were not implemented, these benefits could not be attributed to the other project features alone.

4. improved water circulation and boat access between main basins;

5. deceleration of loss of spawning areas and other habitats for game fish populations[1];

6. enhanced suppression of undesired aquatic vegetation[1] ;

7. prevention of ephemeral near-shore wetland losses[1];

8. increased exposure of mud-flat habitat[1];

9. improved maintenance of open-water acreage for recreation[1]; and

10. sediment compaction during drawdowns[1].

The Corps' preferred alternative would be exceptionally beneficial to waterfowl, providing additional nesting, resting and breeding habitat, as well as increased foraging capacity and availability of desired foods. Several individual project features are central to this effort:

1. habitat restoration within the sediment retention basin will provide 250 acres of palustrine forested wetlands and 360 acres of WMUs;

2. habitat restoration at Lake Isom NWR will provide an additional 360 acres of waterfowl and shorebird habitat; and

3. hydrologic restoration and expansion of Shelby Lake to 170 acres and creation of adjacent WMUs will provide water management capability on 965 acres of existing agricultural land, providing the capability of producing "hot" foods by means of flooded grain crops and moist soil management units.

Currently, it is anticipated that the preferred alternative, if implemented **in conjunction with** the integrated program of dynamic water level fluctuation combined with periodic major drawdown recommended in the EIS, would have significant positive benefits for the fish and wildlife resources of Reelfoot Lake, as well as a large portion of its watershed.

The Service recommends that a detailed analysis of sediment contamination in areas proposed for excavation be conducted during the planning and specifications stage of the project. This analysis should be consistent with the procedures contained in the Inland Testing Manual developed by the Corps and the U.S. Environmental Protection Agency. If the contaminants in sediment are determined to be bioavailable to Reelfoot's aquatic resources, alternative disposal sites for dredged material may be necessary. We also recommend that a detailed monitoring proposal be developed for all wetland types within and adjacent to Reelfoot Lake. This monitoring should assess vegetation development, abundance, species composition, survival, and growth after project implementation. Direct seeding of desirable wetland tree species may be necessary in some areas.

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SECTION VI

COORDINATION

PART B. PRIME AND UNIQUE FARMLAND

UNITED STATES
DEPARTMENT OF
AGRICULTURE

NATURAL RESOURCES
CONSERVATION
SERVICE

1216-B Stad Avenue
Union City, TN 38261

==

DATE: 23JULY1998

TO: Richard Hite
USACoE
Memphis District

FROM: Jim Needham, DC
Union City Field Office

SUBJ: Prime and Unique Farmland / Wetland Determinations

Richard -

The Prime, Unique and Important Farmland map for Obion County was prepared in the late 70s, and basically indicates that all bottomland areas in the county meet the criteria for one of those designations. This being the case, all of the areas indicated on the topo sheets you faxed will be Prime and/or Unique Farmland.

Regarding the designations of FW or PC for the indicated areas, I have made copies of the maps that we use to highlight potential wetland areas. There should be sufficient copies to provide mosaic coverage of the areas you have marked. It is important to note that the "W" and "FW" designations marked on the photos are potential wetland areas delineated by remote sensing five years of aerial photos, and may or may not actually be a wetland area when evaluated on-site. The remainder of the open fields can be assumed to be "PC" designations, again an assumption without field evaluation.

The information provided here should not be used to summarily complete form AD-1006 for the FFPA. That form should be forwarded for completion as required.

If you need further, let me know.

Jim Needham

U.S. GOVERNMENT PRINTING OFFICE 1984 451-159/1324

U.S. Department of Agriculture

FARMLAND CONVERSION IMPACT RATING

PART I *(To be completed by Federal Agency)*		Date Of Land Evaluation Request 23 June 1999	
Name Of Project Reelfoot Lake Feasibility Study		Federal Agency Involved Memphis District Corps of Engineers	
Proposed Land Use Construction, reforestation, flowage easement		County And State Lake & Obion Co., TN	
PART II *(To be completed by SCS)*		Date Request Received By SCS	
Does the site contain prime, unique, statewide or local important farmland? *(If no, the FPPA does not apply — do not complete additional parts of this form).*	Yes ☐ No ☐	Acres Irrigated	Average Farm Size
Major Crop*(s)*	Farmable Land In Govt. Jurisdiction Acres: %	Amount Of Farmland As Defined in FPPA Acres: %	
Name Of Land Evaluation System Used	Name Of Local Site Assessment System	Date Land Evaluation Returned By SCS	

	Maximum Points	Alternative Site Rating Site A	Site B	Site C	Site D
PART III *(To be completed by Federal Agency)*					
A. Total Acres To Be Converted Directly		2,558			
B. Total Acres To Be Converted Indirectly		680			
C. Total Acres In Site		3,238			
PART IV *(To be completed by SCS)* Land Evaluation Information					
A. Total Acres Prime And Unique Farmland		3,238			
B. Total Acres Statewide And Local Important Farmland		3,238			
C. Percentage Of Farmland In County Or Local Govt. Unit To Be Converted					
D. Percentage Of Farmland In Govt. Jurisdiction With Same Or Higher Relative Value		0			
PART V *(To be completed by SCS)* Land Evaluation Criterion Relative Value Of Farmland To Be Converted *(Scale of 0 to 100 Points)*					
PART VI *(To be completed by Federal Agency)* Site Assessment Criteria *(These criteria are explained in 7 CFR 658.5(b)*					
1. Area In Nonurban Use		20			
2. Perimeter In Nonurban Use		20			
3. Percent Of Site Being Farmed		10			
4. Protection Provided By State And Local Government		5			
5. Distance From Urban Builtup Area	0	0			
6. Distance To Urban Support Services	0	0			
7. Size Of Present Farm Unit Compared To Average		20			
8. Creation Of Nonfarmable Farmland	25	25			
9. Availability Of Farm Support Services		10			
10. On-Farm Investments		10			
11. Effects Of Conversion On Farm Support Services	25	25			
12. Compatibility With Existing Agricultural Use		15			
TOTAL SITE ASSESSMENT POINTS	160	160			
PART VII *(To be completed by Federal Agency)*					
Relative Value Of Farmland *(From Part V)*	100	100			
Total Site Assessment *(From Part VI above or a local site assessment)*	160	160			
TOTAL POINTS *(Total of above 2 lines)*	260	260			

Site Selected: A	Date Of Selection	Was A Local Site Assessment Used? Yes ☒ No ☐

Reason For Selection:

SECTION VII

WETLAND SUMMARY BY CONTOUR

REELFOOT LAKE FEASIBILITY STUDY
Wetlands Habitat Investigation

by Rodney Conger
Ground Water Institute
The University of Memphis

US Army Corps
of Engineers
Memphis District

GROUND WATER INSTITUTE
The University of Memphis

List of Figures

List of Tables

*See attached Plate Index for location of additional plates in set.

Introduction

Reelfoot Lake is located in Lake and Obion Counties in the northwest corner of Tennessee. Bounded by river bluffs to the east and the Mississippi River to the north and west, the area surrounding Reelfoot Lake is relatively flat as it extends into the southwest corner of Fulton County, Kentucky.

In an effort to study the effects of raising the water levels of Reelfoot Lake and Lake Isom immediately to the south, the US Army Corps of Engineers, Memphis District (COE) engaged the Ground Water Institute (GWI) to develop one-foot contour intervals encompassing the area. This contour interval interpolation was performed using existing available data and supplemental data obtained by COE surveys. Additionally, The GWI performed a study of US Fish and Wildlife National Wetlands Inventory (NWI) designated wetlands to determine the area and types of NWI habitats affected by the proposed project.

Project Description

The project as presently being planned will restore, preserve, and protect fish and wildlife habitat in the Reelfoot Lake basin. It will also provide incidental recreational benefits. The major features of the project include a new spillway (with accompanying bridge and outlet channel) at Reelfoot Lake, circulation channels within Reelfoot Lake, a sedimentation basin on Reelfoot Creek, and a new outlet structure and modification of the existing dam embankment on Lake Isom. In addition, water level management routines on both Reelfoot and Lake Isom are being investigated.

Contour Interval Generation

The elevation contour intervals generated for this project represent a mosaic of elevation data from several sources as listed in Table 1.

Table 1. Elevation data sources

Data set	Data type	Description
USGS 30 minute DEM	digital elevation model	raster grid with constant cell spacing
USGS 7.5 minute Quadrangle	topographic contour	digitized as constant elevation vectors
US Army COE hydrographic survey	elevation points	bottom surface elevations of Reelfoot Lake using GPS and soundings
US Army COE land survey	elevation points	land survey points for area north of Reelfoot Lake in Kentucky and dam structure on Lake Isom
US Army COE land survey	topographic contour	land survey contours for area north of Reelfoot Lake in Kentucky and area south of Reelfoot Lake near spillway

Each electronic data set was examined and corrected for obvious errors. US Geological Survey contour interval data were used where errors existed or elevation data were sparse.

To generate contour intervals for Reelfoot Lake, a 50-foot cell size ARC/INFO grid surface was interpolated from the aforementioned data. Contours were generated from this surface in an iterative process that allowed for additional error evaluation of the original data. The elevation source data for Lake Isom consisted only of digitized USGS 7.5-minute topographic contours and projected top of dam elevations. From these, an ARC/INFO triangular irregular network (TIN) was developed to represent the surface. Lake Isom contours were interpolated from that surface.

Figure 1 shows a map of the project area along with National Wildlife Refuge (NWR) boundaries and data source delineations.

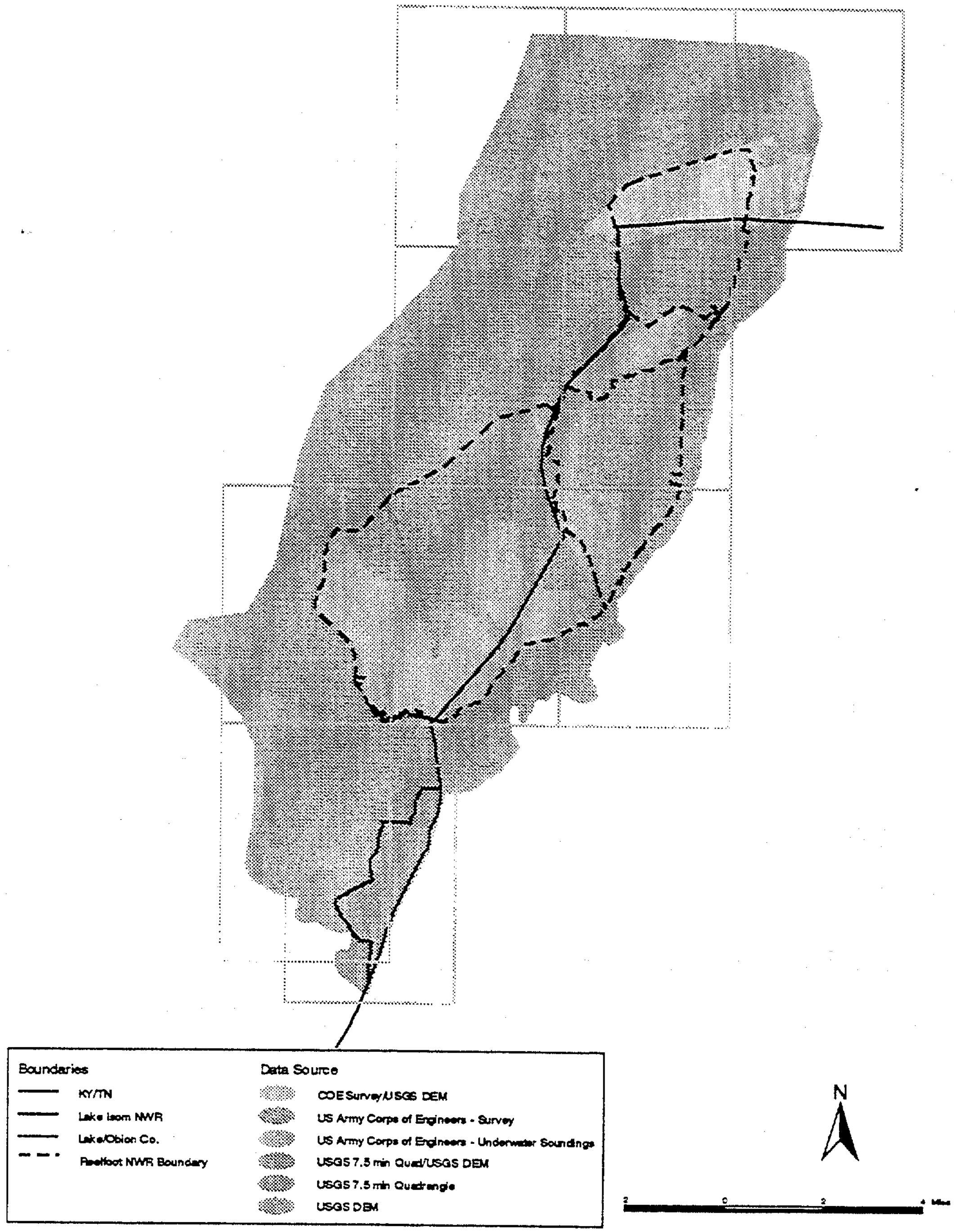


Figure 1. Data source delineations

Wetland Habitat Areas

A primary interest of the study was to determine the type and amount of wetland habitats that would be affected by the proposed project. To facilitate this determination, constant elevation polygons were defined between each of the elevation arcs representing one-foot contour intervals. Next, electronic copies of NWI wetland maps were obtained from the Tennessee Wildlife Resources Agency (TWRA) and corrected for discrepancies with respect to published maps. Wetlands codes were then grouped into habitat types by their primary system and subsystem classifications (refer to Appendix B). A polygon overlay was then created using the one-foot contour polygons and the NWI habitat polygons.

Elevation areas were calculated for five major regions: **1)** Lake Isom (this area includes all contiguous elevation regions up to 285' NGVD surrounding Lake Isom), **2)** subsurface Reelfoot Lake (Upper Blue/Buck Basin), **3)** Reelfoot Lake (lower basin), **4)** Reelfoot Lake outer (this area includes all contiguous elevation regions up to 288' NGVD surrounding Reelfoot Lake), **5)** outwash area (refer to Plate 2). Refer to Appendix C for a listing of areas by elevation contour polygons. Refer to Appendix D for a listing of Wetlands areas for each of the major regions listed above. Note that the dashed red and blue lines shown on the Plate Index and the individual plates have significance with respect to the areas reported in both Appendix C and Appendix D. No areas are reported outside either the dashed red or dashed blue lines. A comprehensive area legend appears in Appendix A

Appendix A

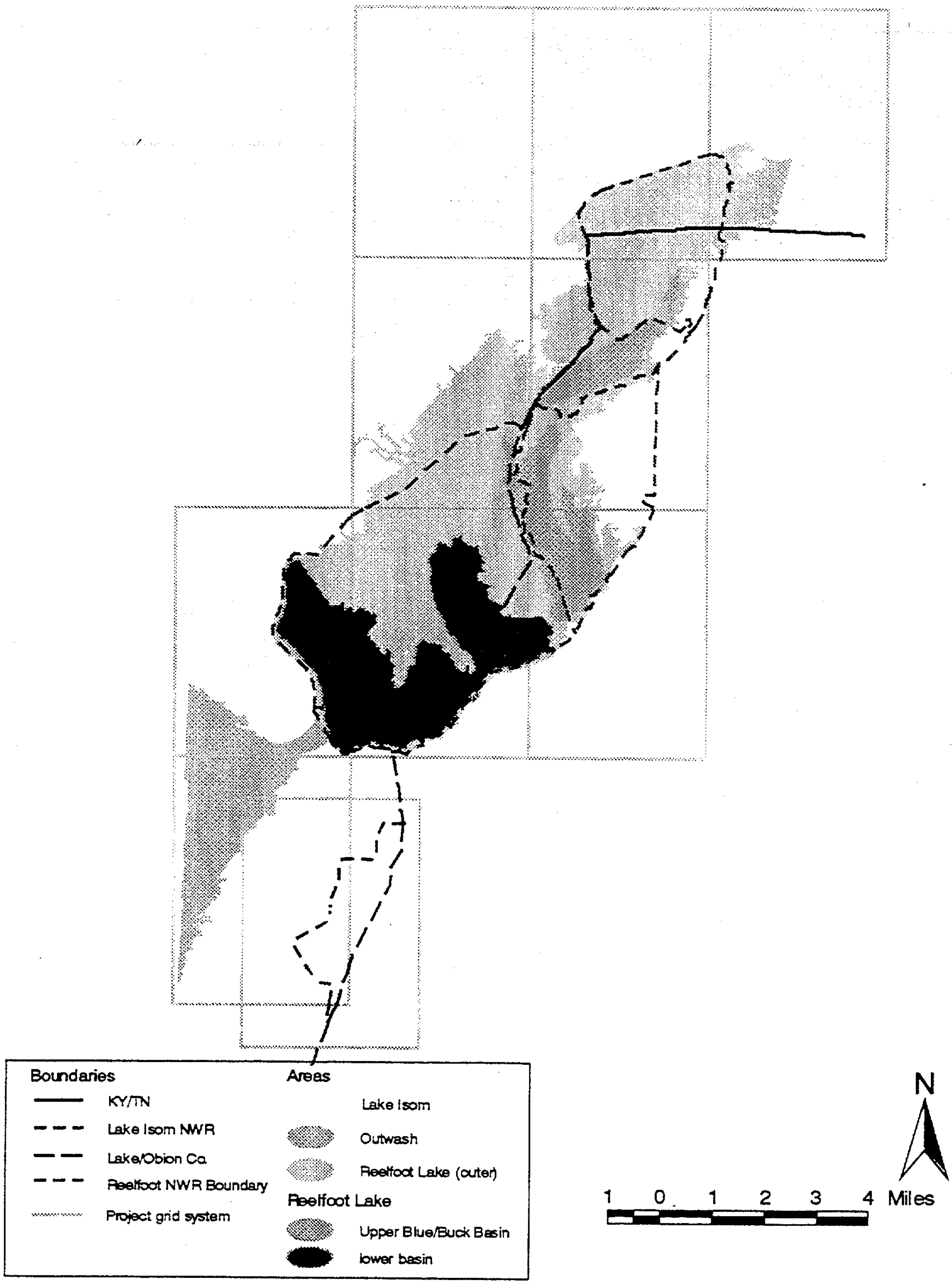


Figure A1. Area legend for reported acreage.

Appendix B

Weltand code - habitat mappings

Bottomland Hardwoods	Forested Swamp	Scrub /Shrub Swamp	Dead Timber	Marsh	Unnamed Habitat	Unclassified /Unknown /Upland	Riverine	Open Water/ Impoundment
PF01A*	PF01F*	PSS*	PFO*5*	L2AB3*	PEM1A*	U	R2*	L2UB*
PF04*	PFO1G*			PAB3*	PEM1C*	UNKNOWN	R3*	L2US*
PF06A	PFO1H*			PEM1F	PEM1Fd		R4*	LIUB*
PF091Cd	PFO2*			PEM1Fh	PEM1G			OW*
PF0A	PFO6F*			PEM1Fx	PEM1h			PAB*
PFO1C	PFO6G			PEM1Gh	PEM1H			PUB*
PFO1Ch	PFO6G			PEM1Hh	PEM1Hx			PUS*
PFO1Cx	PFO6H							
PFO6C*	PFOC							
	PFOF							
	PFOG							

Note: An asterisk (*) indicates a wildcard.

Appendix C

Table C1. Contour interval polygon areas (acres)

elevation (NGVD)	Lake Isom[1]	Reelfoot Lake[1] (outwash area)	Reelfoot Lake[1] (surrounding area)	Reelfoot Lake[2] (Upper Blue/ Buck Basin)	Reelfoot Lake[2] (lower basin)
264-265					35.16
265-266					108.18
266-267			0.03		134.76
267-268			0.50		316.13
268-269			0.56		279.02
269-270			11.10		167.23
270-271			9.53		176.67
271-272			10.24		201.35
272-273			17.61	9.29	196.83
273-274			20.12	80.00	223.23
274-275			21.16	142.78	254.31
275-276			25.51	168.20	320.37
276-277			34.28	266.18	567.95
277-278			42.47	292.03	896.26
278-279		450.16	65.12	423.17	981.34
279-280	1035.51[3]	92.62	77.55	354.16	679.50
280-281	348.07	74.19	146.04	431.07	633.98
281-282	162.09	188.71	270.80	1016.16	445.03
282-283	138.96	917.22	11765.63	13.48	328.23
283-284	162.69	138.06	1914.10		
284-285	225.32	165.75	2002.21		
285-286	6.47[4]	959.62	8955.58		
286-287		110.61	780.11		
287-288		116.46	861.09		
288-289		4.81			
289-290		0.66			
Total	**2079.11**	**3218.86**	**27031.35**	**3196.52**	**6945.53**

Notes:
1. Includes only elevations at and above water surface.
2. Includes only elevations at and below water surface.
3. Includes all elevations below 280 ft
4. Includes all elevations above 285 ft

General note:
Areas for Reelfoot Lake (Upper Blue Basin/ Buck Basin) and Reelfoot Lake (lower basin) may be combined to give a composite area for all subsurface elevations.

Appendix D

Table D1. Wetland habitat areas (acres)

Area	Contour Intervals	Bottomland Hardwoods	Forested Swamp	Marsh	Open Water / Impoundments	Scrub / Shrub Swamp	Unclassified	Unnamed Habitat	Total
Lk Isom	<280	204.50	390.87		152.67	134.55	122.69	30.25	1035.52
	280-281	125.52	21.62		5.57	5.52	184.23	5.60	348.07
	281-282	26.36	3.43				130.33	1.97	162.09
	282-283	9.67	0.32				128.76	0.21	138.96
	283-284	8.57	0.29				153.59	0.25	162.69
	284-285	6.12	0.22				217.48	1.50	225.32
	>285	0.02					6.01	0.45	6.48
	Total	380.76	416.74		158.24	140.07	943.09	40.22	2079.12
Outwash area	278-279	108.92					337.10	4.13	450.16
	279-280	21.30					71.32		92.62
	280-281	16.77					57.41		74.19
	281-282	23.59			68.30		96.82		188.71
	282-283	52.74	2.62		6.76		855.11		917.22
	283-284	3.27			3.04		131.75		138.06
	284-285	4.53			0.29		160.94		165.75
	285-286	36.36	4.53		0.25		916.52	1.96	959.62
	286-287	2.55	2.11				105.96		110.61
	287-288	5.23	1.68				109.55		116.46
	288-289						4.81		4.81
	289-290						0.66		0.66
	Total	275.24	10.94		78.64		2847.96	6.09	3218.86
Reelfoot Lk surr area	266-267			0.30					0.30
	267-268			0.50					0.50
	268-269		0.22	0.34					0.56
	269-270	3.58	2.74	0.32			4.46		11.10
	270-271	2.19	2.66	0.28			4.40		9.53
	271-272	2.52	3.97	0.28			2.96	0.52	10.24
	272-273	3.76	7.19	0.29			5.54	0.83	17.61
	273-274	5.43	8.03	0.30			5.67	0.70	20.12
	274-275	5.78	7.86	0.32			6.63	0.58	21.16
	275-276	9.49	6.85	0.35	0.01		8.33	0.49	25.51
	276-277	15.66	9.72	0.39	0.08		8.00	0.43	34.28
	277-278	18.25	15.16	0.44	0.13		8.10	0.39	42.47
	278-279	25.97	23.88	0.54	2.14		12.22	0.37	65.12
	279-280	22.52	33.02	0.66	2.29		18.72	0.35	77.55
	280-281	27.33	55.62	27.94	10.87		23.94	0.35	146.04
	281-282	46.17	87.34	72.69	23.96	0.55	36.94	3.14	270.80
	282-283	302.41	924.09	1176.96	9065.97	79.75	101.54	114.92	11765.63
	283-284	286.54	447.53	768.38	126.76	9.60	241.60	33.70	1914.10
	284-285	514.52	423.41	329.21	26.56	11.45	647.47	49.59	2002.21
	285-286	1765.09	2060.73	729.78	96.14	78.19	3514.02	711.62	8955.58
	286-287	155.44	109.97	66.52	1.08	2.53	438.65	5.91	780.11
	287-288	200.39	107.46	59.08	2.12	3.72	483.96	4.36	861.09
	Total	3413.02	4337.43	3235.88	9358.10	185.80	5573.14	928.25	27031.63

SECTION VIII

CULTURAL RESOURCES

TENNESSEE HISTORICAL COMMISSION
DEPARTMENT OF ENVIRONMENT AND CONSERVATION
2941 LEBANON ROAD
NASHVILLE, TN 37243-0442
(615) 532-1550

December 15, 1998

Mr. Jimmy McNeil
United States Army Corps of Engineers
Clifford Davis Federal Building
Environmental Planning Division
167 North Main Street, Room B-202
Memphis, Tennessee 38103-1894

RE: COE-M, ARCHAEOLOGICAL ASSESSMENT, REELFOOT SPILLWAY AND LAKE ISOM PROJECT, UNINCORPORATED, LAKE COUNTY, TN

Dear Mr. McNeil:

At your request, our office has reviewed the above-referenced archaeological survey final report in accordance with regulations codified at 36 CFR 800 (51 FR 31115, September 2, 1986). We find that the report meets the Tennessee SHPO Standards and Guidelines For Archaeological Resource Management Studies.

If project plans are changed or archaeological remains are discovered during construction, please contact this office to determine what further action, if any, will be necessary to comply with Section 106 of the National Historic Preservation Act.

Your continued cooperation is appreciated.

Sincerely,

Herbert L. Harper

Herbert L. Harper
Executive Director and
Deputy State Historic
Preservation Officer

HLH/jmb

SECTION IX

HAZARDOUS, TOXIC, AND RADIOACTIVE WASTE

Hazardous, Toxic, and Radioactive Waste (HTRW) Clearance for Reelfoot Lake Feasibility Study

Introduction:

The Corps of Engineers, Memphis District is in the process of completing a study that has focused on water and related land resources problems in the Reelfoot Lake drainage basin (located east of the Mississippi River about 120 miles north of Memphis and 6 miles east of Tiptonville, Tennessee, in Lake and Obion Counties, Tennessee and Fulton County, Kentucky).

This study examined features for fish and wildlife habitat restoration and for flood control. Features examined include construction of an alternative spillway and dredged circulation channels that would improve water level management capabilities; thus improving the lake habitat. Other features include construction of a sediment retention basin on Reelfoot Creek to reduce sediment deposition in the Buck Basin area, construction of waterfowl management units, restoration of Shelby Lake, and construction of features to improve water level management capabilities in the Lake Isom National Wildlife Refuge.

It has been concluded that the measures are feasible and have Federal interest. The state of Tennessee, acting through the Tennessee Wildlife Resources Agency, would sponsor this project.

Purpose:

The purpose of this assessment is to gather and evaluate data regarding the existence or potential for encountering Hazardous, Toxic, or Radioactive sites within or near the project area. The assessment is intended to minimize liability of the Federal government, protect the health and safety of field personnel from undocumented HTRW sources during field investigations, and document the existence of sites that are in need of remediation.

Methodology:

Documentation is based on the analysis of: site investigations (including windshield/ground and aerial surveys); review of historical aerial photographs and topographic quadrangle maps; Federal and state regulatory agency records; and evaluation of the proposed work item and its location. This HTRW report was prepared as per the applicable guidelines established by the following publications:

1. Corps of Engineers Regulation ER 1165-2-132, Water Resources and Authorities for Hazardous, Toxic, and Radioactive Waste for Civil Works Projects, 26 June 1992;

2. Lower Mississippi Valley Regulation 1165-2-9, Water Resources Policies and Authorities for Hazardous, Toxic, and Radioactive Waste for Civil Works Projects, 14 June 1996;

3. American Society for Testing and Materials Standard (ASTM) E1527-97, Standard Practice for Environmental Site Assessments: Phase 1 Environmental Site Assessment Process.

Site Investigations:

Windshield/Ground Surveys were conducted as follows:

- 7/17/96 - Lake Isom & Sediment Basin. Hite, Vandergriff & Mills.
- 8/15/96 - Alternative Spillway and Shelby Lake. Hite & Vandergriff.
- 2/19/98 - Lake Isom. Hite
- 6/25/98 - Lake Isom & Alternative Spillway. R. Martin.

There was no evidence of existing or potential HTRW noted during the aforementioned surveys.

Aerial surveys of the entire study area were made as follows:

- Sept. 1993 - Fixed wing. Hite
- August, 1997 - Helicopter. Billingsley

There was no evidence of existing or potential HTRW noted during the aforementioned surveys.

Photographs/Maps:

Aerial photographs dated 3/28/95 for the entire study area have been examined and no indication of HTRW was observed. See Appendix for Topographical Map of Reelfoot Lake Quadrangle (Scale 1:62,500).

Site Evaluations:

Core drilling for soil samples was conducted as follows:

- August, 1995: Alternative Spillway and Lake Isom
- September, 1997: Shelby Lake and Sediment Dam.

There was no evidence of existing or potential HTRW noted concerning the aforementioned soil samples.

Agency Records:

State of Tennessee

Coordinated with the Tennessee Department of Environment and Conservation (TDEC), Division of Superfund, to obtain any information concerning existing or potential HTRW within or near the project areas. Per correspondence dated 10 July 1998 from Mr. Ron Sells, TDEC, there are no promulgated hazardous waste substance sites within a mile radius of the project areas. Per Mr. Sells, the nearest site is the Old William Heathcott Site located in Fowlkes, Dyer County, Tennessee. See appendix for official correspondence.

USEPA Region 4

Coordinated with the United States Environmental Protection Agency, Region 4, to obtain any information concerning existing or potential HTRW within or near the project areas. The Freedom of Information office completed a file search of the Comprehensive Environmental Response, Compensation and Liability Information System (CERCLIS) and the Resource Conservation Recovery Information System (RCRIS) and determined that there are three (3) potential Superfund sites near the study area. See official correspondence in Appendix.

Lake County, Tennessee	1.) Tiptonville City Dump The Levee Road Tiptonville, Tennessee 38079 EPA I.D. No. – TND 980 558 738
Obion County, Tennessee	2.) Goodyear Tire and Rubber Company Mount Zion Road Union City, Tennessee 38261 EPA I.D. No. – TND 052 110 301
	3.) Texas Gas Transmission Corporation 3 miles north on Highway 45W P.O. Box 9 Kenton, Tennessee 38233 EPA I.D. No. – TND 039 408 679

According to EPA each site has been evaluated and the risk that each site poses to human health and the environment has been determined low enough that, at present, no further remedial action is planned.

National Response Center

Coordinated with the National Response Center (NRC) to obtain information concerning releases/spills in the vicinity of the project areas. The NRC provided copies of actual number of releases and the amount of material released in Lake and Obion Counties, Tennessee, and Fulton County, Kentucky, from 1990 to present. Review of notifications did not indicate any HTRW concerns near or within the actual project areas. See official correspondence in Appendix.

Internet Search

On 4 June 1998 information was obtained from the EPA Internet Site (www.epa.gov.surf) called surf your watershed. This site contained information index of watershed indicators. In addition, information was obtained from the EPA Internet Site (www.epa.gov/superfund) for National Priorities List (NPL) Sites in Tennessee. No CERCLIS sites were located within a mile of the project areas. See appendix for information retrieved.

Conclusion

Based upon information gathered during this assessment, it is reasonable to assume that no hazardous, toxic, or radioactive wastes will be encountered within or near the project areas. However, absence of a historical file on a particular property is not meant to constitute a guarantee that activities have not occurred or the site(s) have never been impacted.

No additional HTRW investigations are recommended. This assessment indicates no apparent risk of encountering hazardous waste sites within the project area. No other analysis is required, unless new information is developed or HTRW is discovered.

PREPARER

This document was prepared by Gregg Williams, Biologist with the Memphis District Planning Division. For additional information contact the aforementioned at (901) 544-3852.

APPENDIX

Correspondence from the Tennessee Department of Environment and Conservation (dated 10 July 1998).

Correspondence from United States Environmental Protection Agency, Region 4 (Dated 20 August 1998)

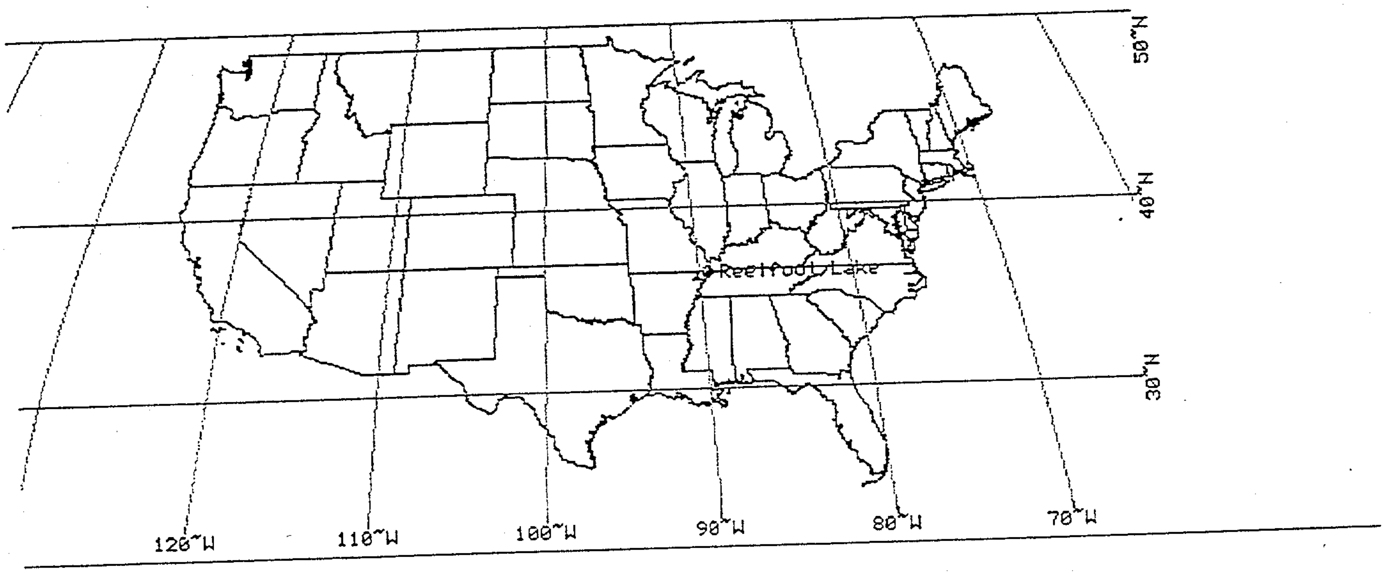
USGS

Geographic Names Information System Map Server

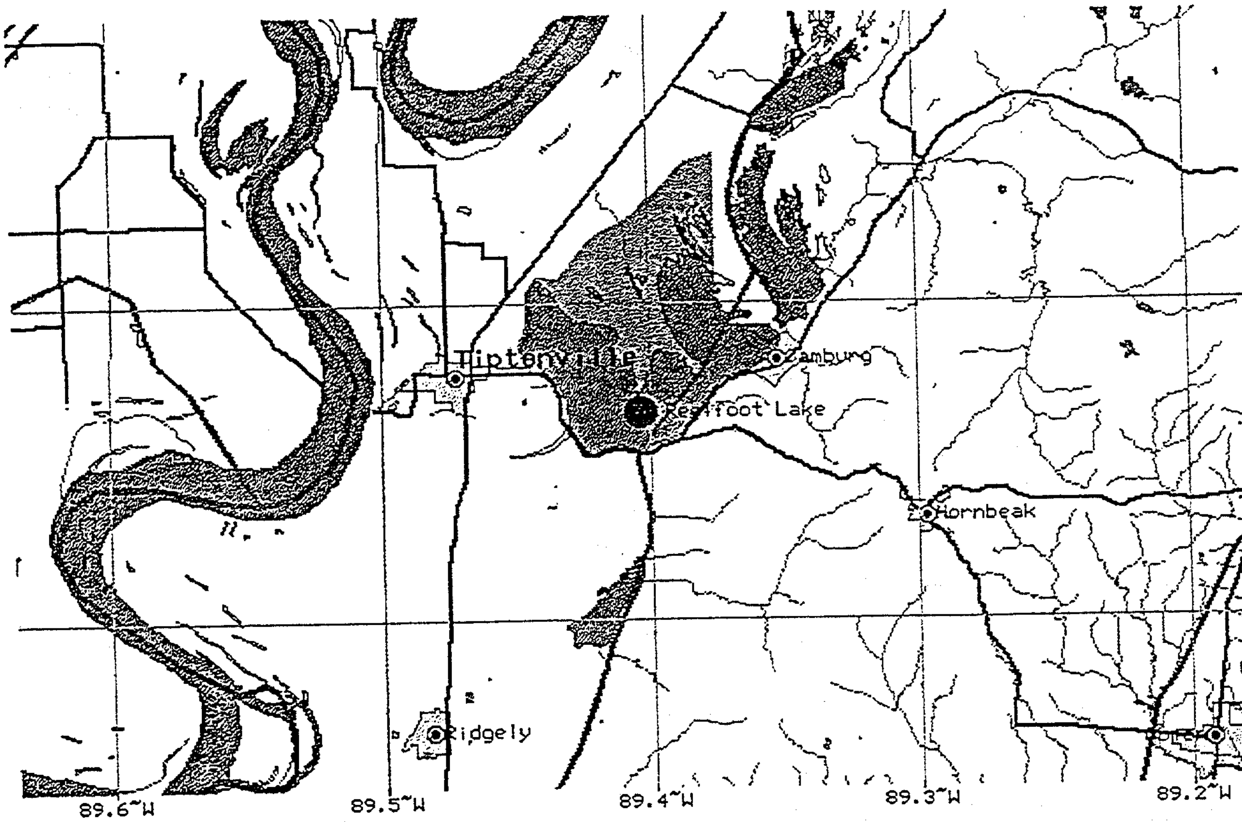
Location of Reelfoot Lake, Tennessee

The following maps are produced using a direct map request from the Tiger Map Server at the U.S. Census Bureau.

Location in United States



Location in region surrounding Reelfoot Lake, Tennessee



| Zoom In | Zoom Out |

| GNIS Query Form | Mapping Information |

URL: *http://mapping.usgs.gov/www/gnis/MapServer*
Maintainer: gnis_manager@usgs.gov
Last modified: 15:09:38 Wed 24 Sep 1997 dlg

USGS

Geographic Names Information System Query Results

REELFOOT LAKE, TENNESSEE -- LAKE

1 Feature records have been selected from GNIS.*

Feature Name:	Reelfoot Lake
Feature Type:	lake
Elevation:	283
State	**County**
Tennessee	Lake
Tennessee	Obion
Variant Name(s)	
Reel Foot Lake	
Latitude Longitude	**USGS 7.5' x 7.5' Map**
362154N 0892413W	Ridgely
362229N 0892230W	Hornbeak
362316N 0892157W	Samburg
362349N 0892304W	Tiptonville

Show Feature Location using maps produced from the U.S. Census Bureau's Tiger Map Server. If this site is busy, try this alternate map site.

Find the Watershed for this feature using the U.S. Environmental Protection Agency's Surf Your Watershed site.

| **GNIS Query Form** | **Mapping Information** |

URL: *http://mapping.usgs.gov/www/gnis/GetDetail*
Maintainer: gnis_manager@usgs.gov
Last modified: 15:09:38 Wed 24 Sep 1997 dlg ⚠ *In some cases, you may see a difference between this record count and the actual number of detail records shown below. This is due to a limitation in the design of the web query, and reflects records with an unknown map name. It was originally designed this way to increase performance on the web. We are working on a major new version of the software that will resolve this issue and add many improvements. In the meantime, your patience and understanding are appreciated. If you have questions, please contact the maintainer as shown below.

| **GNIS Query Form** | **Mapping Information** |

URL: *http://mapping.usgs.gov/www/gnis/GNISQuery*
Maintainer: gnis_manager@usgs.gov
Last modified: 15:09:38 Wed 24 Sep 1997 dlg

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Index of Watershed Indicators

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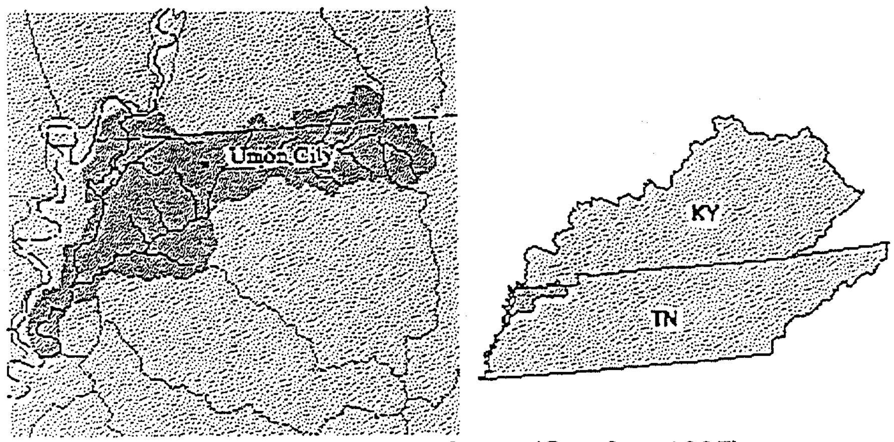
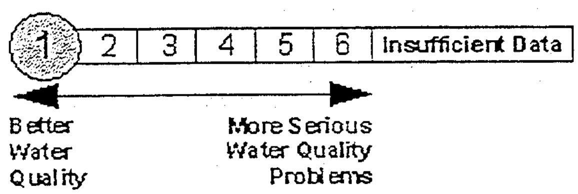
News Flashes:

Obion USGS Cataloguing Unit: 08010202



Overall Watershed Score (October 1997):

Better Water Quality - Low Vulnerability to stressors such as pollutant loadings

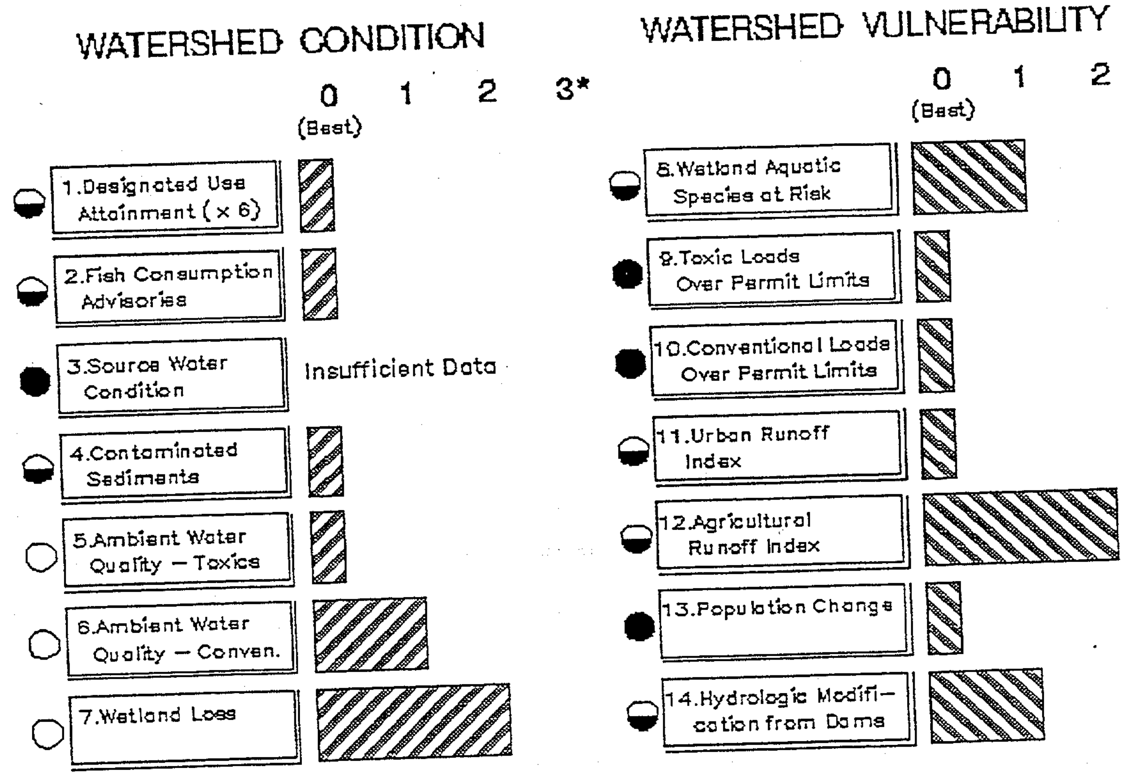


The overall IWI score for this watershed is based on indicators of current condition and future vulnerability displayed below.

The graphic below shows the individual indicators used to score the watershed. The indicators on the left are indicators of the current condition. The indicators on the right show the future vulnerability of the watershed. More information about the indicators and their meaning can be found at the IWI homepage. For more information on a particular indicator for this watershed, select a bar below.

Index of Watershed Indicators Scoresheet - Obion

Scores for:



Legend:

These symbols provide an indication of the quality of the NATIONAL data set. For any specific watershed, more or less data of adequate quality may be available.

● Data Consistent. Sufficient Data Collected.

◒ Data Somewhat Consistent. Additional Data Needed.

○ Data Needs to be Much More Consistent. Much Additional Data Needed

* Watershed condition and vulnerability scores range from zero to three. The higher numbers reflect the more serious problems depicted by the data. Category 1 is the most important. It is the only category that can receive a score as high as three, and its score is then further weighted by a factor of six before it is use to compute the Overall Watershed Score shown above.

IWI information about Places Involving this Watershed

States:
- Kentucky
- Tennessee

Counties:
- Calloway
- Fulton
- Graves
- Hickman
- Dyer
- Gibson
- Henry
- Lake
- Lauderdale
- Obion
- Weakley

Metropolitan Areas: None

Nominated American Heritage Rivers: None

Other Watersheds:

upstream
- 08010203

downstream
- 08010100

- 08010206

Revised April 22, 1998

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TRIS Facilities for:
Obion

USGS Cataloging Unit: 08010202

Facility ID	Facility Name	Facility Address
TND982135212	BROWN SHOE CO UNION CITY PLAN	2315 North Fifth Union City, TN 38261
KYD981029457	EXCEL MFG OF KENTUCKY	800 N College St Fulton, KY 42041
TND050243005	GEORGIA GULF CORP	Hwy 21 W Tiptonville, TN 38079
TND052110301	GOODYEAR TIRE & RUBBER CO#	Mt Zion And Breward Rds Union City, TN 38261
TND051386902	REELFOOT PACKING	Hwy 51 434 W Reelfoot Ave Union City, TN 38261
TND982154569	SARA LEE SAUSAGE DIV	Rt 2 Biffle Rd Newbern, TN 38059
TND041176108	STERLING PLUMBING GROUP	2000 N 5th St Union City, TN 38261
TND041176108	STERLING PLUMBING GROUP	2000 N 5th St Union City, TN 38261
KYD985093434	TURNER DAIRIES	219 E 4th St Fulton, KY 42041

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RCRIS Facilities for:
Obion

USGS Cataloging Unit: 08010202

Facility ID	Facility Name	Facility Address
TND987770310	ALLENS KEY CORNER EXXON	Reelfoot Ave Union City, TN 38261
TN0001079771	BARKER BROS TRUCKING CO	1020 S First St Union City, TN 38261
TND061658415	BLUE BELL CLEANERS & LAUNDRY	111 S Div St Union City, TN 38261
TN0001079730	CALDWELL RUSSELL H	Rrt 1 Box 99 Union City, TN 38261
TN0001066588	CALHOUN BOAT WORKS	Rural Rt 1 Tiptonville, TN 38079
TND987782323	CARQUEST AUTO PARTS OF UNION CITY	204 N 1st St Union City, TN 38261
TN0001079680	CLIFT & DUGGER FLYING SVC	Rrt 1 Troy, TN 38260
TN0001079698	CURREYS WELDING & MACHINE SHOP	222 S Third St Union City, TN 38261
TN0001079714	D&P CO INC	Rrt 4 Union City, TN 38261
TN0001079789	DAVIS & BUCKLES ANIMAL CLINIC	400 W Main St Union City, TN 38261
TN0001079748	DIXIE GUN WORKS INC	Gun Powder Ln Union City, TN 38261
KYD981029457	EXCEL MFG OF KENTUCKY	800 N College St Fulton, KY 42041
KYD981029457	EXCEL MFG OF KENTUCKY	800 N College St Fulton, KY 42041
TND052110301	GOODYEAR TIRE & RUBBER CO#	Mt Zion And Breward Union City, TN 38261
TN0001079672	KEN TENN CONST CO	Old Hwy 51 N 2 Mi Troy, TN 38260
TND981918782	KENTON CUSTOM MOLDING	320 N Main Kenton, TN 38233
TN0001066570	LAKE COUNTY BANNER	200 N/S Church St

TN0001066570	LAKE COUNTY BANNER	Tiptonville, TN 38079
TN0001066596	LAKE COUNTY NURSING HOME CORP	Reelfoot Dr Tiptonville, TN 38079
TN0001079706	LANZER H A CO	201-203-207 S First S Union City, TN 38261
KYD981469349	MIDWAY FABRICATING	801 W Highland Dr Fulton, KY 42041
TND007049265	NANNEY BODY & HYDRAULIC EQUIP. CO INC	360 Thompson St Woodland Mills, TN 3
TND982156259	OBION COUNTY EDUCATION DEPT	One Blk From 4 Way Kenton, TN 38233
TN0001044189	OLIVER OFFICE EQUIPMENT CO	503 S First St Union City, TN 38261
TN0001044189	OLIVER OFFICE EQUIPMENT CO	503 S First St Union City, TN 38261
TN0001079763	POLANDS	Rrt 4 Union City, TN 38261
TND987788593	R S I, INC	Rt 1 Hwy 641 S Puryear, TN 38251
KYD088428248	SHERWIN WILLIAMS CO	300 State Line St W Fulton, KY 42041
TND086021482	SHERWIN WILLIAMS CO	106 N First St Union City, TN 38261
TND981477375	SOUTHEASTERN ATM SVC INC	Rt 1 Box 216 Tiptonville, TN 38079
TND982172363	SOUTHERN MACHINE REPAIR	Airport Rd Union City, TN 38261
TND097909790	STA-RITE IND INC	Char-Gale Dr Union City, TN 38261
TND041176108	STERLING PLUMBING GROUP	2000 N 5th St Union City, TN 38261
TND981755739	SUPERIOR ENTERPRISES INC	915 N First Union City, TN 38261
TN0001079722	TAYLOR JAMES D	Rrt 3 Union City, TN 38261
TND981479298	THOMAS PLATING,INC.	202 Gin St South Fulton, TN 382
TND982154858	UNION CITY FORD-LINC.MERC. INC	Hwy 51 S Union City, TN 38261
TN0001079755	US GYPSUM IND	N 5th St Union City, TN 38261
TN0001079227	VULCAN CORP	505 N Poplar St Kenton, TN 38233
TND987774346	WARTERFIELD GRAIN CO	315 Martin Luther Kir Union City, TN 38[illegible]
TND006387880	WAYMATIC INC	5354 Ken Tenn Rd

TND000387880	WATMATIC INC	South Fulton, TN 382
TN0001044171	WYLIE BARNES TRUCKING CO	Box 111 Troy, TN 38260

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USGS Cataloging Unit: 08010202

No CERCLIS Facility Data found in Envirofacts for USGS Cataloging Unit: 08010202

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PCS Facilities for:
Obion

USGS Cataloging Unit: 08010202

Facility ID	Facility Name	Facility Address
KYD985103639	B & J SANITATION LDFL	Hwy 1099 Hickman, KY 42050
TND987768033	CITY OF NEWBERN	Hwy 77 Bypass Newbern, TN 38059
KYD985102524	FULTON STP	Industrial Pk Rd Fulton, KY 42041
TND052110301	GOODYEAR TIRE & RUBBER CO#	Mt Zion And Breward Rds Union City, TN 38261
KY0001096759	GRADDY'S UNION 76 SVC STA	206 W. Stateline Rd Fulton, KY 42041
TND049114895	GRIFFIN IND INC	Po Box 727 Union City, TN 38261
KYD985102516	ILLINOIS CENTRAL RAILROAD	Hwys 45 & 51 Bypass Fulton, KY 42041
KY0000498212	KY-TN CLAY CO-COLLIER #5	G. Gary Childress P. O. Box 6002 Mayfield, KY 42066
TN0001599125	OBION LAGOON	Obion County Obion Co. Jfo, TN 38240
TN0000472217	SOUTH FULTON STP	134 Broadway Obion Co. Jbo, TN 38257
TN0001725043	TROY OXIDATION LAGOON	105 Westbrook St Troy, TN 38260
KYD985093434	TURNER DAIRIES	219 E 4th St Fulton, KY 42041
TND000870659	UNION CITY STP	Po Box 9 Obion County, TN 38261

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Rivers and Streams in HUC# 08010202

- Biggs Creek
- Cane Creek
- Clover Creek
- Cypress Creek
- Davidson Creek
- Forked Deer River
- Harris Fk
- Mississippi River
- N Reelfoot Creek
- Obion River
- Powell Creek
- Reeds Creek
- Reelfoot Creek
- Reelfoot Lake
- Richland Creek
- Running Reelfoot Bayou
- Running Slough Bayou
- S Reelfoot Creek
- Walnut Creek

USGS science for a changing world

1990 Water Use for 08010202 - Obion

Category	Units	Value
Totals		
Ground-water withdrawals, fresh	Mgal/d	9.48
Ground-water withdrawals, saline	Mgal/d	0.00
Withdrawals, ground water	Mgal/d	9.48
Surface-water withdrawals, fresh	Mgal/d	0.27
Surface-water withdrawals, saline	Mgal/d	0.00
Surface-water withdrawals	Mgal/d	0.27
Fresh-water withdrawals	Mgal/d	9.75
Saline withdrawals	Mgal/d	0.00
Withdrawals	Mgal/d	9.75
Reclaimed wastwater	Mgal/d	0.00
Fresh consumptive use	Mgal/d	1.98
Saline consumptive use	Mgal/d	0.00
Consumptive use, total	Mgal/d	1.98
Conveyance losses	Mgal/d	0.00
Population		
Total population of the area	thousands	54.67
Public Supply		
Population served by ground water	thousands	34.93
Population served by surface water	thousands	0.00
Total Population served	Mgal/d	34.93
Ground-water withdrawals, fresh	Mgal/d	5.09
Surface-water withdrawals, fresh	Mgal/d	0.00
Total withdrawals, fresh	Mgal/d	5.09
Ground-water withdrawals, saline	Mgal/d	0.00
Surface-water withdrawals, saline	Mgal/d	0.00
Total withdrawals, saline	Mgal/d	0.00
Total withdrawals, total	Mgal/d	5.09
Water deliveries, public use and losses	Mgal/d	0.47

Water deliveries, total deliveries	Mgal/d	4.62
Per-capita use	gal/d	145.72
Number of facilities	--	12.00
Commercial		
Ground-water withdrawals, fresh	Mgal/d	0.02
Surface-water withdrawals, fresh	Mgal/d	0.00
Total withdrawals	Mgal/d	0.02
Deliveries from public suppliers	Mgal/d	1.19
Total withdrawals + deliveries	Mgal/d	1.21
Consumptive use, total	Mgal/d	0.10
Domestic		
Self-supplied population	Mgal/d	19.74
Self-supplied ground-water withdrawals, fresh	Mgal/d	1.28
Self-supplied surface-water withdrawals, fresh	Mgal/d	0.00
Total self-supplied withdrawals	Mgal/d	1.28
Per-capita use, self-supplied	Mgal/d	64.84
Public-supplied population	Mgal/d	34.93
Deliveries from public suppliers	Mgal/d	2.51
Per-capita use, public-supplied	gal/d	71.86
Total withdrawals plus deliveries	Mgal/d	3.79
Consumptive use, total	Mgal/d	0.39
Industrial		
Self-supplied ground-water withdrawals, fresh	Mgal/d	1.67
Self-supplied ground-water withdrawals, saline	Mgal/d	0.00
Total self-supplied withdrawals, ground water	Mgal/d	1.67
Self-supplied surface-water withdrawals, fresh	Mgal/d	0.00
Self-supplied surface-water withdrawals, saline	Mgal/d	0.00
Total self-supplied withdrawals, surface water	Mgal/d	0.00
Total self-supplied withdrawals, fresh	Mgal/d	1.67
Total self-supplied withdrawals, saline	Mgal/d	0.00
Total self-supplied withdrawals	Mgal/d	1.67
Reclaimed wastewater	Mgal/d	0.00
Deliveries from public suppliers	Mgal/d	0.92
Total withdrawals plus deliveries	Mgal/d	2.59
Consumptive use, fresh	Mgal/d	0.20
Consumptive use, saline	Mgal/d	0.00
Consumptive use, total	Mgal/d	0.20
Number of facilities	--	2.00
Total thermoelectric power use		
Ground-water withdrawals, fresh	Mgal/d	0.00
Surface-water withdrawals, fresh	Mgal/d	0.00
Surface-water withdrawals, saline	Mgal/d	0.00
Tot withdrawals, surface water	Mgal/d	0.00

Total withdrawals, fresh	Mgal/d	0.00
Total withdrawals	Mgal/d	0.00
Deliveries from public suppliers	Mgal/d	0.00
Total withdrawals plus deliveries	Mgal/d	0.00
Consumptive use, fresh	Mgal/d	0.00
Consumptive use, saline	Mgal/d	0.00
Consumptive use, total	Mgal/d	0.00
Power generation	gigawatt hours/year	0.00
Number of facilities	--	0.00
Fossil-fuel thermoelectric power use		
Ground-water withdrawals, fresh	Mgal/d	0.00
Surface-water withdrawals, fresh	Mgal/d	0.00
Surface-water withdrawals, saline	Mgal/d	0.00
Total withdrawals, surface water	Mgal/d	0.00
Total withdrawals, fresh	Mgal/d	0.00
Total withdrawals	Mgal/d	0.00
Deliveries from public suppliers	Mgal/d	0.00
Total withdrawals plus deliveries	Mgal/d	0.00
Consumptive use, fresh	Mgal/d	0.00
Consumptive use, saline	Mgal/d	0.00
Consumptive use, total	Mgal/d	0.00
Power generation	gigawatt hours/year	0.00
Number of facilities	--	0.00
Geothermal thermoelectric power use		
Ground-water withdrawals, fresh	Mgal/d	0.00
Ground-water withdrawals, saline	Mgal/d	0.00
Total withdrawals	Mgal/d	0.00
Consumptive use, fresh	Mgal/d	0.00
Consumptive use, saline	Mgal/d	0.00
Power generation	gigawatt hours/year	0.00
Number of facilities	--	0.00
Nuclear thermoelectric power use		
Ground-water withdrawals, fresh	Mgal/d	0.00
Surface-water withdrawals, fresh	Mgal/d	0.00
Surface-water withdrawals, saline	Mgal/d	0.00
Total withdrawals, surface water	Mgal/d	0.00
Total withdrawals, fresh	Mgal/d	0.00
Total withdrawals	Mgal/d	0.00
Deliveries from public suppliers	Mgal/d	0.00
Total withdrawals plus deliveries	Mgal/d	0.00
Consumptive use, fresh	Mgal/d	0.00
Consumptive use, saline	Mgal/d	0.00
Consumptive use, total	Mgal/d	0.00
Power generation	gigawatt hours/year	0.00

Number of facilities	--	0.00
Mining use	Mgal/d	0.00
Ground-water withdrawals, fresh	Mgal/d	0.00
Ground-water withdrawals, saline	Mgal/d	0.00
Total withdrawals, ground water	Mgal/d	0.00
Surface-water withdrawals, fresh	Mgal/d	0.00
Surface-water withdrawals, saline	Mgal/d	0.00
Total withdrawals, surface water	Mgal/d	0.00
Total withdrawals, fresh	Mgal/d	0.00
Total withdrawals, saline	Mgal/d	0.00
Total withdrawals	Mgal/d	0.00
Consumptive use, fresh	Mgal/d	0.00
Consumptive use, saline	Mgal/d	0.00
Consumptive use, total		
Livestock (stock) use	Mgal/d	0.46
Total withdrawals, ground water	Mgal/d	0.19
Total withdrawals, surface water	Mgal/d	0.65
Total withdrawals	Mgal/d	0.65
Consumptive use, total		
Livestock (animal specialties) use	Mgal/d	0.00
Total withdrawals, ground water	Mgal/d	0.00
Total withdrawals, surface water	Mgal/d	0.00
Total withdrawals	Mgal/d	0.00
Consumptive use, total		
Total livestock use	Mgal/d	0.46
Ground water	Mgal/d	0.19
Surface water	Mgal/d	0.65
Total withdrawals	Mgal/d	0.65
Consumptive use, total		
Irrigation use	Mgal/d	0.96
Ground-water withdrawals, fresh	Mgal/d	0.08
Surface-water withdrawals, fresh	Mgal/d	0.00
Reclaimed wastewater	Mgal/d	1.04
Total withdrawals, fresh	thousand acres	3.22
Irrigated land, sprayed	thousand acres	0.02
Irrigated land, flooded	thousand acres	3.24
Irrigated land, total	Mgal/d	0.00
Conveyance loss	Mgal/d	0.64
Consumptive use, total		
Hydroelectric power use	Mgal/d	0.00
Ins( )am water use		

Power generation, total	gigawatt hours/year	0.00
Number of facilities	--	0.00
Wastewater treatment		
Number of public wastewater facilities	--	5.00
Number of other facilities	--	3.00
Number of wastewater facilities, total	--	8.00
Returns by public wastewater facilities	Mgal/d	5.47
Reclaimed wastewater released by public wastewater facilities	Mgal/d	0.00
Reservoir evaporation		
Reservoir evaporation	thousand acre-feet	70357.00
Reservoir surface area	thousand acres	48.74

Mgal/d = million gallons per day

This is only a summary of the water-use data USGS has available!
The USGS Water-Use pages have graphics and reports.
You also can download data sets in spreadsheet format and analyze them yourself.

| Water | Water Use | EPA's Surf 08010202 |

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Last update: 10:4:55 Thu 4Jun98
URL: http://water.usgs.gov/

U.S. Department of the Interior
U.S. Geological Survey

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AIRS/AFS Facilities for: Obion

USGS Cataloging Unit: 08010202

Facility ID	Facility Name	Facility Address
KY0000955294	BROWDER GRAIN ELEVATOR	112 E State Line Fulton, KY 42041
KYD981029457	EXCEL MFG OF KENTUCKY	800 N College St Fulton, KY 42041
TND980313290	FARMERS GRAIN CO	5th & Grove St Union City, TN 38261
TND047344452	FORD CONST CO	St Hwy 21 Troy, TN 38260
TND004787768	FORD CONSTRUCTION CO	Martin Hwy East 22 3 Mi Frm Cty Union City, TN 38261
TND050243005	GEORGIA GULF CORP	Hwy 21 W Tiptonville, TN 38079
TN0001228162	JIMMY DEAN FOODS	2000 Biffle Rd Newburn, TN 38059
TND034859967	OBION GRAIN CO INC	Palstine & 6th Street Obion, TN 38240
TND051386902	REELFOOT PACKING	Hwy 51 434 W Reelfoot Ave Union City, TN 38261
TND041176108	STERLING PLUMBING GROUP	2000 N 5th St Union City, TN 38261
TND086016912	SUPERIOR FIREPLACE	503 E Reelfoot Union City, TN 38261
TND987786712	TRI COUNTY ALFALFA	Hwy 78 S Tiptonville, TN 38079
TND980316715	WATERFIELD GRAIN CO	315 W Grove Union City, TN 38261
TND006387880	WAYMATIC INC	5354 Ken Tenn Rd South Fulton, TN 38257
TND007025596	WEST TENN SOYA MILL	Hwy 78 S Tiptonville, TN 38079

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SDWIS Facilities for:
Obion

USGS Cataloging Unit: 08010202

Facility ID	Facility Name	Facility Address
TN0000901	Cloar'S Trailer Park	Obion, TN
TN0000220	Elbridge Water Association	Obion, TN
KY0380193	Hickman Water Department	Fulton, KY
TN0000311	Hornbeak U D	Obion, TN
TN0000935	Mason Hall Development Corp.	Obion, TN
TN0000496	Newbern Water Dept	Dyer, TN
TN0000524	Obion Water Dept	Obion, TN
TN0000575	Reelfoot Utility District	Lake, TN
KY0420538	S Graves Wd- Pilot Oak	Graves, KY
TN0000648	South Fulton Water System	Obion, TN
TN0000711	Trimble Water System	Dyer, TN
TN0000712	Troy Water System	Obion, TN
TN0000720	Union City Water Dept	Obion, TN

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June 04, 1998 @10:02

Safe Drinking Water Violation Report for OBION WATER DEPT

This report was created on 04-JUN-1998
Results are based on data extracted on 03-APR-1998

Violations

The following report lists all Violations reported to EPA for this water system in the last 10 years.

Violation Number	Fiscal Year	ID Source	State ID	Period Beginning Date	Period Ending Date	Type of Violation	Contaminant	Maximum Contaminant Level	Contaminant Level Found
2525145	95	---	00228	01-JAN-1995	31-DEC-1995	Monitoring, Regular	Nitrate	10	---
2525146	95	---	04137	01-JAN-1995	31-DEC-1995	Monitoring, Regular	Asbestos	7000000	---
2404180	94	---	02065	01-JAN-1994	31-JAN-1994	MCL, Monthly (TCR)	Coliform (TCR)	---	---
2594468	94	---	03043	01-JAN-1994	30-JUN-1994	Follow-up and Routine Tap Sampling	Lead & Copper Rule	---	---
2404182	89	---	00407	01-MAR-1989	31-MAR-1989	Monitoring, Regular	Coliform (Pre-TCR)	---	---
2404181	89	---	00053	01-NOV-1988	30-NOV-1988	Monitoring, Regular	Coliform (Pre-TCR)	---	---

Enforcement Actions

The following report lists all Enforcement Actions reported to EPA that have been taken against this water system in the last 10 years.

Fiscal Year	ID Source	State ID	Action Taken	Enforcement Action Date	Violation Number

96	---	00425	St Violation/Reminder Notice	04-APR-1996	2525145
96	---	00426	St Public Notif requested	04-APR-1996	2525145
96	---	01036	St Violation/Reminder Notice	09-FEB-1996	2525146
96	---	01091	St Public Notif requested	09-FEB-1996	2525146
95	---	09923	St Compliance achieved	12-DEC-1994	2594468
95	---	04865	St Violation/Reminder Notice	21-NOV-1994	2594468
94	---	02711	St Violation/Reminder Notice	28-FEB-1994	2404180
94	---	02712	St Public Notif requested	28-FEB-1994	2404180
89	E	00012	St Violation/Reminder Notice	26-JUN-1990	2404181
89	E	00012	St Violation/Reminder Notice	26-JUN-1990	2404182
89	E	00011	St Formal NOV issued	26-JUN-1990	2404181
89	E	00011	St Formal NOV issued	26-JUN-1990	2404182
88	E	00001	St Violation/Reminder Notice	30-SEP-1988	2404183

Need more help? EPA has prepared fact sheets about various regulated drinking water contaminants. For more information on drinking water, you may also go to EPA's Office of Ground Water and Drinking Water Home Page.

Additional Information

In 1996, based on information reported to EPA by the states, 1.5 percent of all systems violated a treatment technique, 7.5 percent of all systems violated an MCL, and 21.2 percent of all systems had a reporting and monitoring violation.

Safe Drinking Water Violation Report for REELFOOT UTILITY DISTRICT

This report was created on 04-JUN-1998
Results are based on data extracted on 03-APR-1998

Violations

The following report lists all Violations reported to EPA for this water system in the last 10 years.

Violation Number	Fiscal Year	ID Source	State ID	Period Beginning Date	Period Ending Date	Type of Violation	Contaminant	Maximum Contaminant Level	Contaminant Level Found
2405051	91	---	01384	01-DEC-1990	31-DEC-1990	Monitoring, Routine Major (TCR)	Coliform (TCR)	---	---

Enforcement Actions

No Enforcement Actions Found. EPA has no record of any Enforcement Actions reported for this water system in the last ten years.

Need more help? EPA has prepared fact sheets about various regulated drinking water contaminants. For more information on drinking water, you may also go to EPA's Office of Ground Water and Drinking Water Home Page.

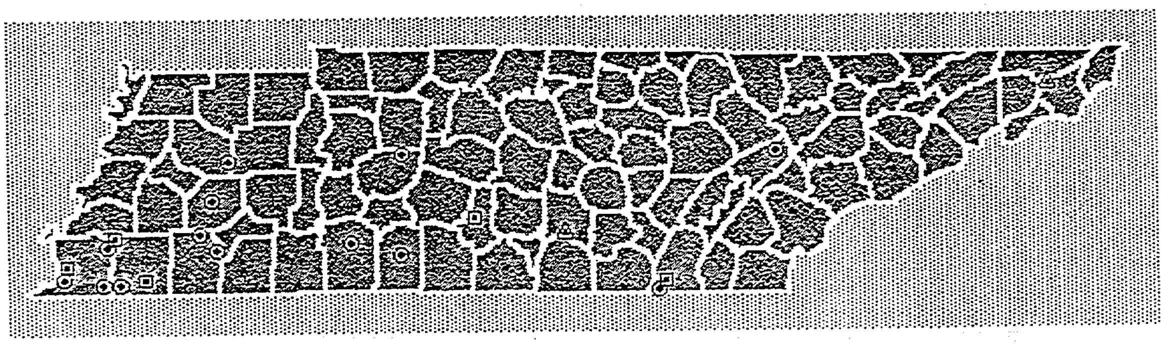
Additional Information

In 1996, based on information reported to EPA by the states, 1.5 percent of all systems violated a treatment technique, 7.5 percent of all systems violated an MCL, and 21.2 percent of all systems had a reporting and monitoring violation.

EPA United States Environmental Protection Agency — *Superfund*

National Priorities List (NPL) Sites in Tennessee

Click on a county to see a list of sites that are located in that county or click on a site for more information about that site. To assist you in finding the site or county of interest, the name of the site and county will appear at the bottom of the browser when you place the mouse pointer over that area on the map.



- Finalized Sites: 18
- Proposed Sites: 20
- Construction Completed Sites: 8
- Deleted Sites: 5
- Partially Deleted Sites: 0

Return to US Map
Basic Site Query
Advanced Site Query

[EPA Home | OSWER Home | Superfund Home | Site Information Home | Contact Us]

URL: http://www.epa.gov/superfund/oerr/impm/products/npl/tn.htm
Last Updated March 5, 1998

NPL Sites in the State of Tennessee

by County

Site Name	CERCLIS ID	Proposed Listing Date	Final Listing Date	Construction Completion Date	Partial Deletion Date	Deletion Date
ANDERSON, ROANE COUNTY						
Oak Ridge Reservation	TN1890090003	7/14/89	11/21/89			

(USDOE)						
CARROLL COUNTY						
Milan Army Ammunition Plant	TN0210020582	10/15/84	7/22/87			
CARTER COUNTY						
American Bemberg Plant	TND980558563	9/25/97				
COFFEE/FRANKLIN COUNTY						
Arnold Engineering Develop. Ctr. (USAF)	TN8570024044	8/23/94				
FAYETTE COUNTY						
Chemet Co.	TND987768546	1/18/94	5/31/94	5/15/96		10/09/96
Gallaway Pits	TND980728992	12/30/82	9/08/83	7/18/95		4/29/96
Ross Metals Inc	TND096070396	12/23/96	4/01/97			
HAMILTON COUNTY						
Amnicola Dump	TND980729172	12/30/82	9/08/83	9/28/93		4/30/96
Tennessee Products	TND071516959	1/18/94	9/29/95			
HARDEMAN COUNTY						
ICG Iselin Railroad Yard	TND987767795	5/10/93	12/16/94			
Velsicol Chemical Corp (Hardeman County)	TND980559033	12/30/82	9/08/83			
HICKMAN COUNTY						
Wrigley Charcoal Plant	TND980844781	6/24/88	3/31/89			
LAWRENCE COUNTY						
Murray-Ohio Dump	TND980728836	12/30/82	9/08/83			
MADISON COUNTY						
American Creosote Works. (Jackson Plant)	TND007018799	10/15/84	6/10/86			
MARSHALL COUNTY						
Lewisburg Dump	TND980729115	12/30/82	9/08/83	9/28/93		2/21/96
SHELBY COUNTY						
Arlington Blending & Packaging	TND980468557	1/22/87	7/22/87	7/24/97		
Carrier Air Conditioning Co.	TND044062222	6/24/88	2/21/90	10/31/95		
Memphis Defense Depot (DLA)	TN4210020570	2/07/92	10/14/92			
North Hollywood Dump	TND980558894	12/30/82	9/08/83	7/01/97		12/31/97
WAYNE COUNTY						
Mallory Capacitor						

Mallory Capacitor Co.	TND075453688	1/22/87	10/04/89	9/24/96		

July 8, 1998

Planning Division
Environmental Analysis Branch

Mr. Ron Sells
Tennessee Department of Environment and Conservation
Division of Superfund
362 Carriage House Drive
Jackson, Tennessee 38305

Dear Mr. Sells:

We are in the process of completing a study that has focused on water and related land resources problems in the Reelfoot Lake drainage basin (located east of the Mississippi River about 120 miles north of Memphis and 6 miles east of Tiptonville, Tennessee, in Lake and Obion Counties, Tennessee and Fulton County, Kentucky).

This study examined features for fish and wildlife habitat restoration and for flood control. Features examined include construction of an alternative spillway and dredged circulation channels that would improve water level management capabilities; thus improving the lake habitat. Other features include construction of a sediment retention basin on Reelfoot Creek to reduce sediment deposition in the Buck Basin area, construction of waterfowl management units, restoration of Shelby Lake, and construction of features to improve water level management capabilities in the Lake Isom National Wildlife Refuge.

It has been concluded that the measures are feasible and have Federal interest. The state of Tennessee, acting through the Tennessee Wildlife Resources Agency, would sponsor this project. We are requesting that your office send the Memphis District, Environmental Analysis Branch, a list of any potential or confirmed Hazardous, Toxic, or Radioactive sites within the project area. Enclosed is a copy of the Project Location Map. If you have any questions concerning this submittal, please contact Gregg Williams at (901) 544-3852.

Sincerely,

Dave Reece
Chief, Environmental Analysis Branch

Enclosures

STATE OF TENNESSEE
DEPARTMENT OF ENVIRONMENT AND CONSERVATION
JACKSON ENVIRONMENTAL FIELD OFFICE
362 CARRIAGE HOUSE DRIVE
JACKSON, TENNESSEE 38305-2222

July 10, 1998

Mr. Dave Reece, Chief
Environmental Analysis Branch
Memphis Corp of Engineers
167 North Main Street B-202
Memphis, Tennessee 38103-1894

Ref: 48-000 Possible Hazardous Sites in Lake and Obion Counties

Mr. Reece:

In regard to your July 8, 1998 letter requesting the location of possible hazardous sites in the areas delineated on the map, I have the found that there are no State or Federal promulgated hazardous substance sites in the area. In fact, the nearest site is the Old William Heathcott Site located in Fowlkes, Dyer County, Tennessee.

If I may be of further assistance, please contact me at (901) 661-6204.

Sincerely,

Ron Sells, Manager
Division of Superfund
Jackson Environmental Assistance Center

c: TDSF-JEAC
TDSF-NCO

3 AUG 98 (1605-1610)
PER / OTIS JOHNSON, EPA R
NO INFORMATION CONCERN
HTRW FOUND WITHIN OF
STUDY AREA. MR. JOHN
STATED THAT HE WOULD
A FAX NOTIFYING HIS
FINDINGS.
G.W.

July 8, 1998

Planning Division
Environmental Analysis Branch

Mr. Richard D. Green
Director of Waste Management Division
United States Environmental Protection Agency
Region 4
Atlanta Federal Center
100 Alabama Street, S.W.
Atlanta, Georgia 30303-3104

Dear Mr. Green:

We are in the process of completing a study that has focused on water and related land resources problems in the Reelfoot Lake drainage basin (located east of the Mississippi River about 120 miles north of Memphis and 6 miles east of Tiptonville, Tennessee, in Lake and Obion Counties, Tennessee and Fulton County, Kentucky).

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Sincerely,

Dave Reece
Chief, Environmental Analysis Branch

Enclosures

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 4
ATLANTA FEDERAL CENTER
61 FORSYTH STREET, SW
ATLANTA, GEORGIA 30303-8909

AUG 20 1998

4WD-RPB

Mr. Dave Reece, Chief
Environmental Analysis Branch
Planning Division
Department of the Army
Memphis District Corps of Engineers
167 North Main Street B-202
Memphis, Tennessee 38103-1894

SUBJ: Request for Records

Dear Mr. Reece:

I am writing this letter to acknowledge receipt of your letter dated July 15, 1998, and to respond on behalf of Richard Green, Director of EPA, R4's, Waste Management Division. In your letter you asked Mr. Green to send you a list of any potential or confirmed hazardous, toxic, or radioactive sites in the Reelfoot Lake drainage basin of northwest Tennessee. Otis Johnson of my staff has carefully searched R4's hazardous waste management databases (RCRIS and CERCLIS) and has determined that there are three (3) potential Superfund sites near the study area you defined. The three potential sites are:

Lake County, Tennessee:

(1) Tiptonville City Dump
The Levee Road
Tiptonville, Tennessee 38079
EPA I.D. No. - TND 980 558 738

Obion County, Tennessee:

(2) Goodyear Tire and Rubber Company
Mount Zion Road
Union City, Tennessee 38261
EPA I.D. No. - TND 052 110 301

(3) Texas Gas Transmission Corporation
3 miles north on Highway 45W
P.O. Box 9
Kenton, Tennessee 38233
EPA I.D. No. - TND 039 408 679

The risk each site poses to human health and the environment has been evaluated and determined to be low enough that, at present, no further remedial action is planned.

If you have any questions regarding this reply, please feel free to direct them to Mr. Johnson at (404) 562-8481.

Sincerely,

Narindar M. Kumar, Chief
RCRA Programs Branch
Waste Management division

cc: Tom Tiesler, Director
Tennessee Division of Solid Waste Management

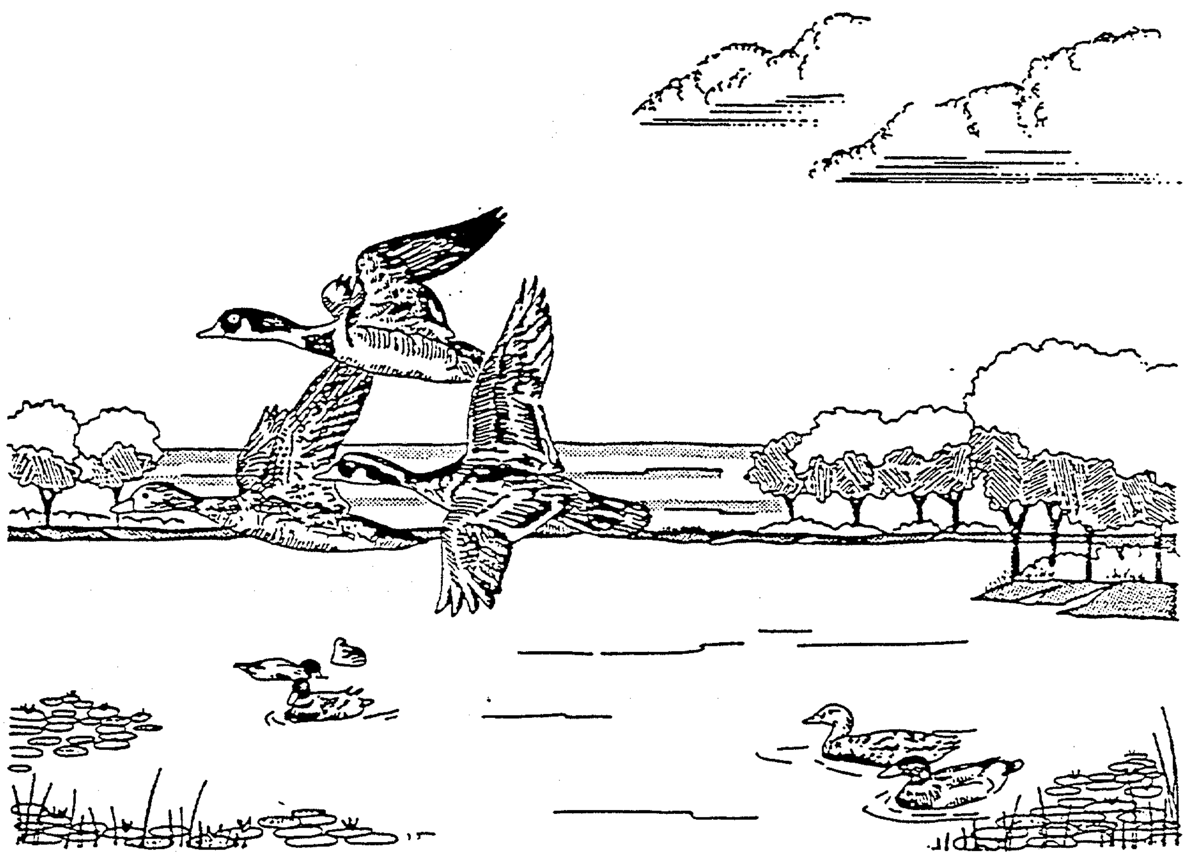
cc: James Haynes, Director
Tennessee Division of Superfund

SECTION X

WATER MANAGEMENT WORKSHOP

NEC-87/04
DECEMBER 1986

WATER MANAGEMENT ALTERNATIVES AT REELFOOT LAKE: RESULTS OF A WORKSHOP



Fish and Wildlife Service

U.S. Department of the Interior

NEC-87/04
December 1986

WATER MANAGEMENT ALTERNATIVES AT REELFOOT LAKE: RESULTS OF A WORKSHOP

by

James Roelle
Adrian Farmer
David Hamilton
Samuel Williamson
National Ecology Center
U.S. Fish and Wildlife Service
2627 Redwing Road
Fort Collins, CO 80526-2899

and

William Seitz
Office of Information Transfer
U.S. Fish and Wildlife Service
1025 Pennock
Fort Collins, CO 80524

Results of a Workshop Sponsored by
Region 4
and
Reelfoot National Wildlife Refuge
U.S. Fish and Wildlife Service

National Ecology Center
Division of Wildlife and Contaminant Research
Fish and Wildlife Service
U.S. Department of the Interior
Washington, DC 20240

DISCLAIMER

This report is a synthesis by the authors of the results of a workshop. As such, the opinions and recommendations expressed are those of the authors and do not necessarily reflect the views of the U.S. Fish and Wildlife Service nor of any of the other agencies represented by the workshop participants. Similarly, mention of trade names does not constitute endorsement or recommendation for use by the Federal Government or by any other agency.

This report should be cited as:

Roelle, J., A. Farmer, D. Hamilton, S. Williamson, and W. Seitz. 1986. Water management alternatives at Reelfoot Lake: results of a workshop. U.S. Fish Wildl. Serv., National Ecology Center, Fort Collins, CO. NEC-87/04. 104 pp.

EXECUTIVE SUMMARY

On August 24-29, 1986, the U.S. Fish and Wildlife Service sponsored a workshop concerning resource management issues at Reelfoot Lake, Tennessee. The objectives of the workshop were to:

(1) develop alternative water management strategies for Reelfoot Lake; and

(2) assess the probable consequences of those alternatives on the resources at Reelfoot.

The workshop was attended by approximately 40 scientists and managers familiar with Reelfoot Lake or with similar ecological situations. The authors of this report facilitated the workshop sessions and recorded discussions and conclusions.

Following a 1-day field trip to Reelfoot Lake, the workshop convened in Memphis, Tennessee. Participants were divided into five working groups (hydrology and sedimentation, aquatic ecology, fish, nonaquatic vegetation, and wildlife) representing general resources of concern. Each of these workgroups was first asked to:

(1) identify the resources that they would consider and the criteria that would be used to evaluate the impacts of alternative management strategies;

(2) define what they believed to be appropriate objectives for those resources; and

(3) develop a preferred management strategy for achieving those objectives.

Following these discussions, the authors of this report and interested participants met to consolidate these preferred strategies and several management alternatives proposed elsewhere into a set for all of the workgroups to use in analyzing impacts. The six alternatives chosen were:

(1) continuation of current management (i.e., maintaining lake level as close as possible to 282.2 ft msl and continuing present forest and wildlife management programs);

(2) a drawdown to expose about 50% of the lake bed to drying, in an effort to consolidate soft sediments and improve water quality and the fishery;

(3) a drawdown in combination with excavation of sediments from certain critical areas;

(4) a watershed treatment alternative designed to reduce sediment inputs to the lake;

(5) a water fluctuation alternative, which would allow lake levels to rise and fall over a greater range in response to the natural moisture regime; and

(6) an alternative involving implementation of a State law recently enacted by the Tennessee legislature (i.e., using the existing control structure to release water only when the lake surface elevation exceeds 283.6 ft msl).

In addition, the Hydrology and Sedimentation Workgroup briefly considered dredging and flushing as ways of dealing with in-lake sediments and nutrients.

There was general agreement among workshop participants that control of sediment input and deposition is the ultimate key to prolonging the life of Reelfoot Lake. Unless this problem is solved, any beneficial effects of other management actions will be temporary at best. As formulated at the workshop, the watershed treatment alternative, which was designed to control sediment input to the lake, consisted of three activities:

(1) acquisition, through fee title or easement, and revegetation of highly erodible areas in the hills east of the lake;

(2) construction of a large sediment retention basin near the mouth of Reelfoot Creek; and

(3) acquisition of the floodplain of Reelfoot Creek below the sediment retention basin and restoration of a natural, meandering, vegetated stream course.

There was nearly unanimous agreement that this would be a highly desirable alternative. Acquisition and revegetation of highly erodible lands would do much to control sediment at its source. Other mechanisms for accomplishing this (e.g., zoning restrictions, continuation of current economic incentives to farmers to institute better soil conservation practices) were also discussed, but were generally judged to be inferior to acquisition. In particular, the current incentive program for farmers has apparently been relatively ineffective.

A large sediment retention basin would probably be effective in trapping any sediment load that still remained after implementing an acquisition program. The feasibility of building such a structure could not be adequately evaluated with information available at the workshop; however, at least several participants thought additional study of this possibility would be warranted. Depending on the success of other programs to control sediment at its source, such a structure might not even be necessary.

Acquisition and restoration of a natural stream course on the floodplain of Reelfoot Creek would limit the amount of sediment picked up by the stream before reaching Reelfoot Lake. This was viewed as a critical aspect of any sediment control alternative; the effectiveness of the sediment control structures already constructed east of the lake has been questioned because the streams tend to regain a high sediment load in channelized downstream reaches.

As formulated at the workshop, the watershed treatment alternative pertained only to Reelfoot Creek. While this creek carries a high proportion of the total sediment load generated in the watershed surrounding Reelfoot Lake, recent studies have shown that other sediment sources are also significant. These include Indian Creek, Bayou du Chien, and a number of small natural drains and ditches that have been channelized for agricultural purposes. In particular, agricultural fields north and west of the lake may be an important source of both water and sediment at times when the water level in the Mississippi River is higher than that of Reelfoot Lake. An effective sediment control program will eventually have to address all of these sources.

Even the most effective sediment control program would do little to solve the problem of the soft sediment layer that has already accumulated on the bottom of the lake. This layer is thought to be a serious detriment to the fishery of Reelfoot Lake, both in terms of limiting spawning sites and preventing development of desirable benthic communities. Three alternatives for solving this problem were considered at the workshop; flushing, dredging, and drawing down the lake to expose bottom sediments to drying. Flushing and dredging were discussed in detail only by the Hydrology and Sedimentation Workgroup. Flushing would involve developing an alternate source of water to try to move accumulated sediments out of the lake. Generally, workgroup members believed that it would be impossible to generate water velocities high enough to move significant amounts of sediment. However, flushing might be effective in removing nutrients. Dredging was also judged to be infeasible, at least for the entire lake, because of high costs; technical problems associated with operating a dredge around stumps, logs, and other organic debris; and the difficulty of disposing of spoil material.

The drawdown alternative was discussed and evaluated by all of the workgroups. The purpose of this strategy would be to expose about 50% of the lake bed to drying by the sun, thus consolidating and oxidizing existing sediment, enhancing water quality, stimulating the growth of desirable benthic communities, and improving the quality of the fishery. The general consensus among workshop participants was that a drawdown is worth trying. The best available evidence, both from similar drawdowns in Louisiana and Florida and from work with disposal of dredge spoil, indicates that sediments would consolidate and not resuspend when the lake was refilled, assuming that sufficient drying occurred. Furthermore, experience in Florida and Louisiana indicates that such a strategy can result in significant benefits in terms of water quality, benthic communities, and the fishery.

However, a drawdown has never been implemented in Tennessee and significant questions regarding potential effectiveness remain.

(1) Drawdowns in Louisiana and Florida are usually implemented in fall or late winter, respectively. The extent to which the impacts from a summer drawdown, such as discussed for Reelfoot Lake, would differ is unknown.

(2) In Louisiana and Florida, a drying period of about 90 days is sufficient to produce adequate consolidation of sediments. The drying time suggested for Reelfoot Lake (120 days) is only an estimate. The extent of drying would depend on a number of unknown factors, including specific climatic conditions during the drawdown and the spatial extent and volume of groundwater inputs to the lake.

(3) As discussed at the workshop, the lake would be drawn down 5.8 ft between about June 1 and July 15. Allowing for 120 days of drying, refilling could begin about November 15. However, the Aquatic Ecology Workgroup questioned whether a drawdown of 5.8 ft could be accomplished in 45 days with the existing control structure. An earlier date for starting the drawdown would impact fish spawning and waterfowl broodrearing, while a later date to start refilling would likely impact early migrating waterfowl.

(4) Sowing ryegrass or millet on the exposed lake bed was suggested as a means of preventing establishment of less desirable vegetation, eliminating unsightly mud flats, and providing food for waterfowl after reflooding. This technique is used effectively in Louisiana and Florida. However, in dredge spoil disposal work, seeding is no longer recommended because vegetation inhibits drying of the substrate. The desirability and effectiveness of this technique under the particular situation that exists at Reelfoot are unknown.

In addition to the above uncertainties, a drawdown would probably have some negative impacts.

(1) The fishable area of the lake would be reduced during the drawdown. This, along with potential fish kills, noxious odors, and possibly unsightly mudflats, would perhaps have adverse effects on the tourism industry. These impacts could be partially offset by certain management techniques (e.g., sowing vegetation on exposed mudflats) and by the fact that a drawdown would allow easy, less expensive repair of facilities such as docks and boat ramps.

(2) During the drawdown, some wildlife species (e.g., reptiles and amphibians, marsh birds, wood ducks) would be negatively impacted. In the fall following the drawdown, early migrating waterfowl would also be impacted by lower water levels. Impacts on early migrating waterfowl, however, could be mitigated by developing additional capabilities to provide open water and food (e.g., moist soil units). Later migrating waterfowl would benefit from flooding of ryegrass or millet planted during the drawdown.

(3) In the spring following a drawdown, corn production on the Refuge would be impaired if the water level was allowed to stay at 283.2 ft msl until June 1. This would in turn mean a reduced food supply for waterfowl in the following fall. Again, however, this impact could be offset by purchasing additional agricultural lands at higher elevations.

Despite these uncertainties and possible negative impacts, participants generally believed that the potential benefits are substantial and that such a strategy is worth trying. They pointed out, however, that a drawdown at Reelfoot should be viewed as an experiment and that managers should be given considerable latitude to respond to specific conditions that may arise during implementation.

Participants, particularly those in the Fish Workgroup, also identified a number of actions that should be taken in concert with a drawdown. These included: implementation of a rough fish removal program while the lake is drawn down; exclusion of crappie from the commercial harvest during the drawdown; cleaning existing channels; dredging or excavating necessary drainage ditches to ensure proper drying; marking cleared channels and stump fields; and mapping the topography of the lake bed. In addition, members of the Hydrology and Sedimentation Workgroup suggested that it might be desirable to excavate dried sediments from certain critical areas. While excavation might have some minor negative impacts (e.g., physical structure for fish spawning would be reduced somewhat), benefits in terms of improved access and increased sediment retention capacity would probably be more significant.

Benefits from a drawdown would not be permanent, particularly if sediment inputs to the lake continue at their current rate. The best available evidence, again from Louisiana and Florida, indicates that drawdowns would be required on the order of every 6-10 years. The exact interval cannot be predicted for Reelfoot; members of the Fish Workgroup suggested several factors that should be monitored to determine the need to repeat the action. In addition, they suggested that a water fluctuation strategy, designed to mimic more closely the water levels that would occur in a natural, unregulated situation, would help to extend the interval between required drawdowns.

In the water fluctuation alternative, water levels would be allowed to rise naturally through the winter and would then be held relatively constant through March, April, and May to allow fish to complete their spawning activities. In naturally wet years, this level might be 284.0 ft msl; in dry years it might be only 282.0 ft msl. Following fish spawning, water levels would be drawn down a minimum of 2 ft. Occasionally, water levels might be drawn down earlier than June 1 if it was desirable to eliminate a particular year class of fish. Members of the Fish Workgroup believed that this strategy would improve fish spawning, consolidate and oxidize some organic sediment around the lake margin, and generally promote development of a more natural ecosystem.

This alternative would likely not have major impacts on hydrology and sedimentation. From the aquatic ecology perspective, it would probably be beneficial in enhancing water quality, reducing nutrient concentrations, and controlling emergent and submergent vegetation. Cutgrass and swamp loosestrife might tend to become established on exposed areas, but these species could probably be controlled with periodic flooding and herbicides. However, it is less clear that this alternative would be acceptable from the perspective of forested wetlands and wildlife.

The problem with respect to these resources concerns the timing of fluctuations. In general, water levels above 282.2 ft msl after March 1 would reduce corn production on the Refuge and thus impair the ability of the Refuge to meet its objective for wintering waterfowl. In principle, water level fluctuation was viewed as desirable from the perspective of forested wetlands. However, it was recommended that, with occasional exceptions (perhaps 1 year in 4), water levels should be at or below 282.2 ft msl by May 1 to avoid stress on bottomland hardwoods. Thus, the conditions most desirable for wildlife and forested wetlands would be inconsistent with those most desirable for fish, except in relatively dry years.

This potential conflict could be alleviated to some extent by acquiring and developing additional lands for waterfowl food production. The plan suggested by the Nonaquatic Vegetation Workgroup would require a total of 800 acres of agricultural land at 284.0 ft msl or higher, about half of which would have to be acquired in fee title or easement from private sources. In any year, 400 acres of this higher ground would be seeded to corn and 400 acres to green browse. Lower areas, some of which are presently used for soybean production, would be converted to moist soil units (600-800 acres) and greentree areas (600 acres). The moist soil units would provide food resources for waterfowl immediately; greentree areas would not produce mast for about 30 years. In the short term, development of these areas would alleviate the conflicts between fish spawning and waterfowl food production. However, implementation of the water fluctuation alternative as proposed at the workshop would still stress bottomland hardwoods. The extent of mortality that would result, if any, is unknown. In the long term, distribution of the species associations in the bottomland hardwood forest would change in response to the new water management regime. Additional land currently in agricultural production could be used to mitigate losses of forested wetlands if that land was used for bottomland vegetation.

The water management strategy contained in a State law recently enacted by Tennessee was generally perceived as the poorest of the alternatives analyzed at the workshop. While this strategy would have some short-term benefits, such as increasing fishable area and allowing some fluctuation in lake level, there would also be several negative impacts, including those on wildlife and forested wetlands described above for the water fluctuation alternative. In addition, the State law alternative would significantly increase the potential for flooding of areas surrounding the lake and for failure of the existing control structure. Furthermore, any benefits of this alternative would be relatively short-lived, because it does not address any of the real causes of problems at Reelfoot. In a few years (perhaps 20-30?), conditions in the lake would be very similar to those that currently exist.

In addition to analyzing these management alternatives, participants at the workshop suggested a variety of research and monitoring activities that should be initiated. While there was considerable variation in these suggestions, two general points were made. First, a successful monitoring program must be in place before any new water management strategy is implemented and must continue both during and after implementation. Information from such a program will be of little use unless it covers all three of these phases. Second, the monitoring program should be developed around a standardized scheme for stratification of sampling so that results from different studies can be related.