EXHIBIT B, Appendix C

***Evaluation of Site-Specific Thermal Standards at Marion Power Plant*,**

AMEC Environmental & Infrastructure, Inc., October 2013.

Evaluation of Site-Specific Thermal Standards at Marion Power Plant

Submitted in Support of NPDES Permit Renewal

Prepared for:

Southern Illinois Power Cooperative
11543 Lake of Egypt Road
Marion, IL 62959

Prepared by:

AMEC Environment & Infrastructure, Inc.
3199 Riverport Tech Center Drive
Maryland Heights, Missouri

AMEC Project No. 3250115515

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William J. Elzinga, MS
Senior Principal Scientist

Wayne Ingram

D. Wayne Ingram, PE
Principal Engineer

Executive Summary

This report summarizes the data from water quality and fisheries surveys performed on the Lake of Egypt in Southern Illinois. Its purpose is to provide supporting evidence for a site-specific rule change in the National Pollutant Discharge Elimination System (NPDES) permit for Southern Illinois Power Cooperative (SIPC)'s Marion Power Plant. Under the current permit, the thermal limitations are:

- Lake temperatures at the edge of the 26-acre mixing zone shall not exceed the following maximums (60 degrees Fahrenheit [°F] from December through March; 90°F from April through November) by more than 1 percent of the hours in a 12-month period.
- At no time shall the water temperature at the edge of the mixing zone exceed these maximums by more than 3°F.
- Maximum temperature rise above natural temperature must not exceed 5°F (2.8°C).

The proposed revised standards are as follows:

- Lake temperatures at the edge of the 26-acre mixing zone shall not exceed the following maximums by more than 1 percent of the hours in a 12-month period:
    - 72°F from December through March;
    - 90°F from April through May;
    - 101°F from June through September; and
    - 91°F from October through November
- At no time shall the water temperature at the edge of the mixing zone exceed these maximums by more than 3°F.

The rationale for proposing these revised standards is as follows:

1. The requested relief is necessary to accommodate current operating conditions.
2. The requested relief would not alter the Lake of Egypt's existing thermal regime. The Marion Station's thermal discharge affects a small percentage of the 2,300-acre lake.
3. Assessments of the effects of the proposed changes on representative important species indicate that under normal summer conditions, habitats would remain within thermal tolerance limits throughout the lake. Under a modeled condition that simulated rarely expected extreme conditions, there were still extensive areas in the lake that fish could utilize as thermal refugia.
4. Surveys from 2010 and earlier years indicate that fish populations in the Lake of Egypt have adapted to warm temperatures. Increased thermal loading associated with the operation of a new boiler in 2003 did not appear to negatively affect the fish community. Species composition and abundance estimated by these surveys suggest that the populations are healthy and self-sustaining.
5. Potentially beneficial effects include higher, stable water temperatures in the late winter and early spring that may promote earlier spawning, improved survival, and increased

growth and development of the early life stages of several species, notably largemouth bass. Additionally, the warmer conditions in the Lake of Egypt almost certainly enhance the population of threadfin shad (important forage species) by preventing winter mortality.

6. Lake of Egypt is considered to be a “low impact area” for five other biotic categories including phytoplankton, zooplankton and meroplankton, habitat formers, shellfish and macroinvertebrates, and other vertebrate wildlife. There is no evidence of appreciable harm to any of the biotic categories addressed in the U.S. Environmental Protection Agency (USEPA)’s draft guidance for 316(a) demonstrations.
7. Fish kills in the Lake of Egypt have not occurred historically, and are not likely to occur as a result of these proposed standards. For the majority of the year, water temperature conditions are well below their temperature tolerance thresholds. During the periods of highest lake temperatures, there is an abundance of thermal refugia. Fish can migrate laterally to other areas of the lake, or can move downward in the water column to avoid stressful conditions.

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°C	degrees Celsius
CFB	circulating fluidized bed
CSHE	Coefficient of Surface Heat Exchange
CWA	Clean Water Act
CWIS	circulating water intake structures
°F	degrees Fahrenheit
GEMSS	Generalized Environmental Modeling System for Surface Waters
GLLVHT	Generalized Longitudinal Lateral Vertical Hydrodynamic Transport
IEPA	Illinois Environmental Protection Agency
m	meters
MGD	million gallons per day
mg/L	milligrams per liter
mm	millimeter
msl	mean sea level
MW	megawatts
MWAT	maximum weekly average temperature for growth
NPDES	National Pollutant Discharge Elimination System
RIS	representative important species
SIPC	Southern Illinois Power Cooperative
T_{eq}	surface equilibrium temperature
UILT	upper incipient lethal temperature
USEPA	U.S. Environmental Protection Agency
WARM	Water & Atmospheric Resources Monitoring

1.0 Introduction

1.1 Regulatory Background and Report Purpose

Electric utilities are typically obligated to submit applications for re-issuance of the National Pollutant Discharge Elimination System (NPDES) permit once every 5 years. Section 316(a) of the Clean Water Act (CWA) provides for the regulation of thermal discharges.

As Special Condition No. 7 of the February 2007 NPDES permit for Southern Illinois Power Cooperative (SIPC)'s Marion Power Plant, the Illinois Environmental Protection Agency (IEPA) required the utility to comply with Illinois Administrative Code 302.211(f) and Section 316(a) of the CWA by demonstrating that the thermal discharge from the plant "will not cause and cannot reasonably be expected to cause significant ecological damage to the Lake of Egypt."

The purpose of this report is to fulfill the requirements of Special Condition No. 7, which asks SIPC to perform a heated effluent demonstration, and to support a request for a less stringent thermal effluent limit. This report evaluates the potential for SIPC's thermal effluent discharges to cause significant ecological damage to the Lake of Egypt by describing the existing environmental conditions using field measurements, predicting future conditions through application of computer models, and examining historical and current fisheries data to determine whether populations will be adversely affected by plant operations. This report further evaluates whether the Lake of Egypt provides conditions capable of supporting shellfish, fish, and wildlife and will continue to do so even under the requested relief.

1.2 Station and Lake Descriptions

SIPC is a consumer-owned generation and transmission cooperative, with headquarters in Marion, Illinois. The coal-fired Marion Power Plant is located approximately 7 miles south of the City of Marion and consists of a 173 megawatt (MW) net cyclone boiler, and a 109 MW net circulating fluidized bed (CFB) boiler. The cyclone boiler came on line in 1978, and provides steam to one large turbine, whereas the CFB boiler came on line in 2003 and provides steam to three small turbines. All four turbines use once-through cooling with a common intake and discharge. The plant draws water from the Lake of Egypt, which was created by SIPC in 1963, by impounding the south fork of the Saline River. The original stream ran in a northerly direction, so the dam impounding the lake is at its northern end. In this report, lake sections will be referred to as "lower," referring to areas close to the dam at the northern end, and "upper," referring to areas more distant from the dam toward the southern end. The plant is located along the northwest bank of the lake (Figure 1-1), and for the purposes of this study, is considered to be in the lower section. The once-through cooling water discharges back into a cove of the lake separated from the intake structure by a narrow peninsula (Figure 1-2). The additional boiler that became operational in 2003 resulted in increases of water use and volume of thermal water discharged into the lake.

SIPC owns the land around the lake up to the 50-year high water elevation, but does allow access for fishing and recreational activities to shoreline residents and members of the public. The Lake of Egypt is approximately 2,300 acres in surface area and has approximately 93 miles of shoreline. The lake level generally varies between 499 and 501 feet mean sea level (msl) (MACTEC, 2007). The average depth is 18 feet, with a maximum of 52 feet.

1.3 Existing Regulatory Requirements

Currently, the NPDES permit for SIPC's Marion Power Plant requires that:

- Lake temperatures at the edge of the 26-acre mixing zone shall not exceed the following maximums (60 degrees Fahrenheit [°F] from December through March; 90°F from April through November) by more than 1 percent of the hours in a 12-month period.
- At no time shall the water temperature at the edge of the mixing zone exceed these maximums by more than 3°F.
- Maximum temperature rise above natural temperature must not exceed 5°F (2.8 degrees Celsius [°C]).

2.0 Master Rationale for Demonstration

2.1 Master Rationale Overview

The following key points summarize the existing status of the fishery of Lake of Egypt and the findings of this report with respect to the proposed thermal limits and their effect on sustaining the balanced and indigenous community:

- *Game Fish Representative Important Species (RIS) Status.* Observed temperatures outside the mixing zone at the lower end of the lake were within the tolerance limits of RIS such as channel catfish, bluegill, and largemouth bass when the plant was at full capacity. Based on modeling results, proposed thermal limits under normal late summer weather conditions would only result in avoidance or adaptive behaviors in localized areas within the lower lake. More thermally sensitive species such as white and black crappie are expected to similarly adapt their behavior to avoid limiting surficial water temperatures under stressed conditions.
- *Threadfin Shad Support.* Existing and proposed thermal limits will continue to sustain threadfin shad overwintering survival which will benefit the food base of largemouth bass and other predators.
- *Community Stability.* The resident fish community has been stable in terms of composition and abundance over the past 13 years. Proposed thermal limits are expected to sustain similar community composition and abundance such that its stability will not be adversely affected.
- *Habitat Availability.* There is abundant habitat available, both horizontally throughout the lake and vertically in the water column, as refuge from localized sub-optimum thermal conditions. These habitat refuge areas will similarly be available under the proposed thermal limits.

Therefore, these patterns indicate that the thermal conditions in the Lake of Egypt have been protective of a balanced indigenous community. Moreover, the temperature thresholds proposed as part of the requested site-specific rule revision reflect current thermal conditions and will continue to be protective of the balanced indigenous community.

This document represents a hybrid, Type III, demonstration because it uses a combination of predictive and empirical (i.e., retrospective) assessment methods and data to analyze the biological effects of the proposed thermal limits. The Marion Plant/Lake of Egypt site is one of low potential impact.

2.2 Key Conclusions and Recommendations of the Master Rationale

Data from previous studies and the 2010 study indicate that the Lake of Egypt has historically supported and continues to support a high quality sport fishery. Fish populations in the lake have adapted to the condition of warmer water, and have ample areas available for thermal refuge. Increased thermal loading associated with the operation of a new boiler in 2003 has not negatively affected the fish community, and SIPC does not intend to increase generating capacity in the future. Moreover, stable, higher water temperatures in late winter and spring likely promote growth and development for most species, and support the survival of threadfin shad, an important subset of the forage base.

Results of field measurements and hydrodynamic modeling demonstrated that temperatures well above the current NPDES limit (90°F) are routinely present in the summer at the mixing zone boundary. Furthermore, ambient lake temperatures frequently exceed this threshold in the warmest periods of the year. We recommend that the thermal limitations in the NPDES permit for SIPC's Marion Power Plant be changed from the current conditions of:

- Lake temperatures at the edge of the mixing zone shall not exceed the following maximums (60°F from December through March; 90°F from April through November) by more than 1 percent of the hours in a 12-month period, and
- At no time shall the water temperature at the edge of the mixing zone exceed these maximums by more than 3°F.
- Maximum temperature rise above natural temperature must not exceed 5°F (2.8°C).

to:

- Lake temperatures at the edge of the 26-acre mixing zone shall not exceed the following maximums by more than 1 percent of the hours in a 12-month period,
    - 72°F from December through March;
    - 90°F from April through May;
    - 101°F from June through September; and
    - 91°F from October through November
- At no time shall the water temperature at the edge of the mixing zone exceed these maximums by more than 3°F.

The rationale for proposing these revised standards is as follows:

1. The proposed change would not alter the Lake of Egypt's existing thermal regime (i.e., dissipation of heat within the lake or have an effect in altering natural lake stratification).
2. Assessments of the effects of the proposed changes on representative important species indicate that under normal summer conditions, habitats would remain within thermal tolerance limits throughout the lake. Under a modeled condition that simulated rarely-expected extreme conditions, there were still extensive areas in the lake that fish could utilize as thermal refugia.
3. Surveys from 2010 and earlier years indicate that fish populations in the Lake of Egypt have adapted to warm temperatures. Species composition and abundance estimated by these surveys suggest that the populations are healthy and self-sustaining.
4. Potentially beneficial effects include higher, stable water temperatures in the late winter and early spring that may promote earlier spawning, improved survival, and increased growth and development of the early life stages of several species, notably largemouth

bass. Additionally, the warmer conditions in the Lake of Egypt almost certainly enhance the population of threadfin shad by minimizing winter mortality.

5. Fish kills in the Lake of Egypt have not occurred historically, and are not likely to occur as a result of these proposed standards. For the majority of the year, water temperature conditions are well below the temperature tolerance thresholds of the representative important species. Even during the periods of highest lake temperatures, there is an abundance of thermal refugia. Fish can migrate laterally to other areas of the lake, or can move downward in the water column, to avoid stressful conditions.

The five other biotic categories considered in USEPA's Technical Guidance Manual are either: (a) unaffected (or beneficially affected) by the heated effluent – such as submerged aquatic vegetation and wildlife, or (b) consist of species that are not threatened/endangered, of commercial importance (macroinvertebrates and shellfish), and/or generally have short life spans, reproduce rapidly or are expected to exhibit only localized population shifts (phytoplankton and zooplankton). It is reasonable to conclude that the plant's discharge will cause no appreciable harm to these resident communities in the lake.

3.0 Representative Important Species

In this evaluation of lake temperature effects on the fishery of the Lake of Egypt, AMEC (formerly MACTEC) selected five species that have commercial and/or ecological importance and that can be considered representative for other species occupying the same trophic group. Representative important species (RIS) selected for this analysis include threadfin shad, gizzard shad, channel catfish, bluegill, and largemouth bass.

Representative important species are those that have the biological requirements representative of a balanced, indigenous community from the body of water being considered. Categories considered in the RIS designation include: commercially or recreationally valuable species; threatened or endangered species; and species (e.g., prey species) that are necessary for the survival of the aforementioned species. In the Lake of Egypt, channel catfish, bluegill, largemouth bass and crappies (white and black) are recreationally important, and threadfin shad and gizzard shad are considered an important prey species for largemouth bass. Channel catfish, bluegill, largemouth bass and crappies are appropriate selections as RIS in part because their populations have been collected and analyzed in previous studies on the Lake of Egypt fishery (Appendix C, Chapter 9). No threatened or endangered species have been collected in previous surveys of the lake.

While undocumented, it is likely that four of these RIS – gizzard shad, channel catfish, bluegill, and largemouth bass – were initially introduced into the lake following its construction in 1963. Nonetheless, these four species have been referred to as species of fish “normally associated with Southern Illinois reservoirs.” (see Appendix D, page 1). SIPC introduced threadfin shad in the 1970s to enhance the forage base for predator species. Although the populations of all five have been either initiated or supplemented by stocking, they are currently maintained by natural reproduction.

In support of the following discussion, Tables 3-1, 3-2 and 3-3 present the results of electrofishing within Lake of Egypt during 2010. The intent of this sampling program was to provide more recent supplemental data to that previously collected as part of the more comprehensive studies by Heidinger et al (2000) in the late 1990s and the work previously performed in the vicinity of the CWIS as part of the Impingement Mortality Characterization Study (MACTEC, 2007). Tables 3-1, 3-2 and 3-3 provide general compositional information about the resident fish community and can be used to identify relative abundances of taxa within the fishery and the spatial characteristics of the more dominant taxa. For those taxa that are less well represented caution should be exercised in inferring conclusions regarding their spatial patterns and response to thermal conditions. Table 3-4 provides a comparison of the ten most dominant taxa from these historical data sets and can be used to reflect the general stability of the primary taxa within the lake. Again, some caution should be exercised in comparing data of less well represented taxa (e.g. threadfin shad, gizzard shad, channel catfish, etc.) as these sampling programs differed in their intent and intensity. For example, the absence of threadfin shad and gizzard shad from electrofishing collections in 2005 and 2006 suggests a notable change in the resident fish community from that documented by Heidinger et al (2000). In reality however, this is an artifact of a lower overall electrofishing sampling effort. As documented in sampling using other gear types (gill nets, impingement samples) both gizzard shad and threadfin shad were well represented in the vicinity of the intake structure in both 2005 and 2006 and are expected to be similarly represented in the current fish community.

3.1 Threadfin Shad

Threadfin shad is a primary forage species in the Lake of Egypt. It has been stocked into the lake beginning in 1971, in an attempt to increase the forage base of the fishery. While threadfin shad are not indigenous to Lake of Egypt, they were selected as a representative important species because they are a primary forage fish for largemouth bass and are a crucial component in support of the food web for the Lake of Egypt ecosystem. Although threadfin shad have rarely been among the most numerous species in electrofishing surveys, their numbers in impingement samples taken at the circulating water intake structures (CWIS) indicate that they are abundant in the lake (MACTEC, 2007). Additionally, large numbers of schooling threadfin shad have been observed during other surveys, but their small size and offshore habitat preference makes them less susceptible to the survey gears used. It is planktivorous, its habits are similar to the closely related gizzard shad, and in lakes it generally occurs in the upper five feet of water (Pflieger, 1997). Threadfin shad do not live as long or grow as large as gizzard shad, however, and are sensitive to low temperatures (e.g., less than 45°F). Threadfin shad spawning generally occurs between April and August when temperatures are greater than 68°F [University of California-Davis (UCD), 2010]. Eggs hatch in three to six days, and develop into juveniles approximately two to three weeks later, depending on water temperature (UCD, 2010).

Threadfin shad were collected from the Lake of Egypt in all studies since 1997, but never in large numbers. In the Impingement Mortality Characterization Study, threadfin shad was reported to be the most commonly impinged species in both years (2005 and 2006), where it accounted for 66 and 78 percent of the total, respectively (MACTEC, 2007). There is no clear evidence of any population change for this species since the 2003 boiler replacement. In 2010 field studies, 36 threadfin shad were collected; most (33) of which were collected during the July survey (Table 3-1). The catch rate was greater in the upper portion of the lake (i.e., farther from the power plant) than in the lower lake (Table 3-2). However, as stated previously, electrofishing catch rates were low and do not support substantive conclusions about temporal or distributional patterns within the lake. The average length of threadfin shad was higher in the lower lake [71.6 millimeter (mm)] than in the upper lake (50.3 mm) (Table 3-3). Most of the specimens collected were young-of-the-year and age I+ fish, and were 40 to 70 mm in length (Figure 3-1).

Table 3-1. Species Composition and Abundance in July and August Electrofishing Samples (Combined Stations) from Lake of Egypt, 2010

Species	July	August
Gizzard shad	8	3
Threadfin shad	33	3
Common carp		1
Black bullhead		13
Yellow bullhead	22	6
Channel catfish	8	5
Blackstripe topminnow	1	
Inland silverside	5	1
Green sunfish	39	10
Warmouth	17	22
Bluegill	792	597
Longear sunfish	177	118
Redear sunfish	61	87
Sunfish hybrid	2	6
Largemouth bass	79	111
White crappie		1
Black crappie	5	8
Total	1249	992

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Table 3-2. Species Composition and Catch-Per-Effort (#/hour) in Electrofishing Samples from Upper and Lower Lake Sections (Combined Months) in Lake of Egypt, 2010 (Power Plant Discharge and Intake are in the Lower Lake Section)

Species	(#/hour)	(#/hour)
Gizzard shad	1.6	0.9
Threadfin shad	9.6	1.0
Common carp	0.0	0.1
Black bullhead	0.3	1.8
Yellow bullhead	1.0	3.7
Channel catfish	3.0	0.6
Blackstripe topminnow	0.0	0.1
Inland silverside	0.3	0.7
Green sunfish	12.2	1.8
Warmouth	2.0	4.9
Bluegill	129.1	146.9
Longear sunfish	59.6	16.8
Redear sunfish	18.8	13.4
Sunfish hybrid	0.3	1.0
Largemouth bass	20.1	19.0
White crappie	0.3	0.0
Black crappie	2.6	0.7
Total	260.9	213.5

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Table 3-3. Comparison of Average Length and Biomass for Each Species Between Survey Periods and Between Lake Sections for Electrofishing Samples from Lake of Egypt, 2010

Species	July		August		Upper Lake		Lower Lake	
	(mm)	(grams)	(mm)	(grams)	(mm)	(grams)	(mm)	(grams)
Gizzard shad	321.4	2751	372.3	1533	347.0	2119	325.5	2165
Threadfin shad	53.0	51	71.0	10	50.3	39	71.6	22
Common carp	--	--	629.0	3538	--	--	629.0	3538
Black bullhead	--	--	218.4	2088	225.0	161	217.8	1927
Yellow bullhead	169.8	2014	177.3	578	146.0	201	174.5	2391
Channel catfish	520.9	10467	557.6	7871	544.1	13305	514.5	5033
Blackstripe topminnow	46.0	1	--	--	--	--	46.0	1
Inland silverside	60.0	8	45.0	1	63.0	2	56.4	7
Green sunfish	109.2	1264	116.5	362	114.1	1364	100.1	262
Warmouth	119.5	831	93.0	457	116.0	283	102.5	1005
Bluegill	92.4	11379	95.1	7744	100.0	6245	91.0	12878
Longear sunfish	103.8	3941	96.0	2182	101.2	3833	99.8	2290
Redear sunfish	131.5	2747	154.7	5386	146.9	3213	144.1	4920
Sunfish hybrid	139.0	122	108.3	169	120.0	30	115.4	261
Largemouth bass	305.3	42072	321.9	64603	281.2	26786	331.0	79889
White crappie	--	--	330.0	397	330.0	397	--	--
Black crappie	187.8	559	174.4	643	181.0	711	177.2	491

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Checked by: WJE/1-27-12

Table 3-4. Catch Rates (# fish/hour) of the Ten Most Abundant Species in Electrofishing Surveys at Lake of Egypt (Between-Year Comparability, SIU Electrofishing Data was Limited to Fall Samples in the Lake Segment Nearest the Circulating Water Intake Structures [CWIS])

Species	SIU-C[a]		MACTEC[b]		MACTEC 2010
	1997	1998	2005	2006†	
Gizzard shad	19.2	15.9			
Threadfin shad		1.3			3.7
Common carp	1.2	1.4	2.0	4.0	
Golden shiner	1.2				
Black bullhead					
Yellow bullhead				2.0	2.9
Channel catfish					1.3
Blackstripe topminnow			3.0		
Brook silverside		1.4			
Inland silverside			1.0	4.0	
Green sunfish	11.2		1.0	3.0	5.0
Warmouth			3.0	2.0	4.0
Bluegill	130.1	93.0	56.0	100.0	141.4
Longear sunfish	23.0	9.5	4.0	2.0	30.0
Redear sunfish	56.1	39.8	20.0	46.0	15.1
Hybrid sunfish		1.3			
Largemouth bass**	65.7	56.1	21.0	67.0	19.3
White crappie	4.8				
Black crappie	2.5	3.8	1.0		1.3

[a] Source: Heidinger et al. 2000, as summarized in MACTEC, 2007

[b] Source: MACTEC, 2007
†Only nine total species collected.
**The lake is fished heavily for this species during commercial tournaments.

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Checked by: WJE/1-27-12

3.2 Gizzard shad

Gizzard shad is a forage species in the Lake of Egypt during its young-of-year life stage. Older size classes of gizzard shad become too large for large predators such as largemouth bass to feed upon. Gizzard shad were selected as a representative important species because they serve as a forage fish for largemouth bass and support the food web for the Lake of Egypt ecosystem. It is planktivorous, its habits are similar to the closely related threadfin shad, and in lakes it generally occurs in the upper portion of the water column. Gizzard shad spawning generally occurs between April and May. Eggs hatch in two to seven days, depending on water temperature. Sexual maturity is reached at Age II or III (Pflieger, 1997).

Although gizzard shad have not been a common species in electrofishing surveys, they have been collected during every survey year since 1997 (MACTEC, 2007). Their offshore habitat preference makes them less susceptible to the survey gears used and their numbers are likely underestimates of their actual abundances. In the Impingement Mortality Characterization Study, gizzard shad was reported in both years (2005 and 2006), where it accounted for 2.5 and 3.7 percent of the total biomass, respectively (MACTEC, 2007). There is no clear evidence of any population change for this species since the 2003 boiler replacement. In 2010 field studies, 11 gizzard shad were collected; 8 of which were collected during the July survey (see Table 3-1). The catch rate was slightly greater in the upper portion of the lake (i.e., farther from the power plant) than in the lower lake (see Table 3-2). However, as stated previously, electrofishing catch rates were low and do not support substantive conclusions about temporal or distributional patterns within the lake. The average length of gizzard shad was higher in the upper lake (347.0 mm) than in the lower lake (325.5 mm) (see Table 3-3). All of the individuals collected were large adults greater than 260 mm in total length (Figure 3-2).

3.3 Channel Catfish

Channel catfish were selected as a representative important species because they are a recreational species that are highly prized as a game and food fish. Adults prefer habitats with woody debris and bank cavities, and generally are found in deeper water during daylight hours (Pflieger, 1997). Due to their nocturnal habits and habitat preferences, channel catfish have not been collected in large numbers in daytime electrofishing surveys at the Lake of Egypt. Even so, they have been encountered in all study years since 1997. Spawning generally occurs in the spring at temperatures ranging from 70 to 82°F, and eggs hatch in 3 to 10 days (Hubert, 1999). The larval stage lasts for 12 to 16 days (Fishbase, 2010).

Channel catfish abundance does not appear to have decreased since the boiler replacement in 2003, as electrofishing catch rates were slightly greater for this species in the 2010 survey (Table 3-4). Thirteen channel catfish were collected from the Lake of Egypt in 2010 surveys (see Table 3-1). The difference was slight between July and August, but the catch rate was greater in the upper portion of the lake (see Table 3-2). However, as stated previously, electrofishing catch rates were low and do not support substantive conclusions about temporal or distributional patterns within the lake. All but two of the individuals collected were large adults (greater than 500 mm in total length) and were probably age V+ or older (Figure 3-3). All specimens appeared to be in excellent condition, with no external abnormalities found.

3.4 Bluegill

Bluegill is the numerically dominant species in the Lake of Egypt (see Table 3-4). It is primarily an invertivore as an adult, and as a juvenile is an important forage component. Bluegill is a desirable pan fish and is much pursued by anglers. Bluegill were selected as a representative important species because they are a primary forage fish for predator fish such as largemouth bass and are a highly sought after recreational species. Temperature maxima for spawning range from 82 to 93°F (ESE, 1988), and the maximum temperature for embryo survival is 93°F (Brungs and Jones, 1977). Spawning reportedly occurs from late May through August at temperatures ranging from 67 to 80°F (Cornish and Welke, 2004). Eggs hatch in about 2 days at a temperature of 77°F (Merriner, 1971), and the larval stage lasts for approximately 30 days at 74.3°F (Fishbase, 2010).

Bluegill has historically been the most abundant species in the Lake of Egypt and was again the numerical dominant in 2010 electrofishing surveys. Bluegill numbers, as represented by electrofishing catch-per-effort have varied considerably but have not decreased since the boiler replacement in 2003 (see Table 3-4). Abundance was moderately greater in July than in August, and catch rates were similar in the upper and lower portions of the lake (see Table 3-2). A bimodal length frequency distribution was evident in both portions of the lake, with the 60 to 79 mm and 90 to 119 mm groups generally being the most numerous (Figure 3-4). These individuals fall within the II+ and III+ age groups. The condition of the bluegills collected was very good, with only 0.1 percent of the individuals exhibiting external anomalies.

3.5 Largemouth Bass

Largemouth bass is the primary predator species in the Lake of Egypt, and is one of the most important North American warm-water sport fishes (Smith, 2002). Largemouth bass were selected as a representative important species because they are a highly sought after sportfish for the Lake of Egypt fishery. It commonly spends the day in deeper water or lurking near cover, and then moves to shallower water in the evening to feed (Pflieger, 1997). Optimal spawning temperatures for largemouth bass vary between 60 and 75°F (Heidinger, 1975). Eggs hatch in three to four days at temperatures of 60 to 67°F (Kramer and Smith, 1960), and the period of larval development to the juvenile stage is 19 days at 67°F (Fishbase, 2010).

Largemouth bass has been common or abundant in electrofishing surveys at the Lake of Egypt since 1997. Annual variability in abundance likely reflects the relatively small sample sizes of the surveys; periodic bass fishing tournaments may also be a factor in the variability. Its abundance does not appear to have decreased since the boiler replacement in 2003, as electrofishing catch rates were similar for this species in the 1997 and 2007 surveys (see Table 3-4). In 2010, it was the third most numerous species in both July and August, with a total of 190 individuals collected (see Table 3-1). Catch rates were nearly identical in the upper and lower portions of the lake (see Table 3-2). This species was particularly abundant along the riprap shoreline of the spillway in the lower lake. Largemouth bass of all length categories between 40 and 480 mm were encountered (Figure 3-5). In both the upper and lower portions of the lake, individuals between 300 and 460 mm were most numerous, and probably represented III+ to V+ age fish. Young-of-the-year specimens were also collected during both survey periods. External abnormalities were more prevalent on largemouth bass than on other species, with over 16 percent of individuals having at least one anomaly. The most frequently observed maladies were hook scars on the mouth, lesions on the mouth and body, and emaciation. Since largemouth bass was the only common species with such a high incidence of abnormalities, it was felt that this trend reflected angling pressure rather than degraded environmental conditions. Large numbers of bass tournaments are held in the Lake of Egypt annually, and it is likely that a substantial proportion of the population has been caught and handled. The stress of this experience was almost certainly associated with many of the cases of external abnormalities.

3.6 White and Black Crappie

White crappie generally occurs in sand-bottomed and mud-bottomed pools and backwaters of creeks and small to large rivers, and lakes and ponds (Fishbase, 2013a). White crappie is often found in turbid water where it is frequently more abundant than black crappie (Pope and Willis, 1998). White crappie is generally more abundant in lakes and reservoirs greater than 5 acres in area. It is often associated with structural features such as submerged trees, stumps, aquatic vegetation and boulders. White crappie also prefers low velocity habitats such as pools and backwaters of rivers and lakes (Edwards et al, 1972b). Black crappie is a species that also inhabits lakes, ponds, sloughs, and backwaters and pools of streams. It usually occurs among vegetation over mud or sand, most common in clear water. Lake of Egypt provides a fringe of floating-leaved aquatic vegetation throughout much of the lake. Younger individuals of both species feed on planktonic crustaceans and free-swimming dipteran larvae, whereas larger size classes feed on small fishes (Fishbase 2013a,b). Optimal spawning temperatures for white crappie varies between 60 and 68°F (Edwards et al, 1972b) whereas spawning temperatures for black crappie varies between 64 and 68°F (Edwards et al, 1972a). Both white and black crappie (collectively, “crappies”) were selected as a RIS because they are a both a sought after sportfish for the Lake of Egypt fishery and are species that are more thermally sensitive. SIPC stocked Lake of Egypt with black crappie fingerlings in 2008, 2009, and 2010.

Crappies have not been dominant taxa within electrofishing collections from Lake of Egypt. According to earlier assessments by Heidinger from 1988 and 1990, crappie historically demonstrated good populations at Lake of Egypt. Heidinger also noted that crappie populations are cyclical and that for both 1998 and 1990, they were likely at a low point. More recent investigations of Lake of Egypt by Heidinger et al (2000) reported the collection of both black and white crappie in electrofishing results however, abundances between survey years (1997 and 1998) were variable among species and reaches of the lake. Annual variability in abundance within Lake of Egypt likely reflects the relatively small sample sizes of the surveys; extensive fishing pressure and the characteristic cyclical population trends of these species within larger reservoirs. As stated by Pope and Willis (1998), factors such as turbidity, water level fluctuation, the abundance of aquatic vegetation and many other environmental factors often contribute to the cyclical nature of crappie populations in impoundments.

4.0 Biotic Category Rationales

In its 1977 draft of the 316(a) Technical Guidance Manual (U.S. Environmental Protection Agency [USEPA], 1977), the USEPA lists six biotic categories that should initially be considered in a demonstration study. These are:

- Phytoplankton;
- Zooplankton and meroplankton (organisms with planktonic larval stages);
- Habitat formers;
- Shellfish and macroinvertebrates;
- Fish; and
- Other vertebrate wildlife

Categories for which the site can be considered low impact do not need to be studied in detail for the demonstration. In this report, only fish were examined in detail. The Lake of Egypt was considered a low impact site for the other five categories, and the following section outlines the justification for this approach. In each case, results of studies at this and other similar sites in southern and central Illinois indicated that there has been, and will continue to be, no appreciable harm to the balanced, indigenous community. The following narratives provide the rationales for each of the required biotic categories.

4.1 Phytoplankton

The criteria to determine whether the site is a low impact area for phytoplankton are as follows:

1. A shift toward nuisance species of phytoplankton is not likely to occur;
2. There is little likelihood that the discharge will alter the indigenous community from a detrital to a phytoplankton-based system; and
3. Appreciable harm to the balanced indigenous community is not likely to occur as a result of phytoplankton community changes caused by the heated discharge.

Lake of Egypt is an open water impounded lacustrine system (rather than one characterized by mangrove swamps, salt marshes, freshwater swamps, rivers, or streams which are detrital based), it is considered to be an ecosystem that has a phytoplankton-based food web (USEPA, 1977). No studies specific to phytoplankton have been performed on Lake of Egypt. However, in spite of the absence of this information a sufficient basis exists by which to conclude that the Lake of Egypt is a low impact area for phytoplankton in consideration of the proposed site-specific standard:

- A detailed study on a central Illinois artificial cooling lake of similar size (Lake Sangchris) concluded that the operation of a larger generating station (1,232 MW as compared to the 282 MW Marion Power Plant) did not appear to be deleterious to its phytoplankton community (Moran, 1981a).
- Studies performed by Heidinger et al (2000) on Newton Lake found that rates of photosynthesis were notably higher during the summer months but were similar to the range of values from other lakes. Additionally, while there were some decreases in mean

total phytoplankton densities in July and August, there was not a significant change in the rate of photosynthesis.

- The resident community in the Lake of Egypt has developed under the environmental conditions (i.e., heated influence in the downstream end of the lake) that are similar to the conditions that will persist in the future, and there has thus far been no indication of phytoplankton community impairment.
- A biotic characteristic of the phytoplankton community is that members of this group generally have short life spans and reproduce rapidly. If there were any temporary effects on the community, there are extensive areas outside the zone of thermal influence that could act as either refugia or sources of recolonization potential.
- There have been no recent occurrences of algal blooms on the Lake of Egypt that suggest that the aquatic ecosystem (and associated water quality) is prone to or susceptible to a shift to the predominance of nuisance populations of phytoplankton. While some incidences of historical plankton blooms have been reported, these occurred prior to the improvements to the Goreville wastewater treatment plant and the general conversion of shoreline homes from septic systems to a combined sewer system (SIPC, 2004). Subsequent to these measures water quality of the lake has shifted away from the strongly eutrophic condition reflected by such nutrient loading, suggesting that the historical plankton blooms were not attributable to the thermal influence of the Marion Plant. Based on the observation that the fish community has remained similar since the establishment of the lake (Heidinger, 2007), it is reasonable to infer that there has not been a shift in the food base.

- Although no site-specific data have been collected to describe the phytoplankton communities at Lake of Egypt, it is expected that their composition would be similar to that of other regional cooling lakes. Some community compositional variations may exist between regions of the lake that are thermally influenced, but notable differences in community composition are expected to be localized to the mixing zone area. Potential variations beyond the mixing zone are likely to be insignificant in altering the overall primary productivity of the ecosystem. Accordingly, no significant disruption to related trophic levels or the biotic community at large is expected.

The lack of a community shift toward nuisance phytoplankton species and the presumed stability of the existing assemblages (e.g., no shift from a detritus-based community, no algal blooms after water quality improvements in the system) combine to indicate that there has been, and will be, no appreciable harm to the balanced indigenous community for this biotic category.

4.2 Zooplankton and Meroplankton

The criteria to determine whether the site is a low impact area for zooplankton and meroplankton are as follows:

1. Changes in the zooplankton and meroplankton community in the study area that may be caused by the heated discharge will not result in appreciable harm to the balanced indigenous fish and shellfish populations;

2. The heated discharge is not likely to alter the standing crop, relative abundance, with respect to natural population fluctuations in the far-field study area from those values typical of the receiving water body segment prior to plant operation;
3. The thermal plume does not constitute a lethal barrier to the free movement (drift) of zooplankton and meroplankton.

While no studies of the zooplankton or meroplankton communities have been performed on Lake of Egypt, a sufficient basis exists to demonstrate that the Lake of Egypt is an area of low impact for this biological component. Evidence supporting this conclusion includes the following:

- Related studies performed at a manmade cooling lake, Lake Sangchris, demonstrated that in comparison to an unheated manmade reservoir (Lake Shelbyville), the diversity of zooplankters did not differ significantly between heated and unheated arms of Lake Sangchris (i.e., spatially)(Waite, 1981). Thermal loading was noted to be associated with a decrease in both biomass and abundance. Thermal effluents at Lake Sangchris, however, provided for enhanced zooplankton communities during autumn, winter and spring.
- Related studies performed by Heidinger *et al* (2000) on Newton Lake found that zooplankton densities varied widely among segments within the lake, but there were no specific trends between seasons, location or by water temperatures.
- The fact that the fish community of Lake of Egypt has remained similar and stable since the establishment of the lake suggests that the underlying trophic levels represented by zooplankton (food source for many fish species) and fish meroplankton have not been appreciably harmed by the thermal discharge. It is likely that any shifts that may have occurred in the standing crop or relative abundances of far-field community members have been naturally induced.
- The resident community in the Lake of Egypt has developed under the environmental conditions (i.e., heated influence in the downstream end of the lake) that are similar to the conditions that will persist in the future, and there has thus far been no indication of zooplankton community impairment. A wide-spread plant-induced shift in the composition of this biological component in the absence of a markedly altered thermal regime is therefore, unlikely.
- As with phytoplankton, members of the zooplankton community generally have short life spans and reproduce rapidly. If there were any temporary effects on the community, there are extensive areas outside the zone of thermal influence that could act as either refugia or sources of recolonization potential.
- Finally, the location of the discharge at the far downstream (north) end of the lake minimizes potential negative effects of the thermal plume constituting a barrier, or attractant, to the free movement of these organisms throughout the lake.

- Although no site-specific data have been collected to describe the zooplankton and meroplankton communities at Lake of Egypt, It is expected that the composition of zooplankton and meroplankton communities at Lake of Egypt would be similar to that of other regional cooling lakes. Some community compositional variations may exist between regions of the lake that are thermally influenced, but notable differences in community composition are expected to be localized to the mixing zone area. Potential variations in community structure beyond the mixing zone are likely to be insignificant in altering the overall trophic structure of the ecosystem. Accordingly, no significant disruption to related trophic levels or the biotic community at large is expected.

The unlikelihood of a detrimental impact on the existing zooplankton and meroplankton assemblages, coupled with the lack of a barrier to their movement indicate that the proposed site specific thermal standard will not cause appreciable harm to the balanced indigenous community for this biotic category.

4.3 Habitat Formers

The criteria to determine whether the site is a low impact area for habitat formers are as follows:

1. The heated discharge will not result in any deterioration of the habitat formers community, or that no appreciable harm to the balanced indigenous community will result from such deteriorations; and
2. The heated discharge will not have an adverse impact on threatened or endangered species as a result of impact upon habitat formers.

Habitat formers are organisms that provide cover, foraging, or spawning habitat for other species. In Lake of Egypt, the only organisms that could be considered habitat formers are the rooted aquatic macrophytes. No systematic studies of aquatic vegetation have been performed on Lake of Egypt. However, field observations have noted aquatic vegetation along shallow shorelines, particularly in the downstream (northern) end of the lake. This pattern is comparable to results reported by Moran (1981b). In ESE (1995), it was reported that communities in warmer areas of the upper Illinois River drainage were not impaired in comparison to the sampled communities in cooler areas. At the Lake of Egypt, areas supporting aquatic macrophytes are predominantly in the downstream portions of the system. Since these areas are relatively near the plant discharge, it suggests that the thermal effluent has not and will not result in the deterioration of the aquatic macrophyte community. The importance of this biological category to the balanced indigenous community largely consists of its use by small fish (i.e., forage species such as minnows and/or young-of-the-year of larger species). Since the fish community has remained stable and of similar composition since the establishment of the lake, it is reasonable to conclude that there has not been a deterioration of the habitat former community. Further, no threatened or endangered fish species are present in the Lake of Egypt, thus no adverse impact would be expected to species of concern even if the thermal discharge had a negative effect on habitat formers. Therefore, there is unlikely to be any appreciable harm to the balanced, indigenous community for this biotic category.

4.4 Shellfish and Macroinvertebrates

The criteria to determine whether the site is a low impact area for shellfish and macroinvertebrates are as follows:

1. There should be no reductions in the standing crops of shellfish or macroinvertebrates unless it can be shown that such reductions will cause no appreciable harm to the balanced indigenous community in the water body.

2. There should be no reductions in the diversity of this biological category unless it can be shown that the critical functions of the macroinvertebrate fauna are being maintained in the water body as they existed prior to the introduction of heat.
3. It must be shown that either: (a) macroinvertebrates do not serve as a major forage for the fisheries, (b) food is not a factor limiting fish production in the water body, or (c) drifting invertebrate fauna are not harmed by passage through the thermal plume.
4. The thermal plume does not impact areas that serve as spawning or nursery sites for important shellfish or macroinvertebrate fauna.

While no systematic studies of the shellfish or macroinvertebrate communities have been performed on Lake of Egypt, considerable rationale exists to support the conclusion that this is a low impact biotic component.

- Based on the characteristics of similar Illinois impoundments, there are no species of commercial or recreational value present in the lake. In other studies of central Illinois cooling lakes, results indicated that the macroinvertebrate communities were dominated by larvae from the insect order Diptera, oligochaetes and sphaerid clams (Webb, 1981; Heidinger et al., 2000). Macroinvertebrate taxa found in the Lake of Egypt in the 2007 impingement study included the Asiatic clam *Corbicula*, the crayfish *Orconectes*, and the grass shrimp *Palaemonetes*. None of these are state or federally listed species.
- The area of thermal influence is very small in relation to the 2,300-acre lake. Additionally, there is a deep, hypolimnetic area in the vicinity of the thermal discharge, which is less thermally affected than surface or near-surface waters. Within and beyond the mixing zone the thermal plume is mostly surficial, and does not markedly elevate the temperatures of the benthic environment, even under stressed conditions. Consequently, no reductions in the standing crop or diversity of the benthic community are expected. Webb (1981) reported that, in Lake Sangchris in central Illinois, macroinvertebrate assemblages were similar between areas influenced by thermal discharge and uninfluenced control areas, and it is similarly unlikely that a substantial detrimental influence exists in the Lake of Egypt.
- Although macroinvertebrates likely serve as an important forage component in Lake of Egypt, the relative stability of the fish community in terms of composition and abundance indicate that food availability does not limit fish production. Plankton is another critical subset of the forage base, supporting the threadfin and gizzard shads that are important prey of the lake’s piscivores. Benthic invertebrate abundance therefore is not a major factor limiting the production of fish species such as largemouth bass.
- As for the last item in the criteria for this biotic category, since there are no important (i.e., commercially or recreationally important) shellfish or macroinvertebrate species in the Lake of Egypt, there are no spawning or nursery sites associated with them. The lack of a reduction in the abundance or diversity of shellfish and macroinvertebrates, and the absence of a barrier to the free movement of these organisms formed by the thermal plume combine to indicate that there has been, and will continue to be, no appreciable harm to the balanced indigenous community for this biotic category.

4.5 Fish

The most important biotic category, in terms of economic importance and sensitivity to alterations in the thermal conditions of the lake, is the fishery. Numerous fisheries investigations have been conducted on Lake of Egypt within the past 30 years; but these have primarily focused on game fish and issues relating to recreational fishing and were used to support management recommendations for the fishery (Heidinger 1988, 1990, 2007). Data from these studies included general population assessments for each target sport fish species as well as age and growth characteristics. Information contained in these reports is valuable in terms of characterizing the fish community prior to 2003. From 2005 through 2007, AMEC performed fish surveys using electrofishing, seining, and gill netting methods in the Lake of Egypt, and collected impingement samples from the intake of the Marion Plant. AMEC performed additional electrofishing surveys in 2010. Information from the MACTEC studies will be used to characterize the Lake of Egypt fish community after the 2003 boiler replacement at the Marion Plant.

4.5.1 Composition and Abundance of Fish Communities Before and After the 2003 Boiler Replacement

A comparison of fish species encountered in studies of the Lake of Egypt prior to, and after, the boiler replacement at the Marion Plant in 2003 is presented in Table 4-1. The pre-replacement data were collected from 1997 through 1999 (Heidinger et al., 2000), and the post-replacement data were collected from 2005 through 2007 and in 2010. Species composition was similar between these periods, as 23 of 31 species were collected in both periods. The exceptions were limited to species that are only present in low numbers in the lake. The fish community includes pelagic species (i.e., gizzard shad, threadfin shad, hybrid striped bass, white bass), species commonly associated with littoral habitats (i.e., largemouth bass, crappies, and sunfishes), and species more commonly characterized as benthic-dwelling (i.e., channel catfish, yellow bullhead, and darters). The lake has been compositionally dominated by centrarchids (ten species), with no other family represented by more than four species.

Electrofishing surveys performed in 1997 and 1998 (Heidinger et al., 2000) and in 2005, 2006, and 2010 (MACTEC, 2007) (Appendix A) and the present study) indicate that compositionally, the fish community in the Lake of Egypt has remained similar. Bluegill, redear sunfish, and largemouth bass have consistently been the most abundant species (see Table 3-4). Longear sunfish has also been consistently common and occasionally abundant. Other species that have occasionally been common include gizzard shad, green sunfish, and white crappie. The pelagic community members are not as vulnerable to the sampling gear, and their numbers are likely underestimates of their actual abundances. Annual variation in their numbers is not necessarily indicative of a shift in community composition.

Table 4-1. Fish Species Collected from Lake of Egypt Prior to and After the 2003 Boiler Replacement at the Marion Power Plant

Species	Common Name	Before Replacement*)	After Replacement†
Dorosoma cepedianum	Gizzard shad	X	X
Dorosoma petenense	Threadfin shad	X	X
Cyprinus carpio	Common carp	X	X
Notemigonus crysoleucas	Golden shiner	X	X
Opsopoedus emiliae	Pugnose minnow		X
Pimephales notatus	Bluntnose minnow	X	
Minytrema melanops	Spotted sucker	X	X
Ameiurus melas	Black bullhead		X
Ameiurus natalis	Yellow bullhead	X	X
Ictaluras notatus	Channel catfish	X	X
Noturus gyrinus	Tadpole madtom	X	X
Esox americanus	Grass pickerel	X	X
Esox niger	Chain pickerel	X	
Fundulus notatus	Blackstripe topminnow	X	X
Gambusia affinis	Mosquitofish	X	X
Labidesthes sicculus	Brook silverside	X	
Menidia beryllina	Inland silverside	X	X
Morone chrysops	White bass	X	X
Morone chrysops x saxatilis	White x striped bass	X	
Lepomis cyanellus	Green sunfish	X	X
Lepomis gulosus	Warmouth	X	X
Lepomis humilis	Orangespotted sunfish	X	X
Lepomis macrochirus	Bluegill	X	X
Lepomis megalotis	Longear sunfish	X	X
Lepomis microlophus	Redear sunfish	X	X
Micropterus punctulatus	Spotted bass	X	
Micropterus salmoides	Largemouth bass	X	X
Pomoxis annularis	White crappie	X	X
Pomoxis nigromaculatus	Black crappie	X	X
Etheostoma flabellare	Fantail darter		X
Percina sp.	Darter sp.	X	

* *Heidinger et al. (2000) – study utilized electrofishing and seining.*

† *MACTEC (2007) and the present study – studies utilized electrofishing, impingement collections, gill netting, and seining.*

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4.5.2 Results of 2010 Fish Surveys

4.5.2.1 Temporal Comparison

Electrofishing surveys were performed at nine stations in the Lake of Egypt in 2010 with five stations in the lower and 4 in the upper sections of the lake (Figure 4-1). The five stations in the lower section of the lake were subdivided into two subsets to reduce the handling stress on collected fish. A total of 2,241 fish representing 16 species and one hybrid were collected (see Table 3-1). Bluegill was the dominant species by number in both July and August collections. Longear sunfish and largemouth bass were second and third, respectively, in terms of abundance in both months. Other common species were redear sunfish, green sunfish, and warmouth. Threadfin shad and yellow bullhead were common in July, but not in August. Taxonomic richness was similar between months, with 13 and 15 species collected in July and August, respectively. The average lengths of most species increased slightly between July and August collections (see Table 3-3). The exceptions to this pattern included inland silverside, warmouth, longear sunfish, hybrid sunfish, and black crappie. Biomass was greater in July for most species. The exceptions to the trend were common carp, black bullhead, redear sunfish, sunfish hybrid, largemouth bass, and black crappie.

4.5.2.2 Spatial Comparison

Most common or abundant species (i.e., bluegill, redear sunfish, and largemouth bass) had similar catch rates between the upper and lower portions of the lake (see Table 3-2). However, the catch rates of threadfin shad, channel catfish, green sunfish, longear sunfish, and black crappie were considerably greater in the upper lake. In contrast, black and yellow bullheads were collected more frequently in the lower lake. Differences in the average lengths of various species between lake sections were generally slight, and likely reflected random variation. The exception to this pattern was largemouth bass, for which individuals averaged 331 millimeters (mm) in the lower lake as opposed to 281 mm in the upper lake. This appeared to reflect the greater abundance of large individuals near the spillway, which is in the lower lake immediately northeast of the discharge, in comparison to all other areas surveyed. Largemouth bass abundance was greater in this area despite its higher water temperatures. The nearshore habitat at this station consisted primarily of riprap, and the spaces between these large rocks were preferred habitat for many species, including largemouth bass and the forage species they preyed on. Biomass for most species paralleled the spatial pattern of catch rates. In instances where catch rates were similar but biomass was greater in the lower lake (e.g., bluegill, redear sunfish, and largemouth bass), it reflected the greater amount of sampling effort expended there (ten stations versus four stations in the upper lake).

Spatial patterns evident in the 2010 surveys were comparable to those of previous studies, and indicate that the fish community in the Lake of Egypt has remained stable over the 12- to 13-year period considered. For example, bluegill, redear sunfish, and largemouth bass have consistently been among the most abundant species in the lake (see Table 3-4). Between-year variability in the abundances of these species is likely associated with factors such as differences in the amount of sampling effort and natural variation in recruitment success. No persistent pattern of increase or decrease over time was noted for these species.

4.6 Other Vertebrate Wildlife

The criteria to determine whether the site is a low impact area for other vertebrate wildlife are as follows:

- It must be shown that the site is one of low potential impact for other (i.e., non-fish) vertebrate wildlife and
- that they will not suffer appreciable harm from plant operations.

Sport species such as ducks (e.g., mallard, wood duck) and Canada geese are commonly observed on Lake of Egypt, along with other waterfowl such as herons and various shorebirds (L. Hopkins, SIPC, personal communication). Migratory waterfowl such as teal, scaup, mergansers, and other species are expected to use Lake of Egypt during the spring and fall as foraging/resting areas. Beaver and muskrat lodges have not been observed, suggesting that they are either uncommon or not present at Lake of Egypt. In other studies of wildlife use on lakes used for cooling, Sanderson and Anderson (1981) found that winter concentrations of waterfowl were approximately equal on areas of Lake Sangchris that were influenced by thermal discharge and on uninfluenced areas.

The observed use of the Lake of Egypt by numerous species of wildlife, coupled with the lack of negative effects of plant operations on truly aquatic species, indicate that the proposed thermal standard will not cause appreciable harm to the balanced indigenous community for this biotic category.

5.0 Engineering and Hydrological Data

5.1 Hydrological Data

Physicochemical (i.e., water temperature, dissolved oxygen, and water depth) and fisheries data collected from Lake of Egypt in previous years as well as the results of surveys and temperature measurements made in 2010 were available for this evaluation. Heidinger et al. (2000) documented the occurrence of lake stratification with regard to temperature in the vicinity of the intake structure (Figure 5-1). During their period of measurement (1998-1999), the lake in this area was stratified for nearly the entire year. The exception occurred in March, during a period in which Midwestern lakes generally undergo mixing and turnover. The normal seasonal pattern of higher temperature/lower dissolved oxygen concentrations in the summer and the inverse pattern of these conditions in the winter are illustrated in Figures 5-2 and 5-3. Measurements taken at the surface near the intake structure indicated that water temperature ranged from winter lows in the upper 40°s to summer highs in the low 90°s. Near surface dissolved oxygen levels generally exceeded 8 milligrams per liter (mg/L) in the spring and summer months, but occasionally decreased to below 5 mg/L in late summer and early fall.

5.1.1 Water Temperature

Water temperature profiles were measured along five transects on June 12, August 1, and September 6, 2006 (MACTEC, 2007). In mid-June, surface water temperatures greater than 5°F above ambient levels were estimated to be present over a 4.5-acre area within the historic 26-acre mixing zone (Figure 5-4). Temperatures at the edge of the mixing zone were approximately 84°F and values along all transects were well below the 90°F allowable maximum. In early August, surface temperatures were greater than 5°F above ambient over an area of approximately 80 acres (Figure 5-5). At the edge of the mixing zone, the temperature was approximately 98°F, and temperatures were above 95°F at all locations along each transect. In early September, the area where temperatures exceeded 5°F above ambient was approximately 63 acres (Figure 5-6). The temperature at the edge of the mixing zone ranged from 90 to 92°F, and temperatures in the mid-80s were present in the intake cove and across the lake from the thermal discharge. Tables summarizing temperature measurements at each transect and depth location are provided in Appendix B.

Water temperature measurements were taken concurrently with fisheries and bathymetric surveys in July and August, 2010. Surface temperatures measured on July 14, 2010 decreased from approximately 98°F at the discharge to approximately 94°F at the eastern edge of the mixing zone (Figure 5-7). Temperatures in the lower portion of the lake, but outside the mixing zone, decreased to the upper 80s in the intake cove (Figure 5-8). Otherwise, surface temperatures remained near or above 90°F within the approximately 150-acre area of the lower lake where measurements were taken. Water temperatures were measured at depths of 2 and 8 feet at each of the electrofishing sampling stations during fisheries surveys in July and August 2010 (see Figure 2-1). Water temperatures at sampling stations in the lower portion of the lake (Stations 1 through 5) ranged from 91 to 94°F in July and from 88 to 101°F in August

(Table 5-1). Stations in the upper portion of the lake varied between 85 and 88.5°F during both survey periods. Variation in water temperature between depths was substantial at Stations 2 through 5 in mid-August, with differences ranging from 3.1 to 7.6°F. In late July, however, differences between depths at stations in the lower lake did not exceed 1.5°F. In the upper lake, temperature variation between depths was less than 1°F at Stations 6, 7, and 9. At Station 8, a larger depth difference (2.1 to 2.7°F) was measured in both July and August.

Table 5-1. Water Temperature (°F) at Depths of 2 Feet and 8 Feet near Electrofishing Stations in Lake of Egypt, July and August 2010[a]

Station	July 22, 2010		August 17, 2010	
	2 feet	8 feet	2 feet	8 feet
Lower Lake				
1	94.3	94.1	90.1	88.3
2	94.3	94.3	94.5	88.9
3	93.9	93.0	100.6[b]	93.0
4	93.4	91.9	95.9	92.8
5	92.3	90.9	95.9	89.1
Upper Lake				
6	88.2	88.2	87.8	87.6
7	87.4	86.9	88.5	87.3
8	88.0	85.3	88.5	86.4
9	87.3	87.4	88.2	87.4

[a] No fish kills were noted during either the July or August surveys.

[b] Measurement was taken inside the mixing zone, near the discharge outfall.

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5.1.2 Bathymetry

The Lake of Egypt is a relatively narrow 2,300-acre water body with several tributary branches (see Figure 1-1). The lake is approximately 6.2 miles long from the dam on the northern end (lower lake) to its most upstream southeastern extent (upper lake). AMEC performed a bathymetric study of the lower end of the Lake of Egypt in July 2010 to provide more specific information as to the physical configuration of the discharge area, mixing zone and lower lake. As is illustrated in Figure 5-9, the bathymetric study indicates the narrowness of the shallow (less than [<] 10 feet) nearshore littoral zone habitat in the lower half of the lake. Extensive areas of water 25 to 40 feet deep are present in the main body of the lake, including the cove containing the intake structure. The cove into which the heated effluent is discharged, however, primarily consists of water less than 20 feet in depth. This area is characterized by a very shallow fringe area (2 to 5 feet in depth) that surrounds a central channel with depths ranging from 10 to 25 feet. This depth trend is also present in the other two major coves in the upper half of the lake.

5.2 Hydrothermal Modeling

5.2.1 Introduction

The objective for this modeling effort was to provide information for the Lake of Egypt for both potential summer and winter conditions that would result in higher than normal seasonal water temperatures due to maximum heat loading and infrequent summer and winter weather climate conditions. Model results were then used to provide water temperature information and supporting information for the assessment of the Marion Power Plant impacts on the Lake of Egypt aquatic biota.

Critical warm water temperatures occur during the dry late summer months when surface inflows to the lake and outflows from the lake are low. For late summer model conditions it was assumed that the Lake of Egypt behaves essentially as a closed system with little water inflow and outflow relative to lake volume during those critical seasonal periods. Lake temperatures are determined by the lake volume, surface area, mixing, interaction with climatic conditions, and the plant's thermal discharge. To predict potential future thermal conditions associated with the cooling water discharged from the SIPC Marion power plant to the Lake of Egypt, a hydrodynamic and transport model of the lake was used. The model calculates an energy balance based on lake mixing and surface heat losses (or gains) from three-dimensional cells formed by a horizontal grid and vertical layers. The lake model was developed using the Generalized Longitudinal Lateral Vertical Hydrodynamic Transport (GLLVHT) which is described in Edinger (2002). The GLLVHT model uses the same computational algorithms and is a fixed input parameter version of the model Generalized Environmental Modeling System for Surface waters (GEMSS), a time-varying, finite difference numerical model.

A hydrodynamic model was selected for this analysis because of the configuration of the Lake of Egypt and the hydrodynamic and hydrologic conditions. A plume type of model, while applicable to a near-field area within the northern end of the lake, would not be able to model the overall lake configuration, including boundaries, and would not be appropriate to analyze far-field thermal conditions for this water body.

GLLVHT model inputs include lake bathymetry, climate parameters, boundary conditions including heat input sources, and initial water temperature profile. Bathymetric data for the lake obtained by AMEC as described above were discretized into 500 ft squares forming an X-Y grid. Vertical layers of uniform depth (18 inches) were used to complete the three-dimensional representation of the water body. Weather/climatic data used as input for the model included dewpoint temperature, wind direction and velocity, and solar radiation. These inputs are used to calculate circulation and to estimate the temperature of the lake surface at equilibrium using a heat balance for the lake. Heat losses (or gains) from the lake surface and between individual layers in the lake profile are tracked and water temperatures updated at a six minute time step interval by the model.

Initially, a time period ending July 22, 2010, was simulated to calibrate the model to lake temperatures measured on that date. AMEC used weather data from the Illinois Climate Network for Carbondale (SIU station) and plant operating data to simulate lake temperatures for July 2010. Lake temperature data collected July 22, 2010 and cooling water discharge temperature data from the corresponding period were used to calibrate the predicted temperatures made by the model. Agreement between measured field temperatures and model simulation results provided confidence in the predictive modeling simulations. After completion of model calibration, AMEC used the model to predict lake water temperatures during summer (end of July 2010) and winter (late February 2011).

Following calibration of the model to match July 22, 2010 conditions, a simulation was performed with the model to assess potential lake temperatures under more extreme weather conditions. A similar simulation of lake temperatures was also made using observed plant cooling water discharge temperatures, flow rates, and weather data from late February 2011. However, the only lake water temperature data available for the winter period was the cooling water intake temperature, which was presumed to be representative of the lake. No field measurements of thermal profiles within the lake were available for the winter period.

These potential less typical conditions, summer or winter, are referred to as “stressed” conditions in the discussion below, reflecting a set of weather/climatic conditions for each, that are considered to be rarely exceeded in terms of potentially generating warmer lake temperatures. The simulation did not include any increase in generation capacity or thermal load to the lake from SIPC plant operations. As described in Section 5.2.3.6, supplemental modeling was performed in response to comments by the Illinois Environmental Protection Agency (IEPA) to evaluate thermal conditions during transitional months in both the spring and fall.

The development of model inputs, calibration and predictions are described in greater detail in Sections 5.2.2 and 5.2.3.

5.2.2 Model Inputs

Inputs used by the GLLVHT model include:

- Lake Bathymetry – Lake boundaries were approximated by a rectangular grid representing the horizontal and vertical dimensions of the lake. The Lake of Egypt model used 26 vertical layers.
- Lake Inflow/Outflow – Hydrologic inputs to and outflows from the lake, including both surface and groundwater flows, were assumed to be zero during both summer and winter modeled conditions based on review of long-term stream flow records of regional U.S. Geological Survey monitored streams and review of Lake of Egypt observed water levels that are often below the spillway level.
- Climatic Conditions – Climatic parameters including solar radiation, wind speed and direction, and dew point temperature were used to determine model inputs. Inputs for observed conditions/calibration scenarios used summer weather for the 30 days prior to

July 22, 2010 and a similar time period during February 2011. For the stressed condition, statistical estimates of these parameters were made from a local long-term meteorological station (Section 5.2.2.2).

- Heat Load to the Lake – The quantity of heat discharged in cooling water circulation was determined from plant measurements of cooling water flow rate and temperature rise during July 2010 and February 2011.
- Initial Water Temperatures – The initial water temperatures in the lake, which were uniform laterally but varying with depth, were based on water temperature measurements made June 12, 2010 for the summer model; only intake temperatures were available for the February model and the temperature profile was assumed based on literature values for winter lake temperatures.

5.2.2.1 Model Grid

Two model grids were developed such that the first covers the entire lake with 500-foot by 500-foot [(152 meters (m) by 152 m)] grid cells. A second grid covering the lower half of the lake was developed with 230 feet by 230 feet (70 m by 70 m) grid cells. The shape of the lake was approximated by superimposing the grid cells over an outline of the lake shoreline obtained from a U.S. Geological Survey 1:24,000 scale topographic map of the lake. Lake bathymetry was based on results of mapping conducted in July 2010, available topographic information, and supplemented with data from fishing maps. Maximum lake depth used in the model was 40 feet (12.2 meters) and the water column was discretized into a maximum of 27 layers of 18 inches (0.457 m).

5.2.2.2 Weather Conditions

Weather conditions are not used directly as model inputs. Solar radiation, wind speed, and dew point temperature are instead used to calculate a Coefficient of Surface Heat Exchange (CSHE) and a surface equilibrium temperature (T_{eq}) for the lake that become input for the model . The CSHE, in units of Watts/square meter/°C, is the rate at which heat is gained or lost at the lake surface. When lake surface temperature is above the equilibrium temperature, the lake loses heat to the atmosphere at the rate of CSHE times the temperature difference between the lake equilibrium temperature and the actual lake water temperature. A positive value corresponds to lake warming and a negative value results in cooling of the lake surface. Twenty-two years of daily weather data (1990 to 2012) were obtained from the SIU–Carbondale weather station, which is operated as part of the Illinois Climatic Network (ICN) – Water & Atmospheric Resources Monitoring (WARM) Program–www.isws.illinois.edu/warm/datatype.asp. For development of the T_{eq} input forthe stressed conditions models, daily data for the summer months (June 1 to August 31) and winter months (January 1 to March 31) were used to calculate themaximum 30-day running average T_{eq} value for both summer and winter periods during each year. A frequency analysis was performed on each series to estimate the probability of exceedance. Model inputs for summer and winter conditions were based on the 95% non-exceedance event corresponding to an average occurrence frequency of approximately once in 20 years. However, following the occurrence of a March 31, 2012 30-day average T_{eq} value of 18.2°C (64.8°F), the winter stressed condition T_{eq} value selected was

17.0°C (62.6°F). Results are shown in Table 5-2. The T_{eq} values are given as both percentile values and the annual non-exceedance probability from frequency analysis. A 30-day averaging period is appropriate for use in the Lake of Egypt equilibrium model with constant inputs. Additional discussion of T_{eq} relationships to the model and modeling of transition conditions during fall and spring is provided in Appendix F.

5.2.2.3 Generating Plant Heat Load

An important input variable in determining temperature impacts of the Marion Power Plant on the lake is the heat load to the lake resulting from the discharge of power plant cooling water. Heat load to the lake under "normal" conditions was based on power plant records from July 2010. For the stressed conditions, heat loads were calculated from plant data (cooling water intake and discharge temperatures and flow rates) recorded for January through February 2011 (winter) and July through August 2010 (summer). These plant data are recorded at four-hour intervals. The stressed condition model heat load inputs were 724 MW for summer and 674 MW for the winter period. These values are approximately equal to the maximum 14-day running average heat loads for the winter 2011 period and summer 2010 period and are equal to the 68th percentile values (Tables 5-3 and 5-4) of the instantaneous heat load rates during those same periods (i.e., approximately one-third of the instantaneous heat load values in each case exceeded the heat load used for the stressed condition model). The standard deviations of the instantaneous data values for these winter and summer periods were 39 MW and 61 MW, respectively, or approximately 6 percent and 9 percent of the mean values for these periods.

5.2.2.4 Initial Conditions

Water temperature profiles were collected at ten lake locations on June 12, 2010. The profiles began 9000 feet upstream from the dam and extended towards the dam. These temperatures were used to establish the initial water temperatures in the model layers at the start of summer simulated conditions. For the February 2011 model scenario, only cooling water intake temperatures were available during January and an initial temperature profile was estimated.

5.2.2.5 Model Sensitivity

The model uses an energy balance approach to simulate lake temperatures. The thermal mass of the volume of water in the lake (estimated to be 41,400 acre-ft) makes the model relatively insensitive to small variations in thermal loading to the lake over the 30-day period simulated. Solar radiation, cloud cover, dew point temperature, and wind are used to calculate the two weather related model inputs: equilibrium temperature (T_{eq}) and the coefficient of surface heater exchange (CSHE). Modeled lake temperatures were found to be most sensitive to the input value used for T_{eq}. An increase of 1°C used for T_{eq} in the model resulted in nearly a 1°C increase in the lake temperature simulated. The calculated equilibrium temperature was reduced by 1.0°C as part of model calibration to provide a better fit of simulated temperatures to July and August 2011 measured temperatures. In contrast, lake temperatures were found to be relatively insensitive to values used for the CSHE. Increasing the CSHE by 33 percent from 30 to 40 Watts per square meter per degree Celsius ($W/m^2/°C$) showed no impact on maximum surface temperature near the outfall and reduced the surface temperatures for mid and upper lake areas by roughly 0.8°F (0.4°C).

5.2.3 Model Results

The model was used to simulate two summer and two winter lake conditions. Summer weather conditions and lake temperatures for July 2010 were used to calibrate the model. Summer and winter "stressed" scenarios were developed to represent relatively infrequent but not extreme summer and winter weather conditions. Model inputs for the two scenarios are shown in Table 5-5 and Table 5-6. A comparison of the model predicted summer 2010 temperatures with measured temperatures is provided in Table 5-7.

Table 5-2. Summary of Percentile Data and Non-Exceedance Probability Estimates for 30-day Running Average

Percentile	Summer (Jun-Aug 1990-2012)		Winter (Jan-Mar 1990-2012)	
	Lake Surface Equilibrium Temperature (T_{eq}) °F	Coefficient of Surface Heat Exchange (CSHE) (W/m²/°C)	Lake Surface Equilibrium Temperature (T_{eq}) °F	Coefficient of Surface Heat Exchange (CSHE) (W/m²/°C)
100%	91.6 (33.1 °C)	34.8	64.8 (18.2 °C)	23.9
95%	90.7 (32.6 °C)	31.0	58.3 (14.6 °C)	22.8
90%	89.8 (32.1 °C)	29.7	55.6 (13.1 °C)	22.0
80%	89.4 (31.8 °C)	28.6	54.5 (12.5 °C)	21.1
60%	87.4 (30.8 °C)	27.4	53.1 (11.7 °C)	18.7
50%	87.2 (30.7 °C)	26.9	52.5 (11.4 °C)	17.5
40%	86.2 (30.1 °C)	26.4	51.4 (10.8 °C)	16.1
20%	83.9 (28.8 °C)	25.3	50.4 (10.2 °C)	13.5
10%	83.4 (28.6 °C)	24.6	49.8 (9.9 °C)	13.0
5%	83.2 (28.4 °C)	23.9	47.1 (8.4 °C)	12.5
Annual Probability of Non-Exceedance				
99%	95.0 (35.0 °C)		64.8 (18.2 °C)	
98%	93.6 (34.2 °C)		62.6 (17.0 °C)	
96%	92.1 (33.4 °C)		60.6 (15.9 °C)	
95%	91.6 (33.1 °C)		59.9 (15.5 °C)	
90%	90.1 (32.3 °C)		57.7 (14.3 °C)	
80%	88.7 (31.5 °C)		55.4 (13.0 °C)	

Table 5-3. Heat Load to Lake of Egypt for January – February 2011

	Flow	Delta T		Heat Discharged to Lake (MW)				
				From Percentile Data[a]	From Plant Time Series Data[b]	Running Averages[b]		
Percentile	MGD	°F	°C			7-day	14-day	30-day
0%	186.9	26.0	14.4	494.0	532.0	602	612	638
5%	186.9	30.0	16.7	570.0	570.0	606	618	642
10%	186.9	31.0	17.2	589.0	589.0	612	621	643
20%	186.9	32.0	17.8	608.0	608.0	628	638	646
25%	186.9	32.0	17.8	608.0	617.4	643	650	647
30%	186.9	33.0	18.3	626.9	626.9	651	656	650
40%	186.9	34.0	18.9	645.9	645.9	656	658	656
50%	186.9	34.0	18.9	645.9	650.7	658	660	658
60%	186.9	35.0	19.4	664.9	664.9	662	662	660
68%	186.9	36.0	20.0	683.9	674.4	664	662	662
70%	186.9	36.0	20.0	683.9	674.4	664	662	662
75%	186.9	36.0	20.0	683.9	674.4	665	663	662
80%	186.9	36.0	20.0	683.9	683.9	666	663	662
90%	186.9	37.0	20.6	702.9	693.4	668	665	663
95%	186.9	37.0	20.6	702.9	702.9	672	667	664
100%	249.1	38.0	21.1	962.3	721.9	675	670	665

[a] Heat load from percentile flow and temperature data

[b] Percentile values of time series heat load as calculated from time series constructed from filtered plant records

Table 5-4. Heat Load to Lake of Egypt for July– August 2010

	Flow	Delta T		Heat Discharged to Lake (MW)				
				From Percentile Data[a]	From Plant Time Series Data[b]	Running Averages[b]		
Percentile	MGD	°F	°C			7-day	14-day	30-day
0%	277.0	16.0	8.9	450.4	561.8	654	664	686
5%	290.9	18.0	10.0	532.2	605.4	656	667	687
10%	290.9	19.0	10.6	561.8	606.1	663	669	687
20%	290.9	20.0	11.1	591.4	635.7	672	674	688
25%	290.9	20.0	11.1	591.4	650.5	674	678	689
30%	290.9	21.0	11.7	620.9	650.5	679	679	689
40%	290.9	22.0	12.2	650.5	680.1	681	685	690
50%	290.9	22.0	12.2	650.5	708.4	692	698	692
60%	290.9	23.0	12.8	680.1	706.4	695	700	694
68%	290.9	24.0	13.3	709.6	724.4	703	701	695
70%	290.9	24.0	13.3	709.6	739.2	706	703	695
75%	290.9	25.0	13.9	739.2	739.2	716	706	698
80%	290.9	25.0	13.9	739.2	742.2	720	712	699
90%	290.9	26.6	14.8	786.5	770.2	729	719	703
95%	290.9	27.0	15.0	798.3	798.3	733	721	704
100%	290.9	29.0	16.1	857.5	842.7	749	722	706

[a] Heat load from percentile flow and temperature data – 4-hour time series value

[b] Percentile values of time series heat load as calculated from time series constructed from filtered plant records

Table 5-5. Summary of Model Inputs for Lake of Egypt Thermal Simulations – Summer

Input Parameter	July 2010		Stressed Condition	
	Value	Source	Value	Source
Wind Direction	From South	Predominant wind direction	From South	Prevailing summer wind direction
Wind Speed	2.14 m/s	Avg. Wind Speed during 30 days prior to 7/22/2010	1.68 m/s	20% non-exceedance probability for 30-day running average for January through March (1990 to 2011)
Cooling Water Discharge	291 MGD (12.74 m^3/sec)	30-day average calculated from Plant data for June-July 2010	291 MGD (12.74 m^3/sec)	Maximum 14-day running average for Jun-July 2010
Temperature Rise in Discharge Water	20.5 ºF (11.4 °C)	Avg. calculated from Plant Data June-July 2010	24.5 ºF (13.6 °C)	Estimated from plant data, cooling discharge, and plant generating capacity
Coefficient of Surface Heat Exchange	28.8 W/m^2/°C	Calculated from weather data for June-July 2010 normal weather inputs	28.8 W/m^2/°C	Calculated from stressed weather inputs
Lake Equilibrium Temperature	30.2 °C	Calculated from normal weather inputs	91.4 ºF (33 °C)	Calculated from stressed weather inputs
Heat Load Added to Lake	608 MW	Calculated from cooling water discharge and temperature rise	724 MW	Calculated from cooling water discharge and temperature rise
Simulation Time	30 days	steady state model	30 days	Steady state model
Horizontal Grid Size	500'x500' and 230'x230'	Entire lake and upper 1/3 included	500'x500' and 230'x230'	Entire lake and upper 1/3 included
Vertical Layers	27 layers (18 in. deep) (500'x500' grid 24 layers (20 in. deep)	Maximum lake depth 40 feet (12.2 m)	27 layers (18 in. deep) (500'x500' grid	Maximum lake depth 40 feet (12.2 m)
Initial Lake Temperature Conditions	29.2 ºC (surface) to 14.0 ºC (bottom)	Averaged from 10 temperature profiles collected June 12, 2006 in lower lake	Same as for July 2010 simulation	Averaged from 10 temperature profiles collected June 12, 2006 in lower lake

W/m^2/°C= watts per square meter per degree
°C = degrees Celsius
m^3/sec = cubic meters per second

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Checked by: DWI/10-2-2013

Table 5-6. Summary of Model Inputs for Lake of Egypt Thermal Simulations – Winter

Input Parameter	Normal Conditions		Stressed Conditions	
	Value	**Source**	**Value**	**Source**
Wind Direction	From West	Avg. wind direction Jan-Feb 2011	From West	Prevailing winter wind direction
Wind Speed	7.7 mph (3.46 m/s)	30-day avg. wind speed for Jan-Feb 2011	5.8 mph (2.61 m/s)	10% non-exceedance probability for 30-day running average for January through March (1990 to 2011)
Cooling Water Discharge	187 MGD (8.19 m^3/sec)	Cooling water discharge Jan-Feb 2011	187 MGD (8.19 m^3/sec)	Cooling water discharge for Jan-Feb 2011
Temperature Rise in Discharge Water	34.7 ºF (19.3 ℃)	Cooling water temperature rise Feb 2011	35.5 ºF (19.7 ℃)	Maximum 14-day running average for Jan-Feb 2011
Coefficient of Surface Heat Exchange	16.9 W/m^2/℃	Calculated from 30 day avg. weather data Jan-Feb 2011	19.0 W/m^2/℃	Calculated for stressed weather inputs
Lake Equilibrium Temperature	41 ºF (5.0 ºC)	Calculated from30 day avg. weather data Jan-Feb 2011	62.6 ºF (17.0 ℃)	Calculated for 95% non-exceedance using annual maximum weather inputs (Jan-Mar 1990-2011)
Heat Load Added to Lake	660 MW	Calculated from cooling water discharge and temperature rise	674 MW	Calculated from cooling water discharge and temperature rise
Simulation Time	30 days	steady state model	30 days	Steady state model
Horizontal Grid Size	500'x500' and 230'x230'	Entire lake and upper 1/3 included	500'x500' and 230'x230'	Entire lake and upper 1/3 included
Vertical Layers	27 layers (18 in. deep) (500'x500' grid	Maximum lake depth 40 feet (12.2 m)	27 layers each 18 inch depth	Maximum lake depth 40 feet (12.2 m)
Initial Lake Temperature Conditions	2.9 to 4.0°C	January Lake Profile Temperatures estimated from literature	2.9 to 4.0°C	January Lake Profile Temperatures estimated from literature

W/m^2/°C = watt per square meter per degree Celsius
℃ = degrees Celsius
m^3/sec = cubic meters per second

Prepared by: CJE/9-26-2013
Checked by: DWI/10-2-2013

Table 5-7. Comparison of Model Predicted Water Temperatures with Measured Temperatures on July 22, 2012

Station	2 feet Depth			8 feet Depth		
	Measured	Simulated	Difference	Measured	Simulated	Difference
Lower Lake						
1	94.28	94.82	-0.54	94.28	94.64	-0.36
2	94.28	94.64	-0.36	94.10	94.46	-0.36
3	93.92	93.92	0.00	93.02	92.84	0.18
4	93.38	93.20	0.18	91.94	92.30	-0.36
5	92.30	93.20	-0.90	90.86	93.20	-2.34
Mean	93.63	93.96	-0.32	92.84	93.49	-0.65
Std. Dev.	0.83	0.77	0.43	1.45	1.02	0.97
Upper Lake						
6	88.16	91.04	-2.88	86.36	90.32	-3.96
7	87.44	87.62	-0.18	86.90	87.08	-0.18
8	87.98	86.72	1.26	85.82	87.08	-1.26
9	87.26	89.60	-2.34	87.44	86.72	0.72
Mean	87.71	88.75	-1.03	86.63	87.80	-1.17
Std. Dev.	0.43	1.95	1.92	0.70	1.69	2.03

All Temperatures in Table 5-7 are in degrees Fahrenheit

5.2.3.1 Summer Conditions-Baseline Scenario

The GLLVHT is a hydrodynamic steady-state equilibrium model that uses fixed-value input parameters. That is, climate and heat load to the lake are assumed to remain constant over a selected 30-day period in mid-summer. The T_{eq} value reflecting weather conditions was derived from 30-day running averages. Figure 5-10 illustrates lake surface temperatures generated by the model calibrated to measured temperatures under July 2010 (“normal”) weather conditions.

For conditions that occurred during July 2010, the model predicts a surface temperature of 95.0°F within the area of the 26-acre mixing zone, which decreases to 94.5°F near its outer boundary. Most of the lake, and all of the upper lake, remained at an ambient temperature near or below 94°F. These values are similar to field measurements recorded in mid-July 2010, but somewhat lower than field measurements collected from early August 2006 (see Section 3.1.1).

5.2.3.2 Summer Conditions-Stressed Scenario

Lake temperatures generated from inputs for the assumed “stressed” condition are illustrated in Figure 5-11. These inputs were modified to simulate stressed conditions for the lake, corresponding to:

- a warm summer with less cloud cover and higher humidity, low average wind speed; and
- Weather conditions based on an annual probability of non-exceedance of 95 percent, for the annual maximum 30-day running average, corresponding to an average return interval for these climatic conditions of 20 years.

Thermal load to the lake by the power plant was assumed to be 724 MW, based on the maximum thermal load that occurred during the July 2010 baseline simulation. The stressed model predicts an average surface temperature of 99.7°F for the area nearest the discharge. Surface water temperatures of 97°F or greater would be expected to be found throughout much of the lower lake. Under this scenario, surface temperatures for even the distant arms of the upper lake would be expected to exceed 90°F. The difference in predicted temperatures between the July 2010 and "stressed condition" models was an increase of approximately 6°F in the lower lake.

5.2.3.3 Winter Conditions-Normal Condition

Winter temperature conditions were simulated for late February 2011 using observed weather data and plant discharge heat input records from that date. Lake temperature data for this time period were not available; simulated lake temperatures were checked against plant temperature data from influent cooling water temperatures. Temperatures estimated from February 2011 weather and thermal loading show a maximum surface temperature in the lower lake of 52°F (Figure 5-12). Temperatures in the upper lake ranged from 40 to 49°F. The February 2011 weather parameters controlling predicted lake temperatures were near normal. The simulated lake water temperatures along cross section "B" demonstrate predicted values of approximately 48°F at mid-depth, which are similar to the recorded intake water temperatures.

5.2.3.4 Winter Conditions-Stressed Scenario

Surface temperatures for the simulation for stressed winter conditions are presented in Figure 5-13. The T_{eq} input value was taken from the 98 percent non-exceedance value of annual maximum 30-day T_{eq} values for January-March at Carbondale, Illinois between 1990 and 2012. A 30-day T_{eq} value of 64.8″F (18.2°C) occurred at the end of March 2012. It is also noted that the winter stressed condition simulation is based on climatic data extending to the end of March. Because March is included in the defined winter period, "winter" season temperatures are characterized by the warming temperatures evident in later March that are uncharacteristically high relative to the February 2011 results. Accordingly, the predicted surface temperatures for the "winter" stressed condition range from 16 to 18°F warmer than the February 2011 predicted temperatures (based on observed data), with the differences larger in the lower area of the lake than at the upper end.

5.2.3.5 Cross-Sectional Profiles of Each Scenario

Cross-sectional diagrams of model results under "normal" and "stressed" conditions are illustrated in Figures 5-14 and 5-15 for the summer period and in Figures 5-16 and 5-17 for the winter period.

For both summer model scenarios, cross sections within the mixing zone indicate that warmer water temperatures are closest to the discharge (see Figure 5-12). Water temperature decreases considerably with depth. The temperature reduction is generally 5 to 7°F from the surface to approximately mid-depth, then remains approximately uniform to the bottom. Otherwise, the patterns are nearly identical, but temperatures are approximately 7°F higher in the "stressed" scenarios. In the cross sections from outside the mixing zone, there is much less of a difference along the transverse axis (see Figure 5-13). The warmest water is in the center of the cross section, and generally cools approximately 2°F moving toward either shore. The depth profile again reflects a substantial decrease (3 to 4°F) from the surface to approximately one-third of the depth of the water column. The spatial patterns are very similar between the “normal” and “stressed” scenarios, with surface temperatures approximately 5 °F higher in the latter model.

5.2.3.6 Supplemental Modeling of Spring and Fall Conditions

As requested by IEPA, SIPC also performed supplemental modeling of spring (April through May) and fall (October through November) conditions to support the recommendation of adjusted criteria for these transitional periods between winter and summer. Modeling was performed in a manner similar to that described above for the winter and summer periods. However, the supplemental modeling was performed using additional recent operational data for these periods. Climatic inputs were based on 30-day running averages of conditions prior to May 31 (spring) and October 1 (fall). Results for this supplemental modeling work are presented separately in Appendix F and were used to recommend the adjusted thermal criteria described in Section 7.4.

6.0 Rationale for Proposed Alternate Effluent Limitation

6.1 Existing Permit Conditions

Currently, SIPC's NPDES permit requires that temperatures at the outside edge of its 26-acre mixing zone cannot exceed seasonally varying maxima (60°F in December through March; 90°F in April through November) for more than one percent of the hours in a 12-month period. Additionally, the permit requires that water temperature at the edge of the mixing zone cannot exceed these maxima by 3°F at any time. Section 316(a) of the CWA provides a process for modification of any effluent limitation proposed for the control of the thermal component of a discharge. Specifically, it states that when the power plant owner/operator can demonstrate that an effluent limitation is more stringent than necessary, then it can apply for a variance to its permit. In Illinois, authority under Section 316(a) to grant alternate thermal limits for heated effluent discharges to artificial cooling lakes has been delegated to the Illinois Pollution Control Board. Under Illinois regulations, the discharger must demonstrate that conditions in the artificial cooling lake receiving the heated discharge will be environmentally acceptable, and remain capable of supporting shellfish, fish, and wildlife. SIPC is seeking an alternate thermal limit applicable to the heated effluent from the Marion Power Plant to the Lake of Egypt. The results of this study, and previous studies, indicate that existing thermal limitations are more stringent than necessary, and that the plant's operations have caused no appreciable harm to the biological communities in the Lake of Egypt. Furthermore, no appreciable harm is expected as a result of the requested maximum temperatures.

6.2 Biothermal Assessment

6.2.1 No Anticipated Alteration of Lake of Egypt's Thermal Regime

SIPC does not anticipate any increase in thermal loading from plant operations to the Lake of Egypt. Accordingly, foreseeable future conditions and the resulting temperature regime will likely be consistent with those of the current conditions. In terms of the horizontal characteristics of the temperature regime, the areas in which warmer conditions occur are, and will continue to be, small in comparison to the rest of the lake. Additionally, current plant operations would not alter the vertical stratification of the lake under normal seasonal conditions. Even an increase in thermal conditions within the lake (e.g., as may occur in extreme climatological conditions) would be unlikely to have an effect on the horizontal or vertical characteristics of its thermal regime. As discussed in Section 2.1, under the present conditions, the lake is stratified with regard to temperature for much of the year (Heidinger et al., 2000), with deeper areas consistently available as thermal refugia.

6.2.2 Biotic Categories Eliminated from Detailed Consideration

Lake of Egypt is considered to be a "low impact area" for the biotic categories including phytoplankton, zooplankton and meroplankton, habitat formers, shellfish and macroinvertebrates, and other vertebrate wildlife. There is no evidence that the thermal discharge of the Marion Plant will cause appreciable harm to any of these categories. The lack of a community shift toward nuisance phytoplankton species and the presumed stability of the existing assemblages (e.g., no shift from a detritus-based community, no algal blooms after water quality improvements in the system) combine to indicate that there has been, and will be, no appreciable harm to the balanced indigenous community for this biotic category. The unlikelihood of a detrimental impact on the rapidly reproducing zooplankton and meroplankton assemblages, coupled with the lack of a barrier to their movement indicate that the proposed site specific thermal standard will not cause appreciable harm to the balanced indigenous community for this biotic category. Since the fish community has remained stable and of similar composition since the establishment of the lake, it is reasonable to conclude that there has not been a deterioration of the habitat former community. Further, no threatened or endangered fish species are present in the Lake of Egypt, thus no adverse impact would be expected to species of concern even if the thermal discharge had a negative effect on habitat formers. The lack of a reduction in the abundance or diversity of shellfish and macroinvertebrates, and the absence of a barrier to the free movement of these organisms formed by the thermal plume combine to indicate that there has been, and will continue to be, no appreciable harm to the balanced indigenous community for this biotic category. Finally, the observed use of the Lake of Egypt by numerous species of wildlife, coupled with the lack of negative effects of plant operations on aquatic species, indicate that the proposed thermal standard will not cause appreciable harm to the balanced indigenous community for this biotic category.

6.2.3 Representative Important Fish Species

The five representative important species considered in this study are each tolerant of warm summer temperatures. The following discussion is centered on summer thermal conditions as these are considered to be potentially more limiting to fish than winter conditions. Accordingly, summer lake surface temperature distribution data as presented in Table 6-1 are discussed in conjunction with published thermal tolerance data (Table 6-2). Even under “stressed” conditions, there would be extensive areas of suitable habitat available to them.

The upper incipient lethal temperature (UILT) tolerance range of threadfin shad is 93 to 97°F (Wrenn, 1975). Under the conditions of the hydrothermal model simulations discussed previously, this species would have almost no areas of the lake (of a total of 2,217) above the upper boundary of its tolerance range in “normal” summer conditions (see Table 6-1). Under “stressed” conditions, approximately 884 acres of the lake would be below the UILT range on the surface. However, considering the vertical aspect of the water column, the lower third of the lake within the mixing zone and the lower two-thirds of the lake outside the mixing zone would be within the temperature tolerance limits for threadfin shad. Additionally, there are no barriers to the movement of threadfin shad from areas that may be thermally less suitable to habitats characterized by cooler temperatures. Consequently, thermal conditions under the “normal” and “stressed” scenarios would not represent conditions in which the populations of this species are likely to be harmed.

Table 6-1 Lake of Egypt Surface Acreage[1] by Water Temperature (°F) in Normal and Stressed Summer Model Scenarios

Temperature	Normal	Stressed
<85	0	0
<86	655	0
<87	928	0
<88	1070	0
<89	1217	0
<90	1382	0
<91	1580	0
<92	1812	737
<93	2029	884
<94	2215	1029
<95	2217	1179
<96	2217	1382
<97	2217	1606
<98	2217	1892
<99	2217	2111
<100	2217	2217
<101	2217	2217
<102	2217	2217
<103	2217	2217
<104	2217	2217

[1] *Note: acreage totals are less than total lake surface area (approx. 2300 acres) due to model boundary inconsistencies*

Prepared by: BSM/10-2-13
Checked by: WJE/10-2-13

Table 6-2. Maximum Weekly Average Temperatures (°F) for Growth and Upper Incipient Lethal Temperatures (°F) of Representative Important Species

Species	MWAT (Growth)		UILT	
	Yoder [j]	Other Historical Literature	Yoder [j]	Other Historical Literature
Threadfin shad	--	--	--	91.9[a]
Gizzard shad	89.4	93.2[b]	96.4	97.7[f]
Channel catfish	92.3	93.2[i]	100.9	96.8[b]
				98.6[g]
				96.8[h]
Bluegill*	90.3	93.2[i]	97.5	98.6[b]
				100.9[e]
				106.7[c]
Largemouth bass	87.6	90.9[i]	94.1	96.8[b]
				98.1[c]
				99.1[d]
White Crappie	85.8	82[b]	90.5	91.4[b]
Black Crappie	86.0	81[b]	94.5	91.4[b]

Sources: [a]Monirian et al. (2010); [b]Brungs and Jones (1977); [c]Carlander (1977); [d]Fields et al. (1987); [e]Reutter and Herdendorff (1976); [f]WSU (1995); [g]Brown (1974); [h]Yoder and Gammon (1976); [i]ESE (1988); [j] Yoder and Rankin (2005) and Yoder et al. (2006).
**Note: Observed lower lake surface temperatures in which bluegill were represented by high catch rates ranged between 94 and 98 F.*

Prepared by: MCB 10-2-2013
Checked by: WJE 10-2-2013

For gizzard shad, the maximum weekly average temperature for growth (MWAT) and the UILT are considered to be 89°F and 96°F, respectively (see Table 6-2). Considering the predicted conditions from the model simulations discussed previously, this species would have almost no areas of the lake above the UILT threshold under normal summer conditions. Under “stressed” conditions, approximately 1,382 acres of the lake would be less than the UILT above this range on the surface. Additionally, approximately 1,217 acres of the lake would be less than the MWAT for gizzard shad under “normal” conditions, whereas no surface areas would be less than the MWAT value under the modeled “stressed” conditions (see Table 6-1). Even so, much more of the lake’s area would be suitable when considering deeper waters. Under “normal” modeled conditions, gizzard shad would have the lower half of the water column available inside the mixing zone and the entire water column available outside the mixing zone. Under the “stressed” model conditions, it is expected that gizzard shad would exhibit avoidance behavior of the mixing zone and near mixing zone areas, as no depths in the mixing zone and only waters deeper than 35 feet outside the mixing zone would be available in the lower half of the lake. Additionally, there are no barriers to the movement of gizzard shad from areas that may be thermally less suitable to habitats characterized by cooler temperatures. Consequently, thermal conditions under the “normal” and “stressed” scenarios would not represent conditions in which the populations of this species are likely to be harmed.

For channel catfish, the MWAT for growth and the UILT tolerance are considered to be 92°F and 101°F, respectively (see Table 6-2). Considering the predicted conditions from the model simulations discussed previously, almost no surface water areas of the lake would exceed the UILT under either normal or stressed summer conditions. By comparison, approximately 1,812 acres and 737 acres of surface waters would be less than the MWAT under normal and stressed conditions, respectively (see Table 6-1). Even so, much more of the lake’s area would be suitable when considering deeper waters. Under “normal” modeled conditions, channel catfish would have the lower half of the water column available inside the mixing zone and the entire water column available outside the mixing zone. Under the “stressed” model conditions, it is expected that channel catfish would exhibit avoidance behavior of the mixing zone and near mixing zone areas, as no depths in the mixing zone and only waters deeper than 35 feet outside the mixing zone would be available in the lower half of the lake. Additionally, there are no barriers to the movement of channel catfish from areas that may be thermally less suitable to habitats characterized by cooler temperatures. Consequently, thermal conditions under the “normal” and “stressed” scenarios would not represent conditions in which the populations of this species are likely to be harmed.

Reported tolerance values of bluegill are notably variable, with UILT values ranging from 97.5 to 106.7°F for adults, and a MWAT values ranging between 90 and 93°F (see Table 6-2). Given that bluegill catch rates were observed to be very high near the warmwater discharge of the Marion Plant during July 2010 electrofishing surveys where measured surface water temperatures ranged from 94-98°F, 93°F was selected as the most appropriate MWAT value, and 98°F was selected as the UILT value. Under the “normal” summer conditions predicted by the hydrothermal model, the entire lake would have surface water temperatures below the UILT. Additionally, 2029 acres of surface waters of the lake would be less than the maximum weekly average value. Under the modeled “stressed” conditions, approximately 1,892 surface acres would be below the UILT, whereas approximately 884 acres of surface water would be below the MWAT value (see Table 6-1). However, with regard to deeper waters, temperatures below the UILT would be evident in the lower third of the water column within the mixing zone, and lower two-thirds of the water column outside the mixing zone. No depths in the mixing zone, and only the deepest (>35 feet) areas of the lower lake outside the mixing zone, would be below the bluegill’s maximum weekly average temperature under these extreme conditions. As stated for other RIS, there are no barriers to the movement of bluegill from areas that may be thermally less suitable to habitats characterized by cooler temperatures. Consequently, thermal conditions under the “normal” and “stressed” scenarios would not represent conditions in which the populations of this species are likely to be harmed.

For largemouth bass, the MWAT for growth and the UILT values are considered to be 88°F and 94°F, respectively (see Table 6-2). Considering the predicted conditions of the model simulations discussed previously, this species would have approximately 2,215 surface acres of the lake less than the UILT under "normal" summer conditions. Under "stressed" conditions, approximately 1029 surface acres of the lake would have temperatures less than the UILT (see Table 6-1). But even in these "stressed" conditions, deeper waters would be suitable. Specifically, the deeper third of the water column within the mixing zone, and the deeper two-thirds of the water column outside the mixing zone would be below the short-term tolerance limits for largemouth bass. Approximately 1,070 surface water acres would be less than the MWAT value under normal conditions, but no surface waters of the lake would be less than the MWAT value under "stressed" conditions. However, as described above the cooler, deeper water does provide habitat suitability under these conditions to sustain largemouth bass communities. Furthermore, largemouth bass were collected at very similar catches rates between the upper and lower portions of the lake during July 2010 electrofishing surveys (see Table 3-2), indicating that this species is well adapted to warmer surface temperatures. Under "normal" modeled conditions, largemouth bass would have the deeper third of the water column available inside the mixing zone and the deeper two-thirds of the column available outside the mixing zone. Under the "stressed" model conditions, no depths in the mixing zone or in the areas immediately outside the mixing zone would be below the largemouth bass maximum weekly average temperature. There are no barriers to the movement of largemouth bass from areas that may be thermally less suitable to habitats characterized by cooler temperatures. Consequently, thermal conditions under the "normal" and "stressed" scenarios would not represent conditions in which the populations of this species are likely to be appreciably harmed.

For white and black crappie (collectively," crappie"), the MWAT for growth and the UILT values are considered to be 85.8°F and 90.5°F, respectively (see Table 6-2). Considering the predicted conditions of the model simulations discussed previously, this species would have approximately 1,580 surface acres of the lake less than the UILT under "normal" summer conditions. Under "stressed" conditions, none of the surface acres of the lake would have temperatures less than the UILT (see Table 6-1). While such surface waters may be limiting to crappie under these "stressed" conditions, deeper waters would be suitable. Under both "normal" and "stressed" summer conditions, all areas of the lake would have surface water temperatures that exceed the MWAT value of 85.8°F. However, as described above the cooler, deeper water are considered to provide habitat suitability under these conditions to sustain crappie communities. According to earlier assessments by Heidinger from 1988 and 1990, crappie historically demonstrated good populations at Lake of Egypt. Heidinger also noted that crappie populations are cyclical and that for both 1998 and 1990, they were likely at a low point. More recent investigations of Lake of Egypt by Heidinger et al (2000) reported the collection of both black and white crappie in electrofishing results. As is shown in Table 6-3, crappie catch between upper (Segment 2) and lower (Segment 1) reaches of the lake were generally low and not consistent between years. However, the sustained presence of crappie within the lake and the anecdotal reports of periodically good crappie catches (SIPC, personal communication) suggest that, while thermally influenced, Lake of Egypt continues to support a viable crappie population. Additionally, it is noted that there are no barriers to the movement of crappie from areas that may be thermally less suitable to habitats characterized by cooler temperatures. In conclusion, whereas crappie habitat (?) may be limited under summer conditions of thermal stress, the availability of acceptable thermal refugia at depth coupled with the observed continued presence of both white and black crappie within the lake over the years, supports the conclusion that thermal conditions under the “normal” and “stressed” scenarios do not represent conditions in which the populations of this species are likely to be appreciably harmed.

Table 6-3. Summary of Crappie Electrofishing Catch from 1997 and 1998

	Total Effort	Total Number	Catch per Unit Effort
1997			
White Crappie			
Segment 1[a]	>6 hours	29	4.8
Segment 2		7	2.5
Black Crappie			
Segment 1	>6 hours	15	1.0
Segment 2		7	1.6
1998			
White Crappie			
Segment 1	>5 hours	3	0.5
Segment 2		1	0.2
Black Crappie			
Segment 1	>5 hours	21	3.8
Segment 2		13	2.3

Source: Heidinger et al, 2000

[a] Segment 1-lower, near dam; Segment 2-upper

In summary, summer temperatures predicted by the “normal” simulation of the hydrothermal model would be within the upper incipient lethal temperature tolerances of all RIS throughout the Lake of Egypt. When considering the maximum weekly average temperatures to promote growth, 188 to 1,289 acres (8.4 to 58.1 percent) in the lower portion of the lake’s surface waters would be excluded. Even so, sub-surface areas would be suitable even in the mixing zone. Under the worst case scenario conditions predicted by the “stressed” model, these species would still have the majority of the lake’s surface waters available at temperatures below their short-term maximum levels; and an even larger area would be available in consideration of sub-surface waters. When considering the lower maximum weekly averages of these species, however, they would presumably be confined to sub-surface waters; but considerably larger areas of sub-surface water would consist of cooler waters and be available for RIS use.

6.2.4 Effects on RIS Spawning and Recruitment

Potential effects of an enhanced thermal regime on the reproductive cycles of RIS can be considered by examining published literature characterizing typical reproductive biology of each species, coupled with prior work done at Lake of Egypt and other cooling lakes within Illinois. Of potential concern is that the thermal regime induced by plant operations accelerates gamete formation and initiate spawning in advance of the aquatic ecosystem’s capacity to support them. The following narrative evaluates this potential by examining:

1. Published spawning temperatures and timing for RIS
2. Reported literature from other Illinois cooling lakes, and
3. Observed trends in larval fish abundance and recruitment in Lake of Egypt

Gizzard Shad/Threadfin Shad

Gizzard shad typically spawns at temperatures ranging from 50 to 88°F (Fishbase, 2012b), but optimal spawning temperatures for gizzard shad range from 60 to 75°F (Heidinger, 1975). Within Illinois spawning typically occurs in April, May and June (Smith, 2002). By comparison, threadfin shad typically spawns at temperatures ranging from 58 to 81°F from April through July (Fishbase, 2012a).

Early spawning by *Dorosoma* spp. has been documented in other regional lakes that receive thermal effluents. Lake Sangchris, also located in central Illinois, receives thermal effluent from the Kincaid Generating Station (Larimore and Tranquilli, 1981). During 1975-1977, gizzard shad larvae were collected as early as April 22 in both the discharge arm and the intake arm. Water temperatures in the discharge arm ranged from 69 to 75 °F whereas temperatures in the intake arm were only 64°F. Little difference was noted in the temporal distribution of gizzard shad between the discharge and intake arms.

As is summarized in Table 6-4, monitored temperatures during the spring at Lake of Egypt demonstrated earlier lake warming, with optimal spawning temperatures for *Dorosoma* spp. reached within the lower (northern) portion of the lake in March (1998 only) and April (1998 and 1999)(Heidinger et al, 2000). The differential warming of the lake by thermal effluent resulted in optimal spawning temperatures lagging within the upper (southern) portion of the lake until late April extending into May. Hatching temperatures for gizzard shad were calculated to range from 63-92°F in 1998 and from 63-89°F in 1999.

Prior ichthyoplankton studies performed at Lake of Egypt from 1998 to 1999 by Heidinger et al (2000) documented the spawning cycles of *Dorosoma* spp. Presumably, this taxon included representatives of both threadfin shad and gizzard shad. In fact, the representation of multiple species by these larval taxonomic groupings may, in part, also explain the presence of multiple spawning peaks in 1998 and 1999 in each zone of the lake (Table 6-5).

Figures 3-1 and 3-2 summarize the length frequency data for threadfin shad and gizzard shad based on electrofishing in 2010. Sample sizes for gizzard shad are small and do not allow for substantive discussion regarding recruitment. Catch rates of both gizzard shad and threadfin shad from 1998 and 1999 were also variable (Heidinger et al, 2000), reflecting the pelagic, schooling nature of these species and the inefficiencies of sampling gear. However, the sample size for threadfin shad is more representative from the upper (unheated) end of the lake and reflects good recruitment of threadfin shad in Lake of Egypt. Substantial catch rates of gizzard shad were also obtained during impingement studies in the lower (heated) end of the lake from 2005 to 2007 and demonstrate good recruitment of young of the year individuals.

Based on the above discussion, it is evident that the thermal effluents of the Marion Power Plant result in higher water temperatures and earlier spawning within the heated (northern) reaches of Lake of Egypt. However, based on similar catch rates of young of the year threadfin shad, the thermal regime does not appear to adversely affect the recruitment of this species into the population. It is likely that gizzard shad, while not well represented in collections from Lake of Egypt, is similarly not adversely affected.

Largemouth Bass

Optimal spawning temperatures for largemouth bass range from 60 to 75°F (Heidinger 1975) and such temperatures within Illinois typically occur in May and June (Smith 2002). At 60-67°F, largemouth bass eggs hatch in 4 to 5 days (Wallus and Simon, 2008). Life stage duration for the larval stage is 19 days (Fishbase, 2012d).

Early spawning by largemouth bass has been documented in other regional lakes that receive thermal effluents. Lake Sangchris, also located in central Illinois, receives thermal effluent from the Kincaid Generating Station (Larimore and Tranquilli, 1981). During 1975-1977, spawning in Lake Sangchris occurred at 59-70°F in early April to mid-May in the heated area of the lake and late April to mid-May in other areas. Additionally, Tranquilli and Perry (1981) used the maturation stage of the gonads of female largemouth bass, as well as their gonadosomatic index (GSI: gonad weight relative to total body weight), to estimate spawning dates in Coffeen Lake. Earlier spawning behavior in Coffeen Lake relative to Lake Sangchris was attributed to the warmer temperatures in Coffeen Lake. Tranquilli and Perry (1981) also demonstrated spatial dissimilarity in largemouth bass spawning within Coffeen Lake. Specifically, in the heated, eastern arm of the lake, largemouth bass began spawning in mid or late March, but did not begin spawning in the western arm until late April or May.

Monitored temperatures during the spring at Lake of Egypt (from 1998 and 1999) demonstrated earlier lake warming that reached optimal near surface spawning temperatures of largemouth bass within the lower (northern) portion of the lake in March in both years (Table 6-4). The differential warming of the lake by thermal effluent resulted in optimal spawning temperatures lagging within the upper (southern) portion of the lake until April.

Prior ichthyoplankton studies performed at Lake of Egypt from 1998 to 1999 by Heidinger et al (2000) provides some information about the spawning cycles of largemouth bass. Similar to the findings reported by Tranquilli and Perry (1981), spawning within the heated regions of Lake of Egypt occurred somewhat earlier than within the unheated portions of the lake. Hatching temperatures within Lake of Egypt were calculated to be between 63 and 92°F in 1998 and between 63 and 89°F in 1999, and larvae were evident in collections from late April through early June (Heidinger et al, 2000).

Based on results of electrofishing in 2010, recruitment between heated and unheated reaches of Lake of Egypt appears to be similar (Figure 3-5). Heidinger et al (2000) also noted that recruitment of largemouth bass in Lake of Egypt was relatively similar between 1998 and 1999.

Based on the above discussion, it is evident that the thermal effluents of the Marion Power Plant result in higher water temperatures and earlier spawning within the heated (northern) reaches of Lake of Egypt. However, based on similar catch rates of young of the year and

Age I fish, the thermal regime does not appear to adversely affect the recruitment of largemouth bass into the population.

Table 6-4. Summary of Reproductive Temperature Characteristics of Selected RIS in Lake of Egypt.

Year	(Published Spawning Temperature °F)	Initial Date Spawning Temperatures Achieved		Hatching Range Temperature (F)[1]	
		Zone 1 (Lower)	Zone 2 (Upper)	Beginning Temp	Ending Temp
1998	Sunfishes (67-80)	April 21	May 9	67	91
	Gizzard shad (61-70)	March 16	April 21	63	92
	Largemouth Bass (60-75)	March 16	April 21	NA[2]	NA[2]
	Channel catfish (70)	April 21	May 9	NA[3]	NA[3]
	White and black crappie (60-68)	March 16	May 9	NA[3]	NA[3]
1999	Sunfishes (67-80)	April 27	May 7	74	87
	Gizzard shad (61-70)	April 1	April 13	63	89
	Largemouth Bass (60-75)	March 14	April 13	NA[2]	NA[2]
	Channel catfish (70)	April 27	May 7	NA[3]	NA[3]
	White and black crappie (60-68)	April 1	April 13	NA[3]	NA[3]

[1] Hatching temperatures derived by linear regression
[2] Hatching range temperatures fall within the range of gizzard shad for that year
[3] Not calculated
Source: derived from Heidinger et al, 2000

Table 6-5. Summary of Reported Hatch Characteristics of Selected RIS in Lake of Egypt.

Year	Taxon	Initial Hatching Peak		No. Principal Hatching Peaks[1]	
		Zone 1 (Lower)	Zone 2 (Upper)	Zone 1 (Lower)	Zone 2 (Upper)
1998	*Lepomis*	5/15	5/18	2	5
	Dorosoma	4/06	4/17	4	3
1999	*Lepomis*	5/06	5/22	3	6
	Dorosoma	4/11	4/12	3	4

[1] Spawning peaks and temperatures derived by linear regression
Source: Modified from Heidinger et al, 2000

Bluegill

Optimal spawning temperatures for bluegill range from 67 to 80 °F (Cornish and Welke 2004) and spawning in Illinois is similar to that of other *Lepomis* spp. whereby spawning occurs in May and continues into the summer over excavated nests (Smith 2002). Optimal temperatures for successful embryo development are 72-81°F, and development will occur from 72-93°F (Stuber et al, 1982). At 67°F, bluegill eggs hatch in 2 to 3 days (Wallus and Simon, 2008). Life stage duration for the larval stage is 30 days (Fishbase, 2012)

Prior ichthyoplankton studies performed at Lake of Egypt from 1998 to 1999 by Heidinger et al (2000) documented the spawning cycles of *Lepomis* spp. Bluegill is likely to be the dominant *Lepomis* species, although other species may reasonably be expected to be present. In fact, the representation of multiple species by these larval taxonomic groupings may also in part, explain the presence of a large number of spawning peaks, particularly of *Lepomis*, particularly in Zone 2 (Table 6-5). However, *Lepomis* taxa are also known to spawn cyclically over the course of the season, thus also contributing to peaks in larval abundance. Heidinger et al (2000) estimated that initial spawning within Lake of Egypt occurred at 67°F in 1998 and at 74°F in 1999. Optimal spawning temperatures for bluegill were ranged from 67-91°F in 1998 and from 74-87°F in 1999 (Table 6-4). These temperatures were reached within the lower (northern) portion of the lake in April and within the upper portion of the Lake in early May (Table 6-4). However, due to differential warming of the lake from the thermal effluent, optimal spawning temperatures lagged within the upper (southern) portion of the lake until May.

Based on results of electrofishing in 2010, recruitment between heated and unheated reaches of Lake of Egypt appears to be similar (Figure 3-4). Heidinger et al (2000) also noted that recruitment of bluegill in Lake of Egypt was good and relatively similar between 1998 and 1999.

Based on the above discussion, it is evident that the thermal effluents of the Marion Power Plant result in higher water temperatures and earlier spawning of bluegill within the heated (northern) reaches of Lake of Egypt. However, based on similar catch rates of young of the year and Age I fish, the thermal regime does not appear to adversely affect the recruitment of bluegill into the population.

Channel Catfish

Channel catfish spawns in late spring and early summer (generally late May through mid-July) when temperatures reach about 70°F. At 67 to 85°F, channel catfish eggs hatch in 4 to 5 days (Simon and Wallus, 2004).The optimal temperature range for growth of channel catfish fry is 84-86°F (McMahon and Terrell, 1982)

Optimal spawning temperatures for channel catfish within the lower (northern) portion of the lake were reached in April based on monitored temperatures during the spring at Lake of Egypt (from 1998 and 1999 (Table 6-4). Due to differential warming of the lake from the thermal effluent, optimal spawning temperatures lagged within the upper (southern) portion of the lake until May. Prior ichthyoplankton studies performed at Lake of Egypt from 1998 to 1999 by Heidinger et al (2000) did not document the spawning cycles of channel catfish. However, based on the differential temperature patterns within the lake, it is likely that spawning in the lower (heated) region of the lake was advanced relative to that in the upper (unheated) sections.

Electrofishing surveys have been conducted as part of this assessment and by Heidinger et al (2000). Notably, catch rates for channel catfish in 2010 were similar as those reported from 1998 and 1999 and were characteristically low and composed of larger (older) individuals. It was concluded by Heidinger et al (2000) that the lack of smaller fish in the 1999 samples was not attributable to recruitment failure since younger specimens taken in the fall of 1998 were also represented in the spring of 1999. While complete life history, recruitment and growth information for channel catfish is relatively lacking within Lake of Egypt, the apparent absence of effects on recruitment seem to point to the absence of thermal effects on this species.

White and Black Crappie

Both white and black crappie spawn in late spring and early summer (generally late May through mid-July) when temperatures exceed 60°F (white crappie) or 64°F (black crappie) (Wallus and Simon, 2008). At 65 to 67°F, white crappie eggs hatch in approximately 2 days whereas black crappie hatches in 2 to 3 days at 65°C (Wallus and Simon, 2008).

Optimal spawning temperatures for crappie within the lower (northern) portion of the lake were reached in March or the first week of April based on monitored temperatures during the spring at Lake of Egypt (from 1998 and 1999 (Table 6-4). Due to differential warming of the lake from the thermal effluent, optimal spawning temperatures lagged within the upper (southern) portion of the lake until early May. Prior ichthyoplankton studies performed at Lake of Egypt from 1998 to 1999 by Heidinger et al (2000) did not document the spawning cycles of crappie. However, based on the differential temperature patterns within the lake, it is likely that spawning in the lower (heated) region of the lake is advanced relative to that in the upper (unheated) sections.

Electrofishing surveys have been conducted as part of this assessment and by Heidinger et al (2000). Notably, catch rates for crappie were generally low and somewhat variable in both studies. Complete life history, recruitment and growth information for crappie is relatively lacking within Lake of Egypt and potential direct inferences regarding thermal effects on recruitment are limited. However, a somewhat bimodal spawning cycle in the lower and upper portions of the lake are likely to be supported by an accompanying productivity of organisms within lower trophic levels. Further, the apparent successful recruitment of other centrarchid taxa (bluegill, largemouth bass, etc.) which have similar spawning seasons provides indirect evidence of the absence of significant thermal effects on this species.

6.2.5 Adaptability and Available Refugia

The fish community in the Lake of Egypt consists primarily of species that are tolerant of warm summer temperatures. Species-specific studies of temperature tolerance suggest that most fish in the lake would rarely encounter their temperature maxima. Moreover, these maxima likely underestimate the tolerances of these species, as they are derived from laboratory studies, and that in the field organisms can adapt and acclimate to higher values (ASA, 2008).

Additionally, there is evidence that fish can recover from short-term thermal stress by utilizing lower temperature refuge areas within the system when necessary (Coutant, 2003). There is a large amount of habitat available as thermal refuge in the Lake of Egypt. Considering only the surface area, the mixing zone is only a 26-acre subset of an approximately 2,300-acre lake. Resident populations can simply avoid areas that are above their temperature tolerance. Evidence of this behavior was observed in July and August 2010 electrofishing surveys, where no individuals were captured in the area immediately surrounding the discharge structure. There is also an available refuge with greater depth, i.e., temperatures are 3 to 7°F lower in the bottom half of the water column as compared to the surface (see Sections 2.3 and 3.4).

Past and current studies have demonstrated that fish populations in the Lake of Egypt are healthy. Sport species such as largemouth bass, bluegill, and redear sunfish are abundant and generally in good condition. The prevalence of external abnormalities on largemouth bass appears to be more associated with angling pressure rather than thermal effects.

6.2.6 Beneficial Thermal Effects

Higher, stable water temperatures in winter and early spring are hypothesized to promote earlier spawning, improved survival, and increased growth/development in the early life stages of several species, notably largemouth bass (ASA, 2008). For this species, earlier spawning and a prolonged growing season may result in faster growth, in particular to the size at which piscivory begins, and may lead to improved overwinter survival (ASA, 2008). For channel catfish and bluegill, higher temperatures may extend the spawning seasons and promote growth throughout the year. Accelerated development to the less temperature-sensitive juvenile life stages may likewise promote overwinter survival for these species. Anecdotal evidence to support the presence of early spawning for several species in the Lake of Egypt was indicated by the presence of young-of-the-year juveniles in seine samples collected in early spring as part of 316(b) studies (MACTEC, 2007).

Threadfin shad is a valuable forage species for several game species (Heidinger and Imboden, 1974). One of the limitations to its successful establishment in Illinois lakes was its inability to overwinter under normal temperature regimes. At the recommendation of Dr. Roy Heidinger (formerly of SIU-Carbondale), threadfin shad were stocked in Lake of Egypt in the 1970s to provide a more effective forage species (see Section 3.1). Since that initial stocking event, the warmer conditions in the Lake of Egypt have sustained the population of threadfin shad by minimizing winter mortality. Thus the forage base, particularly for largemouth bass, is preserved between years, adding to the overall condition and health of the fish community.

6.2.7 Potential for Fish Kills

Fish kills associated with elevated water temperatures can occur under conditions of high elevated temperatures (often associated with lower dissolved oxygen saturation levels) coupled with habitat limitations that prevent escape and avoidance. Mortality may occur for a given species when temperatures in the water body exceed the species' short term maximum temperatures AND where there are no, or limited, areas of thermal refuge available. Small, closed systems with little depth or habitat heterogeneity are particularly vulnerable to periodic fish kills. Such conditions are not present in the Lake of Egypt.

The fish populations of the lake, as reflected by the RIS, are adapted to warm-water conditions. For the majority of the year, water temperature conditions are well below their temperature tolerances. Moreover, during the periods of highest lake temperatures, there is an abundance of habitats that act as thermal refugia. Fish can migrate laterally to other areas of the lake, or can move downward in the water column to avoid stressful conditions. Additionally, as demonstrated in Section 6.2.4, such refuge areas are large relative to the areas that may present unfavorable conditions for a given species.

Fish kills can also occur in the winter under conditions of prolonged low water temperatures. The only species among the Lake of Egypt fish community vulnerable to mortality from prolonged low water temperatures is the threadfin shad and gizzard shad, with the threadfin shad being more sensitive to prolonged low water temperatures. The warmer water temperatures produced from the plant discharge sustain these shad species by minimizing winter mortality. If an un-planned outage occurred at the Marion Power Plant for a prolonged period of time during the winter, mortality could occur to shad species as a result of the decreased water temperatures. In order to guard against this potential scenario, SIPC conducts planned outages for plant maintenance in the spring and fall of each year to minimize the chance of an un-planned outage. Thereby, reducing the probability of temperature induced winter mortality in threadfin shad and gizzard shad.

Finally, the likelihood of thermal-induced fish kills in a cooling lake is also indicated by the history of fish kills. In the Lake of Egypt there have been no past incidences of summer fish kills. This again indicates that community members have adapted to the changing physical conditions. The absence of historical thermal-related fish kills, combined with no anticipated increase in thermal loading, suggest that future fish kills are extremely unlikely.

6.3 Continuing Efforts

SIPC stocked threadfin shad into the Lake of Egypt in 1971 in an attempt to expand the forage base of the system (Heidinger, 1977). This has resulted in improvements in fish condition and overall fishery quality (Heidinger, 1990). The utility has also stocked species such as walleye, hybrid striped bass, inland silverside, and black crappie with the intention of improving the lake’s fishery (Table 6-6). SIPC will remain committed to the support and enhancement of the Lake of Egypt ecosystem through stocking programs and lake management.

Table 6-6. Summary of Fish Species Stocked in Lake of Egypt

Year	SIPC Sponsorship	Fish Stocked	Number
1971	Yes	Threadfin shad	2, 300 adults
1985	Yes	Walleye	8,000 4”-6” fingerlings
1986	Yes	Hybrid Striped Bass	250,000 fry 500 1”-2” fingerlings
1987	Yes	Hybrid Striped Bass	15,000 1.5”-2” fingerlings
1987	Yes	Inland silverside	500 adults
1988	Yes	Hybrid Striped Bass	15,000 1”-2” fingerlings
1989	Yes	Hybrid Striped Bass	15,000 1”-2” fingerlings
1990	Yes	Hybrid Striped Bass	15,000 1”-2” fingerlings
2008	Yes	Black Crappie	15,000 2”-3” fingerlings
2009	Yes	Black Crappie	20,000 2”-3” fingerlings
2010	Yes	Black Crappie	20,000 2”-3” fingerlings

Source: Heidinger, 1990; SIPC unpublished.

Prepared by/Date: WJE/1-27-12
Checked by/Date: SRC/1-27-12

7.0 Summary of the Path Forward

The proposed thermal limit should be based on historical data, anticipated operating conditions, multiple scientific lines of evidence, and also viewed in relation to other Illinois artificial cooling lakes. The following sections provide this discussion.

7.1 Comparison with Other Illinois Cooling Lakes

To assess the general regulatory environment in Illinois, we compared the thermal limitations at the Lake of Egypt with those listed in the NPDES permits of several other Illinois power plants with cooling lakes. At three of these plants, Baldwin, Dresden, and LaSalle County, temperature limitations on the thermal effluent are the same as for the Marion Plant on the Lake of Egypt. However, the locations where water temperatures are measured for the three plants are in the rivers receiving water from the cooling lakes. For the other five plants, water temperatures are measured at some point in the lake itself. But mixing zones comparable to that of the Marion Plant (i.e., 26 acres in area) were only established for the Coffeen Plant and Newton Plant cooling lakes. The temperature restrictions for the Newton and Coffeen cooling water lakes were also noted to be much less restrictive than those for SIPC's Marion Plant on the Lake of Egypt.

7.2 Summarization of the Fish Community Status

The following key points summarize the existing status of the fishery of Lake of Egypt and the findings of this report with respect to the proposed thermal limits and their effect on sustaining the balanced and indigenous community:

- *Game Fish RIS Status.* Observed temperatures outside the mixing zone at the lower end of the lake were within the tolerance limits of RIS such as channel catfish, bluegill, and largemouth bass when the plant was at full capacity. Based on modeling results, proposed thermal limits under normal late summer weather conditions would only result in avoidance or adaptive behaviors in localized areas within the lower lake.
- *Threadfin Shad Support.* Existing and proposed thermal limits will continue to sustain threadfin shad overwintering survival which will benefit the food base of largemouth bass and other predators.
- *Community Stability.* The resident fish community has been stable in terms of composition and abundance over the past 13 years. Proposed thermal limits are expected to sustain similar community composition and abundance such that its stability will not be adversely affected.
- *Habitat Availability.* There is abundant habitat available, both horizontally throughout the lake and vertically in the water column, as refuge from localized sub-optimum thermal conditions. These habitat refuge areas will not change under the proposed thermal limits.

Therefore, these patterns indicate that the thermal conditions in the Lake of Egypt have been protective of a balanced indigenous community. Moreover, the higher water temperature thresholds proposed as part of the requested site-specific rule revision will continue to be protective of the balanced indigenous community.

7.3 Suggested Mixing Zone and Compliance Monitoring Location

Based on recent discussions held with the IEPA it is recommended that the 26-acre mixing zone be maintained as indicated on Figures 5-10 to 5-13. The eastern (downstream) boundary of this area generally corresponds to the 101°F isotherm as predicted in the summer stressed condition modeling scenario. Additionally, it is recommended that the monitoring point for compliance be established at the edge of the mixing zone boundary. Establishment of the compliance monitoring point at this location is technically more feasible than other locations within the open lake and provides a reasonable measure of security for installed equipment.

7.4 Conclusions and Recommendations

Data from previous studies and the 2010 study indicate that the Lake of Egypt has historically supported and continues to support a high quality sport fishery. Fish populations in the lake have adapted to the condition of warmer water, and have ample areas available for thermal refuge. Increased thermal loading associated with the operation of a new boiler in 2003 has not negatively affected the fish community, and SIPC does not intend to increase generating capacity in the future. Moreover, stable, higher water temperatures in late winter and spring likely promote growth and development for most species, and support the survival of threadfin shad, an important subset of the forage base.

Results of field measurements and hydrodynamic modeling demonstrated that temperatures well above the current NPDES limit (90°F) are routinely present in the summer at the mixing zone boundary. Indeed, ambient lake temperatures frequently exceed this threshold in the warmest periods of the year. Based upon the hydrodynamic modeling performed for the Lake of Egypt (including spring and fall periods), and the results of the above biothermal assessment, we recommend that the thermal limitations in the NPDES permit for SIPC's Marion Power Plant be changed from the current conditions of:

- Lake temperatures at the edge of the mixing zone shall not exceed the following maximums (60°F from December through March; 90°F from April through November) by more than 1 percent of the hours in a 12-month period, and
- At no time shall the water temperature at the edge of the mixing zone exceed these maximums by more than 3°F.
- Maximum temperature rise above natural temperature must not exceed 5°F (2.8°C).

to:

- Lake temperatures at the edge of the mixing zone shall not exceed the following maximums by more than 1 percent of the hours in a 12-month period:
    - 72°F from December through March;
    - 90°F from April through May;
    - 101°F from June through September; and
    - 91°F from October through November
- At no time shall the water temperature at the edge of the mixing zone exceed these maximums by more than 3°F.

The rationale for proposing these revised standards is as follows:

1. The proposed change would not alter the Lake of Egypt's existing thermal regime (i.e., natural lake stratification). The Marion Station's thermal discharge affects a small percentage of the 2,300-acre lake.
2. Assessments of the effects of the proposed changes on representative important species indicate that under normal summer conditions, habitats would be within thermal tolerance limits throughout the lake. Under a modeled condition that simulated rarely-expected extreme conditions, there were still extensive areas in the lake that fish could utilize as thermal refugia.
3. Surveys from 2010 and earlier years indicate that fish populations in the Lake of Egypt have adapted to warm temperatures. Species composition and abundance estimated by these surveys suggest that the populations are healthy and self-sustaining.
4. Potentially beneficial effects include higher, stable water temperatures in the late winter and early spring that may promote earlier spawning, improved survival, and increased growth and development of the early life stages of several species, notably largemouth bass. Additionally, the warmer conditions in the Lake of Egypt almost certainly enhance the population of threadfin shad by minimizing winter mortality.
5. Fish kills in the Lake of Egypt have not occurred historically, and are not likely to occur as a result of these proposed standards. For the majority of the year, water temperature conditions are well below the temperature tolerance thresholds of the representative important species. Even during the periods of highest lake temperatures, there is an abundance of thermal refugia. Fish can migrate laterally to other areas of the lake, or can move downward in the water column, to avoid stressful conditions.
6. The five other biotic categories considered in USEPA's Technical Guidance Manual are either: (a) unaffected (or beneficially affected) by the heated effluent – such as submerged aquatic vegetation and wildlife, or (b) consist of species that are not threatened/endangered, of commercial importance (macroinvertebrates and shellfish), and/or generally have short life spans and reproduce rapidly (phytoplankton and zooplankton). It is reasonable to conclude that the plant's discharge will cause no appreciable harm to these resident communities in the lake.

7. The point of compliance monitoring is recommended to be at the the edge of the mixing zone.

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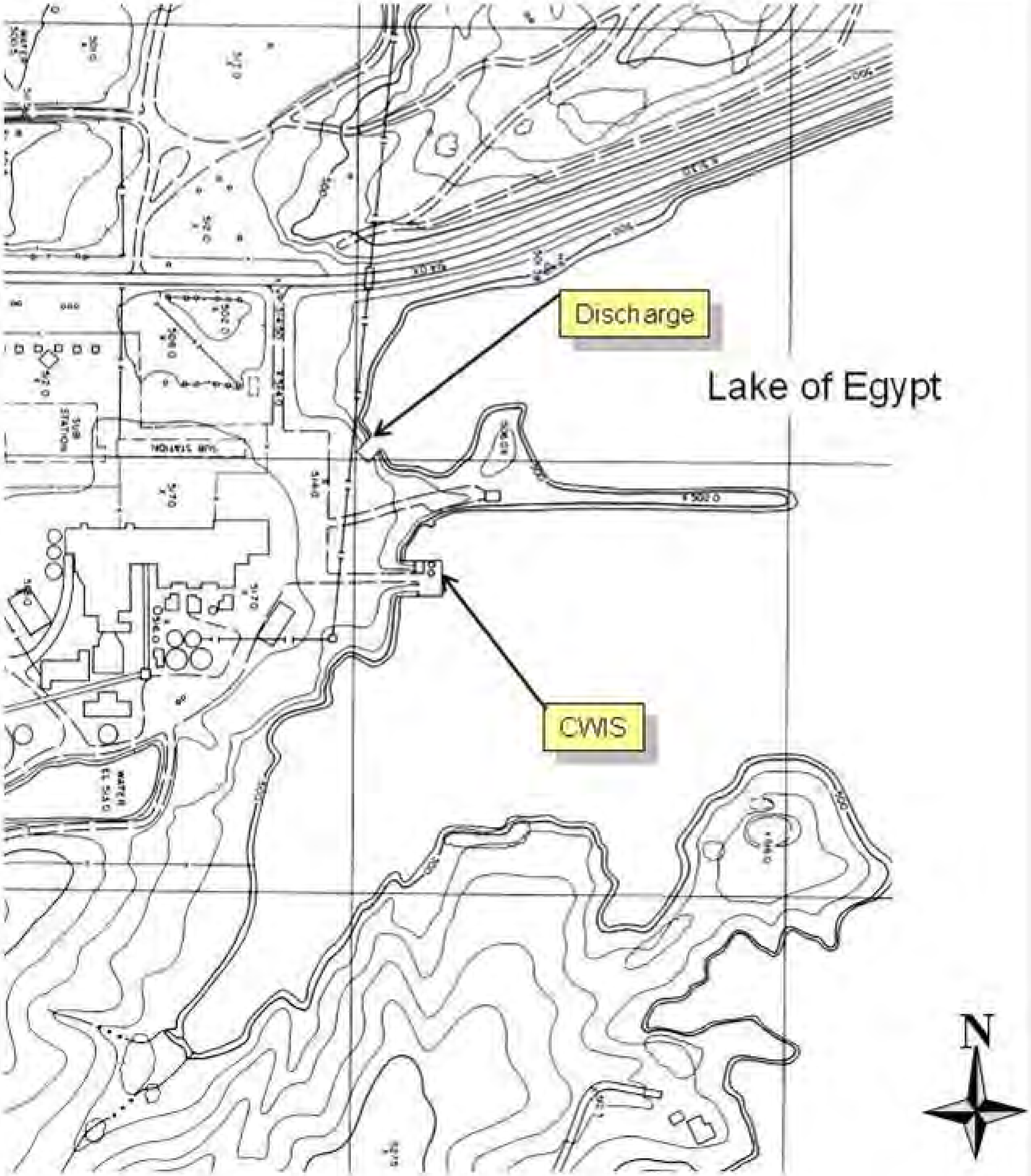
Figures

Figure 1-1: Map of Lake of Egypt Showing Location of SIPC's Marion Plant

Created by: CGS
Approved by: WJE
Checked by: SBM
October 22, 2010



Approximate Scale.
200 0 200
feet

DRAWN BY:	CGS
CHECKED BY:	WJE
DATE:	1-27-11
Revisions:	
PROJECT NO.:	3250065201

Figure 1-2. Close-up of Northwest Section of the Lake of Egypt Showing Intake and Discharge Areas

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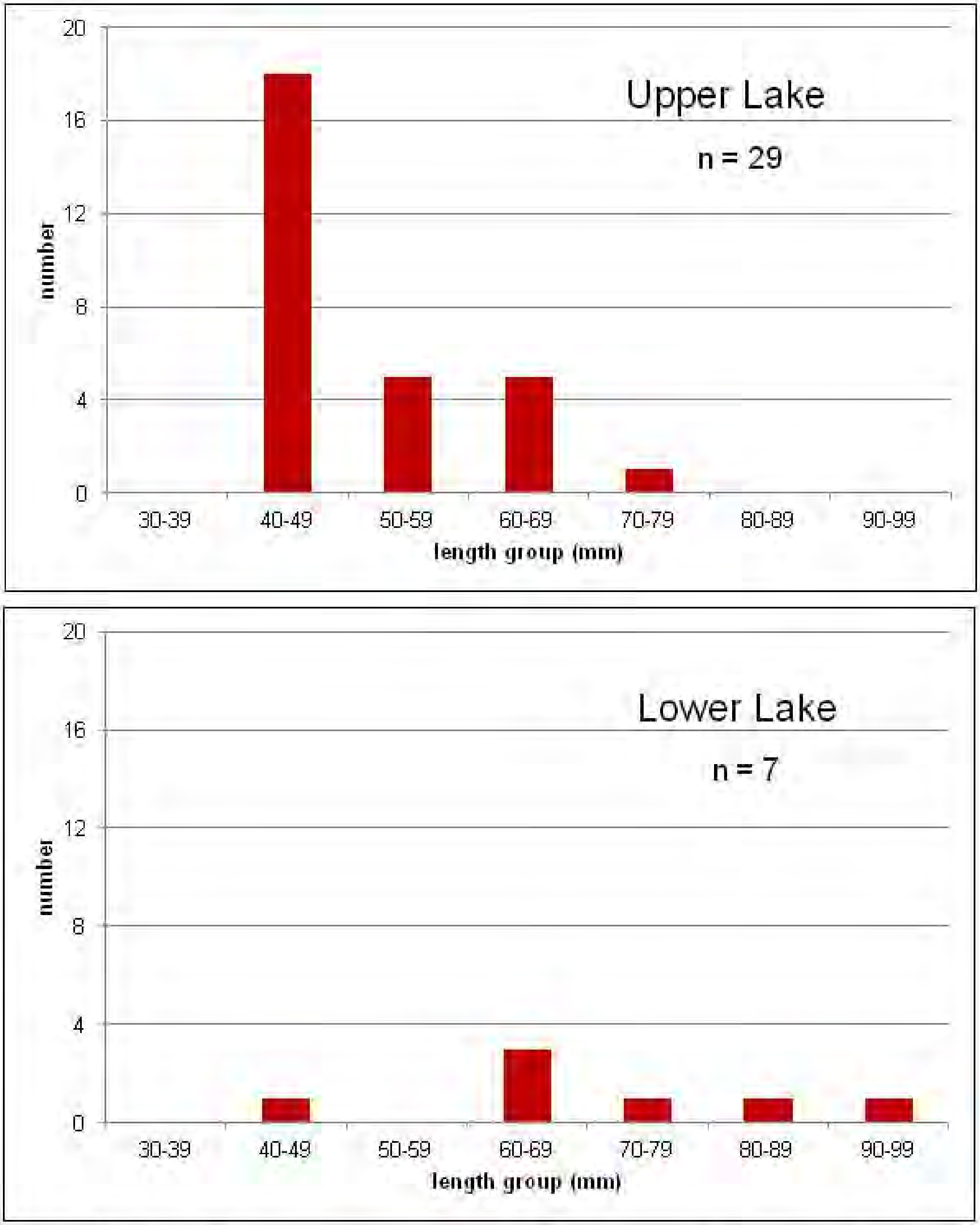

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DATE:	4-26-12
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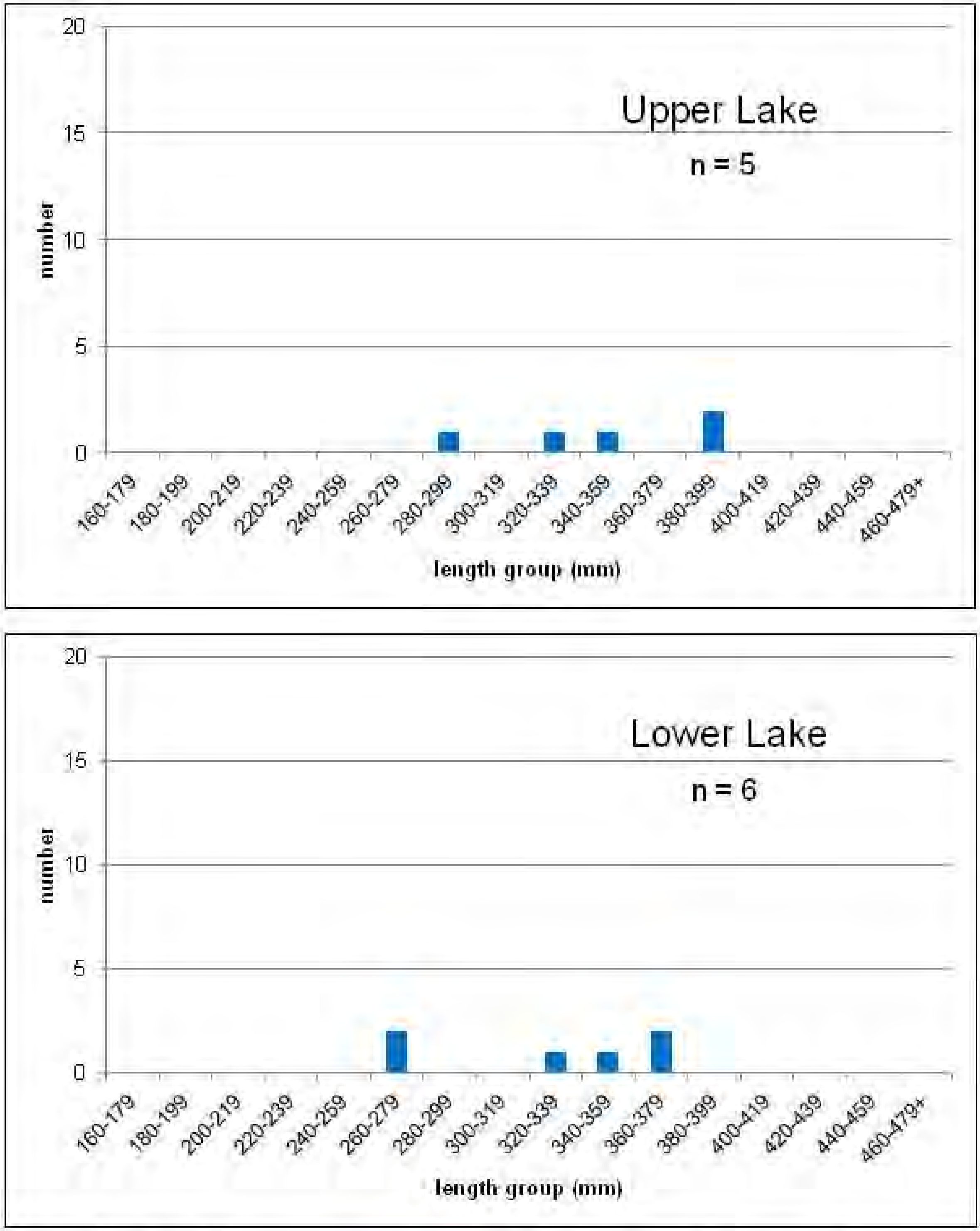
SIPC

Figure 3-1. Length Frequency Histograms for Threadfin Shad from the Upper and Lower Portions of the Lake of Egypt, Summer 2010.



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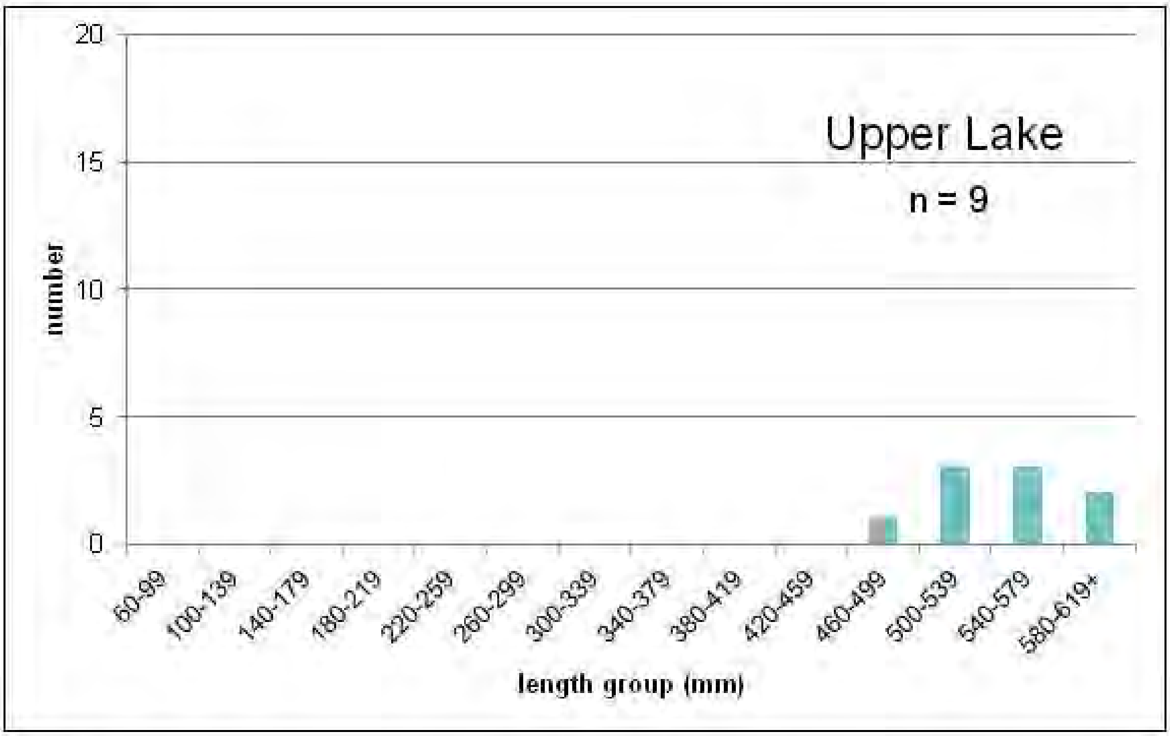
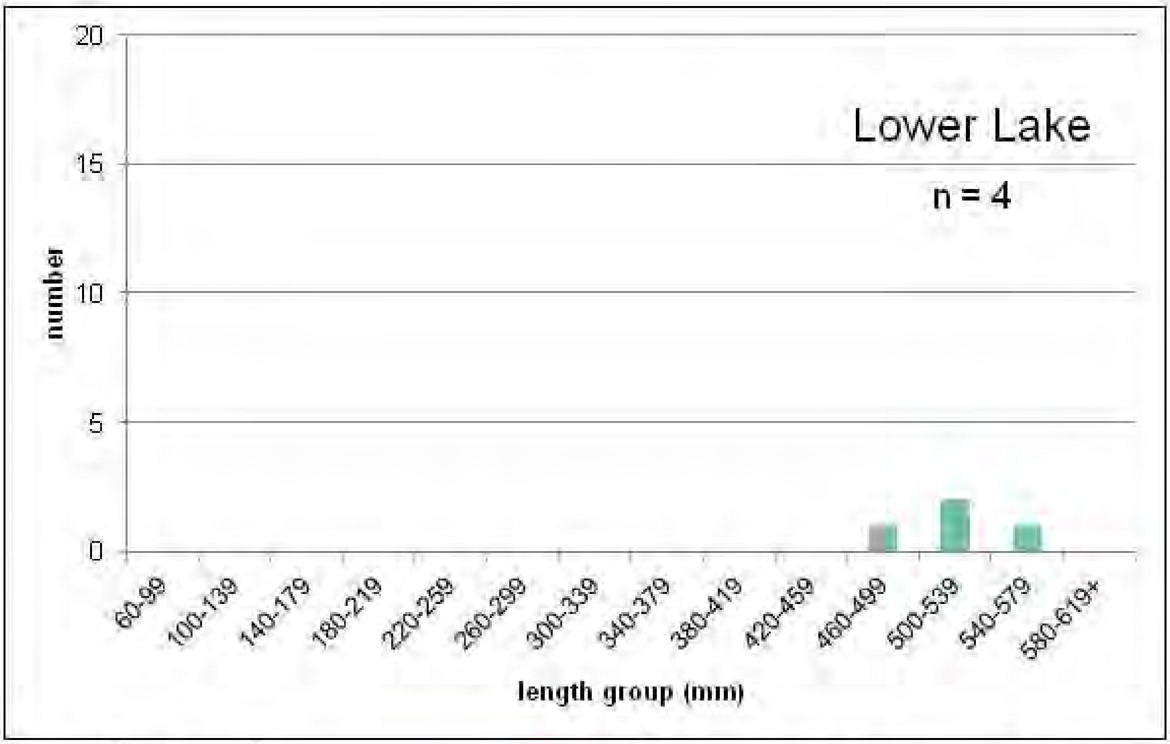
DATE:	4-26-12
PROJECT NO.: 3250115515	

Figure 3-2. Length Frequency Histograms for Gizzard Shad from the Upper and Lower Portions of the Lake of Egypt, Summer 2010.





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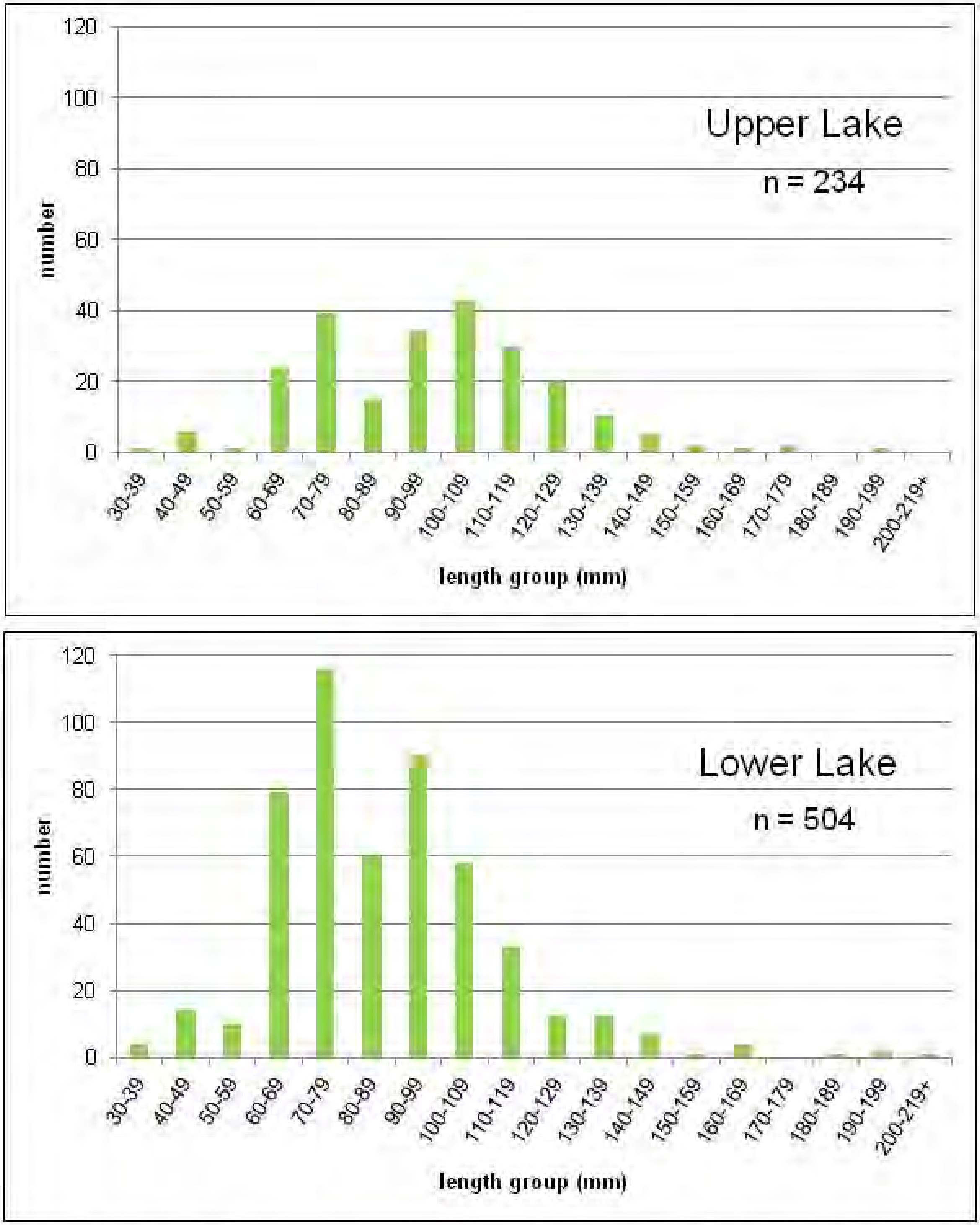
DATE:	4-26-12
PROJECT NO.: 3250115515	

Figure 3-3. Length Frequency Histograms for Channel Catfish from the Upper and Lower Portions of the Lake of Egypt. Summer 2010.



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3250115515	

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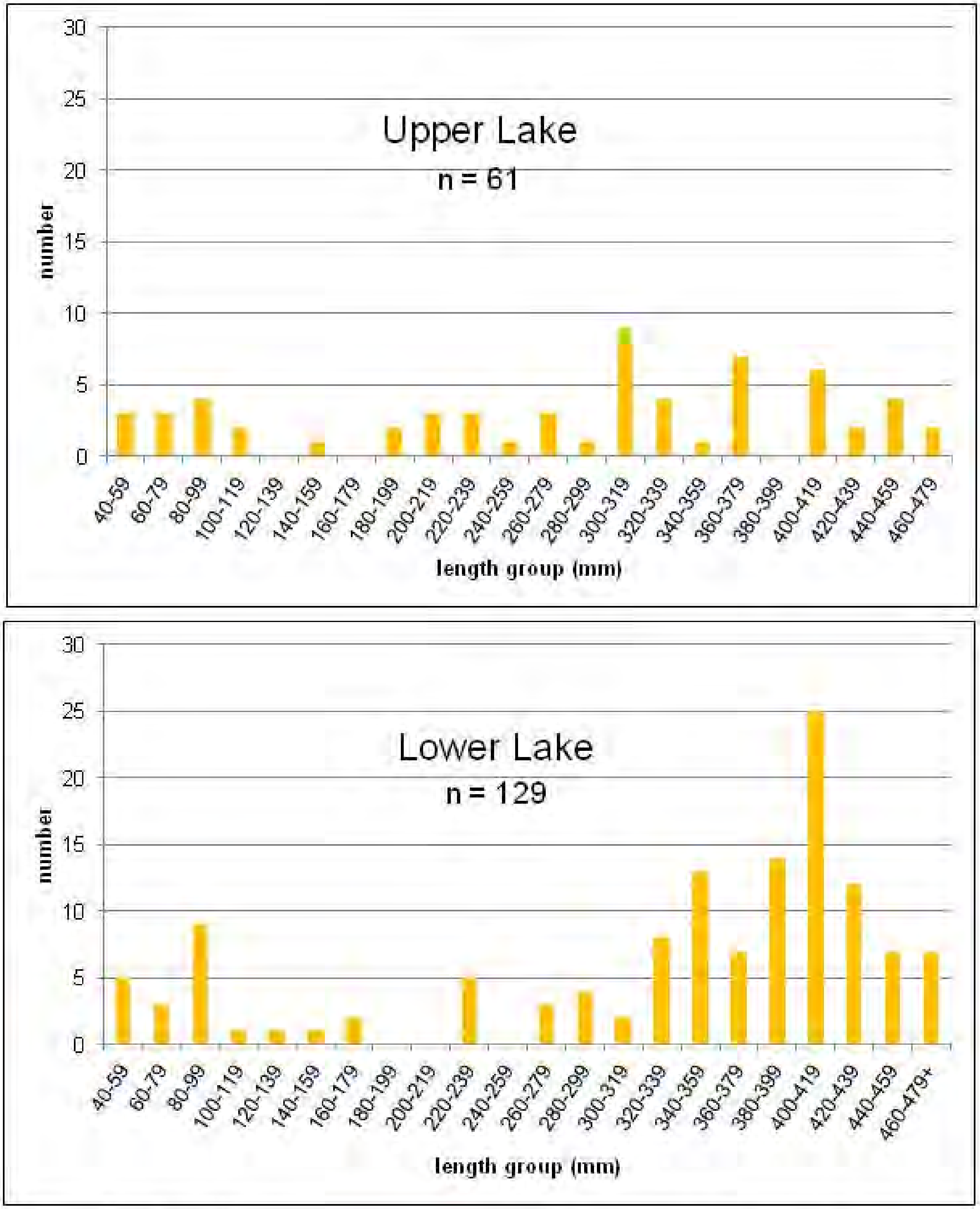
Figure 3-4. Length Frequency Histograms for Bluegill from the Upper and Lower Portions of the Lake of Egypt. Summer 2010.



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DATE:	4-26-12
PROJECT NO.: 3250115515	

Figure 3-5. Length Frequency Histograms for Largemouth Bass from the Upper and Lower Portions of the Lake of Egypt, Summer 2010.

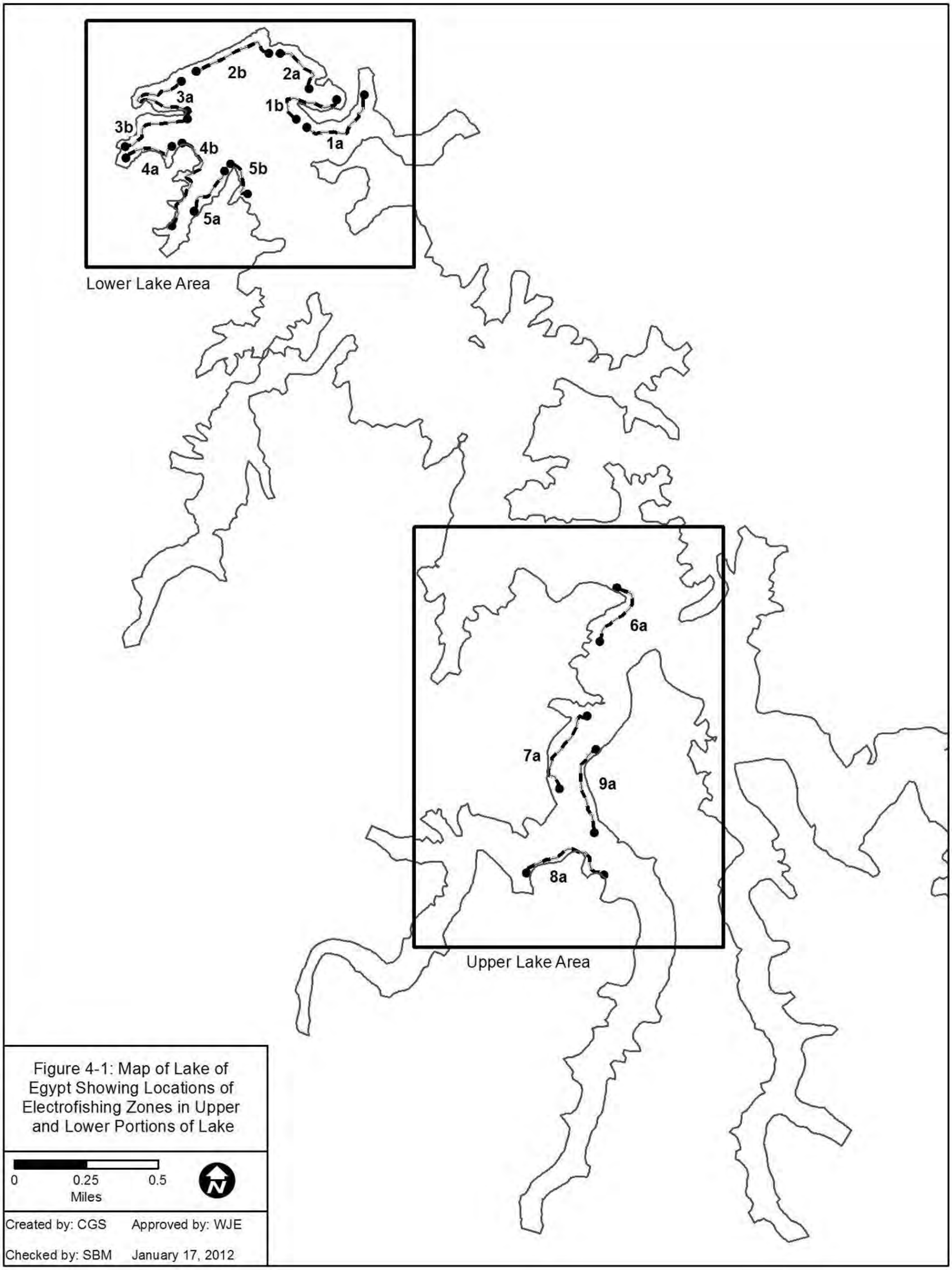


Figure 4-1: Map of Lake of Egypt Showing Locations of Electrofishing Zones in Upper and Lower Portions of Lake

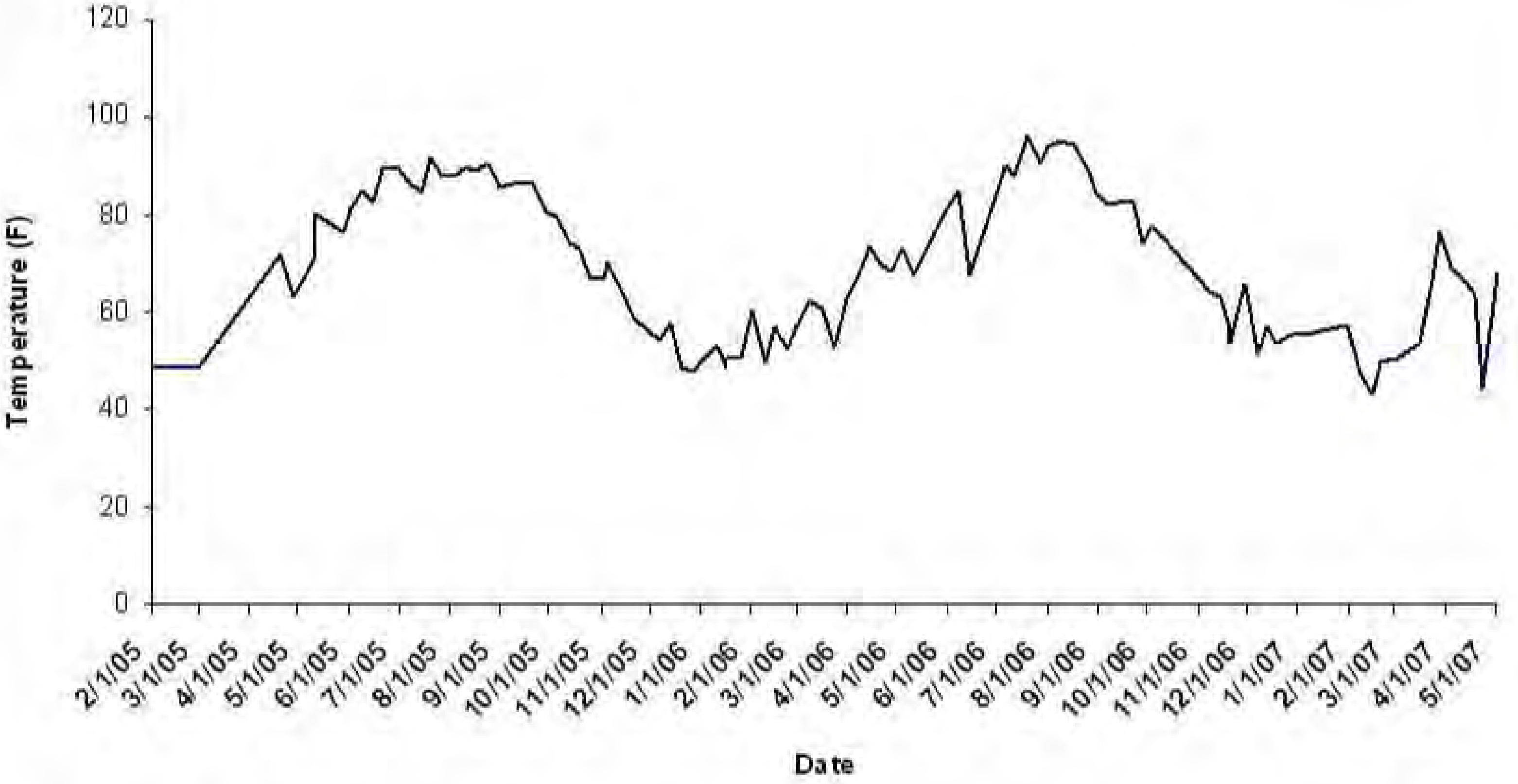
Created by: CGS Approved by: WJE

Checked by: SBM January 17, 2012

Heidinger et al, 2000

DRAWN BY:	CGS
CHECKED BY:	WJE
DATE:	10/15/2010
PROJECT NO.:	3250065201

Figure 5-1. 1998 Lake of Egypt Temperature in the Vicinity of the CWIS.



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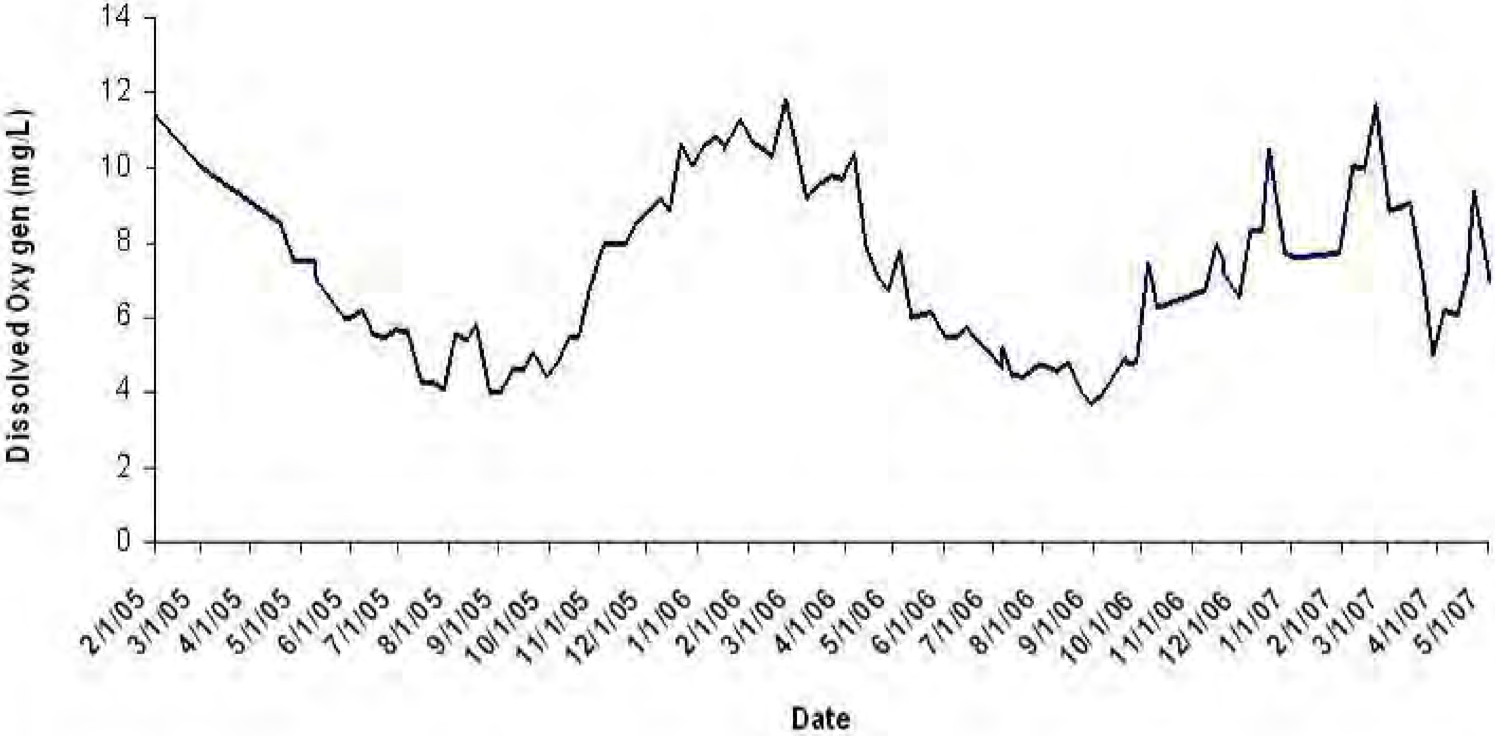
DATE:	10/15/2010
PROJECT NO.:	3250065201

Figure 5-2. Water Temperature near the CWIS, February 2005 through May 2007



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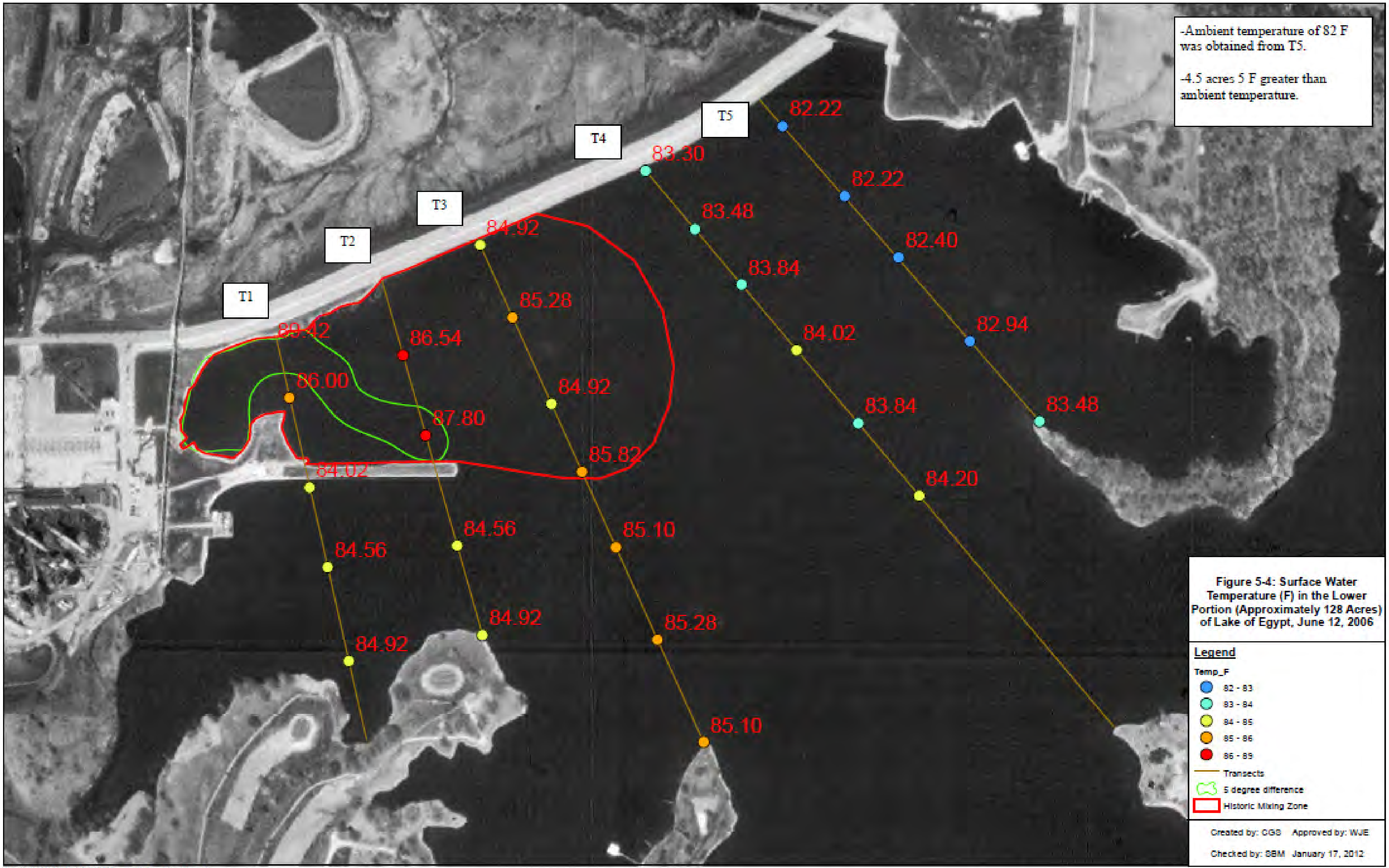
DATE:	10/15/2010
PROJECT NO.:	3250065201

Figure 5-3. Dissolved Oxygen Concentration near the CWIS, February 2005 through May 2007



-Ambient temperature of 82 F was obtained from T5.

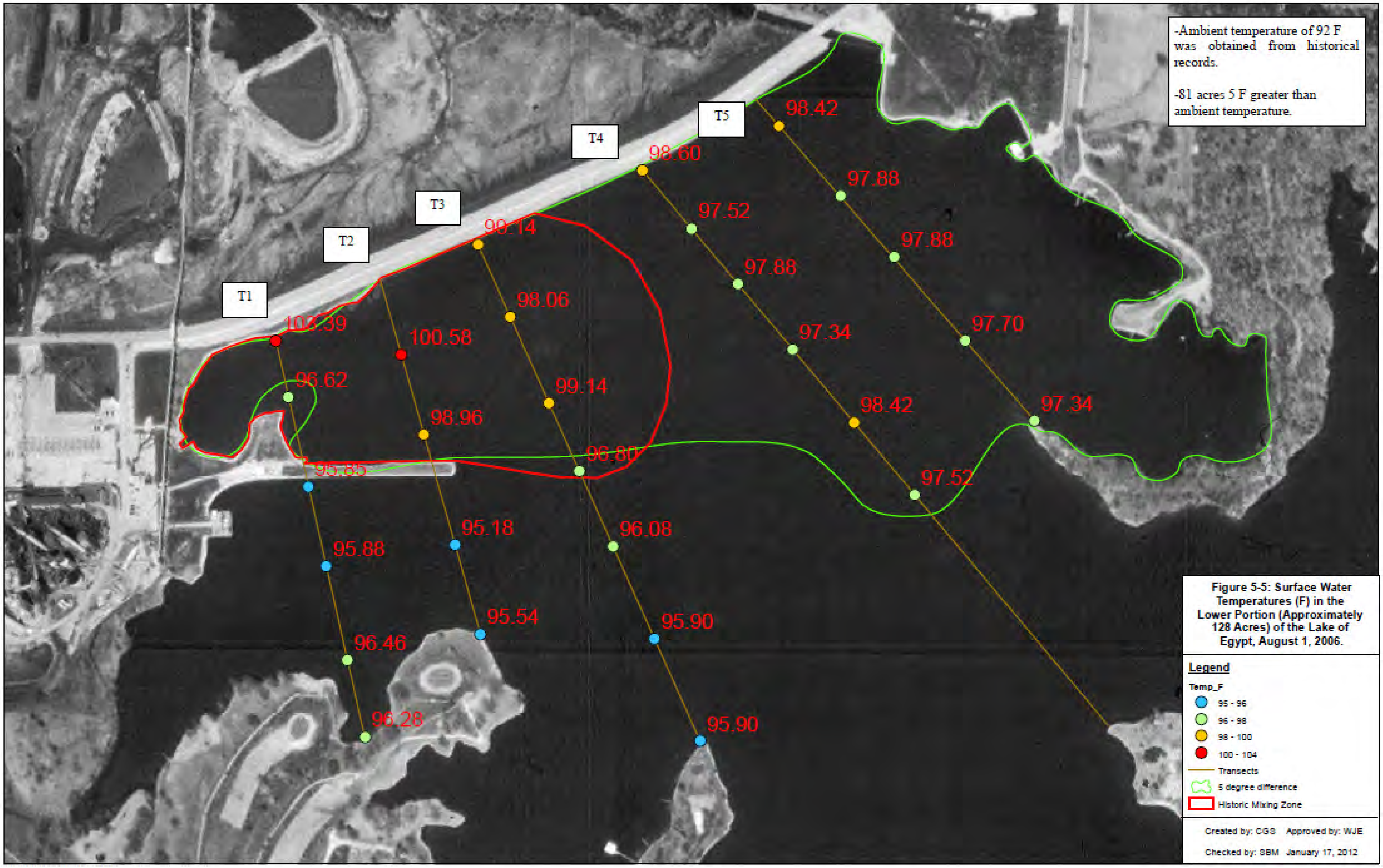
-4.5 acres 5 F greater than ambient temperature.

Figure 5-4: Surface Water Temperature (F) in the Lower Portion (Approximately 128 Acres) of Lake of Egypt, June 12, 2006

Created by: CGS Approved by: WJE

Checked by: SBM January 17, 2012

K:\I_GIS\3250065201_SIPC070702_august_thermal_profile.mxd



-Ambient temperature of 92 F was obtained from historical records.

-81 acres 5 F greater than ambient temperature.

Figure 5-5: Surface Water Temperatures (F) in the Lower Portion (Approximately 128 Acres) of the Lake of Egypt, August 1, 2006.

Created by: CGS Approved by: WJE

Checked by: SBM January 17, 2012

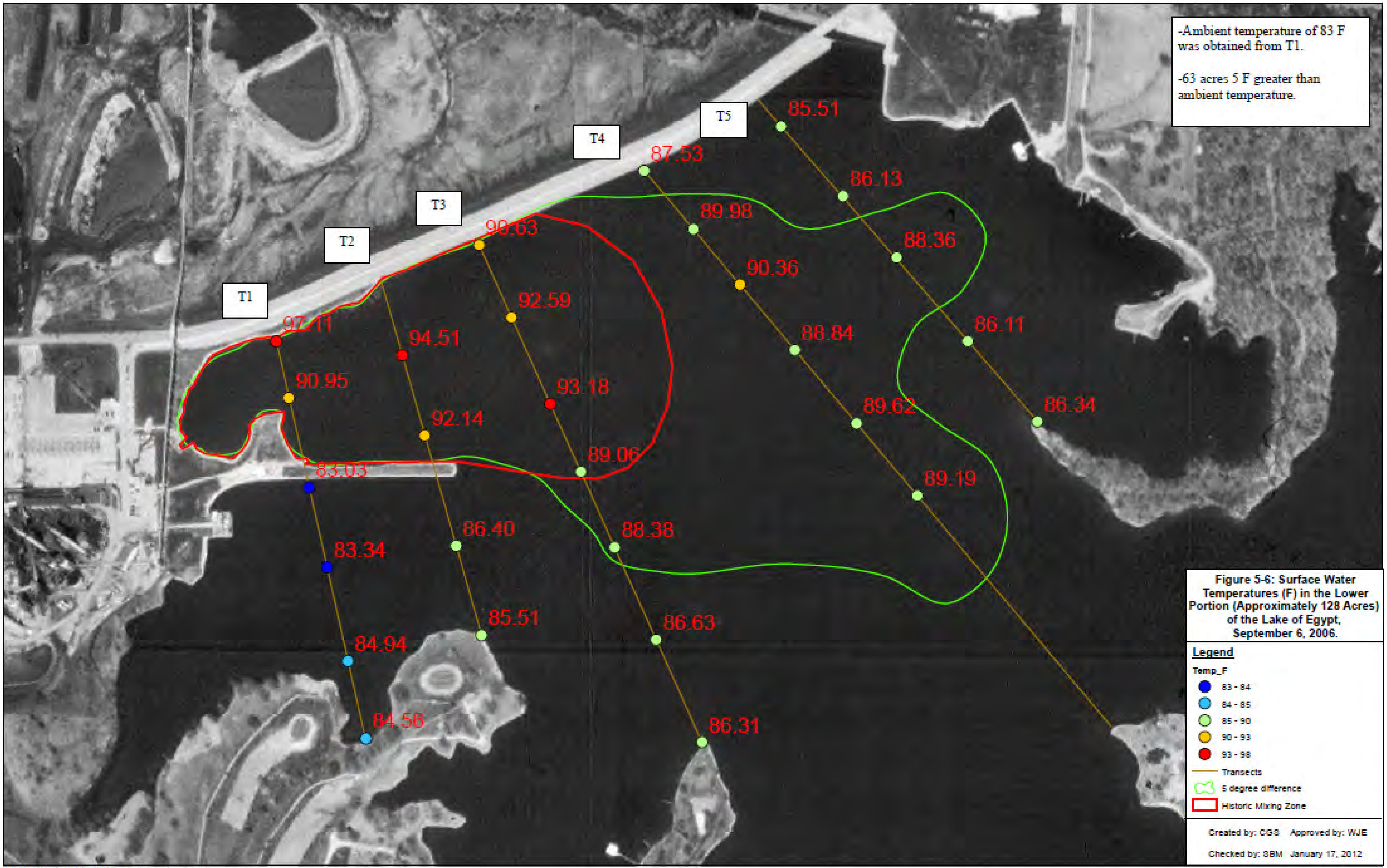


Figure 5-6: Surface Water Temperatures (F) in the Lower Portion (Approximately 128 Acres) of the Lake of Egypt, September 6, 2006.

-Ambient temperature of 83 F was obtained from T1.

-63 acres 5 F greater than ambient temperature.

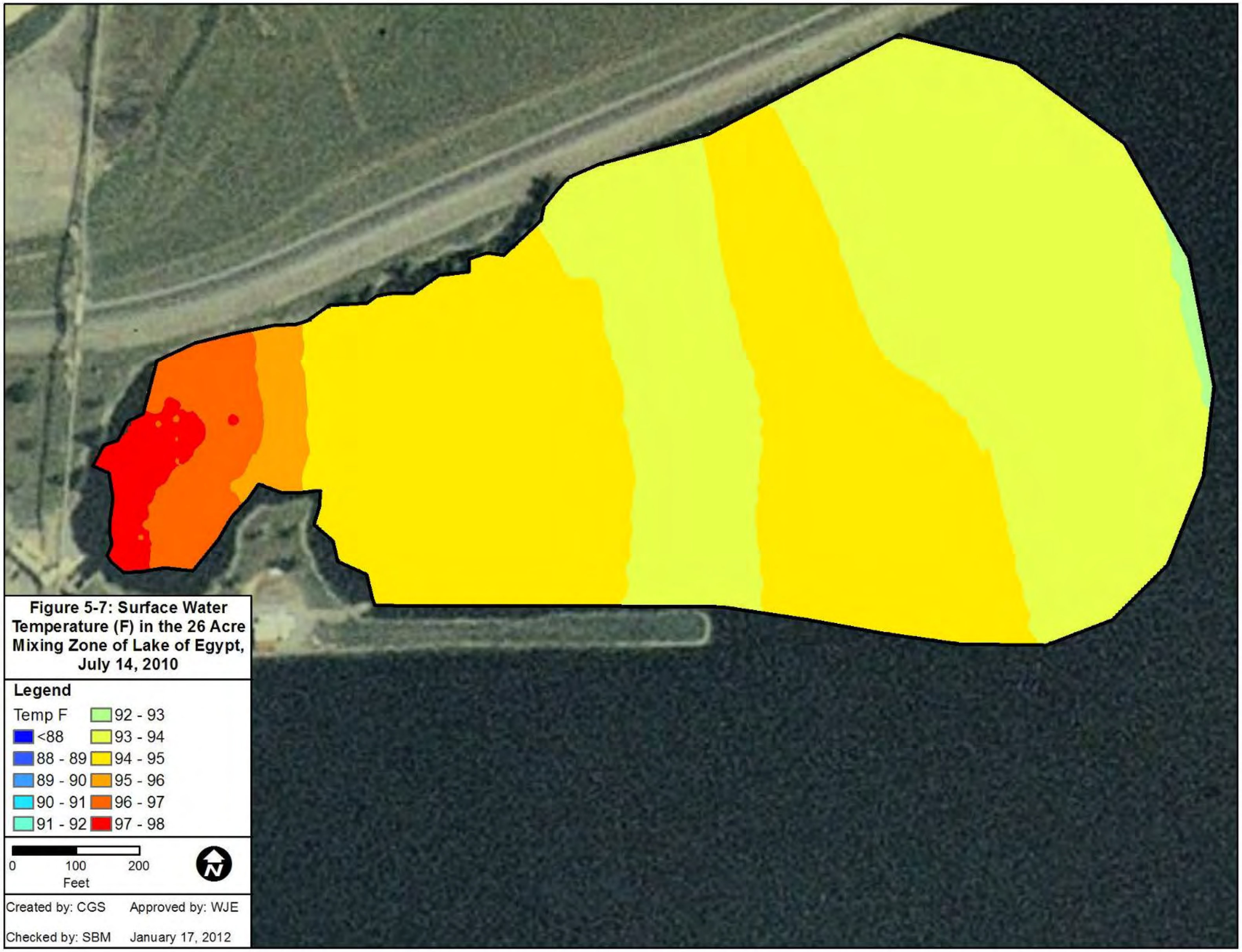


Figure 5-7: Surface Water Temperature (F) in the 26 Acre Mixing Zone of Lake of Egypt, July 14, 2010

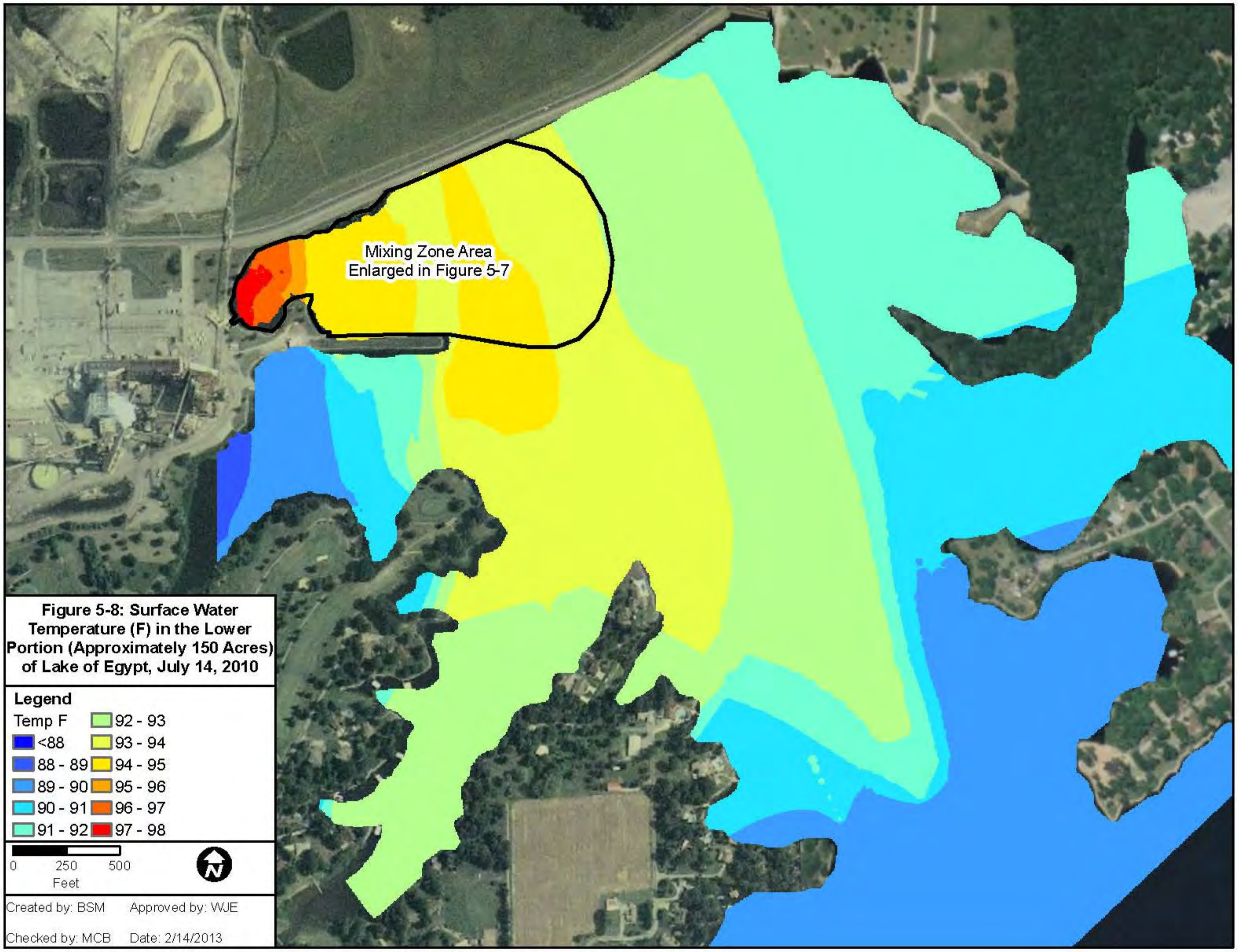


Figure 5-8: Surface Water Temperature (F) in the Lower Portion (Approximately 150 Acres) of Lake of Egypt, July 14, 2010

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Checked by: MCB Date: 2/14/2013

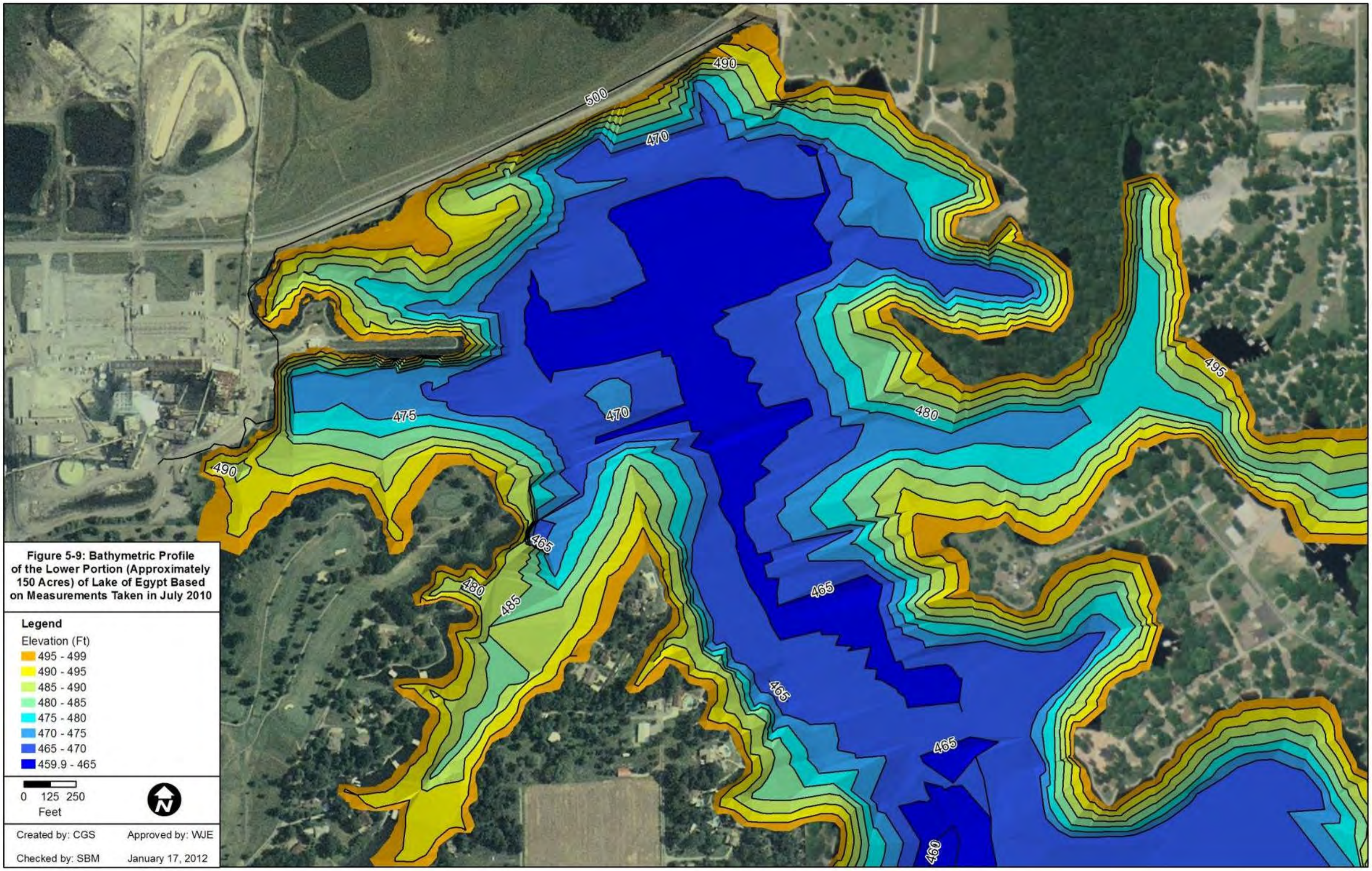

Figure 5-9: Bathymetric Profile of the Lower Portion (Approximately 150 Acres) of Lake of Egypt Based on Measurements Taken in July 2010

Legend

Elevation (Ft)

- 🟧 495 - 499
- 🟨 490 - 495
- 🟩 485 - 490
- 🟩 480 - 485
- 🟦 475 - 480
- 🟦 470 - 475
- 🟦 465 - 470
- 🟦 459.9 - 465

Created by: CGS   Approved by: WJE

Checked by: SBM   January 17, 2012

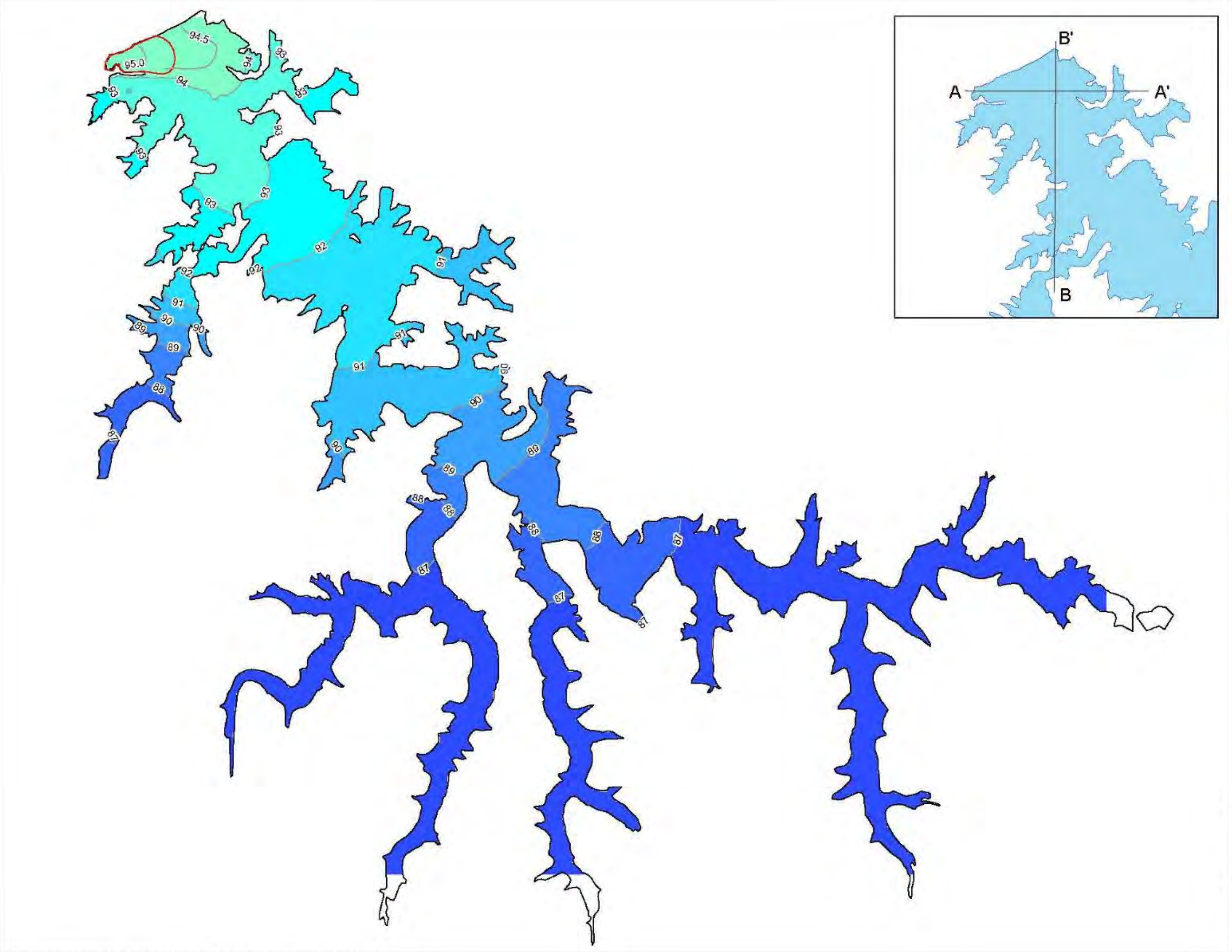

Figure 5-10: Hydrothermal Model Output
Summer Period Normal
Condition (April-November)

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Checked by: MCB Date: 2/14/2013

K:\1_GIS\3250065201_SIPC\a_MXD\2013\Fig_5_10_Summer_Normal_130214.mxd

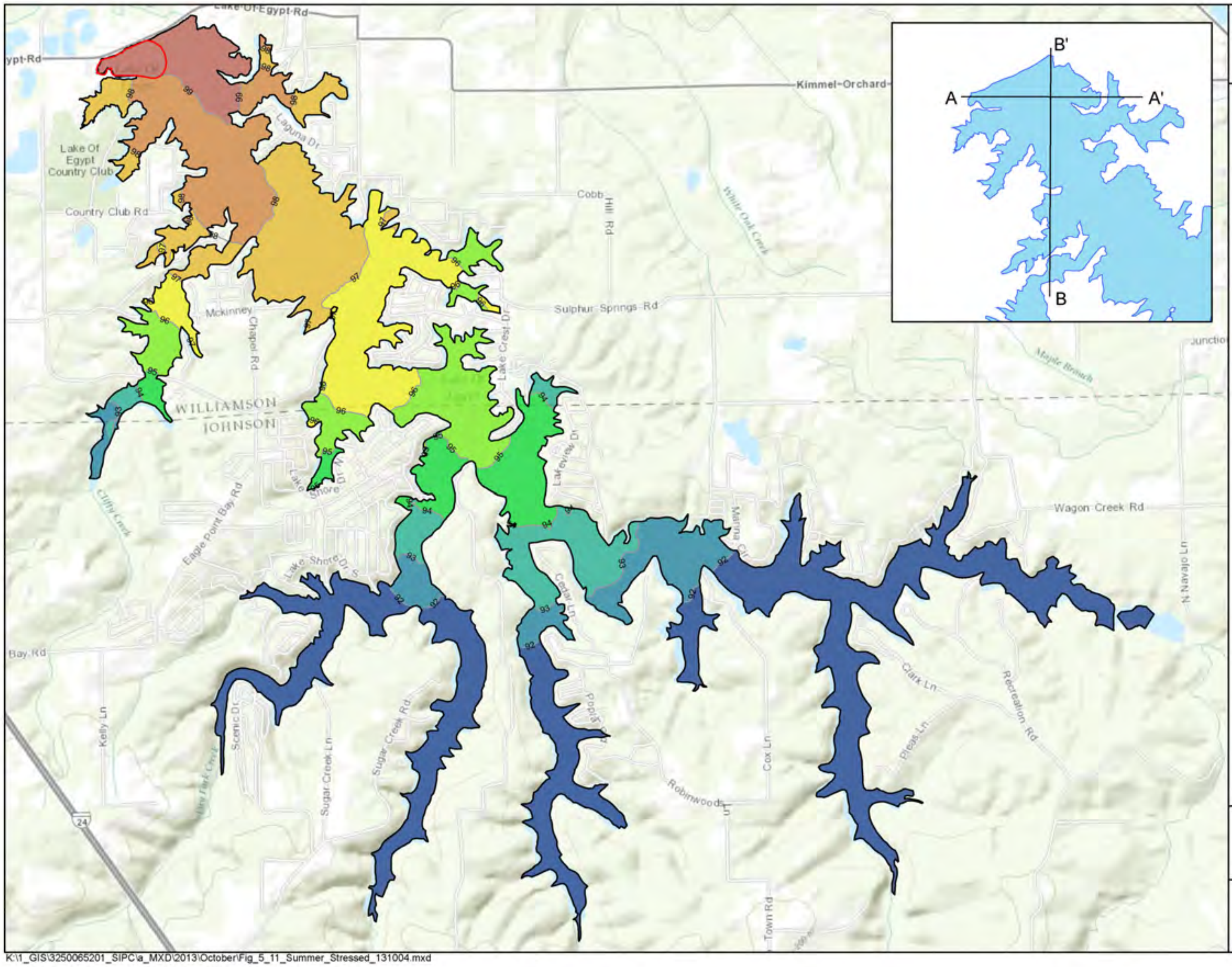


Figure 5-11: Hydrothermal Model Output
Summer Period Stressed
Condition (April-November)

Legend

Mixing Zone

Temp F

- 🟦 90.1 - 91
- 🟦 91.1 - 92
- 🟩 92.1 - 93
- 🟩 93.1 - 94
- 🟩 94.1 - 95
- 🟨 95.1 - 96
- 🟧 96.1 - 97
- 🟧 97.1 - 98
- 🟥 98.1 - 99

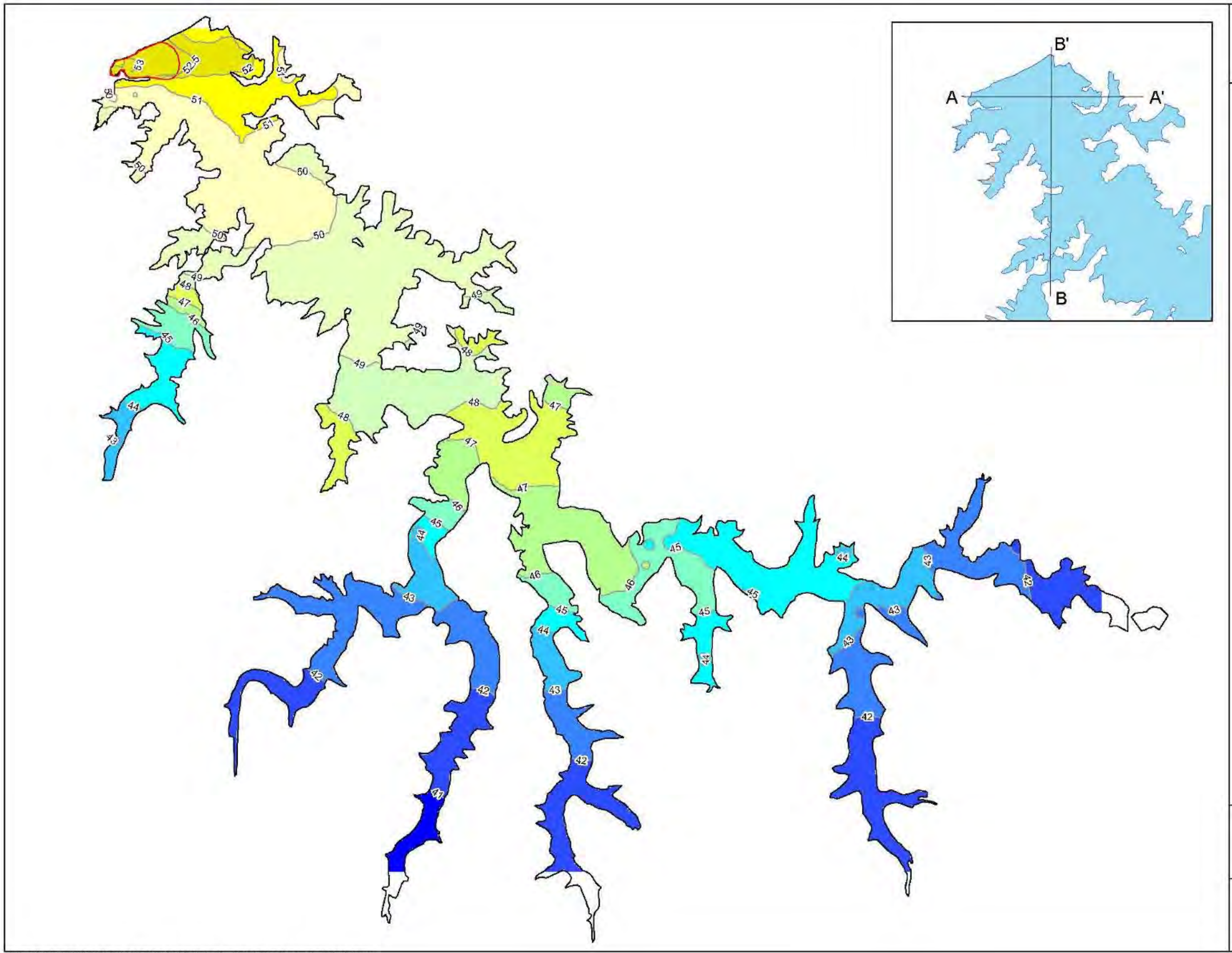
0 0.25 0.5
Miles

Created by: BSM Approved by: WJE

Checked by: MCB Date: 10/4/2013

K:\1_GIS\3250065201_SIPC\a_MXD\2013\October\Fig_5_11_Summer_Stressed_131004.mxd

Figure 5-12: Hydrothermal Model Output
Winter Normal
Condition (Jan.-Feb., 2011)



Legend

- Mixing Zone
- Winter Observed Temps

Temp F

🟦	40.9 - 41
🟦	41.1 - 42
🟦	42.1 - 43
🟦	43.1 - 44
🟦	44.1 - 45
🟩	45.1 - 46
🟩	46.1 - 47
🟨	47.1 - 48
🟩	48.1 - 49
🟨	49.1 - 50
🟨	50.1 - 51
🟨	51.1 - 52
🟨	52.1 - 53

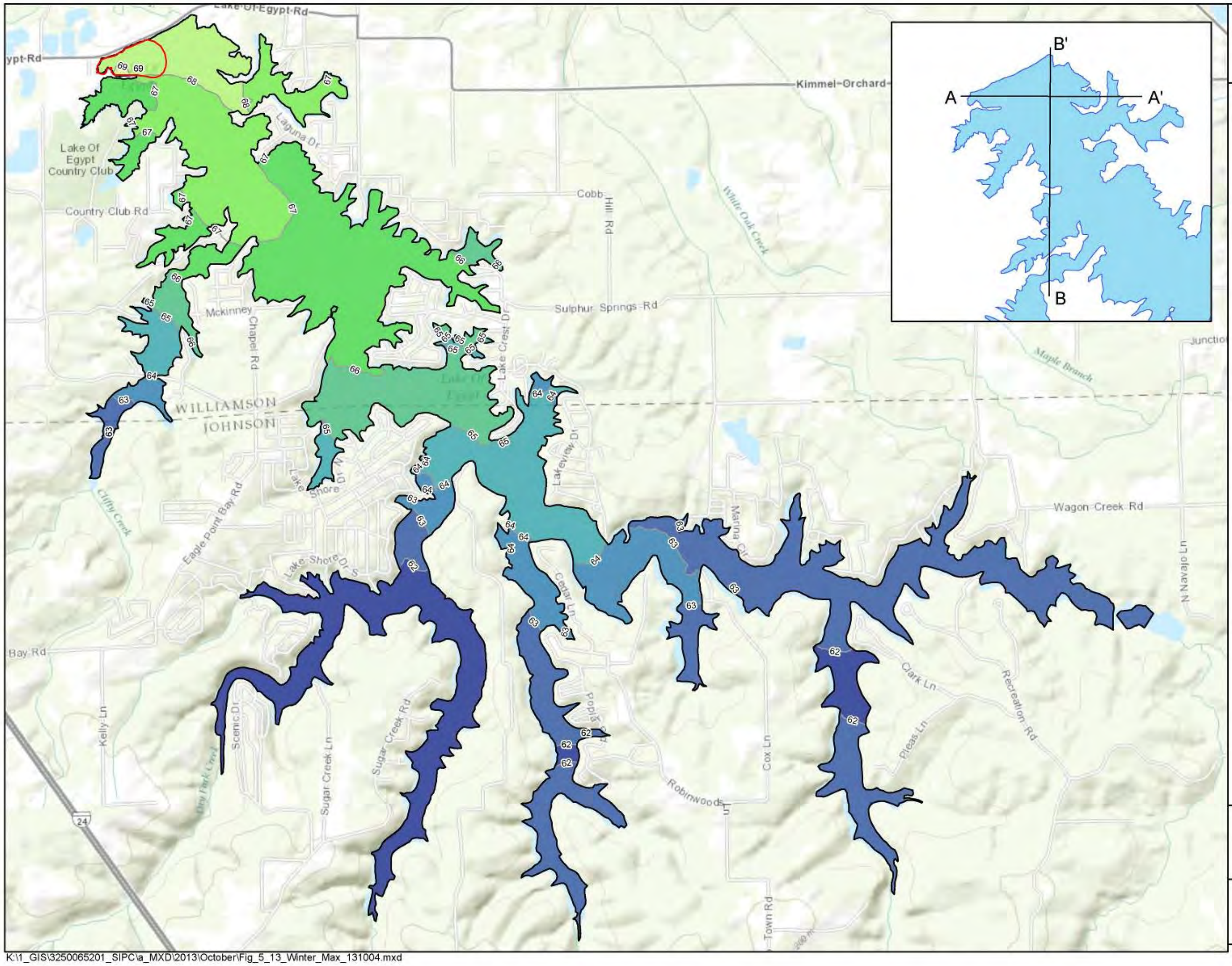
0 0.25 0.5
Miles

Created by: BSM Approved by: WJE

Checked by: MCB Date: 2/14/2013

K:\1_GIS\3250065201_SIPC\a_MXD\2013\Fig_5_12_Winter_Normal_130214.mxd

Figure 5-13: Hydrothermal Model Output
Winter Period Maximum
Condition (December-March)

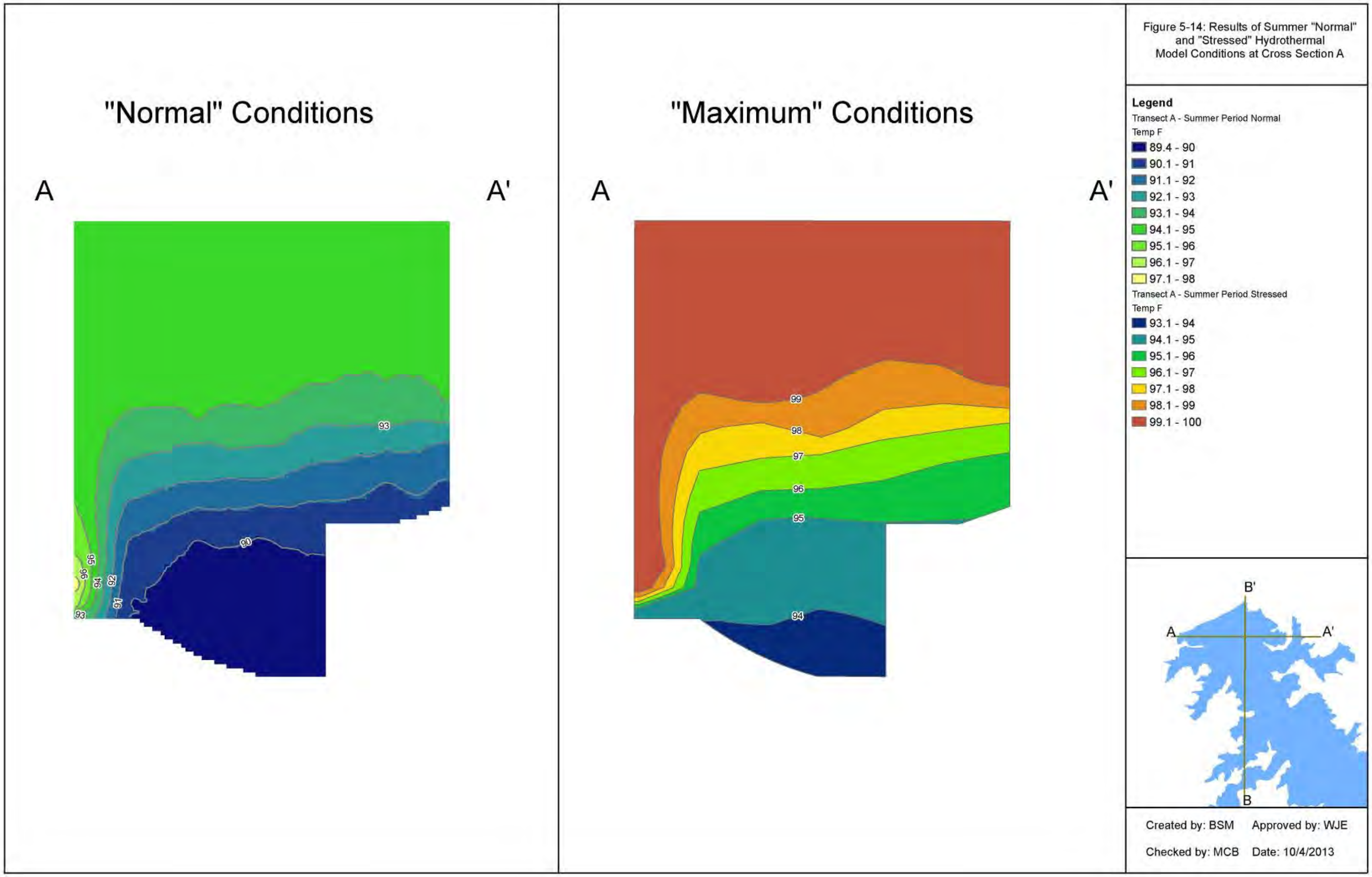


Created by: BSM Approved by: WJE

Checked by: MCB Date: 10/4/2013

K:\1_GIS\3250065201_SIPC\a_MXD\2013\October\Fig_5_13_Winter_Max_131004.mxd

Figure 5-14: Results of Summer "Normal" and "Stressed" Hydrothermal Model Conditions at Cross Section A



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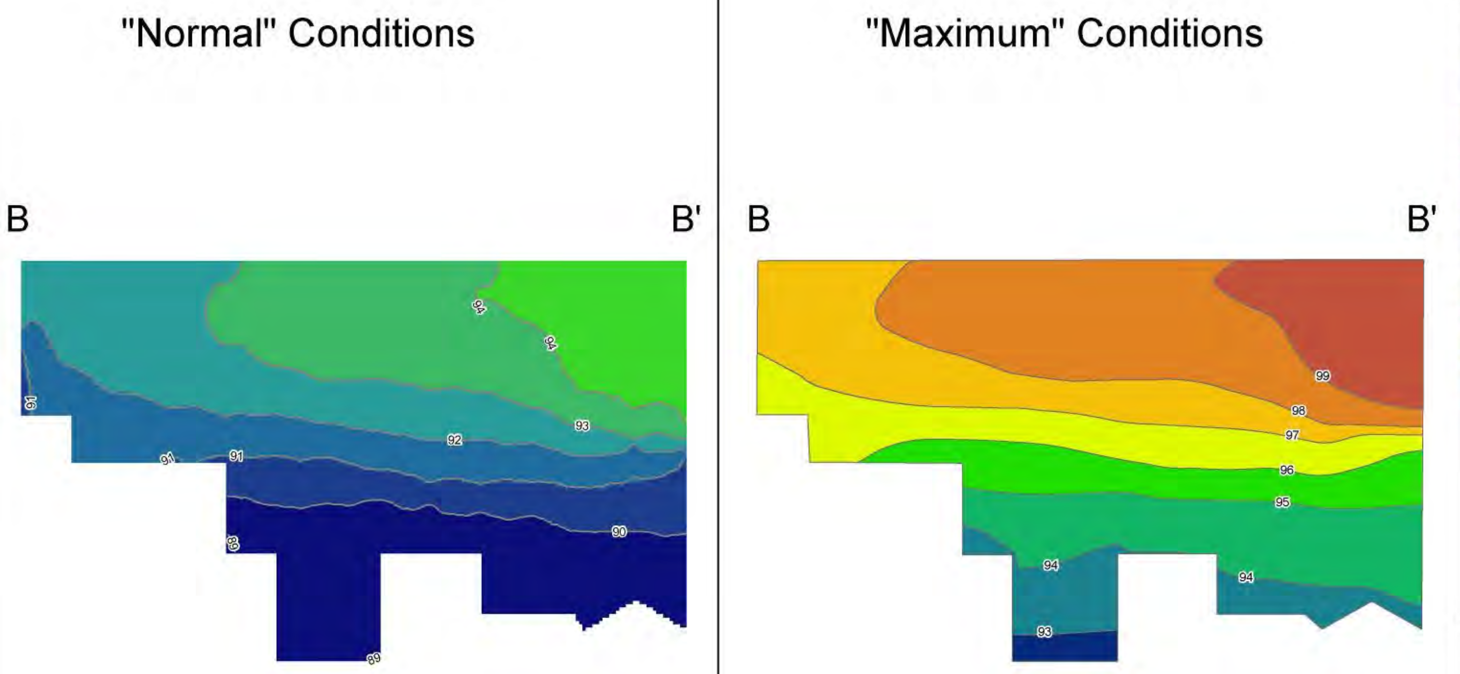
Checked by: MCB Date: 10/4/2013

Figure 5-15: Results of Summer "Normal" and "Stressed" Hydrothermal Model Conditions at Cross Section B



Legend

Transect B - Summer Period Normal

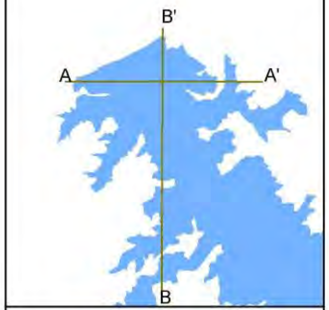
Temp F

- 🟦 89.4 - 90
- 🟦 90.1 - 91
- 🟦 91.1 - 92
- 🟦 92.1 - 93
- 🟩 93.1 - 94
- 🟩 94.1 - 95
- 🟩 95.1 - 96
- 🟩 96.1 - 97
- 🟨 97.1 - 98

Transect B - Summer Period Stressed

Temp F

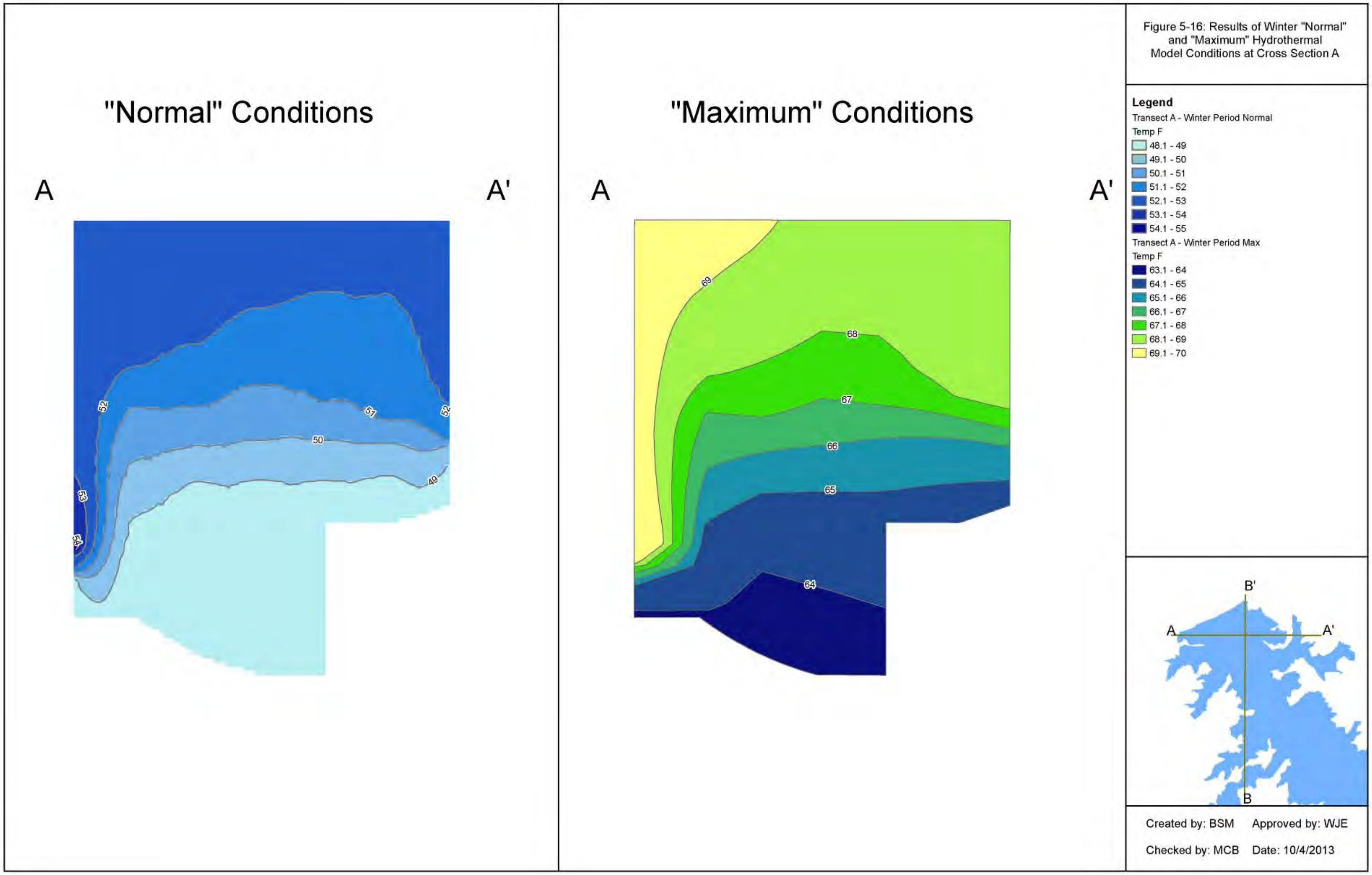
- 🟦 92.1 - 93
- 🟦 93.1 - 94
- 🟩 94.1 - 95
- 🟩 95.1 - 96
- 🟨 96.1 - 97
- 🟧 97.1 - 98
- 🟧 98.1 - 99
- 🟥 99.1 - 100



Created by: BSM Approved by: WJE

Checked by: MCB Date: 10/4/2013

Figure 5-16: Results of Winter "Normal" and "Maximum" Hydrothermal Model Conditions at Cross Section A



Legend

Transect A - Winter Period Normal

Temp F

- ▨ 48.1 - 49
- ▨ 49.1 - 50
- ▨ 50.1 - 51
- ▨ 51.1 - 52
- ▨ 52.1 - 53
- ▨ 53.1 - 54
- ▨ 54.1 - 55

Transect A - Winter Period Max

Temp F

- ▨ 63.1 - 64
- ▨ 64.1 - 65
- ▨ 65.1 - 66
- ▨ 66.1 - 67
- ▨ 67.1 - 68
- ▨ 68.1 - 69
- ▨ 69.1 - 70

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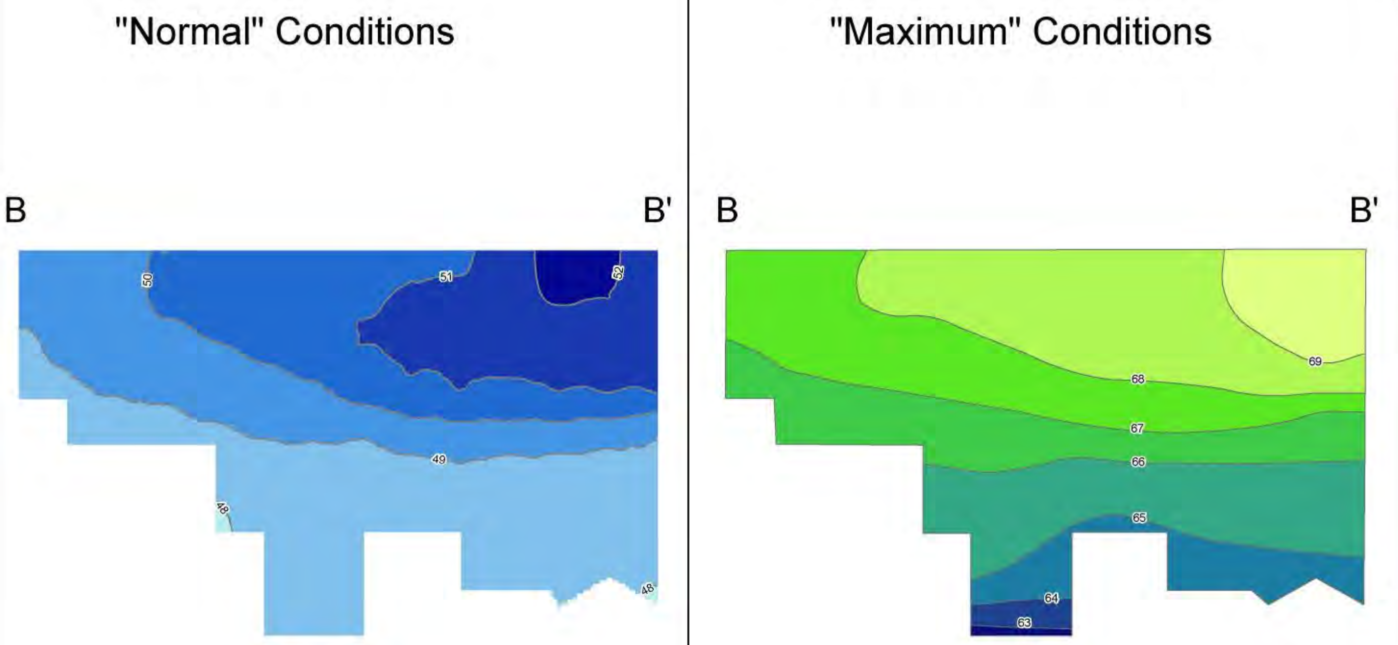
Checked by: MCB Date: 10/4/2013

Figure 5-17: Results of Winter "Normal" and "Maximum" Hydrothermal Model Conditions at Cross Section B



Legend

Transect B - Winter Period Normal

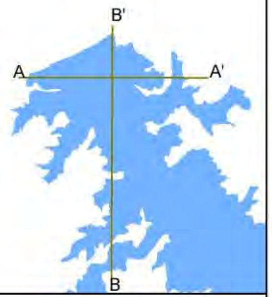
Temp F

▨ 47.8 - 48
▨ 48.1 - 49
▨ 49.1 - 50
▨ 50.1 - 51
▨ 51.1 - 52
▨ 52.1 - 53

Transect B - Winter Period Max

Temp F

▨ 62.1 - 63
▨ 63.1 - 64
▨ 64.1 - 65
▨ 65.1 - 66
▨ 66.1 - 67
▨ 67.1 - 68
▨ 68.1 - 69
▨ 69.1 - 70



Created by: BSM Approved by: WJE

Checked by: MCB Date: 10/4/2013