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WATER RESOURCE AND HUMAN-USE VALUES ASSESSMENT: LAKE MONROE, VOLUSIA AND SEMINOLE COUNTIES, FLORIDA

REVISED SEPTEMBER 2008

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT

WATER RESOURCE AND HUMAN-USE VALUES ASSESSMENT: LAKE MONROE, VOLUSIA AND SEMINOLE COUNTIES, FLORIDA

Prepared for:

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Revisions

The following are the revisions to the December 2006 report:

Page No.	Line No.	Was	Changed to
5-32	10	Mace's (2006a) recommended MFLs	the recommended MFLs by Mace (2006a)
5-44	13	RM 14.8	RM 14.3
5-44	14	RM 19.8	RM 19.2
5-44	14	RM 24.9	RM 23.7
5-44	15	RM 34.1	RM 33.9
5-44	15	RM 48.4	RM 47.9
5-44	21	RM 9.8	RM 8.8
5-44	24	RM 19.8	RM 19.2
5-44	24	RM 24.9	RM 23.7
5-44	24	RM 31.6	RM 30.8
5-44	25	RM 34.1	RM 33.9
5-48	7	0.37	0.36 (due to round off error)
5-48	10	no measurable changes	less than 0.01 ppt change
5-48	11	RM 67.8	RM 67.1
5-51	2	RM 19.8	RM 19.2
5-51	2	0.37	0.36
5-51	7	RM 24.9	RM 23.7
5-51	11	RM 34.1	RM 33.9
5-51	15	RM 48.4	RM 49.9
5-51	24	0.19	0.18
5-51	27	0.38	0.37
5-54	4	0.87	0.97
5-61	1	On the other hand	Additionally
5-61	11	April, May, and June	May and June
5-61	22	1.3 1.3 1.0 0.6 0.5	1.3 1.4 1.1 0.6 0.8
5-62		Replace Figure 5-17	
5-63	6	0.65 0.74 0.51 0.30 0.23	0.64 0.75 0.52 0.30 0.62

Page No.	Line No.	Was	Changed to
5-63	7	1.31 1.33 1.04 0.62 0.47	1.28 1.36 1.07 0.61 0.77
5-63	8	1.93 1.93 1.52 1.04 0.70	1.88 1.98 1.57 1.04 0.90
5-63	14	991 1,308 521 574 36	967 1,169 590 437 102
5-63	15	1,960 2,249 1,173 1,103 80	1,913 2,111 1,140 1,007 124
5-63	16	3,037 3,221 1,830 1,622 133	2,937 3,018 1,732 1,211 154
5-67	20-21	0.3 0.5 0.8	0.8 0.5 0.3
5-68	16	28.5 28.8 29.0 29.3	27.6 27.9 28.1 28.4
5-70	6	9.0	8.8
5-70	7	19.8	19.2
5-70	8	34.1	33.9
5-70	9	50.3	49.9
5-71	7	9.0	8.8
5-71	8	11.4 20.62 11.97 0.13 0.26 0.38	10.6 21.78 11.86 0.12 0.24 0.35
5-71	9	14.8	14.3
5-71	10	19.8	19.2
5-71	11	24.9 7.01 5.20 0.17	23.7 7.46 5.76 0.18
5-71	12	34.1 2.90 1.25 0.12 0.26 0.39	33.9 2.74 1.15 0.12 0.25 0.38
5-71	13	42.9	42.3
5-71	14	48.4	47.9
5-71	15	50.3	49.9
5-71	16	60.9	60.2
5-71	17	67.8	67.1
5-72	8	1,103	1,007
5-146	25	On the other hand	Additionally

ACKNOWLEDGEMENT

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ACRONYMS, ABBREVIATIONS, AND UNITS OF MEASURE

ºC	degrees Celsius
CDM	Camp, Dresser & McKee
cfs	cubic foot per second
Chl *a*	chlorophyll *a*
cm	centimeter
CUP	consumptive use permit
CWA	Clean Water Act
DO	dissolved oxygen
DWSP	District Water Supply Plan
ECT	Environmental Consulting & Technology, Inc.
EFDC	Environmental Fluid Dynamic Code
EPA	U.S. Environmental Protection Agency
ºF	degrees Fahrenheit
F.A.C.	Florida Administrative Code
FDEP	Florida Department of Environmental Protection
FDOT	Florida Department of Transportation
FFWCC	Florida Fish and Wildlife Conservation Commission
FLEPPC	Florida Exotic Plant Pest Council
FMA	Fun Maritime Academy
FPL	Florida Power & Light Company
fps	foot per second
F.S.	*Florida Statutes*
ft	feet
ft-NGVD	feet National Geodetic Vertical Datum
$g/m^2/yr$	gram per square meter per year
HEC-RAS	Hydrologic Engineering Center River Analysis System
HRT	hydraulic retention time
I	Interstate
JU	Jacksonville University
$lb/ft^2/day$	pound per square foot per day
lb_f/ft^2	pound force per square foot
LSJR	Lower St. Johns River
MA	Minimum Average
MEC	Mactec Engineering & Consulting, Inc.
MFH	Minimum Frequent High
MFL	Minimum Frequent Low
MFLs	minimum flows and levels
MGD	million gallons per day
m^3/sec	cubic meter per second
mg/L	milligram per liter
mi^2	square mile
MLLW	mean low low water
mm	millimeter

ACRONYMS, ABBREVIATIONS, AND
UNITS OF MEASURE
(Continued, Page 2 of 2)

mph	miles per hour
MSJR	Middle St. Johns River
msl	mean sea level
Pa	Pascal, Newton per square meter
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
ppt	part per thousand
RM	River Mile
SAV	submerged aquatic vegetation
SJRLM	St. Johns River at Lake Monroe
SJRND	St. Johns River near DeLand
SJRWMD	St. Johns River Water Management District
SR	State Road
SSARR	Streamflow Synthesis and Reservoir Regulation
TMDL	total maximum daily load
TN	total nitrogen
TP	total phosphorus
TSI	Trophic State Index
TSS	total suspended solids
µg/L	microgram per liter
U.S.	U.S. Highway
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
USJR	Upper St. Johns River
USJRB	Upper St. Johns River Basin
WRV	water resource value

EXECUTIVE SUMMARY

The St. Johns River at Lake Monroe (SJRLM), Volusia and Seminole counties, has been identified as a potential alternative surface water supply source for east-central Florida in the *2005 District Water Supply Plan* (DWSP) (St. Johns River Water Management District [SJRWMD], 2006). The 2003 East Central Florida Water Supply Planning Initiative also identified the SJRLM Project as one of 11 potential water supply developments that could be incorporated into a 2004 interim update to the DWSP (Vergara, 2004). Development of alternative water supply sources is required to avoid projected environmental impacts to regional water resource features, such as springs, isolated wetlands, and lakes, that would result if increased ground water withdrawals were used to meet projected future water supply needs. To protect ecological resources, human-use and water resource values (WRVs), and quantify safe yields from this reach of the St. Johns River, SJRWMD is currently establishing minimum levels for Lake Monroe, as mandated by Section 373.042, *Florida Statutes (F.S.*). Minimum flows and levels (MFLs) define a minimum hydrologic regime required to protect the water resources or ecology of the area, and result in the determination of water availability and setting the maximum limit of the permitted water withdrawals (Section 373.042, *F.S.*).

SJRWMD's Lake Monroe recommended MFLs determination included an extensive evaluation of topographic, soil, and vegetation data collected within the plant communities associated with the river floodplain (Mace, 2006a). The ecosystems that exist in the Lake Monroe floodplain were categorized by SJRWMD biologists based on topography, soil, and vegetation characteristics observed along seven transects through the wetland communities.

Based on the evaluation of hydric soils and wetland communities, SJRWMD recommended three minimum surface water levels for Lake Monroe: Minimum Frequent High (MFH) level, Minimum Average (MA) level, and Minimum Frequent Low (MFL) level. The technical evaluation is included in the report *Preliminary Minimum Levels Determination: Lake Monroe in Volusia and Seminole Counties* (Mace 2006a). Hydrologic models were developed by Robison (2004a) to evaluate the recommended MFLs, and to provide SJRWMD an implementation tool to assist in making water management decisions.

According to Section 62-40.473, Florida Administrative Code (*F.A.C.*), the establishment of MFLs should consider the protection of water resources; natural seasonal fluctuation of water flows or levels; and environmental water resource values (WRVs) associated with coastal, estuarine, aquatic, and wetland ecology, including:

1. Recreation in and on the water (Rule 62-40.473[1][a], *F.A.C.*).
2. Fish and wildlife habitats and the passage of fish (Rule 62-40.473[1][b], *F.A.C.*).
3. Estuarine resources (Rule 62-40.473[1][c], *F.A.C.*).
4. Transfer of detrital material (Rule 62-40.473[1][d], *F.A.C.*).
5. Maintenance of freshwater storage and supply (Rule 62-40.473[1][e], *F.A.C.*).
6. Aesthetic and scenic attributes (Rule 62-40.473[1][f], *F.A.C.*).
7. Filtration and absorption of nutrients and other pollutants (Rule 62-40.473[1][g], *F.A.C.*).
8. Sediment loads (Rule 62-40.473[1][h], *F.A.C.*).
9. Water quality (Rule 62-40.473[1][i], *F.A.C.*).
10. Navigation (Rule 62-40.473[1][j], *F.A.C.*).

Environmental Consulting & Technology, Inc. (ECT), was contracted by SJRWMD to conduct an assessment to consider whether these 10 WRVs are protected under the recommended MFLs hydrologic conditions for Lake Monroe.

ECT utilized SJRWMD documents containing hydrologic and ecological information in the Lake Monroe area, field reconnaissance, information in the scientific literature, and expert opinion to assess whether these 10 WRVs are protected under the recommended MFLs hydrologic conditions for Lake Monroe. The results of this assessment are summarized in Table ES-1.

In summary, ECT concludes that the recommended MFLs for Lake Monroe will protect all 10 WRVs listed in Section 62-40.473, *F.A.C.* Recommendations for further study have been made.

Table ES-1. WRVs Protection Assessment Summary for Lake Monroe MFLs Regime

	Resource or Value	MFLs Protects the Resource: Yes (1)	MFLs Protects the Resource: No (2)
a.	Recreation in and on the water	×	
b.	Fish and wildlife habitats and the passage of fish	×	
c.	Estuarine resources	×	
d.	Transfer of detrital material	×	
e.	Maintenance of freshwater storage and supply	×	
f.	Aesthetic and scenic attributes	×	
g.	Filtration and absorption of nutrients and other pollutants	×	
h.	Sediment loads	×	
i.	Water quality	×	
j.	Navigation	×	

Notes:

(1) Recommended MFLs allow for decline in water levels, but the resource value will be protected.
(2) Recommended MFLs would allow water levels to decline such that WRVs are not protected.

Source: ECT, 2006.

1.0 INTRODUCTION

The St. Johns River at Lake Monroe (SJRLM), Volusia and Seminole counties, has been identified as a potential alternative surface water supply source for east-central Florida in the *2005 District Water Supply Plan* (DWSP) (St. Johns River Water Management District [SJRWMD], 2006). The 2003 East Central Florida Water Supply Planning Initiative also identified the SJRLM Project as one of 11 potential water supply development projects that could be incorporated into a 2004 interim update to the DWSP (Vergara, 2004). Development of alternative water supply sources is required to avoid projected environmental impacts to regional water resource features, such as springs, isolated wetlands, and lakes, that would result if increased ground water withdrawals were used to meet projected future water supply needs. To protect ecological resources, human-use and water resource values (WRVs), and quantify safe yields from this reach of the St. Johns River, SJRWMD is currently establishing minimum levels for Lake Monroe, as mandated by Section 373.042, *Florida Statutes* (*F.S.)*. The minimum flows and levels (MFLs) designate the minimum hydrologic/hydraulic conditions that must be maintained in the river to protect the water resources or ecology of the area by setting the maximum limit of the permitted water withdrawals (Section 373.042, *F.S.*).

Section 62-40.473, Florida Administrative Code (*F.A.C.*), states: "In establishing minimum flows and levels pursuant to Section 373.042, consideration shall be given to the protection of water resources, natural seasonal fluctuations in water flows or levels, and environmental values associated with coastal, estuarine, aquatic, and wetlands ecology." Relevant factors that relate to specific elements of water resources and ecology must be considered in any MFLs development. The establishment of MFLs determines whether or not water may be available for other reasonable beneficial uses. Once MFLs have been established, they provide technical input to future water supply development and consumptive use permitting. Rule 40C-8.011(5), *F.A.C.*, states that MFLs "…are used as a basis for limitations on withdrawals of ground water and surface water, for reviewing proposed surface water management and storage systems and stormwater management systems, and for imposing water shortage restrictions." In addition, MFLs can be used to reduce current water use allocation for systems that are over allocated.

SJRWMD's MFLs determination for Lake Monroe included an extensive evaluation of topographic, soil, and vegetation data collected within the plant communities associated with the river floodplain (Mace, 2006a). The ecosystems that exist in Lake Monroe were categorized by SJRWMD biologists based on topography, soil, and vegetation characteristics observed along seven transects through the wetland communities. Hydrologic models were developed by Robison (2004a) to implement the MFLs for Lake Monroe, and to provide SJRWMD a basis for decision-making as to how best to manage surface water withdrawals.

Based on the evaluation of hydric soils and wetland communities, SJRWMD considered three minimum surface water levels for Lake Monroe: Minimum Frequent High (MFH) level, Minimum Average (MA) level, and Minimum Frequent Low (MFL) level (Mace, 2006a). The elevations of these recommended MFLs at Lake Monroe and their associated return intervals and durations are listed in Table 1-1.

Table 1-1. Recommended Minimum Surface Water Levels for Lake Monroe

Recommended Minimum Levels	Elevation (ft-NGVD 1929 datum)	Duration	Return Interval
MFH Level	2.8	30 days	2 years
MA Level	1.2	180 days	1.5 years
MFL Level	0.5	120 days	5 years

Source: Mace, 2006a.

Robison (2004a) used an interactive hydrologic modeling approach to determine the maximum surface water withdrawal rate allowable under the recommended MFLs. Based on this analysis, it was determined that 180 cubic feet per second (cfs) could be withdrawn from and upstream of Lake Monroe. The hydrologic conditions resulting from the 180-cfs withdrawal henceforth will be referred to as the **recommended MFLs hydrologic conditions** for Lake Monroe.

According to Section 62-40.473, *F.A.C.*, the establishment of MFLs should consider the protection of water resources; natural seasonal fluctuation of water flows or levels; and environmental WRVs associated with coastal, estuarine, aquatic, and wetland ecology, including

a. Recreation in and on the water (WRV-1) (Rule 62-40.473[1][a], *F.A.C.*).
b. Fish and wildlife habitats and the passage of fish (WRV-2) (Rule 62-40.473[1][b], *F.A.C.*).
c. Estuarine resources (WRV-3) (Rule 62-40.473[1][c], *F.A.C.*).
d. Transfer of detrital material (WRV-4) (Rule 62-40.473[1][d], *F.A.C.*).
e. Maintenance of freshwater storage and supply (WRV-5) (Rule 62-40.473[1][e], *F.A.C.*).
f. Aesthetic and scenic attributes (WRV-6) (Rule 62-40.473[1][f], *F.A.C.*).
g. Filtration and absorption of nutrients and other pollutants (WRV-7) (Rule 62-40.473[1][g], *F.A.C.*).
h. Sediment loads (WRV-8) (Rule 62-40.473[1][h], *F.A.C.*).
i. Water quality (WRV-9) (Rule 62-40.473[1][i], *F.A.C.*).
j. Navigation (WRV-10) (Rule 62-40.473[1][j], *F.A.C.*).

Environmental Consulting & Technology, Inc. (ECT), was contracted by SJRWMD to assess if the minimum hydrologic regime defined by minimum levels protects the relevant WRVs.

SJRWMD has prepared two documents associated with the MFLs determination for Lake Monroe:

- *Middle St. Johns River Minimum Flows and Levels Hydrologic Methods Report*, by C. Price Robison, P.E. (2004a).
- *Preliminary Minimum Levels Determination: Lake Monroe in Volusia and Seminole Counties*, by Jane Mace (2006a).

These documents contain information about the hydrological and ecological considerations that were used by SJRWMD to develop recommended MFLs for Lake Monroe. This information was used by ECT, along with field reconnaissance, information in the scientific literature, and other best available information, to evaluate whether the WRVs listed in Section 62-40.473, *F.A.C.*, are protected by the recommended MFLs hydrologic conditions for Lake Monroe.

2.0 STUDY AREA

The St. Johns River is a north-flowing river with a very low hydraulic gradient. The river has its source near Blue Cypress Lake in Indian River County along the east coast of Florida (Figure 2-1). The St. Johns River is the longest north-flowing river in the United States, with an overall drainage basin area of about 9,430 square miles (mi^2) (Morris, 1995). The direct watershed of the St. Johns River, not including any tributaries, is about 2,623 mi^2 (Morris, 1995). The river discharges into the Atlantic Ocean east of Jacksonville, Florida, more than 300 miles from the source. The St. Johns River has an average discharge of approximately 6,500 cfs at its mouth and is classified as a major river (Morris, 1995).

SJRWMD has divided the St. Johns River watershed into four hydrologic basins: Upper St. Johns River (USJR), Middle St. Johns River (MSJR), Lake George, and Lower St. John River (LSJR) basins (Adamus *et al*., 1997). The Lake Monroe reach of the St. Johns River is in the MSJR basin, from river mile (RM) 161 at U.S. Highway (U.S.) 17-92 near the western outlet of Lake Monroe, to RM 169 at State Road (SR) 415 near the eastern inlet of the lake. The total direct drainage area of the Lake Monroe Planning Unit (4D) of the MSJR basin is about 88,938 acres, or 139.0 mi^2 (URS, 2001). Figure 2-2 shows the boundary of the Lake Monroe sub-basin.

Stage and flow gauges have been maintained by the U.S. Geological Survey (USGS) at SR 44 west of DeLand (RM 144) since 1933, and at U.S. 17-92 west of Lake Monroe since 1920. The total drainage area of the St. Johns River at U.S. 17-92 is approximately 2,582 mi^2 (USGS, 2004).

The influence of the tide can be seen in water level records from the St. Johns River mouth to Lake George, approximately 110 miles from the ocean. Tidal influence has also been documented in Lake Monroe. Negative (upstream) daily net river flow into Lake Monroe occurs occasionally, about 8.3 percent of the time, according to the daily flow data at U.S. 17-92 recorded by USGS from May 1, 1987, through September 30, 1989;

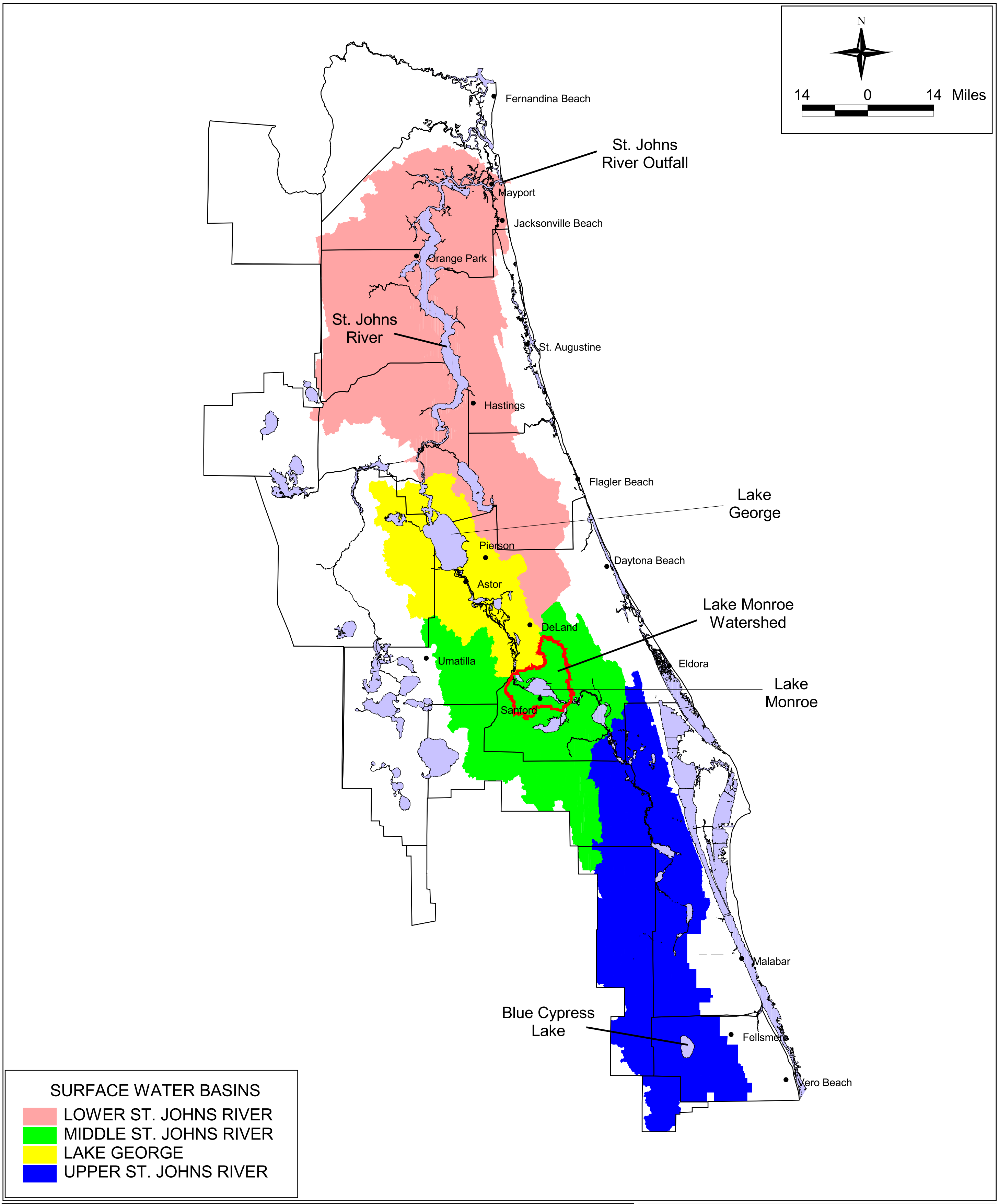

FIGURE 2-1.

ST. JOHNS RIVER NEAR LAKE MONROE LOCATION MAP

Sources: SJRWMD, 2004; ECT, 2004.

ECT

Environmental Consulting & Technology, Inc.

FIGURE 2-2.
LAKE MONROE SUB-BASINS
(PLANNING UNIT 4D)

Sources: SJRWMD, 2004; ECT, 2004.

ECT
Environmental Consulting & Technology, Inc.

and from March 4, 1995, through June 6, 2006. Hydraulically, the St. Johns River at Lake Monroe reach is affected by both upstream headwater and downstream backwater conditions of stage and flow.

Lake Monroe is one of the larger lakes within the MSJR basin. The lake is about 6 miles long, 4 miles wide, and has a surface area of 8,546 acres at a stage of 0.0 foot National Geodetic Vertical Datum (ft-NGVD) (Mactec Engineering & Consulting, Inc. [MEC], 2004). The total length of the lake shoreline is about 21.2 miles. The Lake Monroe sub-basin is approximately 88,938 acres (URS, 2001), located in northwestern Seminole County and southwestern Volusia County. The lakeshore is highly altered by manmade structures. The majority of the natural wetlands are located at the east and west shores of the lake. Most of the south shore is lined with seawall and is bordered by U.S. 17-92 and the City of Sanford River Walk. A portion of the north shore is lined with riprap and seawall, and is bordered by Lake Shore Drive and the residential developments of the Town of Enterprise and the City of Deltona. A narrow, wooded buffer exists between most of the north lakeshore and the roadway bordering the lake. The total length of the seawall, riprap, and shoreline with steep bank is estimated to be 6.5 miles according to measurements on available maps. The Stone Island development, located in the northeastern part of the lake is mostly developed into low-density housings. The northwestern shore of the lake is bordered by Interstate (I)-4. Other cities in the Lake Monroe sub-basin include DeBary, Orange City, Lake Mary, Orlando, Winter Park, Altamonte Springs, Apopka, and DeLand. These cities are located within 20 miles of Lake Monroe; therefore, the lake is accessible to a large population within 1-hour travel time.

The Lake Monroe watershed is within the highest growth rate potential area of Seminole County, especially the I-4 corridor that is designated as higher intensity planned development for industrial, office, commercial, and residential use (URS, 2001).

Lake Monroe is classified as eutrophic with fair water quality (URS, 2001). Lake Monroe historically received untreated stormwater and municipal wastewater treatment plant discharges. High concentrations of phosphorus were measured along the southern shore of Lake Monroe near the City of Sanford Water Reclamation Facility outfall, which discharged into the lake until 1989 (URS, 2001). The City of Sanford has since then shifted to water reuse and expanded its effluent spray field, but the City still has wet-weather discharge into the lake. Other municipalities with utility services in the sub-basin have also implemented water reuse programs. The reduction of wastewater discharges resulted in decreasing phosphorus levels in Lake Monroe. Nitrogen and turbidity levels in the lake were also decreasing as of 1995. However, conclusive water quality trends have not been established (Camp, Dresser & McKee [CDM], 1996).

The major industrial facilities in the vicinity of Lake Monroe include the Florida Power & Light Company (FPL) Sanford-DeBary Power Plant on the north shore of the St. Johns River west of U.S. 17-92, and Progress Energy Turner Plant on the north shore of Lake Monroe, which is a peaking unit operated only infrequently to meet high-demands.

Marinas are located at the south shore of Lake Monroe and in the St. Johns River east and west of the lake. These marinas can accommodate large vessels, up to 100 ft long, and have boat repair shops. Federal navigation channels were dredged by the U.S. Corps of Engineers (USACE) to allow deep-water access and docking for the vessels. Figure 2-3 shows the location of the navigation channels.

MEC conducted a bathymetric survey of Lake Monroe in 2004 under a SJRWMD contract (Figure 2-4). Based on the bathymetric map and USGS topographic maps, stage versus lake area and stage versus lake volume relationships were established (Figures 2-5 and 2-6, respectively).

The bathymetric map shows that about 53 percent of the lake is deeper than 6 ft when the stage is 0.0 ft-NGVD. Isolated, small areas (44 acres) in the lake have depths greater than 10 ft, and the deepest location (14 ft) is at the I-4 crossing near the lake outlet. There are two channels that connect the St. Johns River to Lake Monroe at the eastern lake entrance: the original natural meandering channel and a dredged, straight channel (Monroe Canal). There is only a single connecting channel at the lake’s western outlet.

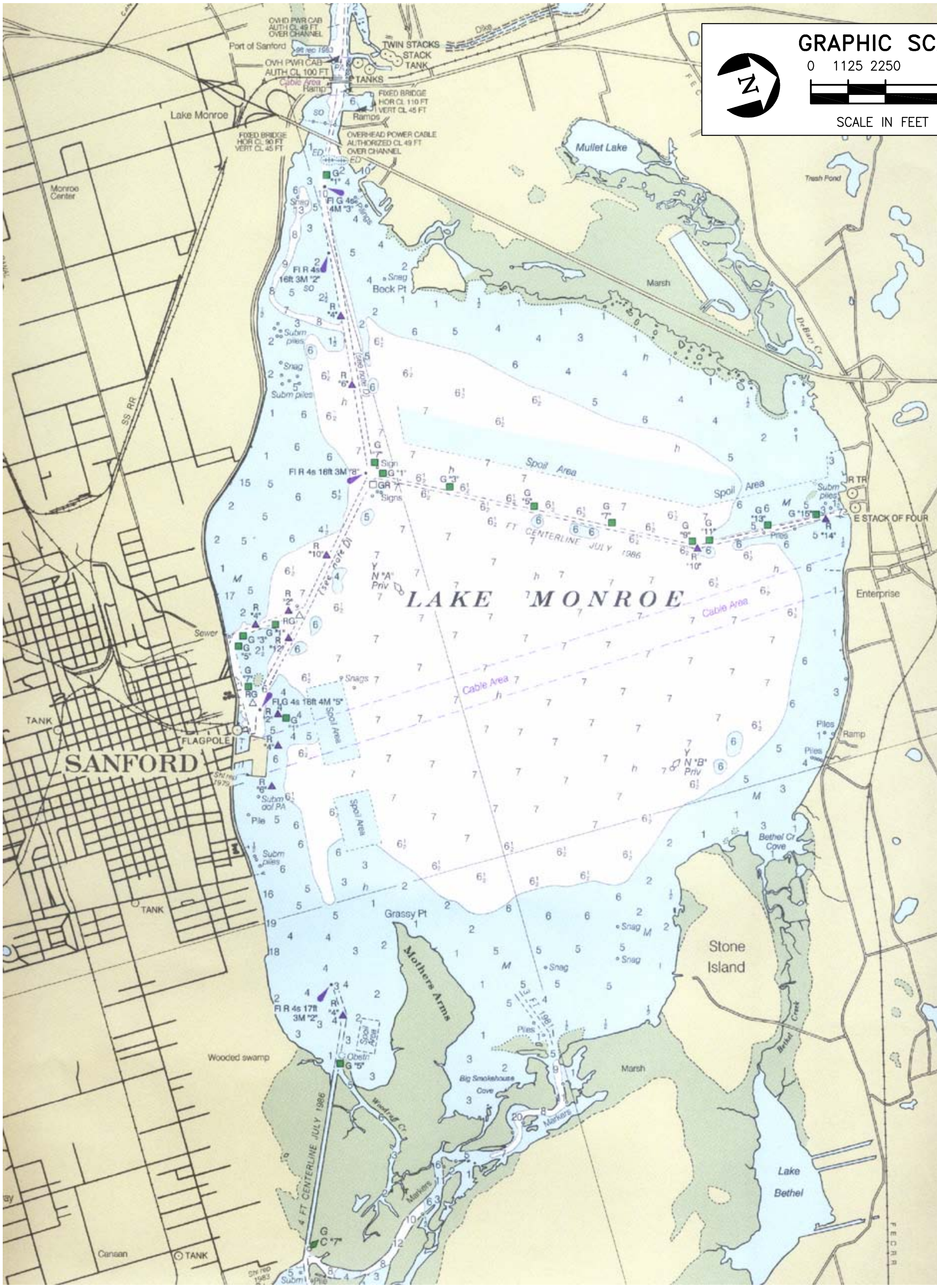

FIGURE 2-3.

LAKE MONROE NAVIGATION CHART

Sources: NOAA, 2002; ECT, 2004.

ECT

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M:\acad\060355\Lake Monroe contours.mxd

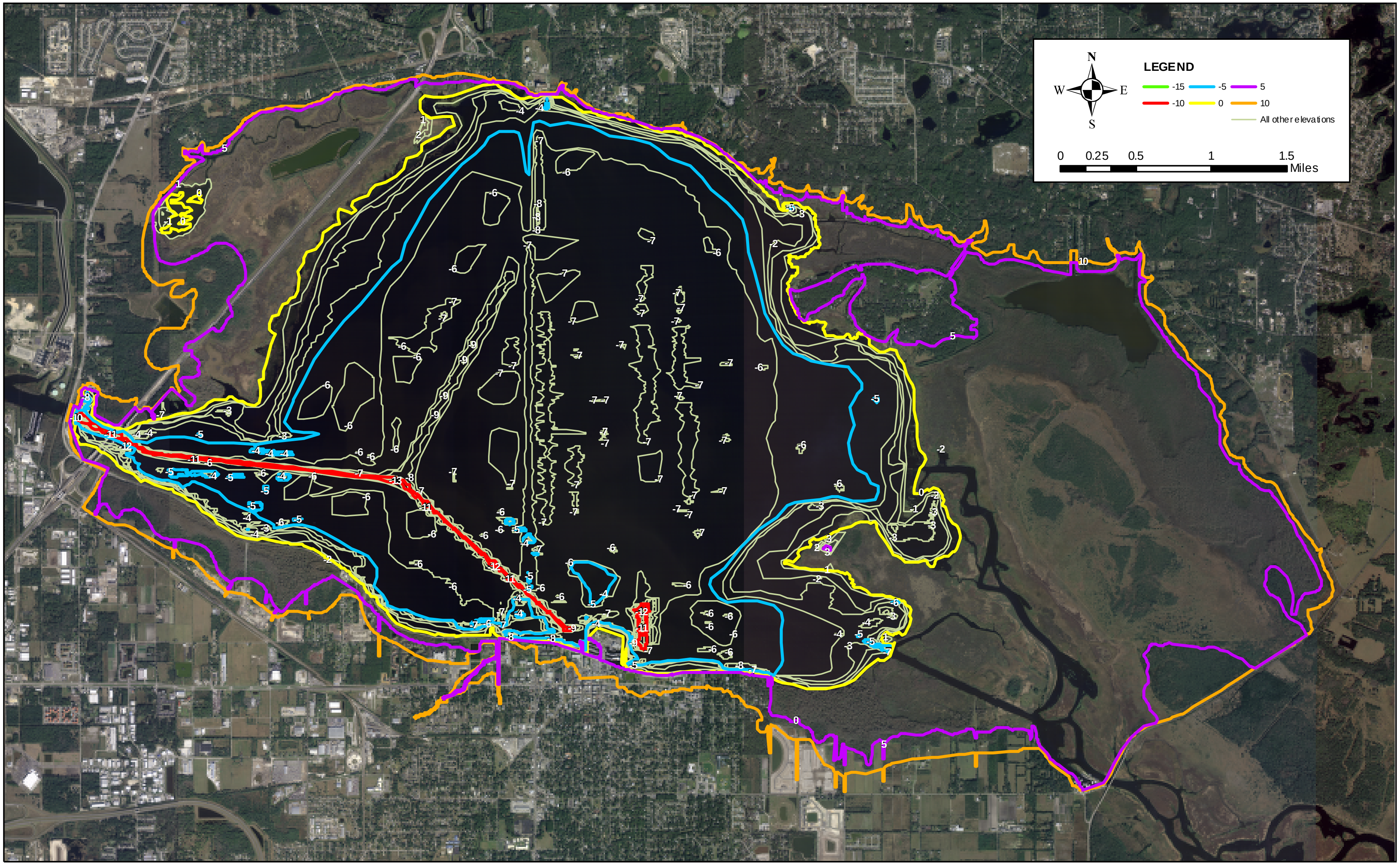

FIGURE 2-4.
LAKE MONROE BATHYMETRY

Source: MEC, 2004.

* Images were flown on January 1, 2004.

ECT
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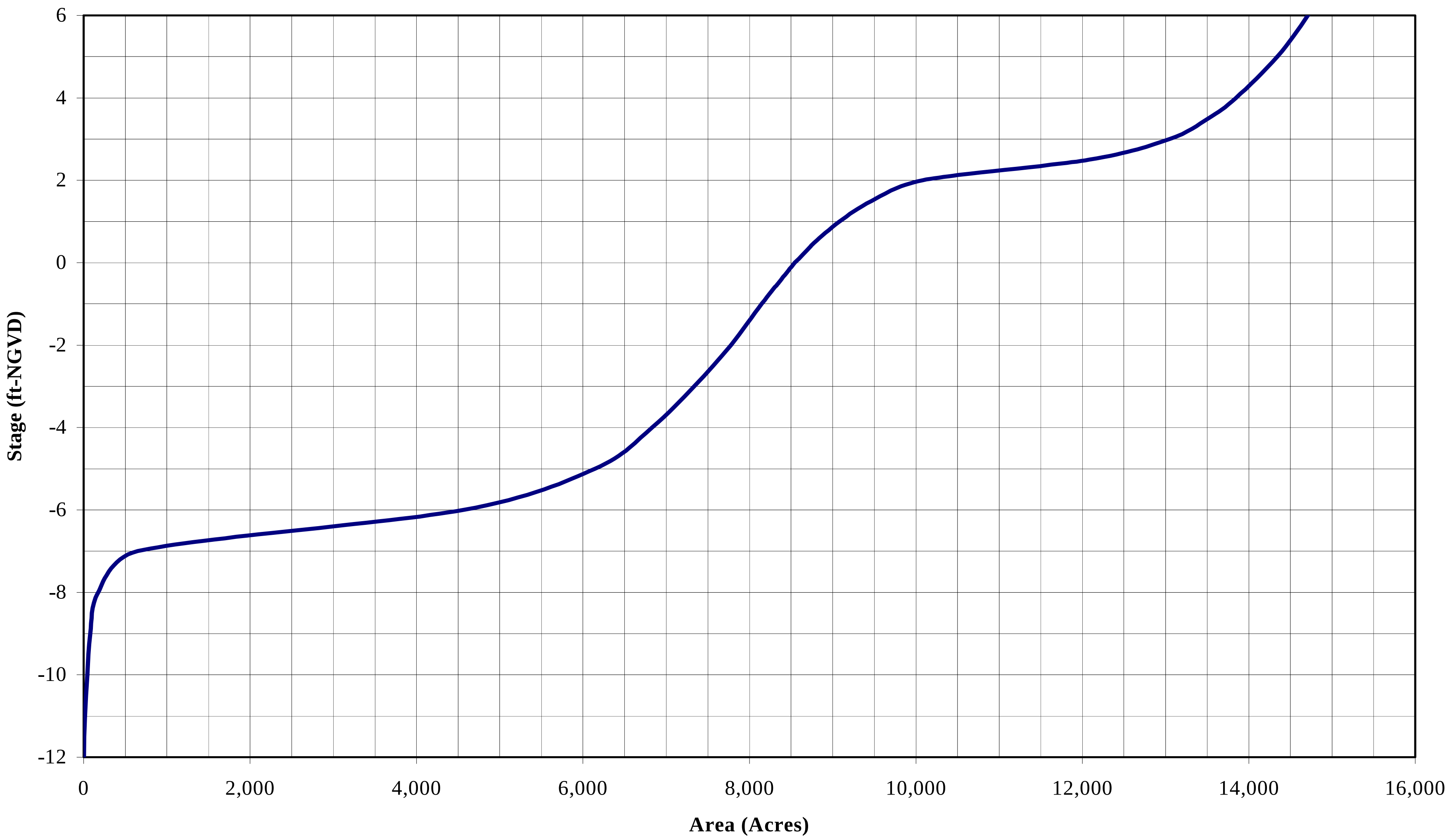

FIGURE 2-5.

LAKE MONROE STAGE/AREA CURVE

Source: ECT, 2006.

ECT
Environmental Consulting & Technology, Inc.

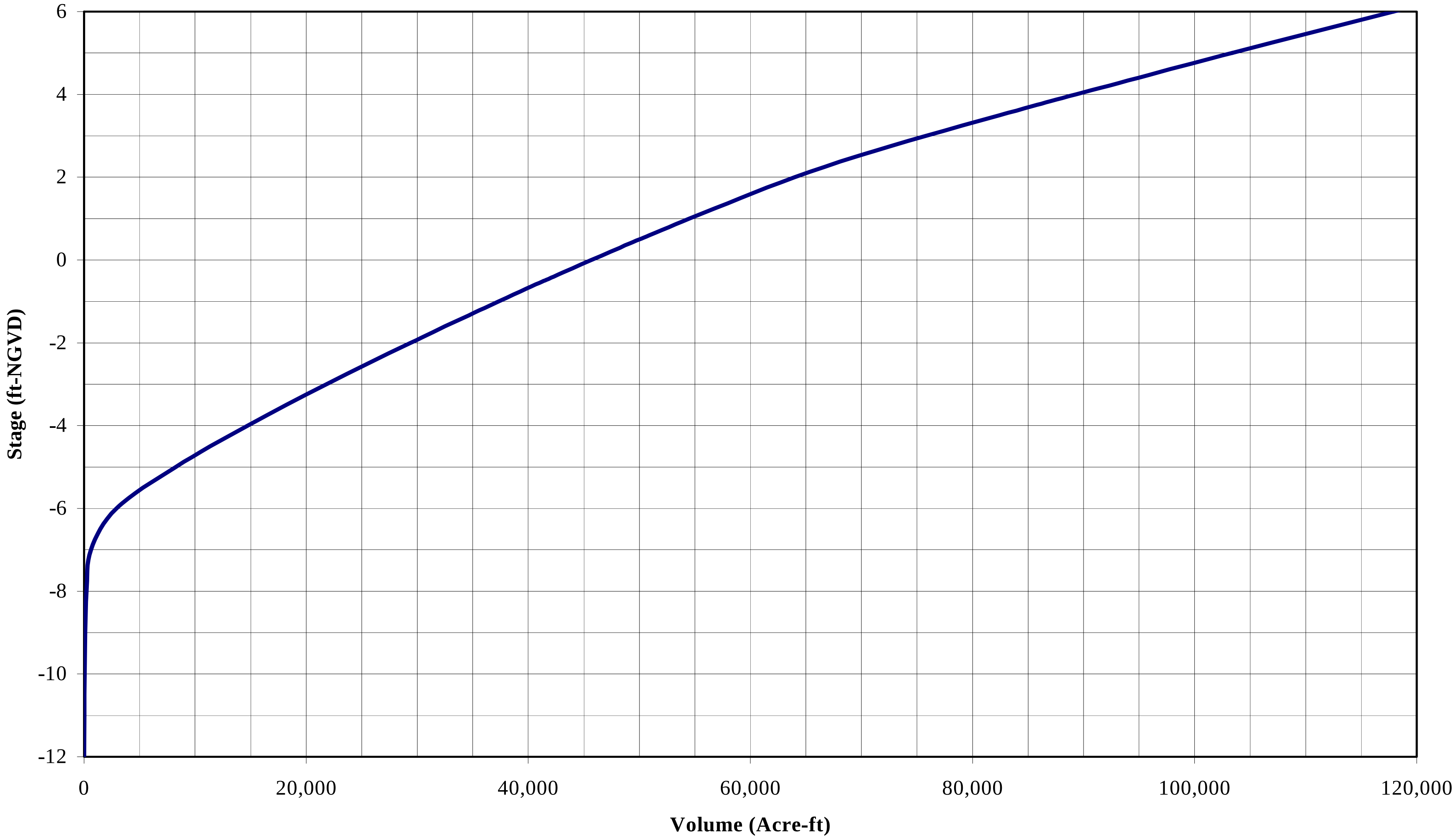

FIGURE 2-6.

LAKE MONROE STAGE/VOLUME CURVE

Source: ECT, 2006.

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There are two springs that contribute freshwater flows to Lake Monroe: Gemini Springs and Green Springs (Figure 2-7); both are third magnitude springs (1- to 10-cfs average flow). Gemini Springs is the source water of Mullet Lake (Figure 2-7), which connects to Lake Monroe via Gemini Springs Run at the northeastern limit of the I-4 crossing. Another small lake, Lake Bethel (Figure 2-3), is connected to Lake Monroe via Bethel Creek along the northern boundary of Stone Island.

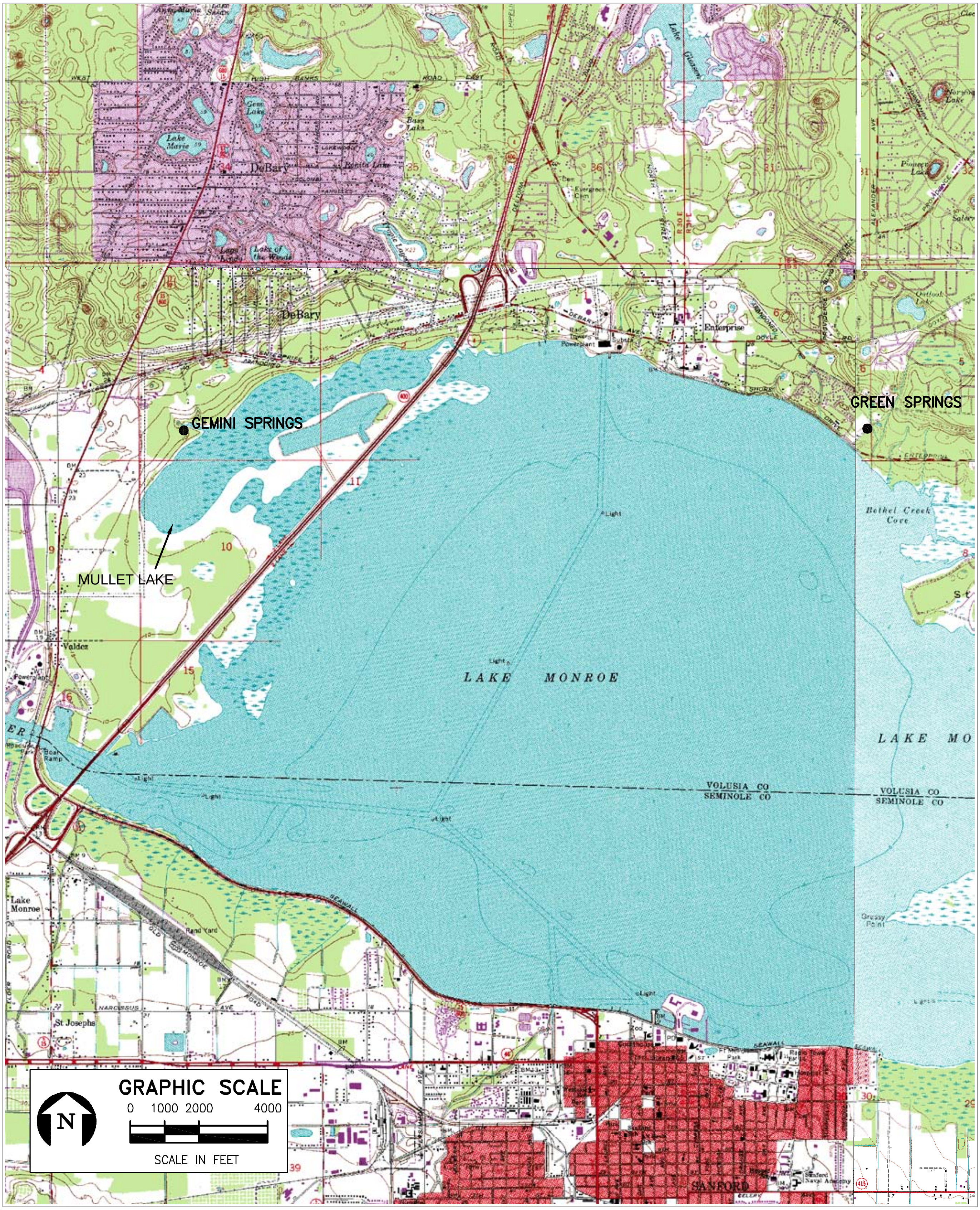

FIGURE 2-7.

LOCATION OF GEMINI AND GREEN SPRINGS

Sources: Quads: Osteen, Orange City, Lake Helen, FL, 1980 & Sanford, FL, 1988.

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3.0 EXISTING DATA

3.1 STAGE

Monthly water levels were recorded in the St. Johns River at U.S. 17-92 from July 1920 through January 1940. Daily water levels have been recorded at the U.S. 17-92 gauge by the USGS (Stations 02234499 and 02234500) since August 1, 1941 (USGS, 2004). The data records through June 6, 2006, are presented in Figure 3-1.

According to the stage data at U.S. 17-92, the minimum daily stage (water level) during the period 1920-2006 was -0.52 ft-NGVD and the maximum daily stage was 8.5 ft-NGVD (Figure 3-1). The average stage from August 1, 1941, through June 6, 2006, was 1.90 ft-NGVD, and the median stage was 1.50 ft-NGVD. For comparison with other river reaches, the maximum and minimum daily stage values at Palatka for data through 1991 were 3.90 and -1.46 ft-NGVD, respectively; at Jacksonville, these values were 6.0 and -2.09 ft-NGVD, respectively (ECT, 2002a). At the headwaters, the typical water level at Blue Cypress Lake (RM 311) in Indian River County ranges from 23 to 24 ft-NGVD. Water levels in the Blue Cypress area are managed by SJRWMD to meet the goals of the Upper St. Johns River Basin (USJRB) project that include environmental protection and flood control (ECT, 2002a).

A duration analysis of water levels at U.S. 17-92 (Figure 3-2) indicates that 90 percent of the time the water level of Lake Monroe equals or exceeds 0.43 ft-NGVD and 10 percent of the time the water level equals or exceeds 4.01 ft-NGVD. An analysis of the monthly average stages at Lake Monroe for the period of 1941-2006 (Figure 3-3) shows that the lowest monthly average stage occurs in May (0.89 ft-NGVD).

Morris (1995) indicated that the variability in the water level in the upper reaches of the LSJR can be attributed to the elevation of the tide, the volume of freshwater flowing into and out of the reach, wind, and barometric pressure. The effect of astronomical tide is greatly diminished to negligible levels in Lake Monroe. However, long periods of fluctuation of the water level in the Atlantic Ocean caused by the barometric pressure,

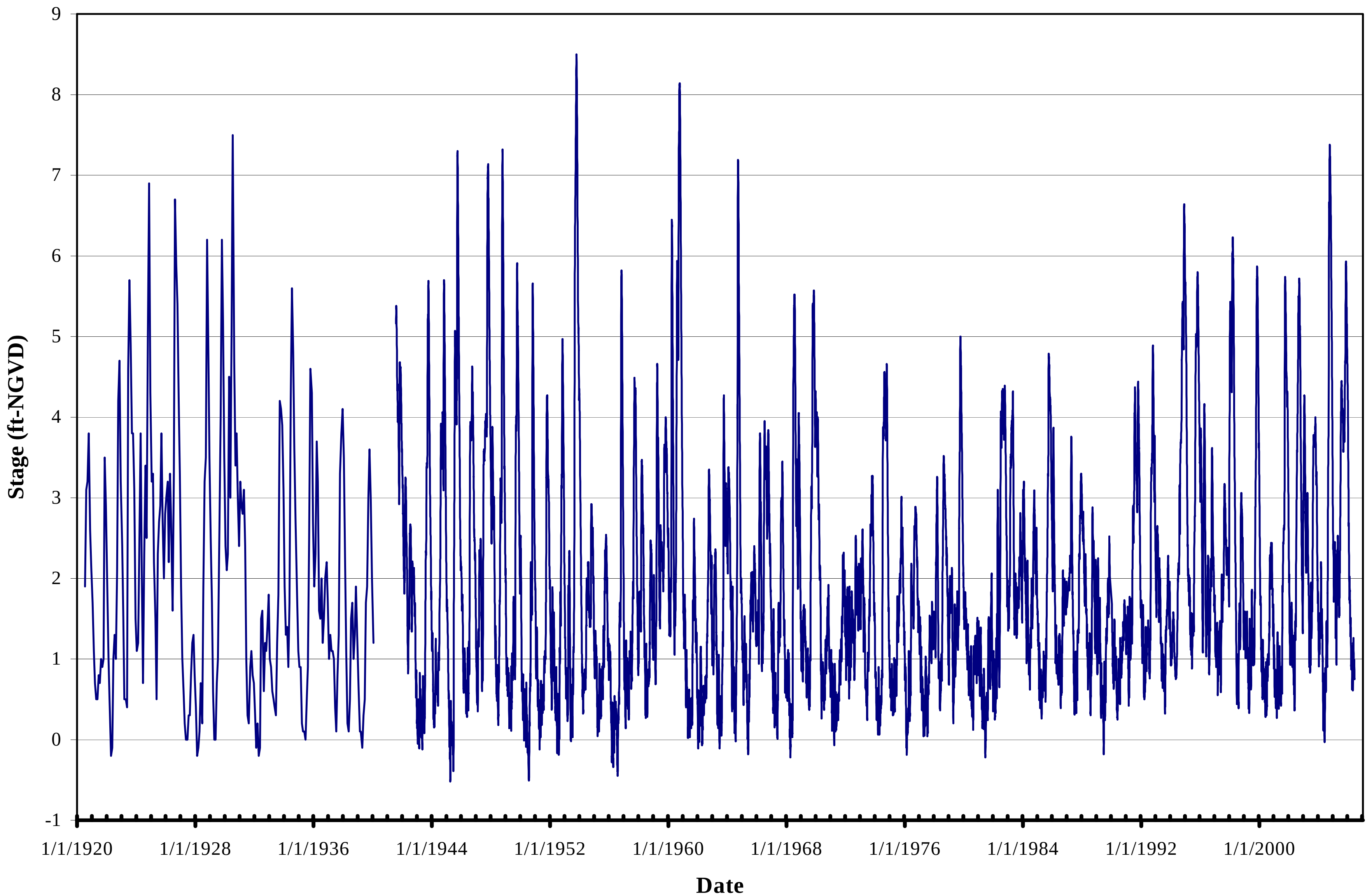

FIGURE 3-1.

LAKE MONROE STAGE (JULY 1920—OCTOBER 2006)

Source: ECT, 2006.

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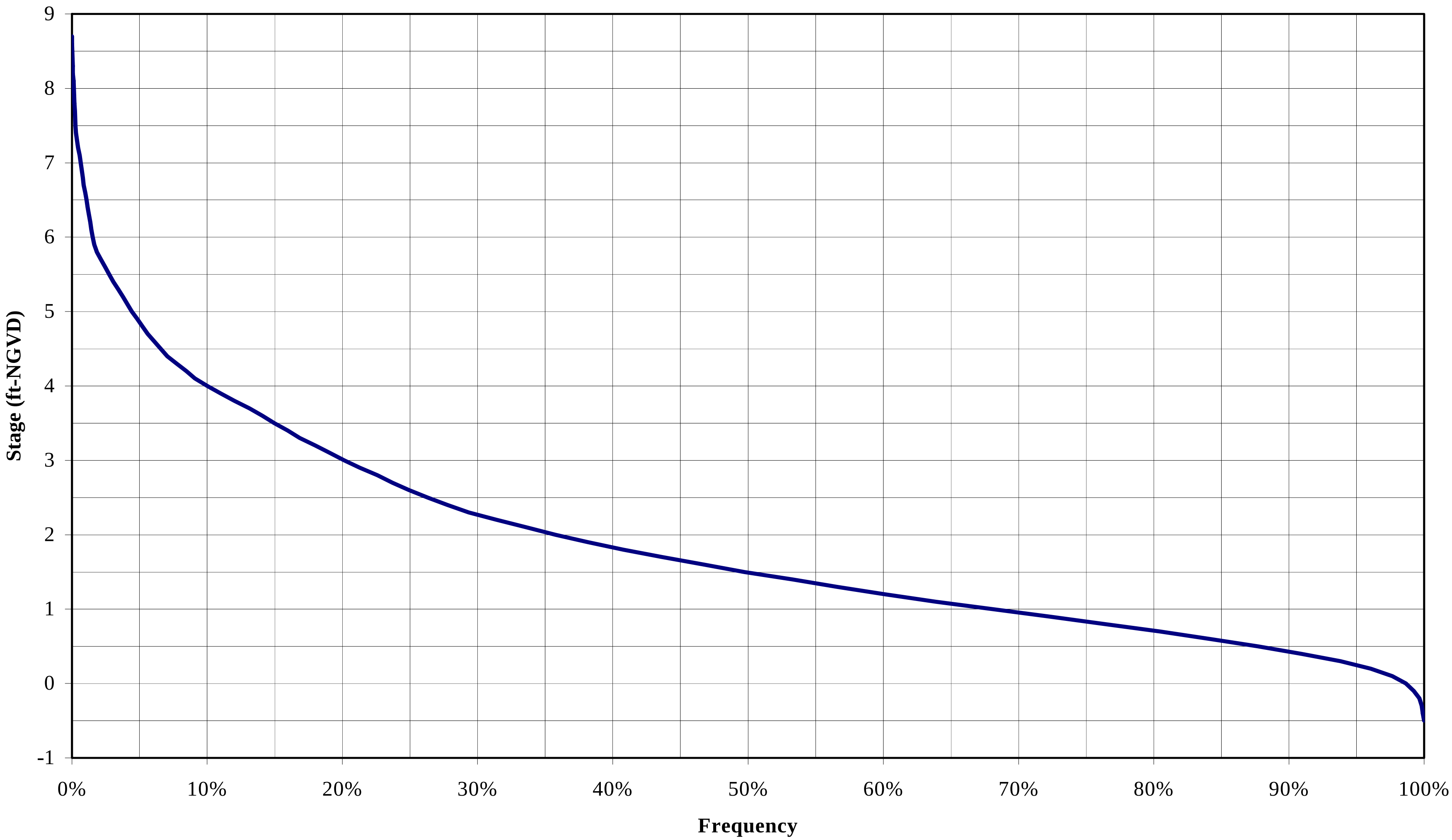

FIGURE 3-2.

LAKE MONROE STAGE DURATION CURVE (1941-2006)

Source: ECT, 2006.

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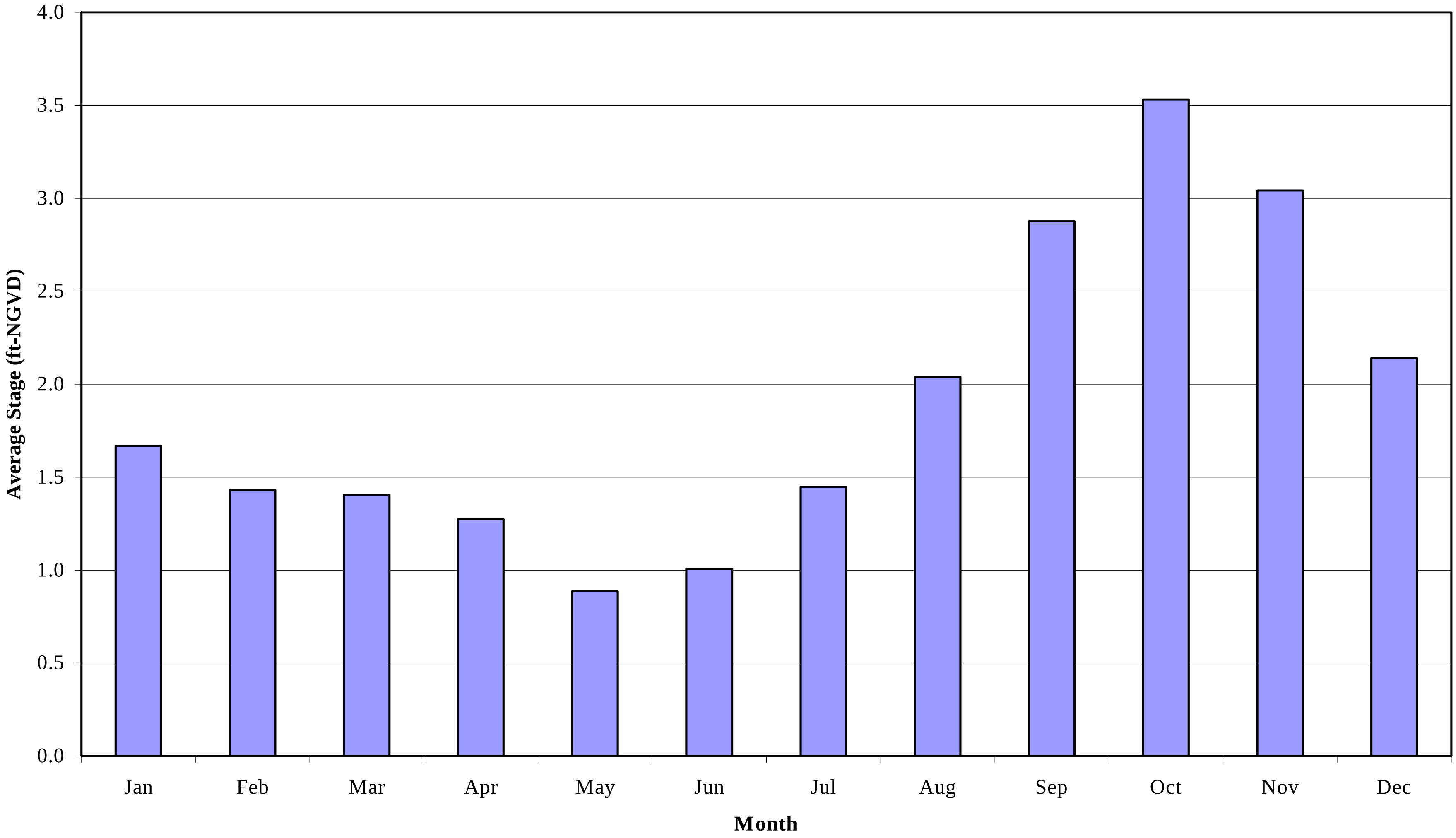

FIGURE 3-3.

MONTHLY AVERAGE WATER LEVEL AT LAKE MONROE (1941-2006)

Source: ECT, 2006.

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storm surge, and large weather systems are measurable in Lake Monroe. These factors induce flow reversal in the St. Johns River at U.S. 17-92. Semi-diurnal tidal effects can reach Lake George, 110 miles upstream from the St. Johns River mouth (Sucsy, 2005). The effects of the ocean water level fluctuations of sub-tidal frequency can cause flow reversal as far as 160 miles upstream from the river mouth (Anderson and Goolsby, 1973). Sucsy (2005) demonstrated the correlation between daily discharges at Mayport and DeLand during a drought year (Figure 3-4). The sea level effects of tidal and sub-tidal frequencies tend to impose lower limits on the St. Johns River stage within a long river segment where the channel bottom elevation is much lower than the sea level.

3.2 FLOW

The USGS has been reporting flow data at the St. Johns River near Sanford at U.S. 17-92 (Station 02234500) from May 1, 1987, through September 30, 1989; and from March 4, 1995, until the present. The mean average daily flow rate at the U.S. 17-92 gauge through June 6, 2006, was 2,410 cfs for the period of record. The maximum positive (downstream) daily average flow for this period was 11,400 cfs. The maximum negative (upstream) daily average flow at the U.S. 17-92 gauge was -2,160 cfs. According to the flow data analysis by ECT, negative flow usually lasts just a few days, except in times of drought when negative flow may last for more than 1 week. A daily flow hydrograph and flow duration analysis for the period 1987-2006 are presented in Figures 3-5 and 3-6, respectively. Examination of average monthly flow data (Figure 3-7) indicated that the low flow period occurs in May (860 cfs) and June (928 cfs). The stage/discharge relation is presented in Figure 3-8.

3.3 RETENTION TIME

Retention time is defined as the volume of a water body divided by the flow rate. Lake retention time represents the amount of time a substance may reside in the lake after the substance is introduced into the lake, which can be an important factor on lake water quality. Lake retention time is a function of both lake volume and flow rate. When the water level in Lake Monroe is lowered, the lake volume will be reduced, which tends to

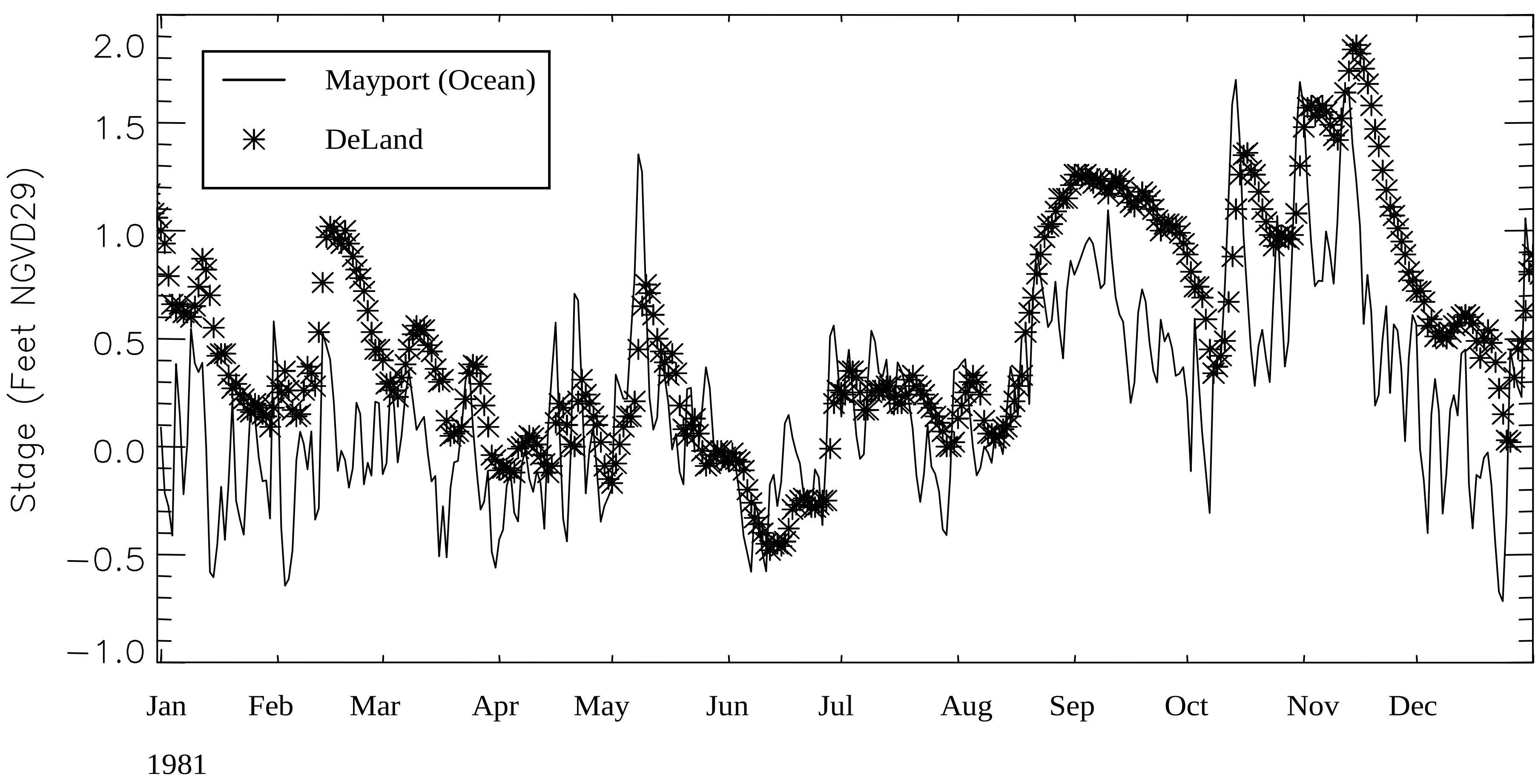

FIGURE 3-4.

DAILY STAGE AT MAYPORT (OCEAN) AND DELAND AT RIVER MILE 142
DURING THE DROUGHT YEAR OF 1981

Source: ECT, 2006.

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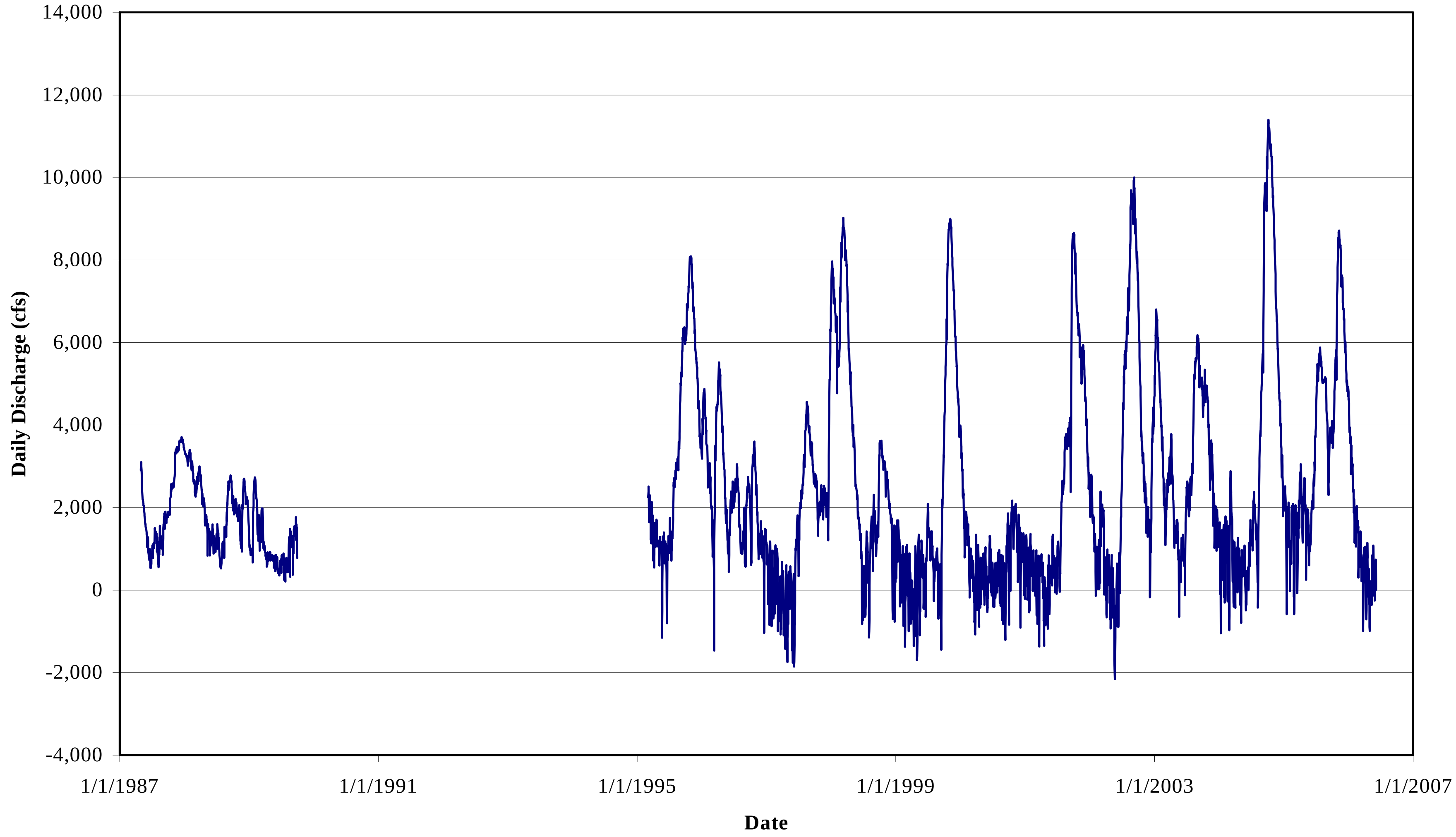

FIGURE 3-5.

DAILY AVERAGE FLOW AT ST. JOHNS RIVER NEAR SANFORD (1987-2006)

Source: ECT, 2004.

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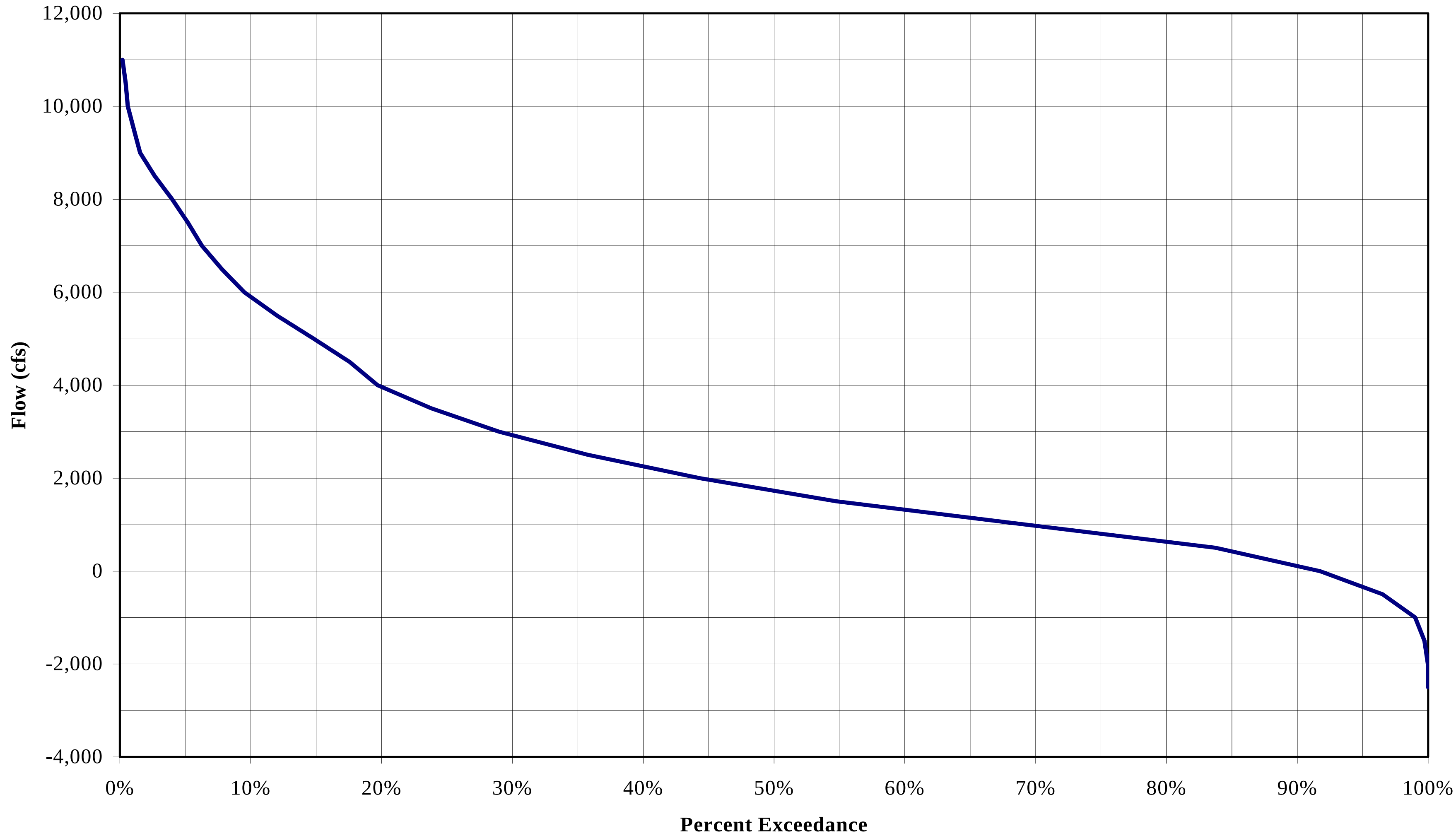

FIGURE 3-6.

ST. JOHNS RIVER FLOW DURATION CURVE NEAR SANFORD (1987-2006)

Source: ECT, 2006.

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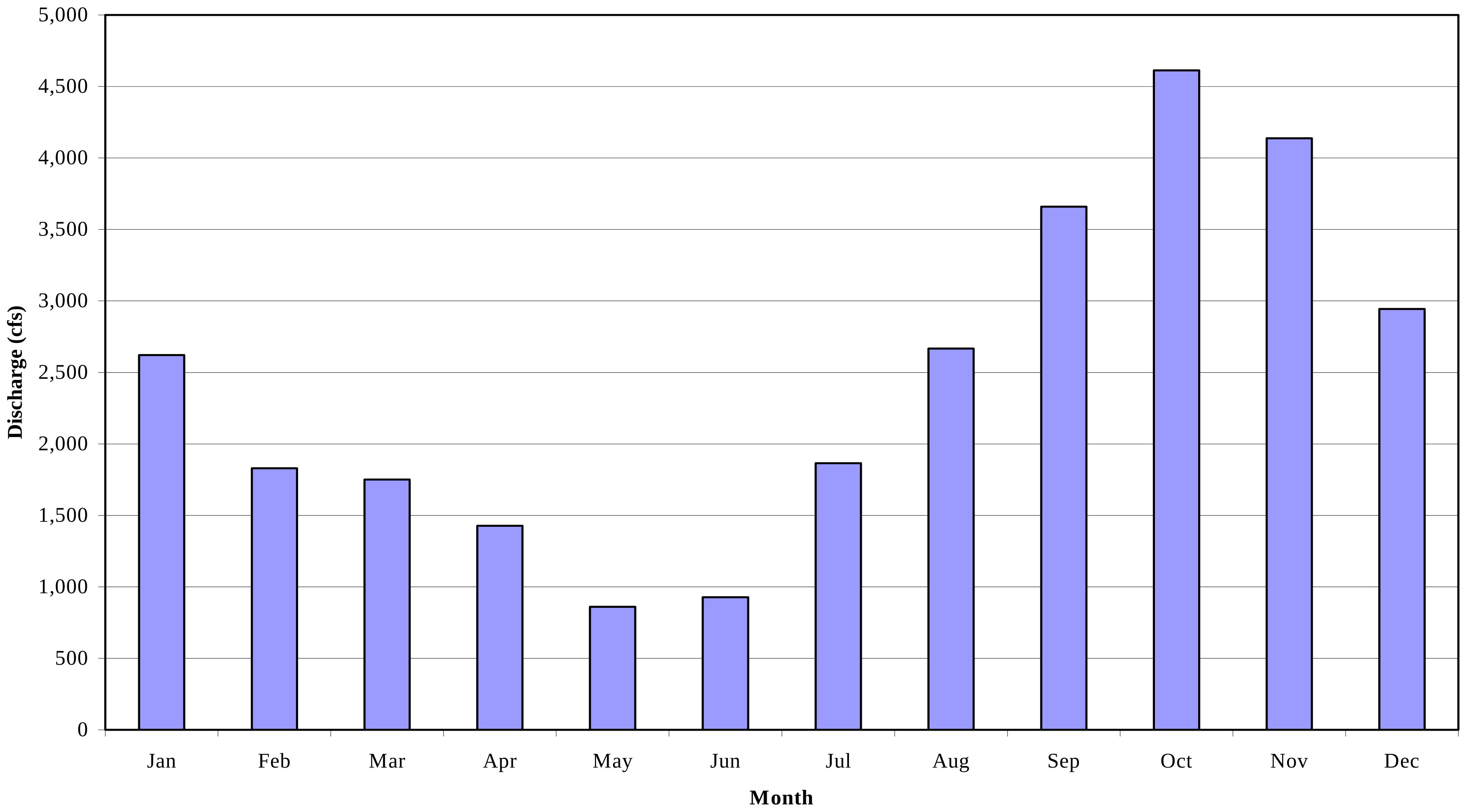

FIGURE 3-7.

MONTHLY AVERAGE ST. JOHNS RIVER FLOWS NEAR SANFORD (1987-2006)

Source: ECT, 2006.

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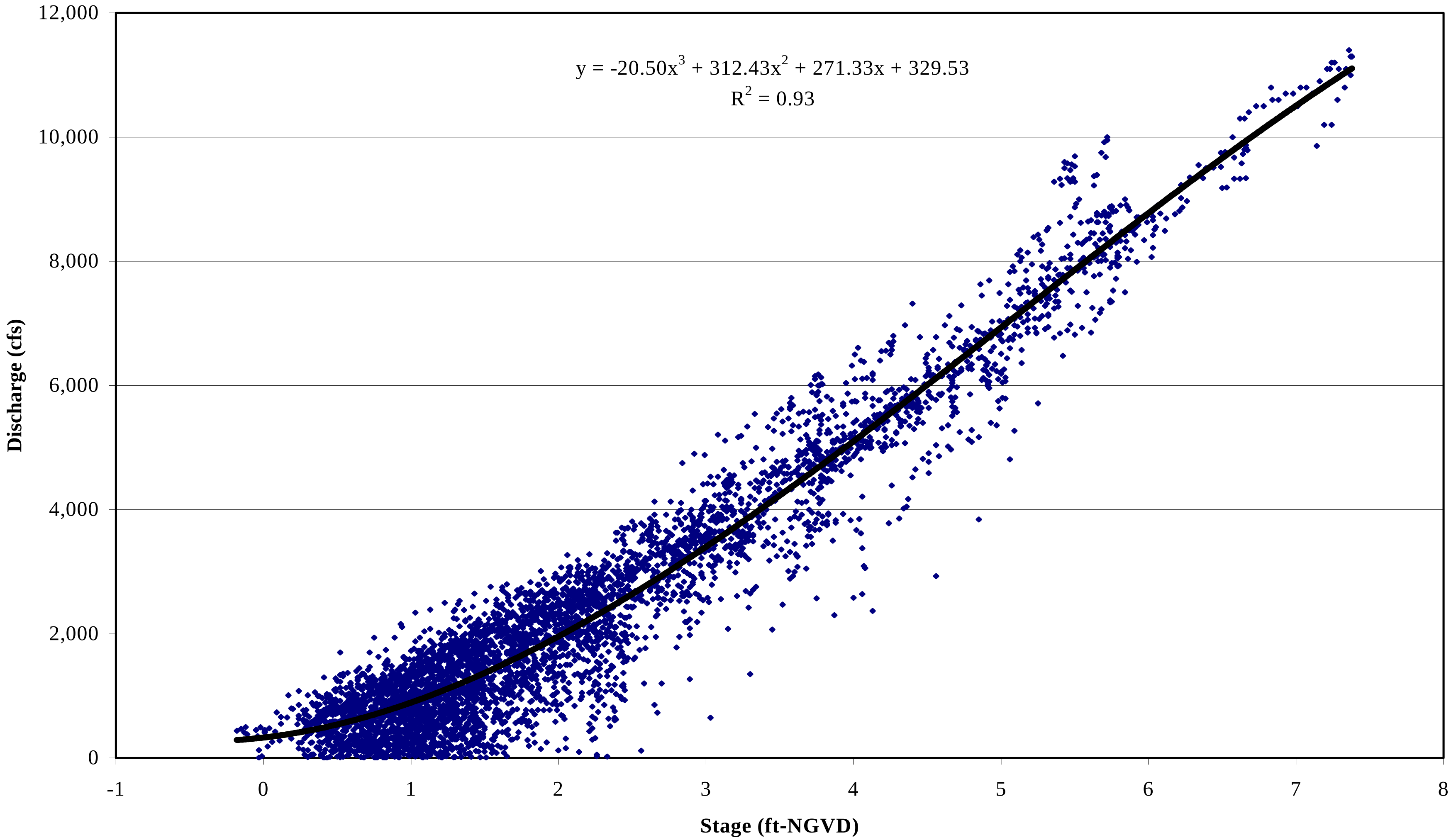

FIGURE 3-8.

STAGE/DISCHARGE CURVE

Source: ECT, 2006.

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reduce the retention time. However, a lower stage is related to a lower flow rate (Figure 3-8), which tends to increase the retention time. The retention time calculation (Table 3-1 and Figure 3-9) shows that the net effects of a lower stage is an increase in retention time. The analysis shows that the retention time is 76 days when water level is at -0.5 ft-NGVD and 70 days at a stage of 0.0 ft-NGVD. At a median stage of 1.5 ft-NGVD, the lake retention time is 22 days. The flow rates in Table 3-1 were derived from the stage/discharge curve (Figure 3-3), and the areas and volumes in Table 3-1 were derived from Figures 2-5 and 2-5, respectively.

3.4 WIND DATA

St. Johns River discharge plays a minor role in the hydrodynamics and current circulation in Lake Monroe due to the large cross section of the lake. Robison (2004b) showed that the average current velocity in Lake Monroe is typically less than 0.05 foot per second (fps). Thus, wind-induced current and circulation may be more important than the freshwater discharge in lake hydrodynamics during low flow conditions.

Examination of the wind rose data (Figure 3-10) and windspeed class frequency distribution (Figure 3-11) collected at Orlando International Airport from 1995 to 2004 show that the average windspeed in Orlando is about 7.7 miles per hour (mph) and the prevailing wind directions are from the north and the east. This probably explains why the south shore is hardened with a seawall. Approximately 64 percent of the winds were in the windspeed class of between 4 and 11 knots (4.5 and 12.7 mph). Approximately 16.5 percent of the winds were faster than 11 knots (12.7 mph).

Table 3-1. Lake Monroe Retention Time Calculations

Elevation (ft-NGVD)	Area (Acres)	Volume (Acre-ft)	Flow (cfs)	Retention Time (days)
-0.52	8,340	41,294	276	75.5
-0.50	8,347	41,461	275	76.1
-0.40	8,387	42,298	272	78.3
-0.30	8,427	43,138	277	78.6
-0.20	8,467	43,983	288	77.0
-0.10	8,506	44,832	306	74.0
0.00	8,546	45,684	330	69.9
0.10	8,594	46,541	360	65.2
0.20	8,642	47,403	396	60.3
0.30	8,689	48,269	438	55.5
0.40	8,737	49,141	487	50.9
0.50	8,785	50,008	540	46.7
1.00	9,081	54,478	892	30.8
1.50	9,469	59,120	1,370	21.8
2.00	10,083	64,010	1,958	16.5
2.50	12,082	69,537	2,640	13.3
3.00	13,045	75,824	3,402	11.2
3.50	13,511	82,451	4,226	9.8
4.00	13,844	89,285	5,100	8.8
5.00	14,342	103,393	6,934	7.5
6.00	14,708	117,900	8,775	6.8
7.00	15,015	132,785	10,507	6.4
8.00	15,252	147,912	12,000	6.2
8.50	15,370	155,567	12,620	6.2

Source: ECT, 2006.

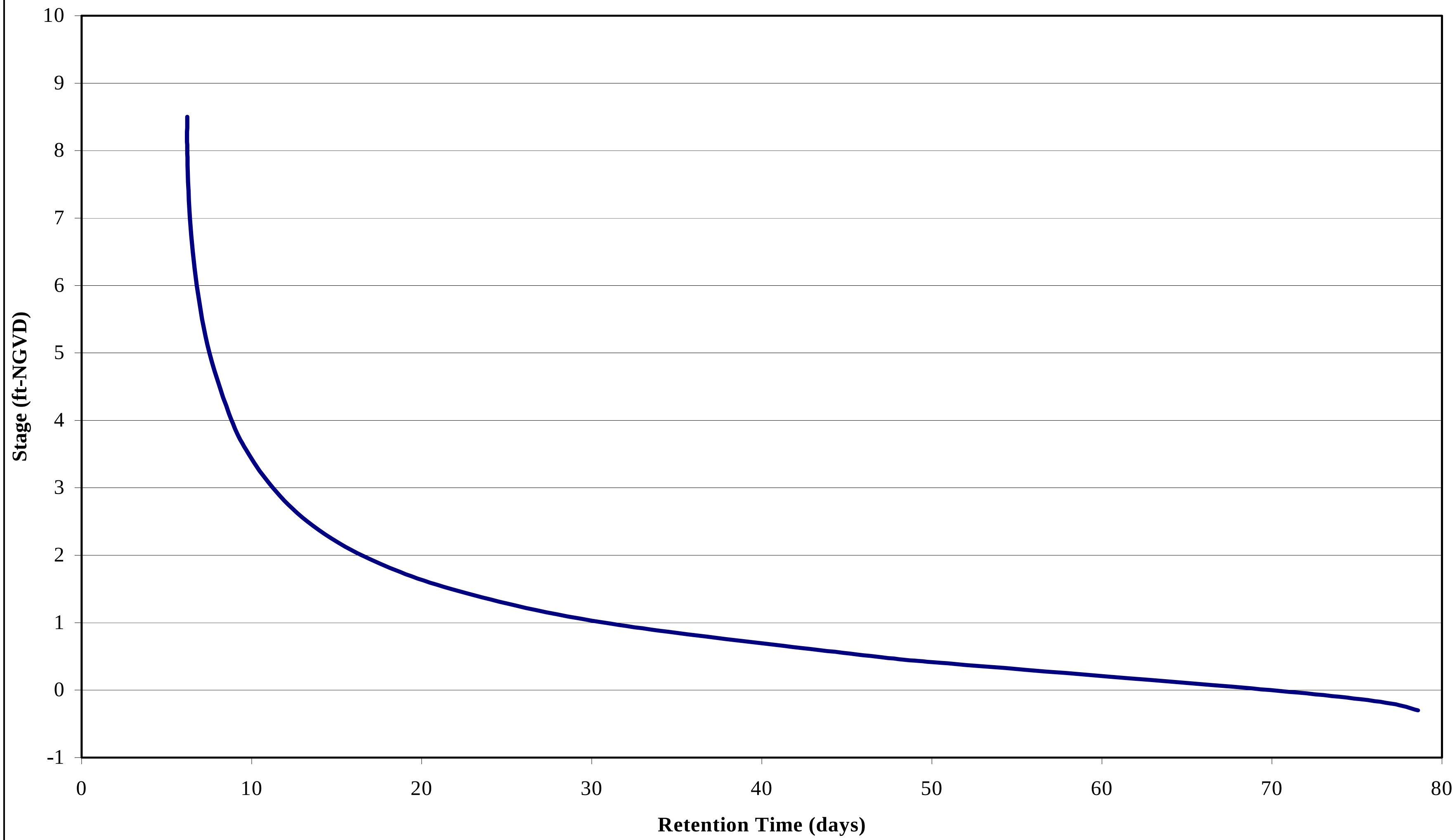

FIGURE 3-9.

RETENTION TIME VS STAGE

Source: ECT, 2006.

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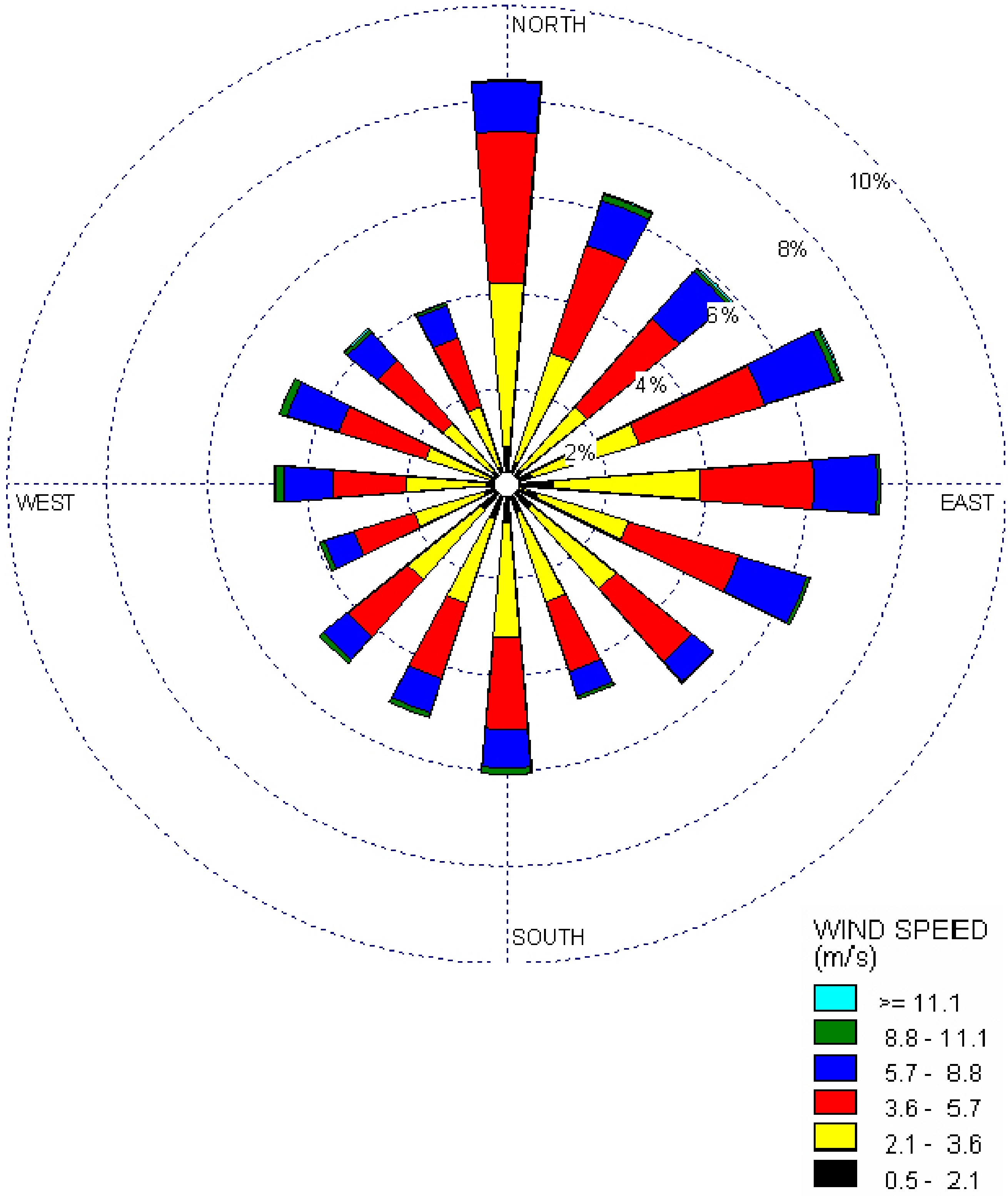

FIGURE 3-10.

TEN-YEAR WIND ROSE FOR ORLANDO INTERNATIONAL AIRPORT (1995-2004)

Source: ECT, 2006.

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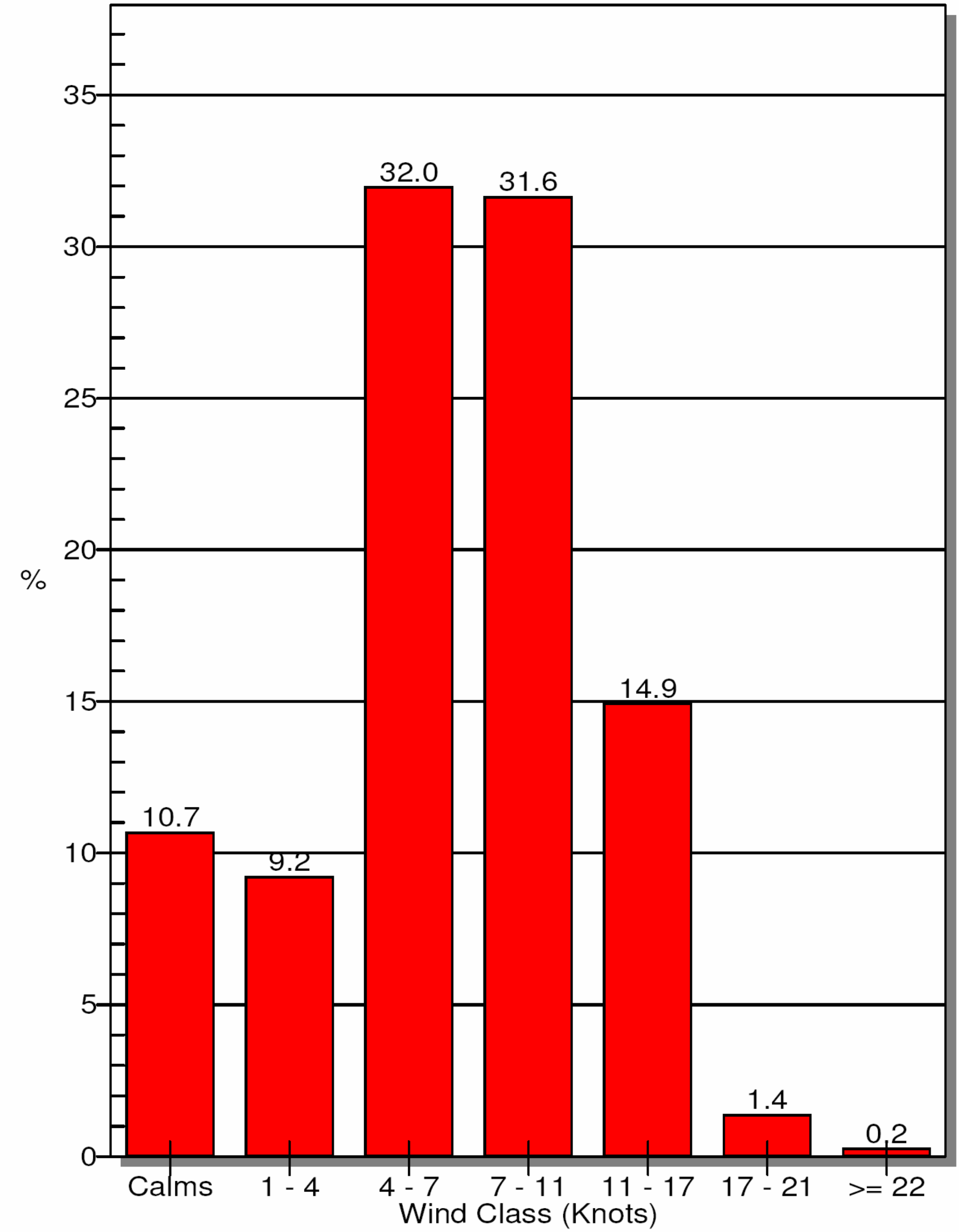

FIGURE 3-11.

WIND CLASS FREQUENCY DISTRIBUTION
(ORLANDO INTERNATIONAL AIRPORT, 1995-2004)

Source: ECT, 2006.

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4.0 RECOMMENDED MINIMUM LEVELS FOR LAKE MONROE

4.1 MINIMUM LEVELS DETERMINATION

Mace (2006a) surveyed seven transects of various lengths through the Lake Monroe floodplain for vegetation, soil characteristics, and ground surface elevation. These transects were located in five different areas of the floodplain (Figure 4-1):

- Lake Monroe Park at the west shore (Transect No. 1).
- North of Celery Road at the southeast shore (Transect Nos. 2 and 3).
- Lake Monroe Conservation Area at the east shore (Transect No. 4).
- Gemini Springs Park at the northwest shore (Transect No. 5).
- West shore east of I-4 (Transect Nos. 6 and 7).

The transect data are presented in Appendix A.

Mace (2006a) used the above-mentioned transect data to determine the recommended MFLs. These recommended MFLs include critical elevations and their associated durations, and return intervals (frequencies) (Table 1-1).

To further illustrate the distribution of ground elevation for various vegetation communities, Mace (2006b) conducted frequency analyses of ground elevations (i.e., ground elevation duration curve) of each of the seven transects for hardwood swamp (primary criterion for MFH), shallow marsh (primary criterion for MA), and deep marsh (primary criterion for MFL) (Figures A-8 through A-11, Appendix A). The frequency analysis demonstrated that the recommended MFLs elevation components (Table 1-1) closely represent the typical elevations of the associated vegetation communities. The ground elevation duration curves also demonstrated that similar communities have similar ranges and stage distribution at different locations.

4.2 HYDROLOGIC AND HYDRAULIC MODELS

Robison (2004a) conducted hydrologic modeling to evaluate and implement MFLs developed for Lake Monroe. Analysis of the hydrologic model output can assist in

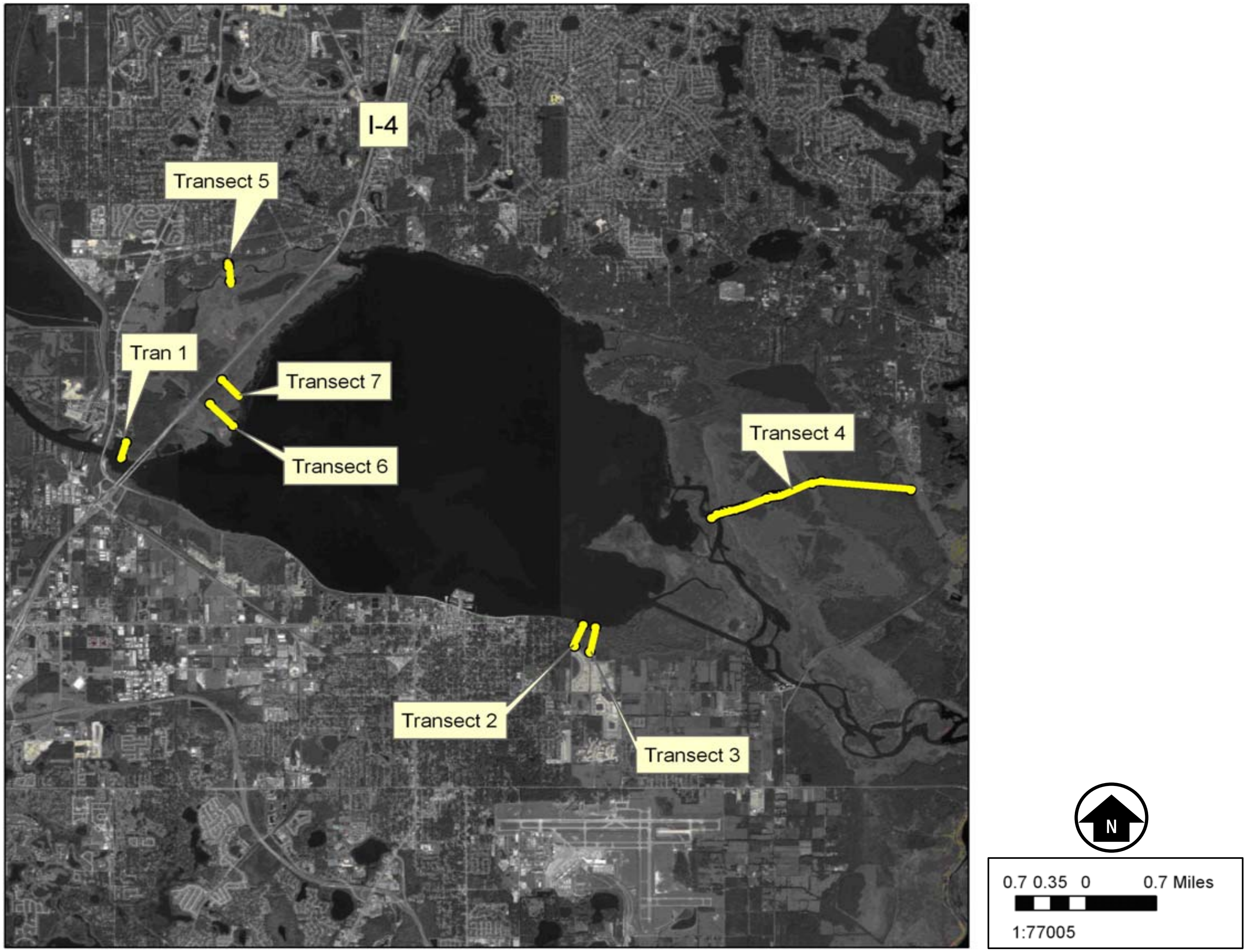

FIGURE 4-1.

ECOLOGICAL SURVEY TRANSECT LOCATIONS

Source: Mace, 2006.

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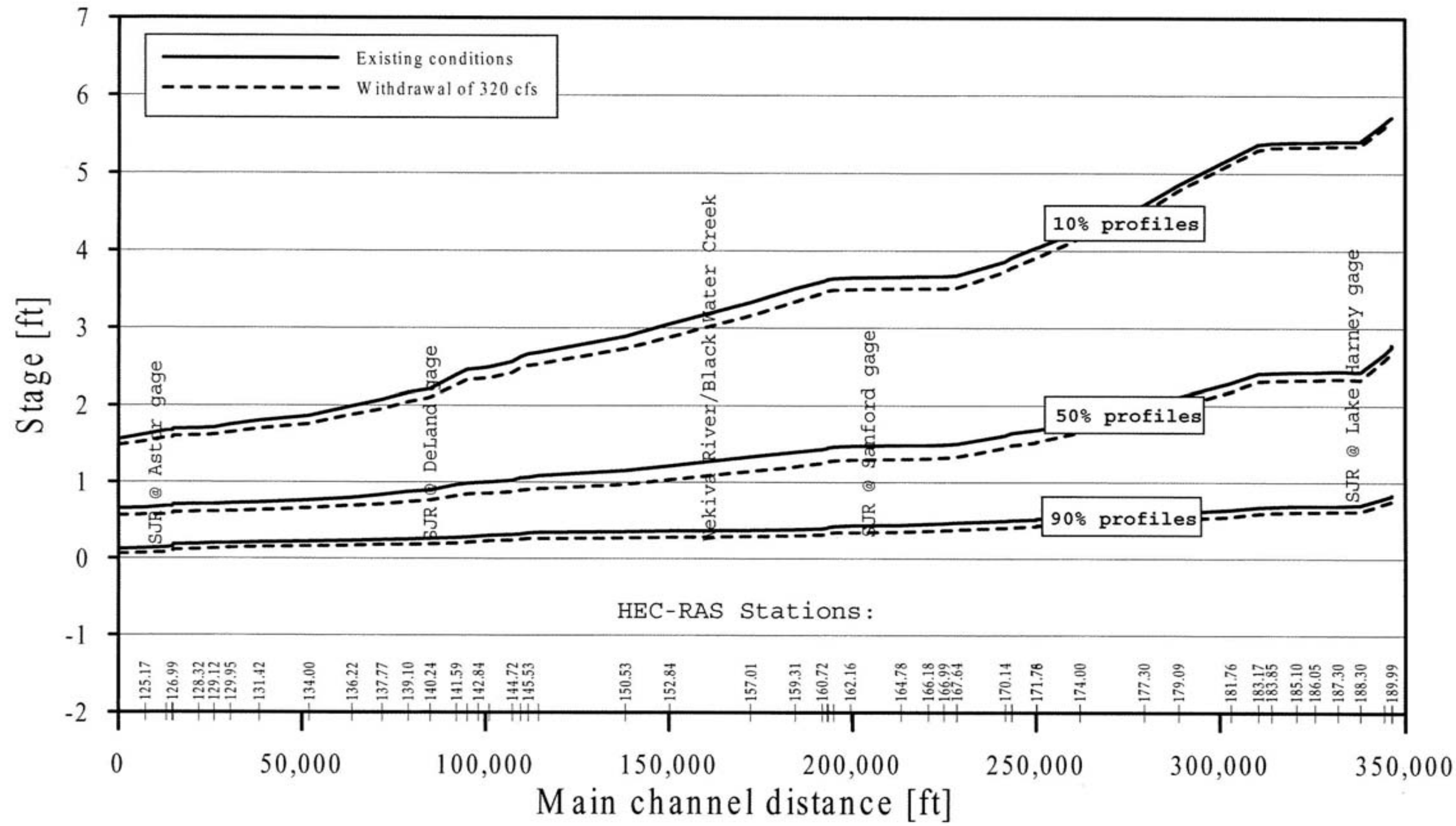
decision making regarding surface water withdrawals from the St. Johns River. The modeling effort by Robison (2004a) utilized two separate models: a hydrologic model, Streamflow Synthesis and Reservoir Regulation (SSARR) (USACE, 1986); and a hydraulic model, Hydrologic Engineering Center River Analysis System (HEC-RAS) (USACE, 1997).

Calibration of the SSARR model by Robison (2004a) was conducted using hydrologic data collected from 1952 to 1998. Robison (2004a) indicated that simulated stage duration agreed with existing conditions within ± 0.2 ft (~ 2.5 inches). Simulated maximum and minimum stages at Lake Monroe were generally accurate within 0.5 ft of observed values.

In addition to the SSARR model, Robison (2004a) used HEC-RAS to develop water surface profiles from the St. Johns River at Astor (SR 40) to Lake Harney (Figure 4-2) and compute river channel velocities (Figure 4-3; Robison, 2002, personal communication).

Using the hydraulic model simulation results, Robison (2004a) performed frequency analyses of Lake Monroe water levels for various durations under existing conditions and under various surface water withdrawal scenarios. The frequency-duration analyses by Robison (2004a) were used to evaluate the withdrawal limit that would meet the recommended MFLs at Lake Monroe. The frequency analysis encompassed four types of event: maximum average stages, minimum average stages, maximum stages continuously exceeded, and minimum stages continuously not exceeded. The tabular and graphical results of the frequency-duration analysis for Lake Monroe stage are presented in Appendix B. An example of the graphical frequency-duration analysis is presented in Figure 4-4 for the recommended MFH water level, Additionally, Dr. Peter Sucsy of SJRWMD conducted hydrodynamic modeling for the LSJR with the Environmental Fluid Dynamic Code (EFDC) to assess the effects of surface water withdrawal on the salinity regime in the St. Johns River estuary. Mehta and Jain (2006) also conducted hydrodynamic and sediment transport modeling for Lake Monroe with the EFDC model to assess the effects of surface water withdrawal on lake hydrodynamics and sediment



Note: Percentiles refer to discharge exceedances.

FIGURE 4-2.

WATER SURFACE PROFILES FOR THE MSJR FROM HEC-RAS SIMULATIONS FOR 10TH, 50TH, AND 90TH PERCENTILE FLOW CONDITIONS

Source: Robison, 2004.

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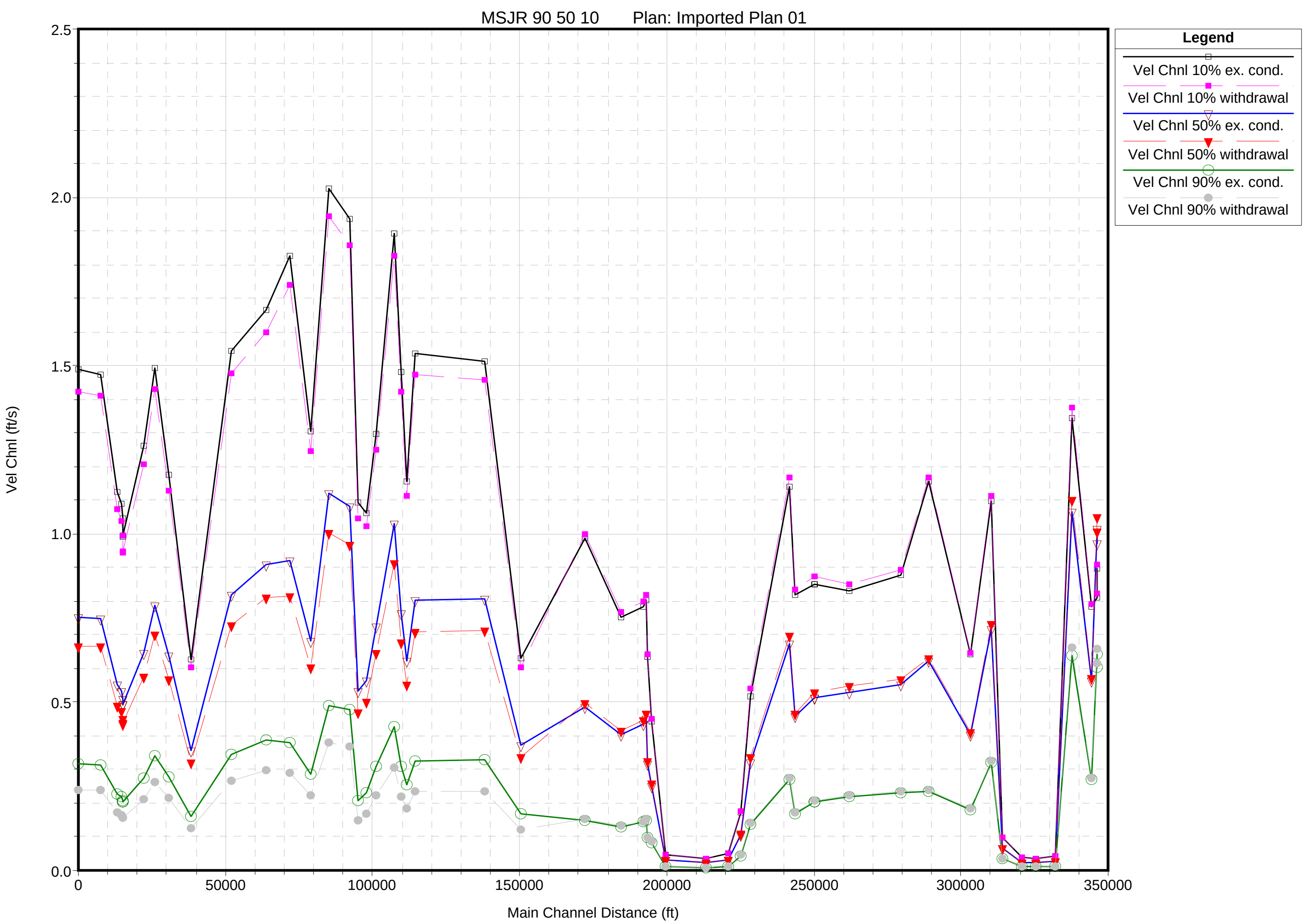

FIGURE 4-3.

CHANNEL VELOCITY PROFILES FOR THE MSJR AS DETERMINED FROM HEC-RAS SIMULATIONS

Source: Robison, 2004.

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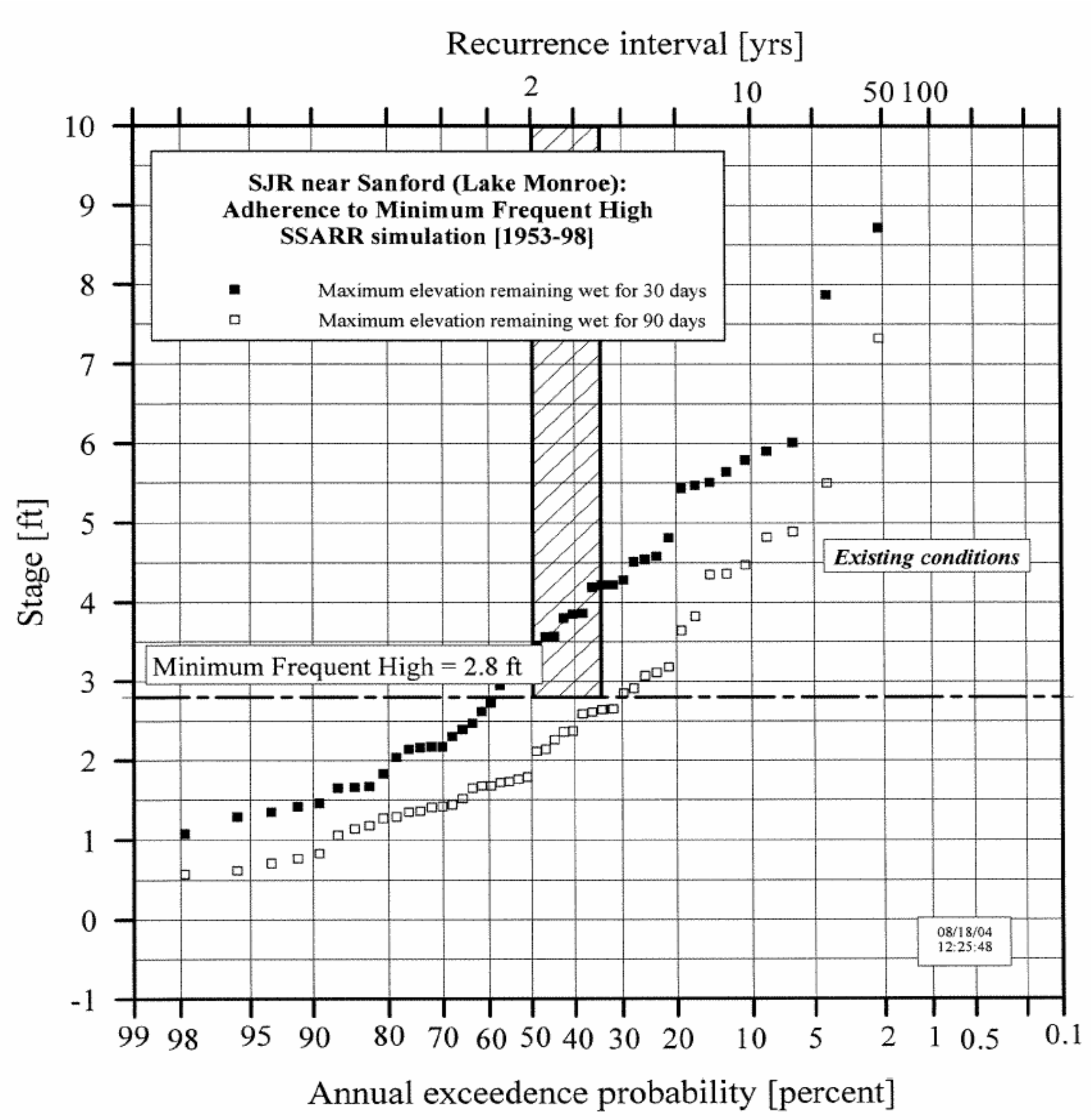

FIGURE 4-4.

GRAPHICAL EXAMPLE OF THE FREQUENCY-DURATION ANALYSIS FOR THE MFH WATER LEVEL

Source: Robison, 2004.

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transport. These two modeling efforts are described in Sections 5.4 and 5.9 of this WRV assessment.

4.3 MAXIMUM FRESHWATER WITHDRAWAL LIMITS

Based on the hydrologic and hydraulic modeling results obtained by Robison (2004a), SJRWMD considers a maximum surface water withdrawal limit of 240 cfs from the St. Johns River near DeLand (SJRND) and a maximum withdrawal limit of 180 cfs at Lake Monroe. The maximum withdrawal limit of 240 cfs from the SJRND is the cumulative withdrawal from the St. Johns River, and includes the maximum withdrawal of 180 cfs from Lake Monroe. The stage duration curves for the existing and 180-cfs withdrawal conditions from Lake Monroe (Figure 4-5) are based on hydraulic modeling results provided by Robison (2004b). The model simulation results (Robison, 2004b) showed that the maximum lake water drawdown in Lake Monroe by a 180-cfs maximum withdrawal from Lake Monroe was 0.25 ft. The surface water drawdowns at various percentiles are shown in Table 4-1.

Table 4-1. Lake Monroe Water Level Drawdown Frequency by 180-cfs Withdrawal

Percentile[1]	Drawdown[2] (ft)
1	0.09
5	0.10
10	0.10
20	0.10
30	0.10
40	0.11
50	0.11
60	0.12
70	0.13
80	0.13
90	0.14
95	0.15
99	0.20

(1) Non-exceedance frequency.
(2) Drawdown = baseline daily lake level – daily lake level with 180-cfs withdrawal from Lake Monroe.

Source: ECT, 2006.

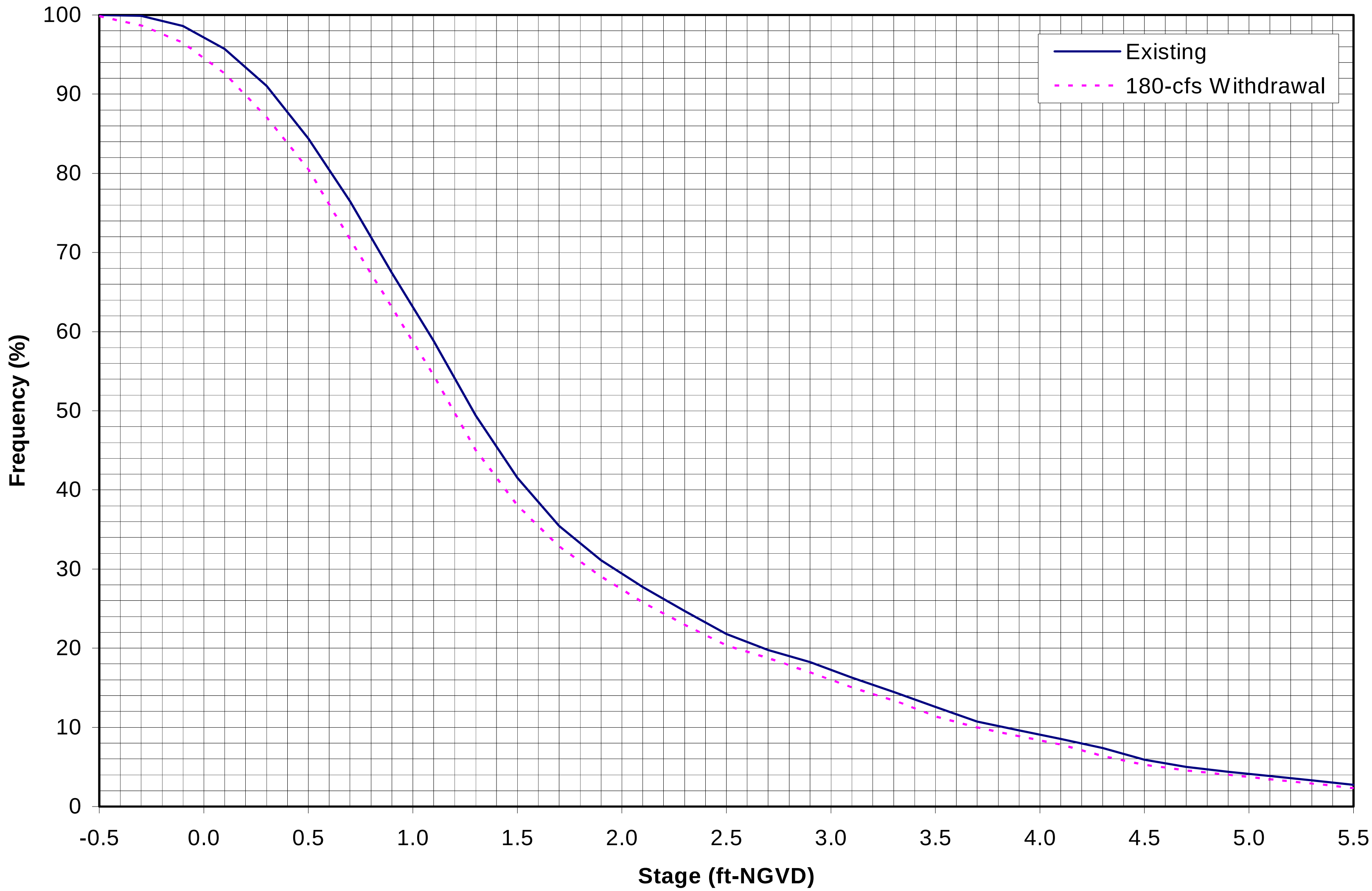

FIGURE 4-5.

LAKE MONROE STAGE DURATION CURVES FOR EXISTING AND 180-CFS WITHDRAWAL CONDITIONS

Source: ECT, 2004.

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Two maximum withdrawal rates were used in this WRV assessment. In Section 5.4 of this report, ECT evaluated if a maximum cumulative surface water withdrawal limit of 240 cfs from the SJRND is protective of the estuarine resources (WRV-3). To evaluate the remaining nine WRVs, a maximum withdrawal limit of 180 cfs from Lake Monroe was considered.

5.0 WATER RESOURCE VALUE EVALUATIONS

5.1 GENERAL METHODOLOGY

Environmental and hydrological evaluations are presented in the following sections to determine if the recommended MFLs hydrologic conditions for Lake Monroe will provide protection of the 10 WRVs listed in Section 62-40.473, *F.A.C.* The WRVs span a full range of water-related functions of various natural resources that provide beneficial use to human activities and ecologic communities. Each of the 10 WRVs may represent a broad class of functions, natural processes, and activities that require protection. To facilitate the process of determining if the recommended MFLs hydrologic conditions for Lake Monroe protect these classes of functions, processes, and activities, SJRWMD provided the following four-step hierarchical approach for the assessment that was also implemented by HSW Engineering, Inc. (2004) for the WRVs evaluation of the St. Johns River near SR 50:

- Step 1—Restate the WRV in terms of criteria that are specific to the water body being evaluated.
- Step 2—Identify a representative function/process/activity of that specific WRV.
- Step 3—Identify a general indicator parameter for the protection of the lake-specific WRV in terms of flow and/or level, and duration.
- Step 4—Identify specific indicator parameter(s) for the protection of the lake-specific WRV in terms of flow and/or level, and duration.

Table 5-1 summarizes the hierarchical approach to the WRVs evaluation.

A basic assumption of the WRV evaluation methodology is that the existing long-term hydrologic regime protects the 10 WRVs. A hydrologic event in Lake Monroe is defined by the hydrologic components of water level (ft-NGVD) and duration (days). The threshold events relevant to each WRV are determined during Step 4 of the hierarchical approach. The return intervals (expressed in number of events per century) of such threshold events are then determined for the existing and MFLs hydrologic regimes.

Table 5-1. Four-Level Hierarchical Approach to Evaluate WRVs Protection by MFLs Regime at Lake Monroe

WRV Name	Function	General Indicator	Specific Indicator
Recreation in and on the water	Recreational boat passage	Maintain recreational boating	Minimum water level of 0.5 ft-NGVD for safe boat passage and berthing, with critical durations of 30, 60, and 183 days.
Fish and wildlife habitat and the passage of fish	Fish passage for large species in lake; passage for small forage species onto floodplain; suitable habitat for wildlife	Provide access to aquatic and wetland environments required by fish and wildlife	Minimum stage of -3 ft-NGVD to protect in-lake fish passage with 365-day duration. Minimum stages of 1.3 and 1.7 ft-NGVD for wildlife habitat protection and fish passage onto floodplain with critical durations of 30, 60, 90, and 120 days. Minimum stage of -0.4 ft-NGVD to protect littoral zone vegetation with critical duration of 14, 60, and 90 days. Minimum stages of 1.8 and 3.8 ft-NGVD for woody debris with critical duration of 60 and 90 days. Minimum stages of 2.8, 1.2, and 0.5 ft-NGVD for wetland communities with critical durations of 30, 183, and 120 days, respectively.
Estuarine resources	Productivity of coastal systems and associated natural resources	Maintain salinity regime in the estuary	5-ppt isohaline shift during the dry season by water withdrawal and *Vallisneria* response to salinity changes. Change of mean daily maximum salinity by water withdrawal within the area of 5-ppt average salinity. 2-ppt isohaline shift by water withdrawal during the dry season (salinity threshold for bullhead and coastal shiner). 15-ppt isohaline shift by water withdrawal during the dry season (salinity threshold for oyster drill).
Transfer of detrital material	Supply and distribution of nutrients	Provide detrital export from marsh, maintain in-lake transfer of detrital material	Minimum flood level of 3.3 ft-NGVD (upper range of hardwood swamp elevation) with critical durations of 1, 14, and 30 days. Minimum flood level of 5.3 ft-NGVD (when critical shear stress is exceeded) with durations of 1 and 14 days.
Maintenance of freshwater storage and supply	Reasonable and beneficial use of surface and ground water	Protect existing uses	No interference with existing users. Water intake structure elevations.
Aesthetic and scenic attributes	Passive recreation	Maintain visual setting at selected points	Optimal stage of 1.7 ft-NGVD (lakeshore edge elevation of hardwood swamps) for scenic and wildlife viewing, with critical durations of 60, 90, and 120 days. A threshold stage of 0.9 ft-NGVD for sediment exposure (14-, 30-, 60-, and 90-day duration). A threshold stage of 1.5 ft-NGVD for water clarity (30-, 60-, and 90-day duration).

Table 5-1. Four-Level Hierarchical Approach to Evaluate WRVs Protection by MFLs Regime at Lake Monroe

WRV Name	Function	General Indicator	Specific Indicator
Filtration and absorption of nutrients and other pollutants	Ecosystem and water quality protection	Transformation of nutrients by wetland vegetation and absorption of nutrients by soil	Threshold stages of 4.0 ft-NGVD for hardwood swamp filtration; 2.3 ft-NGVD for shallow marsh filtration, 1.0 ft-NGVD for deep marsh filtration and -0.4 ft-NGVD for in-lake vegetation filtration (14-, 30-, and 60-day duration). Threshold stage of 0.0 ft-NGVD for near-shore soil oxidation (30- and 60-day duration).
Sediment loads	Sediment transport	Maintain sediment transport in the lake	Threshold stage of 5.3 ft-NGVD when bottom shear stress exceeds the critical shear stress (1 and 14-day duration). Bottom shear stress and resuspension flux.
Water quality	Productive aquatic community	Maintain DO concentrations and good water quality	Trophic State Index (TSI); stage-water quality parameters relationship; threshold stage of 2.0 (30-day duration) and 3.0 ft-NGVD (183-day duration) to maintain fair water quality.
Navigation	Area access	Continue legal operation of commercial vessels	Minimum stage of -0.5 ft-NGVD for safe commercial vessel navigation, with critical durations of 1, 14, and 30 days.

Source: ECT, 2006.

Water withdrawals that appreciably increase the return intervals of low water events or appreciably decrease the return intervals of high water events beyond a designated threshold that allows for ecosystem recovery will result in harm.

5.2 WRV-1: RECREATION IN AND ON THE WATER

5.2.1 INTRODUCTION

Lake Monroe is one of the top-10 black crappie (speck) fishing hot spots in Florida listed by the Florida Fish and Wildlife Conservation Commission (FFWCC) (Allen, 1999). The lake is within 1-hour driving time from a large high growth area including Orlando, Sanford, Deltona, DeBary, Orange City, Lake Mary, Winter Park, Altamonte Springs, Apopka, and DeLand. The total population in the greater metropolitan area of Orlando and Deltona was estimated to be about 2.3 million people (Brinkhoff, 2004). Because navigation channels exist in Lake Monroe, the lake serves the needs of deepwater access and water-related recreation for a large local population as well as out-of-state tourists.

Lake Monroe, one of the larger lakes in the MSJR basin, is part of the main stem of the MSJR and is basically a widening of the river. Recreational boating, fishing, and tourism on the St. Johns River and Lake Monroe provide the surrounding communities with important economic resources. Many of the businesses along the St. Johns River and Lake Monroe rely on and cater to these tourists providing daily and weekly boat rentals, canoe rentals, river tours, and fishing guides.

Lower water level events in Lake Monroe and the St. Johns River occur naturally and periodically, with May being the typical period of lowest water. Recreational boating and waterfront businesses can be affected by lowered water levels. Extreme low water levels, if occurring, may prevent use of some docks, slips, and boat ramps, and can impede river access.

5.2.2 METHODOLOGY

A four-level hierarchical approach, described in Section 5.1, was used to assess whether the recommended MFLs hydrologic conditions for Lake Monroe will provide protection to recreation in and on the water.

Recreation in and on the water (WRV-1) is defined as the active use of water resources and associated natural system for personal activity and enjoyment. The primary function of WRV-1 is to provide recreational boat passage. The general indicator for WRV-1 protection is to maintain recreational boating. The specific indicator is the frequency of water level being lower than the threshold stage of 0.5 ft-NGVD for critical durations of 30, 60, and 183 days.

The following sections describe the water-related recreation facilities and define the legal recreation activities in the Lake Monroe area, identify the primary recreational functions to be protected, identify the indicator parameter for recreation protection in terms of stage and duration, and identify the specific indicator parameters for recreation protection in terms of stage and duration.

The assessment uses best available information including literature, field reconnaissance, interviews with marina harbormasters and park personnel, and frequency-duration information provided by Robison (2004b).

5.2.3 RECREATION FACILITIES AND ACTIVITIES

Recreation activities in and on Lake Monroe include boating, fishing, water skiing, jet skiing, and tourism. Hunting is not allowed on the lake. Fishing activities are carried out either onshore at the seawall or on small boats (typically 16 ft in length). Speck fishing in Lake Monroe usually begins in October and continues through March. Other popular catches include largemouth bass, catfish, bream, bluegill, redear sunfish, and shad. The peak of shad fishing begins in December and continues through March.

The most predominant recreation in the Lake Monroe area is boating (both motor boats and sailboats). Boat ramps and marinas serve as launching, docking, and mooring areas for vessels, and they are essential to water recreation activities. Three large marinas and several boat ramps are located on the lakeshore or in the St. Johns River near the inlet and outlet of the lake. They are described as follows:

- Monroe Harbour Marina is a full-service marina at the south shore of Lake Monroe near the City of Sanford River Walk. The marina consists of 250 wet slips and a dry stack with a capacity of 120 boats. The marina can accommodate vessels up to 90 ft in length; the average length of the boats is about 31 ft. The draft of the boats ranges from 4 to 6 ft. The average, and typical, draft of the boats is about 4.5 ft. The water depth in the marina ranges from 1.8 to 6.5 ft when the lake level is at mean sea level (msl). The typical water depth in the harbor is 5 ft (ranges from 1.8 to 6.5 ft) when the lake level is at msl. In this section of the report, the term msl is considered to be the same as the NGVD datum. About 30 percent of the boats in the wet slips are sailboats. Larger, fixed keel sailboats typically need a water depth of 6 ft to navigate. According to the harbormaster of the marina, occasionally some large vessels were not allowed to enter the harbor for mooring because the water depth in some berths was too shallow for large boats during drought conditions. Nevertheless, the entrance channel has adequate depth (about 12 ft at msl) at all times. The marina owns a small dredger that can perform occasional minor maintenance dredging (under Environmental Resource Permit no. 590829199) when needed. About 10 percent of the boats in the wet slip are used regularly. The boats in the dry stack are used more frequently than those in wet slips. Most of the boat usages are for weekend day trips.
- The Rivership Romance is a 98-ft refurbished 1940s Great Lakes steamer. The vessel is used for leisurely luncheon and dinner cruises, and is also popular for wedding parties. The 96-ton cruise ship is 38 ft wide with a draft of 8.5 ft. It is docked inside the Monroe Harbour Marina and sails daily for a luncheon cruise. Dinner cruises are operated on Friday and Saturday evenings. The ship can accommodate 200 people and sails 3 to 4 hours for each cruise. It usually sets out toward DeBary; occasionally, it sails further north. According to the operator of the Rivership Romance, the berth and navigational channel have sufficient depth such that a cruise has never been cancelled due to low water conditions since the start of cruise operation in 1981.

- Fun Maritime Academy (FMA), located inside the Monroe Harbor Marina, offers sailing lessons, provides rental services for sailboats and power boats, and organizes regatta for various classes of sailboats. FMA owns five 22-ft Catalinas with swing keels. The boats have a draft of 1.5 ft when the keel is up, and have a draft of 5 ft when the keel is down.
- Sanford Boat Works & Marina is a full-service marina located on the south shore of the St. Johns River near the inlet of Lake Monroe. The marina is near the eastern end of the Monroe Canal and is at the upstream limit of the marked federal navigation channel in the St. Johns River. The marina consists of 178 wet slips and 30 spaces for land storage. About half of the wet slips are covered. The size of boats in the marina ranges from 14 to 64 ft. The most common vessels in the marina are 26-ft mono-hull or pontoon boats. The average depth of the marina is about 6.5 ft and the minimum depth at low water is about 5 ft. The draft of the boats in the marina is usually less than 4.5 ft. According to the dockmaster of the marina, boats have no problem getting in and out of the marina. However, the boaters have to exercise caution during drought conditions. From 1925 to present, the water level never dropped to a level that made vessels in the marina become landlocked. Some shoaling has occurred between Markers 2 and 4, but it has not prevented boats from sailing into the lake.

  About 15 percent of the boats in the marina are used regularly, 60 percent of the boats are used monthly, and 25 percent of the boats are rarely used (two or three times a year), according to the dockmaster. Most of the boat usages are weekend day trips. Not many boaters take their boat out cruising for 1 to 2 weeks duration.
- Hidden Harbour Marina is located at the Port of Sanford, an industrial complex on the south shore of the St. Johns River near the western outlet of Lake Monroe. The marina consists of 235 wet slips and a dry storage with a capacity of 250 boats. The size of the boats in the marina ranges from 25 to 75 ft with an average boat length of 33 ft. About 10 percent of the boats in the marina are sailboats. The average draft of the boats is 3 ft and the

maximum draft is 5 ft. The harbor was dredged to 9 to 12 ft below msl; therefore, low water is usually not a problem to marina operation. According to the harbormaster, when the water level drops below msl or 1 ft below msl, navigation can become difficult for some boaters. The boats in Hidden Harbour Marina are frequently used. Many owners sail almost every weekend during the boating season (March to November). Most of the boat usages are weekend day trips. The most popular destinations are Blue Spring and Silver Glen Springs. Some people take multi-day trips to Palatka or Jacksonville occasionally. Boat owners usually trailer their boats to more distant places by road, in order to save travel time.

- Lake Monroe Park is operated by Volusia County Leisure Services and is located on the north shore of the St. Johns River east of U.S. 17-92 near the outlet of Lake Monroe. The park has two wide boat ramps; each can handle two simultaneous launches. There are plenty of parking spaces and the ramps can accommodate temporary tie up for many boats at one time. The boat launching and turning area was dredged to a depth of 30 ft below msl. According to a park employee, Mr. Hank Baskell, the annual boat launch count is about 15,000.
- Lake Monroe Wayside Park is located at the south shore of the St. Johns River at the outlet of Lake Monroe near I-4. The park is maintained by Seminole County Parks and Recreation and has a public boat ramp with two small tie-up docks.
- Lake Monroe Boat Ramp is located at the north shore of Lake Monroe and is maintained by the City of Deltona Parks and Recreation Department. There are 12 parking slots near the ramp and no boat staging area or other facilities.
- Mariners Cove Park is located near Stone Island and is maintained by Volusia County. The park has a small boat ramp with a short tie-up dock. The ramp provides access to Lake Monroe via a 1-mile-long dredged channel. The channel has sufficient depth for average boat travel. However, the dense floating aquatic plants in the canal and near the entrance can be a

nuisance for boat navigation. The boat ramp area is at a low elevation and is subject to flooding. The ramp became inaccessible after the flooding caused by Hurricane Jeanne in 2004.

- River Oaks Estate is a gated residential community located on the north shore of the Gemini Springs Run. There are 52 private docks in the complex.

The three marinas have full-service capabilities and are equipped with private ramps, travel lifts, sewer pump-out facilities, fueling stations, marine stores, repair shops, showers, and restaurants. There are no individual docks on the south shore of the lake except for a covered dock near the Lake Monroe Inn. There are several private docks along the north shore of the lake.

As shown in Figure 2-3, navigation channels have been dredged in Lake Monroe and in the St. Johns River at both ends of the lake. According to the hydrographic survey conducted by USACE, Jacksonville District, in June 2001, the minimum middle-half channel depth was 10.9 ft in a river segment from the SR 44 Bridge at Crows Bluff to the U.S. 17-92 Bridge near Lake Monroe Park (USACE, 2001). The authorized project depth for this channel was 12 ft at mean low low water (MLLW) level. MLLW is essentially the same as msl in Lake Monroe area. Spot shoaling was located from green Daybeacon No. 43 to green Light-63 near Lake Beresford. Shoaling was also located from red Light-116, extending eastward for approximately 2,000 ft near Hidden Harbour Marina. The controlling centerline depth of the navigation channel from U.S. 17-92 to Beacon-7 was 9 ft at MLLW; the controlling depth from Beacon-7 to the Sanford turning basin was 6 ft at MLLW. The channel depth from Beacon 7 to Progress Energy Turner Plant at the north shore was 6.5 ft at MLLW. The depth of the Monroe Canal was 4 to 5 ft at MLLW. Shoaling occurred near green Light-15 near Turner Plant and extended 1,000 ft northward. Shoaling also occurred about 2,000 ft west of red Light-2 to 600 ft east of red Daybeacon-4. The channel markers are shown in Figure 2-3.

Volusia County conducted a boating activity study of the St. Johns River and the Intercoastal Waterway in Volusia County and several bordering counties from July 1994, to May 1995 (Volusia County, 1996). The purpose of this study was to collect data that described and quantified the boating activities, patterns, and composition of pleasure boat types in the area. Data were collected to depict the summer and winter boating patterns within the County. The data were collected using several methodologies: ramp intercept interviews, aerial surveys, boat ramp trailer census, shoreline dock surveys, marina surveys, and a mail survey to 2,050 registered Volusia County boaters. Some of the following information was taken from the study.

The results of the Volusia County boating activity study indicated that the main use of the St. Johns River was for recreational purposes, with traveling and fishing being the two major boating activities, accounting for 86 percent of all activities. The data indicated that there were 50 percent more boats on the river during the summer than the winter. However, there was a marked increase in the number of recreational fishermen during the winter compared to the summer period.

Most of the boats on the river were outboard engine powerboats, with an average of 100 horsepower. The size class most observed was the Class 1 boat (16 to 25 ft), followed by the Class A boat (less than 16 ft). These two class sizes accounted for 88 percent of the boats observed. The majority of boaters stored their boats at home on a trailer. For those who stored their boats at marinas in wet slips, the primary type of boat was a Class 2 powerboat (26 to 39 ft).

The survey found that the most common destination for boaters on the St. Johns River was the Silver Glen Springs area, located adjacent to Lake George, commonly referred to as *The Glen*. The interviews with the harbormasters near Lake Monroe also verified that Silver Glen is one of the most popular destinations of the boats in all three marinas in the Lake Monroe area.

According to the interviews with harbormasters in the Lake Monroe area in 2004 and the recreation survey conducted by ECT (2002a), low water conditions could impact the daily operations of commercial business in varying degrees. However, up to the present, low water levels in Lake Monroe can be considered as an inconvenience or nuisance and have not caused severe problems that jeopardize the operation of the facilities. All marinas in the area reported abilities to provide services during low water levels, with some limitations. Monroe Harbour Marina, which is the shallowest of the three marinas, sometimes could not allow large vessels into the marina during low water events. At a lake stage of 0.5 ft-NGVD, the fuel dock in Monroe Harbor Marina has a depth of 4.6 ft, which may exclude some larger, deep draft sailboats from fueling services. According to the dockmaster of Sanford Boat Works & Marina, the marina and boat users could *survive* low water conditions, such as 0.5 ft-NGVD, for a few months. However, this low water level condition could become a serious problem if these conditions were to last 6 months or longer; boat owners might relocate their boats to other areas. Many businesses reported that high water levels caused by floods were a greater concern.

Most of the individual boaters and many businesses along the St. Johns River have adapted to the naturally fluctuating water levels. These adaptations include installation of depth finders on rental boats, avoiding known shallow areas, trimming engines, selectively docking boats with larger drafts in deeper slips, supervised use of docks and ramps by knowledgeable persons, and minor maintenance dredging activities.

The typical depths of the marina berths in the Lake Monroe area at a stage of 0.0 ft-NGVD and the typical draft of the boats are summarized as follows:

Marina	Typical Depth of Mooring Berths (ft) at a Stage of 0.0 ft-NGVD	Typical Boat Draft (ft)
Monroe Harbour Marina	5	4.5
Sanford Boat Works & Marina	5.5	<4.5
Hidden Harbor	10	3

5.2.4 RECREATION ASSESSMENT

Recreation in and on the water is defined as *legal* water sports and activities. The legal activities include fishing, skiing, swimming, and boating. Most of these recreational activities are supported by boats. In addition, the recreation survey described in Section 5.2.3 indicates that the most predominant recreation activity in the Lake Monroe area is boating. Therefore, recreational boat passage is determined to be the primary function to be protected, and maintaining recreation boating is the criteria to evaluate WRV-1.

Boaters cannot operate a boat safely when the water depth is near the draft of the boat. Therefore, low water level is used as the general indicator for the protection of recreation in and on the water, namely boat passage.

According to the water depths and water-dependent recreation facilities information presented in Section 5.2.3, a stage of 0.5 ft-NGVD at Lake Monroe can be considered a threshold stage that will provide safe boat passage for recreational vessels. When Lake Monroe stage is at or above this threshold stage, safe boat passage can be provided for all boats launched at the public boat ramps, all vessels in Hidden Harbor Marina, Sanford Boat Works & Marina, and most of the vessels in Monroe Harbour Marina, while cautious boating practices are exercised.

Recreational boaters are known to be able to adapt their boating schedule to weather changes. For example, boaters are willing to delay their boating activities due to severe rainfall, thunderstorm, high winds, or hurricanes. Short-term bad weather conditions (a few days to a few weeks) are not likely to deter boaters from getting on the water at a later date. Similarly, short-term low water level conditions are not likely to change boater's recreational patterns. According to the harbormasters of the marinas in Lake Monroe area, although a low stage of 0.5 ft-NGVD may cause inconvenience to boaters, it does not jeopardize water recreation activities or boating-related businesses, unless this stage (0.5 ft-NGVD) persists for longer than 6 months. Therefore, critical low water durations of 30, 60, and 183 days were selected as critical durations for recreation WRV assessment.

Based on the frequency-duration information provided by Robison (2004b), the frequency of occurrence for the water level not exceeding the threshold stage (0.5 ft-NGVD) for durations of 30, 60, and 183 days were determined for both the existing and the recommended MFLs hydrologic conditions (Table 5-2). The selection of the longest duration of 183 days was based on interviews with the harbor masters in the Lake Monroe area.

Table 5-2. Frequency Analysis of Threshold Stage for Recreation Protection

Threshold Stage (ft-NVGD)	Duration (Days)	No. of Years in a Century Threshold Stage is Continuously Not Exceeded*		
		Existing	MFLs	Difference
0.5	30	36	38	2
0.5	60	27	36	9
0.5	183	3	6	3

* Water levels fall below the threshold stage for the indicated duration.

Source: ECT, 2006.

The frequency analysis indicates that, under existing conditions, the threshold stage of 0.5 ft-NGVD would be continuously not exceeded for 30 days, 36 times in 100 years (Table 5-2). Under the recommended MFLs hydrologic conditions, the threshold stage would be continuously not exceeded for 30 days, 38 times in a century; an increase of 2 dewatering events per 100 years when compared to existing hydrologic conditions. Similarly, the threshold stage of 0.5 ft-NGVD would be continuously not exceeded for 60 days, 27 times in 100 years under existing hydrologic conditions (Table 5-2). Under the recommended MFLs hydrologic conditions, the threshold stage would be continuously not exceeded for 60 days, 36 times in a century; an increase of 9 dewatering events per 100 years when compared to existing hydrologic conditions. The analysis for the 183-day duration, where additional boating problems might occur, shows that the number of times in a century that water levels would continuously not exceed the threshold stage of 0.5 ft-NGVD would be increased from 3 times under the existing conditions to 6 times under the recommended MFLs hydrologic conditions. Thus, this prolonged low water condition is infrequent under both existing and MFLs hydrologic conditions. According to the opinion of the harbor master of the Monroe Harbor Marina, in general the changes in low water conditions predicted for the recommended MFLs hydrologic conditions (Table 5-2) are neither unreasonable nor unacceptable because boaters readily adapt to low water conditions.

5.2.5 SUMMARY

Boating and recreational fishing activities in Lake Monroe are supported by three commercial marinas, four public boat ramps, and a private community docking facility. Based on information presented in Section 2.2.3, the water depths in the area can support most of the boating needs when Lake Monroe stage is at or higher than a threshold stage of 0.5 ft-NGVD.

Historically lake water levels have caused inconvenience for larger boats when the water level is below 0.5 ft-NGVD. Part of the problem is that some private facilities, such as the Monroe Harbor Marina, may have inadequate dredged depth to accommodate large vessels. Nevertheless, boaters seem to be able to adapt to low water conditions by going around shoals and exercising caution. Low water conditions (i.e., lower than 0.5 ft-NGVD) may cause additional problems for boating activities when they persist for an extended period of time (e.g., 6 months).

The results of frequency analysis (Table 5-2) showed that the additional occurrence of aggravating conditions for boating under the recommended MFLs hydrologic conditions for Lake Monroe is not substantial (9 events or less in a century). The frequencies of water level continuously falling below the threshold stage 0.5 ft-NGVD for 6 months would be 3 and 6 events per 100 years under the existing and recommended MFLs hydrologic conditions, respectively. This represents an increase of 3 events in a century. The analysis shows that the recommended MFLs hydrologic conditions for Lake Monroe would not unreasonably nor unacceptably change the frequency of the threshold events. Therefore, the recommended MFLs for Lake Monroe will protect recreation in and on the water.

It is ECT's recommendation that detailed bathymetric surveys of Lake Monroe be conducted periodically, especially in navigation channels and marina basins, to verify the threshold stage for safe boat passage. ECT also recommends that the marina basins be periodically dredged to maintain a minimum depth that can accommodate the largest boat anticipated by the facilities at a stage of 0.5 ft-NGVD or other verified threshold stage.

The navigation channels, especially near Monroe Canal, should be periodically dredged to prevent shoaling.

5.3 <u>WRV-2: FISH AND WILDLIFE HABITATS AND THE PASSAGE OF FISH</u>

5.3.1 INTRODUCTION

Fish and aquatic invertebrates are an important part of food chains, which lead to larger amphibious and terrestrial animals such as alligators, snakes, wading birds, and otters. Changes in populations of these organisms may give an early warning to potential impacts to their environment. Fish and aquatic invertebrates are dependent on the quantity and quality of the waters in which they live. Therefore, these aquatic organisms can be vulnerable to changes in water levels, especially high and low water events, in lakes and streams.

5.3.2 METHODOLOGY

WRV-2 is defined as aquatic and wetland environments required by fish and wildlife (including endangered, endemic, listed, regionally rare, recreationally or commercially important, species) to live, grow, and migrate. These environments include hydrologic regimes (i.e., frequencies, and durations of flooding and drought events) sufficient to support the life cycles of wetland and wetland-dependent species.

The representative functions of WRV-2 are fish passage for selected fish species onto the floodplain, passage for large species within the lake, and suitable habitat for wildlife. The general indicator for the assessment of the protection of WRV-2 is to provide access to aquatic and wetland environments required by fish and wildlife. The specific indicators are a minimum stage of -3.0 ft-NGVD to protect in-lake fish passage (365-day duration); minimum stages of 1.3 and 1.7 ft-NGVD for fish and wildlife protection (30-, 60-, 90-, and 120-day duration); a minimum stage of -0.4 ft-NGVD to protect littoral zone vegetation (1-, 14-, 30-, and 60-day duration); and a minimum stage of 3.8 ft-NGVD (60- and 90-day duration) to protect the woody debris habitat.

ECT conducted a search of published literature to identify the fish, aquatic invertebrates, and listed species that occur in the vicinity of Lake Monroe and to establish their habitat requirements.

5.3.3 FISHERIES

The composition of the fish fauna of the St. Johns River is well known from studies by McLane (1955), Tagatz (1967), and the FFWCC (unpublished). The St. Johns River system is unusual in that many marine fauna occur in Lake George and portions of the MSJR because of the tidal influence and the presence of salt springs that drain into the river (Beck, 1965; Tagatz, 1967). This situation results in an unusual mixture of marine and freshwater species. Although the species which could be expected to occur in the study area are known, the population levels of these species are generally not known. In addition, population sizes are not static, but can be expected to change from year to year, even in the absence of changes in water level and flows which might be brought about by the water withdrawals as limited by the recommended MFLs.

Table 5-3 provides a summary of habitat preferences for selected fishes known from Lake Monroe or nearby areas of the St. Johns River. For purposes of discussion, the fishes of Lake Monroe and the St. Johns River were divided into four groups based on their preferred habitats and expected responses to potential impacts from water withdrawals. These groups, which are discussed in the following paragraphs, are (1) primarily marine and estuarine species; (2) anadromous species; (3) river channel and open lake species; and (4) littoral, intermittent tributary and floodplain species.

Marine and Estuarine Fishes

Atlantic stingray, ladyfish, tarpon, Atlantic menhaden, bay anchovy, gafftopsail catfish, Atlantic needlefish, Atlantic silverside, gulf pipefish, snook, gray snapper, spotfin mojarra, yellowfin mojarra, Atlantic croaker, red drum, striped mullet, white mullet, naked goby, and southern flounder are primarily marine and estuarine species which occur at least as far upstream as Lake George; many of these species occur much further upstream. The salinity assessment presented in Section 5.4 indicates that a cumulative

Table 5-3. Habitat Preferences for Selected Fish Species Occurring in the St. Johns River at Lake Monroe

Scientific Name	Common Name	Habitat	References
Lepisosteus osseus	Longnose gar	Adults in large rivers, juveniles in small streams, occasionally enter brackish water	Springer and Woodburn, 1960; Suttkus, 1963; Swingle and Bland, 1974
Lepisosteus platyrhincus	Florida gar	Main river channels, pools in small creeks, lakes and ponds, occasionally enter brackish water	Barnett, 1972; Gunter and Hall, 1965; Mountain, 1972; Suttkus, 1963; Tabb and Manning, 1962
Amia calva	Bowfin	Sluggish, weedy waters	Barnett, 1972
Anguilla rostrata	American eel	Adults in fresh water, undercut banks of rivers, ponds; spawn in Sargasso Sea	Graff and Middleton, 2002; Smith, 1968; Springer and Woodburn, 1960; Swingle and Bland, 1974
Alosa sapidissima	American shad	Enter St. Johns River when temperature falls below 20°C	Leggett, 1973
Dorosoma cepedianum	Gizzard shad	Large, mud bottom, highly eutrophic lakes	Barnett, 1972; Swingle and Bland, 1974
Dorosoma petenense	Threadfin shad	Open water in lakes	Barnett, 1972; Gunter and Hall, 1965; Swingle and Bland, 1974
Notemigonus crysoleucas	Golden shiner	Permanent open water with a depth of 0.5 meter or more, most common along outer edge of vegetation; fry and juveniles in shallow weedy areas	Barnett, 1972; Swingle and Bland, 1974
Notropis chalybaeus	Ironcolor shiner	Swamp streams, spring runs, rivers and bayou ponds in moving water	Barnett, 1972; Marshall, 1946
Notropis maculatus	Taillight shiner	Ponds and lakes on or near the bottom at a depth of 2-3 meter	Barnett, 1972; Beach, 1974; Gunter and Hall, 1965
Notropis petersoni	Coastal shiner	Found in nearly all flowing water and occasionally in stagnant pools.	Barnett, 1972; Cowell and Resico, 1975; Gunter and Hall, 1965
Pteronotropis welaka	Bluenose shiner	Deeper holes and quiet, weedy water	Gilbert, 1978
Erimyzon sucetta	Lake chubsucker	Nearly every available aquatic habitat; young school in moderate current but adults prefer quiet, vegetated backwaters	Barnett, 1972; Swingle and Bland, 1974

Table 5-3. Habitat Preferences for Selected Fish Species Occurring in the St. Johns River at Lake Monroe

Scientific Name	Common Name	Habitat	References
Ameiurus brunneus	Snail bullhead	Streams with rock bottoms and moderate to swift current	Gilbert, 1978
Ameiurus catus	White catfish	Deep portions of rivers and large connecting lakes	Barnett, 1972; Gunter and Hall, 1965
Ameiurus natalis	Yellow bullhead	Quiet heavily vegetated areas in streams and ponds	Barnett, 1972; Tabb and Manning, 1962
Ameiurus nebulosus	Brown bullhead	Common in ponds, less common in flowing water	Barnett, 1972; Swingle and Bland, 1974
Ictalurus punctatus	Channel catfish	Deep portions of river channel and in large connecting lakes	Barnett, 1972; Gunter and Hall, 1965; McMahon and Terrell, 1982; Swingle and Bland, 1974
Noturus gyrinus	Tadpole madtom	Sand or silt bottom eddies near vegetation or under leaves and other rubble	Barnett, 1972
Esox americanus	Redfin pickerel	Quiet, weedy areas of rivers, sluggish swamp streams, and pond margins	Barnett, 1972; Graff and Middleton, 2002
Esox niger	Chain pickerel	Common in rivers and large lakes in heavily vegetated areas or where fallen logs are present	Barnett, 1972; Swingle and Bland, 1974; Graff and Middleton, 2002
Aphredoderus sayanus	Pirate perch	Sluggish fish which swim infrequently, occupy dense vegetation	Parker and Simpco, 1975; Swingle and Bland, 1974; Graff and Middleton, 2002
Cyprinodon variegatus	Sheepshead minnow	Shallow areas next to shoreline which are without vegetation	Gunter and Hall, 1965; Mountain, 1972; Springer and Woodburn, 1960; Swingle and Bland, 1974; Tabb and Manning, 1962
Fundulus chrysotus	Golden topminnow	Common in shallow, current-free areas with dense vegetation	Barnett, 1972; Gunter and Hall, 1965; Swingle and Bland, 1974; Tabb and Manning, 1962
Fundulus lineolatus	Lined topminnow	Vegetated margins of lakes, ponds, and swamp stream pools, at outer edge of vegetation	Barnett, 1972
Fundulus seminolis	Seminole killifish	On bottom of lakes from near shore to depths of 2 meters	Barnett, 1972; Gunter and Hall, 1965; Tabb and Manning, 1962

Table 5-3. Habitat Preferences for Selected Fish Species Occurring in the St. Johns River at Lake Monroe

Scientific Name	Common Name	Habitat	References
Jordanella floridae	Flagfish	Shallow areas of ponds and streams, usually near vegetation	Barnett, 1972; Gunter and Hall, 1965; Tabb and Manning, 1962
Lucania goodei	Bluefin killifish	Vegetated areas in springs, swamp streams, rivers, ponds and lakes, usually in dense vegetation	Barnett, 1972; Gunter and Hall, 1965; Tabb and Manning, 1962
Lucania parva	Rainwater killifish	Heavily vegetated areas, usually at salinity greater than 25 ppt	Gunter and Hall, 1965; Mountain, 1972; Springer and Woodburn, 1960; Swingle and Bland, 1974; Tabb and Manning, 1962
Gambusia holbrooki	Mosquitofish	Almost any fresh water body, usually in shallow water near vegetation	Barnett, 1972; Gunter and Hall, 1965; Swingle and Bland, 1974; Tabb and Manning, 1962
Heterandria formosa	Least killifish	Usually near surface in heavy vegetation	Barnett, 1972; Gunter and Hall, 1965; Tabb and Manning, 1962
Poecilia latipinna	Sailfin molly	Shallow, densely vegetated shorelines	Barnett, 1972; Gunter and Hall, 1965; Mountain, 1972; Swingle and Bland, 1974; Tabb and Manning, 1962
Labidesthes sicculus	Brook silverside	Open water of lakes, streams, river channels	Barnett, 1972; Gunter and Hall, 1965
Morone saxatilis	Striped bass	Inshore coastal waters, ascending rivers; some populations landlocked; spawns in fresh or nearly freshwater at head of estuaries or rivers	Fischer, 1978
Acantharchus pomotis	Mud sunfish	Low gradient streams and ponds with dense vegetation	Gilbert, 1978
Elassoma evergladei	Everglades pygmy sunfish	Shallow margins of ponds, streams, and rivers; as water rises in spring, moves into extremely shallow areas with or without cover	Barnett, 1972; Swingle and Bland, 1974; Rubenstein, 1981; Tabb and Manning, 1962
Elassoma okefenokee	Okefenokee pygmy sunfish	Margins of rivers	Barnett, 1972
Enneachanthus gloriosus	Bluespotted sunfish	Lakes and rivers wherever dense vegetation in present	Barnett, 1972; Gunter and Hall, 1965; Swingle and Bland, 1974
Lepomis auritus	Redbreast sunfish	Flowing water and connecting lakes	Barnett, 1972; Tabb and Manning, 1962

Table 5-3. Habitat Preferences for Selected Fish Species Occurring in the St. Johns River at Lake Monroe

Scientific Name	Common Name	Habitat	References
Lepomis gulosus	Warmouth	Sluggish swamp streams and ponds in dense cover	Barnett, 1972; Swingle and Bland, 1974; Graff and Middleton, 2002
Lepomis macrochirus	Bluegill	Ponds, lakes, low velocity streams; prefers velocity <10 cm/sec	Barnett, 1972; Gunter and Hall, 1965; Stuber *et al.*, 1982a; Swingle and Bland, 1974; Graff and Middleton, 2002
Lepomis marginatus	Dollar sunfish	Pond margins, eddies along margins of swift streams; rarely numerous	Barnett, 1972; Swingle and Bland, 1974
Lepomis microlophus	Redear sunfish	Lakes and sluggish currents in streams, usually in deep areas	Barnett, 1972; Gunter and Hall, 1965; Swingle and Bland, 1974; Tabb and Manning, 1962
Lepomis punctatus	Spotted sunfish	Common in streams, usually in areas less than 1 meter deep with dense cover	Barnett, 1972; Swingle and Bland, 1974; Tabb and Manning, 1962
Micropterus salmoides	Largemouth bass	All permanent bodies of water; adults near cover; fry and fingerlings in shallow, current-free, vegetated areas	Barnett, 1972; Chew, 1974; Stuber, *et al.*, 1982b; Swingle and Bland, 1974; Tabb and Manning, 1962
Pomoxis nigromarginatus	Black crappie	Open water of lakes and ponds; prefers clear water	Barnett, 1972; Edwards, *et al.*, 1982; Swingle and Bland, 1974
Etheostoma fusiforme	Swamp darter	Sand and mud bottomed lakes, swamp stream, and rivers	Barnett, 1972
Etheostoma olmstedi	Tessellated darter	Small to medium-sized streams, out of main current	Gilbert, 1978
Mugil cephalus	Striped mullet	Primarily marine and estuarine, often entering fresh water to the heads of streams	Fischer, 1978; Futch and Dwinell, 1977; Gunter and Hall, 1965; Moore, 1974; Mountain, 1972; Springer and Woodburn, 1960; Swingle and Bland, 1974; Tabb and Manning, 1962

Source: ECT, 2008.

maximum withdrawal limit of 240 cfs from the SJRND, which includes a maximum withdrawal of 180 cfs from Lake Monroe, may have only a minor influence on the salinity in the LSJR estuary. Therefore, the composition of estuarine and marine fish species will be protected under the recommended MFLs hydrologic conditions.

Anadromous Fishes

Shortnose sturgeon, blueback herring, hickory shad, and striped bass are anadromous species. These species ascend the river and streams to spawn, but return to the sea as adults. These species primarily use the main river channel, and potential water withdrawals should not affect these species. Therefore, anadromous species will be protected under the recommended MFLs hydrologic conditions for Lake Monroe. Another anadromous species, the American shad (*Alosa sapidissima*), occurs from Labrador to Florida (Page and Burr, 1991). The St. Johns River American shad population is the southernmost population of the species (Harris and McBride, 2004). The shad spawn from late November to March (Harris and McBride, 2004). They prefer shallow flats in rivers near the mouths of creeks (Breder and Rosen, 1966) and in areas with water velocities of 1.0 to 3.0 fps (Harris and McBride, 2004). The eggs are demersal and non-adhesive. To survive, they need oxygen levels of at least 4 milligrams per liter (mg/L) (Harris and McBride, 2004). Williams *et al*. (1975) collected shad eggs from the St. Johns River. Most eggs were collected upstream of Lake Monroe (Figure 5-1). Water velocity under the existing conditions within Lake Monroe is generally less than 0.2 fps (Jain and Mehta, 2006); much too low to support successful spawning by American shad. After hatching, the larvae seem to survive best in areas with low flow; however juveniles need increased flow rates to trigger downstream migration (Harris and McBride, 2004).

Therefore, it appears that American shad do not use Lake Monroe for spawning due to low water velocity within the lake. Newly hatched larvae may use the waters of the lake for feeding and growth, but the advent of the rainy season would increase water flow and trigger migration downstream to the ocean. These conditions are compatable with the recommended MFLs hydrologic conditions for Lake Monroe.

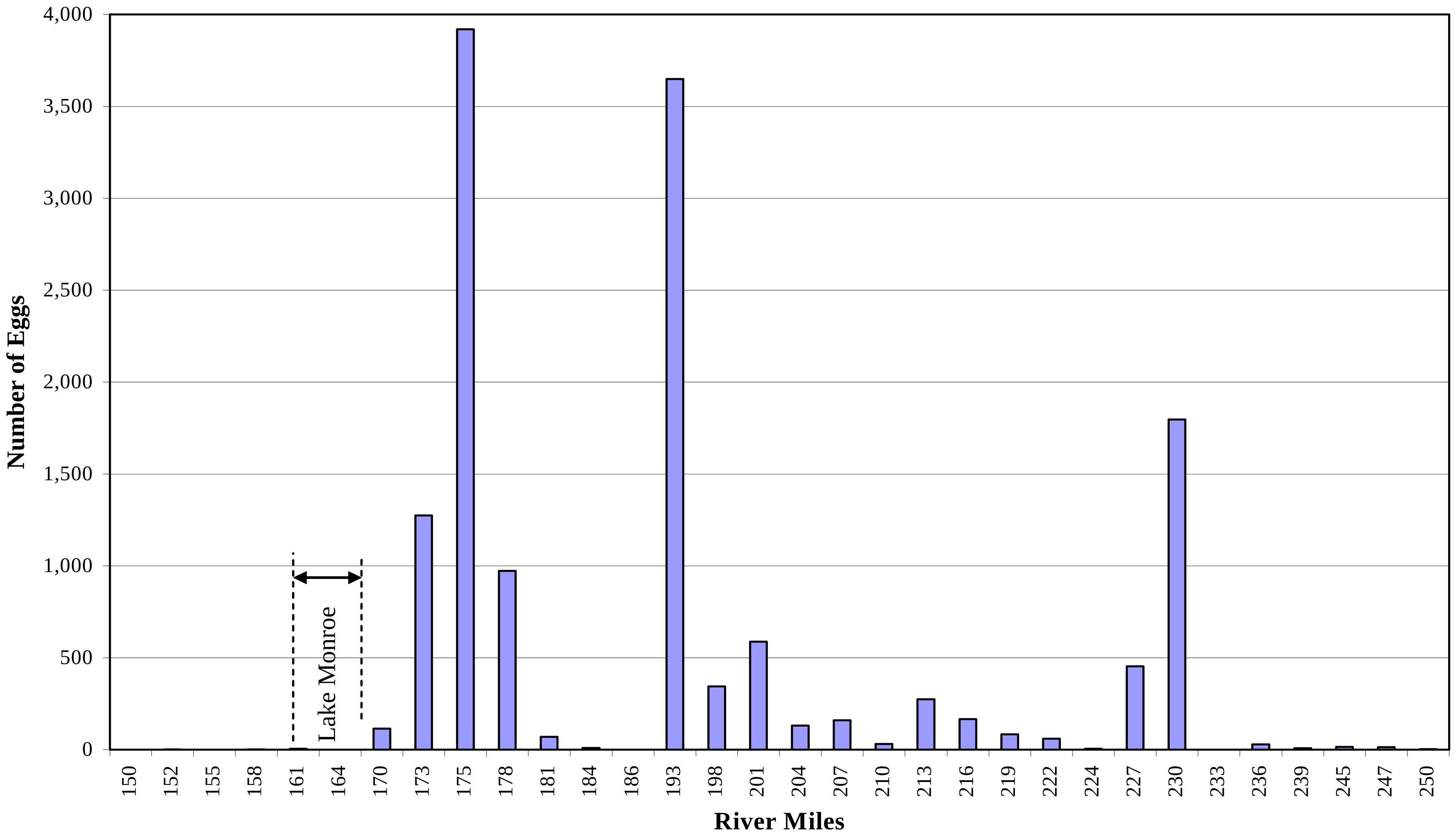

FIGURE 5-1.

NUMBERS OF AMERICAN SHAD EGGS COLLECTED IN THE ST. JOHNS RIVER BY RIVER MILES

Source: Williams *et al*., 1975.

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River Channel and Open Lake Fishes

Longnose gar, gizzard shad, threadfin shad, golden shiner, ironcolor shiner, redeye chub, coastal shiner, pugnose minnow, lake chubsucker, snail bullhead, white catfish, channel catfish, brook silverside, redbreast sunfish, largemouth bass, black crappie, and blue tilapia utilize the main channel of the St. Johns River and open waters of Lake Monroe.

Florida gars also use the main channel, but are as likely to use the floodplain and backwater pools and oxbows (Table 5-3). The young of many of these species utilize the flooded swamps and marshes as a nursery during the rainy season (Graff and Middleton, 2002). Most of the open waters of Lake Monroe are relatively deep (5 to 10 ft); potential water withdrawals as limited by the MFLs would leave adequate water depth in the main channel to support these species.

Bald eagles, a state/federally threatened species, are fish-eating birds, which can find ample feeding habitat in Lake Monroe. Tall trees in the floodplain forests could provide suitable nest sites; however, much of the lake's shoreline has been developed. Nevertheless, several active and inactive nests are located near Lake Monroe (Figure 5-2). As discussed above, the recommended MFLs hydrologic conditions will not adversely affect the fishes on which bald eagles feed, nor would they affect existing nesting sites.

The wading birds utilizing the St. Johns River and its floodplain include roseate spoonbill, little blue heron, snowy egret, reddish egret, tricolored heron, and white ibis (all state species of special concern). Two wading bird rookeries have been reported for Lake Monroe (Figure 5-2). One rookery near the western end of the lake was active in 1999 and contained fewer than 50 nests of the great blue heron. The other colony near Stone Island was inactive in 1999. Wading birds depend on the cycle of flooding and drying of the river's floodplain marshes and swamps, but also can feed along the shores of the main river channel. White ibis, in particular, feed extensively on crayfish as well as floodplain fishes, which are abundant along river floodplains. As discussed in the following section, white ibis and floodplain fish species that enter floodplain marshes and

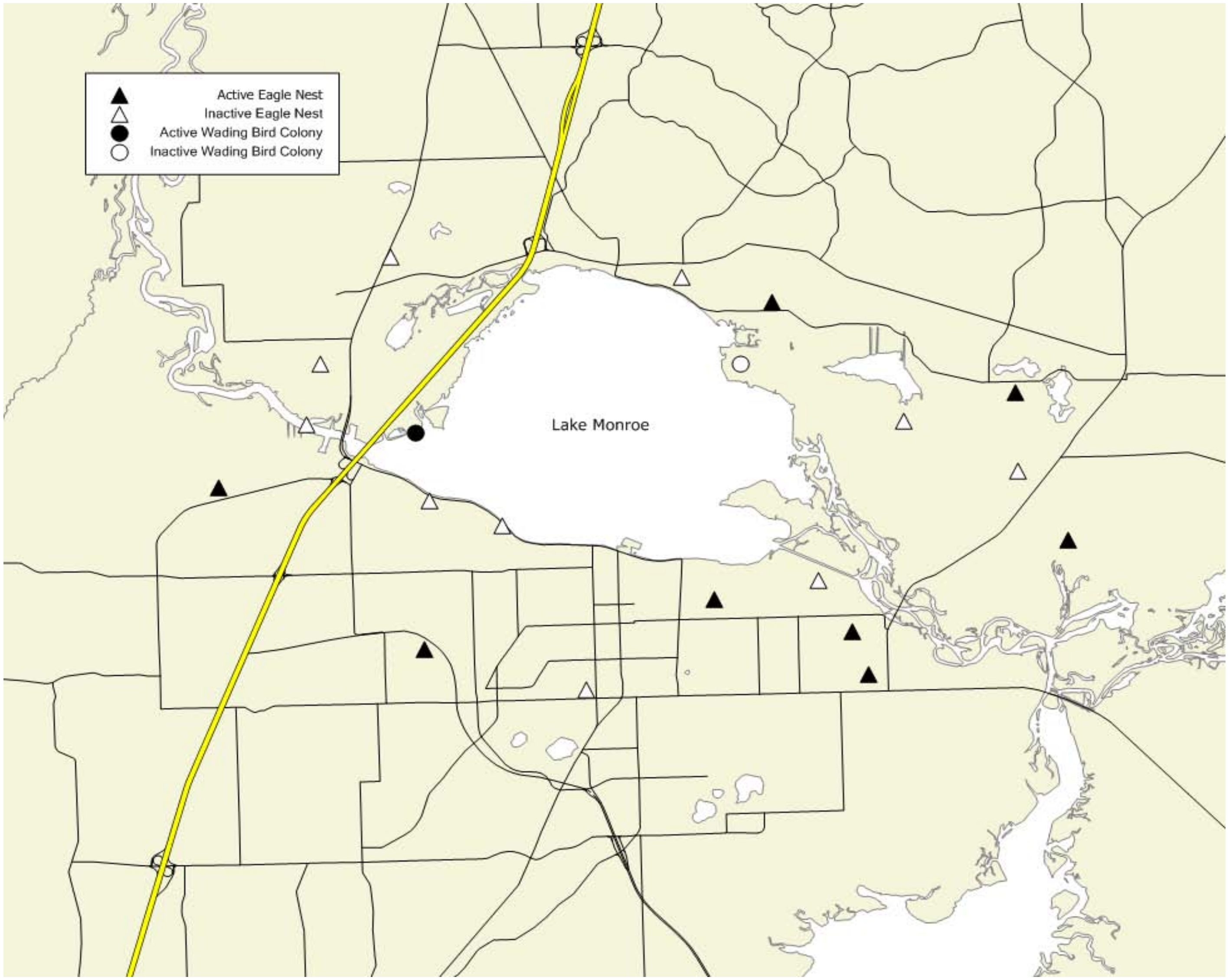

FIGURE 5-2.

LOCATIONS OF BALD EAGLE NESTS AND WADING BIRD COLONIES NEAR LAKE MONROE, FLORIDA

Source: FNAI, 2001.

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swamps and constitute an important element in the food supply of wading birds will be protected under the recommended MFLs hydrologic conditions.

Littoral, Intermittent Tributary, and Floodplain Fishes

Bowfin, American eel, redfin pickerel, chain pickerel, eastern mudminnow, common carp, bluenose shiner, yellow bullhead, brown bullhead, tadpole madtom, pirate perch, golden topminnow, marsh killifish, flagfish, pygmy killifish, bluefin killifish, mosquitofish, least killifish, sailfin molly, mud sunfish, everglades pygmy sunfish, bluespotted sunfish, warmouth, dollar sunfish, spotted sunfish, and swamp darter occupy the margins of the lake as well as backwaters and streams where a remnant population survives the dry season in deeper holes (Table 5-3). Many of these species (especially the killifish, mosquitofish, and pygmy sunfish) mature rapidly and reproduce throughout the wet season so that their population expands rapidly. Lower dry season water levels may dry out shallow pools and ponded floodplain areas in some instances, such as along Transect 7 (Mace, 2006a). However, sufficient refuges should remain in deeper holes in the floodplain, such as alligator holes (Kushlan, 1974), vegetated areas near the lake's shoreline, and tributaries to the St. Johns River to allow repopulation of floodplain sloughs during the rainy season.

Floodplain marshes and forests support many invertebrates and vertebrates other than fishes (Ewel, 1990; Kushlan, 1990). Mace (2006a) conducted extensive vegetation studies in the floodplains adjacent to Lake Monroe to determine MFLs that would ensure the survival of the floodplain plant communities. Since these plant communities are protected by the proposed MFLs, it is reasonable to believe that non-aquatic animals that rely on these communities will also be protected.

Littoral vegetation provides an important substrate for aquatic invertebrates and provides cover for small fishes. The littoral zone vegetation in Lake Monroe was surveyed by ECT ecologists on May 23, 2006, when the lake water level was 0.75 ft-NGVD. The purpose of the survey was to identify and map the generalized locations of littoral vegetation, describe the dominant components comprising littoral vegetation, and measure water levels at the lakeward edge of representative littoral zone vegetation. Figure 5-3 shows the locations of the significant expanses of littoral vegetation and water depths at various locations at the lakeward edge of the vegetation at the time of the survey. The littoral vegetation is comprised of a combination of emergent, submergent, and natant plant species and was estimated to occupy approximately 308 acres of Lake Monroe. For mapping purposes, natant species are included with emergent species and are designated emergent in Figure 5-3.

The dominant emergent plant species in the Lake Monroe littoral zone is softstem bulrush (*Scirpus tabernaemontana*). Less common emergents include common reed (*Phragmites australis*), cattail (*Typha* sp.), and denseflower knotweed *(Polygonum glabrum*). Cattail and denseflower knotweed were most common on the margins of Monroe Canal and the original river channel entering the lake upstream. The dominant natant species is spatterdock (*Nuphar advena*).

Submerged vegetation is dominated by tapegrass (*Vallisneria americana*), hydrilla (*Hydrilla verticillata*), coontail (*Ceratophyllum demersum*) and filamentous algae. Filamentous algae formed significant mats in places and was growing on the tapegrass as an epiphyte. The only places in which hydrilla and coontail were observed were locations with significant populations of tapegrass. It is believed that populations of hydrilla and possible coontail that could grow in deeper areas of the lake beyond the limit for tapegrass are controlled by the USACE's periodic spot spraying program as these plants rarely occurred outside areas inhabited by tapegrass.

The lakeward edge of the littoral vegetation was observed to be in a depth of 0.4 to 2.9 ft of water (Figure 5-3). This is consistent with maximum depths reported by other investigations (Table 5-4). The average water depth at the lakeward edge of the littoral vegetation was 1.7 ft. On the day of the littoral vegetation survey (May 23, 3006), the elevation of the water surface of Lake Monroe was 0.8 ft-NGVD. Thus, the average elevation of the waterward edge of the littoral zone vegetation was -0.9 ft-NGVD. Setting a threshold of -0.4 ft-NGVD ensures an average water depth of 0.5 ft at the waterward extent of littoral vegetation. The frequency that water levels would not exceed (fall

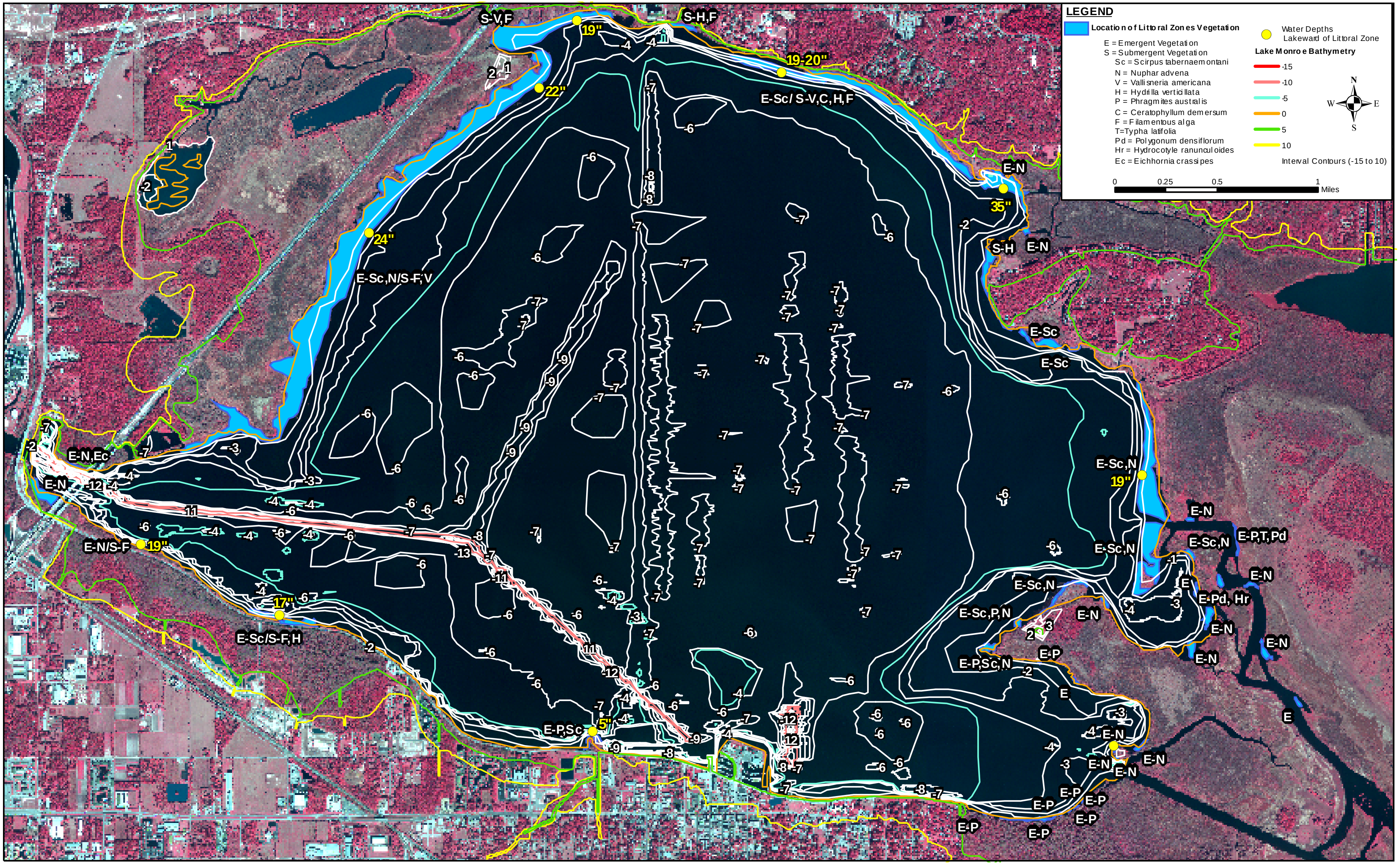

FIGURE 5-3.
LOCATION OF FLOATING/EMERGENT AND SUBMERGENT VEGETATION LITTORAL ZONES IN RELATION TO BATHYMETRY AT LAKE MONROE, MAY 2006.
Source: MEC, 2004; ECT, 2006.

* Images were flown on January 1, 2004.

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below) the threshold stage of –0.4 ft-NGVD for durations of 14, 60, and 90 continuous days remained unchanged when comparing the existing and the recommended MFLs hydrologic conditions (Table 5-5).

Table 5-4. Ranges in Reported Water Depths for Selected Wetland Plants

Species	Water Depths (ft)	Reference
Nuphar sp.	-1.67 to -6.67	Hammer, 1991
	-0.67 to -3.33	USACE, 1993
	-1 to -3	Melton, 1996
Phragmites sp.	+1 to -5	Hammer, 1991
	To -1.67	ISSG Global Invasive Species Database
Scirpus sp.	+0.33 to -6.67	Hammer, 1991
	0 to -1.67	USACE, 1993
	-0.25 to -1	Melton, 1996
	0 to -1	Slattary *et al*., 2003
Typha sp.	+0.33 to -2.33	Hammer, 1991
	Wet substrate to -2	Slattary *et al*., 2003
Vallisneria sp.	-0.16 to -3.33	Hammer, 1991

Source: ECT, 2006.

Table 5-5. Frequency Analysis of Threshold Stage for Littoral Zone Vegetation in Lake Monroe

Threshold Stage (ft-NVGD)	Duration (Days)	No. of Years in a Century Threshold Stage is Continuously Not Exceeded*		
		Existing	MFLs	Difference
-0.4	14	<2	<2	0
-0.4	60	<2	<2	0
-0.4	90	<2	<2	0

* Water levels fall below the threshold stage for the indicated duration.

Source: ECT, 2006.

In several areas, floodplain swamps were observed to be adjacent to areas of littoral vegetation. Substrate, such as that provided by the swamps, is of prime importance to benthic invertebrates providing sites for resting, food acquisition, reproduction, and development (Thorp and Covich, 1991). Exposed root mats and woody debris are among the important substrates for aquatic invertebrates (Anonymous, 2002). These structures on the floodplain were visually estimated to extend from 1 to 3 ft above the May 23, 2006, lake level of 0.8 ft-NGVD (i.e., 1.8 and 3.8 ft-NGVD, respectively).

The results of frequency analysis (Table 5-6) indicate that, water withdrawals under the recommended MFLs for Lake Monroe would not appreciably decrease the frequency that the threshold stages (i.e., 1.8 and 3.8 ft-NGVD) for woody debris habitat are continuously exceeded for 60 or 90 day durations, in comparison to existing hydrologic conditions. Therefore, the recommended MFLs hydrologic conditions will protect woody debris habitat.

Table 5-6. Frequency Analysis of Threshold Stage for Woody Debris in Lake Monroe

Threshold Stage (ft-NVGD)	Duration (Days)	No. of Years in a Century Threshold Stage is Continuously Exceeded*		
		Existing	MFLs	Difference
1.8	60	70	64	6
1.8	90	51	50	1
3.8	60	27	26	1
3.8	90	17	17	0

* Water levels rise above the threshold stage for the indicated duration.

Source: ECT, 2006.

The following plants, present in or around Lake Monroe, are considered invasive by the Florida Exotic Plant Pest Council (FLEPPC) and are on the 2005 list (FLEPPC, 2005). They are: taro (*Colocasia esculenta*), water hyacinth (*Eichhornia crassipes*), water lettuce (*Pistia stratiotes*), hydrilla (*Hydrilla verticillata*) camphor tree (*Cinnamomum camphorum*), Chinese tallow tree (*Sapium sebiferum*), and alligator weed (*Alternanthera* *philoxeroides*). All are listed as Category I invasive plants except for alligator weed which is classified as Category II. FLEPPC defines Category I species as “those altering native plant communities by displacing native species, changing community structures or ecological functions, or hybridizing with natives.” They define Category II species as those plants that “have increased in abundance or frequency but have not yet altered Florida plant communities to the extent shown by Category I species.”

Mace (2006a) recorded the presence and cover abundance for all the above-listed invasive plants that were found during vegetation sampling along seven transects (Appendix A) in the wetland communities bordering Lake Monroe. Mace used a variant of the Daubenmire Cover Scale (1968) to estimate the percent cover for all plant species that occurred along the seven transects. Taro occurred along Transects 1 and 2 and was recorded as rare (less than 1 percent cover) in Transect 1 and scattered to numerous (1 to 25 percent cover) along Transect 2. Water hyacinth was described as abundant (26 to 50 percent cover) at the beginning of Transect 3 and abundant in a deep marsh along Transect 4. Water lettuce occurred as scattered (1 to 10 percent cover) in a deep marsh along Transect 4 and in a deep marsh along Transect 7. Camphor tree was described as scattered (1 to 10 percent cover) in an oak hammock along Transect 5. Chinese tallow tree was observed in a wet prairie along Transect 7 and its abundance described as scattered (1 to 10 percent cover). Alligator weed was described as numerous to abundant (11 to 50 percent cover) in a deep marsh along Transect 4.

ECT ecologists observed hydrilla, water hyacinth and water lettuce during the May 2006 survey of the littoral zones. Hydrilla is most abundant in the littoral vegetation on the north side of Lake Monroe growing amongst *Vallisneria* and *Ceratophyllum*. Hydrilla has been called the “perfect weed” because of the extensive adaptive attributes it possesses (Langeland, 1996). Water hyacinth and water lettuce occurred sporadically as small floating colonies on the lake, most commonly seen on the western side of the lake and in the river where flow exits the lake. These aquatic nuisance plants would likely be dominant in the lake if not for periodic maintenance by the USACE via spot chemical spraying. It is believed that the abundance of hydrilla in the littoral zone along the north shore is due to avoidance of chemical spraying in this area to protect *Vallisneria* beds.

Hydrilla, water hyacinth, and water lettuce are open-water species whose spread is controlled only by an active maintenance program using herbicides.

Chinese tallow tree tolerates a wide range of soil and hydrological conditions, even continuous freshwater flooding, and is tolerant of drought and fire (Barrilleaux and Grace, 2000; Jones and Sharitz, 1990; Bogler, undated; Conner, 1994). According to Bogler (undated), once established, Chinese tallow tree can only be controlled by continual maintenance including manual and mechanical control or basal bark application of herbicide (the most effective method). Camphor tree occurs in drier disturbed sites such as roadsides but has invaded natural areas such as mesic hammocks, upland pine woods and scrubland (Langeland and Burks, 1998). Taro can form dense stands along lakes and rivers outcompeting native plants and is a particular problem along the St. Johns River and its tributaries (Langeland and Burks, 1998). Taro is capable of growing in a wide range of dry to wet sites (de la Pena, 1983). Taro was not seen growing on the shore or in the littoral zones in Lake Monroe during the May 2006 survey and has likely been controlled by the USACE maintenance program. Mace (2006a) found taro in hydric hammock and hardwood swamp communities inland from the lake where taro would not be controlled as populations at the lake's edge seem to be. Alligator weed was also not seen on the lake's shoreline but was recorded by Mace as an abundant plant in a deep marsh adjacent to the St. Johns River historic channel. Alligator weed is a fast-growing pest plant that can grow in transitional areas tending toward upland, but is most common in wetlands and shorelines of lakes and rivers. In Florida, there has been success in the control of alligator weed by the flea beetle (Buckingham, 1996), which may explain the absence of large populations of alligator weed at the edges of the lake.

In summary, water hyacinth, hydrilla, and water lettuce populations in Lake Monroe are controlled only through continual maintenance by spot spraying of herbicides. Taro and alligator weed seem to be controlled by periodic maintenance in the lake but are locally abundant in some wetlands associated with Lake Monroe. Camphor tree is restricted in oak hammocks occurring on elevated areas within wetlands. Chinese tallow tree has invaded a wet prairie along Transect 7 near I-4 on the west side of the study area but does not appear to be invading relatively undisturbed wetland communities remaining along the shore of Lake Monroe. The presence of Chinese tallow trees near I-4 may be due to extensive disturbance to the wetlands on the western shore of Lake Monroe caused by construction of the interstate highway.

Little information is available to link invasive plant species to changes in water levels. However, other discussions in this document, such as the effects on the woody debris habitat, has shown that changes to frequency of inundation along the shores of Lake Monroe due to water withdrawal as limited by the recommended MFLs would be minor (Table 5-6).

It has been suggested that invasive species gain a foothold as a result of disturbance to natural habitats (Myers and Ewel, 1990). However, the recommended MFLs by Mace (2006a) were designed to protect native plant communities adjacent to Lake Monroe as they presently exist. All remnant native habitats have been subjected to disturbance of varying degrees due to alterations to hydrology and vegetation caused by past disturbances including highway construction; filling of wetlands for development, especially on the southern shore of the lake; clearing of uplands for agriculture or residential use; and channeling of natural drainages. These disturbances have allowed plant species considered to be undesirable to gain a foothold in many of the wetland associations adjacent to the lake (Mace, 2006a).

It is concluded that the recommended MFLs hydrologic conditions for Lake Monroe will not result in an increase in populations of invasive plants because these species are tolerant to a wide range of hydrologic conditions (dry to flooded) and the USACE conducts routine maintenance control programs within the lake and along the shoreline. Any changes in water depth in the littoral zones and wetlands under the recommended MFLs hydrologic conditions for Lake Monroe would not be substantial enough to create widespread conditions favorable to large increases in the area affected by invasive exotic plants due to reasons explained in the preceding paragraphs.

5.3.4 PASSAGE OF FISH

Two aspects of fish passage were evaluated: the ability of large fish to pass through Lake Monroe and the ability of small forage fish to move onto the floodplains during high water periods.

Shortnose sturgeon (*Acipenser brevirostrum*) is the largest fish that may be found within Lake Monroe. The maximum length of this fish is approximately 4.7 ft with a body depth of about 7 inches. The bottom elevation of the navigation channel in Lake Monroe ranges from -4 to –12 ft-NGVD (Section 5.2.3). A minimum stage of –3.0 ft-NVGD was selected as a conservative threshold to allow free passage of shortnose sturgeon. Lake Monroe water levels would never fall below the threshold stage of –3.0 ft-NGVD under either the existing or the recommended MFLs hydrologic conditions (Table 5-7). Therefore, the recommended MFLs will protect fish passage in Lake Monroe.

Table 5-7. Frequency Analysis of Threshold Stage for Fish Passage in Lake Monroe

Threshold Stage (ft-NVGD)	Duration (Days)	No. of Years in a Century Threshold Stage is Continuously Not Exceeded*		
		Existing	MFLs	Difference
-3.0	365	0	0	0

* Water levels fall below the threshold stage for the indicated duration.

Source: ECT, 2006.

Fishes, especially small forage fishes, move onto the floodplain during periods of high water. Mosquitofish are representative of several species that do not require access to the floodplain for their own survival, but whose population fluctuations in response to flooding patterns provide an important source of food for many wading birds and other animals. Juvenile mosquitofish and mollies have been observed to occupy the shoreline areas of streams and ponds in water only a few millimeters (mm) deep. These species exhibit a positive rheotaxis and will force their way upstream against any trickle of water entering their pond or stream (L.J. Swanson unpublished data). In this way, they colonize floodplains at the very beginning of the rainy season. Since these live-bearing fishes grow and mature rapidly and spawn at approximately 30-day intervals, population growth during the wet season can be substantial. During the dry season, subsiding water levels concentrate the expanded population into shallow, isolated pools and ditches. Wading birds, including the endangered wood stork, rely on these concentrations of fish to supply sufficient food to produce eggs and to feed their young through fledging (Bancroft *et al.*, 1990; Kushlan, 1990). Wading birds need shallow water to forage efficiently. Great egrets, for instance, need water less than 0.83 ft (10 inches) deep, while smaller herons need water less than 0.5 ft (6 inches) deep (Bancroft *et al*., 1990). Low water levels during the rainy season may not allow sufficient expansion of fish populations, while high water levels during the dry season will not concentrate the fish populations into shallow pools. Either situation may result in adverse conditions for the birds to nest or to raise their young to fledging.

Mosquitofish are abundant in shallow water, including the shallow marsh portions of the floodplain. They are representative of small forage fish that occupy the floodplain. Adult female mosquitofish reach a length of about 3 inches (males are smaller) and a maximum body depth of nearly 1 inch. According to the transect data collected by Mace (2006a), the average elevation of shallow marshes at Lake Monroe was computed to be 1.2 ft-NVGD. Allowing an average water depth of 0.1 ft (1.4 inches) of water over the shallow marsh habitat results in a threshold value of 1.3 ft-NVGD for passage of mosquitofish onto the floodplain. A duration of 30 days at this stage would allow one reproduction cycle on the floodplain (Breder and Rosen, 1966).

The results of frequency analysis indicate that, under existing conditions, the threshold stage of 1.3 ft-NGVD would be continuously exceeded for 30 days 95 times in 100 years (Table 5-8). Under the recommended MFLs hydrologic conditions, the threshold stage would be continuously exceeded for 30 days 92 times in a century; a decrease of 3 flooding events per 100 years when compared to existing hydrologic conditions. Similar results were observed for the 60-, 90-, and 120-day durations analyses. A comparison of the existing and recommended MFLs hydrologic conditions indicates that the number of times the threshold stage of 1.3 ft-NGVD would be continuously exceeded for a duration of 60, 90, and 120 days would decrease by 2, 5, and 5 times per century, respectively, under the recommended MFLs hydrologic conditions (Table 5-8).

Table 5-8. Frequency Analysis of Threshold Stage for Wildlife Habitat and Fish Passage onto the Floodplain

Threshold Stage (ft-NVGD)	Duration (Days)	No. of Years in a Century Threshold Stage is Continuously Exceeded*		
		Existing	MFLs	Difference
1.3	30	95	92	3
1.3	60	86	84	2
1.3	90	78	73	5
1.3	120	63	58	5
1.7	30	83	81	2
1.7	60	73	68	5
1.7	90	59	51	8
1.7	120	47	45	2

* Water levels rise above the threshold stage for the indicated duration.

Source: ECT, 2006.

Warmouth are abundant in quiet, weedy water, including the marsh portions of the floodplain. They are representative of larger forage fish that occupy the floodplain. Adults reach a length of about 10 in. and a maximum body depth of about 4 in.. As previously discussed, the average elevation of shallow marshes at Lake Monroe was computed to be 1.2 ft-NVGD (Mace, 2006a). Allowing an average water depth of 0.5 ft of water over the shallow marsh habitat results in a threshold stage of 1.7 ft-NVGD for passage of warmouth onto the floodplain.

The results of frequency analysis indicates that, under existing conditions, the threshold stage of 1.7 ft-NGVD would be continuously exceeded for 30 days 83 times in 100 years (Table 5-8). Under the recommended MFLs hydrologic conditions, the threshold stage would be continuously exceeded for 30 days 81 times in a century; a decrease of 2 flooding events per 100 years when compared to existing hydrologic conditions. Similar results were observed for the 60-, 90-, and 120-day durations analyses. A comparison of the existing and recommended MFLs hydrologic conditions indicates that the number of times the threshold stage of 1.7 ft-NGVD would be continuously exceeded for a duration of 60, 90, and 120 days would decrease by 5, 8, and 2 times per century, respectively, under the recommended MFLs hydrologic conditions (Table 5-8).

The recommended MFLs hydrologic conditions will not appreciably change the frequency of occurrence for conditions unfavorable to fish passage onto the floodplain. Therefore, the recommended MFLs for Lake Monroe will protect wildlife and fish passage onto the floodplain.

5.3.5 WETLAND COMMUNITIES

Mace (2006a) conducted extensive topographic, soil, and vegetation surveys in three vegetation communities adjacent to Lake Monroe—hardwood swamp, shallow marsh, and deep marsh—to determine the recommended MFLs. Frequency analyses were conducted (Table 5-9) to verify if water levels under the recommended MFLs hydrologic conditions provide protection for the wetland communities. The threshold stage and critical duration for each vegetation community corresponds to the definition of minimum levels presented in Table 1-1: 2.8 ft-NGVD water level with 30 days duration for hardwood swamp, 1.2 ft-NGVD water level with 183 days duration for shallow marsh, and 0.5 ft-NGVD water level with 120 days duration.

Table 5-9. Frequency Analysis of Threshold Stage for Wetland Communities in Lake Monroe

Threshold Stage (ft-NVGD)	Duration (Days)	No. of Years in a Century Threshold Stage is Continuously Exceeded*		
		Existing	MFLs	Difference
2.8	30	59	58	1
Threshold Stage (ft-NVGD)	**Duration (Days)**	**No. of Years in a Century Threshold Stage is Continuously Not Exceeded†**		
		Existing	MFLs	Difference
1.2	183	28	35	7
0.5	120	10	20	10

* Water levels rise above threshold stage for the indicated duration.
† Water levels fall below threshold stages for the indicated duration.

Source: ECT, 2006.

The results of the frequency analysis (Table 5-9) show that the threshold stage (2.8 ft-NGVD) for hardwood swamp protection under existing conditions would be continuously exceeded for 30 days 59 times in 100 years. Under the recommended MFLs hydrologic conditions, the threshold stage would be continuously exceeded for 30 days 58 times in a century; a decrease of 1 flooding event per 100 years when compared to existing hydrologic conditions.

Similar frequency analyses were conducted to determine the increases in the number of times the threshold stages for shallow marsh (1.2 ft-NGVD) and deep marsh (0.5 ft-NGVD) would be continuously not exceeded for the assigned durations. Results indicate that the threshold stage of 1.2 ft-NGVD for shallow marsh would be continuously not exceeded for a duration of 183 days 7 more times per century under the recommended MFLs hydrologic conditions, as compared to the existing hydrologic conditions (Table 5-9). Similarly, the threshold stage of 0.5 ft-NGVD for deep marsh would be continuously not exceeded for a duration of 120 days 10 more times per century under the recommended MFLs hydrologic conditions, as compared to the existing hydrologic conditions (Table 5-9).

In ECT's opinion, the recommended MFLs hydrologic conditions will protect wetland communities in Lake Monroe because the frequency of the high and low water level threshold events associated with the mean elevations of hardwood swamps, shallow marshes, and deep marshes (i.e., 2.8, 1.2, and 0.5 ft-NGVD, respectively), would not be appreciably or unreasonably altered.

5.3.6 SUMMARY

The results of frequency analysis showed that water withdrawals under the recommended MFLs for Lake Monroe would not unreasonably nor unacceptably change the frequency of the threshold stages with critical durations required: (1) to protect littoral zone vegetation and emergent floodplain wetlands; exposed roots and woody debris habitat; in-lake and floodplain fish passage; and (2) to prevent expansion of invasive nuisance and exotic vegetation. Based upon the findings of the WRV assessment, it is concluded that the recommended MFLs hydrologic conditions for Lake Monroe will protect fish and wildlife habitat and fish passage.

5.4 WRV-3: ESTUARINE RESOURCES

5.4.1 INTRODUCTION

An estuary is a dynamic ecoregion where saltwater from the ocean meets the freshwater from the watershed. The mixing/transport of the estuarine water is driven by the forces of tides, freshwater flows, and meteorologic phenomena. It is also affected by density stratification in the estuary. The LSJR receives approximately 60 percent of its total freshwater flow from sources upstream of Buffalo Bluff, including the Upper and Middle St. Johns River basins and the Lake George basin (Morris, 1995). Therefore, the salinity distribution in the LSJR may be influenced by the freshwater inflow from the Lake George and MSJR basins.

The estuarine resources such as fish and wildlife, aquatic vegetation, and water quality are affected by instream salinity concentrations, which are dependent on freshwater inflows. As described in Section 4.3, SJRWMD currently assumes maximum withdrawal limits of 180 and 240 cfs from Lake Monroe and the SJRND, respectively. The cumulative maximum withdrawal of 240 cfs from the SJRND includes the maximum withdrawal of 180 cfs from Lake Monroe. Because the salinity and estuarine resources are dependent on the total freshwater inflow, a maximum withdrawal limit of 240 cfs from the SJRND, the cumulative reduction of the LSJR flows, was considered when assessing estuarine resources protection. The LSJR is defined as the 101-mile river segment of the St. Johns River from its confluence with the Ocklawaha River to its mouth at the Atlantic Ocean. Prominent features in the LSJR and river mile designations are presented in Figures 5-4 through 5-6.

5.4.2 METHODOLOGY

Dr. Peter Suscy of SJRWMD simulated the salinity conditions within the LSJR basin under various reductions in freshwater inflow regimes with the three-dimensional EFDC model developed by Dr. John Hamrick (Hamrick, 1992a; 1992b). To isolate the effects of the freshwater flow regimes alone, the model simulations for the various flow scenarios

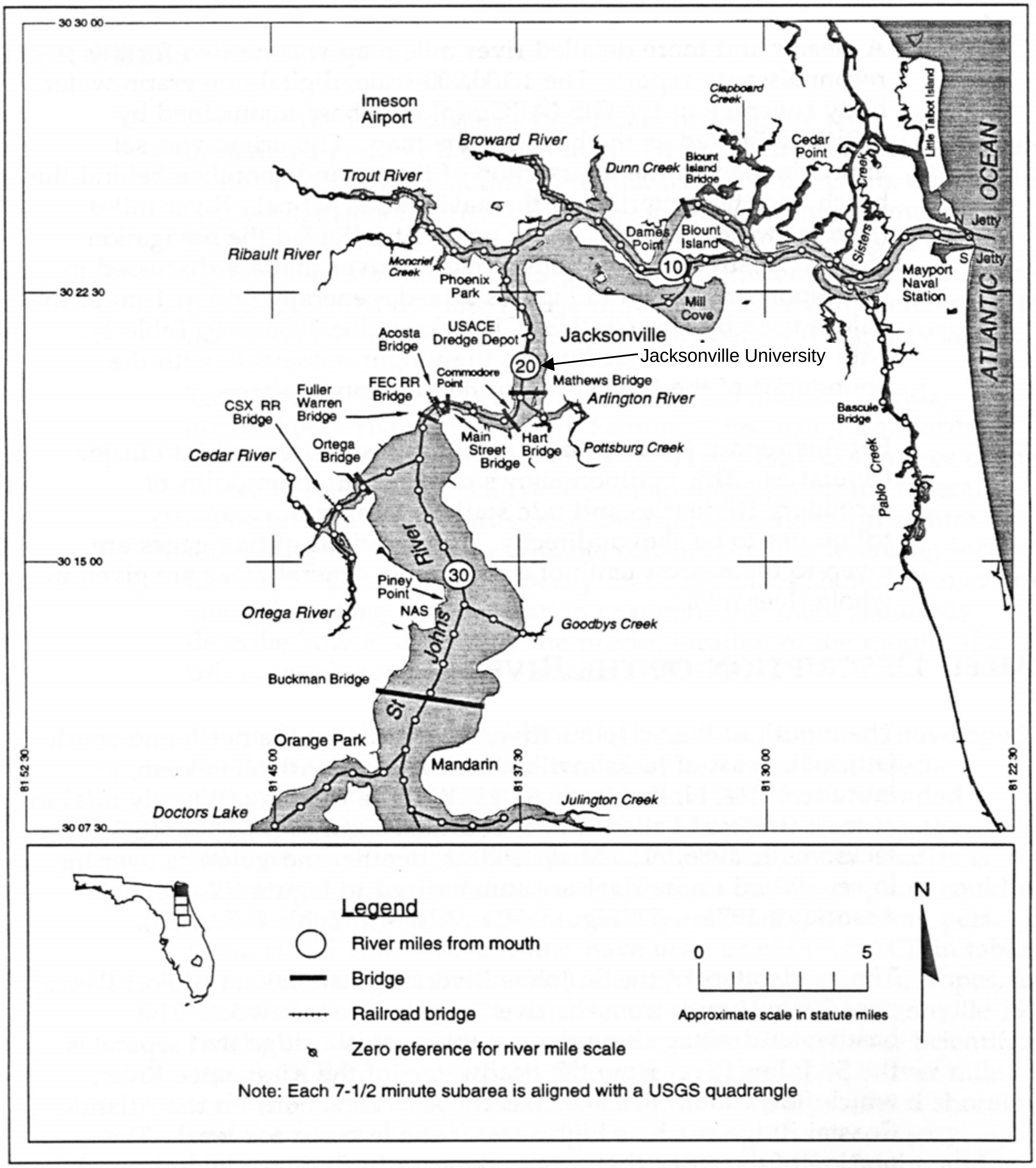

FIGURE 5-4.
LOCATION MAP, BY RIVER MILE, FOR SIGNIFICANT LOCATIONS ON THE ST. JOHNS RIVER BETWEEN THE RIVER MOUTH AND JULINGTON CREEK

Source: Morris, 1995.

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Environmental Consulting & Technology, Inc.

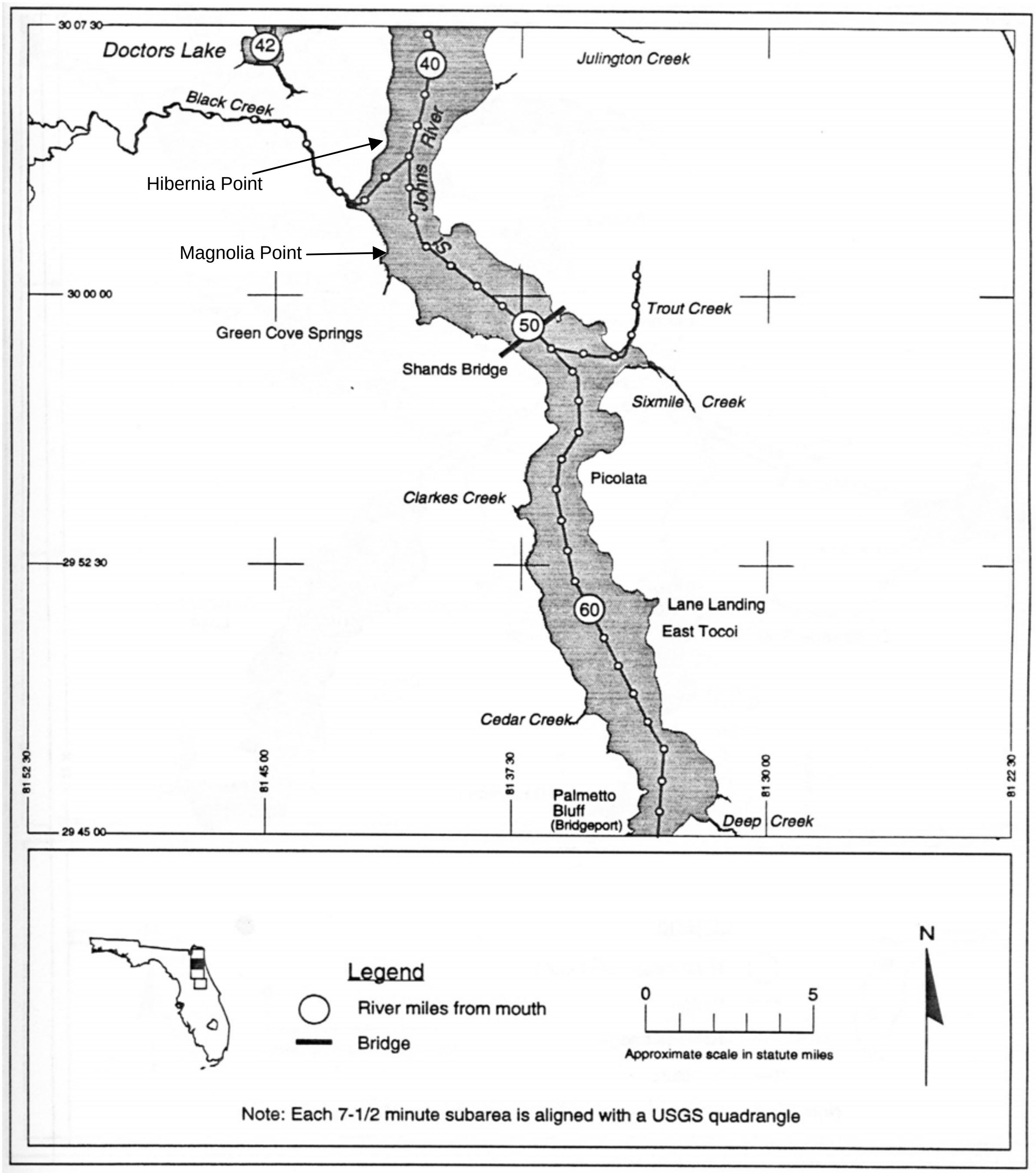

FIGURE 5-5.
LOCATION MAP, BY RIVER MILE, FOR SIGNIFICANT LOCATIONS ON THE ST. JOHNS RIVER BETWEEN JULINGTON CREEK AND DEEP CREEK

Source: Morris, 1995.

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Environmental Consulting & Technology, Inc.

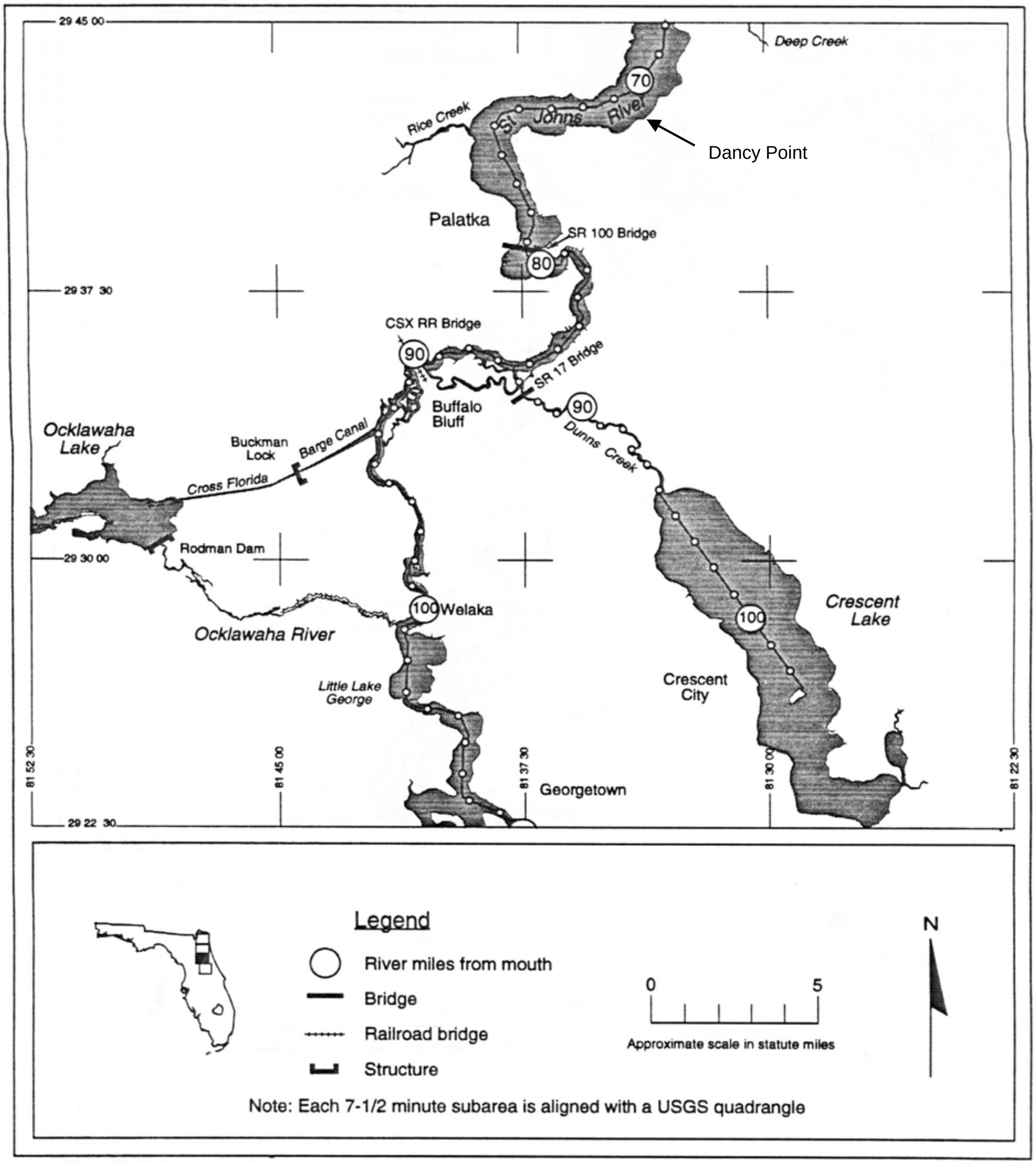

FIGURE 5-6.
LOCATION MAP, BY RIVER MILE, FOR SIGNIFICANT LOCATIONS ON THE ST. JOHNS RIVER BETWEEN A LOCATION NORTH OF RICE CREEK AND GEORGETOWN

Source: Morris, 1995.

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used the same tidal and meteorological conditions, while only freshwater inflow rates were varied. ECT quantified the change in salinity regimes by comparing the daily maximum, daily average, and daily minimum salinities; the isohaline shifts; and the cumulative frequency of average daily salinity among four different freshwater inflow conditions for various locations along the river.

SJRWMD has previously applied the EFDC model in the LSJR basin for the purpose of establishing total maximum daily load (TMDL) of nutrients and other pollutants in the watershed. The model was calibrated by SJRWMD (Sucsy and Morris, 2002) with tide and salinity data collected in the river. The model grid configuration is shown in Figure 5-7.

ECT evaluated a total of four freshwater-flow scenarios using the EFDC model results as part of the salinity assessment in the LSJR:

- Baseline (existing) freshwater flow conditions.
- Maximum withdrawal limit of 240 cfs from the SJRND (as limited by the MFLs adopted at SR 44).
- Withdrawal limit of 120 cfs from the SJRND (50 percent less than the maximum withdrawal rate defined by the MFLs adopted at SR 44).
- Withdrawal limit of 360 cfs from the SJRND (50 percent more than the maximum withdrawal rate defined by the MFLs adopted at SR 44).

The average daily flow at the SJRND was 3,041 cfs; therefore, the maximum withdrawal rate of 240 cfs from the SJRND will limit the freshwater withdrawal to 7.9 percent of the historic average flow at DeLand.

The function of the estuarine resources WRV is the productivity of coastal systems and their associated natural resources that depend on the habitat where oceanic saltwater meets freshwater.

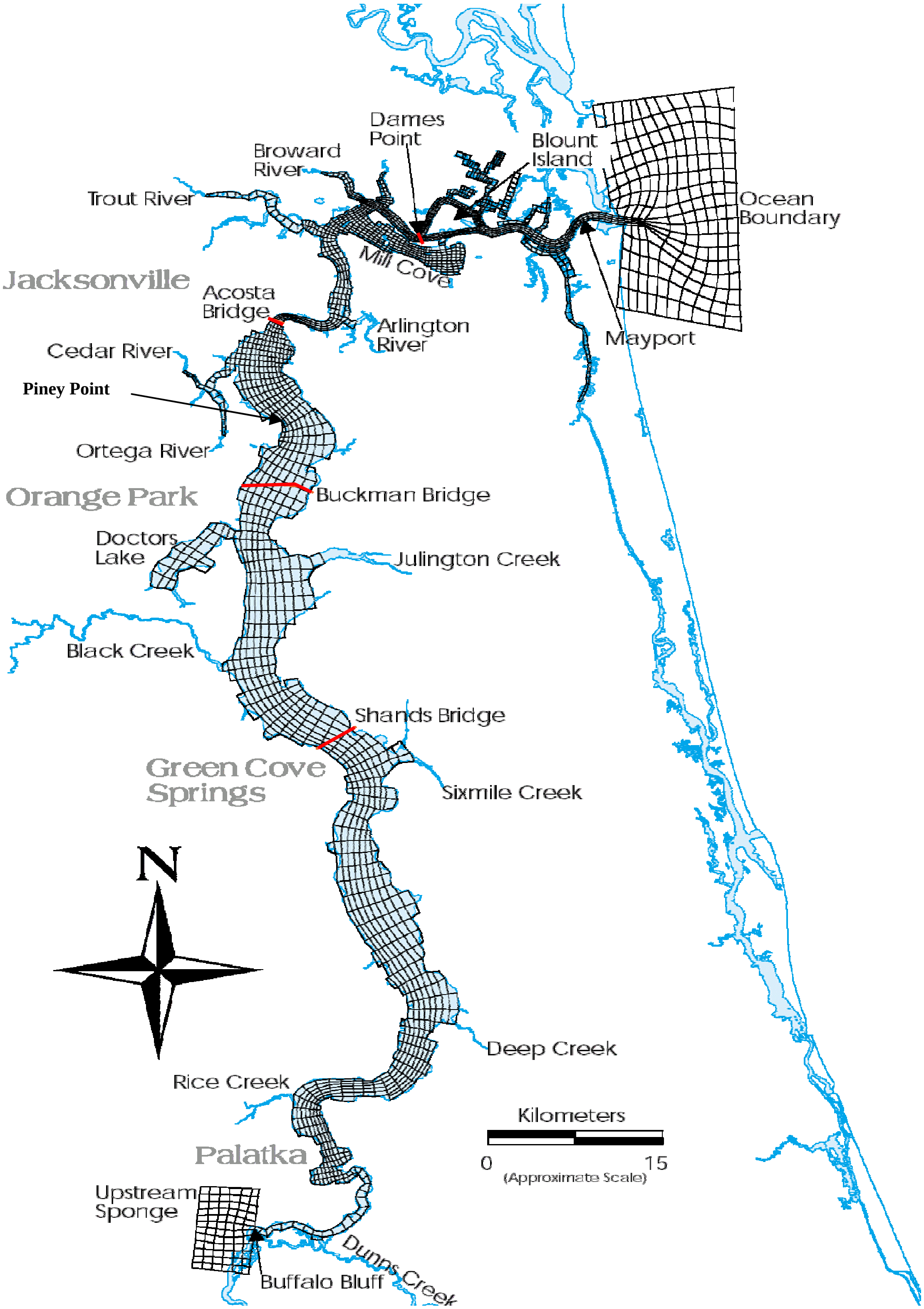

FIGURE 5-7.

BOUNDARY-FITTED MODEL GRID OF THE LOWER ST. JOHNS RIVER

Source: SJRWMD, 2002.

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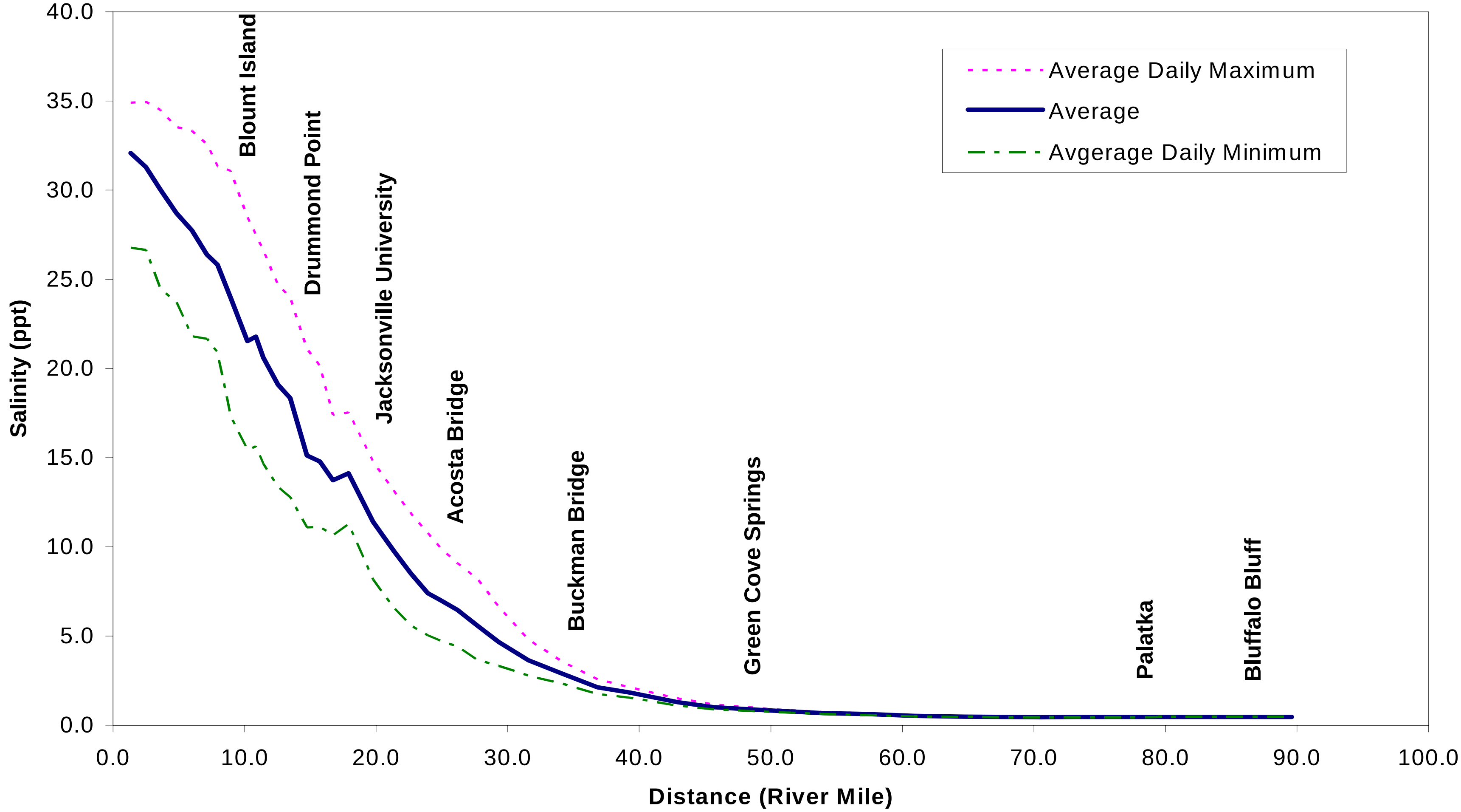
The general indicators of WRV-3 protection are to maintain salinity regime in the estuary and to protect coastal systems and their associated natural resources. Specific indicators of protection are the shift of salinity isohalines by water withdrawal; the *Vallisneria americana* response to salinity regime changes; of selected aquatic species response to salinity regime changes; and changes in the absolute daily maximum, daily mean, and absolute daily minimum salinities.

5.4.3 BASELINE SALINITY CHARACTERIZATION

Maximum, average, and minimum salinities for each day within the 5-year simulation period (1995 through 1999) were computed at 60 time-series output locations throughout the LSJR system. Averages of the daily maximum, daily average, and daily minimum salinities for the 5-year simulation period were computed and are presented in Figure 5-8. The results indicate that the average salinity near the river mouth is about 32.1 parts per thousand (ppt), and is reduced to 15.1 ppt at Drummond Point (RM 14.3), 11.4 ppt at the Jacksonville University (JU) (RM 19.2), 7.5 ppt at the Acosta Bridge (RM 23.7), 2.7 ppt at the Buckman Bridge (RM 33.9), and 0.9 ppt at Green Cove Springs (RM 47.9). The daily salinity fluctuations were computed at each location by taking the difference between daily maximum and daily minimum salinity. The 5-year average of the daily salinity fluctuations was then computed for each location. Figure 5-9 shows the averages of daily salinity fluctuations at various locations along the main stem of the river. The results show that the average daily salinity fluctuation is about 8.1 ppt near the river entrance, and the greatest salinity fluctuation occurs near Blount Island (RM 8.8) with an average daily fluctuation range of 13.8 ppt. Further upstream from this point, the diminishing salt exchange with the ocean gradually reduces salinity fluctuation to 6.6 ppt at JU (RM 19.2), 5.8 ppt at Acosta Bridge (RM 23.7), 2.0 ppt at Piney Point (RM 30.8), and 1.1 ppt at Buckman Bridge (RM 33.9).

5.4.4 SALINITY INCREASE DUE TO FRESHWATER FLOW REDUCTION

Similar to the baseline case, the 5-year average salinity was computed at various locations along the river for each surface water withdrawal scenario and was compared to the baseline case. Figure 5-10 presents the longitudinal profiles of the 5-year average



Note: All salinity values are vertically averaged.

FIGURE 5-8.

MODEL-SIMULATED LONGITUDINAL SALINITY PROFILES IN THE ST. JOHNS RIVER—BASELINE CONDITIONS (1995-1999)

Source: ECT, 2004.

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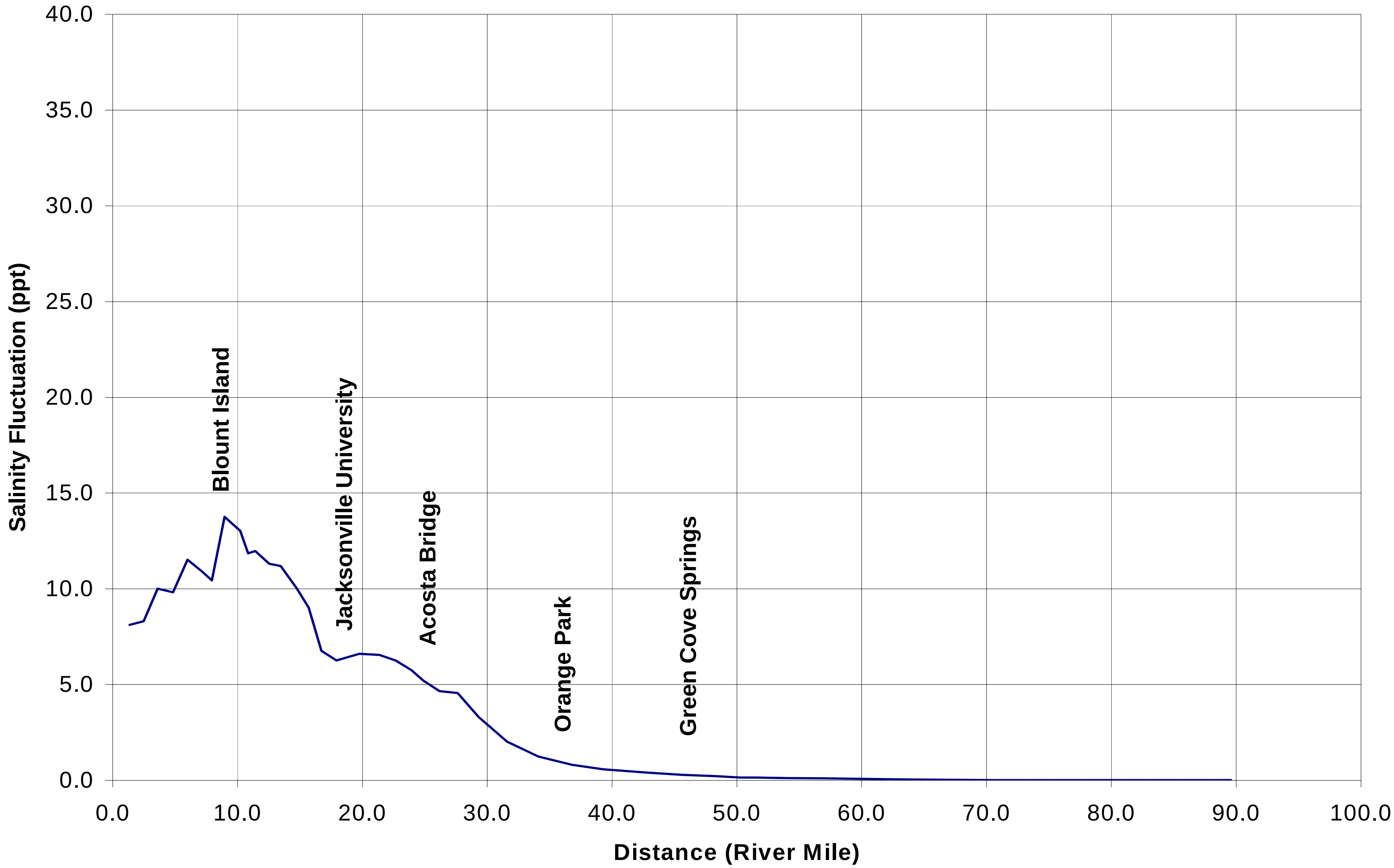

FIGURE 5-9.

AVERAGE DAILY FLUCTUATIONS OF SALINITY IN THE ST. JOHNS RIVER (1995-1999)

Source: ECT, 2004.

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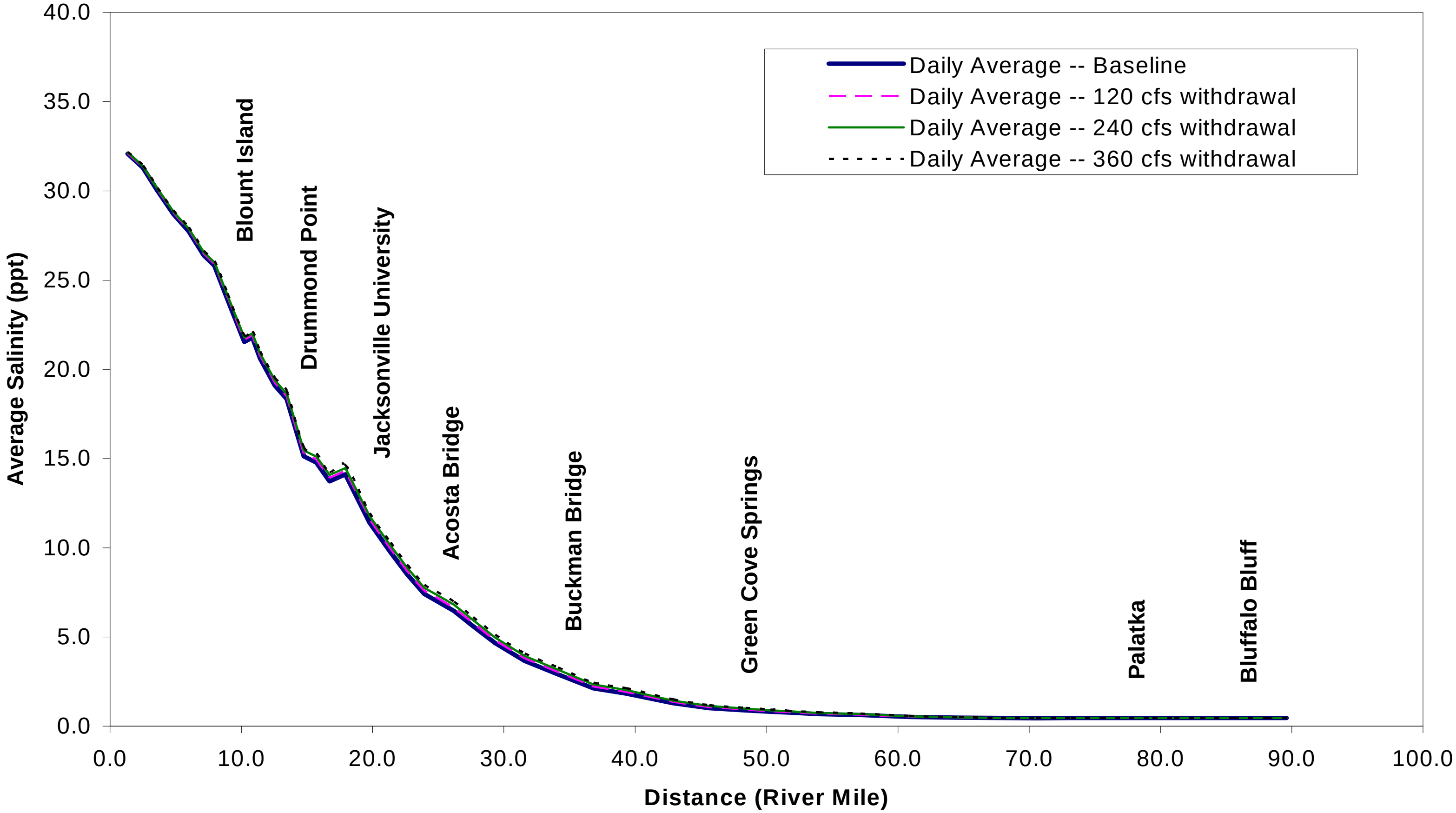

Note: All salinity values are vertically averaged.

FIGURE 5-10.

MODEL SIMULATED LONGITUDINAL AVERAGE SALINITY PROFILES (1995-1999)

Source: ECT, 2004.

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simulated salinity for the baseline and 120-, 240-, and 360-cfs withdrawal scenarios (from the SJRND). The results show that the average salinity increase at any location caused by the withdrawal scenarios will not be large (less than 0.4 ppt increase for a 240-cfs withdrawal limit from the SJRND). Figure 5-11 presents the 5-year average salinity increase along the river for each withdrawal scenario. The results indicate that the greatest average salinity increase occurs near JU. The 5-year average increases of salinity at JU are 0.18, 0.36, and 0.55 ppt for the withdrawal limits of 120, 240, and 360 cfs, respectively, from the SJRND. The 5-year average salinity increases at the Buckman Bridge are 0.12, 0.25, and 0.38 ppt for 120-, 240-, and 360-cfs withdrawal limits, respectively, from the SJRND. There will be less than 0.01 ppt change in average salinity in the river upstream from the Federal Point (RM 67.1) at the various withdrawal rates from the SJRND.

The salinity distribution in an estuary is influenced primarily by the freshwater inflows from upstream and tributaries and by the ocean saltwater transported upstream by tidal currents. At one extreme, the salinity near the mouth of the river is dominated by the ocean background salinity and it is not likely to increase appreciably by the limited freshwater reduction. At the other extreme, the upstream end of a river is dominated by the freshwater inflow and its salinity is near zero and it is not subject to appreciable salinity increase due to moderate freshwater reduction. The river segments between these two extremes will exhibit varying degrees of salinity increases according to bathymetry, tributaries, and width of the river. The model projection shows a maximum salinity increase near JU due to flow reduction ranging from 120 to 360 cfs (Figure 5-11). The location of maximum salinity increase could be an indication that the relative influences from the ocean and freshwater inflow may reach a balance in this stretch of the river near JU.

Figure 5-12 presents the average salinity increase resulting from a maximum withdrawal limit of 240 cfs from the SJRND which includes a maximum withdrawal of 180 cfs from Lake Monroe, compared with the average salinity in the river and the naturally occurring daily salinity fluctuations. The figure shows that the average salinity increase resulting from a maximum withdrawal rate of 240 cfs from the SJRND is quite small compared to

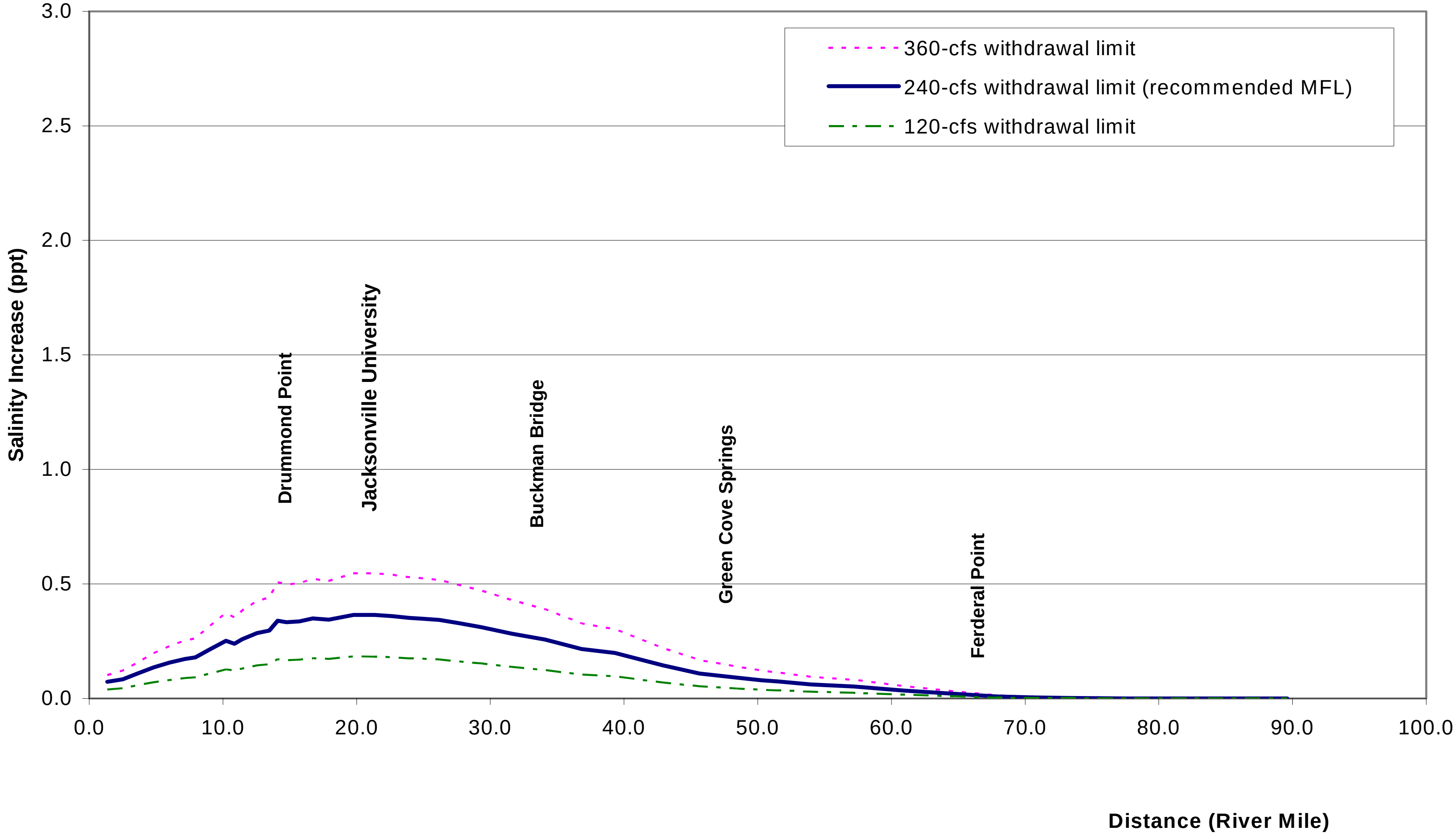

FIGURE 5-11.

AVERAGE SALINITY INCREASE DUE TO FRESHWATER WITHDRAWAL FROM THE SJRND (1995-1999)

Source: ECT, 2004.

Environmental Consulting & Technology, Inc.

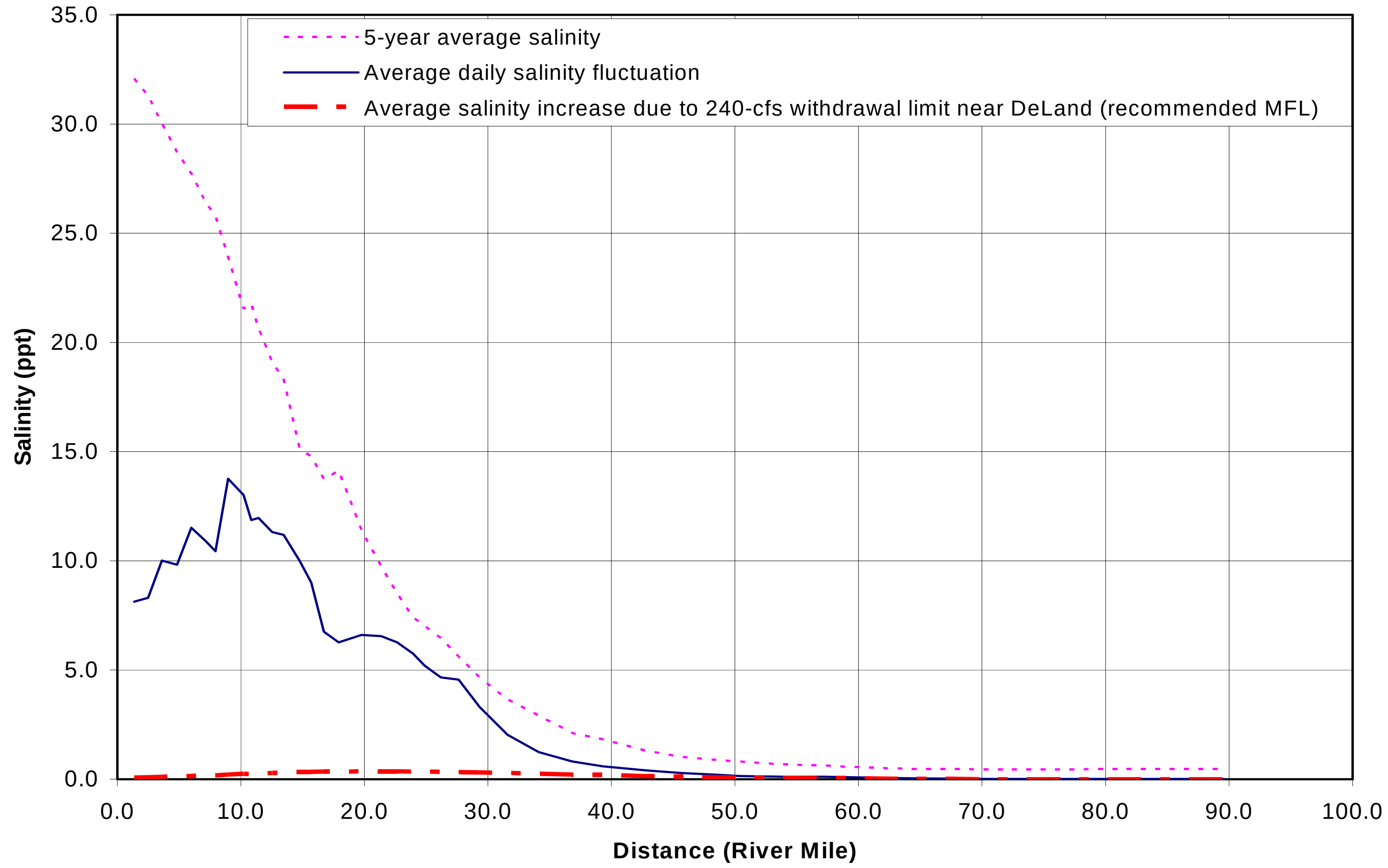

FIGURE 5-12.

AVERAGE SALINITY CHANGES RELATIVE TO DAILY FLUCTUATIONS IN THE ST. JOHNS RIVER (1995-1999)

Source: ECT, 2004.

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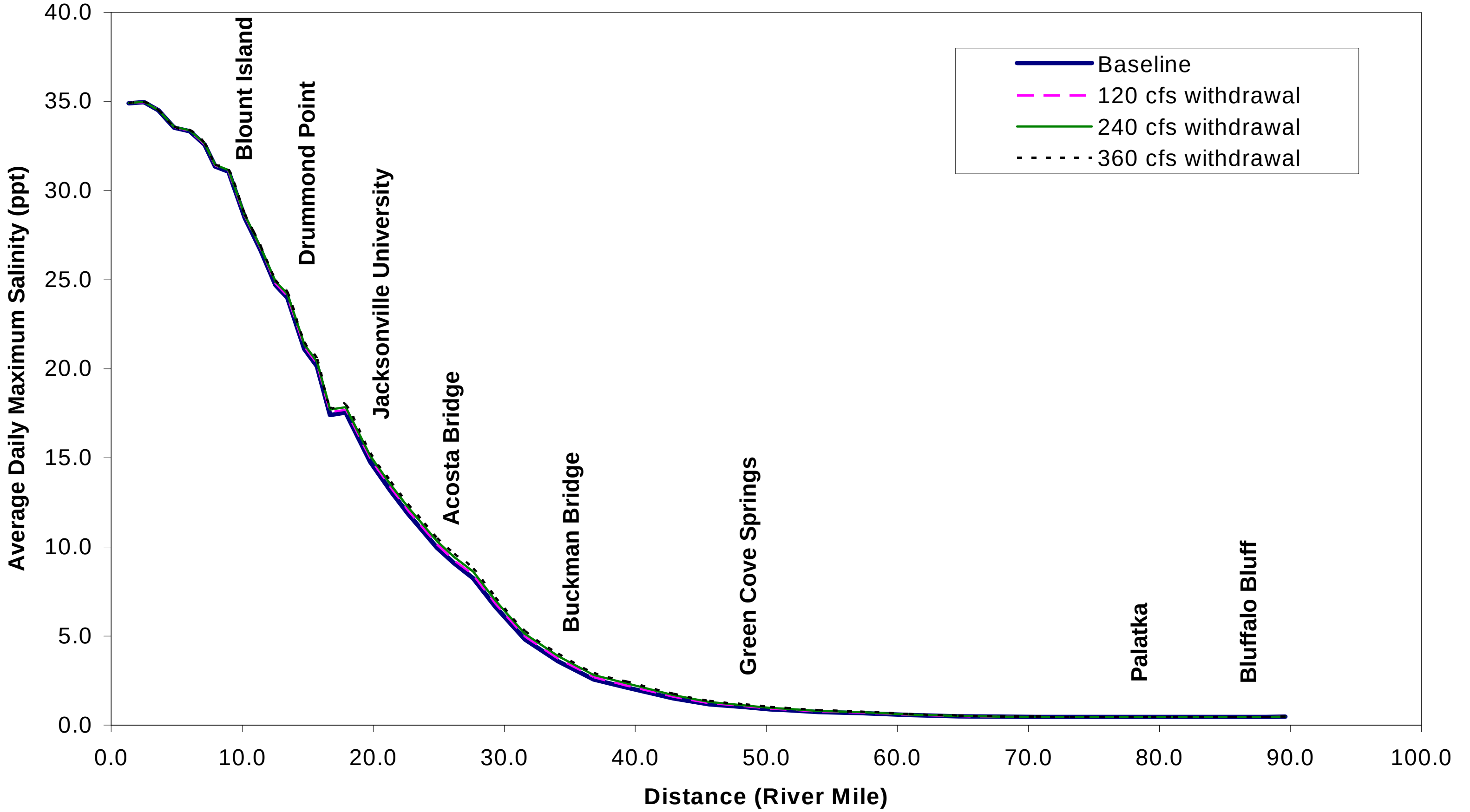
the daily variability of the salinity caused by the tidal transport. For example, the average salinity increase at JU (RM 19.2) is 0.36 ppt, while the average salinity is 11.4 ppt and the average daily salinity fluctuation is 6.6 ppt.

In addition to daily tidal variation in salinity, the salinity in the LSJRB is subject to large seasonal changes according to historic data collected by USGS. For example, the mid-depth salinity variation in the spring of 1999 was 29.1 ppt (according to the salinity data collected by USGS, presented in ECT, 2002b) at the Acosta Bridge (RM 23.7) where the projected 5-year average of the daily salinity variation is 5.8 ppt (Figure 5-9); the projected average salinity increase due to a maximum withdrawal rate of 240 cfs from the SJRND is only 0.35 ppt (Figure 5-11). Similarly, a mid-depth salinity variation of 26.8 ppt was observed in the spring of 1999 at the Buckman Bridge (RM 33.9) (ECT, 2002b) where the projected 5-year average of the daily salinity variation is 1.15 ppt (Figure 5-9); the average salinity increase due to a maximum withdrawal rate of 240 cfs from the SJRND is 0.25 ppt (Figure 5-11). A mid-depth salinity variation of 9.0 ppt was observed in the summer of 1999 at the Shands Bridge (RM 49.9) (ECT, 2002b) where the projected 5-year average of the daily salinity variation is 0.15 ppt (Figure 5-8); the salinity increase due to a maximum withdrawal rate of 240 cfs from the SJRND is only 0.08 ppt (Figure 5-11).

Similarly, Figure 5-13 presents the longitudinal profiles of the 5-year average of the daily maximum salinity for various flow scenarios. Figure 5-14 presents the 5-year average of the daily minimum salinities. The results also indicate that the changes of the daily maximum and minimum salinities will be relatively small at the given withdrawal scenarios. The greatest change of average daily maximum salinity occurs near the Acosta Bridge. The average daily maximum salinity is increased by 0.18, 0.37, and 0.55 ppt for 120-, 240-, and 360-cfs withdrawal limits, respectively, from the SJRND. The largest change of average daily minimum salinity occurs near Drummond Point. The average daily minimum salinity increased by 0.19, 0.37, and 0.56 ppt for 120-, 240-, and 360-cfs withdrawal limits, respectively, from the SJRND.



Note: All salinity values are vertically averaged.

FIGURE 5-13.

MODEL SIMULATED LONGITUDINAL AVERAGE DAILY MAXIMUM SALINITY PROFILES (1995-1999)

Source: ECT, 2004.

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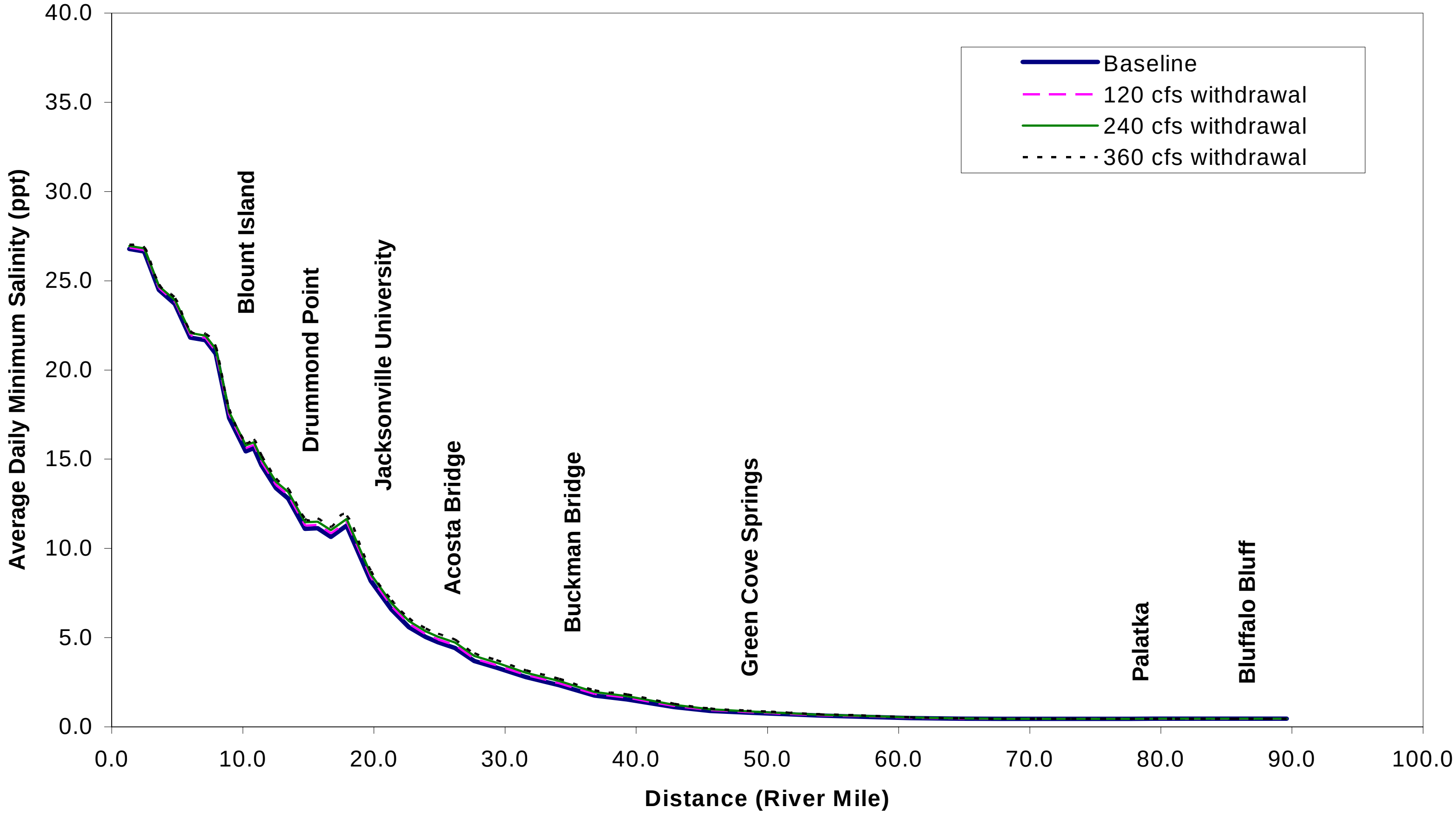
Environmental Consulting & Technology, Inc.



Note: All salinity values are vertically averaged.

FIGURE 5-14.

MODEL SIMULATED LONGITUDINAL AVERAGE DAILY MINIMUM SALINITY PROFILES (1995-1999)

Source: ECT, 2004.

Environmental Consulting & Technology, Inc.

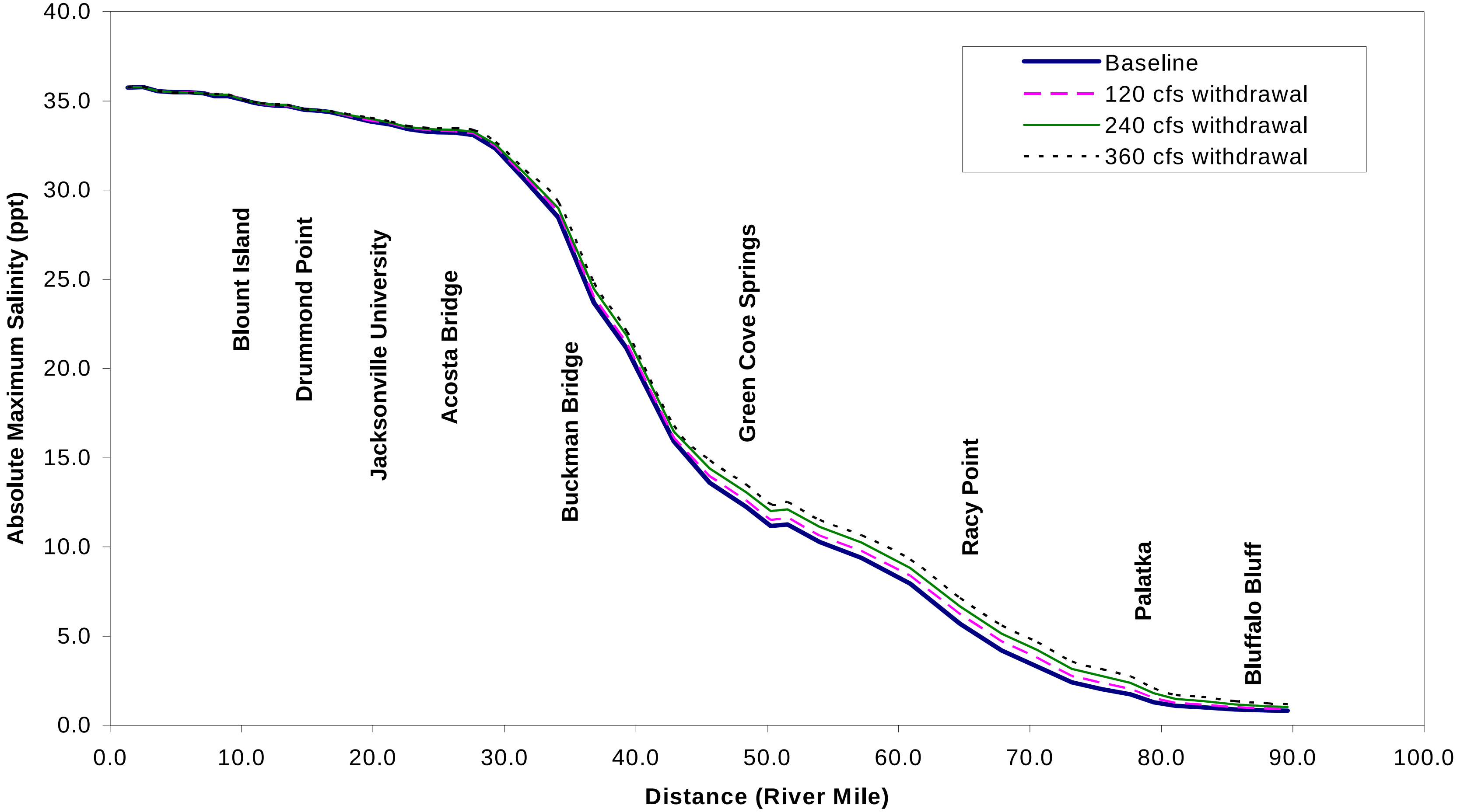
Figure 5-15 shows the longitudinal profiles of the absolute maximum salinity during the 5-year simulation period for the baseline and withdrawal scenarios. The largest change of 5-year maximum salinity due to freshwater withdrawal occurs near Racy Point (0.54, 0.97, and 1.45 ppt increase for 120-, 240-, and 360-cfs withdrawal, respectively, at SJRND). Figure 5-16 shows the longitudinal profiles of the absolute minimum salinity during the 5-year simulation period for the baseline and withdrawal scenarios. In general, freshwater withdrawal up to 360 cfs from SJRND will not cause a perceptible change in absolute minimum salinity (less than 0.01 ppt difference) except at the first 4 river miles near the St. Johns River mouth.

To quantify the change of salinity regime due to freshwater withdrawals from the SJRND which includes the maximum withdrawal from Lake Monroe, frequency analyses were conducted for the daily salinity time-series. Appendix C presents the cumulative frequency analyses results (salinity duration curves) for the daily average salinity at 15 selected locations (11 in the main river and 4 in the tributaries) for various withdrawal scenarios.

According to the salinity duration analysis, the greatest 95th percentile daily salinity increase by a 240-cfs withdrawal limit from the SJRND is 0.97 ppt, occurring near RM 39 between Orange Park and Hibernia Point. The greatest 95th percentile salinity increase by a 120-cfs withdrawal limit from the SJRND is 0.48 ppt, occurring near RM 39. The greatest 95th percentile salinity increase by a 360-cfs withdrawal limit from the SJRND is 1.42 ppt, occurring also near RM 39.

5.4.5 POTENTIAL EFFECTS OF PREDICTED SALINITY CHANGE ON AQUATIC LIFE

Salinity changes within the LSJR basin due to freshwater withdrawals may result in changes in the distribution of fishes and invertebrates. Table 5-10 lists the observed salinity ranges at which selected species have been collected. As described in Section 5.3, many of the species inhabiting the LSJR are of marine or estuarine origin. These species are euyhaline—that is they are adapted to a wide range of salinities. For these marine species, the increase in salinity may result in expansion of the upstream limits of where



Note: All salinity values are vertically averaged.

FIGURE 5-15.

MODEL SIMULATED LONGITUDINAL PROFILES OF 5-YEAR MAXIMUM SALINITY (1995-1999)

Source: ECT, 2006.

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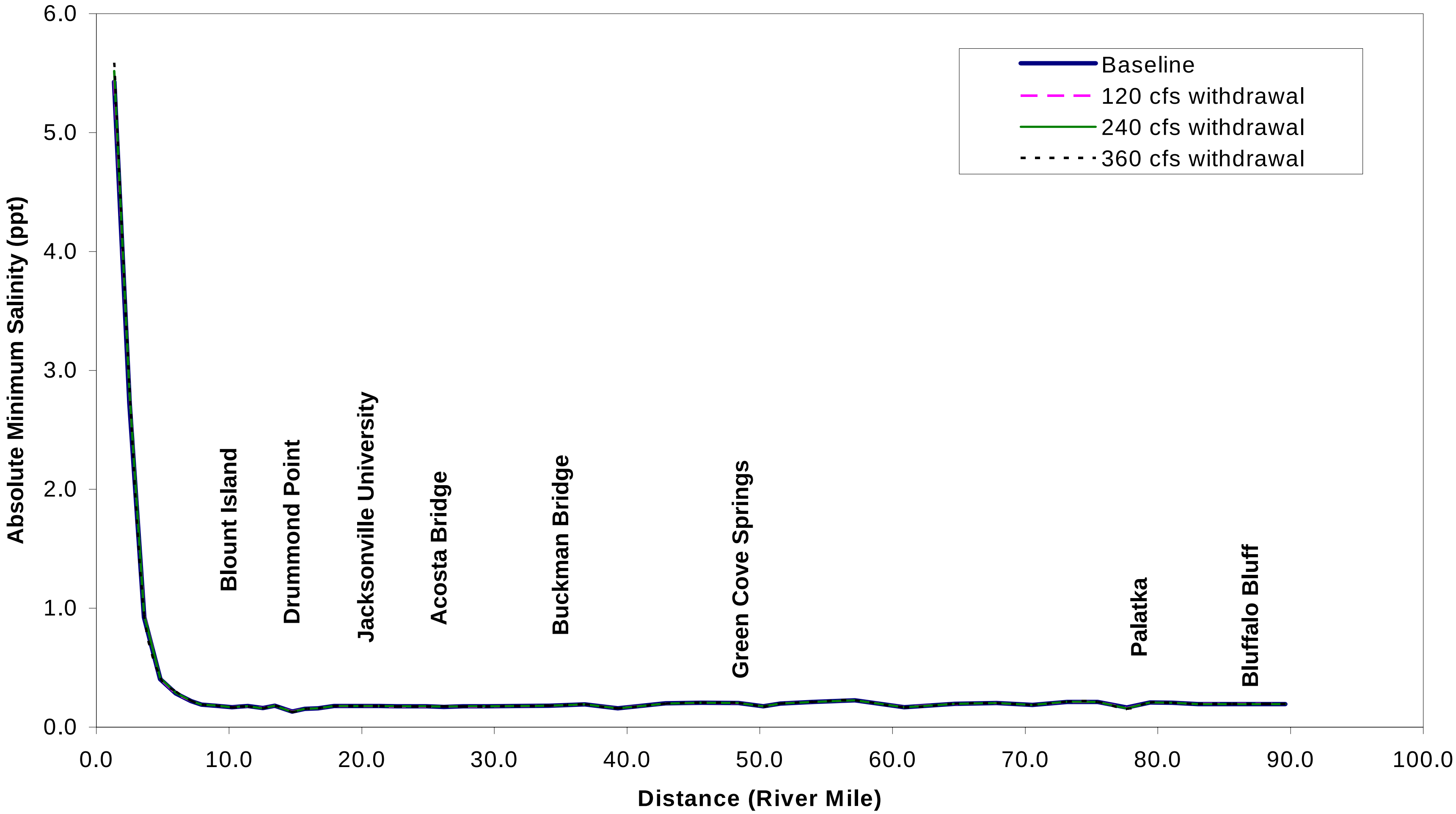
Environmental Consulting & Technology, Inc.



Note: All salinity values are vertically averaged.

FIGURE 5-16.

MODEL SIMULATED LONGITUDINAL PROFILES OF 5-YEAR MINIMUM SALINITY (1995-1999)

Source: ECT, 2006.

Environmental Consulting & Technology, Inc.

Table 5-10. Salinity Ranges for Selected Species

Scientific name	Common name	Salinity Range (ppt)	References
Dasyatis sabina	Atlantic stingray	0.09 - 41	4, 6, 8
Lepisosteus osseus	Longnose gar	1.2 - 26.9	9, 10
Lepisosteus platyrhincus	Florida gar	0 - 26.0	4, 6, 11
Elops saurus	Ladyfish	0 - 35	4, 10, 11
Megalops atlanticus	Tarpon	0 - 35	11
Anguilla rostrata	American eel	0.3 - 29.9	9, 10
Brevoortia tyrannus	Atlantic menhaden	36	1
Dorosoma cepedianum	Gizzard shad	0.0 - 24.7	10
Dorosoma petenense	Threadfin shad	0.0 - 21.7	4, 10
Anchoa mitchilli	Bay anchovy	0 - 36	1, 2, 4, 6, 9, 10, 11
Esox niger	Chain pickerel	0 - 7.5	10
Notemigonus crysoleucas	Golden shiner	1.3 - 10.7	10
Notropis maculatus	Taillight shiner	0.09 - 1.0	4
Notropis petersoni	Coastal shiner	0.12 - 0.65	4
Erimyzon sucetta	Lake chubsucker	0.6 - 14.4	10
Ameiurus catus	White catfish	0.09 - 0.26	4
Ameiurus natalis	Yellow bullhead	0 - 12	11
Ameiurus nebulosus	Brown bullhead	0.4 - 3.5	10
Ictalurus punctatus	Channel catfish	0 - 12.6	4, 10
Noturus leptacanthus	Speckled madtom	0.22	4
Bagre marinus	Gafftopsail catfish	0.17 - 35	4, 6, 9, 10, 11
Aphredoderus sayanus	Pirate perch	0.6 - 19.7	10
Strongulura marina	Atlantic needlefish	0 - 23.0	6, 10
Cyprinodon variegatus	Sheepshead minnow	0 - 31.8	4, 6, 10, 11
Fundulus chrysotus	Golden topminnow	0 - 5	4, 10, 11
Fundulus confluentus	Marsh killifish	0.0 - 20.4	4, 9, 10, 11
Fundulus seminolis	Seminole killifish	0 - 7.3	4, 11
Jordanella floridae	Flagfish	0 - 9	4, 11
Lucania goodei	Bluefin killifish	0 - 12	4, 11
Lucania parva	Rainwater killifish	0 - 28	4, 6, 10, 11
Gambusia holbrooki	Mosquitofish	0 - 30	4, 10, 11
Heterandria formosa	Least killifish	0 - 30.2	4, 11
Poecilia latipinna	Sailfin molly	0 - 33	4, 6, 10, 11
Labidesthes sicculus	Brook silverside	0.12	4
Menidia beryllina	Inland silverside	0 - 33	2, 4, 6, 10, 11
Syngnathus scovelli	Gulf pipefish	0 - 35	4, 9, 10, 11
Centropomus undecimalis	Snook	0 - 35	4, 11
Elassoma evergladei	Everglades pygmy sunfish	0 - 14.4	10, 11
Enneachanthus gloriosus	Bluespotted sunfish	0 - 3.8	4, 10
Lepomis auritus	Redbreast sunfish	0	11
Lepomis gulosus	Warmouth	0.5 - 14.4	10

Table 5-10. Salinity Ranges for Selected Species

Scientific name	Common name	Salinity Range (ppt)	References
Lepomis macrochirus	Bluegill	0 - 13.8	4, 10
Lepomis marginatus	Dollar sunfish	5	10
Lepomis microlophus	Redear sunfish	0 - 14.4	4, 10, 11
Lepomis punctatus	Spotted sunfish	0 - 17.5	10, 11
Micropterus salmoides	Largemouth bass	0 - 17.5	10, 11
Pomoxis nigromarginatus	Black crappie	0 - 2.4	10
Etheostoma olmstedi	Tessellated darter	2.23	3
Lutjanus griseus	Gray snapper	0 - 37	4, 9, 10, 11
Eucinostomus argenteus	Spotfin mojarra	0 - 35	1, 4, 6, 9, 10
Gerres cinereus	Yellowfin mojarra	12 - 35	11
Micropogonias undulatus	Atlantic croaker	0 - 29.8	2, 4, 6, 9, 10
Sciaenops ocellatus	Red drum	0.14 - 34.5	4, 6, 9, 11
Mugil cephalus	Striped mullet	0 - 39.0	1, 4, 5, 6, 9, 10, 11
Mugil curema	White mullet	11.0 - 37.5	1, 4, 5, 6, 9
Dormitator maculatus	Fat sleeper	0.1 - 3.4	10
Gobiosoma bosci	Naked goby	0 - 33.0	4, 9, 10
Microgobius gulosus	Clown goby	0.18 - 33.0	4, 6, 10, 11
Paralichthys lethostigma	Southern flounder	0 - 30.8	4, 10
Trinectes maculatus	Hogchoker	0 - 35	4, 6, 10, 11
Rhithropanopeus harrisii	Mud crab	<1 - 27.5	7
Vallisneria americana	Eel grass	0 - 7	12

1 Futch and Dwinell, 1977.
2 Gallaway and Strawn, 1974.
3 Gilbert, 1978.
4 Gunter and Hall, 1965.
5 Moore, 1974.
6 Mountain, 1972.
7 Odum, 1971.
8 Snelson and Williams, 1981.
9 Springer and Woodburn, 1960.
10 Swingle and Bland, 1974.
11 Tabb and Manning, 1962.
12 Korschgen and Green. 1988.

they can survive, although many of these species already occur throughout the river. Examples include pink shrimp, blue crab, and bay anchovy.

Pink shrimp (*Penaeus duorarum*) are found from Chesapeake Bay through the Gulf of Mexico and the West Indies to Brazil in estuaries and the oceanic littoral zone (Williams, 1965). The densest populations are off southwestern Florida and the southeastern Golfo de Campeche (Mulholland, 1984). Adults live and spawn in highly saline offshore waters (Mulholland, 1984). The larvae are planktonic and develop at sea (Mulholland, 1984) but the postlarvae seek shallow, fresher water in estuaries (Williams, 1965; Mulholland, 1984). As the young shrimp grow, they gradually move into deeper, saltier water (Williams, 1965; Copeland and Bechtel, 1974; Mulholland, 1984). As maturity approaches, they return to the sea. Any increase in salinity resulting from the potential surface water withdrawal would increase the habitat available to pink shrimp.

Blue crabs (*Callinectes sapidus*) are found in estuaries and shallow oceanic waters from Nova Scotia to Uruguay (Williams, 1965). Blue crabs spawn from spring through fall. Mating takes place in low salinity water in the estuaries, following which the females migrate downstream to areas of higher salinity where the eggs are laid and hatched (Williams, 1965). The newly hatched zoeae (larvae) are planktonic but become benthic once they reach the megalops stage (Williams, 1965). They then begin migrating up the estuary to the nursery grounds. The juvenile crabs show a strong preference for lower salinity areas (Colepand and Bechtel, 1974). Therefore, freshwater withdrawal may potentially adversely affect the blue crab habitat.

Bay anchovies (*Anchoa mitchilli*) are found in marine and estuarine waters from the Gulf of Maine to Yucatan, Mexico. While they are occasionally found off of the outer, exposed beaches, they are more frequently found in inshore, brackish waters with muddy bottoms (Fischer, 1978). Larval and juvenile anchovies move into waters of less than 10 ppt (even into freshwater) to feed and grow; maturing fish move downstream when water exceed 12 degrees Celsius (ºC) to salinities between 10 and 15 ppt for spawning (Morton, 1989). Anchovies can be found in complely fresh water to salinities as high as

8 ppt (Morton, 1989). They would not be adversely affected by increases in salinity resulting from potential water withdrawals.

The preceding three species are highly mobile and therefore have the ability to respond to changing salinity by migrating to areas of suitable salinity. The eastern oyster (*Crassostrea virginica*), on the other hand, once the larvae settle on a suitable habitat, no longer have the ability to move. Eastern oysters are found in nearshore, estuarine systems from the Gulf of St. Lawrence, through the Gulf of Mexico, to the Yucatan coast of Mexico (Cake, 1983). Oysters spawn during all but the coldest months of the year. The larvae are planktonic but by migrating vertically they are able to remain in water of suitable salinity (Cake, 1983). At metamorphosis, the larvae sink to the bottom and cement themselves to a suitable substrate (Cake, 1983). Oyster larvae can be found in a wide range of salinities between 7.5 to more than 35 ppt (Cake, 1983). Metamorphosing larvae will settle at salinities from 5 to 35 ppt, but optimal setting occurs at salinities from 18 to 22 ppt (Cake, 1983). Adult oysters can survive in salinities from 5 to 40 ppt (Cake, 1983). Oyster drills (*Urosalpinx* spp.) are predators of oysters, and can be a serious problem at salinities greater than 15 ppt (Cake, 1983). Freshwater withdrawal will not have direct, significant adverse effects on oyster habitat due to the oyster's tolerance to high salinity. However, freshwater withdrawal may create a favorable environment for oyster drills; therefore, may have indirect adverse effects on oyster habitat.

Six species of marine/estuarine origin apparently have evolved permanent freshwater populations in the St. Johns River: Atlantic stingray (*Dasyatis sabina*), Gulf pipefish (*Syngnathus scovelli*), clown goby (*Microgobius gulosus*), Atlantic needlefish (*Strongylura marina*), an isopod (*Cyathura polita*), and mud crab (*Rhithropanopeus harrisi*) (Johnson and Snelson, 1996). These species may be at the lower limit of their physiological tolerance as evidenced by the finding by Johnson and Snelson (1996) of an apparent die off of Atlantic stingrays in Lake Monroe during a period of unusually low conductivity. Any increase in salinity as a result of freshwater withdrawal would, therefore, not have adverse effects on these species.

Additionally, the primary freshwater species (for example, fishes of the families Cyprinidae, Ictaluridae, and Centrarchidae, as well as most insect larvae) are restricted to narrower ranges of salinities (stenohaline), often less than 3 to 5 ppt (although different species may be able to tolerate higher salinity for varying periods of time). In addition, salinity at any point in the river is subject to seasonal changes due to variation in rainfall, and daily/hourly changes due to tidal transport. These natural salinity variations can be seen in Figure 5-12. Most animals are able to move in response to preferred salinity. Plants, however, are fixed in position and are, therefore, subject to ambient conditions.

To quantify the spatial shifts of the fish habitats and the potential loss of freshwater plants habitats due to freshwater withdrawal, salinity model simulation results are presented for the dry season (May and June). The 1-, 2-, 3-, 5-, and 15- ppt average daily maximum salinity isohaline positions during the dry season are determined for various withdrawal scenarios based on the model simulation results and are shown in Figure 5-17. Table 5-11 presents the longitudinal translation of the 1-, 2-, 3-, 5, and 15-ppt average daily maximum salinity isohaline due to freshwater withdrawals from the SJRND during the dry season. Table 5-12 presents the change of the areas with average daily maximum salinity less than 1-, 2-, 3-, 5-, and 15-ppt for each withdrawal scenario. The results show that the 1-ppt average daily maximum salinity isohalines occur near West Tocoi, the 3-ppt isohalines occur near Hibernia Point, the 5-ppt isohalines occur near the Buckman Bridge,and the 15-ppt isohalines occur near the Acosta Bridge. The 240-cfs freshwater withdrawal scenario (from the SJRND) will shift the 1-, 2-, 3-, 5-, and 15-ppt isohalines upstream (southward) by 1.3, 1.4, 1.1, 0.6, and 0.8 mile, respectively. The potential shift of habitats due to a 240-cfs withdrawal from the SJRND in the 1-, 2-, 3-, 5-, and 15-ppt areas are 1,960; 2,249; 1,173; 1,103; and 80 acres, respectively.

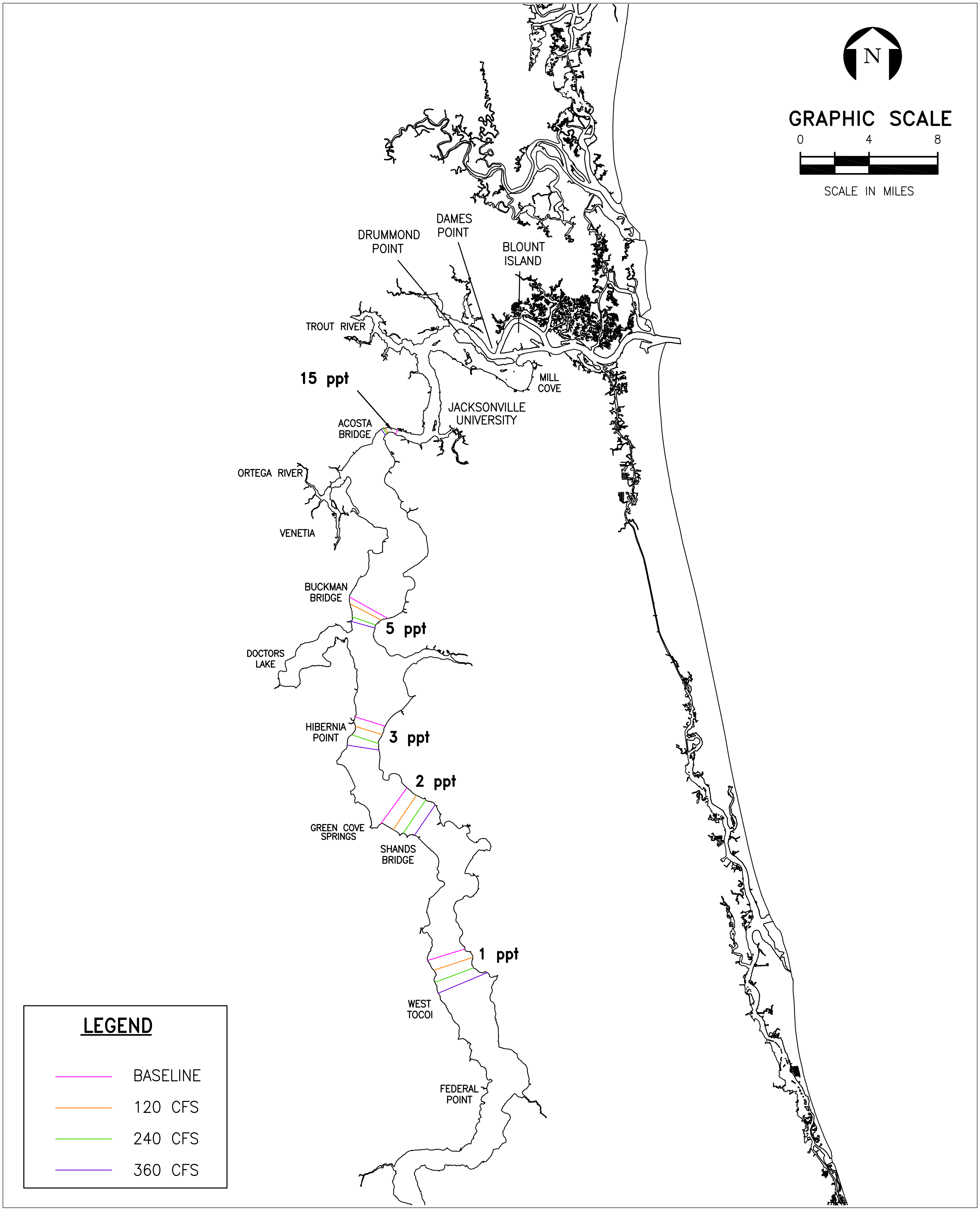


FIGURE 5-17.

AVERAGE DAILY MAXIMUM SALINITY ISOHALINE DURING THE DRY SEASON

Source: ECT, 2008.

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Table 5-11. Average Daily Maximum Salinity Isohaline Position Shifts During the Dry Season Due to Freshwater Withdrawal from SJRND

Withdrawal Scenario (from SJRND)	Isohaline Shift (miles) for Average Daily Maximum salinity in Dry Season				
	1 ppt	2 ppt	3 ppt	5 ppt	15 ppt
120 cfs	0.64	0.75	0.52	0.30	0.62
240 cfs	1.28	1.36	1.07	0.61	0.77
360 cfs	1.88	1.98	1.57	1.04	0.90

Source: ECT, 2008.

Table 5-12. Change of Habitat Areas During the Dry Season Due to Freshwater Withdrawal from SJRND

Withdrawal Scenario (from SJRND)	Area Changes (acres)				
	1 ppt	2 ppt	3 ppt	5 ppt	15 ppt
120 cfs	967	1,169	590	437	102
240 cfs	1,913	2,111	1,140	1,007	124
360 cfs	2,937	3,018	1,732	1,211	154

Source: ECT, 2008.

For the purpose of being conservative, the 5-ppt isohaline was considered to be the upper salinity boundary for freshwater species for the WRV assessment. The withdrawal of freshwater at the rate of 240 cfs from the SJRND would shift the 5-ppt isohaline 0.6 mile upstream. This could result in the corresponding potential effect on 1,103 acres of habitat for freshwater plants such as *Vallisneria americana* (eel grass), which only thrives at salinity less than 6 ppt (Korschgen and Green, 1988). Submerged aquatic vegetation (SAV) is one of the most important biological resources of the LSJR (Burns *et al*., 1997). *Vallisneria americana* is a predominant SAV in the LSJR, which makes up about 62 percent of the total SAV in the river (Sagan, 2002). *Vallisneria* is considered a freshwater species (Metcalf, 1931; Moyle, 1945; Hunt, 1963). However, it can tolerate moderate levels of salinity (Davis and Brinson, 1976; Stevenson and Confer, 1978; Turner *et al*., 1980; Steller, 1985; Carter and Rybicki, 1986; Twilley and Barko, 1990; Kraemer *et al*., 1999; Doering *et al*., 2001; Boustany *et al*., 2003). Salinity tolerance limits were reported in the range of 8 to 20 ppt, and it may vary from population to population (Boustany *et al*., 2003).

Boustany *et al*. (2001) conducted a 6-month laboratory experiment to determine the effects of salinity and light/shading on the growth of *Vallisneria* plant plugs collected from the St. Johns River at Rice Creek. The experiment consisted of a 4-week acclimation period followed by a 5-month treatment period. During the experiment, the plant plugs were subjected to various light conditions and three levels of salinity conditions: ambient (1 ppt), mid level (8 ppt), and high level (18 ppt). The results showed that the overall macrophyte growth was strongest in low salinity (1 ppt) and the growth decreased with increased salinity. The aboveground biomass was completely lost in all 18-ppt salinity treatment and had decreased by 15.8 percent in 8-ppt treatment, whereas the aboveground biomass in 1-ppt treatment had increased by 25 percent at final harvest. When 18-ppt treatments were dropped back to 1 ppt, approximately 20 percent of the plants recovered and grew vigorously because some underground biomass had survived at mid treatment. The experiments also showed that the underground biomass remained virtually unchanged in both the 1-ppt and 8-ppt treatments, and there was a shift in the allocation of resources and growth in favor of roots when *Vallisneria* was subject to elevated salinity. The experiments indicated that roots could tolerate high salinity better than shoots. However, there was a strong negative correlation between total biomass and salinity. The *Vallisneria* survival was increasingly limited with increased salinity. At moderate salinity (8 ppt), the plants may survive but their growth was substantially reduced. Boustany *et al*. (2003) expanded the experiment to determine the *Vallisneria* growth response to salinity pulses of 18 and 12 ppt. During a pulse, the peak salinity was maintained for about 2 days and then the salinity dropped steadily over a period of 2 weeks. The study showed that a salinity pulse at 18 ppt resulted in 22 percent mortality, and two consecutive pulses of 18 and 12 ppt resulted in mortality of 36 percent. At final harvest, the leaf and ramet counts indicated mortality rates of 59.7 percent and 67.8 percent, respectively. The root/shoot ratios increased with salinity pulses, again indicating a shift in biomass to root with salinity exposure.

Boustany *et al.* (2003) conducted an extensive literature search on *Vallisneria* growth response to salinity exposure by other investigators. The following paragraph is a summary of this report.

The study by Doering *et al*. (2001) showed that the mortality at 18-ppt salinity exposure was proportional to the duration of exposure. They concluded that exposure of *Vallisneria* to 18-ppt salinity for 31 days resulted in 50 percent loss of shoots and 90 percent loss after 95 days. They also determined that plants exposed to 18 ppt salinity for 30 days could recover 50 percent of the lost blades and shoots within 30 days, and plants exposed to 18 ppt salinity for 15 days could fully recover. Under constant salinity, cessation of *Vallisneria* growth was reported to occur at a range of salinity: 8.4 ppt (Bourn, 1932 and 1934); 6.66 ppt (Haller *et al*., 1974); and 15 ppt (Doering *et al*., 1999).

As indicated by various studies, the SAV does not simply perish when salinity exceeds a fixed threshold value. Instead, the SAV may tolerate a salinity level of varying ranges depending on many factors, including the toxicity level and the duration of exposure (Dobberfuhl, pers. comm., 2002). It should be pointed out that the isohaline shifts and acreage changes presented in this section are based on certain assumed fixed thresholds. Although the 5-ppt isohaline may be shifted upstream by 0.6 mile at 240-cfs withdrawal limit from the SJRND, the absolute change in mean salinity within the impacted area is only about 0.3 ppt.

The coastal shiner and brown bullhead are two fishes representative of fishes with low tolerance to increased salinity. The coastal shiner (*Notropis petersoni*) is a common minnow in pools and backwaters of creeks and small to large rivers from North Carolina to Mississippi (Page and Burr, 1991). Cowell and Resico (1975) studied the life history of the coastal shiner in Florida. Spawning occurs from March through September at water temperatures of 19 to 27°C. In Florida, the coastal shiner lives for about 1 year, while more northern populations may live for 3 years. They have been recorded at salinities of 0.65 ppt (Gunter and Hall, 1965).

The brown bullhead (*Ameiurus nebulosus*) occurs in sluggish creeks and rivers, lakes, and ponds throughout most of the eastern United States (Page and Burr, 1991). In the Southeast, bullheads spawn from April through late summer in nests in shallow open water, in natural shelters such as under logs and in burrows, and in litter such as tin cans (Jenkins and Burkhead, 1993). In Virginia, bullheads occurred at salinities up to 8 ppt (Jenkins and Burkhead, 1993). Stuber (1982) suggested an upper salinity limit of 2 ppt for the related black bullhead (*A. melas*), a level that is probably also appropriate for the coastal shiner. At withdrawal rates of 120, 240, and 360 cfs, the 2 ppt isohaline would shift 0.74, 1.33, and 1.93 miles upstream, respectively (Table 5-11), reducing the habitat available to these fishes by 1,308; 2,249; and 3,221 acres, respectively (Table 5-12).

As stated previously, oyster drills, predators of oysters, can survive at salinity level of 15 ppt or higher. Surface water withdrawal may increase the oyster drill habitat due to the increased salinity, thus reducing oyster habitat. Withdrawal scenarios of 120-, 240-, and 360-cfs would shift the 15 ppt isohaline of average daily maximum salinity during the dry season upstream by 0.23-, 0.47-, and 0.70-mile (Table 5-11), respectively; therefore expanding the area available to oyster drills by 36-, 80-, and 133-acres, respectively (Table 5-12).

Due to the minor changes in salinity level in the LSJR resulting from a 240-cfs withdrawal from the SJRND, the overall composition of plant and animal species inhabiting the river should not change. The only changes that may occur are minor shifts in the boundary between fresh water and estuarine habitats and their associated faunas. Although it is possible that the minor salinity increases due to surface water withdrawals from the river near DeLand and Lake Monroe could affect distribution of some aquatic species, the effect would be minor because *Vallisneria* (the dominant species) can tolerate a wide range of salinity levels.

As shown in Figure 5-13, freshwater withdrawal from the SJRND in the range of 120 to 360 cfs will not markedly increase the daily maximum salinity in the river. Table 5-13 summarizes the mean daily maximum salinities in 1-, 3-, and 5-ppt daily average salinity zones under existing conditions, 120-, 240-, and 360-cfs maximum withdrawal scenarios (from the SJRND). Table 5-13 shows the mean daily maximum salinities will be increased by 0.1, 0.2, and 0.4 ppt in 1-, 3-, and 5-ppt average salinity zones, respectively, under the maximum withdrawal limit of 240 cfs from the SJRND, which includes the maximum withdrawal of 180 cfs from Lake Monroe. Table 5-13 also shows the absolute instantaneous maximum salinity (the worst condition) within 5 simulation years at Venetia (5-ppt average salinity zone), Buckman Bridge (3-ppt average salinity zone), and Shands Bridge (1-ppt average salinity zone) under baseline and various withdrawal scenarios. The results show that absolute maximum salinity will be increased by 0.8, 0.5, and 0.3 ppt in 1-, 3-, and 5-ppt average salinity zones, respectively, under a maximum withdrawal limit of 240 cfs from the SJRND, which includes the maximum withdrawal of 180 cfs from Lake Monroe. The change of instantaneous maximum salinity is less than 3 percent of the maximum salinity. Table 5-13 also shows that the maximum freshwater withdrawal limit of 240 cfs from the SJRND will not alter the instantaneous minimum salinity.

Table 5-13. Simulated Maximum and Minimum Salinities Under the Baseline and Freshwater Withdrawal Scenarios

Location	Baseline (ppt)	120-cfs Withdrawal (ppt)	240-cfs Withdrawal (ppt)	360-cfs Withdrawal (ppt)
<u>Mean Daily Maximum Salinity</u>				
Venetia (5-ppt average salinity zone)	6.6	6.8	7.0	7.2
Buckman Bridge (3-ppt average salinity zone)	3.4	3.5	3.6	3.8
Shands Bridge (1-ppt average salinity zone)	0.9	0.9	1.0	1.0
<u>Absolute Maximum Salinity</u>				
Venetia (5-ppt average salinity zone)	32.3	32.5	32.6	32.7
Buckman Bridge (3-ppt average salinity zone)	27.6	27.9	28.1	28.4
Shands Bridge (1-ppt average salinity zone)	11.2	11.5	12.0	12.4
<u>Absolute Minimum Salinity</u>				
Venetia (5-ppt average salinity zone)	0.17	0.17	0.17	0.17
Buckman Bridge (3-ppt average salinity zone)	0.18	0.18	0.18	0.18
Shands Bridge (1-ppt average salinity zone)	0.18	0.18	0.18	0.18

Source: ECT, 2008.

5.4.6 EFFECTS OF SALINITY CHANGES ON DISSOLVED OXYGEN

When salinity is increased in the water column, the dissolved oxygen (DO) may decrease because the DO saturation level decreases with increasing salinity. To quantify the changes in DO saturation concentration due to salinity increase resulting from freshwater withdrawal, the saturation DO concentrations at several locations are computed for the baseline and 240-cfs withdrawal condition (from the SJRND) at the average salinity. The saturation DO was computed by a computer program developed by Ivan B. Chou (Chou, 1982), based on the data presented in Clark *et al*. (1971). A water temperature of 30 C (86 degrees Fahrenheit [ºF]) is used for the calculations. Table 5-10 shows the baseline average saturation DO concentration at Blount Island, JU, Buckman Bridge, and Shands Bridge. The average saturation DO concentrations for the 240-cfs withdrawal limit from the SJRND are also presented in Table 5-14. The results show that the change in saturation DO concentration is less than 0.02 mg/L at all locations. Therefore, it is concluded that the decrease in DO concentration due to restricted freshwater withdrawal from the SJRND will be negligible.

5.4.7 SUMMARY

Simulations were provided by SJRWMD using the EFDC model to project changes in the salinity regime of the LSJR that may occur as a result of increased cumulative surface water withdrawals from the SJRND, which includes the water withdrawal from Lake Monroe. An assessment of the effect the projected salinity changes would have on aquatic life in the LSJR was also performed.

The EFDC model was run for the baseline, or existing, flow conditions and for three other flow regimes. These three flow regimes reflect the withdrawal of surface water from the SJRND at the maximum rate of 120, 240, and 360 cfs, which includes the surface withdrawal from Lake Monroe. Statistical analyses for the four simulated scenarios were performed and comparisons were made to quantify the changes in average salinity regime. The results of these analyses are summarized in Table 5-15. The results show that the projected increase in average salinity in the LSJR over the 5-year simulation period due to a maximum withdrawal of 240 cfs from the SJRND is small,

Table 5-14. Dissolved Oxygen Impact Due to Freshwater Withdrawal from the SJRND (at 30ºC)

Location	River Miles	Baseline Conditions Average Salinity (ppt)	Baseline Conditions Saturation DO (mg/L)	240 cfs Withdrawal Average Salinity (ppt)	240 cfs Withdrawal Saturation DO (mg/L)	240 cfs Withdrawal Saturation DO Reduction (mg/L)
Blount Island	8.8	23.93	6.62	24.14	6.61	0.01
Jacksonville University	19.2	11.40	7.16	11.77	7.14	0.02
Buckman Bridge	33.9	2.74	7.53	2.99	7.52	0.01
Shands Bridge	49.9	0.81	7.61	0.89	7.61	<0.01

Source: ECT, 2008.

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Table 5-15. Summary of Salinity Changes in the LSJR due to Freshwater Withdrawal from the SJRND

Location	River Miles	Baseline Conditions: 5-Year Average Salinity (ppt)	Baseline Conditions: Average Daily Fluctuations (ppt)	Daily Average Salinity Increase: 120 cfs Withdrawal (ppt)	Daily Average Salinity Increase: 240 cfs Withdrawal (ppt)	Daily Average Salinity Increase: 360 cfs Withdrawal (ppt)
Blount Island	8.8	23.93	13.76	0.11	0.21	0.31
Dames Point	10.6	21.78	11.86	0.12	0.24	0.35
Drummond Pt.	14.3	15.12	10.00	0.17	0.33	0.50
Jacksonville University	19.2	11.40	6.60	0.18	0.36	0.55
Acosta Bridge	23.7	7.46	5.76	0.18	0.35	0.53
Buckman Bridge	33.9	2.74	1.15	0.12	0.25	0.38
Hibernia	42.3	1.29	0.40	0.07	0.14	0.22
Green Cove Spring	47.9	0.89	0.22	0.04	0.09	0.14
Shands Bridge	49.9	0.81	0.15	0.04	0.08	0.12
West Tocoi	60.2	0.53	0.07	0.02	0.03	0.05
Federal Point	67.1	0.46	0.02	0.00	0.01	0.01
Mill Cove		16.73	1.99	0.17	0.33	0.50
Doctors Lake		1.59	0.05	0.08	0.17	0.26
Trout River		10.41	1.34	0.17	0.34	0.51
Ortega River		3.92	0.82	0.13	0.26	0.39

Source: ECT, 2008.

Y:\GDP-08\SJRWMD\LKMONR\htb5.xls/5-15—9/23/2008 when compared with the daily variability in salinity presently observed in the LSJR caused by tidal transport.

With respect to aquatic life in the LSJR, the projected average increase in salinity as a result of the surface water withdrawals may have a minor effect on the distribution of some aquatic species. The salinity simulation results indicate the 5-ppt isohaline of the average daily maximum salinity during the dry season will be shifted upstream by 0.6 mile. This upstream translation of the saline water may impose slight stress on freshwater plant habitat in a 1,007-acre area. Although the 5-ppt average daily maximum isohaline may be shifted upstream by 0.6 mile under the 240-cfs withdrawal limit from the SJRND, the absolute change in mean salinity within the affected area is only 0.3 ppt; much smaller than the variability of the salinity tolerance range of *Vallisneria* found in the scientific literature. The species composition of the river is not expected to change. In addition, the increase in daily maximum salinity due to a maximum 240-cfs withdrawal from the SJRND, which includes the maximum withdrawal of 180 cfs from Lake Monroe, will also be quite small. For example, the increase in daily maximum salinity will be about 0.4 ppt in the 5-ppt average salinity zone under a 240-cfs withdrawal from the SJRND. The analysis (Table 5-13) also shows that a maximum withdrawal of 240 cfs from the SJRND will not greatly change the absolute maximum salinity in the LSJR. The increase of instantaneous maximum salinities at Venetia (5-ppt average salinity zone), Buckman Bridge (3-ppt average salinity zone), and Shands Bridge (1-ppt average salinity zone) due to 240-cfs withdrawal from the SJRND will be 0.3, 0.5, and 0.8 ppt, respectively.

The potential DO decrease under the recommended MFLs hydrologic conditions is determined to be negligible.

Based on the results of the salinity assessment in the LSJR, ECT concludes that a maximum withdrawal of 240 cfs from the SJRND, as limited by the adopted SR 44 MFLs, which includes the maximum withdrawal of 180 cfs from Lake Monroe, will protect the estuarine resources.

5.5 WRV-4: TRANSFER OF DETRITAL MATERIAL

5.5.1 METHODOLOGY

In the context of WRV associated with the MFLs regime, detrital material is defined as the organic particles or fragments originated from plants and animals. In a broader sense, detrital material may include inorganic particles originated from weathering of igneous, sedimentary, and metamorphic rocks (Watt, 1982), such as sand, silt, and clay. The inorganic or mineral component of the suspended material is discussed separately in Section 5.9 (Sediment Load). Only organic material is discussed in this section.

Detrital material is an important component of the food web in aquatic ecosystems (Mitsch and Gosselink, 1993), and is derived from decomposing plant tissues (often of terrestrial origin); shedding of animal tissues; and dead animals. As the plant and animal matter decomposes, smaller particles are created that may be more easily transported by currents. Tree leaves are the major energy base for streams with forested watersheds (Fisher and Likens, 1973). Certain macroinvertebrates, the shredders, process whole tree leaves to small organic particles (Cummins and Merritt, 1996). The organic particles increase in nutritional value as bacteria and fungi colonize the particles surfaces (Suberkropp, 1992) and become an important source of nutrients that can be recycled in aquatic ecosystems.

Detrital material is deposited on the upland and the floodplain by stormwater runoff or imported into the lake during periods of high water. Inorganic nutrients that stimulate primary productivity of the floodplain vegetation are released as detrital material decomposes. The small particles are fed on by many worms, mollusks, insect larvae, microcrustaceans, and small fishes. These, in turn, are the food of larger crustaceans, fishes, birds, and mammals, including important recreational and commercially-harvested species. Therefore, detrital material is an important component of the food chain and productivity of Lake Monroe and its associated floodplain.

The shredder production and community structure in the ecosystem may be dependent on the type of detrital material available (Benke *et al.*, 2005). Therefore, anthropogenic changes in the watershed, such as land use alteration and urban development, may have large effects on the structure and function of the stream ecosystem (Benke *et al*., 2005). Gessner and Chauvet (2002) suggested the leaf litter processing is a measure of ecosystem function, and a measure to assess anthropogenic impacts on stream ecosystems (Benke *et al*., 2005). The litter breakdown rates can be affected by physical abrasion, aquatic fungi, bacteria, and shredder organisms (Cummins *et al*., 1973, Suberkropp and Klug, 1976; Anderson and Sedell, 1979; Webster and Benfield, 1986). Therefore, hydrology and water chemistry, which can be changed by anthropogenic activities, can control litter processing (Paul and Meyer, 2001). Benke *et al*. (2005) found arthropod shredders were dominant only in forested, non-urban areas; snails would dominate in areas where arthropod shredders were not prevalent. Arthropod shredders and snails are browsers of periphyton, but they can also be effective shredders of living plants and coarse detritus (Brown, 1991; Lombardo *et al*., 2002). Benke *et al*. (2005) suggested that periphyton was limited in headwater streams of the lower St. Johns River, and snails were feeding primarily on detritus.

Elevated nitrogen and phosphorus in streams are often related to a faster rate of processing of detrital material (Suberkropp and Chauvet, 1995; Suberkropp, 1998). Therefore, detrital material also affects stream water quality.

The methodology of detrital material transfer assessment is described here according to the four-level hierarchical approach presented in Section 5.1.

WRV-4 is defined as the movement, by water, of loose organic material and debris and associated decomposing biota. The representative functions of WRV-4 are the supply and distribution of nutrients. The general indicator for the protection of WRV-4 is to provide detrital export from floodplain wetlands and to maintain in-lake transfer of detrital material. Specific indicators of protection are the changes in frequency of occurrence for minimum flood level not exceeding the upper 10th percentile elevation of the hardwood swamp (i.e., 3.3 ft-NGVD threshold stage) with critical durations of 1, 14, and 30 days; and a threshold stage of 5.3 ft-NGVD (when critical shear stress is exceeded [Jain and Mehta, 2006]) with durations of 1 and 14 days. Critical shear stress is the minimum shear stress at the sediment/fluid interface that is required to displace the sediment into suspension.

5.5.2 DETRITAL TRANSFER ASSESSMENT

Physical and chemical characteristics of sediment in Lake Monroe were provided by Anderson *et al*. (2004) and Battelle (2004). According to the sediment analysis by Anderson *et al*. (2004), the organic content of the surface sediment layer in Lake Monroe was typically about 30 percent. However, there were no data on detrital material in Lake Monroe.

Three different approaches were used to assess the transfer of detrital material in Lake Monroe:

- Detrital material processing.
- In-lake transfer of detrital material.
- Floodplain transfer of detrital material.

<u>Detrital Material Processing</u>

Current velocity in streams, through movement of sediments, provides mechanical abrasion to leaf litters and will increase the litter processing rate. Benke *et al*. (2005) found that those streams with higher current velocities tended to have a higher processing rate for both sweetgum and red maple leaves. This correlation between stream velocity and litter processing rate was also supported by other studies (Collier and Winterbourn, 1986; Paul and Meyer, 2001). Jain and Mehta (2006) conducted a hydrodynamic and wave model study to investigate the differences in current velocity and sediment transport in the lake between existing and recommended MFLs hydrologic conditions. The modeling results showed that with a constant streamflow of 3,708 cfs (105 cubic meters per second [m^3/sec]; about the 20^{th} percentile flow – Figure 3-6) and no-wind condition, the highest current velocity in Lake Monroe occurs near the western exit of the lake where the vertical profile average velocity is about 0.23 fps (Figure 5-18 and Table 5-16).

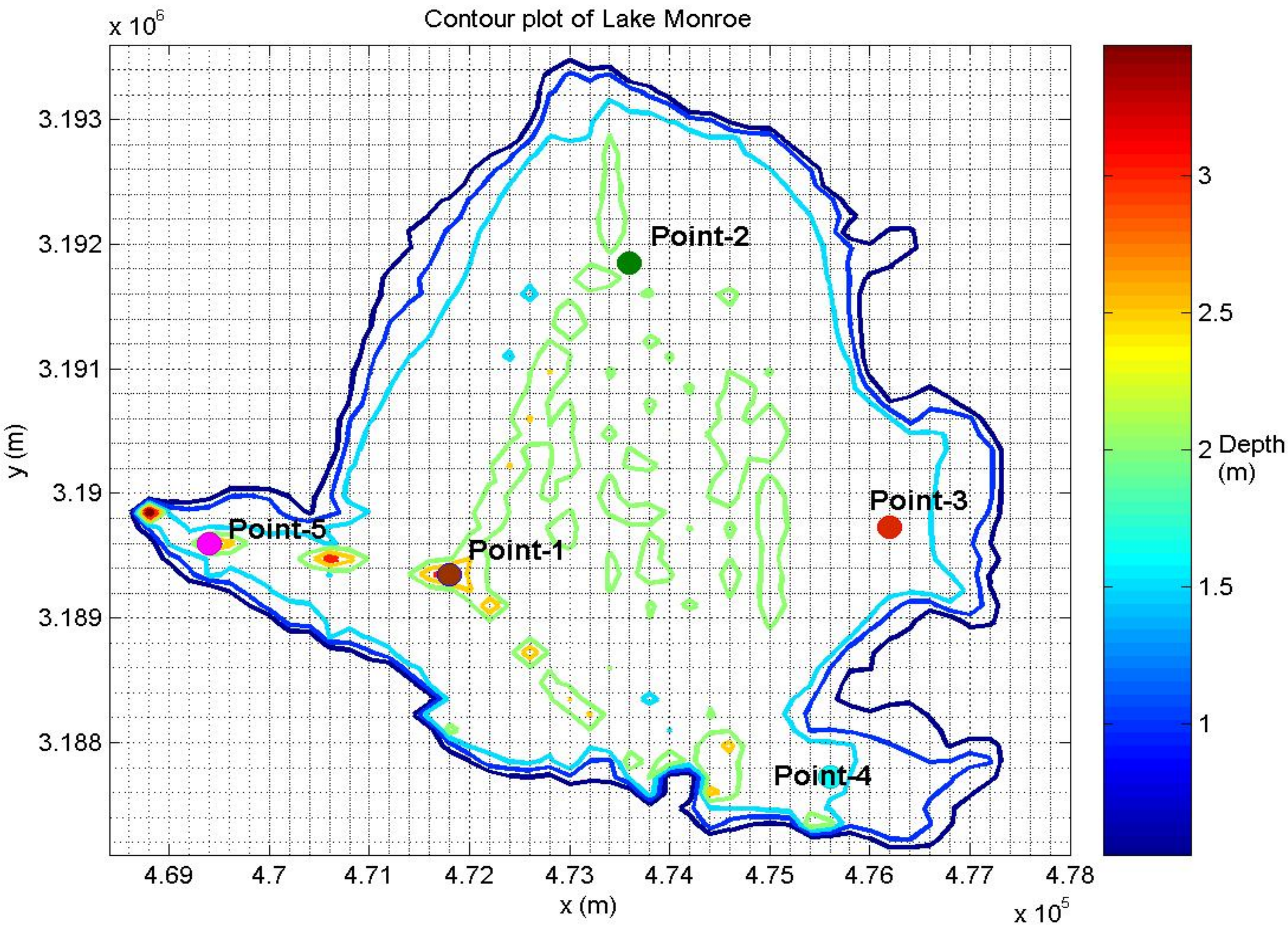

FIGURE 5-18.

SELECTED LOCATIONS FOR HYDRODYNAMIC AND WAVE MODEL OUTPUT ANALYSIS

Source: Jain and Mehta, 2006.

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The current velocities in other parts of the lake, under a 3,708 cfs streamflow, range from 0.04 to 0.17 fps (Figure 5-18 and Table 5-16).

Table 5-16. Simulated Current Velocity at Selected Locations in Lake Monroe

Location	Current Velocity (fps) Existing Conditions 3,708 cfs	Current Velocity (fps) MFLs Conditions 3,543 cfs	Difference (fps)
Point-1	0.16	0.14	0.02
Point-2	0.04	0.03	0.01
Point-3	0.04	0.03	0.01
Point-4	0.05	0.05	0.0
Point-5	0.23	0.22	0.01

Source: Jain and Mehta, 2006.

Such low current velocities do not create sufficient bottom shear stress to transport the sandy or coarse materials that provide an abrasion mechanism to pulverize and break down leaf litter and detrital material. A minimum streamflow of 7,416 cfs (200 m^3/sec), about the 5th percentile value of St. Johns River flow near Sanford (Figure 3-6), would be required for sediment transport (i.e., sandy or coarse material) in Lake Monroe (Jain and Mehta, 2006).

Jain and Mehta (2006) also showed that a water withdrawal of 180 cfs (5 m^3/sec) would reduce the current velocity in Lake Monroe near the western exit by 0.01 fps, and would reduce current velocities in other parts of the lake by 0 to 0.02 fps for flows of 3,708 and 3,531 cfs, respectively; very small velocity reductions. Therefore, a maximum withdrawal limit would not cause unreasonable changes to detrital material processing in Lake Monroe. The modeling effort by Jain and Mehta (2006) will be presented in Section 5.9 with more detail.

<u>In-Lake Transfer of Detrital Material</u>

According to Jain and Mehta (2006), sediment transport would not occur in Lake Monroe until the St. Johns River flow is greater than 7,416 cfs at a stage of 5.3 ft-NGVD

(Figure 3-8). The Lake Monroe retention time is approximately 7.3 days when the lake stage is 5.3 ft-NGVD (Table 3-1). Therefore, a threshold stage for in-lake detrital transfer is 5.3 ft-NGVD and the critical durations are 1 and 14 days (Table 5-17).

Table 5-17. Frequency Analysis of Threshold Stage for In-Lake Detrital Transfer

Threshold Stage (ft-NGVD)	Duration (days)	No. of Years in a Century Threshold Stage is Continuously Exceeded*		
		Existing	MFLs	Difference
5.3	1	22	21	1
5.3	14	20	20	0

* Water levels rise above the threshold stage for the indicated duration.

Source: ECT, 2006.

The results of the frequency analysis indicate that, under existing conditions, the threshold stage of 5.3 ft-NGVD would be continuously exceeded for 1 day 22 times in 100 years (Table 5-8). Under the recommended MFLs hydrologic conditions, the threshold stage would be continuously exceeded for 1 day 21 times in a century; a decrease of 1 flooding event per 100 years when compared to existing hydrologic conditions. A similar analysis indicates that the frequency at which the threshold stage of 5.3 ft-NGVD would be continuously exceeded for 14 days would be unchanged between the existing and recommended MFLs hydrologic conditions (Table 5-17).

In ECT's opinion, the recommended MFLs hydrologic conditions will protect in-lake transfer of detrital material in Lake Monroe because the frequency of flooding of the threshold stage of 5.3 ft-NGVD would not be appreciably decreased.

Floodplain Transfer of Detrital Material

The ecology of the floodplain and aquatic communities is dependent to some extent on the events that deliver detrital material to the system. Although surface runoff can transfer detrital material from uplands to the floodplain or the river, it can deliver only a portion of this material to the lake because of the filtering effects of vegetation. A significant portion of the detrital material transfer occurs during periods of high water events when accumulated detrital materials on the floodplain are detached from the land surface by flood water, due to buoyancy or turbulence, and moved by flow currents. Therefore, maintaining the hydrologic regime characteristics in the Lake Monroe floodplain is essential to the supply and transport of detrital material.

Large quantities of detrital material on the floodplain can be transported to the lake by the flooding events described previously. Hardwood swamp is a large source of detrital material input to Lake Monroe and occurs at elevations greater than other wetland communities. Therefore, an upper 10th percentile of the hardwood swamp elevation (3.3 ft-NGVD) (Mace, 2006b) is considered the threshold stage for the transport of detrital material in the floodplain. During a dynamic flooding event, detrital material may be transferred to the lake within a short time (e.g., 2 weeks). Therefore, frequency analyses were conducted for flood durations of 1, 14, and 30 days (Table 5-18).

Table 5-18. Frequency Analysis of Threshold Stage for Floodplain Transfer of Detrital Material

Threshold Stage (ft-NGVD)	Duration (Days)	No. of Years in a Century Threshold Stage is Continuously Exceeded*		
		Existing	MFLs	Difference
3.3	1	60	55	5
3.3	14	55	53	2
3.3	30	53	49	4

* Water levels rise above the threshold stage for the indicated duration.

Source: ECT, 2006.

The results of the frequency analysis indicates that, under existing conditions, the threshold stage of 3.3 ft-NGVD would be continuously exceeded for 1 day, 60 times in 100 years (Table 5-18). Under the recommended MFLs hydrologic conditions, the threshold stage would be continuously exceeded for 1 day 55 times in a century; a decrease of 5 flooding events per 100 years when compared to existing hydrologic conditions. Similar results were obtained from the 14- and 30-day durations analyses. A comparison of the existing and recommended MFLs hydrologic conditions indicates that the number of times the threshold stage of 3.3 ft-NGVD would be continuously exceeded for a duration of 14 and 30 days would decrease by 2 and 4 times per century, respectively, under the recommended MFLs hydrologic conditions (Table 5-18).

In ECT's opinion, the recommended MFLs hydrologic conditions will protect floodplain transfer of detrital material in Lake Monroe because the frequency of flooding of the threshold stage of 3.3 ft-NGVD would not be appreciably decreased.

5.5.3 SUMMARY

The results of frequency analysis show that water withdrawals under the recommended MFLs for Lake Monroe would not unreasonably nor unacceptably change the frequency of the threshold stages with critical durations required to protect the following: detrital material processing, in-lake transfer of detrital material, and floodplain transfer of detrital material. Based upon the findings of the WRV assessment, it is concluded that the recommended MFLs hydrologic conditions for Lake Monroe will protect the transfer of detrital material.

5.6 WRV-5: MAINTENANCE OF FRESHWATER STORAGE AND SUPPLY

5.6.1 METHODOLOGY

WRV-5 is defined as the protection of existing surface water and/or ground water users. The function of WRV-5 is the reasonable and beneficial use of the surface water and ground water. The general indicator for WRV-5 assessment is to protect existing water uses. The specific indicator of WRV-5 protection is that future freshwater withdrawals as allowed by the recommended MFLs do not interfere with the existing water users.

Maintenance of adequate aquifer levels was assessed by evaluating both surface and ground water withdrawals and also by examining the aquifer recharge characteristics within the study area. Water withdrawal and storage relationships can be complex with respect to how they affect surface water bodies. Ground water withdrawals can indirectly reduce river flows by increasing the amount of induced recharge over a stretch of the river, and by decreasing base flows to the river. The maintenance of freshwater storage could be adversely affected if the withdrawal is in a recharge area, particularly to the Floridan aquifer, which is typically used by production wells.

To assess if WRV-5 was protected by the recommended MFLs hydrologic conditions for Lake Monroe, publications of SJRWMD and the USGS addressing surface and ground water resources in the Lake Monroe area were obtained and reviewed. Characteristics of the surficial and Upper Floridan aquifers were investigated, including the recharge characteristics of the aquifers and how water levels in Lake Monroe might affect the potentiometric levels in these aquifers.

SJRWMD's consumptive use permit (CUP) records were obtained and evaluated to determine which CUPs designated the St. Johns River as the water source. Locations of the CUPs were overlaid on GIS information obtained from SJRWMD to identify those located near the Lake Monroe area. Those CUPs that identified the St. Johns River as their source were inventoried and total pump capacity calculated.

It should be noted that the hydrologic analysis, which was used to implement the recommended MFLs for Lake Monroe, included existing surface water consumptive uses throughout the basin watershed area. The hydrologic analysis, including hydrological model calibration, accounted for existing surface water uses. Therefore, the effect of existing users on the basin water budget is already reflected in the frequency analysis.

5.6.2 AQUIFER CHARACTERISTICS

Three hydrogeologic units are present in the study area. They are the surficial aquifer, the intermediate confining unit, and the Floridan aquifer system. Recharge to the surficial aquifer occurs primarily through rainfall. Recharge to the Floridan aquifer occurs in areas where the elevation of the water table of the surficial aquifer is higher than the elevation of the potentiometric surface of the Floridan aquifer. In those areas where the elevation of the potentiometric surface is higher than the surficial aquifer water table elevation, no recharge occurs. Instead, a potential for upward movement of water from the Floridan aquifer is created that may, at times, provide recharge to the surficial aquifer from the Floridan aquifer. Where the elevation of the potentiometric surface is higher than land surface elevation, artesian conditions will occur. Evidence of the artesian condition in the study area is the presence of springs (Gemini Springs and Green Springs) that discharge to Lake Monroe.

Boniol *et al*. (1993) developed a recharge map of SJRWMD using a GIS database (Figure 5-19). While the established recharge map is regional in scale, the results are consistent with more detailed local studies of the Lake Monroe area conducted by the USGS (Phelps, 1990; Vecchioli *et al*., 1990). In the area of Lake Monroe, the lake and its associated floodplain are shown to be areas of no recharge to the Upper Floridan aquifer, with areas of discharge from the Upper Floridan aquifer being the aforementioned springs. McKenzie-Arenburg and Szell (1990) and McKenzie-Arenburg (1989) also indicated that the river and the floodplain provided no recharge to the Floridan aquifer. Recharge areas to the Upper Floridan aquifer are located in the upland areas adjacent to the floodplain and in areas with higher elevations. Because the lake and its associated floodplain is a discharge area, supplying little or no recharge, the changing water levels under a 180-cfs maximum withdrawal from Lake Monroe should have no effect on ground water recharge.

5.6.3 SPRINGS

Springs contribute a significant percentage of the total river flow in some portions of the St. Johns River, especially during times of low flow (Robison, 2004a). There are two springs (Gemini and Green springs) located in the Lake Monroe study area (Figure 2-7).

Both springs are third magnitude springs (i.e., 1- to 10-cfs discharge). Gemini Springs is about 1 mile south of DeBary and is located in Volusia County’s Gemini Springs Park. Gemini Springs consists of two springs located in small, narrow ravines. The springs flow southeasterly to a pool impounded on its east end by an earthen dam with a concrete weir outlet. Recreational swimming is currently prohibited in the spring pool area due to high coliform bacteria counts in the spring’s discharges.

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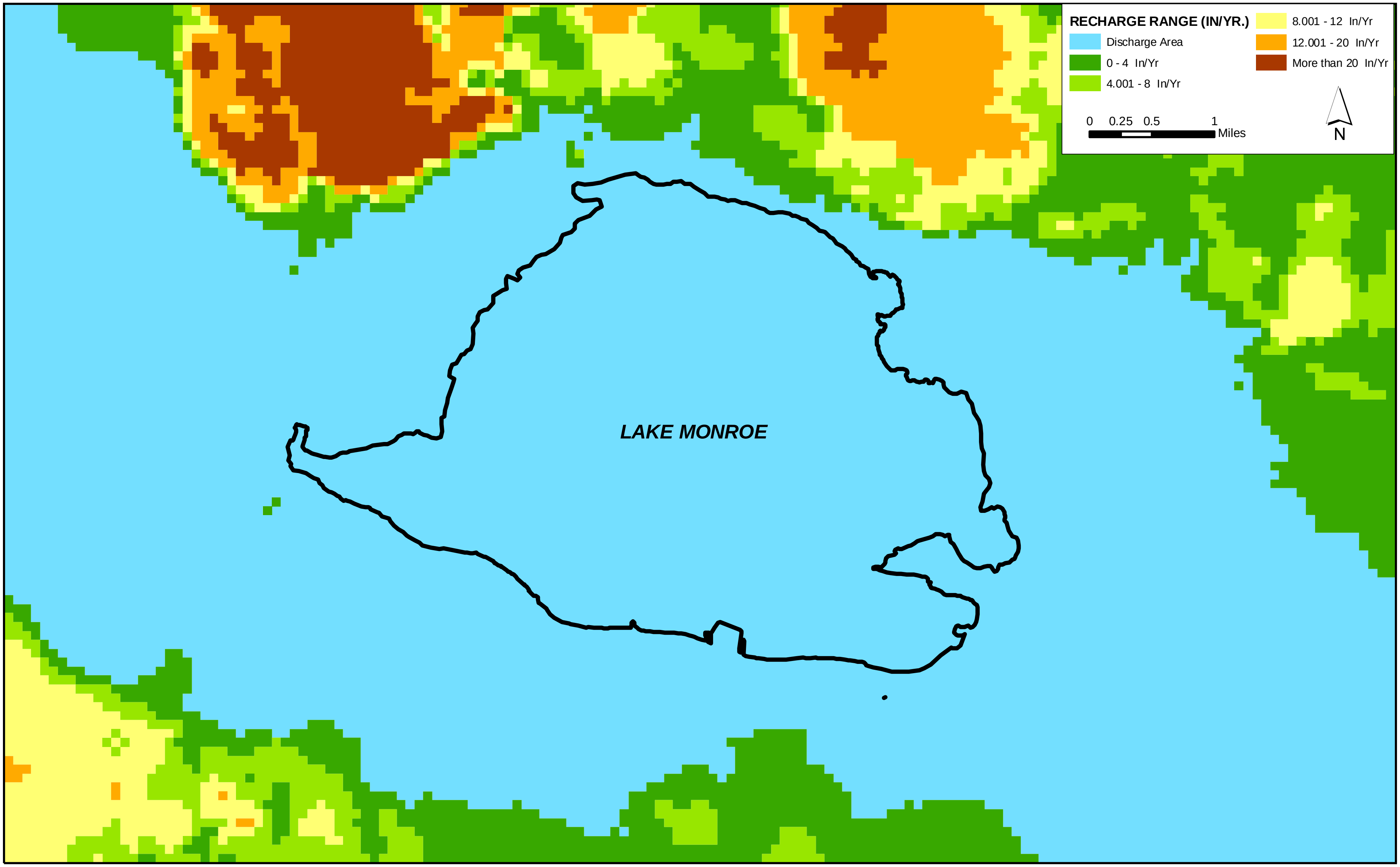

FIGURE 5-19.

FLORIDAN AQUIFER RECHARGE IN THE VICINITY OF LAKE MONROE

Sources: SJRWMD, 2005; ECT, 2006.

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Green Springs is about 5 miles west-northwest of Osteen. Green Springs was recently purchased by Volusia County and will become a County park in the near future. Spring flow discharges into a shallow run 6 ft wide and approximately 0.2 ft deep at the southeast edge of the spring pool, then flows southeast about 100 ft to a small creek which flows south 0.25 mile to Lake Monroe.

The presence of the springs reinforce that Lake Monroe is located in an area of ground water discharge. Because the location of the springs is above the normal fluctuation range of Lake Monroe water levels, it is believed that the spring discharges will not be affected by the maximum withdrawal of 180 cfs from Lake Monroe. Currently, there is an ongoing WRVs assessment study for Green Springs and Gemini Springs.

5.6.4 SURFACE WATER

Figure 5-20 presents the locations of pumps with direct withdrawals from Lake Monroe or nearby areas in the St. Johns River Basin, as identified in CUP records in 2004. According to the SJRWMD Division of Permit Data Services, currently there are no surface water intakes in Lake Monroe. The only water users in the vicinity of Lake Monroe are two facilities located downstream of Lake Monroe just west of U.S. 17-92: FPL's Sanford-DeBary Power Plant and Meadowlea On The River (a mobile home park) (Figure 5-21). The Sanford-DeBary Power Plant's water intake, operated under Permit No. 9202, is permitted to withdraw approximately 180 million gallons per day (MGD) on an annual average basis for cooling water. About 98 percent of the cooling water returns to St. Johns River. Meadowlea On The River uses St. Johns River water for fire protection (Permit No. 4377) and is permitted to withdraw approximately 0.0159 MGD on an annual average basis.

The primary impact to surface water users would occur during periods of low water when pump intakes would be at greater risk of exposure and reduced pumping effectiveness. Pump intakes are typically located at least 3 ft lower than the historic low stages (-0.52 ft-NGVD at Lake Monroe) to ensure non-exposure and to prevent impacts by boats. Evaluation of frequency curves for the existing hydrologic regime and for the maximum

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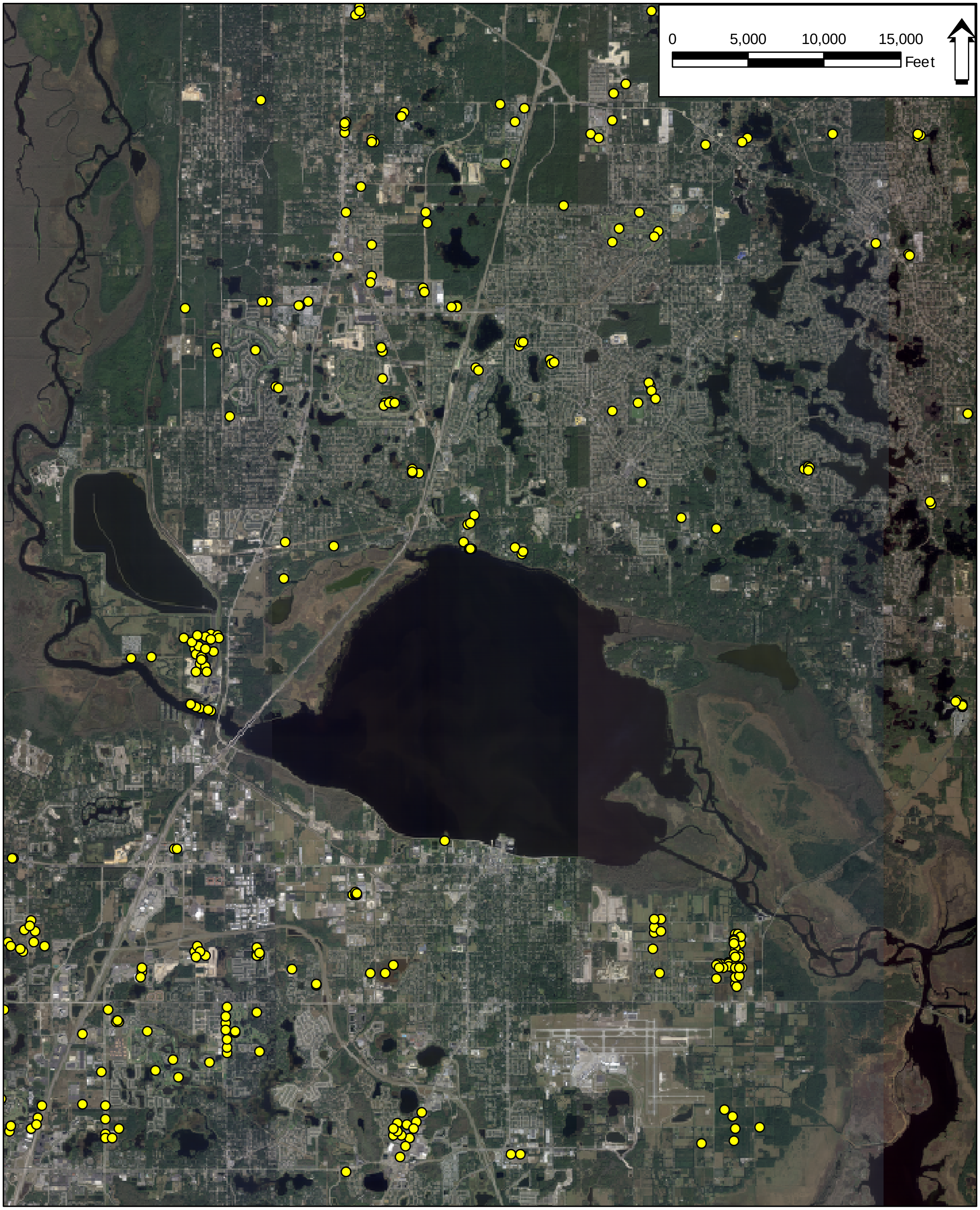

FIGURE 5-20.
CONSUMPTIVE USE PERMITS NEAR LAKE MONROE AS IDENTIFIED IN SJRWMD PERMITTING RECORDS

Sources: SJRWMD, 2004; ECT, 2006.

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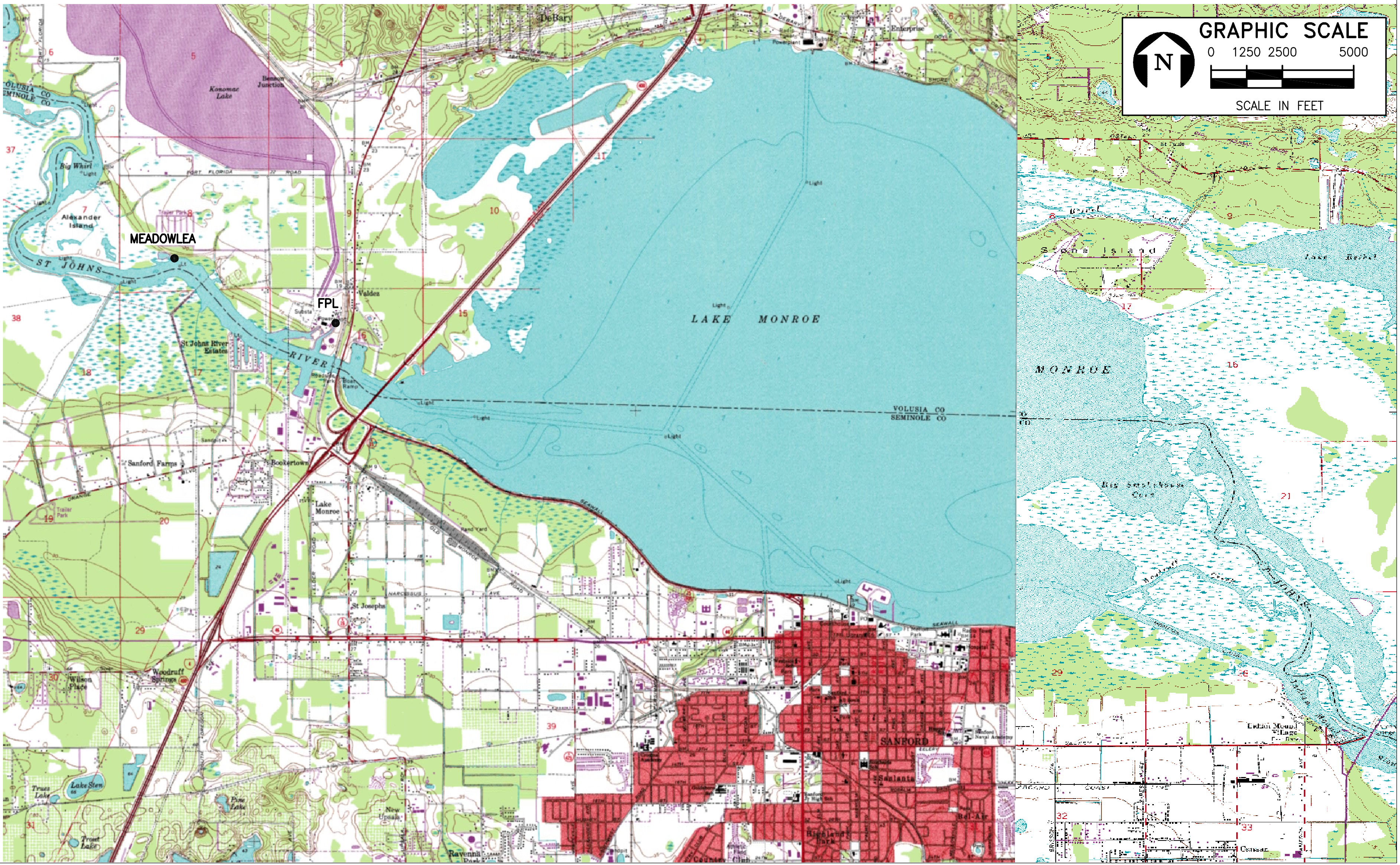

FIGURE 5-21.

WATER INTAKE LOCATIONS NEAR LAKE MONROE

Sources: USGS Quads: Osteen, FL, 1980 and Sanford, FL, 1988; ECT, 2006.

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withdrawal limit (180 cfs) from Lake Monroe under the recommended MFLs hydrologic conditions indicates that for any given frequency and duration, the decrease in elevation by a 180-cfs withdrawal from Lake Monroe will be no more than 0.25 ft at any extreme condition (Section 4.3). Specifically, the Sanford-DeBary Power Plant intakes are large structures with an invert elevation of -12.08 ft-NGVD, according to the design drawing (FPL, 1957), and can sustain extreme low water conditions. The plant has never been shut down due to low water conditions. FPL's engineers recommended that the lowest water level be 0.0 ft-NGVD for operational purposes. Presently, no information on Meadowlea's intake structure is available. This small reduction in the lake stage will not cause the exposure of intakes. Therefore, existing surface water users will be protected by the recommended MFLs hydrologic conditions regime for Lake Monroe.

5.6.5 GROUND WATER

There are a number of permitted wells located in the uplands adjacent to Lake Monroe. Those identified in the SJRWMD CUP records are shown in Figure 5-21. Additionally, shallow wells used for domestic water supply are present. The source of these withdrawals is the surficial aquifer, which is recharged directly by local rainfall on the order of 0-10 inches per year with recharge commonly near zero in stream valleys and low-lying wetlands (Vecchioli *et. al*., 1990). As discussed previously, Lake Monroe is located in a ground water discharge zone and does not provide recharge to either the surficial aquifer or the Upper Floridan aquifer. Therefore, the recommended MFLs for Lake Monroe will protect recharge to ground water aquifers and ground water supplies.

5.6.6 SUMMARY

Upon review of the existing information, it is concluded that the recommended MFLs for Lake Monroe will protect freshwater storage and supplies. This conclusion is based on the following premises:

1. Based on the literature reviewed, Lake Monroe does not provide recharge to either the surficial aquifer or the Upper Floridan aquifer. Therefore, water withdrawals under the recommended MFLs for Lake Monroe will not affect recharge to ground water aquifers and ground water supplies.

2. The MFLs hydrologic analysis, including the model calibration, accounts for all existing surface water consumptive uses throughout the basin area. Therefore, existing water uses are protected from impacts associated with potential future surface water withdrawals.
3. The maximum Lake Monroe stage drawdown by a 180-cfs maximum withdrawal is 0.25 ft, which is not likely to interfere with the existing water users who have water intake in the vicinity of Lake Monroe.

5.7 <u>WRV-6: AESTHETIC AND SCENIC ATTRIBUTES</u>

5.7.1 METHODOLOGY

The aesthetic and scenic attributes (WRV-6) are defined as those features of a waterscape usually associated with passive recreational uses such as bird watching, sightseeing, photography, contemplation, painting, etc., plus other forms of relaxation that usually result in human emotional responses of well being and contentment (HSW, 2004). These human uses can also occur simultaneously with a variety of more active recreational uses (boating, running, hiking/walking, bicycling, etc), in which WRV-6 may play a significant albeit secondary role.

Lake Monroe and its shorelines comprise one of the most visible and accessible water bodies in the MSJR basin, and allows for virtually all of the active and passive uses described previously. The water-dependent active recreational use (WRV-1), which may be affected by WRV-6, was examined in Section 5.2.

Applying the general methodology and hierarchical approach to the WRVs evaluation process described in Section 5.1, the primary function of WRV-6 is passive recreation. The general indicator of assessment is to maintain the visual setting at selected points. The specific indicators of WRV-6 protection are the frequency of water level being lower than the threshold stage, 1.7 ft-NGVD for durations of 60, 90, and 120 days to protect the aesthetic value of the vegetative shoreline; the frequency of water level being lower than the threshold stage of 0.9 ft-NGVD for durations of 14, 30, 60, and 90 days to protect WRV-6 from sediment exposure; and the frequency of water level being lower than the threshold stage of 1.5 ft-NGVD for durations of 30, 60, and 90 days to protect water clarity.

5.7.2 INTRODUCTION

The aesthetic and scenic beauty of a lake and its surrounding area can closely affect recreation activities and thus the local economy stimulated by tourism. Extreme low water levels, when they occur, may adversely impact the aesthetic appearance of residential or commercial establishments and the public use areas around the lake. Extreme low water levels may also expose discharge/ pipes or unsightly debris that may detract from the scenic value of a water body. In addition, extreme low water levels may contribute to fallen shoreline timber due to bank instability and increased turbidity due to sediment resuspension from boat traffic in shallow water. The following section describes factors that may enhance or degrade scenic values. Assessment is provided to evaluate the effects of the recommended MFLs hydrologic conditions for Lake Monroe on aesthetic and scenic attributes.

5.7.3 LAKE MONROE VIEWSHED AND SCENIC AREAS

The term *viewshed* is commonly used in evaluations of aesthetic and scenic attributes of a particular area. A viewshed is defined as an area of land, water, and other environmental elements that is visible from a fixed vantage point. The term is used widely in areas such as urban planning, archaeology, and military science. In urban planning, for example, viewsheds tend to be areas of particular scenic or historic value that are deemed worthy of preservation against development or other change (Wikipedia, 2006). The viewshed of Lake Monroe and the adjacent St. Johns River varies by weather, time of day, etc., and more importantly, the Lake Monroe viewshed is determined by public and private vantage points around the 21.2 miles of Lake Monroe shoreline.

Lake Monroe is one of the largest lakes in the MSJR basin. Within an oval configuration roughly 6 miles long and 4 miles wide, the lake's 8,546-acre surface area (at 0.0 ft-NGVD) provides a 13.4-mi^2 water body that dominates its surrounding landscape. The visibility of Lake Monroe contrasts to the channelized portions of the river within the MSJR. The riverine portion of the St. Johns River is much narrower and more winding, and thus limited in the scope of visibility from adjacent shorelines. The number of adjacent roadways and public facilities at or near Lake Monroe further increases the visibility of the water body.

An approximately 21.2 miles of shoreline surrounding Lake Monroe varies in land use and environmental settings, with most of the south shoreline being developed and urban; and the remaining lake shorelines on the north, east, and west edges being less developed and more naturally vegetated.

Jurisdictions and Land Use

Lake Monroe falls within two counties, with its northern half in Volusia County and its southern half in Seminole County. The Lake Monroe shoreline in the southern half of the lake in Seminole County is primarily developed and urban, with the exception of an area dominated by wetland vegetation at the east end where the St. Johns River flows into the lake. Lake Monroe is highly visible from the southern shoreline in Seminole County, as this shoreline area is largely cleared and developed with adjacent roads, parks, and commercial facilities. Within the northern half of the lake in Volusia County, the shoreline is generally wooded with scattered pockets of single-family residential development.

The City of Sanford, within Seminole County, is the most intensely developed portion of the Lake Monroe shoreline. The City occupies approximately 3 miles of the south shoreline, with just under 2 miles in public ownership as “either resource protection areas or public facilities, including parks” according to Policy 6-1.4.1 (Sanford, 2000).

As the most urban and developed municipality on the Lake Monroe shoreline, The City of Sanford has specific policies in its comprehensive plan to protect, preserve, and enhance the scenic view of the Lake Monroe shoreline; especially in a 2-mile public segment, including the Sanford Riverwalk, which is a popular attraction among the local residents and tourists. These policies in the comprehensive plan (Sanford, 2000) include:

Policy 1-1.2.3: Improve the Image and Function of the Central Core Area and Adjacent Traditional Neighborhood—*Design strategies shall provide a physical theme for development and redevelopment opportunities which prevents "walling off" the waterfront view and which preserves public access. Within the central business district the Lake Monroe Waterfront is virtually unobstructed and the waterfront view is preserved*.

Policy 1-3.3.4: Redevelopment of Waterfront and Historic Downtown—*The Lake Monroe corridor redevelopment shall continue to emphasize design measures which promote a unique waterfront market place theme reinforced by significant pedestrian oriented urban design amenities*.

Policy 6-1.1.9: Utilize Creative Concepts of Urban Design and Conservation of Environmentally Sensitive Open Space—*The plans shall be designed to preserve existing areas of unrestricted access along the shoreline of Lake Monroe and prevent "walling-off" views of the water*.

Objective 6-1.4: Access To Lake Monroe And Its Tributaries. Policy 6-1.4.1: Require Access Points to be Provided as Needed—*The City shall provide both visual and physical access to Lake Monroe by preventing the "walling-off" of the lakefront and preserving public open space systems adjacent thereto*.

Land uses in the City of Sanford and the adjacent unincorporated portion of Seminole County along the south shoreline of Lake Monroe are relatively stable, with most of the adjacent areas designated for development, conservation, and/or public use already in place. According to City of Sanford and Seminole County zoning and comprehensive plan future land use maps (Sanford, 2006), little or no properties could be developed that would affect the viewshed of the south shoreline of Lake Monroe. The remainder of the Seminole County portion of the Lake Monroe shoreline is unincorporated, with most of this shoreline adjacent to the U.S. 17-92 roadway.

Three municipal entities are located along the northern lake shoreline within Volusia County: the City of DeBary, the City of Deltona, and the community of Enterprise. The Cities of Deltona and DeBary each occupy just over 0.50 mile of the lake shoreline. According to zoning and comprehensive plan future land use maps for the Cities of DeBary (DeBary, 2006) and Deltona (Deltona, 2003a and 2003b), there are only a few wooded properties within the cities on the north shoreline of Lake Monroe that could be developed and affect the lake viewshed (DeBary, 2006; Deltona, 2003a and 2003b). Redevelopment of existing single-family properties could occur, but with Volusia County wetland buffer regulations in place, it would appear the development activities within these municipalities would cause little to no effect on the viewshed of the Lake Monroe shoreline.

The historic community of Enterprise within unincorporated Volusia County, between the Cities of Deltona to the east and DeBary to the west contains the most intensely developed area near Lake Monroe within Volusia County. However, the lake shore area is generally rural and wooded.

Volusia County land use regulations for the unincorporated area of Lake Monroe shoreline, depicted on zoning and comprehensive future land use maps (Volusia County, 2005), indicate little to no development that could be anticipated to occur which would change the viewshed of Lake Monroe along the north shoreline, by the reduction of wooded shoreline vegetation and/or development of shoreline areas. As previously stated, existing Volusia County wetland buffer regulations prevents new construction or redevelopment of existing properties from having any noticeable effect on the viewshed of Lake Monroe at the north shoreline.

The future land use element of the Volusia County comprehensive plan (Volusia County, 2005) includes a specific section titled the “Enterprise Local Plan”, which discourages any increase in land use intensities, densities, and conversions of residential land uses to non-residential uses. The local plan, in fact, encourages lower levels of single-family development than the current condition (Volusia County, 2005). Volusia County’s local plan also includes a specific policy (Policy ENT 1.9.2.1) which calls for expansion of those areas currently designated Environmental System Corridor along the banks of Lake Monroe (Volusia County, 2005). These policies, in conjunction with existing environmental regulation of wetlands buffer requirement, should maintain the existing wooded and natural rural character of the Enterprise area fronting Lake Monroe.

Currently, the scenic view of Lake Monroe is not accessible from most of the northern shoreline because of the existing wooded buffer except at the Lake Monroe Boat Ramp.

This inaccessibility is not anticipated to change in the future, according to the comprehensive plan (Volusia County, 2005).

Roadways

The accessibility of Lake Monroe's scenic view is associated, to a large extent, with the existence of adjacent roadways. Some of the adjacent roadways were built in the 1800s to meet transportation needs related to shipping activities on Lake Monroe and the St. Johns River. The roadways adjacent to Lake Monroe include:

- I-4, at the west edge of the lake.
- U.S. 17/92, at the southern edge of the lake, within Seminole County.
- Lakeshore Drive, along the northern side of the lake.

I-4 runs along the western edge of Lake Monroe and spans over the waters at two locations: a high fixed bridge over the southwestern corner of Lake Monroe at the St. Johns River, and a lower fixed span bridge crossing DeBary Creek (Gemini Springs Run) at the northwestern section of Lake Monroe. Large numbers of people can have a limited view of Lake Monroe each day from the elevated bridge spans of I-4, as this section of I-4 carried an average daily traffic rate of 111,500 occupied vehicles in 2005 (Florida Department of Transportation [FDOT], 2006). A 3-mile section of the I-4 roadway is located on a filled marsh causeway along the western shoreline of Lake Monroe between two bridge spans, but visibility to the lake is blocked by heavy tree coverage. The inaccessibility of the lake view is expected to remain unchanged because the property between the roadway and the lake shoreline is designated on Volusia County zoning maps as *Resource Corridor* (Volusia County, 2006a) and will not be developed in the future.

U.S. 17/92, a four-lane, divided arterial highway, becomes a two-lane road (West Seminole Boulevard) when it runs along the south shoreline within Seminole County. U.S. 17/92 crosses the St. Johns River west of Lake Monroe. Unlike I-4, which crosses Lake Monroe at elevations high above Lake Monroe, U.S. 17/92 is at an elevation much closer to the Lake Monroe water surface. Low elevation of U.S. 17/92, combined with the limited amount of structures and/or trees along the adjacent shoreline, allows for a clear view of Lake Monroe from U.S. 17/92. Within the shore front areas between U.S. 17/92 and Lake Monroe, there are either grassed bank area or developed urban shoreline paths maintained by the City of Sanford and Seminole County, all of which are accessible and open to public use. Approximately 11,800 vehicles use this portion of U.S. 17/92 each day (FDOT, 2006); thus many people can have a clear view of Lake Monroe on a daily basis.

CR 5758 follows the north shoreline of Lake Monroe and is named Lakeshore Drive at its west end and Enterprise Osteen Road at its east end. CR 5758 is a narrow and historic rural roadway with no adjacent bike path, sidewalk, and/or trails at this time. Volusia County has designated CR 5758 as one of its 12 Scenic Roadways throughout the County (Volusia County, 2006b). This roadway runs through the historic community of Enterprise, and provides access to scattered lakeside single-family communities along the shoreline of Lake Monroe.

While the lake is visible from some sections of Lakeshore Drive, the amount of vegetation and tree canopy, along with some steep lakeside banks, greatly limits both public access and clear and open views of the lake that the south shore enjoys. Due to its local road status and meandering geometry, the average daily traffic on this Scenic Roadway of Lakeshore Drive and Enterprise Osteen Road carried an average of 2,340 vehicles per day in 2005 (Volusia County, 2006c); much less than the daily traffic along the south shore of Lake Monroe. Because of this Volusia County Scenic Roadway designation, any construction or reconstruction of this roadway will required a public hearing before such improvements can occur, with primary consideration given to preserving or enhancing the scenic characteristics of this road (Volusia County, 2006b). Thus the lack of lake view from CR 5758 will remain unchanged in the future.

<u>Parks and Trails</u>

There are a number of public park, trail, and lake access areas directly adjacent or within the viewshed of Lake Monroe. These various facilities and areas range in terms of intensity of development and use, and are maintained by various municipal entities. These facilities include (in geographic order clockwise, along the shoreline):

1. Riverwalk—City of Sanford and Seminole County.
2. Memorial Park—City of Sanford.
3. Fort Mellon Park—City of Sanford.
4. Lake Monroe Wayside Park—Seminole County.
5. Lake Monroe Park—Volusia County.
6. Lake Monroe-Gemini Springs-DeBary Hall trail—Volusia County.
7. Gemini Springs—Volusia County.
8. Lake Monroe Boat Ramp/Community Center—City of Deltona.
9. Mariner's Cove Park—Volusia County.
10. Lake Monroe Conservation Area—SJRWMD.

The Riverwalk provides the most open view to Lake Monroe among the developed facilities listed above. Constructed and maintained jointly by the City of Sanford and Seminole County, the Riverwalk is a developed urban public plaza and walkway situated on the cleared south shoreline of Lake Monroe, and a key feature of the City of Sanford's downtown redevelopment efforts. The entire 1-mile-long Riverwalk area is located next to a vertical seawall, with no natural shoreline along its constructed length. The first sections of the Riverwalk were constructed in 2004, with Seminole County's Riverwalk Trail extensions planned to continue for an additional 5-mile length west and north to the Volusia County line. Riverwalk Trail, a paved public walkway, will be located between the U.S. 17/92 roadway and the Lake Monroe shoreline, with no seawall along the adjacent shoreline. The Sanford Riverwalk area is a popular place for local residents and tourists to enjoy the scenic view of Lake Monroe. The activities along the Riverwalk include fishing, walking, and nature observation (Figure 5-22).

Incorporated into the Riverwalk are two City of Sanford park facilities. Memorial Park is a passive-type park bordered by a vertical seawall at the Lake Monroe shoreline. Fort Mellon Park is a more active recreational park just inland of the Riverwalk, which has an open and unobstructed view of the lake and enjoys the cooling effects of lake breezes.

Lake Monroe Wayside Park is maintained by Seminole County, on the east side of the U.S. 17/92 roadway and at the western end of Lake Monroe, where the lake joins the St. Johns River. This 3.5-acre park contains boat ramps, as previously described in Section 5.2.3. Lake Monroe Wayside Park, with covered pavilions and fishing areas, is

FIGURE 5-22.

SANFORD RIVERWALK

Source: ECT, 2006.

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also used by the public for non-boating activities. Visibility to Lake Monroe from this facility is somewhat limited. However, a partial view of the St. Johns River can be afforded from a historic swing bridge in the park next to U.S. 17/92. The surrounding shoreline is wooded and natural, with the exception of the nearby U.S. 17/92 bridge spanning over the St. Johns River into Volusia County.

The Lake Monroe Conservation Area, located on the east shore of Lake Monroe, is a large public land tract which extends from Reid Ellis Road off of SR 415 to the east shore of Lake Monroe (SJRWMD, 2000). Currently, hiking trails and primitive campsites within the Lake Monroe Conservation Area are located in the uplands and palm hydric hammock and out of sight of Lake Monroe. However, future recreational opportunities on this property could include lakeshore trails.

Lake Monroe Park is maintained by Volusia County, just north of Lake Monroe Wayside Park on the opposite side of the St. Johns River. Lake Monroe Park is located on the east side of the U.S. 17/92 roadway and at the western end of Lake Monroe, where the lake joins the St. Johns River. Lake Monroe Park was renovated in 2004 and is equipped with boat ramps described in Section 5.2.3 with covered pavilions and fishing areas. This park is also used by the public for non-boating activities. Although Lake Monroe is not directly visible form the Lake Monroe Park, there is a nice and peaceful view of a large turning basin and small section of the St. Johns River. The surrounding shoreline is wooded and natural. Lake Monroe Park also serves as a trailhead to Volusia County's Lake Monroe-Gemini Springs-DeBary Hall trail, which is located inland from the lake shoreline; thus it is not currently or planned to be within the viewshed of Lake Monroe. Part of the trail is within the viewshed of a section of the St. Johns River.

Gemini Springs consists of three springs within 120 ft of each other on the north rim of Lake Monroe. This Volusia County park offers trails, swimming, picnic, and play areas. Gemini Springs is the subject of an ongoing WRVs assessment. Therefore, Gemini Springs is not discussed in this Lake Monroe WRVs assessment report.

To the east, the City of Deltona maintains the Lake Monroe Boat Ramp on the northern shoreline of Lake Monroe. Lake Monroe Boat Ramp is across Lakeshore Drive from a community center facility to the north. This small park-like facility contains a boat ramp as previously described in Section 5.2.3. Lake Monroe is very visible from the Lake Monroe Boat Ramp, which has a limited number of parking spaces available. There are no public facilities other than the boat ramp in this small park

Still further to the east and on the north shoreline, in the community of Enterprise, Mariner's Cove Park is maintained by Volusia County as both an active and passive park. This park has sports and play areas inland from the lake and outside the Lake Monroe viewshed. There is a small boat ramp (as previously described in Section 5.2.3) located on Bethel Creek, a tributary of Lake Monroe. Most of the Mariner's Cove Park is not within the viewshed of Bethel Creek or Lake Monroe, except at a small tie-up dock by the boat ramp.

Scenic Areas

While Lake Monroe can be viewed without obstruction from most of the open southern shoreline, the best way to enjoy Lake Monroe's scenic beauty is perhaps by boats, on which boaters can view a great variety of wildlife and vegetation up close. The most scenic areas on Lake Monroe include:

- The shoreline at the western end of Lake Monroe and the connecting St. Johns River is lined with a variety of trees and vegetation. Because this area is easily accessible by nearby boat ramps and parks, it is a popular place frequented by kayakers.
- The eastern part of the southern shore is populated with dense hardwood forest with towering cypress trees.
- Pleasant scenery can be enjoyed at both shores of Lake Monroe Canal and adjacent areas, where cypress trees, wildlife, waterfowl, wet prairies, freshwater marshes, and cabbage palm island are found throughout the area as shown in Figures 5-22, 5-23, and 5-24.
- The eastern shore, along the Lake Monroe Conservation Area parcel, has large expanses of freshwater marshes with waterfowl.

FIGURE 5-23.

WETLAND AND WILDLIFE ALONG LAKE MONROE CANAL

Source: ECT, 2006.

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FIGURE 5-24.

CABBAGE PALM ISLAND NEAR LAKE MONROE CANAL

Source: ECT, 2006.

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5.7.4 WRV-6 ASSESSMENT

The following sections present the assessment of the effects of the recommended MFLs hydrologic conditions for Lake Monroe on WRV-6 in terms of scenic view visibility, lake edge vegetation, sediment exposure, and water quality.

Visibility of Scenic Views

The size of Lake Monroe's 13.7-mi^2 surface area makes this water body the dominant feature in this area. The lake is large enough that features on far shorelines are generally too distant to be visible. On the other hand, near shorelines are often beneath the line of sight, especially along the south shoreline, the best vantage point, where the adjacent water edge is beneath the hardened structure (seawall, road edge, etc.). The water edge is generally not visible along the southern shoreline, from either U.S. 17/92 or the paved Sanford Riverwalk, unless the viewer stands directly on top of the seawall. The viewshed of the riverine segments of the St. Johns River in the MSJR basin is limited due to the narrower river surface, meandering river course, and tree canopy blocking views to the river from land. The scenic views of Lake Monroe, by contrast, can be enjoyed from many open vantage points, including roadways, parks, trails, and the open and developed south shoreline.

In general, it is believed that the water body becomes more attractive when the viewer is at an elevation closer to the water surface. The lower line of sight makes the water body appear more immense and brings the viewer closer to the water experience. When the water level is much lower than the viewer, say 100 ft, the water body would appear smaller and confined, and the viewer feels detached from the water experience. This is not an issue in Lake Monroe because the lake level never drops to 1 ft below msl. A maximum withdrawal of 180 cfs from Lake Monroe may lower the lake level by less than 0.25 ft at the most, which is not perceptible to viewers on shore at any of the public roadways, parks, and other vantage points described previously. Additionally, with the large range of historic water level fluctuation (Figure 3-1), a maximum lake level drawdown of less than 0.25 ft would be even less noticeable (Robison, 2004b).

Lakeshore Vegetation

Lakeshore vegetation around Lake Monroe contributes greatly to the scenic beauty of the lake. According to transect data presented by Mace (2006a), the lakeshore edge elevation of hardwood swamps is typically 1.7 ft-NGVD. This elevation is also considered an optimal stage in terms of visual setting. Based on the frequency-duration information provided by Robison (2004b), a frequency analysis for the threshold stage of 1.7 ft-NGVD was conducted for durations of 60, 90, and 120 days (Table 5-19).

Table 5-19. Frequency Analysis of Threshold Stage for Aesthetics of Lakeshore Vegetation

Threshold Stage (ft-NVGD)	Duration (Days)	No. of Years in a Century Threshold Stage is Continuously Not Exceeded*		
		Existing	MFLs	Difference
1.7	60	94	95	1
1.7	90	90	91	1
1.7	120	78	82	4

* Water levels fall below the threshold stage for the indicated duration.

Source: ECT, 2006.

The results of the frequency analysis indicate that, under existing conditions, the threshold stage of 1.7 ft-NGVD would be continuously not exceeded for 60 days 94 times in 100 years (Table 5-18). Under the recommended MFLs hydrologic conditions, the threshold stage would be continuously not exceeded for 60 days 95 times in a century; an increase of 1 dewatering event per 100 years when compared to existing hydrologic conditions. Similar results were obtained from the 90- and 120-day durations analyses. A comparison of the existing and recommended MFLs hydrologic conditions indicates that the number of times the threshold stage of 1.7 ft-NGVD would be continuously not exceeded for a duration of 60 and 120 days would increase by 1 and 4 times per century, respectively, under the recommended MFLs hydrologic conditions (Table 5-19).

In ECT’s opinion, the recommended MFLs hydrologic conditions will protect the aesthetics of lakeshore vegetation in Lake Monroe because the frequency of dewatering of the threshold stage of 1.7 ft-NGVD would not be appreciably increased.

Sediment Exposure

The Lake Monroe bottom can be exposed and becomes visible during low water level conditions. The exposed bottom sediment does not necessarily detract from the scenic value of Lake Monroe. For example, an exposed sandy bottom may have the appearance of beaches (Figure 5-25), and exposed mud flat can be foraging grounds for waterfowl (Figure 5-26). However, when trash and unsightly debris are exposed, the view can become unpleasant (Figure 5-27). Exposed sediment can sometimes release unpleasant odors which may also detract from WRV-6 for Lake Monroe.

As discussed previously, due to the steep banks and seawall along most of the Lake Monroe shoreline, the water edge or exposed sediment is usually not visible unless the viewers stand on top of the seawall. The size of Lake Monroe (4 miles wide) also makes exposed sediment at the far shore not visible.

Based on on-site observations of Lake Monroe shoreline conditions, the sediment at the foot of the seawall at Sanford Riverwalk is rarely exposed due to deeper water there. Farther to the west, the sediment at the foot of the seawall near U.S. 17/92 begins to be exposed when the water level drops below 1.0 ft-NGVD, where the water surface area is 9,081 acres (Table 3-1). For the purposes of this analysis, it was assumed that if 1 percent of the lake bottom became exposed, sediment exposure would become a distraction to the scenic views of Lake Monroe. This corresponds to a lake water surface area of 8,990 acres and a stage of 0.85 ft-NGVD (Table 3-1). Therefore, a stage of 0.9 ft-NGVD was used as a threshold criterion to assess WRV-6 protection against sediment exposure. Based on the frequency-duration information provided by Robison (2004b), frequency analysis for the threshold stage of 0.9 ft-NGVD was conducted for durations of 14, 30, 60, and 90 days (Table 5-20).

FIGURE 5-25.

EXPOSED SANDY BEACH ON LAKE MONROE SHORE NEAR U.S. 17/92

Source: ECT, 2006.

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FIGURE 5-26.

MUD FLAT AT EASTERN SHORE OF LAKE MONROE

Source: ECT, 2006.

ECT
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FIGURE 5-27.

EXPOSED DEBRIS NEAR U.S. 17/92

Source: ECT, 2006.

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Table 5-20. Frequency Analysis of Threshold Stage for WRV-6 Protection Against Sediment Exposure

Threshold Stage (ft-NVGD)	Duration (Days)	No. of Years in a Century Threshold Stage is Continuously Not Exceeded*		
		Existing	MFLs	Difference
0.9	14	83	89	6
0.9	30	66	81	15
0.9	60	53	61	8
0.9	90	41	45	4

* Water level falls below the threshold stage for the indicated duration.

Source: ECT, 2006.

The results of frequency analysis indicate that, under existing conditions, the threshold stage of 0.9 ft-NGVD would be continuously not exceeded for 14 days 83 times in 100 years (Table 5-8). Under the recommended MFLs hydrologic conditions, the threshold stage would be continuously not exceeded for 14 days 89 times in a century; an increase of 6 dewatering events per 100 years when compared to existing hydrologic conditions. Similar results were obtained from the 30-, 60-, and 90-day durations analyses. A comparison of the existing and recommended MFLs hydrologic conditions indicates that the number of times the threshold stage of 0.9 ft-NGVD would be continuously not exceeded (dewatered) for a duration of 30, 60, and 90 days would increase by 15, 8, and 4 times per century, respectively, under the recommended MFLs hydrologic conditions (Table 5-20).

In ECT's opinion, the recommended MFLs will protect against increased sediment exposure in Lake Monroe because the frequency of dewatering of the threshold stage of 0.9 ft-NGVD would not be appreciably increased.

<u>Water Clarity and Appearance</u>

When the water level of Lake Monroe decreases, the hydraulic resident time increases (Table 3-1). At extreme low water conditions, the water in Lake Monroe becomes nearly stagnant and algae might appear. During a field trip on May 23, 2006, when the lake stage was 0.75 ft-NGVD, an obvious algae bloom was observed along the north shoreline, especially in the vicinity of the Lake Monroe Boat Ramp (Figure 5-28). The lake view had become aesthetically unpleasant. Water quality data for Lake Monroe also show the effects of low water stage on Chlorophyll *a* (Chl *a*) (Figure 5-29). High turbidity could also be related to low water level, as shown in Figure 5-30. According to typical water quality values for Florida lakes (Friedemann and Hand, 1989), the 50th percentile of Chl *a* and turbidity values in Florida lakes were 18.5 micrograms per liter (µg/L) and 5 JTU, respectively. Examination of Figures 5-29 and 5-30 indicates that the water level in Lake Monroe must be above 1.5 to 2.0 ft-NGVD to have Chl *a* and turbidity values lower than the median values among Florida lakes. Therefore, a lake stage of 1.5 ft-NGVD is considered a threshold stage for WRV-6 protection in terms of water clarity. Based on the frequency-duration information provided by Robison (2004b) frequency analysis for a threshold stage of 1.5 ft-NGVD was conducted for durations of 30, 60, and 90 days (Table 5-21).

Table 5-21. Frequency Analysis of Threshold Stage for Water Clarity

Threshold Stage (ft-NVGD)	Duration (Days)	No. of Years in a Century Threshold stage is Continuously Not Exceeded*		
		Existing	MFLs	Difference
1.5	30	95	96	1
1.5	60	88	91	3
1.5	90	78	87	9

* Water levels fall below the threshold stage for the indicated duration.

Source: ECT, 2006.

FIGURE 5-28.

ALGAE BLOOM NEAR LAKE MONROE BOAT RAMP (MAY 23, 2006)

Source: ECT, 2006.

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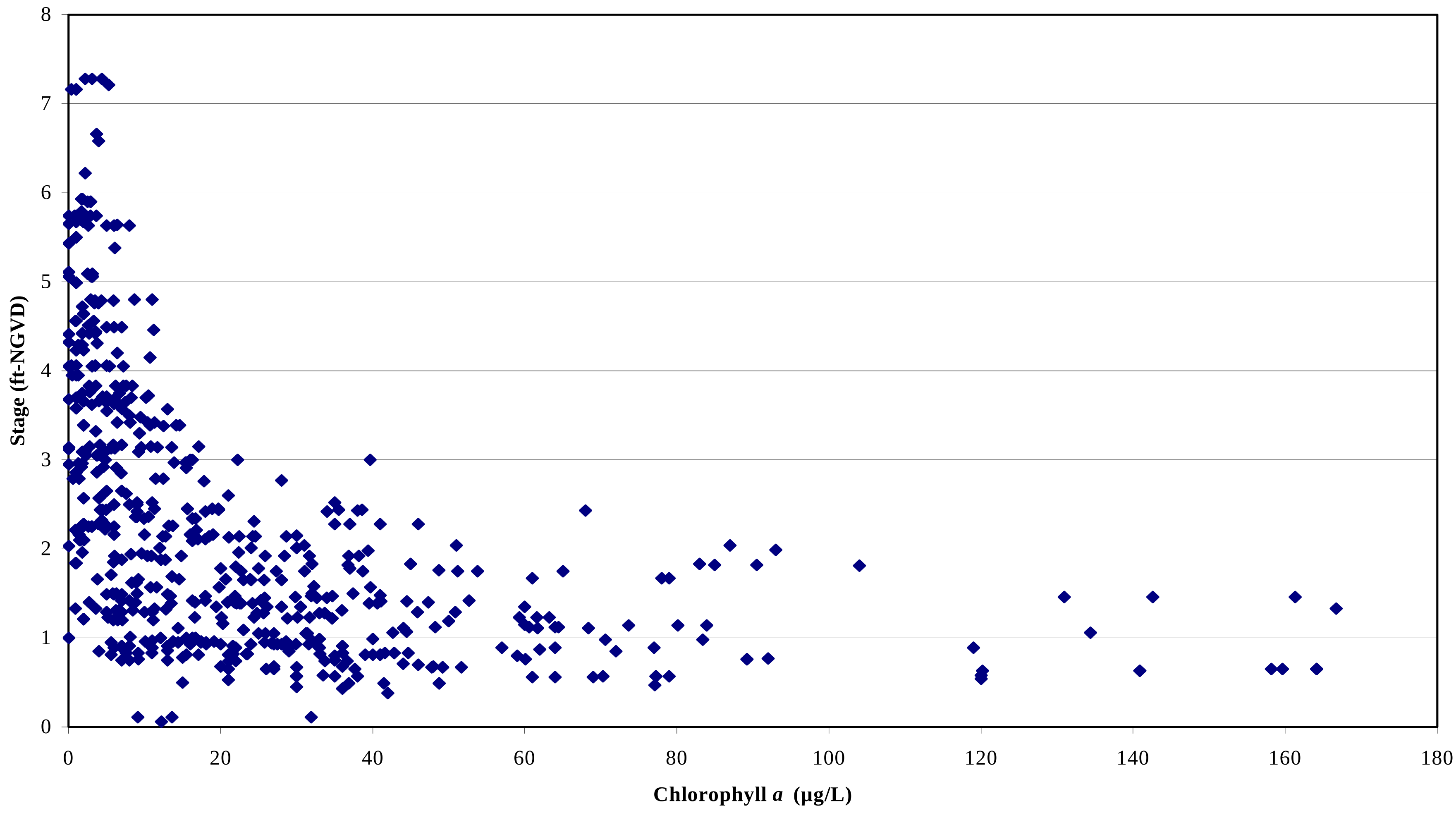

FIGURE 5-29.

Chl *a* VERSUS LAKE MONROE STAGE (ALL LOCATIONS, 1991-2005)

Source: ECT, 2006.

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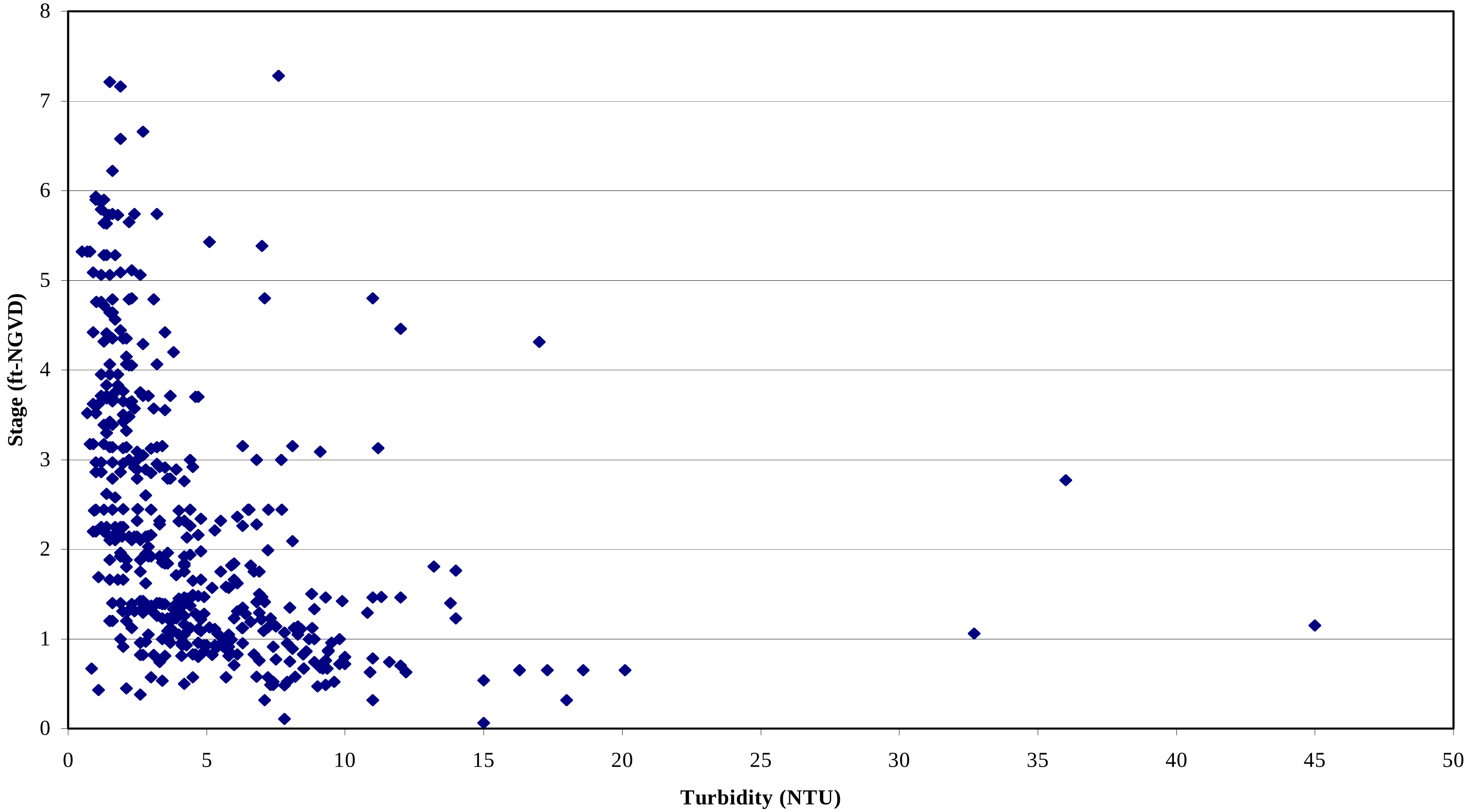

FIGURE 5-30.

TURBIDITY VERSUS LAKE MONROE STAGE (ALL LOCATIONS, 1991-2005)

Source: ECT, 2006.

Environmental Consulting & Technology, Inc.

The results of the frequency analysis indicate that, under existing conditions, the threshold stage of 1.5 ft-NGVD would be continuously not exceeded for 30 days 95 times in 100 years (Table 5-21). Under the recommended MFLs hydrologic conditions, the threshold stage would be continuously not exceeded for 30 days 96 times in a century; an increase of 1 dewatering event per 100 years when compared to existing hydrologic conditions. Similar results were observed for the 60 and 90 day durations analyses. A comparison of the existing and recommended MFLs hydrologic conditions indicates that the number of times the threshold stage of 1.5 ft-NGVD would be continuously not exceeded for a duration of 60 and 90 days would increase by 3 and 9 times per century, respectively, under the recommended MFLs hydrologic conditions (Table 5-21).

In ECT's opinion, the recommended MFLs will protect the water clarity of Lake Monroe because the frequency of dewatering of the threshold stage of 1.5 ft-NGVD would not be appreciably increased.

5.7.5 SUMMARY

The results of frequency analysis show that water withdrawals under the recommended MFLs for Lake Monroe would not unreasonably nor unacceptably change the frequency of the threshold stages with critical durations required to protect the following: aesthetics of lakeshore vegetation, against sediment exposure, and water clarity. Based upon the findings of the WRV assessment, it is concluded that the recommended MFLs hydrologic conditions will protect Lake Monroe's aesthetic and scenic attributes.

5.8 WRV-7: FILTRATION AND ABSORPTION OF NUTRIENTS AND OTHER POLLUTANTS

5.8.1 METHODOLOGY

WRV-7 is defined as the reduction in concentration of nutrients and other pollutants through the processes of filtration and absorption (i.e., the removal of suspended and dissolved materials as these substances move through the water column, soil, or substrate and associated organisms). The representative functions of WRV-7 are ecosystem productivity and water quality protection. The general indicator of WRV-7 protection is the adsorption/transformation of nutrients/pollutants by wetland vegetation and the absorption of nutrients/pollutants by wetland soils and nearshore lake sediments. The specific indicators of protection for the adsorption/transformation of nutrients/pollutants by wetland vegetation are:

Continuously exceeded threshold stages of:

- 4.0 ft-NGVD (the maximum range of the floodplain hardwood swamp elevation)
- 2.3 ft-NGVD (the maximum range of the floodplain shallow marsh elevation)

and continuously not exceeded threshold stages of:

- 1.0 ft-NGVD (the maximum range of the floodplain deep marsh elevation)
- -0.2 ft-NGVD (for in-lake littoral zone vegetation)

for critical durations of 14, 30, and 60 days.

The specific indicators of protection for the adsorption of nutrients/pollutants by wetland soil and nearshore lake sediments are a continuously not exceeded threshold stage of 0.0 ft-NGVD, for durations of 30 and 60 days.

The determination of these threshold stages is described in Sections 5.8.2 and 5.8.3.

Dierberg (2006) evaluated the effects of emergent/submerged vegetation and soils on WRV-7 under the existing and the recommended MFLs hydrologic conditions for Lake Monroe. The following sections are mostly extracted from Dierberg (2006).

5.8.2 EFFECTS OF FLOODPLAIN/LITTORAL VEGETATION ON WRV-7

Emergent fringing wetlands occupy extensive areas in the eastern and western parts of Lake Monroe (Figure 5-3) and provide ecological values with respect to nutrient absorption, wildlife habitat, and water resource values (i.e., erosion and flood control). For example, drainage culverts under I-4 route stormwater runoff through the western herbaceous wetlands before it reaches the lake.

The effect of a surface water withdrawal from Lake Monroe on the herbaceous and woody contiguous wetlands was evaluated because these communities occupy the outermost regions of the lake, and may be affected by a sustained surface water withdrawal, especially in the shallow marshes.

Investigators in Florida (Harris *et al*., 1995; Olila *et al*., 1997; White *et al*., 2004) have reported that water level drawdowns in emergent marshes tend to favor solubility of nutrients, which, in turn, has the potential of producing high nutrient fluxes during reflooding, although this does not occur all the time in other places in the world (DeGroot and Van Wijck, 1993; Baldwin *et al*., 2000). Therefore, the degree of nutrient release and assimilation in the fringing emergent wetlands, as well as the composition of the plant communities, depends to a large extent on the frequency and duration of inundation. According to transect data presented in Mace (2006b), the 2.5th percentile elevations (i.e., close to the maximum elevation) for the three major emergent community types, the hardwood swamp, shallow marsh, and deep marsh, are 4.0, 2.3, and 1.0 ft-NGVD, respectively. The 2.5th percentile was chosen because of the variability and uncertainty in defining the absolute maximum (i.e., zero percentile) elevation. Therefore, elevations of 4.0, 2.3, and 1.0 ft-NGVD were used as the threshold stages for WRV-7 assessment in terms of floodplain and littoral vegetation. In addition to the wetland communities, in-lake vegetation such as *Scirpus* sp. also provides functions for nutrient absorption in Lake Monroe. Based on the vegetation survey conducted by ECT (Section 5.3.3), the threshold stage for in-lake vegetation is -0.4 ft-NGVD.

Based on the frequency-duration information provided by Robison (2004b), frequency analyses for threshold stages of 4.0 ft-NGVD (the upper range of hardwood swamp elevation), 2.3 ft-NGVD (the upper range of shallow marsh elevation), and 1.0 ft-NGVD (the upper range of deep marsh elevation), and -0.4 ft-NGVD (protection for *Scirpus* sp.) were evaluated for durations of 14, 30, and 60 days (Table 5-22).

Table 5-22. Frequency Analysis of Threshold Stage for WRV-7 Protection in Terms of Emergent Vegetative Fringe

Threshold Stage (ft-NVGD)	Duration (Days)	No. of Years in a Century Threshold Stage is Continuously Exceeded*		
		Existing	MFLs	Difference
4.0	14	42	40	2
4.0	30	37	37	0
4.0	60	24	23	1
2.3	14	81	78	3
2.3	30	68	65	3
2.3	60	57	56	1

Threshold Stage (ft-NVGD)	Duration (Days)	No. of Years in a Century Threshold Stage is Continuously Not Exceeded†		
		Existing	MFLs	Difference
1.0	30	81	83	2
1.0	60	61	71	10
-0.4	14	<2	<2	0
-0.4	30	<2	<2	0
-0.4	60	<2	<2	0

* Water level rise above threshold stage for the indicated duration.
† Water level falls below threshold stage for the indicated duration.

Source: Dierberg, 2006.

Frequency analysis (Table 5-22) indicates that water levels under the recommended MFLs for Lake Monroe would not appreciably decrease the frequency that the threshold stages for maximum elevations of hardwood swamp and shallow marsh (i.e., 4.0 and 2.3 ft-NGVD, respectively) are continuously exceeded for 14, 30, or 60 day durations, in comparison to existing hydrologic conditions. Similar analyses determined that water levels under the recommended MFLs for Lake Monroe would not appreciably increase the frequency that the threshold stages for maximum elevations of deep marsh and in-lake littoral vegetation beds (i.e., 1.0 and –0.4 ft-NGVD, respectively) are continuously not exceeded for 14, 30, or 60 day durations, in comparison to existing hydrologic conditions.

Slightly more frequent low stage events attributable to water withdrawals under the recommended MFLs, would not necessarily cause the export of excess nutrients to the pelagic zone of the lake. Although the fringing wetland communities are hydrologically connected to the open water over the long term, the wetland communities have a delayed linkage to the pelagic zone in the short term. Bathymetry, weak advection, and ground water interactions can delay the water and materials exchange between littoral and pelagic zones in the lake.

Even though the more extensive herbaceous wetland communities along the eastern and western shorelines of Lake Monroe are less hydrologically isolated from the pelagic zone than the forested wetlands primarily because of the lower ground elevations (Mace, 2006b), the dense herbaceous wetland plants can still provide an imposing physical barrier to water exchange between the wetland and adjacent open lake waters. In practical terms, the delay provides an opportunity for biogeochemical processes in each zone to proceed somewhat independent of each other. Thus, nutrient cycling can occur within the wetland communities to the extent that assimilation of upland-originating nutrients, or those released *in situ*, may occur before there is exchange with the open water.

A concerted effort has been made to determine the phosphorus exchanges between littoral (both submerged and emergent biotypes) and pelagic zones under low and high water levels in Lake Okeechobee (Sheng and Lee, 1991; Dierberg, 1992; Dierberg, 1993a; Sheng, 1993; Harris *et al*., 1995; Havens, 1997). It was concluded that there were water quality differences between the littoral and pelagic zones. Phosphorus generated in the littoral zone is retained by biological uptake under phosphorus-limited conditions and by a lack of hydraulic exchange under low and intermediate water levels. When water levels are high, leading to more water exchange between the littoral and pelagic zones, the littoral zone likely serves as a phosphorus sink for the imported phosphorus.

In ECT's opinion, the recommended MFLs hydrologic conditions will protect the adsorption/transformation of nutrients/pollutants by wetland vegetation and the absorption of nutrients/pollutants by wetland soils and nearshore lake sediments because the frequencies of flooding and dewatering of these critical elevations would not be appreciably altered.

5.8.3 EFFECTS OF WETLAND SOILS AND NEARSHORE LAKE SEDIMENTS ON WRV-7

Nearshore Lake Sediment

One of the concerns regarding an increased frequency and duration of desiccation caused by surface water withdrawals is the oxidation of the labile organic nutrient pool. This oxidation can result in the conversion of organic nutrients into labile inorganic nutrients, which can be subsequently released to the water column.

The minimum elevation of Lake Monroe deep marshes (0.0 ft-NGVD) is considered to be the threshold stage for WRV-7 protection in terms of the effect of nearshore sediment. Based on the frequency-duration information provided by Robison (2004b), the frequency of occurrence for the water level falling below the threshold stage (0.0 ft-NGVD) for durations of 30 and 60 days were determined for both the existing and recommended MFLs hydrologic conditions (Table 5-23).

The results of frequency analysis indicate that, under existing conditions, the threshold stage of 0.0 ft-NGVD would be continuously not exceeded for 30 days 6 times in 100 years (Table 5-23). Under the recommended MFLs hydrologic conditions, the threshold stage would be continuously exceeded for 30 days 16 times in a century; an increase of 10 dewatering events per 100 years when compared to existing hydrologic conditions. Similar results were obtained from the 60-day duration analysis. A comparison of the existing and recommended MFLs hydrologic conditions indicated that the number of times the threshold stage of 0.0 ft-NGVD would be continuously not exceeded (dewatered) for a duration of 60 days would increase by 2 times per century, under the recommended MFLs hydrologic conditions (Table 5-23).

In ECT's opinion, the recommended MFLs hydrologic conditions will protect the adsorption of nutrients/pollutants by nearshore lake sediments because the exposure of these sediments would not be appreciably increased.

Table 5-23. Frequency Analysis of Threshold Stage for WRV-7 Protection in Terms of Nearshore Sediment

Threshold Stage (ft-NVGD)	Duration (Days)	No. of Years in a Century Threshold Stage is Continuously Not Exceeded*		
		Existing	MFLs	Difference
0.0	30	6	16	10
0.0	60	4	6	2

* Water level falls below the threshold stage for the indicated duration.

Source: ECT, 2006.

Wetland Soils

Dierberg (2006) conducted a field study on June 20, 2006, to investigate the herbaceous wetland near Transect 7. The Lake Monroe stage level was 0.5 ft-NGVD, which corresponds to the 88th percentile of the lake stage. This low water condition presented an opportunity to survey the wetland communities, soils, and ground water elevations under very dry conditions. At about 60 meters inland from the shoreline, the ground water elevation in the peat and muck soils of the deep marsh was about 0.5 ft (15 centimeters [cm]) below ground level. The thick peat and muck layers, and the shallow ground water surface, attest to an environment that is hydrated and anoxic below ground even under very dry conditions. These conditions inhibit the oxidation of soils and the concomitant release of nutrients. Because of the low ground elevations and high ground water table, the soils and plant communities of the deep marsh will remain protected by the recommended MFLs hydrologic conditions for Lake Monroe.

5.8.4 SUMMARY

Dierberg (2006) established three threshold stages based on ground elevations of the various wetland types (submerged, hardwood swamp, and shallow and deep marsh) to evaluate the effects of the recommended MFLs hydrologic conditions on nutrient assimilation and adsorption in Lake Monroe. Frequency analyses were conducted for each threshold stage and for durations of 14, 30, and 60 days (Table 5-22). The frequency analyses results indicated that the recommended MFLs hydrologic conditions for Lake Monroe would not appreciably affect the frequencies of flooding or dewatering of threshold stages (Table 5-22).

The WRV-7 assessment indicated that the recommended MFLs hydrologic conditions for Lake Monroe would have negligible effects on the nutrient assimilation and adsorption resource value of all the littoral zones within and surrounding Lake Monroe. The recommended MFLs hydrologic conditions would not markedly affect WRV-7 in emergent wetland communities because of high water table elevations during drought in the deep marsh, a likely low soil phosphorus content in the shallow marsh, minor increase (less than 10 more events in a century) in the frequency of threshold dewatering events, and the hydraulic disconnection between emergent wetlands and the open water of Lake Monroe.

Based on the WRV-7 assessment conducted by Dierberg (2006), it is concluded that the recommended MFLs will protect WRV-7.

5.9 WRV-8: SEDIMENT LOADS

5.9.1 METHODOLOGY

For purposes of this assessment, sediment load is defined as the transport of inorganic materials, suspended in water, which may settle or rise, often depending on the turbulence and velocity of water. Inorganic particles include sand, silt, and clay. The representative function of WRV-8 is the sediment transport in the lake. The general indicator for WRV-8 protection is to maintain sediment transport in the lake. The specific indicators of protection are velocities in the lake and changes in sediment transport by the recommended maximum freshwater withdrawal limit. The results of a hydrodynamic and sediment transport modeling study conducted by Jain and Mehta (2006) were used to assess WRV-8.

5.9.2 SEDIMENT DATA

According to Anderson *et al.* (2004), the only exposed geologic units near Lake Monroe are of Recent Age, and consist of fine to coarse quartz sands with a thickness of approximately 10 to 80 ft (3 to 25 meters). The sand deposits are interbedded with clay layers. Shell fragments are present in the vicinity of the St. Johns River. The clay layers rest unconformably upon Pliocene or late Miocene Age deposits of sticky blue clay and shell beds (Nashua marl), which are underlain by the Hawthorn Group containing interbedded calcareous clay and limestone sediment of middle Miocene Age (Anderson *et al*., 2004).

Sediment data collected by Anderson *et al*. (2004) indicated that Lake Monroe has a mean floc thickness of 0.5 ft (15 cm) and sediment thickness of 0.1 to 0.7 ft (3 to 20 cm). Three primary sediment types were identified on the bottom of Lake Monroe: gyttja, peat, and sand/clay/grey mud (Anderson *et al*., 2004). Gyttja is the nutrient-rich, organic, decomposed material at the lake bottom; which is composed of marl, remains of plankton and decomposed plant, shells of diatoms, and fecal material (Rook, 2004). Generally, the upper sediment layers consisted of low density organic gyttja overlying low density peat or high density sand/clay/grey mud. However, in some sandy cores, there was little or no organic layer at the sediment surface (Anderson *et al*., 2004). Radiometric dating by Anderson *et al*. (2004) indicated that sedimentation rates in Lake Monroe were low (0.5 ft of organic-rich gyttja in the last 100 years). Prior to 1880 to 1900, Lake Monroe was most likely a shallow marsh. Conditions seem to have changed around 1900 and fine grained, organic-rich gyttja began to form in Lake Monroe (Anderson *et al*., 2004). The sources of the modern gyttia layer could be nutrient loading or an allochthonous source from the drainage basin.

Anderson *et al*. (2004) analyzed sediment data collected at 60 locations. Table 5-24 summarizes the floc and sediment depths in Lake Monroe. Figures 5-31 and 5-32 present the maps of floc and sediment thickness in Lake Monroe. Table 5-25 shows the percentage of organic matter in gyttja, peat, and sand/clay/mud layers in Lake Monroe.

Table 5-24. Summary of Floc and Sediment Depths in Lake Monroe

Statistics	Floc (ft)	Sediment (ft)
Mean	0.20	4.35
Standard Deviation	0.15	1.94
Median	0.16	4.69
Minimum	0	0.75
Maximum	0.66	8.2

Source: Anderson *et al*., 2004.

Table 5-25. Summary Statistics of Organic Matter in Lake Monroe

Statistics	Organic Matter (%)		
	Gyttja	Peat	Sand/Clay/Mud
Mean	35.3	61.0	7.0
Standard Deviation	22.9	14.8	11.9
Minimum	2.8	7.7	0.6
Maximum	81.9	93.0	64.0

Source: Anderson *et al*., 2004.

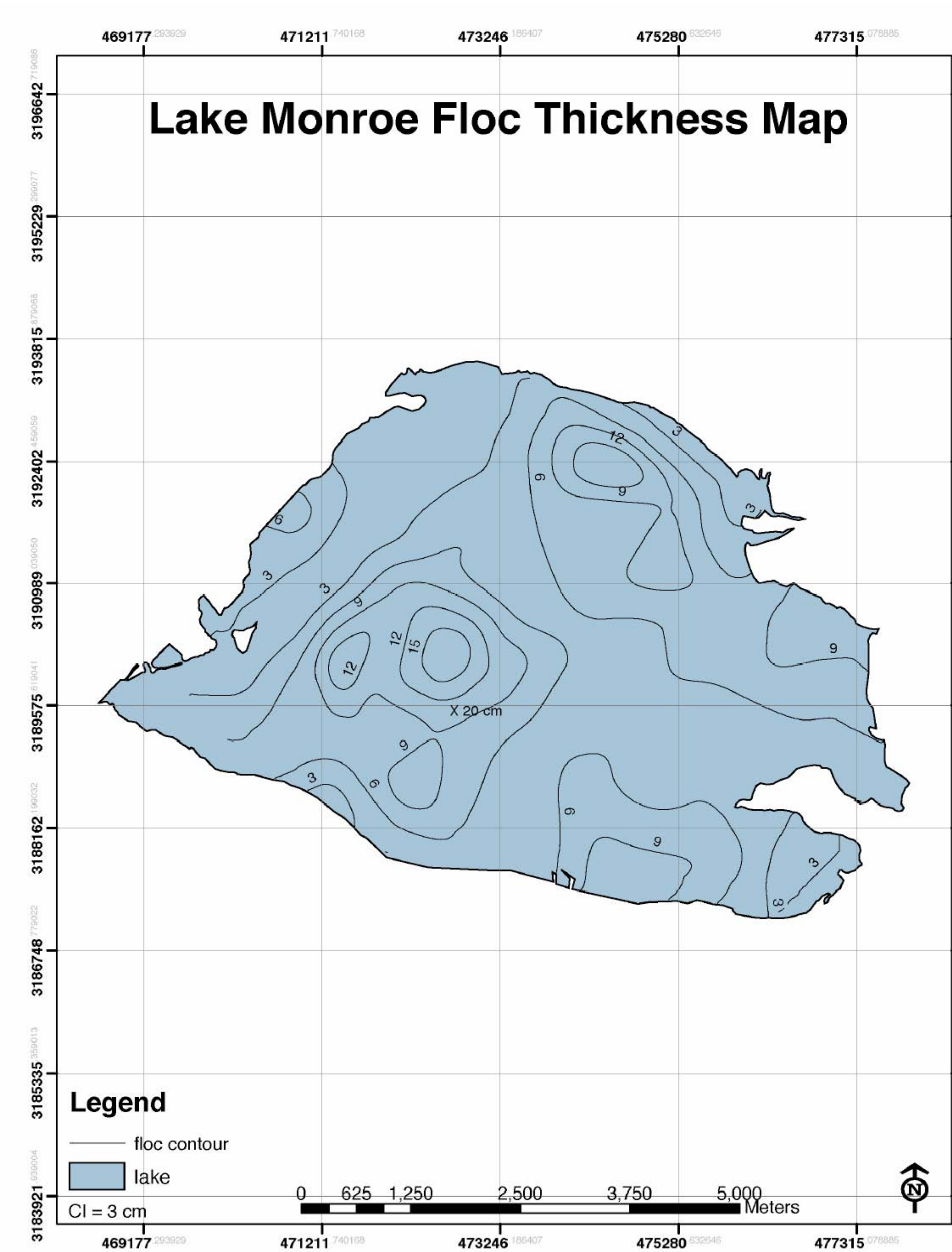

FIGURE 5-31.

FLOC THICKNESS MAP FOR LAKE MONROE

Source: Anderson *et al*., 2004.

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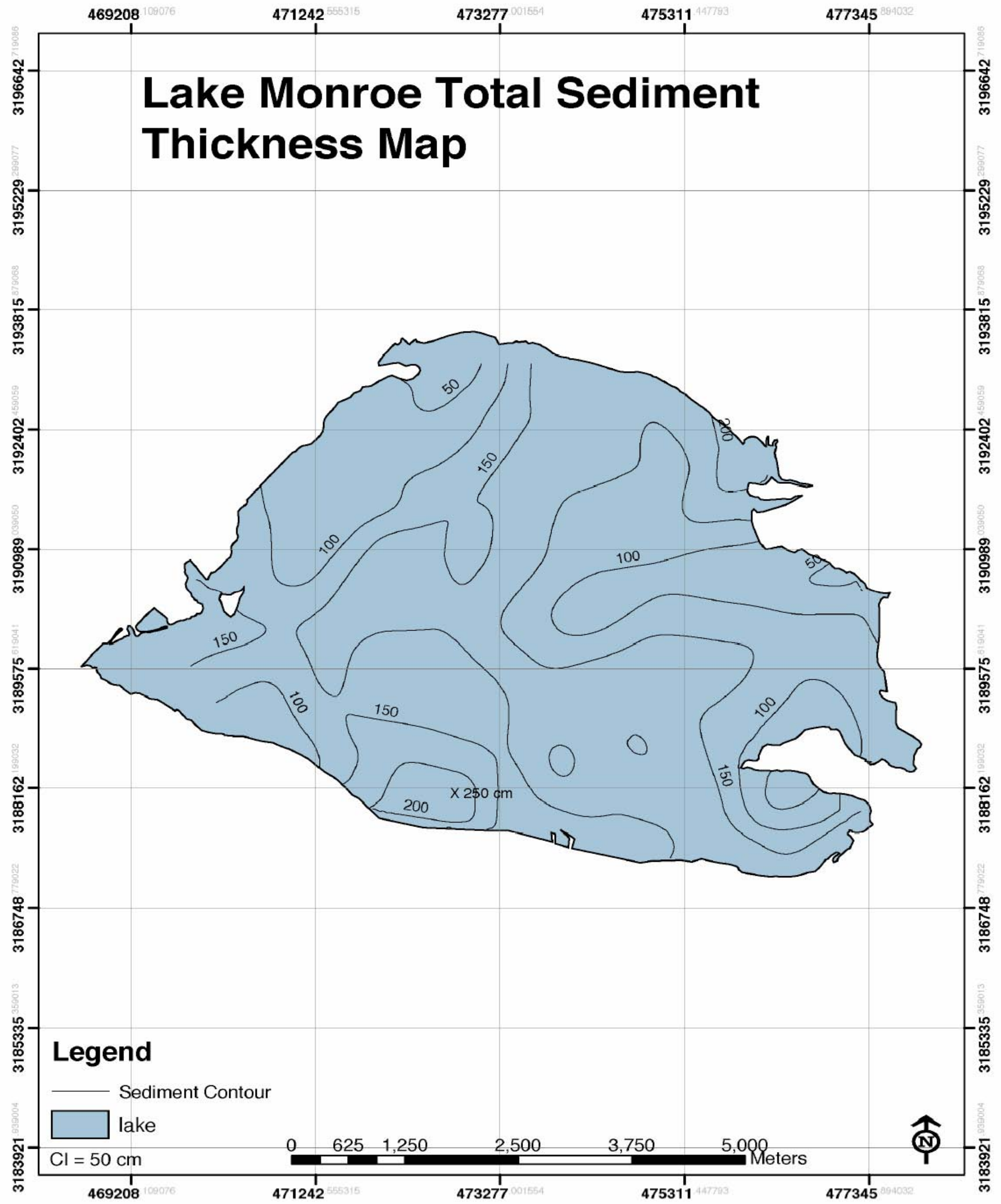

FIGURE 5-32.

SEDIMENT THICKNESS MAP FOR LAKE MONROE

Source: Anderson *et al*., 2004.

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Battelle (2004) conducted sediment sampling and analysis at eight locations in Lake Monroe. Figure 5-33 presents the sediment sampling locations. Figure 5-34 shows the grain-size distribution of the surface sediment samples. Table 5-26 presents the sediment fractions, median grain size (D_{50}), and other sediment characteristics. The data showed that most of the sediment fraction in Lake Monroe is sand and silt. The clay content ranges from 1.4 to 2.5 percent.

Table 5-26. Summary of Sediment Grain Size Data in Lake Monroe

Station	Clay (%)	Silt (%)	Sand (%)	Mud (%)	D_{25} (mm)	D_{50} (mm)	D_{75} (mm)
LMAC	2.5	65.4	32.1		0.020	0.041	0.076
MONA	1.4	18.1	80.5	19.5	0.104	0.242	0.378
MONB	2.0	57.1	40.9	59.1	0.024	0.050	0.099
MONC	1.8	63.7	34.5	65.5	0.023	0.046	0.080
MOND	2.2	25.5	72.3	27.7	0.049	0.105	0.154
MONE	2.4	65.2	32.4	67.6	0.020	0.041	0.078
MONF	1.8	31.4	66.8	33.2	0.037	0.110	0.186
MONG	1.5	32.3	66.2	33.8	0.039	0.118	0.423
Average	2.0	44.8	53.2	43.8	0.040	0.094	0.184

Source: Battelle, 2004.

Battelle (2004) conducted a sediment quality study throughout SJRWMD. Several sampling sites were located in Lake Monroe (Figure 5-33). Lake Monroe sediment contained slightly elevated levels (higher than the reference concentration) of polynuclear aromatic hydrocarbon (PAH), total polychlorinated biphenyl (PCB), total DDT, chlordane, arsenic, chromium, copper, lead, and mercury. It was concluded that the slightly elevated contamination that was identified in parts of this lake was quite spotty and was generally isolated in a few areas with high organic carbon in the sediment and was, as a whole, of no significant concern.

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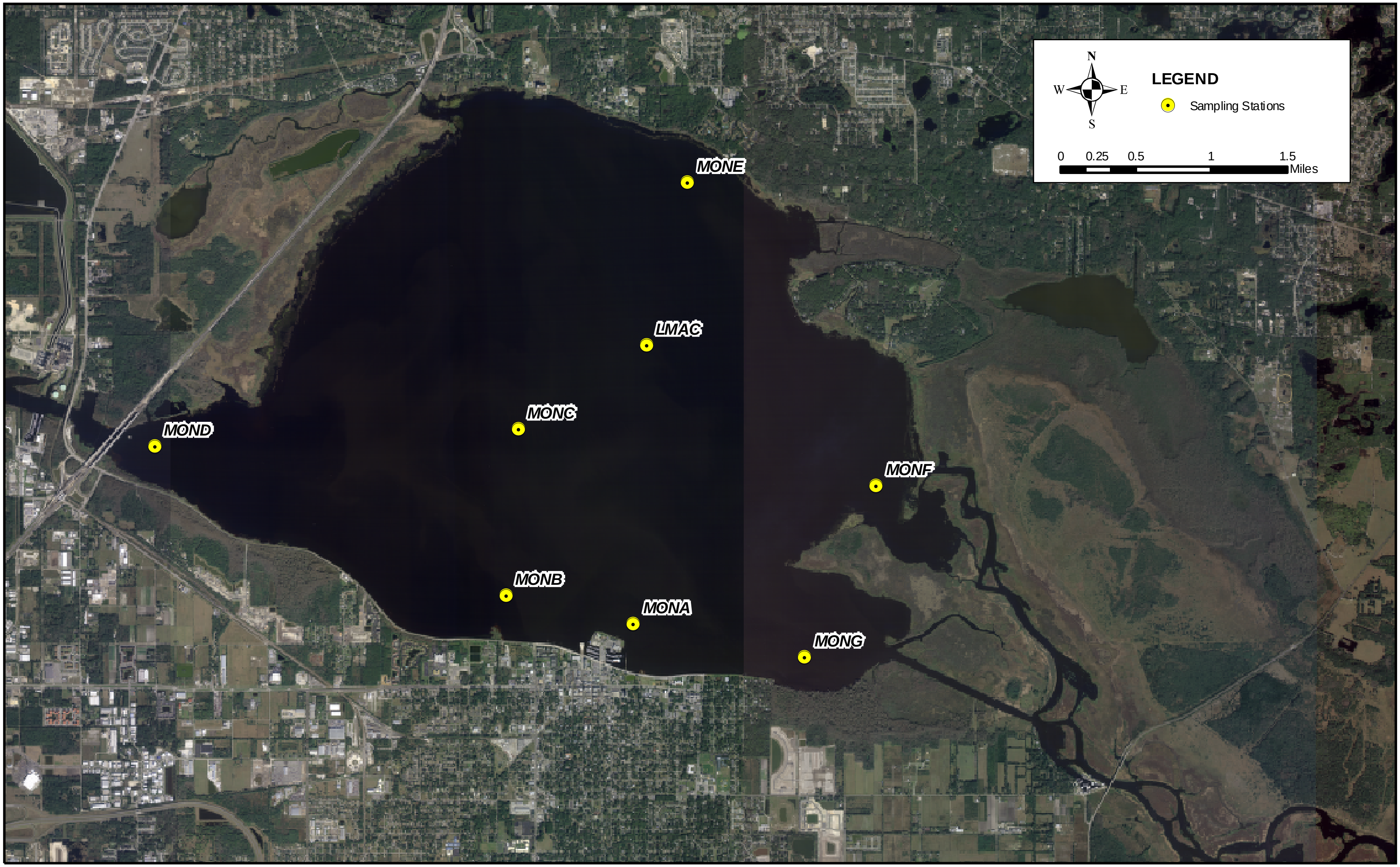

FIGURE 5-33.

SEDIMENT SAMPLING STATIONS

Source: ECT, 2006; Battelle,2004.

* Images were flown on January 1, 2004.

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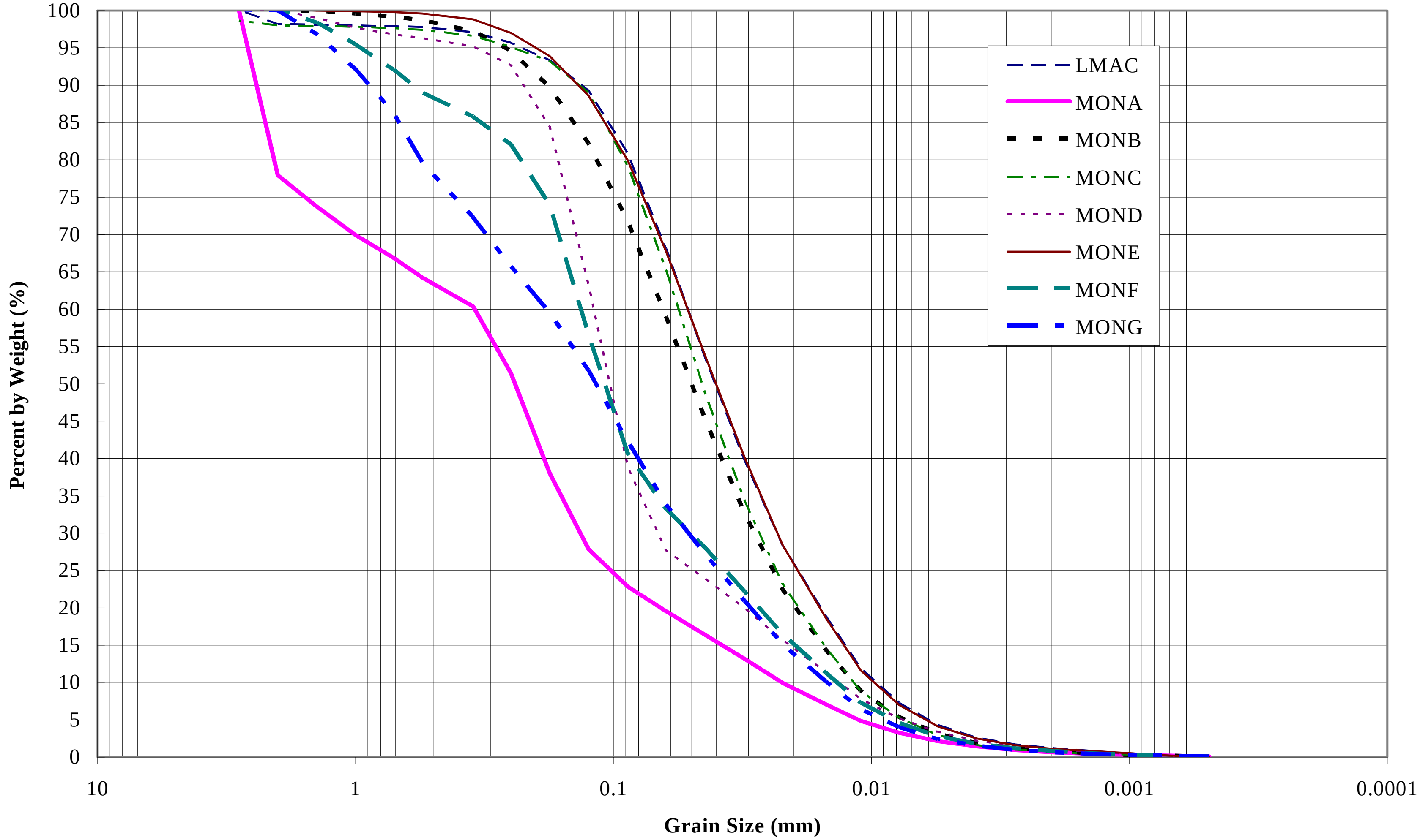

FIGURE 5-34.

LAKE MONROE SEDIMENT GRAIN SIZE DISTRIBUTION AT VARIOUS LOCATIONS

Sources: ECT, 2004; Battelle, 2004.

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5.9.3 SEDIMENT TRANSPORT PROCESSES

Sediments can be carried to and deposited in water bodies such as Lake Monroe and the St. Johns River by wind, stormwater surface runoff, or river flow. Larger sediment particles are usually deposited rather quickly to the floodplain and the river bed, while smaller sediment particles are transported by river flow in two modes: suspended load and bed load. The suspended load is supported by turbulence and transported by the river current. When water velocity decreases, the turbulent intensity also decreases, causing larger particles of sand and silt to be deposited to the river bottom and become part of the bed load. The bed load material is transported by shear stress at the water/sediment interface or by turbulence at the boundary layer. When the river flow velocity increases, the turbulence may cause some finer bed load particles to be suspended in the water column and become suspended load; thus bottom erosion occurs. Because the river flow changes seasonally, the riverbed constantly adjusts hydrodynamically by erosion and deposition cycles. A mature river usually reaches a quasi-equilibrium state and does not exhibit long-term erosion or deposition, although short-term seasonal changes of riverbed may occur.

Mehta *et al*. (2004) evaluated sediment transport and detrital transfer changes related to MFLs for the SJRWMD. They noted the following differences between transport in lakes and rivers:

1. In lakes, hydrodynamic forcing is mainly by wind-generated waves, except during storms when wind-induced surging plays a role. Wind-induced forced oscillations (seiching) are usually less important. In rivers, sediment is transported by short-term high flows, and in such circumstances much of the sediment transport occurs under high freshwater flow conditions. In bays and river mouths, tidal flows dominate except when river discharge is high. Wave action, storm surge, and salinity-induced circulation provide additional hydrodynamic forcing for sediment transport.
2. In most cases, sediment transport (due to wave action) in lakes is confined to fine-grained (<63 micrometers) material which is mainly transported as suspended load.

3. In lakes, rivers, or estuaries, the primary sediment sources are specified in terms of external load, but there can be sources interior to the water bodies including local production of detritus and detrital material transfer from the banks and shores. Naturally, the bottom can also be a source depending on the strength of flow, sediment composition and compaction (density) and patterns of accumulation.

Long-term physical alteration of a lake or river (e.g., through dredging, flow augmentation, or water withdrawal) can change the bed and sediment transport regime accordingly. The alteration of the sediment loads and sediment transport regime may subsequently influence the bottom sediment composition, for example, in the case of water withdrawals, because more fine material may be deposited due to flow reduction.

As described previously, a reduction in river flow may cause some suspended sediment to be settled out of the water column and be deposited to the bed. This new or increased accumulation of bed load material may adversely affect benthic processes by smothering organisms. The sediment may also affect navigation if large-scale deposition occurs, usually at the downstream segment of a water body following a substantial flood event. Freshwater withdrawal, however, does not increase flood flows; therefore, will not affect navigation in terms of episodic shoaling.

River sediments may be created by the erosion of upstream soils and subsequent downstream transport. The distance of travel from the point of origin depends on the flow rate, velocity, and sediment characteristics. Additionally, when biogenic organic particles make up a significant fraction of the sediments, there is an opportunity for absorption of toxic materials on the surface of these biogenic particles. When the river flows through an area of past or present industrial or agriculture development, pollutants such as toxic compounds and metals can enter the sediments. These contaminated sediments can be transported downstream by sufficient flows.

Sediment particles can be resuspended; transported; and redistributed by wind, tide, river flow, and motorboat propeller-induced turbulence. If the sediment particles contain toxics or metals, this contaminated material may be resuspended and transported from the point of origin to other segments of the river. Since some of these materials are resistant to biological breakdown, they can remain in the aquatic system for long periods of time. The alteration of the sediment quality in the bed may also affect the water quality.

According to Keller and Schell (1993), as sediments bind nutrients from the watershed, the sediment nutrient content has an effect on the quality of sediments. Growth of benthic algae and bacteria are stimulated by the presence of nutrients. Such growth activities can reduce DO concentrations and alter the sediment/water interface redox potential. Metals that are absorbed to organic particles can be released into the water column when the sediments become anoxic, which can have a water quality and biological impact.

5.9.4 SEDIMENT TRANSPORT MODELING

Jain and Mehta (2006) conducted a hydrodynamic and sediment transport modeling study to evaluate the effects of a freshwater withdrawal from Lake Monroe on the sediment transport in the lake. This section summarizes Jain and Mehta's (2006) modeling study results.

The modeling methodology and assumptions are summarized as follows:

- EFDC, a three-dimensional hydrodynamic model, described in Section 5.4.2, was used to simulate the current velocity in Lake Monroe.
- SWAN, a numerical wave model developed by Booij *et al*. (1999) was used to simulate wind-induced wave field and the wave-induced bottom shear stress.
- The SWAN model considers wave generation by wind, dissipation by white-capping, dissipation by depth-limited wave breaking, dissipation by bottom friction, and wave-wave interactions.
- A formulation by Soulsby *et al*. (2004) was used to determine the combined wave-current shear stress.
- The critical bottom shear stress, or the critical threshold for the incipient transport of fine-grained bottom material, was determined by Mehta *et al*. (2004) with the Soulsby et al. (2004) formulation.

- It was assumed that the relationship between resuspension flux and shear stress developed for Newnans Lake in north-central Florida was applicable to Lake Monroe. An assessment of organic rich sediment transport behavior by Gowland *et al*. (2006) appears to support this assumption.
- Floodplain was not included in the model.
- Sediment resuspension and entrainment were considered in the model. However, settling of sediment in suspension was not simulated.

Model Setup

The model used a rectangular grid system with grid dimensions of 561 ft (200 meters) in the x-direction and 410 ft (125 meters) in the y-direction. Three sigma-stretched vertical layers were used in the model. Figure 5-35 shows the model grid configuration for Lake Monroe.

Model Input and Boundary Conditions

The downstream head boundary condition was specified at the west end of Lake Monroe near U.S. 17/92. The upstream flow boundary condition was specified at the east end of Lake Monroe. It was assumed that 70 percent of the St. Johns River discharge flows into the lake via the Lake Monroe Canal, and the remaining 30 percent of the discharge was evenly distributed between two small braided channels to the north. A spatially uniform wind condition was applied to the lake water surface.

Model Calibration

Real-time daily flow and stage data at the St. Johns River near Sanford were used for EFDC model calibration. The hourly windspeed and direction data at Orlando International Airport were also used to calibrate the model. The calibration period was from July 24 through October 2, 1998.

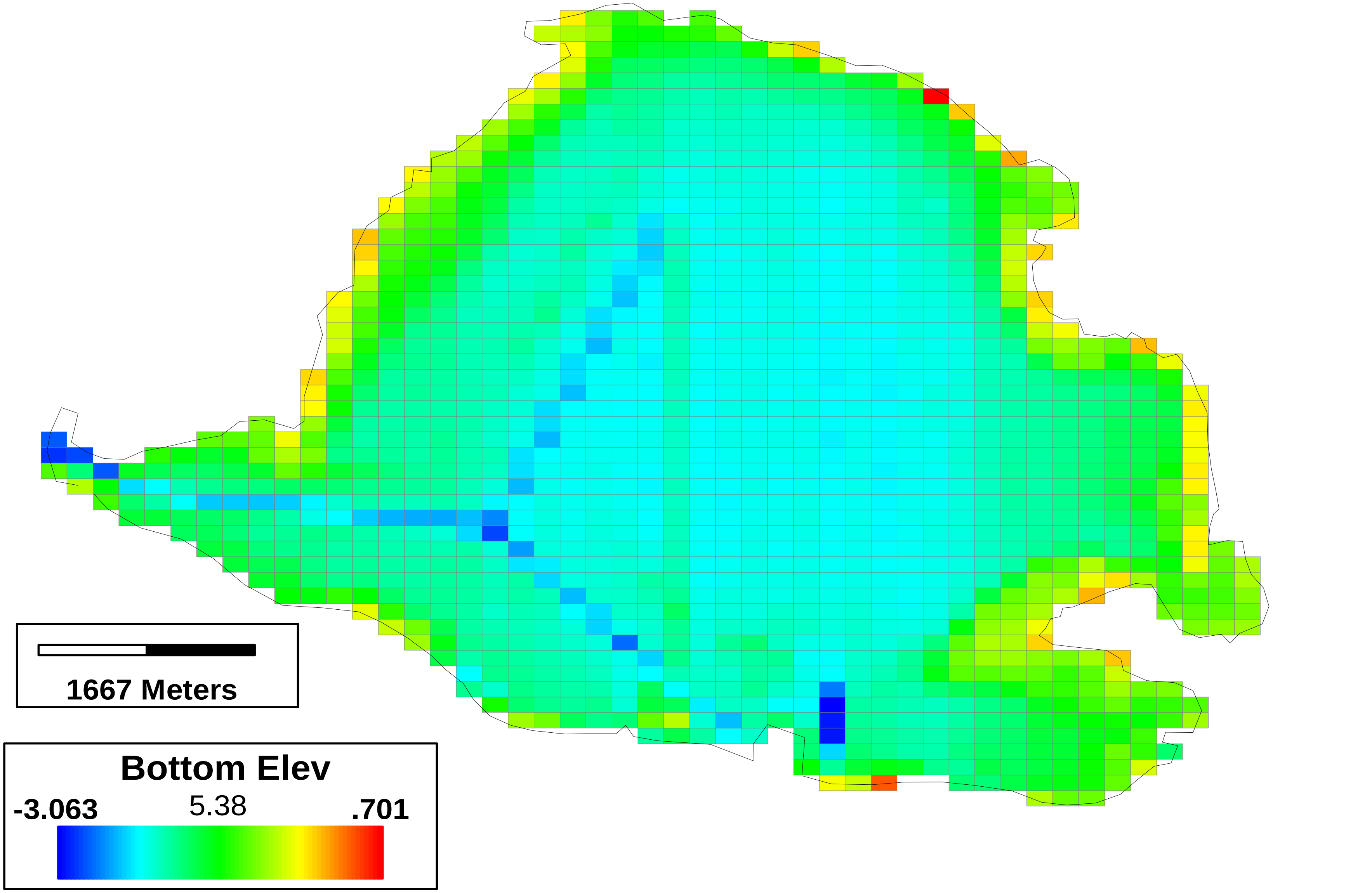

FIGURE 5-35.

EFDC MODEL GRID CONFIGURATION FOR LAKE MONROE

Source: Jain and Mehta, 2006.

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Model Testing and Sensitivity Analysis

After the model was calibrated, seven constant flow conditions (ranging from 1,059 to 18,081 cfs) and six constant windspeed conditions (ranging from 5.6 to 33.5 mph) were used to test the model and to determine the effects of river flows and windspeed on bottom shear stress and sediment resuspension in Lake Monroe.

Model Simulations

Jain and Mehta (2006) conducted model simulations for four flow conditions:

- A constant flow rate of 3,708 cfs (105 m^3/sec), which represents an approximately 20^{th} percentile flow condition. The corresponding lake stage is approximately 3.2 ft-NGVD.
- A constant flow of 3,531 cfs (100 m^3/sec), which represents the recommended MFLs hydrologic conditions (i.e., a 180-cfs withdrawal condition) at the 20^{th} percentile flow. The corresponding lake stage is approximately 3.1 ft-NGVD.
- A constant flow of 379 cfs, which represents the 90^{th} percentile flow condition. The corresponding lake stage is 0.44 ft-NGVD.
- A constant flow of 199 cfs, which represents the recommended MFLs hydrologic conditions (i.e., a 180-cfs withdrawal condition) at the 90^{th} percentile flow. The corresponding lake stage is 0.30 ft-NGVD.

Two constant windspeeds were used for each flow scenario: calm and 16.8 mph. A steady wind direction from the east was used for the model simulations.

The model simulation results for the eight modeling scenarios described above were analyzed at five lake locations (Figure 5-18).

5.9.5 RESULTS

According to Jain andf Mehta (2006), the critical shear stress of the heterogeneous bottom sediment ranges from 0.0001 pound force per square foot (lb_f/ft^2 ;0.005 Newton per square meter [Pa]) for very fine colloidal material to 0.0021 lb_f/ft^2 (0.1 Pa) for coarse, sandy material.

The results of the sediment transport modeling study by Jain and Mehta (2006) showed that for the streamflow alone to resuspend coarse material in Lake Monroe, a minimum flow of 7,063 cfs (200 m^3/sec) is required. The study also indicates that sediment transport of coarse material in Lake Monroe requires a windspeed exceeding 28 mph (12.5 m/sec), and the transport of fine sediment requires a windspeed of 11.2 mph (5 m/sec).

Table 5-27 shows the summary of the model simulation results for on bottom shear stress. Table 5-28 shows the changes in resuspension flux (the vertical mass transfer from the bed load into the suspended load) in Lake Monroe due to the reduction in streamflow allowed under the recommended MFLs (i.e., 180-cfs reduction). Data analysis indicates that the current velocity will change only slightly under the recommended MFLs hydrologic conditions (Table 5-27).

Table 5-27. Bottom Shear Stresses From Model Simulations

Location	Wind-speed (mph)	Flow (cfs)	Current Speed (fps)	Bottom Shear Stress Current (lb_f/ft^2)	Bottom Shear Stress Wave (lb_f/ft^2)	Bottom Shear Stress Combined (lb_f/ft^2)
Point-1	0	3708	0.157	0.000052	0	0.000052
Point-1	0	3531	0.144	0.000044	0	0.000044
Point-1	16.8	3708	0.157	0.000052	0.000022	0.000066
Point-1	16.8	3531	0.144	0.000044	0.000022	0.000057
Point-2	0	3708	0.036	0.000031	0	0.000031
Point-2	0	3531	0.032	0.000024	0	0.000024
Point-2	16.8	3708	0.036	0.000031	0.000029	0.000091
Point-2	16.8	3531	0.032	0.000024	0.000029	0.000078
Point-3	0	3708	0.036	0.000031	0	0.000031
Point-3	0	3531	0.031	0.000024	0	0.000024
Point-3	16.8	3708	0.036	0.000031	0.000011	0.000064
Point-3	16.8	3531	0.031	0.000024	0.000011	0.000054
Point-4	0	3708	0.049	0.000063	0	0.000063
Point-4	0	3531	0.046	0.000052	0	0.000052
Point-4	16.8	3708	0.049	0.000063	0.000015	0.00011
Point-4	16.8	3531	0.046	0.000052	0.000015	0.00010
Point-5	0	3708	0.233	0.00146	0	0.0014
Point-5	0	3531	0.217	0.0012	0	0.0012
Point-5	16.8	3708	0.233	0.0014	0.00002	0.0016
Point-5	16.8	3531	0.217	0.0012	0.00002	0.0014
Point-1	0	379	0.006	0.0000008	0	0.0000008
Point-1	0	199	0.001	0.0000000	0	0.0000000
Point-1	16.8	379	0.006	0.0000008	0.000022	0.000024
Point-1	16.8	199	0.001	0.0000000	0.000022	0.000022
Point-2	0	379	0.002	0.0000001	0	0.0000001
Point-2	0	199	0.001	0.0000000	0	0.0000000
Point-2	16.8	379	0.002	0.0000001	0.000029	0.000030
Point-2	16.8	199	0.001	0.0000000	0.000029	0.000029
Point-3	0	379	0.001	0.0000001	0	0.0000001
Point-3	0	199	0.001	0.0000000	0	0.0000000
Point-3	16.8	379	0.001	0.0000001	0.000011	0.000011
Point-3	16.8	199	0.001	0.0000000	0.000011	0.000011
Point-4	0	379	0.002	0.0000001	0	0.0000001
Point-4	0	199	0.001	0.0000000	0	0.0000000
Point-4	16.8	379	0.002	0.0000001	0.000015	0.000015
Point-4	16.8	199	0.001	0.0000000	0.000015	0.000015
Point-5	0	379	0.008	0.0000014	0	0.0000014
Point-5	0	199	0.003	0.0000003	0	0.0000003
Point-5	16.8	379	0.008	0.0000014	0.000018	0.000021
Point-5	16.8	199	0.003	0.0000003	0.000018	0.000018

Source: Jain and Mehta, 2006.

Table 5-28. Resuspension Flux Changes Due to Flow Reduction Under the Recommended MFLs Hydrologic Conditions

Location	Resuspension Flux ($lb/ft^2/day$)					
	3,708 cfs	3,532 cfs	Difference	379 cfs	199 cfs	Difference
Point-1	770	648	122	0	0	0
Point-2	0	0	0	0	0	0
Point-3	0	0	0	0	0	0
Point-4	14	0	14	0	0	0
Point-5	1,978	1,748	230	0	0	0

Source: Jain and Mehta, 2006.

The model results indicated that the resuspension fluxes and their changes under high flow conditions depended primarily on location within Lake Monroe. For example at Point-1 and Point-5, which are in the dredged channel and down-wind, the combined stresses are relatively high and both sites experienced similar shear stress reductions. Point-3 is up-wind and did not experience adequate wave-current forcing to cause the resuspension of even very fine matter. As Point-2 is down-wind from Point-3, it experienced higher shear stresses than Point-3. However, these shear stresses were still too low to entrain fine matter. At Point-4, which is up-wind, the resuspension flux was very low and became negligible, even with the reduction in discharge caused by the recommended MFLs hydrologic conditions.

The sediment transport modeling results indicated that the recommended MFLs hydrologic conditions may slightly reduce the resuspension flux in Lake Monroe at flows of approximately 3,700 cfs. The model simulations indicated that the wind wave-induced bottom shear stress becomes greater than the flow-induced bottom shear stress at the 90^{th} percentile flow condition when the windspeed was 16.8 mph. However, the combined shear stress at this low flow condition was less than the critical shear stress. Therefore, the recommended MFLs hydrologic conditions would have no effect on sediment resuspension flux (Table 5-28).

According to Jain and Mehta (2006), sediment transport would not occur in Lake Monroe until the St. Johns River flow is greater than 7,416 cfs. The stage/discharge curve (Figure 3-8) indicates that the lake stage is 5.3 ft-NGVD when the St. Johns River discharge near Sanford is 7,416 cfs. Based on the retention time information (Table 3-1), the Lake Monroe retention time is approximately 7.3 days when the lake stage is 5.3 ft-NGVD. Therefore, a threshold stage for in-lake sediment transport is 5.3 ft-NGVD and the critical durations are 1 to 14 days (Table 5-29).

Table 5-29. Frequency Analysis of Threshold Stage for In-Lake Sediment Transport

Threshold Stage (ft-NGVD)	Duration (days)	No. of Years in a Century Threshold Stage is Continuously Exceeded*		
		Existing	MFLs	Difference
5.3	1	22	21	1
5.3	14	20	20	0

* Water level rises above threshold stage for the indicated duration.

Source: ECT, 2006.

The results of frequency analysis indicate that, under existing conditions, the threshold stage of 5.3 ft-NGVD would be continuously exceeded 1 day 22 times in 100 years (Table 5-29). Under the recommended MFLs hydrologic conditions, the threshold stage would be continuously exceeded for 1 day 21 times in a century; a decrease of 1 flooding event per 100 years when compared to existing hydrologic conditions. The 14-day duration analysis indicated that there would be no change in the frequency that the threshold stage of 5.3 ft-NGVD would be continuously exceeded under the two hydrologic conditions (Table 5-29).

5.9.6 SUMMARY

The sediment transport in Lake Monroe would not be markedly altered under the recommended MFLs hydrologic conditions (i.e., a 180 cfs withdrawal) for Lake Monroe because of the following reasons:

- Flow velocity reduction in Lake Monroe due to the flow reduction allowed by the recommended MFLs hydrologic conditions is quite small.
- The increase in bottom shear stress in Lake Monroe due to the flow reduction allowed under the recommended MFLs hydrologic conditions is quite small.
- The increase in resuspension flux in Lake Monroe due to the flow reduction allowed under the recommended MFLs hydrologic conditions is quite small.
- The flow reduction allowed under the recommended MFLs hydrologic conditions would have no effect on resuspension flux under low flow/low stage (e.g., 0.4 ft-NGVD) conditions.
- The flow reduction allowed under the recommended MFLs hydrologic conditions would decrease the number of times the threshold stage of 5.3 ft-NGVD is flooded by only 1 and 0 times within a 100-year period for duration of 1 and 14 days, respectively.

Therefore, it is concluded that the recommended MFLs for Lake Monroe will protect sediment transport processes (WRV-8).

5.10 WRV-9: WATER QUALITY

5.10.1 INTRODUCTION

The federal Clean Water Act (CWA) requires each state to conduct water quality assessments to determine whether streams, lakes, and estuaries meet their designated uses. This information is updated and reported every 2 years to the U.S. Environmental Protection Agency (EPA). The EPA compiles all of the state reports to prepare the biennial National Water Quality Inventory. This process is mandated by Section 305(b) of the CWA, and the state reports are commonly referred to as 305(b) Reports. In Florida, the 305(b) Report is also a primary source of information for the eventual development of the draft "Impaired Waters" list for the state. An impaired water is defined by the State of Florida in Chapter 62-303, *F.A.C.*, as a water body or water body segment that does not meet its applicable water quality standards, due in whole or in part to discharges of pollutants from point or nonpoint sources. Subsection 303(d) of the CWA requires each state to submit to the EPA a list of waters not meeting water quality standards or not supporting their designated uses. The approved list of impaired waters is also known as the 303(d) List. Lake Monroe is on the Florida Department of Environmental Protection (FDEP) 303(d) list of impaired waters for nutrients and DO and is currently scheduled for total maximum daily loads (TMDLs) development in 2008 (FDEP, 2004).

For purposes of WRVs assessment, water quality (WRV-9) is defined as the chemical and physical properties of the water column in Lake Monroe and its vicinity. The representative function of water quality is to maintain an aquatic community that is not impacted by nutrients and other pollutants. The general indicator for water quality protection is to maintain concentrations of DO, nutrients, and other pollutants at levels that will not negatively impact the health of the aquatic communities. Specific indicators for WRV-9 assessment are Trophic State Index (TSI), the relationship between stage and water quality parameters, and threshold stages of 2.0 and 3.0 ft-NGVD with critical durations of 30 and 183 days.

5.10.2 METHODOLOGY

Two methods were used to assess WRV-9: evaluating the effect of a reduction in hydraulic retention time (HRT) on water quality, and evaluating the effect of a reduction in lake stage on water quality.

Dierberg (2006) conducted a water quality modeling study to assess the effects of water levels under the recommended MFLs hydrologic conditions and the associated HRT on nutrient filtration and absorption in Lake Monroe. The changes in phosphorus concentrations in the water column under existing and the recommended MFLs hydrologic conditions were assessed with empirical models that include external and internal phosphorus loading. The hydrologic component of internal phosphorus loading models was examined probabilistically by evaluating three percentile levels for lake stages: 10^{th}, 50^{th}, and 90^{th} percentile. The expected phosphorus concentration changes were also predicted for the driest month (May) and the wettest month (October). Lake stages, surface areas, volumes, flows, and HRTs shown in Table 3-1 were used in the internal loading models.

Two different modeling approaches were used in the assessment of the effect of HRT on phosphorus concentrations in the water column:

- Approach 1—Net and gross estimates of internal loading from the phosphorus budget (Nürnberg, 1998).
- Approach 2—Gross estimates of internal loading from release rate (RR) and anoxic factor (AF) according to Nürnberg (1995, 2006). Total phosphorus (TP) in the upper sediment reported by Anderson *et al*. (2004) was used by the model.

The HRT analysis is presented in Section 5.10.4.

One of the effective measures to classify lake water quality is the TSI, which measures the potential for algal or aquatic weed growth. Lake Monroe was qualitatively assessed based on the TSI classification for lakes. A *good*, *fair*, or *poor* rating was assigned to Lake Monroe water quality depending on the outcome of the qualitative assessment. Relationships between the lake stage and TSI were explored. Individual TSIs based on Chl *a*, total nitrogen (TN), and TP were plotted against lake stage. Chl *a* data were assembled for dry and wet seasons to further explore the seasonality effects of the lake stage on Chl *a* TSI. Based on the monthly average St. Johns River flow near Sanford (Section 3.2, Figure 3-7), April through June was considered a dry season and September through November was considered a wet season. The TSI analysis is presented in Section 5.10.5.

5.10.3 WATER QUALITY DATA

The water quality of Lake Monroe has been monitored at 23 locations since 1991 by FDEP, LAKEWATCH, Volusia County, and the SJRWMD. Water quality data were obtained from the Florida STORET water quality database, SJRWMD, and USGS for various locations in Lake Monroe. The sampling frequencies of the water quality parameters vary from biweekly to quarterly. The dates of sample collection were also provided in the database. Based on the water quality data collection date and the historic stage time series data near Lake Monroe, ECT determined the lake stages at the time of water quality data collection for the purpose of exploring the possible relationship between lake stages and water quality. Figure 5-36 shows selected water quality monitoring stations in Lake Monroe.

Two different data sets were considered for the analysis of the water quality in Lake Monroe. The first data set consisted of the water quality parameters collected at the center of Lake Monroe (Station LMAC), where the quantity of data were most abundant. The second data set consisted of the aggregation of data collected from all Lake Monroe stations, including LMAC (ALL). After the data were downloaded, associated remark codes were evaluated. Data with quality control problems were excluded from the analyses.

Analytical results of the water quality parameters for Station LMAC and ALL are summarized in Tables 5-30 and 5-31, respectively. Summary statistics for the data collected at other locations in Lake Monroe are presented in Appendix D. The mean value, standard deviation, maximum value, minimum value, the median value, and the 90th percentile value for each constituent are presented in the tables. The period of record for each constituent and the total number of data values that were available for the calculations are also presented in the tables.

The following paragraphs summarize water quality of Lake Monroe with respect to Florida water quality standards for some of the water quality parameters, such as DO, pH, alkalinity, and turbidity.

DO concentration is a very important characteristic of the water, as it has a significant effect on the health of the aquatic life. Higher DO concentrations are usually found in colder or fast-flowing waters. Lower oxygen concentrations are usually found in warmer waters, or waters with high oxygen demand, such as those waters that drain swamps. During the study period, analysis showed that the median DO concentration in Lake Monroe was 6.8 mg/L, which is well above the FDEP Class III water quality standard

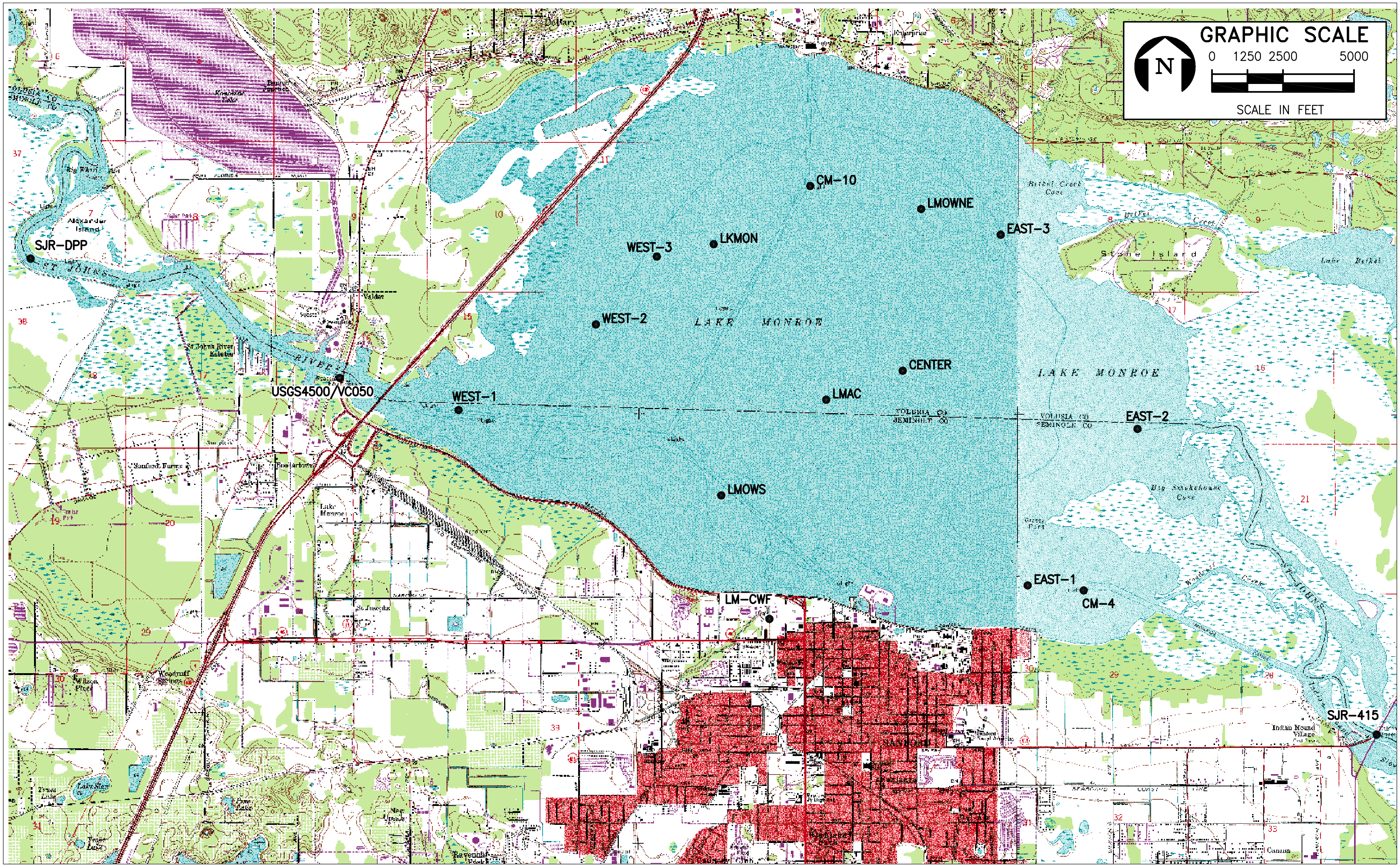

FIGURE 5-36.

LAKE MONROE SJRWMD WATER QUALITY STATIONS

Sources: USGS Quads: Osteen, FL, 1980 and Sanford, FL, 1988; ECT, 2006.

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Table 5-30. Water Quality Data at Station LMAC in Lake Monroe (1991 through 2005)

Parameter	Unit	Mean	Standard Deviation	Maximum	Minimum	Median	90th Percentile	No. of Values
Alkalinity	mg/L	55.20	15.48	88.62	2	54.12	74.43	107
Chloride	mg/L	249.1	121.4	572.5	69.1	301.0	326.6	107
Chlorophyll *a*	µg/L	32.17	36.58	166.7	0.01	24.38	61.48	109
Chlorophyll *a* , Corrected	µg/L	28.48	35.19	165.8	0	21.4	59.70	107
Color	PCU	189.49	135.10	500	40	150	400	108
Conductance	umhos/cm	1,004	466	2,230	350	915	1,720	119
DO	mg/L	7.23	2.45	11.39	1.87	7.67	10.02	118
Oxygen Percent Saturation	%	85.1	19.5	125.9	57.2	83.1	109.4	15
Dissolved Solids	mg/L	587.50	263.85	1630	101	568.5	935.1	108
Hardness	mg/L	189.6	82.9	396	68.9	179.3	282	91
Nitrite + Nitrate	mg/L	0.05	0.06	0.251	0	0.03	0.12	107
Nitrogen, Ammonia	mg/L	0.05	0.06	0.328	0.001	0.032	0.109	105
Nitrogen, Kjeldahl	mg/L	1.73	0.56	3.51	0.38	1.60	2.30	109
Nitrogen, Total	mg/L	1.76	0.57	3.52	0.39	1.70	2.21	79
Orthophosphate, as P	mg/L	0.045	0.056	0.488	0.001	0.033	0.080	105
Phosphorus, Total	mg/L	0.095	0.059	0.578	0.036	0.086	0.126	109
pH	s.u.	7.67	0.75	9.44	6.33	7.63	8.661	120
Salinity	ppt	0.49	0.26	1.2	0.17	0.4	0.89	42
Secchi Depth	meter	0.56	0.16	1.15	0.3	0.5	0.7	112
Sulfate	mg/L	68.2	48.6	210	1	52	131	109
Total Organic Carbon	mg/L	22.49	4.41	32.55	14.4	22	29.88	109
Total Suspended Solids	mg/L	11.56	9.62	52	0	9	22.2	109
Turbidity	NTU	5.57	4.13	20.1	0.9	4.6	11.22	109
Water Temperature	°C	23.72	5.33	33.34	11	23.9	30	120

Source: ECT, 2006.

Table 5-31. Lake Monroe Water Quality Data (1991 through 2005, all stations)

Parameter	Unit	Mean	Standard Deviation	Maximum	Minimum	Median	90th Percentile	No. of Values
Alkalinity	mg/L	52.79	19.17	236.52	2	50.7	73.34	274
Chloride	mg/L	242.2	123.9	662.0	69.1	227.3	415.7	346
Chlorophyll *a*	µg/L	22.83	27.92	166.7	0.01	13	53.12	607
Chlorophyll *a*, Corrected	µg/L	24.84	34.05	254.8	0	13.68	56.23	421
Color	PCU	168.2	109.6	500	10	150	320	343
Conductance	umhos/cm	978	466	2,673	1	877	1,648	688
Dissolved Oxygen	mg/L	6.81	2.21	13.8	0.08	6.84	9.552	687
Oxygen Percent Saturation	%	75.5	18.3	125.9	5.7	78.3	94.1	230
Dissolved Solids	mg/L	586.0	273.0	1630	58	550	941.8	343
Fecal Coliform	#/100mL	26.97	67.43	675	0	5	54.5	232
Hardness	mg/L	172.4	79.6	407.0	68.9	154.3	281.0	254
Nitrite + Nitrate	mg/L	0.05	0.06	0.371	0	0.027	0.14	543
Nitrogen, Ammonia	mg/L	0.05	0.07	0.81	0	0.029	0.1121	334
Nitrogen, Kjeldahl	mg/L	1.53	0.53	4.49	0.2	1.4	2.1	536
Nitrogen, Total	mg/L	1.58	0.51	4.51	0.218	1.477	2.12	466
Orthophosphate, as P	mg/L	0.04	0.04	0.488	0.001	0.026	0.080	552
Phosphorus, Total	mg/L	0.090	0.048	0.578	0.010	0.081	0.140	713
pH	s.u.	7.60	0.74	9.83	5.99	7.49	8.67	686
Salinity	ppt	0.54	0.38	5.88	0.17	0.47	0.89	346
Secchi Depth	meter	0.61	0.21	1.72	0.06	0.6	0.9	666
Sulfate	mg/L	66.18	46.97	210	1	52.2	130.7	324
Total Organic Carbon	mg/L	23.18	5.08	34.2	5.5	23.8	29.76	315
Total Suspended Solids	mg/L	11.56	14.39	152	0	8	22.29	588
Turbidity	NTU	4.73	4.23	45	0.5	3.6	9.13	488
Water Temperature	°C	23.78	5.22	33.34	10.1	24.35	30.10	690

Source: ECT, 2006.

(FDEP, 2006) of 5.0 mg/L for Class III surface waters. The designated uses of Class III surface waters in the State of Florida include recreation, and propagation and maintenance of a healthy, well-balanced population of fish and wildlife.

pH is a measure of hydrogen ion concentration in waters. Concentrations of hydrogen ions in water control speciation of many other geochemicals, influence dissolutions and precipitation, and determine whether the water will support aquatic life. Data analyses showed that Lake Monroe had a median pH of 7.5, which is within the Florida Class III surface waters criteria range of 6.0-8.5.

Alkalinity is a measure of the water's ability to tolerate additional acidity without changing the pH significantly. Water with high alkalinity is referred to as well-buffered, because the pH is only slightly lowered by the addition of acidic rainfall. Poorly buffered water, or water with a low alkalinity, will generally have a lower pH due to rainfall. Median alkalinity of Lake Monroe was 50.7 mg/L. This value is well above Florida Class III surface water criteria, which states that the alkalinity shall not be depressed below 20 mg/L.

Turbidity is an expression of the optical property of the water that causes light to be scattered and absorbed rather than transmitted (Clesceri *et al*., 1998). Turbidity in water is caused by suspended matter such as clay, silt, and organic matter and by plankton and other microscopic organisms that interfere with the passage of light through the water. High turbidity provides a medium for microbial growth in surface waters. It also may indicate the presence of microbes. A turbidity value of less than or equal to 29 NTU above natural background conditions is specified for Florida Class III surface water criteria. During the study period from 1991 to 2005, median turbidity in Lake Monroe was 3.6 NTU.

5.10.4 EFFECTS OF HYDRAULIC RETENTION TIME ON WATER QUALITY

This section presents the HRT analysis conducted by Dierberg (2006) based on the methodology described in Section 5.10.2.

Empirical models by Søndergaard *et al*. (2001) predict that water column TP concentrations in lakes will increase with lower flushing rates and higher HRTs. An increase in the in-lake TP concentrations in Lake Monroe may occur to some degree over the long term because the flow reduction allowed by the recommended MFLs would cause an increase in HRT (Table 3-1). Since Chl *a*, which represents algal biomass, is a common measure of water quality, the link between predicted HRT and increased Chl *a* concentration is also examined using the site-specific relationship between stage and historical Chl *a* data collected in Lake Monroe.

Nitrogen and Phosphorus Limitation

Chl *a* and the limiting nutrient concentrations are usually correlated in nitrogen- or phosphorus-limited lakes (Smith, 1982; Dierberg and Brezonik, 1985; Havens and Nürnberg, 2004), at least until an upper limit of Chl *a* concentration is reached and factors other than nutrients become limiting (Ahlgren *et al*., 1988). At a station located in the center of Lake Monroe (Station LMAC), the correlation between TN and Chl *a* concentrations (r^2=0.57) was higher than the correlation between TP and Chl *a* concentrations (r^2=0.05), suggesting a nitrogen limitation. However, the mean nitrogen-to-phosphorus ratio for the water column at Station LMAC is 18:1, suggesting nitrogen and phosphorus co-limitation (Sakamoto, 1966; Smith, 1982; Forsberg and Ryding, 1980).

Hydrology and Phosphorus Retention

The hydrologic/hydraulic modeling results by Robison (2004b) under the existing and the recommended MFLs hydrologic conditions were used for the HRT analysis. The water quality modeling results by Dierberg (2006) indicate that almost 50 percent of the inflow phosphorus mass is retained within the lake at the lower flows corresponding to the 90th percentile. The predicted phosphorus retention coefficient more than tripled from the low (90th percentile) to the high (10th percentile) stages, while the difference between the driest (May) and wettest (October) months is almost two-fold (Table 5-32).

Table 5-32. Comparison of Hydrologic Factors and Predicted Phosphorus Retention Coefficient in Lake Monroe Under Existing and Recommended MFLs Hydrologic Conditions

	Existing Conditions			Recommended MFLs Hydrologic Conditions		
Stage Conditions	Stage (ft-NGVD)	HRT (days)	Phosphorus Retention Coefficient	Stage (ft-NGVD)	HRT (days)	Phosphorus Retention Coefficient
10^{th} percentile*	3.94	8.9	0.15	3.80	9.2	0.16
50^{th} percentile	1.39	22.9	0.31	1.29	25.5	0.33
90^{th} percentile	0.44	49.2	0.49	0.30	55.5	0.51
Lowest Month (May)	0.78	37.8	0.43	0.67	41.2	0.45
Highest Month (Oct)	2.45	13.6	0.23	2.33	14.4	0.24

*Exceedance percentile.

Source: Dierberg, 2006.

The most significant HRT changes due to the flow reductions allowed under the recommended MFLs hydrologic conditions occur when the lake level is at or less than the 90^{th} percentile stage (Table 5-32). At this percentile, water withdrawals may increase the HRT by 6.3 days, compared to the existing conditions. For May, the month that historically has the lowest stage levels, the HRT increases by 3.4 days (from 37.8 days to 41.2 days) under the recommended MFLs hydrologic conditions. Overall, the changes in HRT are minor (less than 13 percent increase from the existing conditions (Table 5-32). Additionally, the changes in the predicted phosphorus retention coefficient within Lake Monroe (Table 5-32) due to the flow reductions allowed under the recommended MFLs hydrologic conditions are minor and within a narrow range (4.1 to 6.7 percent increase in relative terms in both dry and wet seasons). Therefore, it is concluded that the changes in lake stages under the recommended MFLs hydrologic conditions will not have appreciable effect on the predicted phosphorus retention in Lake Monroe.

Internal Phosphorus Loading

The available nutrient and hydrologic data at the major inflow to Lake Monroe (St. Johns River at SR 415) covered only an 8.5-month period from January 18 to September 30,

2005. Table 5-33 presents the net internal phosphorus loading and predicted TP concentration under the existing and recommended MFLs hydrologic conditions based on 2005 data.

Table 5-33. Comparison of Net Internal Phosphorus Loading and Predicted TP Concentrations in Lake Monroe from Empirical Models under Existing (2005) and Recommended MFLs Hydrologic Conditions

	Existing Conditions (2005)			Recommended MFLs Hydrologic Conditions		
Stage Conditions	Net Internal Phosphorus ($g/m^2/yr$)	TP* (µg/L)	TP† (ug/L)	Net Internal Phosphorus ($g/m^2/yr$)	TP* (µg/L)	TP† (ug/L)
10th percentile	0.75	53	47	0.56	53	49
50th percentile	2.08	209	146	1.93	222	157
90th percentile	3.37	526	273	3.21	573	296
Lowest Month (May)	2.90	381	222	2.72	399	234
Highest Month (Oct)	1.24	104	82	1.62	106	75

Note: $g/m^2/yr$ = gram per square meter per year.

*Gross internal phosphorus load was determined by phosphorus budget in 2005.
†Gross internal phosphorus load was determined by Approach 2.

Source: Dierberg, 2006.

The empirical model results by Dierberg (2006) indicated that, as a percentage of the external loading, the net internal loading under the recommended MFLs hydrologic conditions differs little from the existing conditions (Table 5-33).

The model results also indicated that the recommended MFLs hydrologic conditions may decrease internal phosphorus loading (Table 5-33) at a given stage level or month (except for October) because any surface water withdrawal physically removes phosphorus from Lake Monroe.

Predicted TP Concentrations

Notwithstanding the lower internal phosphorus loading, water withdrawals under the recommended MFLs hydrologic conditions may increase TP concentrations in Lake

Monroe because of the increased HRT without a change in external phosphorus loading. TP concentrations computed by two methods are presented in Table 5-33. The first uses the predicted net internal loadings, while the second relies on the gross internal loading.

The comparison of the existing and the recommended MFLs hydrologic conditions indicated that the largest withdrawal effects on water column TP concentrations (8 to 9 percent increase) would occur when the lake stage is at the 90th percentile. The recommended MFLs flow reduction may increase TP concentration by only 0 to 4 percent when the lake stage is at the 10th percentile. A 5-percent increase in TP concentration due to the recommended MFLs hydrologic conditions may occur during the low-stage month of May, whereas a slight increase or reduction in TP concentration may occur in October, the month with the highest lake stages (Table 5-33).

5.10.5 EFFECTS OF LAKE STAGE ON WATER QUALITY

The assessment of water quality protection will focus on those chemical/physical parameters most likely to negatively impact the biotic components of the river and the effect of lake stage on these parameters. DO is perhaps the most often used indicator for assessing the fitness of a body of water to support aquatic life. The capacity of water to maintain DO tends to decrease as water temperature increases. Turbidity may increase as stages decrease due not only to the presence of unmoving, suspended particulate but also to the growth of microorganisms that attach themselves to undissolved organic and inorganic matter and due to resuspension of bottom sediments by boat propeller wash.

A comparison between the water quality parameter values between LMAC and ALL showed no appreciable difference. Therefore, to better represent the lake water quality, lake aggregated data were considered for further analysis. Lake aggregated data were plotted as functions of lake stage measurements taken at the time of sample collection to determine whether there is a relationship between lake stage and lake water quality While attempting to assess correlation between nutrients and stage, the potential temporal variation of nutrient loading to the lake from the watershed was not considered.

Common Water Quality Parameters

Scatter plots between lake stage and water quality parameters were prepared for stations that are located in shallow areas of the lake, stations located in the center of the lake, and the average of all Lake Monroe stations. The scatter plots of lake stage and various water quality parameters showed that the data were quite scattered with no apparent correlation between lake stage and most of the nutrients, DO, and temperature. Figures 5-37 through 5-42 present correlations of stage with Chl *a*, turbidity, and conductivity, respectively, for ALL and LMAC data. Scatter plots for other water quality parameters for ALL and LMAC data are presented in Appendix D. A comparison between the water quality parameter values between LMAC (Table 5-30) and ALL (Table 5-31), and visual inspection of scatter plots between these two stations showed a similar pattern of variation. Therefore, to better represent the lake water quality, ALL (lake aggregated) data were considered for further analysis. Lake aggregated data were plotted as functions of the lake stage measurements taken at the time of sample collection to determine whether there is a relationship between the lake stage and water quality (Figures 5-37 through 5-42).

The stage/water quality plots should be interpreted with caution. Neubauer (2006) indicated:

> Many water quality parameters might not show correlation with the lake stage. For example, TP concentrations can be high at low lake stages because of algal blooms and high at high lake stages because of phosphorus associated with detritus and sediment that are transported during flood events. TP concentrations may also be low at low stages if a bloom has not yet started or if an algal bloom population crash occurred weeks prior to the sampling event. Similarly, TN, secchi depth, and total suspended solids might also have high values at low stages because of algae and high values at high flows because of suspended particulates. A DO/stage relationship might be even more difficult to develop because temperature and primary production affect DO concentration. Also, diurnal changes in DO might result in very high or very low concentrations within a 12-hour period that might affect correlation with lake stage.

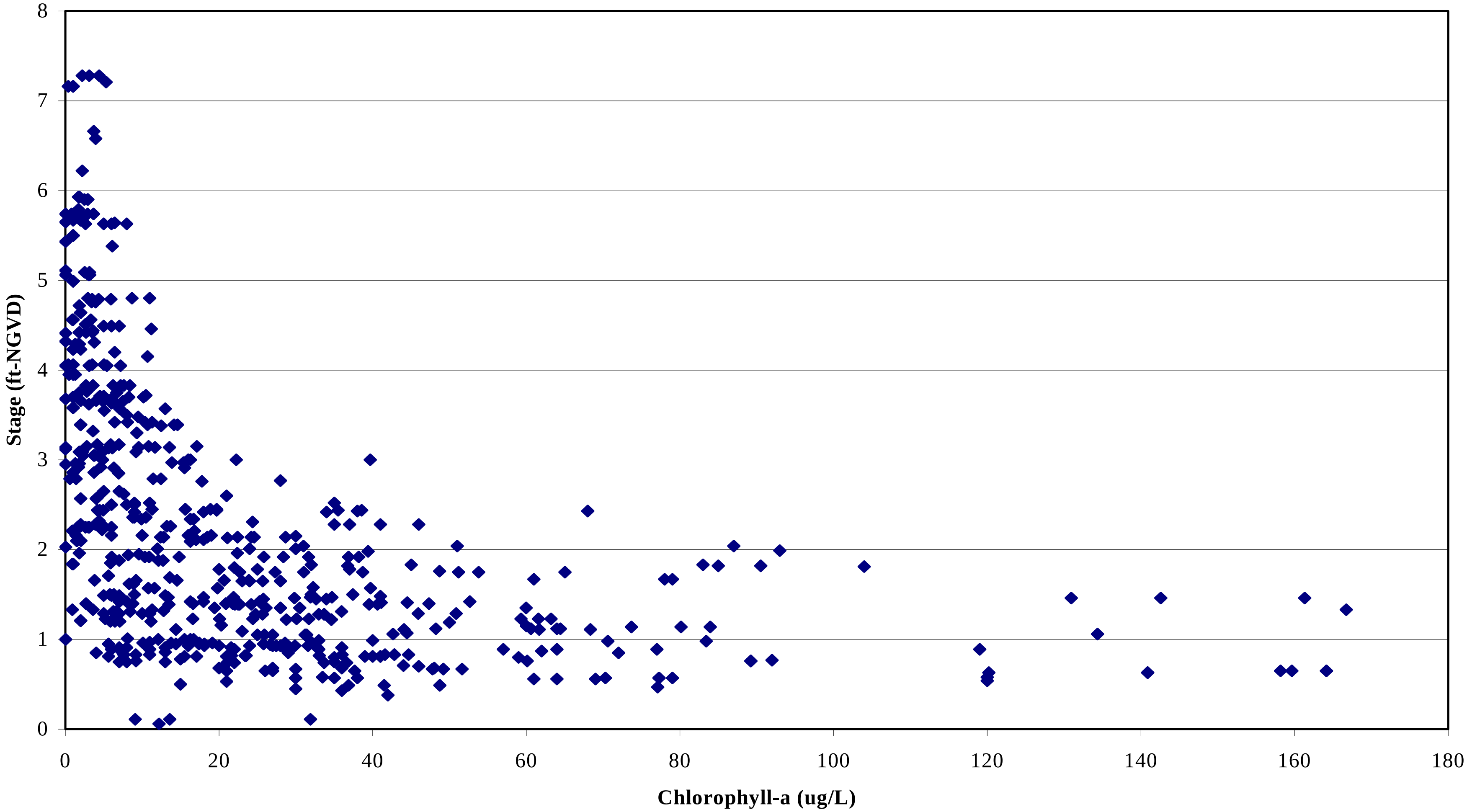

FIGURE 5-37.

Chl *a* VERSUS LAKE MONROE STAGE (ALL LOCATIONS, 1991-2005)

Source: ECT, 2006.

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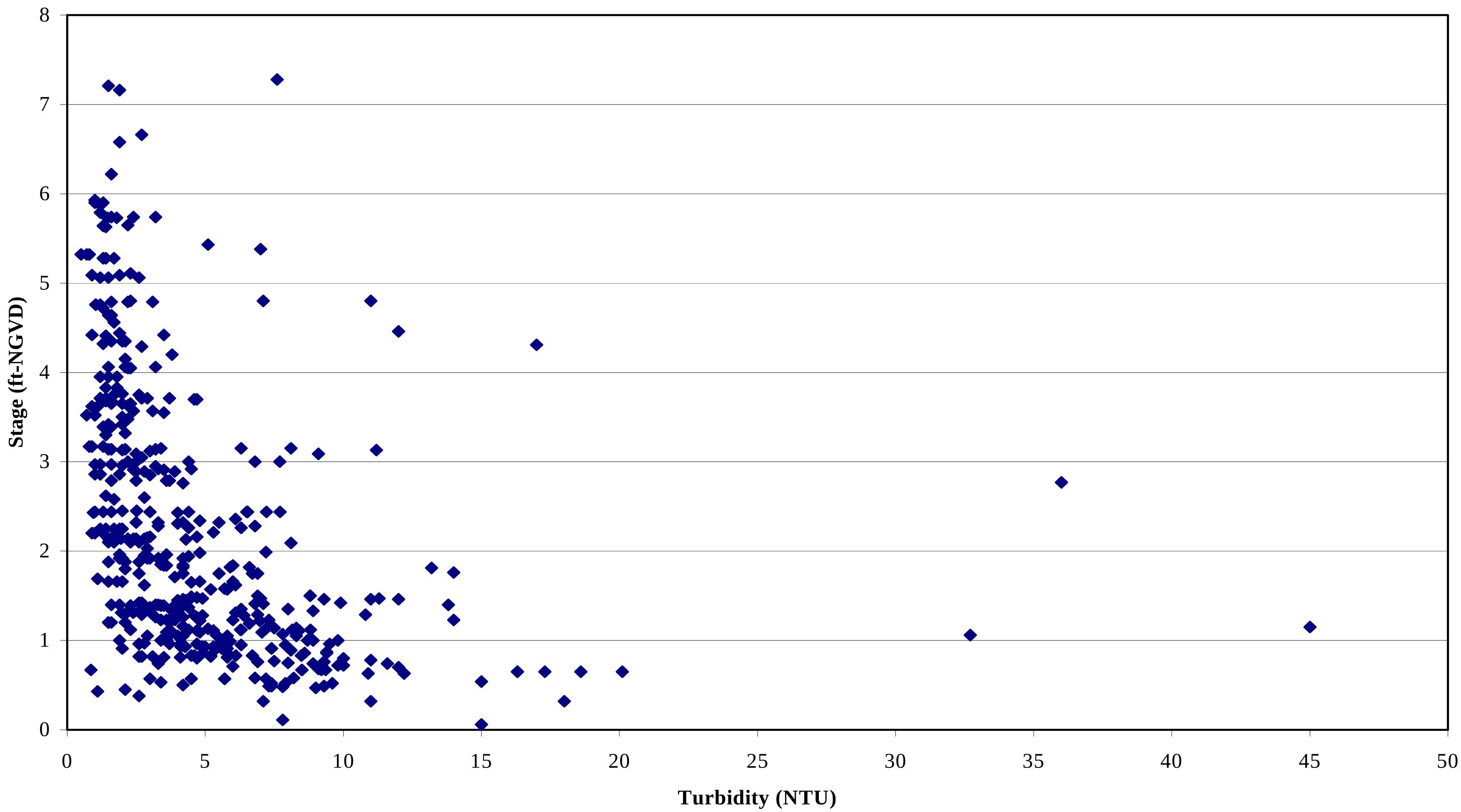

FIGURE 5-38.

TURBIDITY VERSUS LAKE MONROE STAGE (ALL LOCATIONS, 1991-2005)

Source: ECT, 2006.

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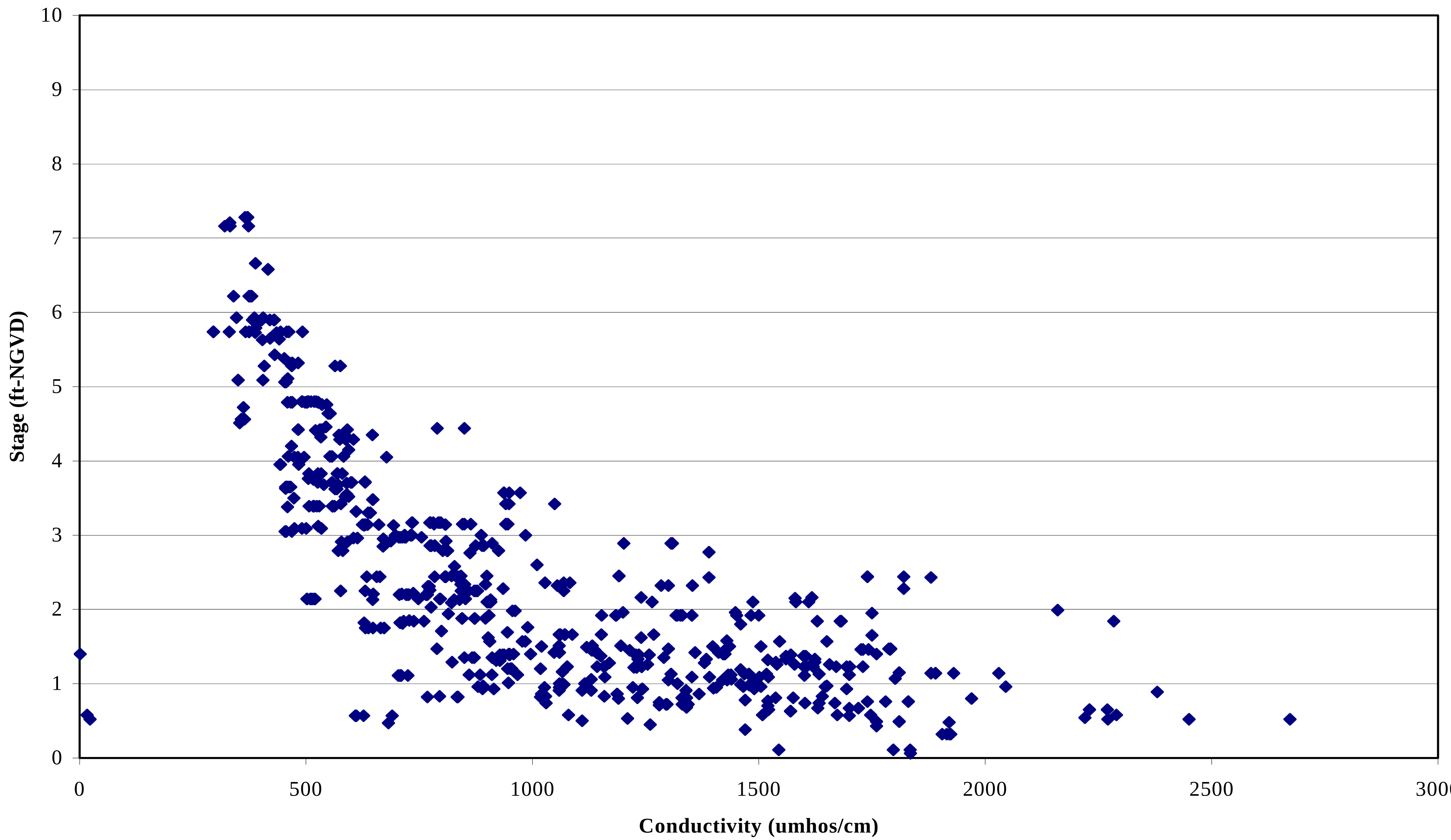

FIGURE 5-39.

CONDUCTIVITY VERSUS LAKE MONROE STAGE
(ALL LOCATIONS, 1991-2005)
Source: ECT, 2006.

ECT
Environmental Consulting & Technology, Inc.

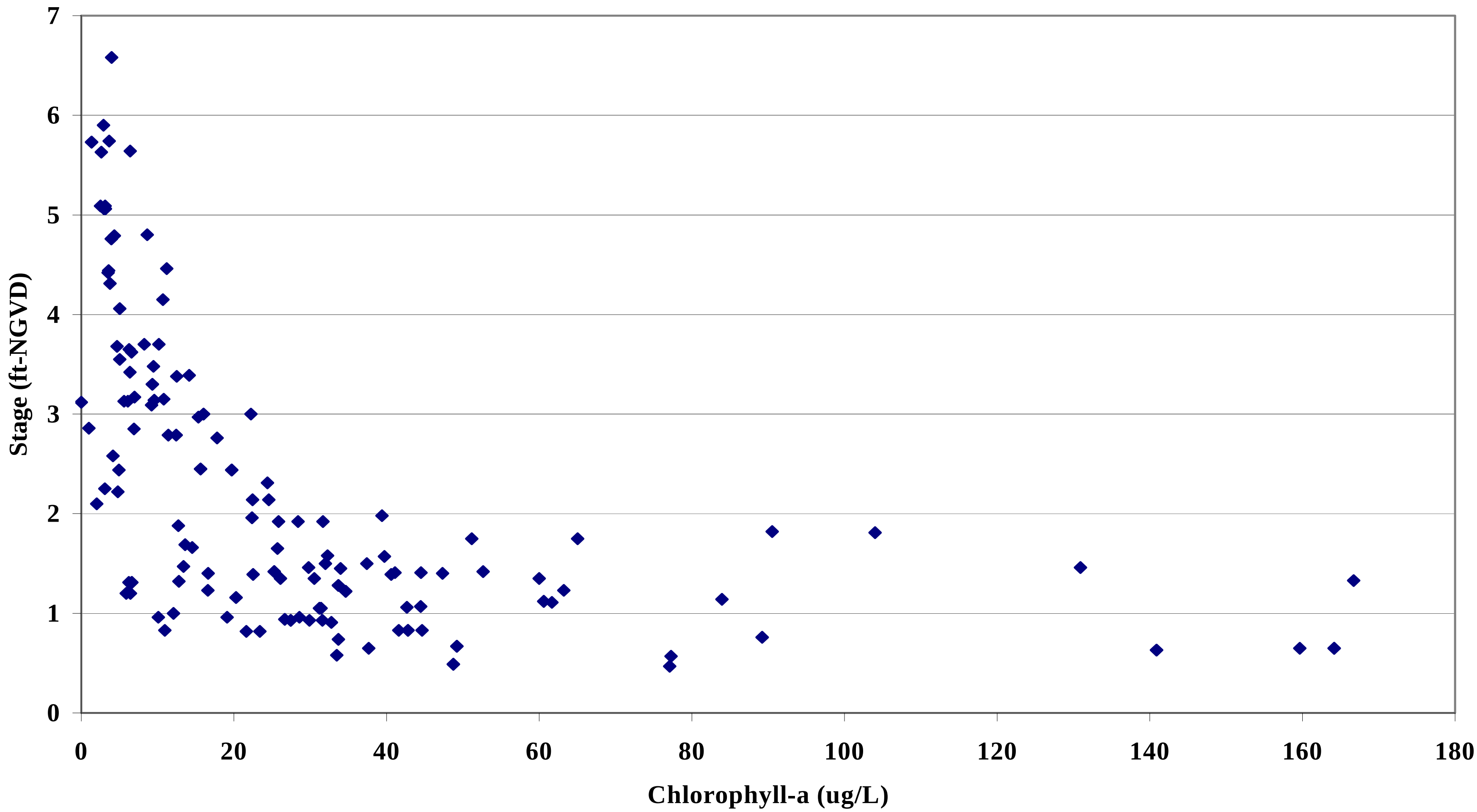

FIGURE 5-40.

Chl *a* VERSUS LAKE MONROE STAGE (LMAC DATA, 1991-2005)

Source: ECT, 2006.

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Environmental Consulting & Technology, Inc.

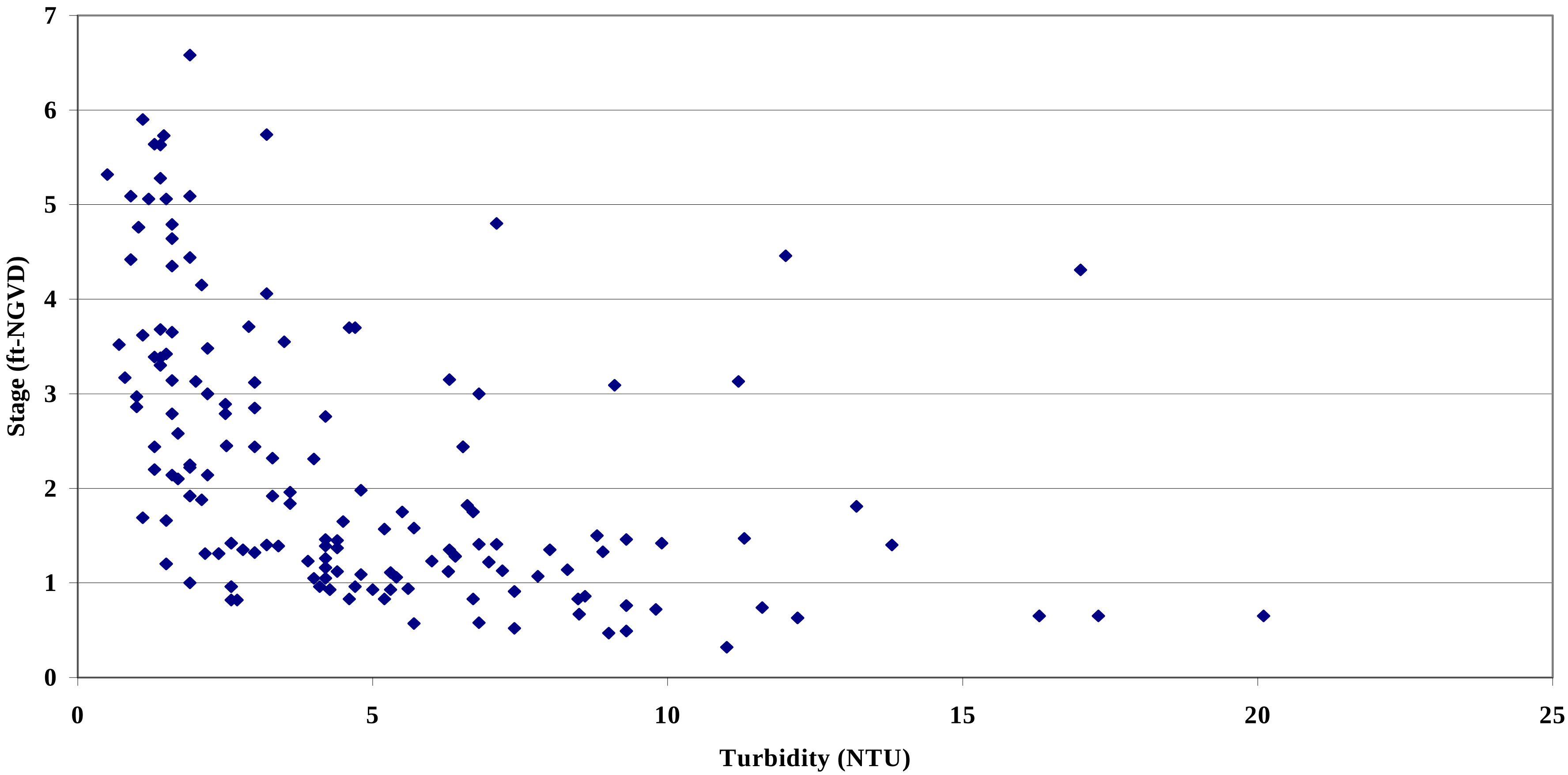

FIGURE 5-41.

TURBIDITY VERSUS LAKE MONROE STAGE (LMAC DATA, 1991-2005)

Source: ECT, 2006.

Environmental Consulting & Technology, Inc.

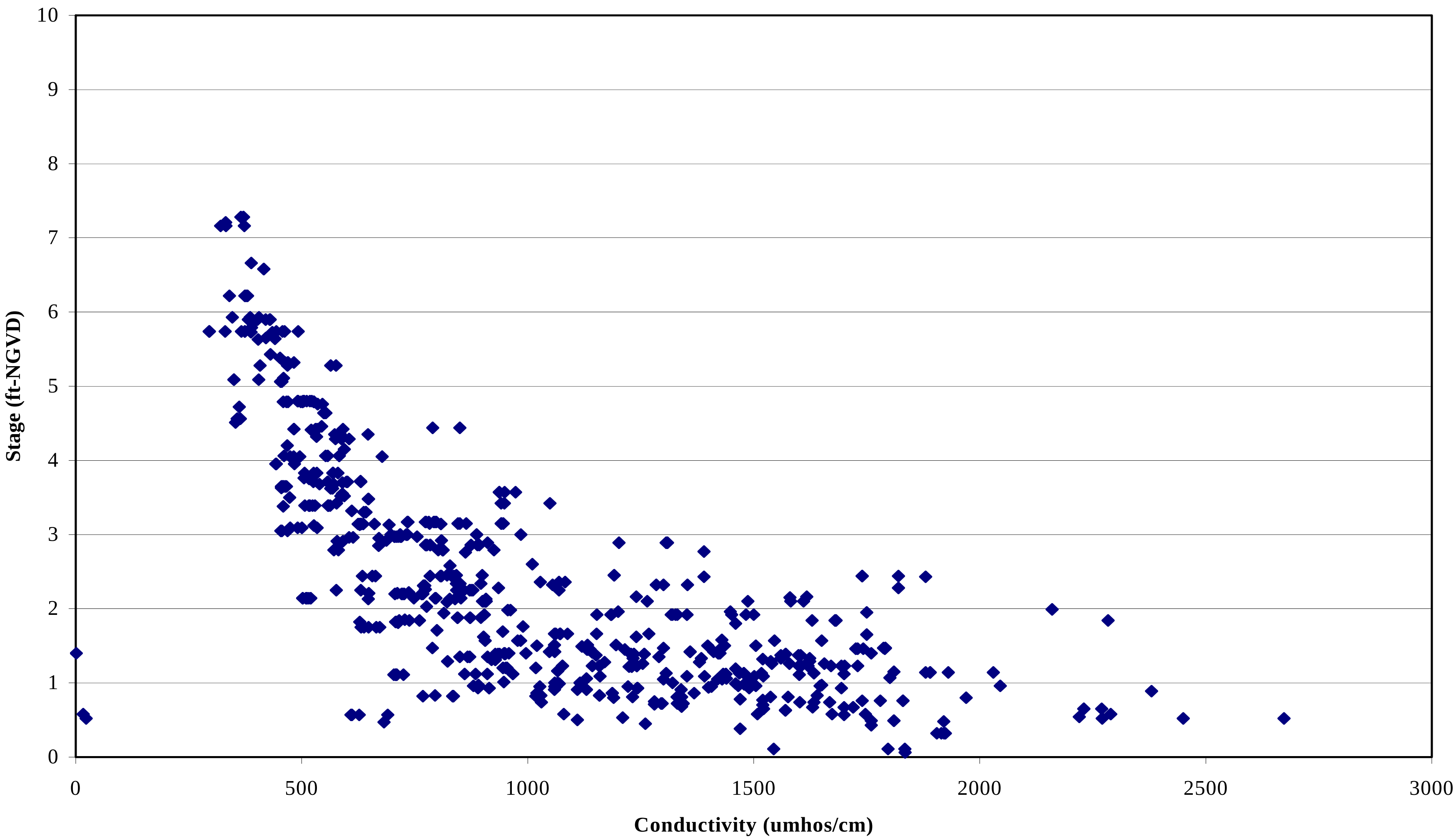

FIGURE 5-42.

CONDUCTIVITY VERSUS LAKE MONROE STAGE (LMAC DATA, 1991-2005)

Source: ECT, 2006.

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Chl a TSI Assessment

Three parameters that make up the TSI, Chl *a*, total nitrogen (TN), and total phosphorus (TP), were assigned a value based on a pre-determined percentile distribution of lakes water quality in Florida (Hand *et al.*, 2000). Following TSI equations were used:

TSI (Chl *a*) = 14.379 ln (Chl *a*) + 16.947

TSI (TN) = 18.48 ln (TN) + 56.811

TSI (TP) = 18.643 ln (TP) + 110.28

Where Chl *a* is measured in µg/L, and TN and TP are measured in mg/L.

A lake can be rated *good* if the TSI value falls between 0 and 59, *fair* if the TSI is in between 60 and 69, and can be considered *poor* if the TSI value is in between 70 and 100 (Hand *et al.*, 2000). The water quality database consisted of multiple data on the same day for Chl *a*, TN, and TP with no significant spatial variability. To avoid over-weighting on some synoptic data, these multiple data were averaged for each day and TSI were calculated accordingly. Individual TSIs were determined for Chl a, TN, and TP. The overall TSI was based on the average of the Chl a, TN, and TP indices.

Table 5-34 presents the yearly TSI values for Lake Monroe and shows that the water quality shifts between *fair* and *good* conditions. Individual TSIs for Chl *a*, TN, and TP were plotted against lake stage. Data analyses showed that the TSIs for TN and TP were not apparently correlated to the lake stage. However, a negative correlation existed between daily average lake stage and Chl *a* TSI (Figure 5-43). Seasonal analysis showed a similar relation between stage and Chl *a* TSI for the dry season (Figure 5-44) and the wet season (Figure 5-45). The analysis also showed the lake water quality shifted toward the poor range during dry seasons. During the data period (1991-2005), annual maximum Chl *a* TSI were always associated with either *fair* or *poor* lake water quality (Figure 5-46).

Table 5-34. Individual Indices for Chl *a*, TP, and TN and Overall TSI for Lake Monroe

Year	Average Chl *a* Value	TSI-Chl *a*	Average TP Value	TSI-TP	Average TN Value	TSI-TN	Overall TSI	Overall Lake Status
1991	18.93	59	0.11	69	-	-	-	-
1992	25.86	64	0.08	63	-	-	-	-
1993*	-	-	-	-	-	-	-	-
1994	16.18	57	0.08	62	-	-	-	-
1995	16.44	57	0.10	67	-	-	-	-
1996	27.14	64	0.08	62	1.42	63	63	FAIR
1997	37.03	69	0.09	66	1.60	65	67	FAIR
1998	20.82	61	0.10	67	1.42	63	64	FAIR
1999	49.19	73	0.10	67	1.85	68	69	FAIR
2000	25.14	63	0.07	60	1.69	67	63	FAIR
2001	37.76	69	0.11	69	1.99	70	69	FAIR
2002	17.80	58	0.09	66	1.45	64	63	FAIR
2003	7.54	46	0.08	63	1.36	62	57	GOOD
2004	15.61	56	0.11	69	1.51	64	63	FAIR
2005	12.08	53	0.07	62	1.36	62	59	GOOD
1991-2005	23.39	61	0.09	65	1.56	65	64	FAIR

*Excluded from the analysis because of a single data for the entire year.

Source: ECT, 2006.

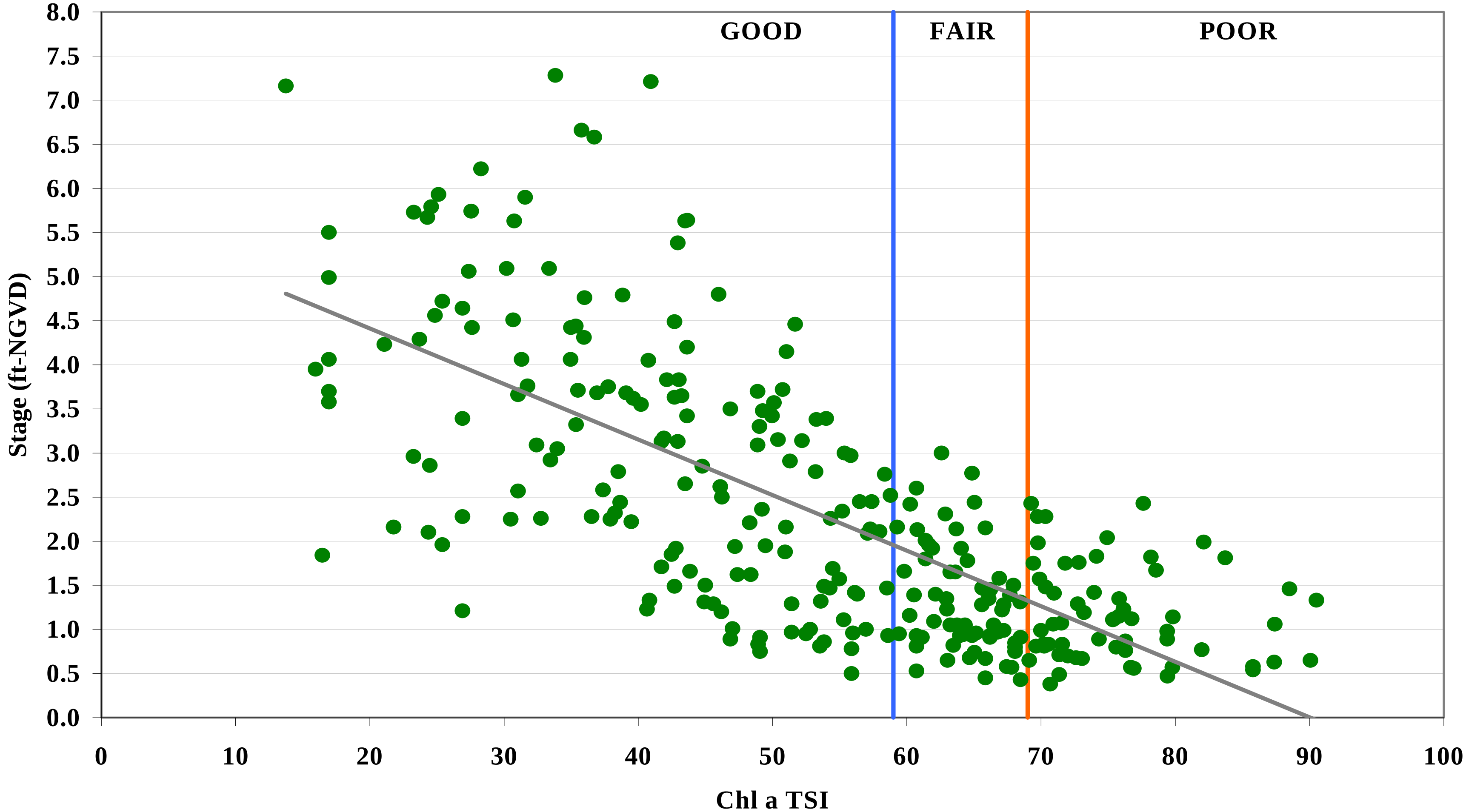

FIGURE 5-43.

DAILY AVERAGE Chl *a* TSI VERSUS LAKE STAGE

Source: ECT, 2006.

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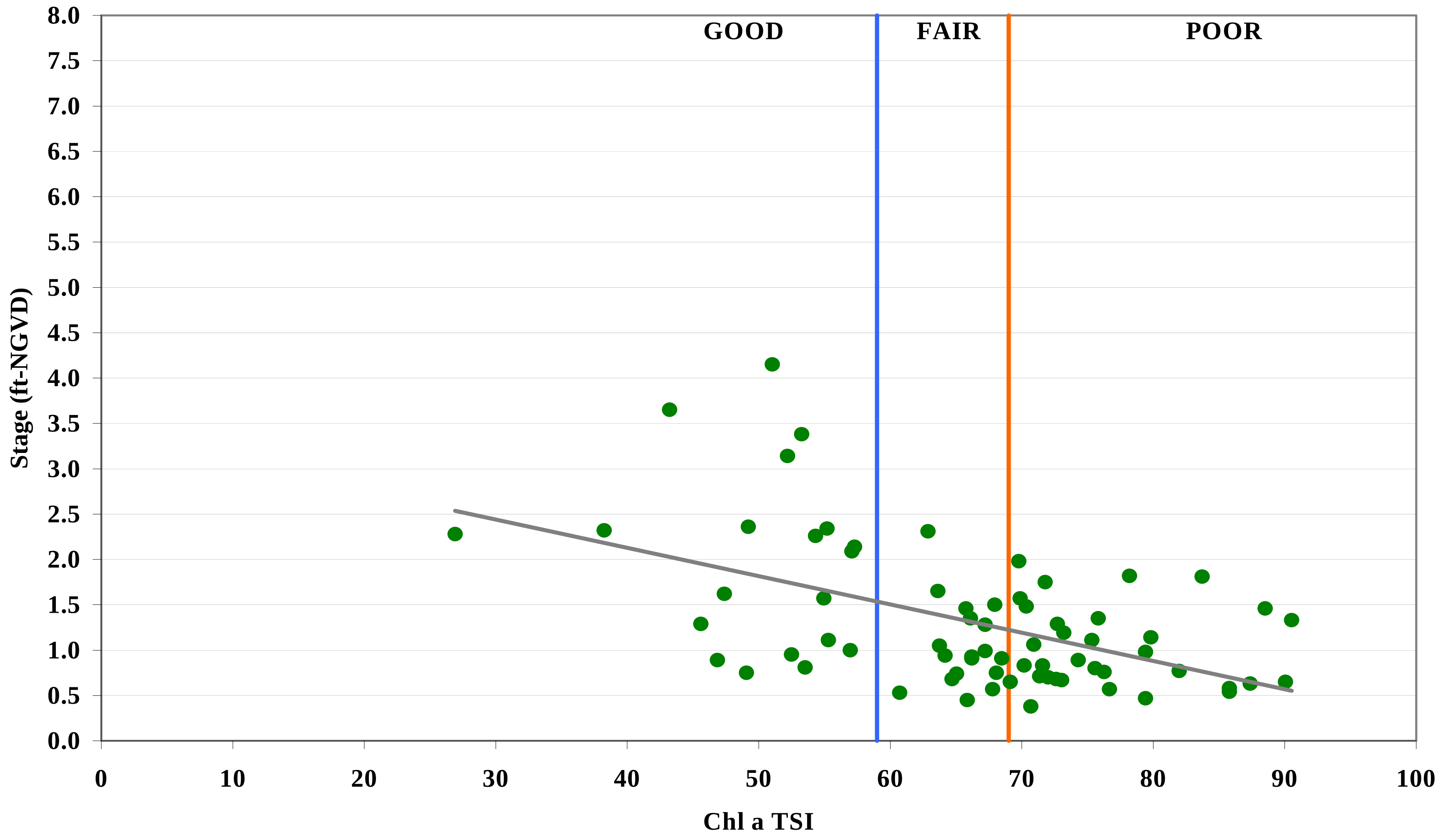

FIGURE 5-44.

DRY SEASON (APRIL-JUNE) Chl *a* TSI VERSUS LAKE STAGE

Source: ECT, 2006.

Environmental Consulting & Technology, Inc.

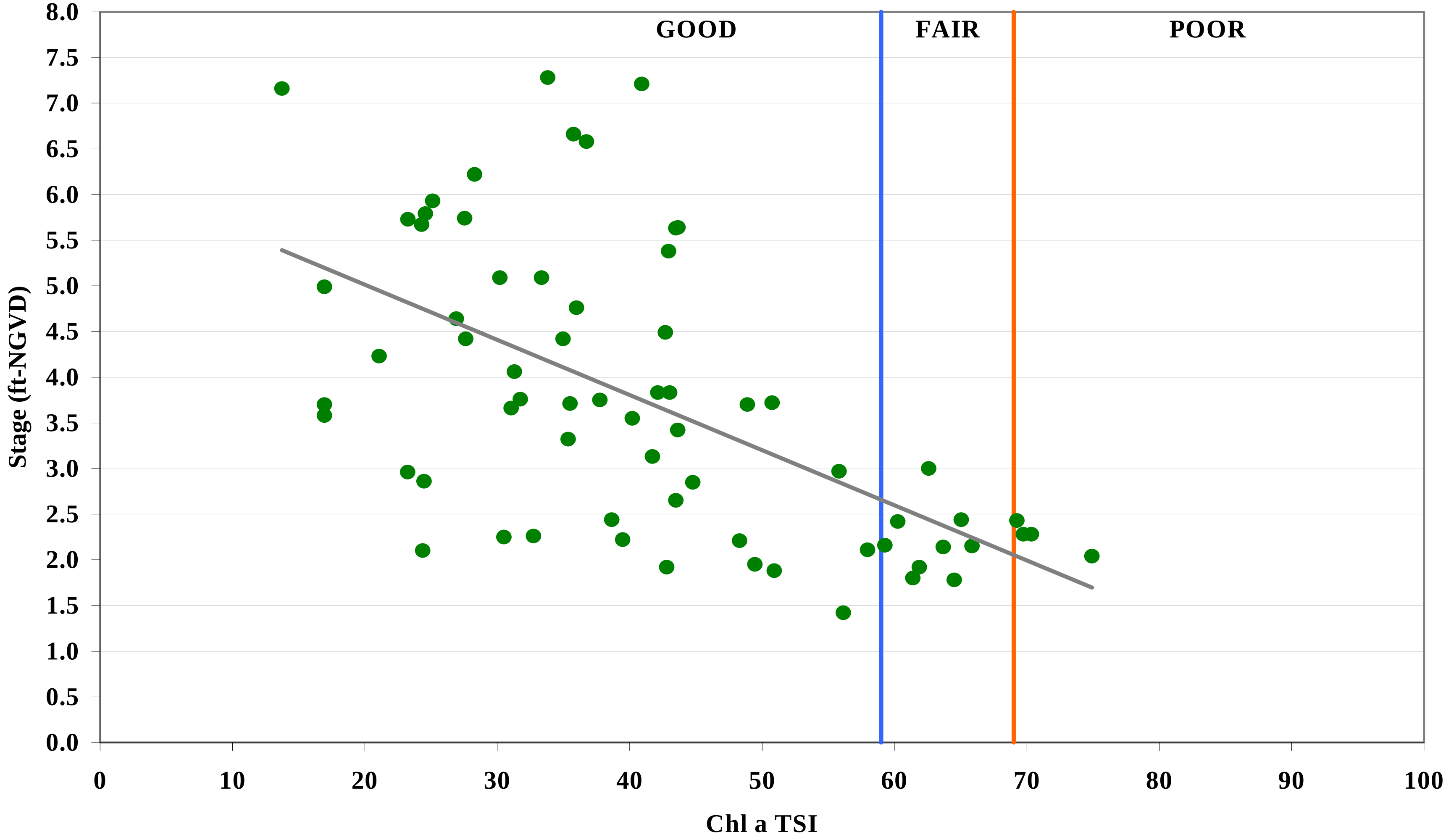

FIGURE 5-45.

WET SEASON (SEPTEMBER-NOVEMBER) Chl *a* TSI VERSUS LAKE STAGE

Source: ECT, 2006.

Environmental Consulting & Technology, Inc.

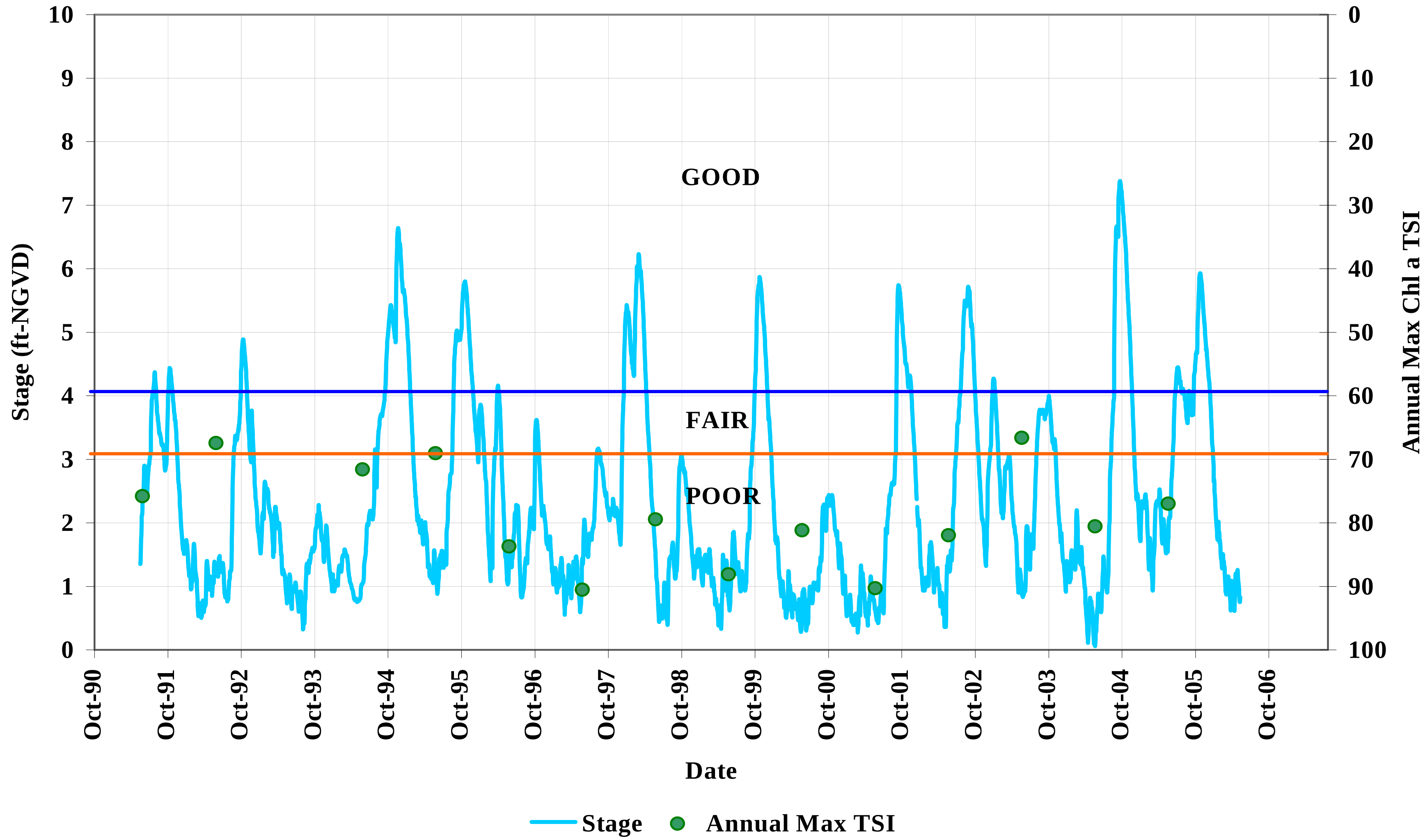

FIGURE 5-46.

ANNUAL MAXIMUM Chl *a* TSI AND LAKE STAGE TIME SERIES

Source: ECT, 2006.

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In order to get a different perspective on the analysis, time series of stage and TSI values were developed (Figure 5-47). The TSI axis was inverted so that higher TSI values correspond with lower stages. For easier visual examination, the time series was further divided into two periods: 1991-1997 and 1998-2005 (Figures 5-48, and 5-49, respectively). Examination of the time series plots indicated that the TSI tends to deteriorate substantially when the stage falls below 2.0 ft-NGVD for 6 months or longer. The time series also revealed that the TSI recovers into the *good* range after stages exceed 3.0 ft-NGVD for at least 30 days. Based on the analysis of Figures 5-47 through 5-49, threshold stages for high-water event (3.0 ft-NGVD for 30 days) and low-water events (2.0 ft-NGVD for 183 days) were determined. Table 5-35 presents the frequency analysis of the threshold stages for high-water and low-water events for existing and 180-cfs withdrawal conditions.

Table 5-35. Frequency Analysis of Thresholds Stages for Chl *a* TSI

Threshold Stage	Duration	No. of Years in a Century Threshold Stage is Continuously Exceeded*		
(ft-NGVD)	(Days)	Existing	MFLs	Difference
3.0	30	57	55	2
Threshold Stage	Duration	No. of Years in a Century Threshold Stage is Continuously Not Exceeded†		
(ft-NGVD)	(Days)	Existing	MFLs	Difference
2.0	183	62	63	1

* Water level rise above threshold stage for the indicated duration.
† Water level falls below the threshold stage for the indicated duration.

Source: ECT, 2006.

The results of the frequency analysis (Table 5-35) show that the threshold stage (3.0 ft-NGVD) under existing conditions, would be continuously exceeded for 30 days 57 times in 100 years. Under the recommended MFLs hydrologic conditions, the threshold stage

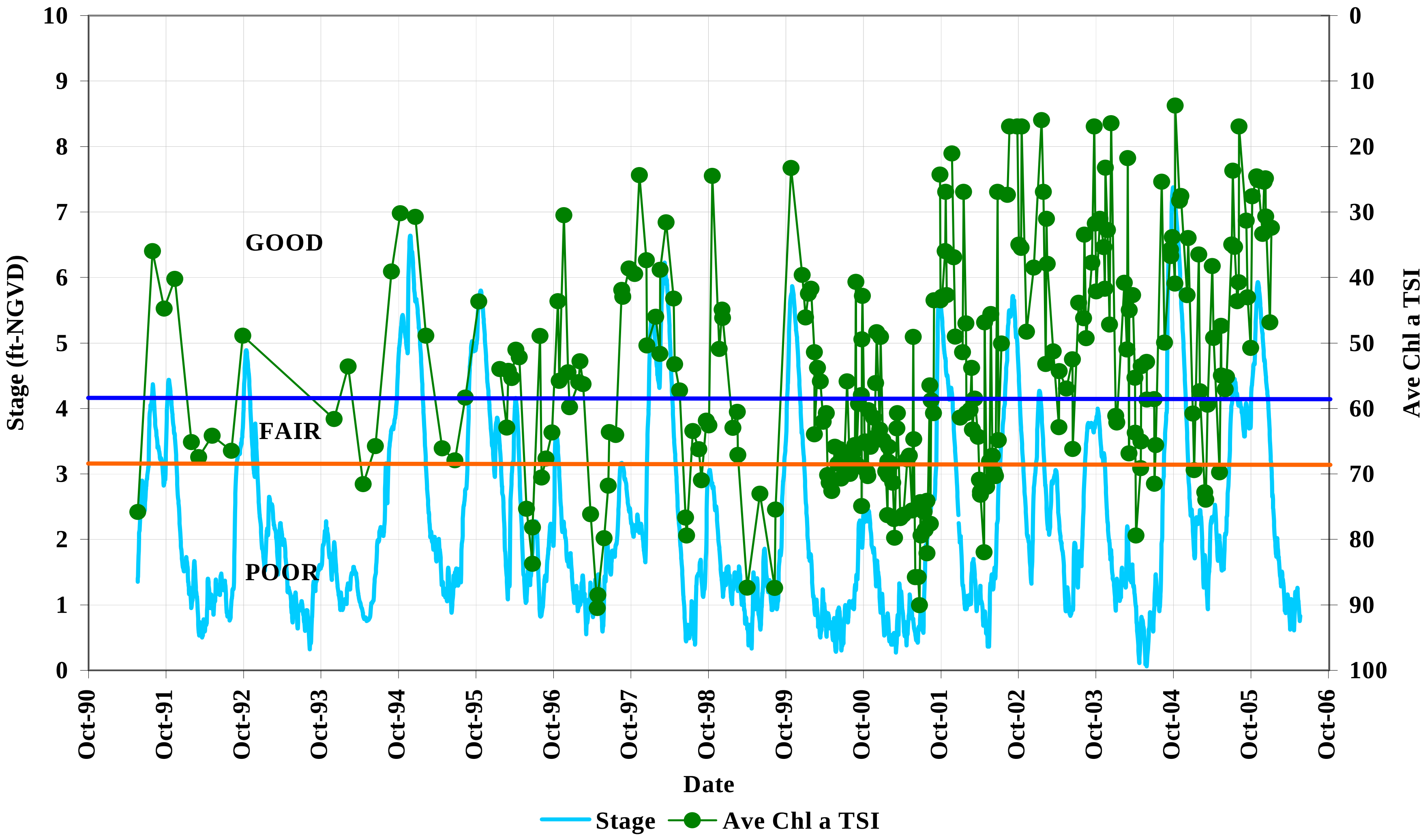

FIGURE 5-47.

DAILY AVERAGE Chl *a* TSI AND LAKE STAGE TIME SERIES (1990-2005)

Source: ECT, 2006.

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Environmental Consulting & Technology, Inc.

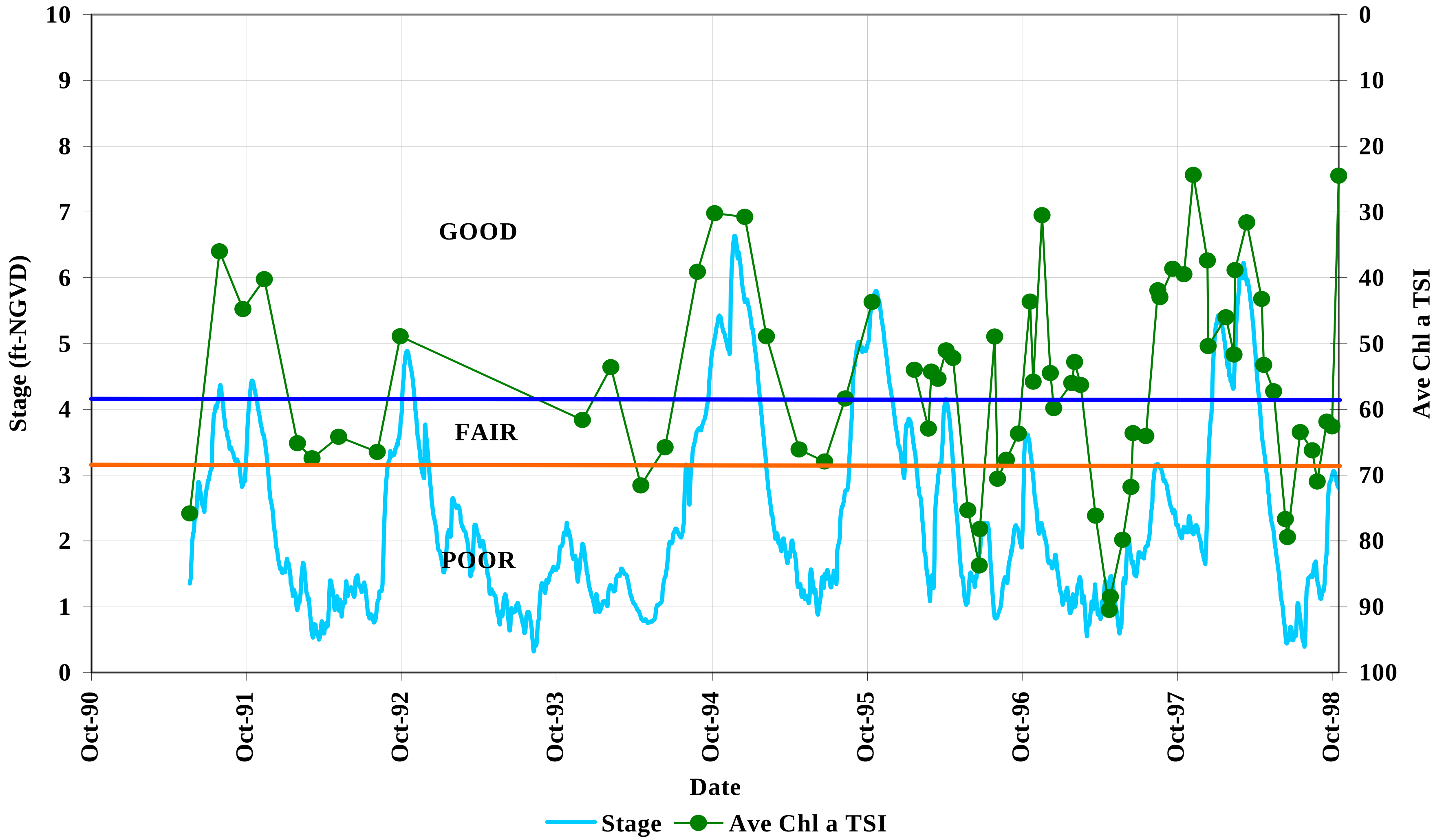

FIGURE 5-48.

DAILY AVERAGE Chl *a* TSI AND LAKE STAGE TIME SERIES (1990-1998)

Source: ECT, 2006.

Environmental Consulting & Technology, Inc.

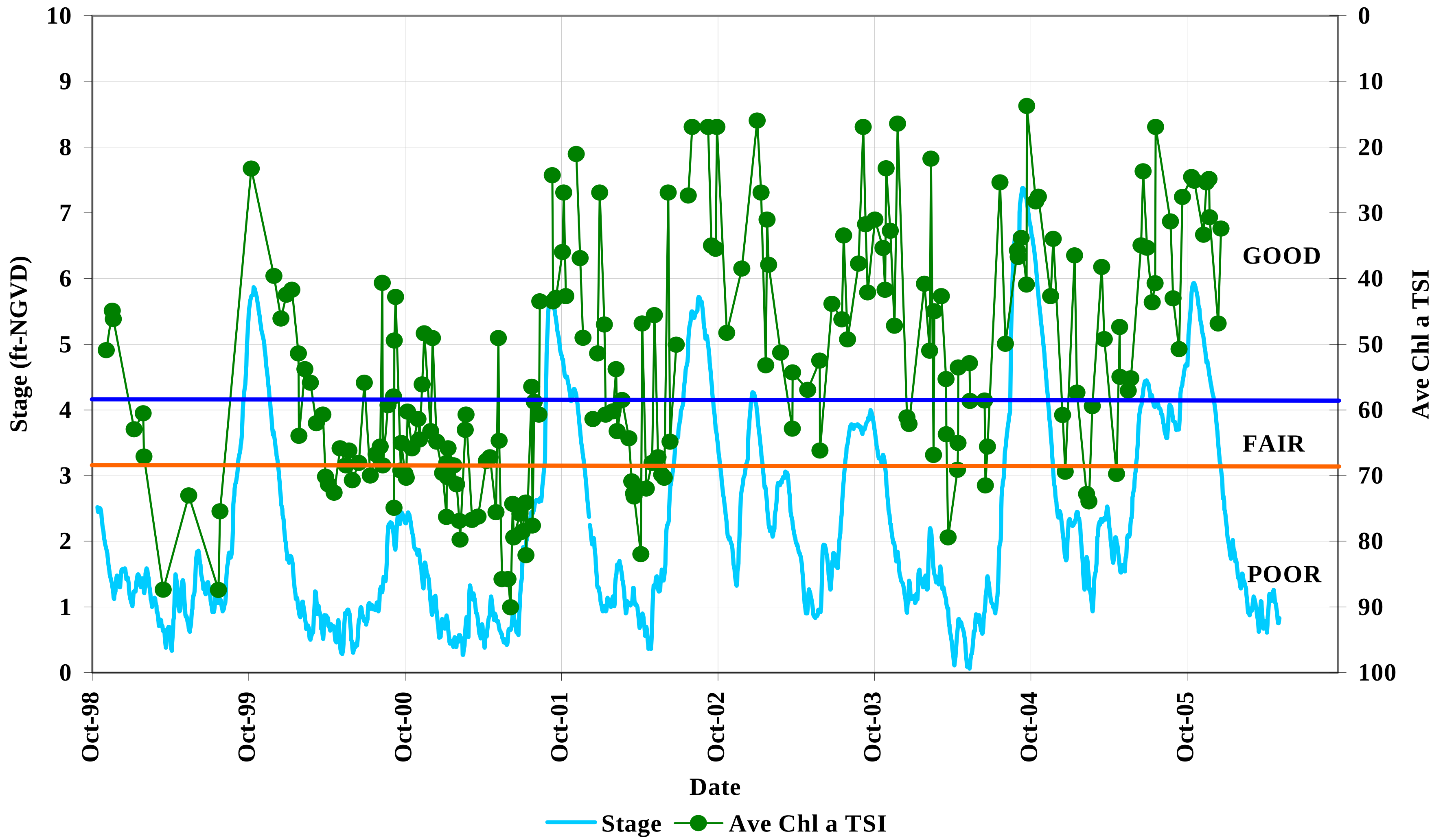

FIGURE 5-49.

DAILY AVERAGE Chl *a* TSI AND LAKE STAGE TIME SERIES (1998-2005)

Source: ECT, 2006.

Environmental Consulting & Technology, Inc.

would be continuously exceeded for 30 days 55 times in a century; a decrease of 2 flooding events per 100 years when compared to existing hydrologic conditions.

Similar frequency analyses were conducted to determine the increases in the number of times the threshold stages (2.0 ft-NGVD) would be continuously not exceeded for a duration of 183 days. Results indicate that the threshold stage dewatering event of 2.0 ft-NGVD would be continuously not exceeded for a duration of 183 days 1 more time per century under the recommended MFLs hydrologic conditions, as compared to the existing hydrologic conditions (Table 5-35).

In ECT's opinion, the trophic state of Lake Monroe would be maintained because the frequency of the flooding or dewatering of critical surface water levels associated with the maintenance of trophic state in Lake Monroe would not change appreciably.

5.10.6 SUMMARY

Water quality assessment results for Lake Monroe are summarized as follows:

- Water quality modeling conducted by Dierberg (2006) showed that flow reductions under the recommended MFLs hydrologic conditions would not appreciably affect HRT, TN, and TP.
- DO in Lake Monroe depresses in the summer months and recovers during the winter, as would be expected in natural systems. However, there is no apparent correlation between DO and the lake stage. A slightly lowered stage (by less than 0.25 ft) caused by flow reductions under the recommended MFLs hydrologic conditions for Lake Monroe would not appreciably affect the DO concentration.
- Frequency-duration analysis indicate that the flow reductions under the recommended MFLs hydrologic conditions would not appreciably alter the frequencies of flooding or dewatering of threshold stages (i.e., 3.0 ft-NGVD for 30 days and 2.0 ft-NGVD for 183 days, respectively).

Based on the evaluation of water quality and hydrologic data, ECT concludes that the recommended MFLs for Lake Monroe will protect water quality.

5.11 WRV-10: NAVIGATION

5.11.1 INTRODUCTION

The primary navigational use of Lake Monroe and the St. Johns River between Lake Monroe and Astor is recreational boating (Volusia County, 1996). There is some commercial use of the waterway, including the transport of building materials, marine products, and fuel oil for the Sanford-DeBary Power Plant and commercial operations such as the Rivership Romance described in Section 5.2. ECT evaluated the existing navigation channels according to bathymetric maps, historic hydrographic surveys, field reconnaissance, and interviews with marina dockmasters and Lake Monroe Park personnel, to determine if the recommended MFLs for Lake Monroe will provide adequate protection of the navigation WRV.

5.11.2 METHODOLOGY

Assessment of recreation in and on Lake Monroe, including navigation of recreational boating, is presented in Section 5.2.

In the context of WRVs protection, the navigation WRV is defined as the safe passage of commercial watercraft (e.g., boats and ships) that are dependent upon sufficient water depth, sufficient channel width, and appropriate water velocities.

The representative function of the navigation WRV is the ability of these watercraft to access the locations they historically have accessed. The general indicator for the protection of the navigation WRV is continued legal operation of tug and barge commercial operations, and eco-tourism activities involving large cruise vessels and related watercraft. The specific indicator of protection is the frequency of occurrence for the water level being lower than the threshold stage (-0.5 ft-NGVD) with critical duration of 1, 14, and 30 days.

5.11.3 NAVIGATION ASSESSMENT

As described in Section 5.2, one of the largest commercial vessels in Lake Monroe is the Rivership Romance, a leisure luncheon and dinner cruise boat that uses the Monroe

Harbour Marina in Lake Monroe near the City of Sanford River Walk as home port. This 96-ton cruise ship is a 98-ft refurbished 1940s Great Lakes steamer with a 38-ft-wide beam and 8.5-ft draft. It operates daily luncheon cruises and weekend dinner cruises. Each cruise lasts about 3 to 4 hours and the route of the cruises is between the Monroe Harbour Marina and the St. Johns River at DeBary. The ship uses the well-marked federal channels for navigation. The authorized project depth of the channels used by Rivership Romance ranges from 9 to 12 ft (Section 5.2.3). According to the cruise ship operator, the navigation channel has sufficient depth such that a cruise has never been cancelled due to low water conditions since it started the operation in 1981. The historic minimum water level in Lake Monroe was -0.52 ft-NGVD on April 5, 1945.

Another primary commercial use of the navigation channel in Lake Monroe area is for the transit of fuel oil to the FPL Sanford-DeBary Power Plant on the St. Johns River at U.S. 17-92, downstream from Lake Monroe. According to FPL personnel, the draft of the tugboat is 6 to 6.5 ft and the draft of the inland barges is 7.0 to 8.5 ft, depending on the loads and river stages. The maximum draft of the barges does not exceed 8.5 ft to ensure sufficient freeboard, and the barges are loaded according to the river stage to prevent potential grounding. Sun State Towing provides the barge transport service to FPL. Discussions with Sun State's agent indicated that navigation of the main river channel had not been a problem, even at low water levels (ECT, 2002a). The problems occurred during flood stages when bridge clearances were reduced and increased currents affected steering of barges. The tug operators did not believe lowering the water level by a few inches from the existing condition would affect navigation. The barge/tug never enter Lake Monroe.

Based on the draft of the largest commercial vessels (8.5 ft for Rivership Romance and the FPL barge) and the depths of the navigation channels, a water level of –0.5 ft-NGVD is believed to be the threshold stage for safe navigation of commercial vessels. According to the frequency-duration information provided by Robison (2004b), frequency analysis of the threshold stage was conducted for durations of 1, 14, and 30 days (Table 5-36).

Table 5-36. Frequency Analysis of Threshold Stage for Navigation Protection

Threshold Stage (ft-NVGD)	Duration (Days)	No. of Years in a Century Threshold Stage is Continuously Not Exceeded*		
		Existing	MFLs	Difference
-0.5	1	<2	3	<3
-0.5	14	<2	<2	0
-0.5	30	<2	<2	0

* Water level falls below threshold stage for the indicated duration.

Source: ECT, 2006.

The frequency-duration analysis indicates that the recommended MFLs hydrologic conditions for Lake Monroe would not change the frequency of the threshold stage of –0.5 ft-NGVD being continuously not exceeded for durations of 14 and 30 days (Table 5-36). However, for a duration of 1 day, the recommended MFLs hydrologic conditions would slightly increase the frequency of the lake stage falling below -0.5 ft-NGVD for 1 day (i.e., 3 events within a century compared to <2 such dewatering events for existing conditions; Table 5-36).

5.11.4 SUMMARY

The federal channels in and near Lake Monroe, maintained by USACE, have sufficient depths for safe navigation of the tugboat, barges, and commercial cruise ship currently operated in the Lake Monroe area. The frequency-duration analysis indicated that the recommended MFLs hydrologic conditions for Lake Monroe would not appreciably change the frequency of water levels falling below the critical threshold stage of –0.5 ft-NGVD. Under the existing condition, there would have been fewer than 2 events in a century that the lake stage fell below -0.5 ft-NGVD for a day. There would only be 3 events in a century that the lake stage would fall below –0.5 ft-NGVD for a day under the recommended MFLs hydrologic conditions. Therefore, ECT concludes that the recommended MFLs for Lake Monroe will protect navigation.

6.0 SUMMARY AND CONCLUSIONS

It is ECT's opinion that the recommended MFLs for Lake Monroe will protect all 10 WRVs listed in Section 62-40.473, *F.A.C.* (Table 6-1).

The WRVs protection assessment for Lake Monroe is summarized as follows:

- The WRVs assessment methodology is a four-level hierarchical approach (Table 5-1) that defines threshold stages and critical durations. The assessment results are based on frequency-duration analysis, computer modeling, best available information, and expert opinion.
- The summary of frequency-duration analyses, based on threshold stages and critical durations, is presented in Table 6-2.
- ECT concludes that the recommended MFLs for Lake Monroe will protect recreation in and on the water, fish and wildlife habitat and fish passage, estuarine resources, transfer of detrital material, maintenance of freshwater storage and supply, aesthetic and scenic attributes, filtration and absorption of nutrients and other pollutants, sediment loads, water quality, and navigation (Table 6-1).

Recommendations for continuing activities and further study include:

- ECT recommends that the marinas should be dredged periodically to allow safe mooring and boat passage. Detailed bathymetric surveys should be conducted within the marina and in navigational channels to verify the threshold stages for safe boat passage.
- ECT recommends continued water quality monitoring in and near Lake Monroe in order to establish a sediment budget in the lake and to provide information for future water quality assessments.

Table 6-1. WRVs Protection Assessment Summary for Lake Monroe MFLs Regime

	Resource or Value	MFLs Protects the Resource Yes (1)	MFLs Protects the Resource No (2)
a.	Recreation in and on the water	×	
b.	Fish and wildlife habitats and the passage of fish	×	
c.	Estuarine resources	×	
d.	Transfer of detrital material	×	
e.	Maintenance of freshwater storage and supply	×	
f.	Aesthetic and scenic attributes	×	
g.	Filtration and absorption of nutrients and other pollutants	×	
h.	Sediment loads	×	
i.	Water quality	×	
j.	Navigation	×	

Notes:

(1) Recommended MFLs allow for decline in water levels, but the resource value will be protected.
(2) Recommended MFLs would allow water levels to decline such that WRVs are not protected.

Table 6-2. Summary of Frequency and Duration Analysis for WRV Evaluation

WRV	Threshold Stage (ft-NVGD)	Duration (Days)	No. of Years in a Century Threshold is Tripped			Remark
			Existing	MFLs	Difference	
Recreation in and on the water	0.5	30	36	38	2	(1), boat passage
	0.5	60	27	36	9	(1), boat passage
	0.5	183	3	6	3	(1), boat passage
Fish and wildlife habitats and the passage of fish	-3.0	365	0	0	0	(1), fish passage
	1.3	30	5	8	3	(2), floodplain access
	1.3	60	14	16	2	(2), floodplain access
	1.3	90	22	27	5	(2), floodplain access
	1.3	120	37	42	5	(2), floodplain access
	1.7	30	17	19	2	(2), floodplain access
	1.7	60	27	32	5	(2), floodplain access
	1.7	90	41	49	8	(2), floodplain access
	1.7	120	53	55	2	(2), floodplain access
	1.8	60	30	36	6	(2), woody debris
	1.8	90	49	50	1	(2), woody debris
	3.8	60	73	74	1	(2), woody debris
	3.8	90	83	83	0	(2), woody debris
	2.8	30	41	42	1	(2), wetland communities
	1.2	183	28	35	7	(1), wetland communities
	0.5	120	10	20	10	(1), wetland communities
	-0.4	14	<2	<2	0	(1), littoral zone
	-0.4	30	<2	<2	0	(1), littoral zone
	-0.4	60	<2	<2	0	(1), littoral zone
Estuarine resources	NA	NA	NA	NA	NA	Section 5.4
Transfer of detrital material	3.3	1	40	45	5	(2), floodplain
	3.3	14	45	47	2	(2), floodplain
	3.3	30	47	51	4	(2), floodplain
	5.3	1	78	79	1	(2), in-lake
	5.3	14	80	80	0	(2), in-lake
Maintenance of freshwater storage and supply	NA	NA	NA	NA	NA	Section 5.6
Aesthetic and scenic attributes	1.7	60	94	95	1	(1), lakeshore vegetation
	1.7	90	90	91	1	(1), lakeshore vegetation
	1.7	120	78	82	4	(1), lakeshore vegetation
	0.9	14	83	89	6	(1), sediment exposure
	0.9	30	66	81	15	(1), sediment exposure
	0.9	60	53	61	8	(1), sediment exposure
	0.9	90	41	45	4	(1), sediment exposure
	1.5	30	95	96	1	(1), water clarity
	1.5	60	88	91	3	(1), water clarity
	1.5	90	78	87	9	(1), water clarity

Table 6-2. Summary of Frequency and Duration Analysis for WRV Evaluation

WRV	Threshold Stage (ft-NVGD)	Duration (Days)	No. of Years in a Century Threshold is Tripped: Existing	MFLs	Difference	Remark
Filtration and absorption of nutrients and other pollutants	0.0	30	6	16	10	(1), soil
	0.0	60	4	6	2	(1), soil
	4.0	14	58	60	2	(2), wetland vegetation
	4.0	30	63	63	0	(2), wetland vegetation
	4.0	60	76	77	1	(2), wetland vegetation
	2.3	14	19	22	3	(2), wetland vegetation
	2.3	30	32	35	3	(2), wetland vegetation
	2.3	60	43	44	1	(2), wetland vegetation
	1.0	14	89	93	4	(1), wetland vegetation
	1.0	30	81	83	2	(1), wetland vegetation
	1.0	60	61	71	10	(1), wetland vegetation
	-0.4	14	<2	<2	0	(1), in-lake vegetation
	-0.4	30	<2	<2	0	(1), in-lake vegetation
	-0.4	60	<2	<2	0	(1), in-lake vegetation
Sediment loads	5.3	1	78	79	1	(2), shear stress
	5.3	14	80	80	0	(2), shear stress
Water quality	3.0	30	43	45	2	(2), TSI
	2.0	183	62	63	1	(2), TSI
Navigation	-0.5	1	<2	3	1	(1)
	-0.5	14	<2	<2	<1	(1)
	-0.5	30	<2	<2	<1	(1)

Note: NA = frequency analysis was not applicable.

(1) Threshold being tripped is defined as stage falls below the threshold stage for the indicated duration.
(2) Threshold being tripped is defined as stage does not exceed the threshold stage for the indicated duration.

Source: ECT, 2006.

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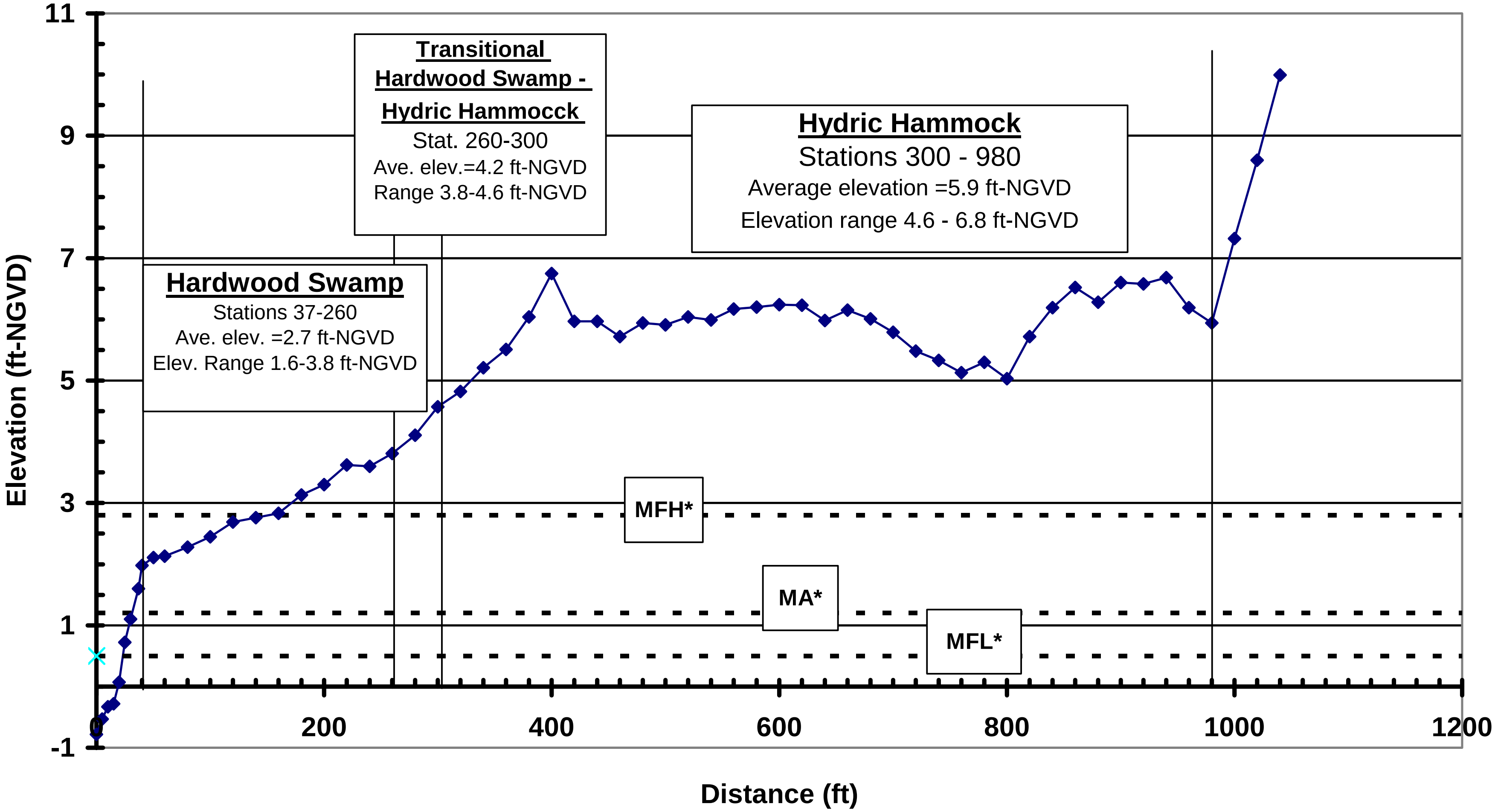
APPENDIX A—TRANSECT DATA

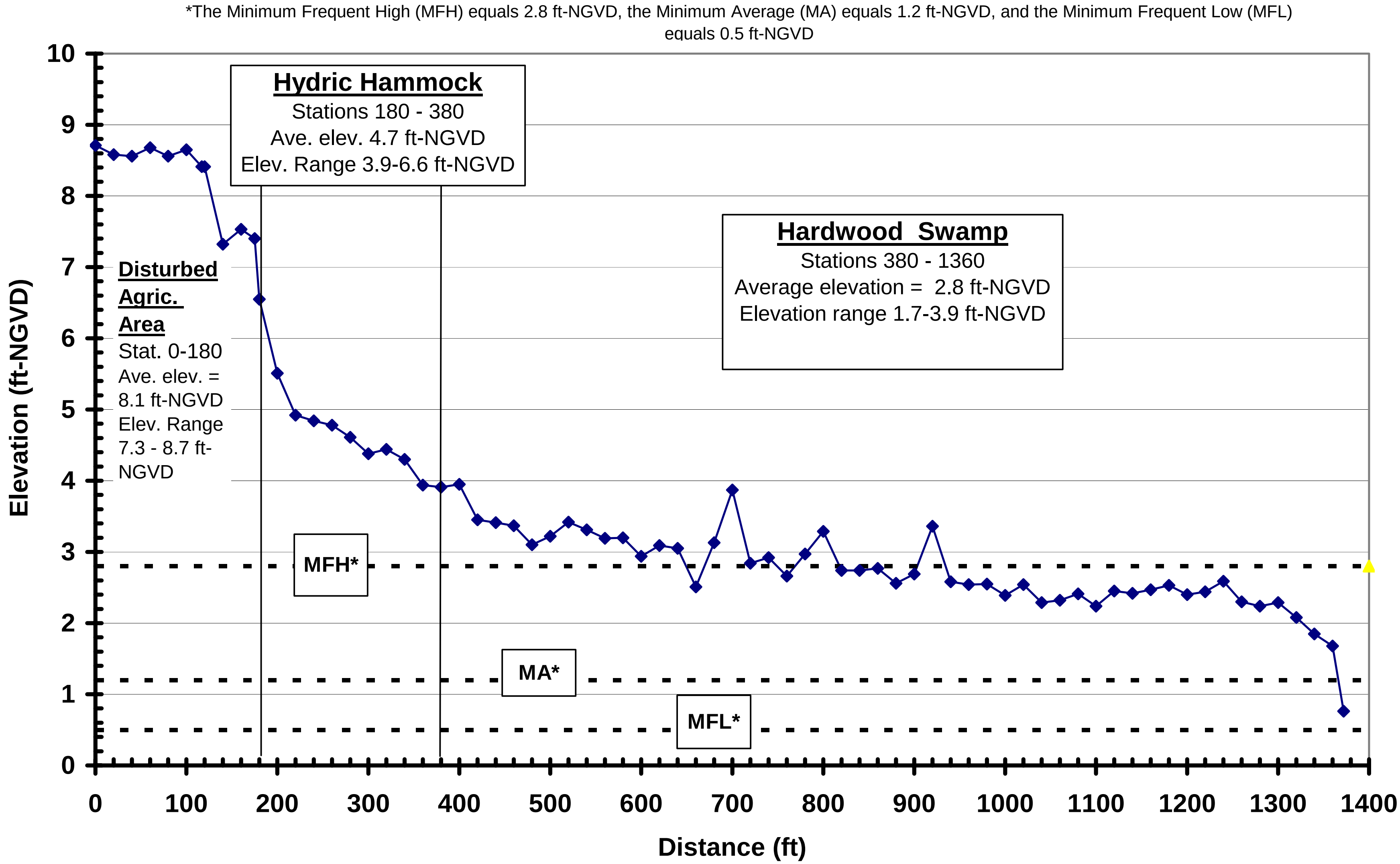
Figure A-1. Lake Monroe Transect 1 Topography with Ecological Communities

*The Minimum Frequent High (MFH) equals 2.8 ft-NGVD, the Minimum Average (MA) equals 1.2 ft-NGVD, and the Minimum Frequent Low (MFL) equals 0.5 ft-NGVD



Source: Mace, 2006a.

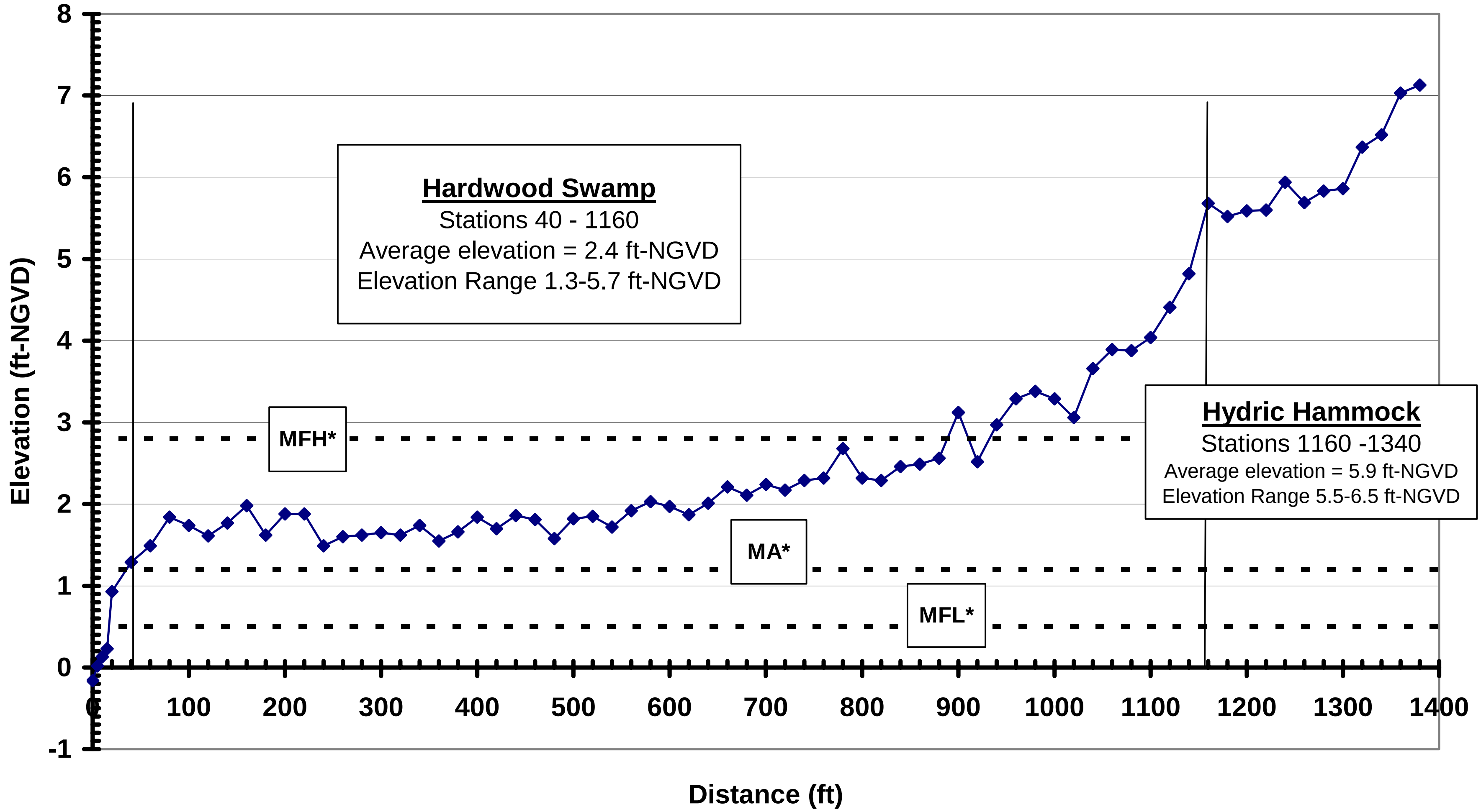
Figure A-2. Lake Monroe Transect 2 Topography with Ecological Communities



Source: Mace, 2006a.

Figure A-3. Lake Monroe Transect 3 Topography with Ecological Communities

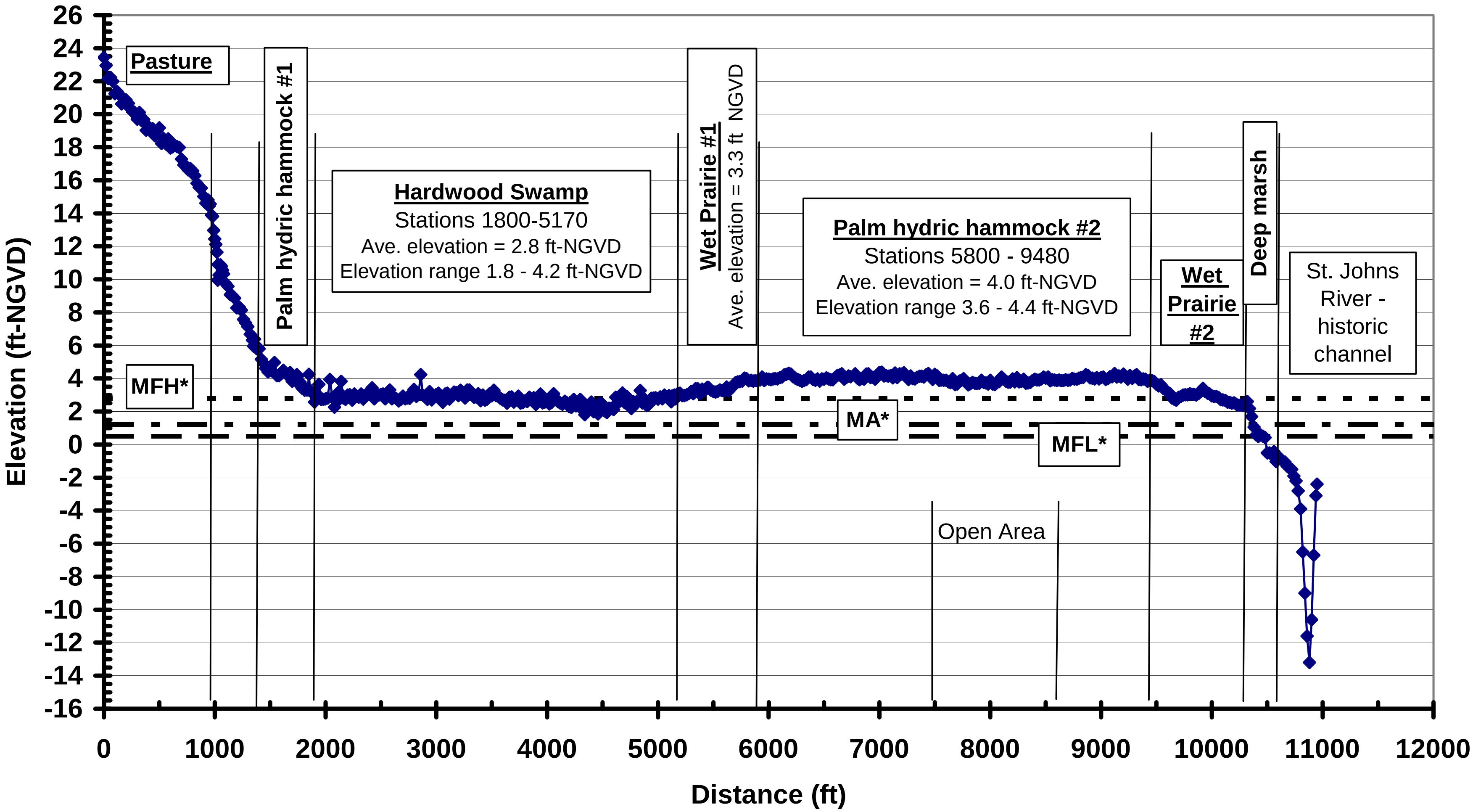
*The Minimum Frequent High (MFH) equals 2.8 ft-NGVD, the Minimum Average (MA) equals 1.2 ft-NGVD, and the Minimum Frequent Low (MFL) equals 0.5 ft-NGVD



Source: Mace, 2006a.

Figure A-4. Lake Monroe Transect 4 Topography with Ecological Communities

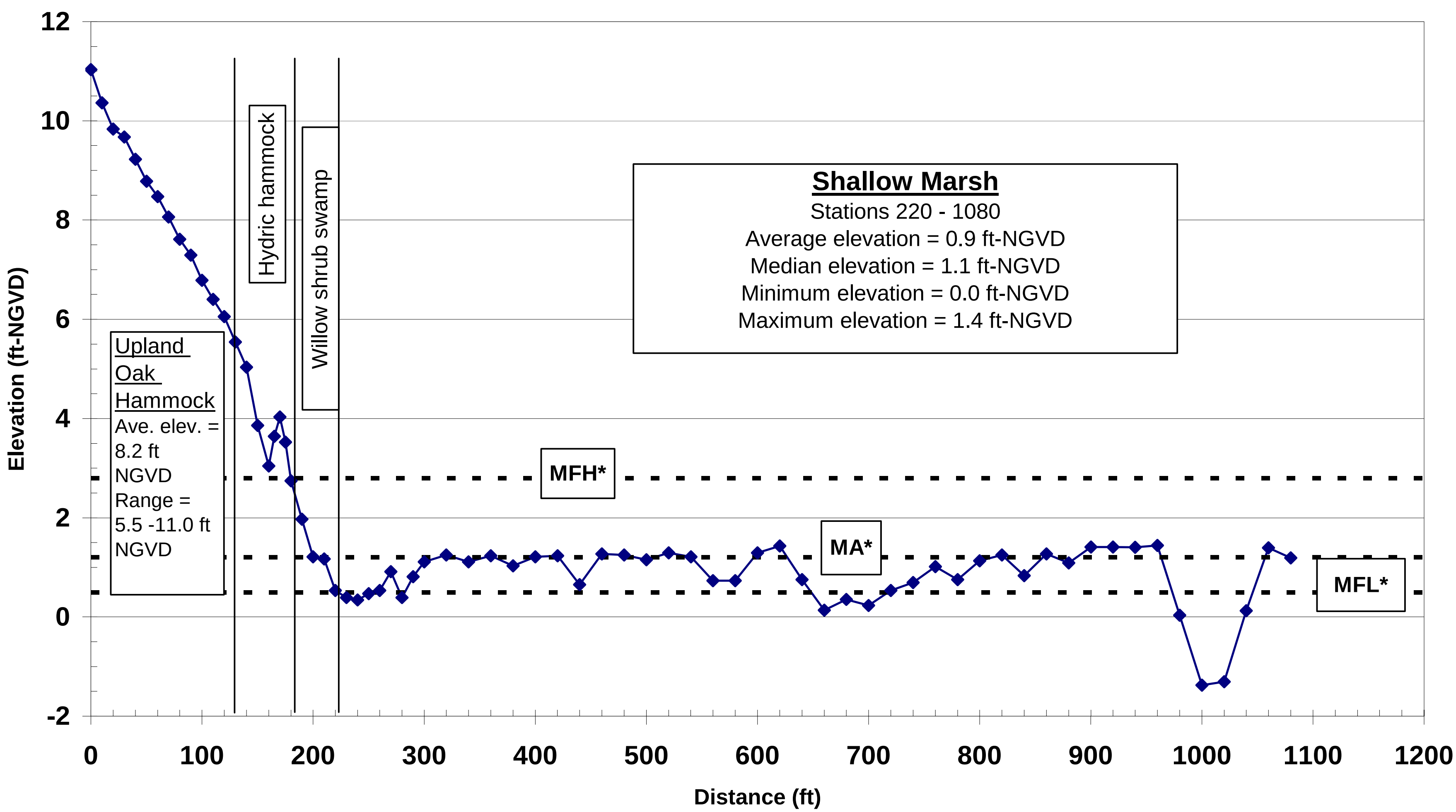
*The Minimum Frequent High (MFH) equals 2.8 ft-NGVD, the Minimum Average (MA) equals 1.2 ft-NGVD, and the Minimum Frequent Low (MFL) equals 0.5 ft-NGVD



Source: Mace, 2006a.

Figure A-5. Lake Monroe Transect 5 Topography with Ecological Communities

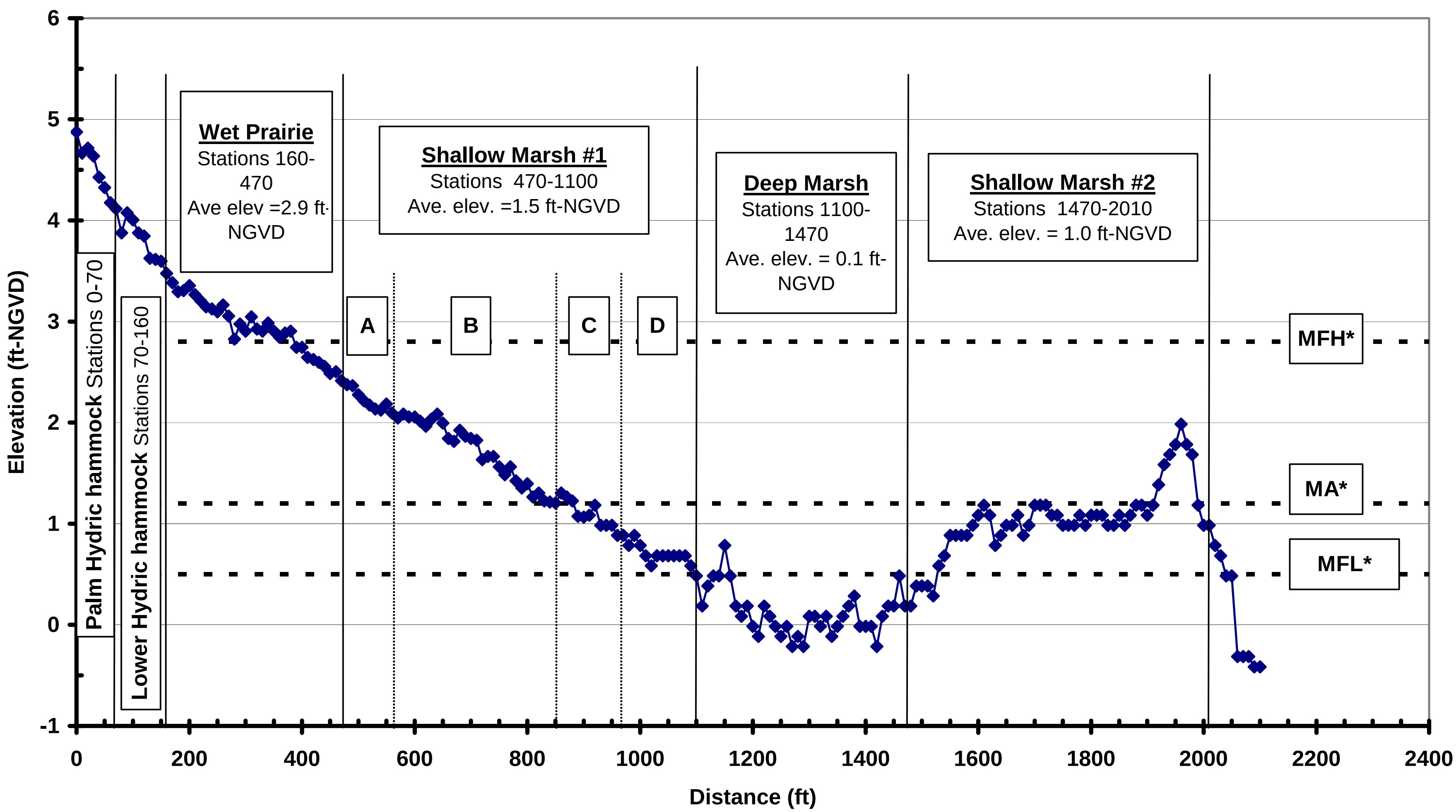
*The Minimum Frequent High (MFH) equals 2.8 ft-NGVD, the Minimum Average (MA) equals 1.2 ft-NGVD, and the Minimum Frequent Low (MFL) equals 0.5 ft-NGVD



Source: Mace, 2006a.

Figure A-6. Lake Monroe Transect 6 Topography with Ecological Communities

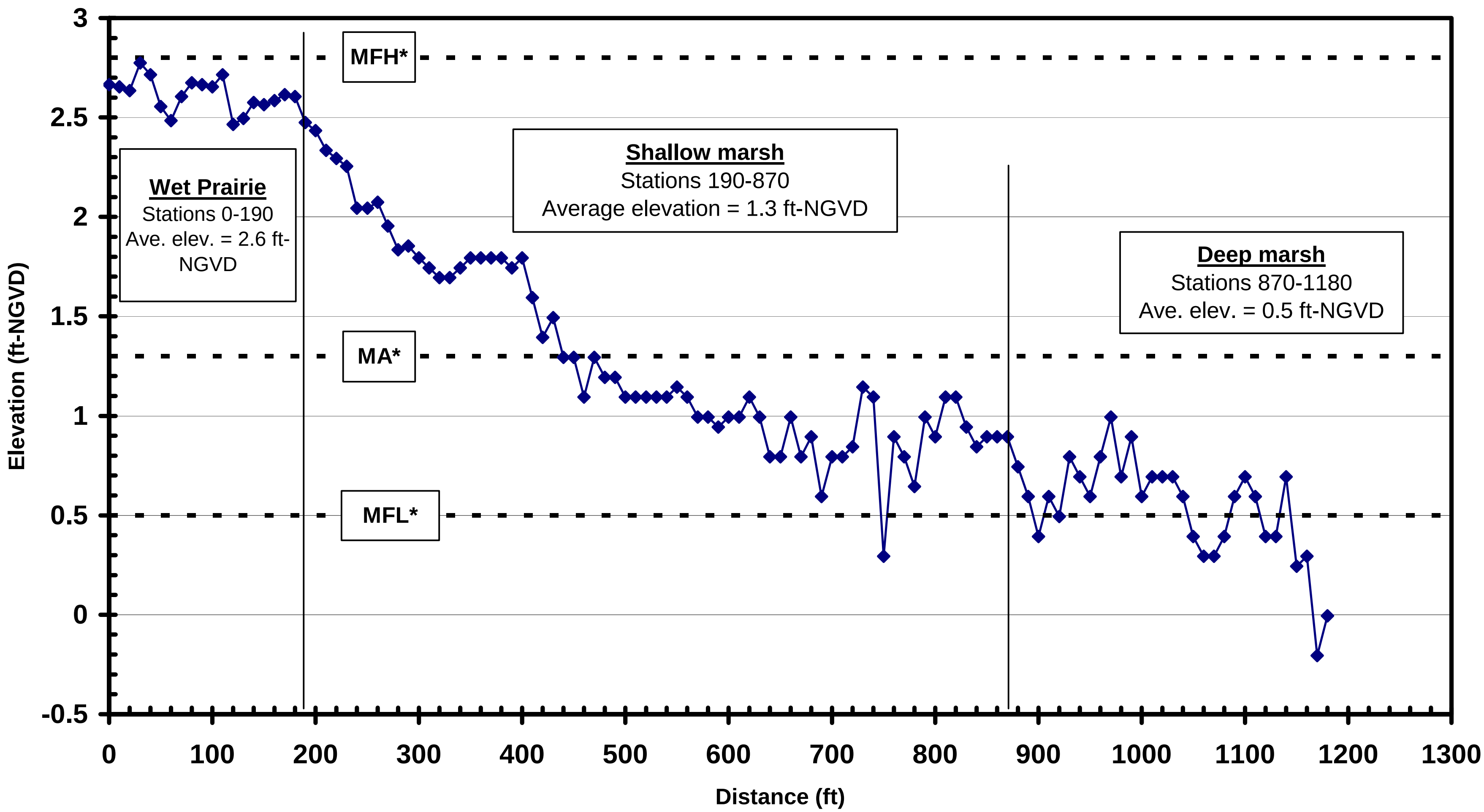
*The Minimum Frequent High (MFH) equals 2.8 ft-NGVD, the Minimum Average (MA) equals 1.2 ft-NGVD, and the Minimum Frequent Low (MFL) equals 0.5 ft-NGVD



Source: Mace, 2006a.

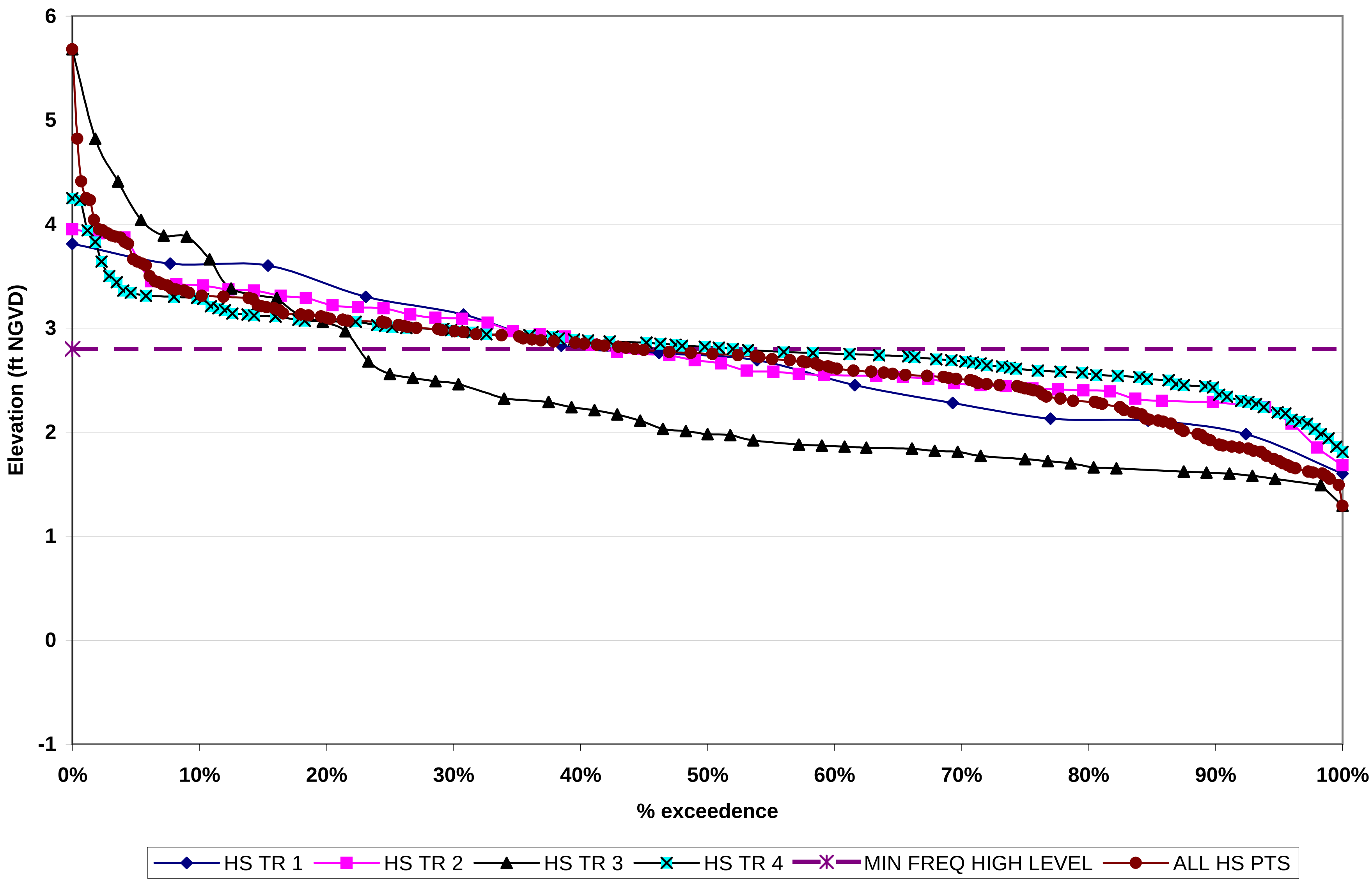
Figure A-7. Lake Monroe Transect 7 Topography with Ecological Communities

*The Minimum Frequent High (MFH) equals 2.8 ft-NGVD, the Minimum Average (MA) equals 1.2 ft-NGVD, and the Minimum Frequent Low (MFL) equals 0.5 ft-NGVD



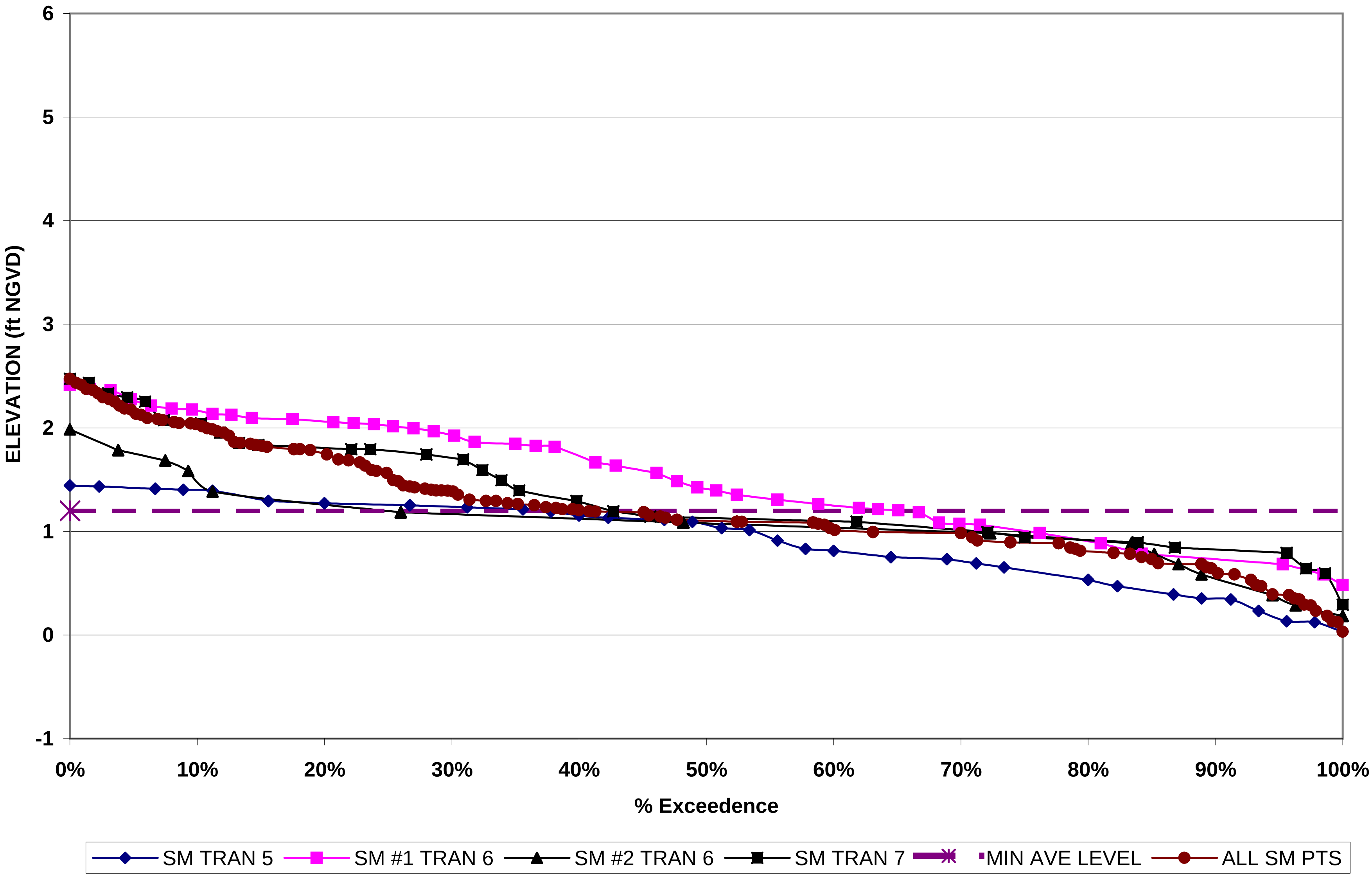
Source: Mace, 2006a.

Figure A-8. Lake Monroe Hardwood Swamps Elevation Percentile Analysis
(Minimum Frequent High Criterion)



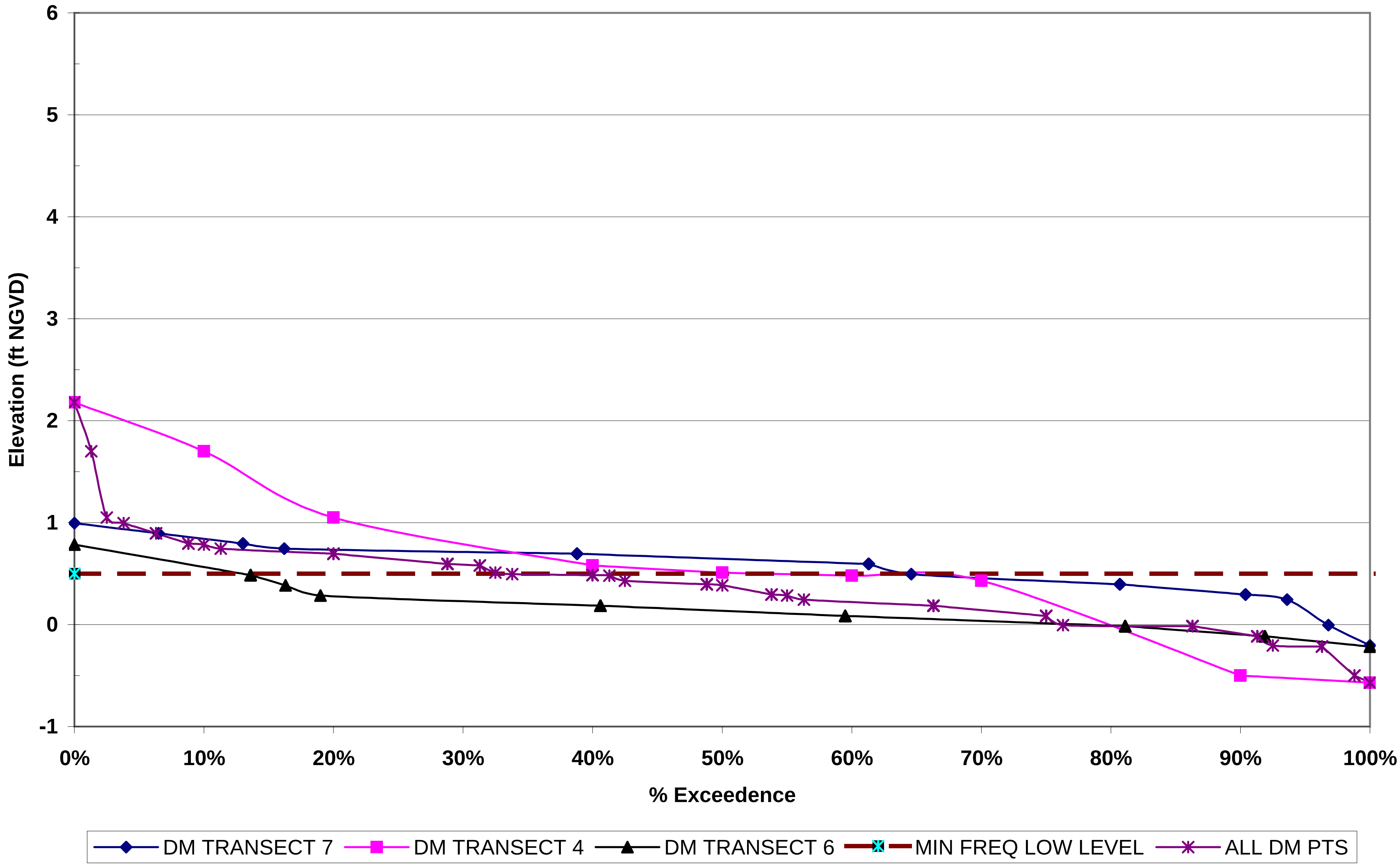
Source: Mace, 2006b.

Figure A-9. Lake Monroe Shallow Marshes Elevation Percentile Analysis
(Minimum Average Criterion)



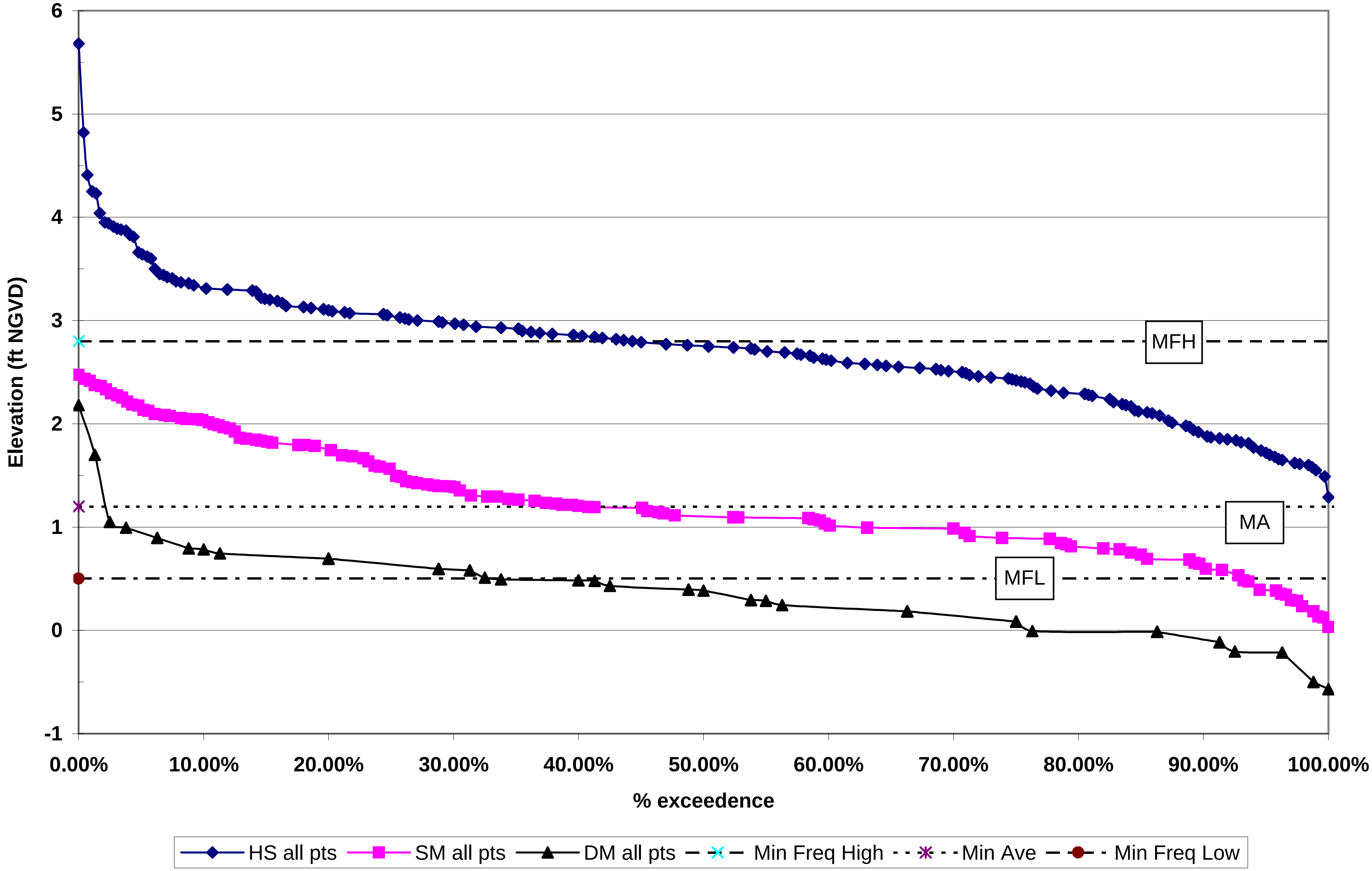
Source: Mace, 2006b.

Figure A-10. Lake Monroe Deep Marshes Elevation Percentile Analysis
(Minimum Frequent Low Criterion)



Source: Mace, 2006b.

Figure A-11. Lake Monroe Elevation Percentile Analysis (Transects Combined for All Communities)



Source: Mace, 2006b.

APPENDIX B—FREQUENCY-DURATION TABLES AND GRAPHS

Table B-1. Frequency-Duration Analysis for Water Level at Lake Monroe Under Existing Conditions (Maximum Stages Continuously Exceeded)

Weibull Prob. (%)	Maximum Stages Continuously Exceeded (ft-NGVD) 1 day	14 days	30 days	60 days	90 days	120 days	183 days	273 days	365 days
2.128	9.08	8.94	8.72	8.02	7.33	6.49	3.24	1.82	1.28
4.255	8.3	8.16	7.87	7.09	5.5	5.17	2.99	1.76	1.2
6.383	6.38	6.21	6.01	5.38	4.89	4.28	2.56	1.49	1.17
8.511	6.31	6.04	5.9	5.01	4.82	4.14	2.45	1.41	0.94
10.638	6.15	6.01	5.79	5.01	4.47	4.04	2.27	1.37	0.78
12.766	6.14	5.95	5.64	4.99	4.36	3.98	2.24	1.34	0.77
14.894	5.97	5.83	5.51	4.71	4.35	3.48	2.17	1.34	0.75
17.021	5.95	5.73	5.47	4.66	3.82	3.18	2.13	1.2	0.71
19.149	5.78	5.63	5.43	4.46	3.64	3.06	2.02	1.19	0.7
21.277	5.36	5.04	4.81	4.45	3.18	2.91	1.89	1.17	0.67
23.404	5.15	4.97	4.58	4.01	3.11	2.4	1.82	1.13	0.6
25.532	5.04	4.88	4.54	3.98	3.07	2.39	1.71	1.11	0.52
27.660	4.81	4.66	4.51	3.79	2.91	2.36	1.66	1.03	0.49
29.787	4.68	4.59	4.28	3.68	2.85	2.24	1.62	1.02	0.46
31.915	4.62	4.49	4.22	3.45	2.65	2.23	1.61	1	0.45
34.043	4.53	4.45	4.22	3.44	2.64	2.05	1.57	0.98	0.43
36.170	4.47	4.36	4.19	3.39	2.61	1.99	1.47	0.94	0.39
38.298	4.44	4.3	3.86	3.32	2.59	1.88	1.41	0.94	0.38
40.426	4.33	4.12	3.85	3.2	2.37	1.86	1.37	0.88	0.36
42.553	4.04	3.92	3.8	3.16	2.36	1.85	1.32	0.87	0.35
44.681	3.82	3.75	3.57	2.99	2.26	1.81	1.17	0.86	0.32
46.809	3.78	3.7	3.56	2.85	2.14	1.71	1.16	0.79	0.3
48.936	3.78	3.67	3.45	2.73	2.11	1.62	1.13	0.78	0.16
51.064	3.61	3.54	3.4	2.57	1.79	1.55	1.11	0.73	0.16
53.191	3.49	3.4	3.28	2.56	1.76	1.48	1.1	0.73	0.1
55.319	3.42	3.26	3.07	2.53	1.73	1.48	1.03	0.71	0.1
57.447	3.36	3.19	2.95	2.23	1.72	1.41	1.02	0.7	0.1
59.574	3.34	3.16	2.73	2.12	1.68	1.35	0.99	0.69	0.07
61.702	3.24	2.94	2.62	2.1	1.68	1.33	0.93	0.62	0.06
63.830	3.22	2.93	2.47	1.9	1.65	1.26	0.9	0.61	0.05
65.957	3.02	2.84	2.39	1.82	1.52	1.26	0.9	0.57	0.05
68.085	2.77	2.68	2.3	1.81	1.44	1.24	0.88	0.57	0.03
70.213	2.75	2.6	2.17	1.8	1.42	1.23	0.86	0.57	0.01
72.340	2.71	2.57	2.17	1.77	1.41	1.21	0.81	0.56	-0.01
74.468	2.69	2.54	2.16	1.62	1.36	1.16	0.8	0.55	-0.03
76.596	2.66	2.43	2.14	1.54	1.35	1.14	0.75	0.5	-0.04
78.723	2.55	2.42	2.04	1.51	1.29	1.13	0.73	0.49	-0.06
80.851	2.55	2.38	1.83	1.48	1.27	1.08	0.72	0.44	-0.07
82.979	2.24	2.1	1.67	1.44	1.18	1.05	0.7	0.39	-0.08
85.106	2.05	1.96	1.66	1.31	1.14	0.93	0.68	0.34	-0.12
87.234	2.03	1.79	1.65	1.27	1.06	0.89	0.6	0.32	-0.13
89.362	2.01	1.7	1.46	1.06	0.83	0.75	0.49	0.3	-0.13
91.489	1.69	1.63	1.42	1.04	0.77	0.66	0.47	0.26	-0.17
93.617	1.6	1.55	1.35	1.02	0.71	0.57	0.44	0.24	-0.19
95.745	1.51	1.43	1.29	0.94	0.62	0.55	0.38	0.23	-0.23
97.872	1.46	1.3	1.08	0.94	0.57	0.53	0.35	0.21	-0.31

Source: Robison, 2004b.

Table B-2. Frequency-Duration Analysis for Water Level at Lake Monroe Under Existing Conditions
(Minimum Stages Continuously Not Exceeded)

Weibull	Minimum Stages Continuously Not Exceeded (ft-NGVD)								
Prob. (%)	1 day	14 days	30 days	60 days	90 days	120 days	183 days	273 days	365 days
2.128	-0.31	-0.15	-0.09	-0.07	0.08	0.33	0.46	0.87	1.24
4.255	-0.23	-0.12	-0.09	0.01	0.16	0.37	0.58	0.95	1.41
6.383	-0.13	-0.03	0.03	0.17	0.19	0.41	0.64	1.01	2.05
8.511	-0.13	-0.02	0.04	0.19	0.36	0.43	0.78	1.03	2.32
10.638	-0.12	-0.01	0.07	0.26	0.38	0.51	0.85	1.4	2.55
12.766	-0.09	0.03	0.09	0.29	0.44	0.56	0.9	1.6	2.71
14.894	-0.07	0.09	0.15	0.31	0.47	0.57	0.95	1.67	2.77
17.021	-0.04	0.11	0.18	0.32	0.51	0.6	0.97	1.75	2.89
19.149	-0.01	0.11	0.2	0.34	0.56	0.62	1	1.8	3.02
21.277	0.01	0.16	0.21	0.35	0.56	0.63	1.07	1.81	3.24
23.404	0.05	0.17	0.26	0.41	0.6	0.66	1.07	1.85	3.42
25.532	0.05	0.18	0.3	0.44	0.62	0.67	1.08	1.89	3.52
27.660	0.09	0.2	0.31	0.54	0.66	0.67	1.17	1.98	3.61
29.787	0.1	0.22	0.31	0.54	0.67	0.78	1.27	1.99	3.72
31.915	0.16	0.27	0.35	0.57	0.68	0.88	1.28	2.02	3.78
34.043	0.21	0.28	0.4	0.57	0.8	0.94	1.29	2.05	3.99
36.170	0.32	0.4	0.54	0.61	0.82	1.01	1.31	2.08	4.02
38.298	0.32	0.41	0.6	0.71	0.87	1.03	1.37	2.32	4.04
40.426	0.35	0.5	0.65	0.73	0.88	1.1	1.42	2.36	4.1
42.553	0.36	0.53	0.7	0.78	0.96	1.19	1.44	2.47	4.18
44.681	0.42	0.55	0.73	0.83	1	1.27	1.46	2.55	4.31
46.809	0.43	0.56	0.73	0.85	1.03	1.27	1.58	2.77	4.33
48.936	0.44	0.6	0.74	0.86	1.05	1.3	1.61	2.81	4.36
51.064	0.46	0.6	0.74	0.87	1.17	1.31	1.64	2.93	4.44
53.191	0.47	0.61	0.75	0.9	1.17	1.35	1.75	2.94	4.47
55.319	0.49	0.63	0.76	0.91	1.19	1.4	1.79	3	4.53
57.447	0.52	0.63	0.78	0.93	1.2	1.41	1.89	3.13	4.6
59.574	0.55	0.68	0.82	0.98	1.2	1.46	1.96	3.24	4.62
61.702	0.57	0.71	0.84	1.02	1.23	1.47	1.99	3.34	4.68
63.830	0.6	0.76	0.9	1.06	1.26	1.55	2.15	3.39	4.81
65.957	0.61	0.77	0.9	1.06	1.31	1.58	2.27	3.48	4.83
68.085	0.66	0.78	0.92	1.06	1.33	1.58	2.45	3.49	5.04
70.213	0.66	0.79	0.93	1.09	1.34	1.63	2.47	3.56	5.36
72.340	0.67	0.8	0.96	1.13	1.38	1.63	2.55	3.66	5.78
74.468	0.75	0.83	0.96	1.14	1.44	1.66	2.55	3.72	5.83
76.596	0.76	0.84	0.97	1.16	1.47	1.69	2.57	3.81	5.95
78.723	0.77	0.86	0.97	1.3	1.51	1.71	2.69	3.91	5.97
80.851	0.78	0.9	0.99	1.3	1.52	1.78	3.08	4.13	6.14
82.979	0.8	0.9	1.09	1.31	1.58	1.81	3.1	4.2	6.15
85.106	0.82	0.92	1.14	1.37	1.59	1.84	3.34	4.33	6.28
87.234	0.84	0.95	1.24	1.44	1.6	1.9	3.6	4.87	6.31
89.362	0.94	1.03	1.27	1.6	1.6	2.02	4.09	5.04	6.38
91.489	0.96	1.08	1.34	1.6	1.99	2.1	4.2	5.15	7.69
93.617	1.03	1.11	1.34	1.67	2.02	2.15	4.65	5.58	7.98
95.745	1.2	1.4	1.61	1.84	2.4	2.75	4.87	6.38	8.3
97.872	1.32	1.41	1.65	2.01	2.75	3.38	6.08	7.03	9.08

Source: Robison, 2004b.

Table B-3. Frequency-Duration Analysis for Water Level at Lake Monroe Under Existing Conditions (Maximum Average Stages)

Weibull Prob. (%)	Maximum Average Stages (ft-NGVD) 1 day	14 days	30 days	60 days	90 days	120 days	183 days	273 days	365 days
2.128	9.08	9.04	8.95	8.66	8.34	7.99	6.71	4.94	3.85
4.255	8.3	8.25	8.14	7.83	7.33	6.84	5.83	4.47	3.6
6.383	6.38	6.25	6.2	5.78	5.58	5.26	4.67	3.88	3.53
8.511	6.31	6.24	6.14	5.78	5.39	5.23	4.6	3.82	3.25
10.638	6.15	6.08	5.99	5.71	5.37	5.13	4.4	3.8	3.16
12.766	6.14	6.07	5.98	5.67	5.34	5.12	4.33	3.73	3.15
14.894	5.97	5.9	5.77	5.66	5.21	4.8	4.24	3.71	3.14
17.021	5.95	5.86	5.72	5.52	5.09	4.66	4.19	3.27	2.83
19.149	5.78	5.72	5.62	5.32	4.99	4.34	3.92	3.16	2.77
21.277	5.36	5.23	4.97	4.68	4.48	4.32	3.38	2.98	2.66
23.404	5.15	5.07	4.91	4.62	4.35	4.21	3.36	2.77	2.49
25.532	5.04	4.96	4.91	4.58	4.26	3.78	3.34	2.69	2.32
27.660	4.81	4.75	4.73	4.38	4	3.72	3.33	2.68	2.11
29.787	4.68	4.63	4.52	4.28	3.92	3.69	3.06	2.63	2.1
31.915	4.62	4.56	4.47	4.21	3.74	3.62	2.99	2.61	2.09
34.043	4.53	4.5	4.41	4.2	3.71	3.3	2.96	2.46	2.06
36.170	4.47	4.44	4.37	4.08	3.61	3.21	2.82	2.46	2.01
38.298	4.44	4.37	4.22	3.81	3.52	3.2	2.7	2.37	1.93
40.426	4.33	4.24	4.12	3.79	3.52	3	2.69	2.26	1.92
42.553	4.04	3.98	3.93	3.76	3.29	2.99	2.63	2.18	1.8
44.681	3.82	3.79	3.73	3.56	3.22	2.95	2.41	2.03	1.78
46.809	3.78	3.75	3.69	3.4	3.17	2.93	2.32	2.02	1.73
48.936	3.78	3.73	3.64	3.39	3.15	2.88	2.25	1.9	1.72
51.064	3.61	3.58	3.53	3.33	3.02	2.74	2.24	1.89	1.62
53.191	3.49	3.45	3.39	3.19	2.97	2.61	2.18	1.88	1.57
55.319	3.42	3.31	3.24	3.1	2.75	2.43	2.14	1.87	1.56
57.447	3.36	3.3	3.16	2.79	2.52	2.33	2.11	1.86	1.55
59.574	3.34	3.29	3	2.63	2.38	2.26	1.89	1.81	1.49
61.702	3.24	3.12	2.9	2.58	2.35	2.14	1.85	1.75	1.47
63.830	3.22	3.06	2.78	2.49	2.23	2.11	1.85	1.72	1.41
65.957	3.02	2.97	2.72	2.41	2.23	2.09	1.83	1.53	1.27
68.085	2.77	2.73	2.7	2.39	2.2	2	1.82	1.5	1.22
70.213	2.75	2.66	2.59	2.32	2.01	1.97	1.79	1.44	1.21
72.340	2.71	2.65	2.55	2.21	1.96	1.87	1.69	1.38	1.17
74.468	2.69	2.63	2.51	2.16	1.94	1.82	1.58	1.38	1.07
76.596	2.66	2.6	2.39	2.12	1.93	1.81	1.52	1.34	1.06
78.723	2.55	2.49	2.35	2.07	1.92	1.77	1.51	1.33	1.04
80.851	2.55	2.47	2.29	1.99	1.88	1.76	1.5	1.26	1.04
82.979	2.24	2.18	2.06	1.72	1.68	1.57	1.41	1.23	0.97
85.106	2.1	2	1.91	1.72	1.53	1.43	1.32	1.2	0.97
87.234	2.05	1.93	1.73	1.63	1.41	1.3	1.16	1.11	0.96
89.362	2.03	1.79	1.72	1.55	1.41	1.25	1.15	1.01	0.87
91.489	1.69	1.67	1.62	1.53	1.33	1.24	1.07	0.94	0.81
93.617	1.6	1.58	1.5	1.33	1.23	1.19	0.99	0.91	0.77
95.745	1.51	1.46	1.42	1.25	1.12	1.01	0.95	0.78	0.62
97.872	1.46	1.39	1.28	1.15	1.05	0.96	0.85	0.73	0.61

Source: Robison, 2004b.

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Table B-4. Frequency-Duration Analysis for Water Level at Lake Monroe Under Existing Conditions (Minimum Average Stages)

Weibull	Minimum Average Stages (ft-NGVD)								
Prob. (%)	1 day	14 days	30 days	60 days	90 days	120 days	183 days	273 days	365 days
2.128	-0.31	-0.22	-0.17	-0.16	-0.11	-0.03	0.15	0.27	0.4
4.255	-0.23	-0.15	-0.14	-0.1	-0.05	0.02	0.23	0.36	0.68
6.383	-0.13	-0.07	-0.04	0.04	0.06	0.12	0.24	0.41	0.68
8.511	-0.13	-0.06	-0.04	0.04	0.12	0.16	0.26	0.51	0.76
10.638	-0.12	-0.05	-0.01	0.05	0.19	0.23	0.31	0.61	0.89
12.766	-0.09	-0.03	-0.01	0.07	0.2	0.29	0.44	0.68	0.94
14.894	-0.07	0.02	0.07	0.17	0.23	0.29	0.47	0.69	1.1
17.021	-0.04	0.05	0.09	0.17	0.24	0.33	0.48	0.76	1.12
19.149	-0.01	0.05	0.11	0.19	0.26	0.33	0.49	0.79	1.23
21.277	0.01	0.07	0.13	0.19	0.29	0.36	0.5	0.82	1.27
23.404	0.05	0.1	0.14	0.22	0.31	0.37	0.51	0.89	1.28
25.532	0.05	0.12	0.17	0.26	0.32	0.37	0.52	0.89	1.36
27.660	0.09	0.16	0.19	0.26	0.33	0.37	0.58	0.9	1.37
29.787	0.1	0.17	0.2	0.3	0.33	0.41	0.63	0.94	1.4
31.915	0.16	0.2	0.28	0.35	0.48	0.53	0.65	0.99	1.41
34.043	0.21	0.25	0.28	0.36	0.49	0.56	0.7	1.02	1.44
36.170	0.32	0.36	0.42	0.46	0.51	0.6	0.73	1.05	1.56
38.298	0.32	0.37	0.44	0.47	0.56	0.68	0.77	1.07	1.61
40.426	0.35	0.43	0.5	0.58	0.66	0.75	0.79	1.09	1.64
42.553	0.36	0.45	0.55	0.64	0.7	0.75	0.87	1.15	1.66
44.681	0.42	0.49	0.57	0.66	0.71	0.78	0.92	1.18	1.82
46.809	0.43	0.51	0.58	0.66	0.71	0.81	0.93	1.2	1.82
48.936	0.44	0.51	0.61	0.67	0.79	0.89	1.07	1.2	1.85
51.064	0.46	0.54	0.61	0.7	0.79	0.91	1.13	1.22	1.85
53.191	0.47	0.54	0.62	0.7	0.8	0.93	1.15	1.24	1.88
55.319	0.49	0.55	0.63	0.72	0.8	0.99	1.17	1.26	1.94
57.447	0.52	0.58	0.63	0.74	0.88	0.99	1.18	1.37	1.95
59.574	0.55	0.6	0.67	0.76	0.9	0.99	1.22	1.41	1.96
61.702	0.57	0.64	0.74	0.83	0.91	1.01	1.22	1.42	2
63.830	0.6	0.69	0.76	0.85	0.93	1.02	1.23	1.44	2.06
65.957	0.61	0.7	0.78	0.9	0.93	1.07	1.25	1.47	2.1
68.085	0.66	0.72	0.79	0.91	0.95	1.07	1.33	1.48	2.1
70.213	0.66	0.73	0.8	0.92	0.99	1.11	1.33	1.59	2.16
72.340	0.67	0.75	0.81	0.92	0.99	1.11	1.35	1.77	2.16
74.468	0.75	0.79	0.83	0.93	1.04	1.12	1.38	1.82	2.17
76.596	0.76	0.8	0.86	0.93	1.05	1.16	1.42	1.89	2.19
78.723	0.77	0.81	0.88	0.94	1.05	1.16	1.45	1.91	2.23
80.851	0.78	0.85	0.88	0.94	1.09	1.17	1.5	1.97	2.33
82.979	0.8	0.87	0.9	1.01	1.1	1.19	1.58	2.03	2.47
85.106	0.82	0.88	0.93	1.15	1.2	1.2	1.67	2.08	2.7
87.234	0.84	0.88	0.99	1.16	1.24	1.29	1.68	2.23	2.94
89.362	0.94	0.99	1.08	1.28	1.24	1.34	1.71	2.3	2.95
91.489	0.96	1.02	1.12	1.29	1.45	1.54	2.11	2.45	3.01
93.617	1.03	1.07	1.12	1.31	1.56	1.76	2.16	2.49	3.16
95.745	1.2	1.29	1.44	1.57	1.75	1.8	2.48	2.74	3.34
97.872	1.32	1.37	1.46	1.62	1.87	2.06	2.6	3.12	3.64

Source: Robison, 2004b.

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Table B-5. Frequency-Duration Analysis for Water Level at Lake Monroe Under 180-cfs Withdrawal Conditions (Maximum Stages Continuously Exceeded)

Weibull	Maximum Stages Continuously Exceeded (ft-NGVD)								
Prob. (%)	1 day	14 days	30 days	60 days	90 days	120 days	183 days	273 days	365 days
2.128	8.94	8.8	8.59	7.86	7.19	6.37	3.1	1.71	1.19
4.255	8.16	8.02	7.72	6.93	5.34	5.05	2.86	1.65	1.1
6.383	6.24	6.08	5.87	5.24	4.76	4.15	2.43	1.38	1.07
8.511	6.19	5.9	5.76	4.86	4.7	4	2.33	1.3	0.84
10.638	6.02	5.86	5.64	4.86	4.32	3.92	2.13	1.26	0.68
12.766	6	5.82	5.5	4.85	4.22	3.86	2.1	1.24	0.68
14.894	5.83	5.69	5.39	4.57	4.22	3.34	2.04	1.23	0.65
17.021	5.8	5.59	5.34	4.52	3.69	3.05	2.01	1.1	0.6
19.149	5.65	5.49	5.29	4.32	3.49	2.94	1.89	1.09	0.6
21.277	5.24	4.92	4.67	4.32	3.05	2.78	1.78	1.07	0.57
23.404	5.03	4.85	4.45	3.88	2.98	2.27	1.71	1.02	0.48
25.532	4.91	4.76	4.42	3.84	2.95	2.26	1.6	1.01	0.4
27.660	4.69	4.54	4.37	3.67	2.78	2.23	1.56	0.93	0.35
29.787	4.55	4.47	4.15	3.55	2.73	2.11	1.51	0.93	0.33
31.915	4.5	4.36	4.1	3.32	2.52	2.1	1.5	0.89	0.32
34.043	4.41	4.33	4.09	3.32	2.52	1.95	1.46	0.88	0.31
36.170	4.35	4.24	4.07	3.26	2.48	1.87	1.37	0.84	0.26
38.298	4.31	4.17	3.73	3.2	2.48	1.78	1.3	0.84	0.26
40.426	4.21	3.99	3.72	3.07	2.25	1.76	1.26	0.78	0.23
42.553	3.91	3.8	3.67	3.03	2.23	1.75	1.23	0.77	0.22
44.681	3.69	3.63	3.45	2.86	2.14	1.7	1.06	0.76	0.18
46.809	3.66	3.58	3.44	2.72	2.02	1.6	1.06	0.69	0.17
48.936	3.66	3.55	3.32	2.6	1.99	1.52	1.02	0.68	0.02
51.064	3.48	3.41	3.28	2.44	1.69	1.46	1.01	0.63	0
53.191	3.36	3.27	3.15	2.42	1.66	1.38	1	0.61	-0.04
55.319	3.3	3.14	2.94	2.4	1.62	1.37	0.93	0.59	-0.05
57.447	3.24	3.06	2.82	2.11	1.61	1.31	0.92	0.59	-0.08
59.574	3.22	3.04	2.6	1.99	1.58	1.25	0.89	0.59	-0.08
61.702	3.13	2.82	2.5	1.97	1.57	1.23	0.83	0.49	-0.09
63.830	3.1	2.8	2.35	1.81	1.54	1.16	0.81	0.49	-0.1
65.957	2.9	2.72	2.26	1.71	1.42	1.15	0.8	0.46	-0.1
68.085	2.65	2.55	2.17	1.7	1.35	1.14	0.78	0.45	-0.13
70.213	2.63	2.47	2.05	1.69	1.33	1.12	0.76	0.45	-0.15
72.340	2.58	2.45	2.04	1.67	1.31	1.09	0.71	0.45	-0.17
74.468	2.57	2.42	2.04	1.51	1.26	1.06	0.69	0.44	-0.19
76.596	2.54	2.31	2.03	1.44	1.25	1.04	0.65	0.37	-0.22
78.723	2.43	2.29	1.92	1.41	1.19	1.03	0.63	0.36	-0.24
80.851	2.42	2.26	1.74	1.37	1.17	0.98	0.62	0.31	-0.25
82.979	2.12	1.99	1.57	1.35	1.08	0.95	0.6	0.26	-0.26
85.106	1.94	1.85	1.56	1.21	1.04	0.83	0.55	0.2	-0.32
87.234	1.91	1.67	1.55	1.17	0.96	0.79	0.48	0.19	-0.32
89.362	1.9	1.59	1.36	0.96	0.72	0.65	0.36	0.16	-0.33
91.489	1.6	1.53	1.32	0.93	0.66	0.53	0.34	0.12	-0.38
93.617	1.51	1.45	1.24	0.92	0.6	0.44	0.31	0.1	-0.39
95.745	1.41	1.33	1.19	0.84	0.5	0.42	0.25	0.09	-0.42
97.872	1.36	1.21	0.98	0.82	0.44	0.41	0.21	0.07	-0.54

Source: Robison, 2004b.

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Table B-6. Frequency-Duration Analysis for Water Level at Lake Monroe Under 180-cfs Withdrawal Conditions (Minimum Stages Continuously Not Exceeded)

Weibull Prob. (%)	Minimum Stages Continuously Not Exceeded (ft-NGVD) 1 day	14 days	30 days	60 days	90 days	120 days	183 days	273 days	365 days
2.128	-0.54	-0.39	-0.3	-0.28	-0.08	0.12	0.32	0.76	1.13
4.255	-0.42	-0.31	-0.29	-0.17	0.01	0.17	0.45	0.84	1.3
6.383	-0.33	-0.22	-0.18	0.01	0.03	0.26	0.53	0.92	1.94
8.511	-0.32	-0.21	-0.14	0.02	0.21	0.27	0.67	0.93	2.21
10.638	-0.32	-0.2	-0.12	0.11	0.22	0.38	0.74	1.28	2.43
12.766	-0.28	-0.14	-0.06	0.13	0.29	0.43	0.79	1.51	2.58
14.894	-0.24	-0.08	-0.01	0.17	0.34	0.44	0.84	1.57	2.65
17.021	-0.19	-0.06	0.01	0.17	0.37	0.48	0.87	1.65	2.76
19.149	-0.17	-0.04	0.05	0.19	0.41	0.49	0.89	1.7	2.9
21.277	-0.15	0	0.08	0.2	0.45	0.51	0.97	1.7	3.13
23.404	-0.13	0.02	0.12	0.29	0.48	0.53	0.97	1.73	3.3
25.532	-0.1	0.03	0.15	0.3	0.48	0.56	0.97	1.79	3.39
27.660	-0.06	0.05	0.17	0.4	0.54	0.56	1.07	1.87	3.48
29.787	-0.05	0.08	0.17	0.4	0.54	0.66	1.17	1.88	3.6
31.915	0.01	0.13	0.21	0.44	0.55	0.78	1.18	1.9	3.66
34.043	0.07	0.14	0.26	0.47	0.68	0.83	1.18	1.94	3.86
36.170	0.18	0.26	0.41	0.51	0.71	0.91	1.21	1.97	3.89
38.298	0.19	0.27	0.5	0.61	0.78	0.93	1.27	2.19	3.91
40.426	0.22	0.39	0.54	0.61	0.78	0.99	1.31	2.24	3.97
42.553	0.23	0.41	0.59	0.67	0.86	1.09	1.34	2.35	4.06
44.681	0.29	0.44	0.63	0.72	0.9	1.17	1.36	2.42	4.19
46.809	0.31	0.44	0.63	0.75	0.93	1.17	1.48	2.65	4.21
48.936	0.31	0.48	0.63	0.76	0.95	1.21	1.51	2.69	4.24
51.064	0.33	0.49	0.64	0.76	1.07	1.21	1.55	2.78	4.31
53.191	0.35	0.5	0.64	0.8	1.07	1.25	1.63	2.81	4.35
55.319	0.36	0.53	0.66	0.81	1.09	1.29	1.68	2.88	4.41
57.447	0.4	0.53	0.69	0.81	1.09	1.31	1.79	3.01	4.47
59.574	0.44	0.58	0.71	0.88	1.1	1.36	1.84	3.13	4.5
61.702	0.45	0.61	0.74	0.92	1.13	1.38	1.89	3.22	4.55
63.830	0.48	0.66	0.79	0.96	1.17	1.45	2.03	3.26	4.69
65.957	0.5	0.67	0.8	0.96	1.21	1.48	2.15	3.35	4.7
68.085	0.54	0.67	0.82	0.97	1.23	1.49	2.32	3.36	4.91
70.213	0.56	0.68	0.83	0.99	1.23	1.52	2.35	3.44	5.24
72.340	0.57	0.7	0.86	1.03	1.28	1.53	2.42	3.53	5.65
74.468	0.65	0.74	0.86	1.04	1.34	1.57	2.42	3.59	5.69
76.596	0.66	0.74	0.87	1.06	1.37	1.59	2.44	3.69	5.8
78.723	0.68	0.76	0.88	1.19	1.41	1.61	2.56	3.78	5.83
80.851	0.68	0.8	0.89	1.2	1.42	1.68	2.94	3.99	6
82.979	0.7	0.8	0.99	1.21	1.49	1.72	2.98	4.08	6.02
85.106	0.71	0.82	1.04	1.27	1.49	1.72	3.22	4.21	6.15
87.234	0.74	0.85	1.14	1.34	1.5	1.79	3.47	4.75	6.19
89.362	0.84	0.93	1.17	1.5	1.5	1.9	3.97	4.89	6.24
91.489	0.86	0.98	1.24	1.5	1.87	1.98	4.08	5.03	7.56
93.617	0.93	1.01	1.24	1.56	1.9	2.02	4.54	5.44	7.84
95.745	1.1	1.3	1.51	1.74	2.27	2.63	4.75	6.24	8.16
97.872	1.22	1.31	1.55	1.9	2.63	3.25	5.93	6.86	8.94

Source: Robison, 2004b.

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Table B-7. Frequency-Duration Analysis for Water Level at Lake Monroe Under 180-cfs Withdrawal Conditions (Maximum Average Stages)

Weibull Prob. (%)	Maximum Average Stages (ft-NGVD) 1 day	14 days	30 days	60 days	90 days	120 days	183 days	273 days	365 days
2.128	8.94	8.9	8.81	8.51	8.19	7.84	6.56	4.81	3.73
4.255	8.16	8.11	8	7.68	7.18	6.69	5.69	4.34	3.47
6.383	6.24	6.13	6.07	5.64	5.44	5.12	4.53	3.75	3.4
8.511	6.19	6.1	6	5.64	5.26	5.09	4.47	3.69	3.12
10.638	6.02	5.94	5.85	5.57	5.24	5	4.27	3.67	3.03
12.766	6	5.94	5.84	5.53	5.2	4.98	4.2	3.6	3.02
14.894	5.83	5.77	5.63	5.52	5.07	4.67	4.11	3.58	3.02
17.021	5.8	5.72	5.58	5.38	4.95	4.51	4.05	3.14	2.7
19.149	5.65	5.59	5.48	5.18	4.85	4.21	3.79	3.04	2.64
21.277	5.24	5.11	4.85	4.56	4.35	4.19	3.25	2.86	2.55
23.404	5.03	4.94	4.79	4.5	4.22	4.08	3.23	2.65	2.37
25.532	4.91	4.83	4.79	4.45	4.13	3.66	3.22	2.57	2.21
27.660	4.69	4.62	4.6	4.25	3.87	3.6	3.2	2.56	2
29.787	4.55	4.51	4.39	4.15	3.8	3.57	2.94	2.52	1.98
31.915	4.5	4.44	4.34	4.08	3.62	3.5	2.87	2.49	1.97
34.043	4.41	4.38	4.29	4.07	3.58	3.17	2.83	2.35	1.93
36.170	4.35	4.31	4.25	3.96	3.49	3.08	2.69	2.33	1.9
38.298	4.31	4.25	4.09	3.68	3.4	3.07	2.58	2.25	1.82
40.426	4.21	4.12	4	3.67	3.39	2.88	2.58	2.15	1.79
42.553	3.91	3.85	3.8	3.63	3.17	2.86	2.51	2.06	1.68
44.681	3.69	3.67	3.61	3.44	3.1	2.82	2.3	1.92	1.66
46.809	3.66	3.63	3.57	3.28	3.05	2.81	2.21	1.91	1.62
48.936	3.66	3.61	3.52	3.26	3.03	2.75	2.13	1.79	1.62
51.064	3.48	3.45	3.4	3.2	2.9	2.62	2.13	1.78	1.52
53.191	3.36	3.32	3.26	3.06	2.85	2.49	2.05	1.76	1.45
55.319	3.3	3.19	3.12	2.97	2.63	2.31	2.03	1.76	1.45
57.447	3.24	3.18	3.04	2.67	2.39	2.21	2	1.75	1.44
59.574	3.22	3.17	2.88	2.5	2.26	2.13	1.78	1.7	1.37
61.702	3.13	3	2.77	2.45	2.24	2.02	1.74	1.64	1.35
63.830	3.1	2.94	2.67	2.37	2.12	2	1.73	1.61	1.29
65.957	2.9	2.84	2.59	2.28	2.11	1.98	1.72	1.42	1.15
68.085	2.65	2.61	2.58	2.26	2.08	1.89	1.71	1.39	1.11
70.213	2.63	2.54	2.46	2.21	1.89	1.86	1.68	1.34	1.1
72.340	2.58	2.52	2.42	2.09	1.85	1.76	1.58	1.27	1.06
74.468	2.57	2.5	2.39	2.06	1.83	1.72	1.47	1.25	0.95
76.596	2.54	2.48	2.26	2	1.82	1.7	1.41	1.23	0.93
78.723	2.43	2.36	2.23	1.96	1.81	1.66	1.41	1.23	0.92
80.851	2.42	2.35	2.18	1.87	1.77	1.66	1.39	1.16	0.91
82.979	2.12	2.06	1.95	1.62	1.58	1.47	1.31	1.12	0.87
85.106	1.99	1.89	1.8	1.62	1.42	1.32	1.21	1.1	0.86
87.234	1.94	1.81	1.62	1.53	1.31	1.2	1.06	1.01	0.84
89.362	1.91	1.68	1.6	1.44	1.3	1.14	1.05	0.9	0.77
91.489	1.6	1.57	1.52	1.43	1.22	1.13	0.96	0.83	0.69
93.617	1.51	1.48	1.4	1.23	1.13	1.08	0.87	0.81	0.63
95.745	1.41	1.36	1.32	1.15	1.01	0.9	0.84	0.65	0.49
97.872	1.36	1.29	1.18	1.06	0.95	0.85	0.74	0.61	0.48

Source: Robison, 2004b.

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Table B-8. Frequency-Duration Analysis for Water Level at Lake Monroe Under 180-cfs Withdrawal Conditions (Minimum Average Stages)

Weibull Prob. (%)	Minimum Average Stages (ft-NGVD) 1 day	14 days	30 days	60 days	90 days	120 days	183 days	273 days	365 days
2.128	-0.54	-0.45	-0.4	-0.38	-0.31	-0.23	-0.03	0.1	0.25
4.255	-0.42	-0.34	-0.34	-0.3	-0.25	-0.18	0.07	0.21	0.54
6.383	-0.33	-0.27	-0.24	-0.15	-0.12	-0.05	0.07	0.27	0.55
8.511	-0.32	-0.26	-0.23	-0.14	-0.05	-0.01	0.09	0.38	0.63
10.638	-0.32	-0.24	-0.2	-0.13	0.02	0.07	0.16	0.46	0.77
12.766	-0.28	-0.21	-0.18	-0.1	0.05	0.14	0.3	0.56	0.82
14.894	-0.24	-0.15	-0.1	0.01	0.08	0.14	0.34	0.57	0.96
17.021	-0.19	-0.11	-0.08	0.02	0.09	0.18	0.36	0.64	1.01
19.149	-0.17	-0.11	-0.05	0.03	0.1	0.19	0.36	0.65	1.12
21.277	-0.15	-0.08	-0.02	0.04	0.14	0.22	0.37	0.7	1.16
23.404	-0.13	-0.05	-0.02	0.07	0.16	0.22	0.38	0.77	1.18
25.532	-0.1	-0.04	0.03	0.11	0.17	0.23	0.39	0.78	1.25
27.660	-0.06	0	0.04	0.12	0.19	0.24	0.45	0.78	1.25
29.787	-0.05	0.02	0.05	0.16	0.2	0.26	0.51	0.83	1.28
31.915	0.01	0.05	0.14	0.21	0.34	0.4	0.52	0.87	1.28
34.043	0.07	0.11	0.14	0.22	0.36	0.43	0.58	0.92	1.33
36.170	0.18	0.22	0.28	0.32	0.38	0.48	0.62	0.93	1.45
38.298	0.19	0.24	0.32	0.35	0.45	0.56	0.65	0.97	1.51
40.426	0.22	0.31	0.39	0.47	0.54	0.63	0.68	0.98	1.51
42.553	0.23	0.33	0.43	0.53	0.59	0.64	0.76	1.04	1.55
44.681	0.29	0.36	0.45	0.54	0.59	0.67	0.81	1.05	1.71
46.809	0.31	0.38	0.46	0.54	0.6	0.69	0.83	1.08	1.71
48.936	0.31	0.38	0.49	0.56	0.68	0.79	0.97	1.1	1.72
51.064	0.33	0.42	0.5	0.59	0.69	0.81	1.02	1.11	1.74
53.191	0.35	0.43	0.51	0.59	0.69	0.83	1.05	1.14	1.74
55.319	0.36	0.43	0.51	0.61	0.7	0.88	1.07	1.16	1.81
57.447	0.4	0.47	0.51	0.63	0.77	0.89	1.08	1.27	1.84
59.574	0.44	0.48	0.56	0.66	0.79	0.89	1.11	1.31	1.84
61.702	0.45	0.53	0.63	0.72	0.81	0.91	1.11	1.32	1.88
63.830	0.48	0.58	0.65	0.75	0.83	0.91	1.13	1.33	1.94
65.957	0.5	0.6	0.67	0.8	0.83	0.97	1.15	1.37	1.99
68.085	0.54	0.61	0.69	0.81	0.85	0.97	1.22	1.38	1.99
70.213	0.56	0.63	0.7	0.81	0.89	1.01	1.23	1.49	2.04
72.340	0.57	0.65	0.7	0.82	0.89	1.01	1.25	1.67	2.05
74.468	0.65	0.69	0.73	0.83	0.94	1.02	1.28	1.7	2.05
76.596	0.66	0.7	0.77	0.83	0.95	1.06	1.3	1.78	2.08
78.723	0.68	0.71	0.78	0.83	0.95	1.06	1.34	1.8	2.12
80.851	0.68	0.75	0.78	0.84	0.99	1.07	1.4	1.85	2.21
82.979	0.7	0.76	0.8	0.91	1	1.09	1.47	1.92	2.34
85.106	0.71	0.78	0.83	1.05	1.1	1.1	1.56	1.95	2.58
87.234	0.74	0.78	0.9	1.06	1.14	1.19	1.57	2.11	2.82
89.362	0.84	0.89	0.98	1.18	1.14	1.24	1.61	2.18	2.82
91.489	0.86	0.92	1.02	1.18	1.35	1.44	1.99	2.34	2.89
93.617	0.93	0.97	1.02	1.21	1.45	1.66	2.05	2.37	3.04
95.745	1.1	1.18	1.34	1.47	1.64	1.69	2.37	2.62	3.22
97.872	1.22	1.27	1.35	1.52	1.76	1.95	2.48	3	3.51

Source: Robison, 2004b.

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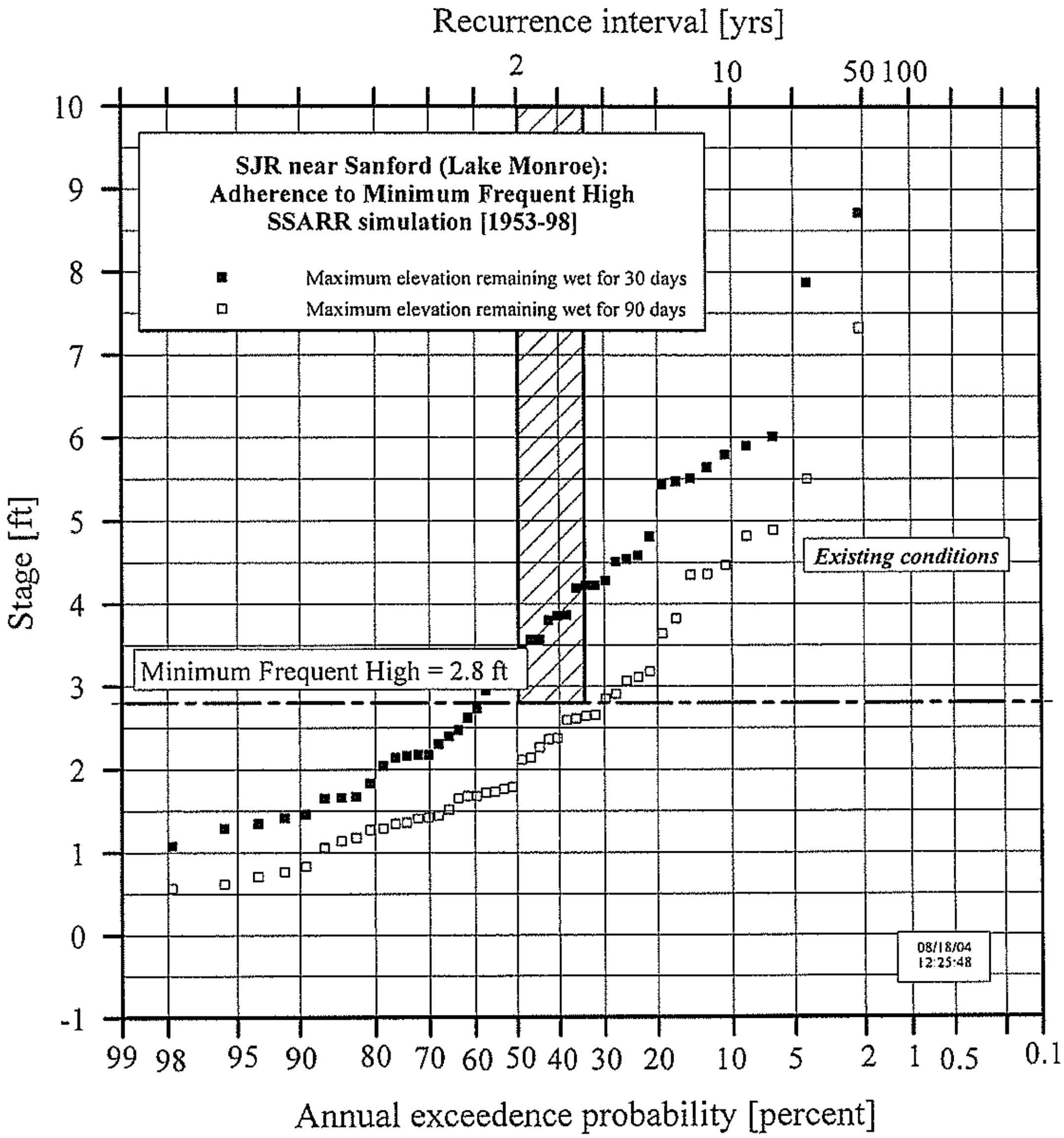


Figure 1 Lake Monroe MFH: existing conditions

Source: Robison, 2002.

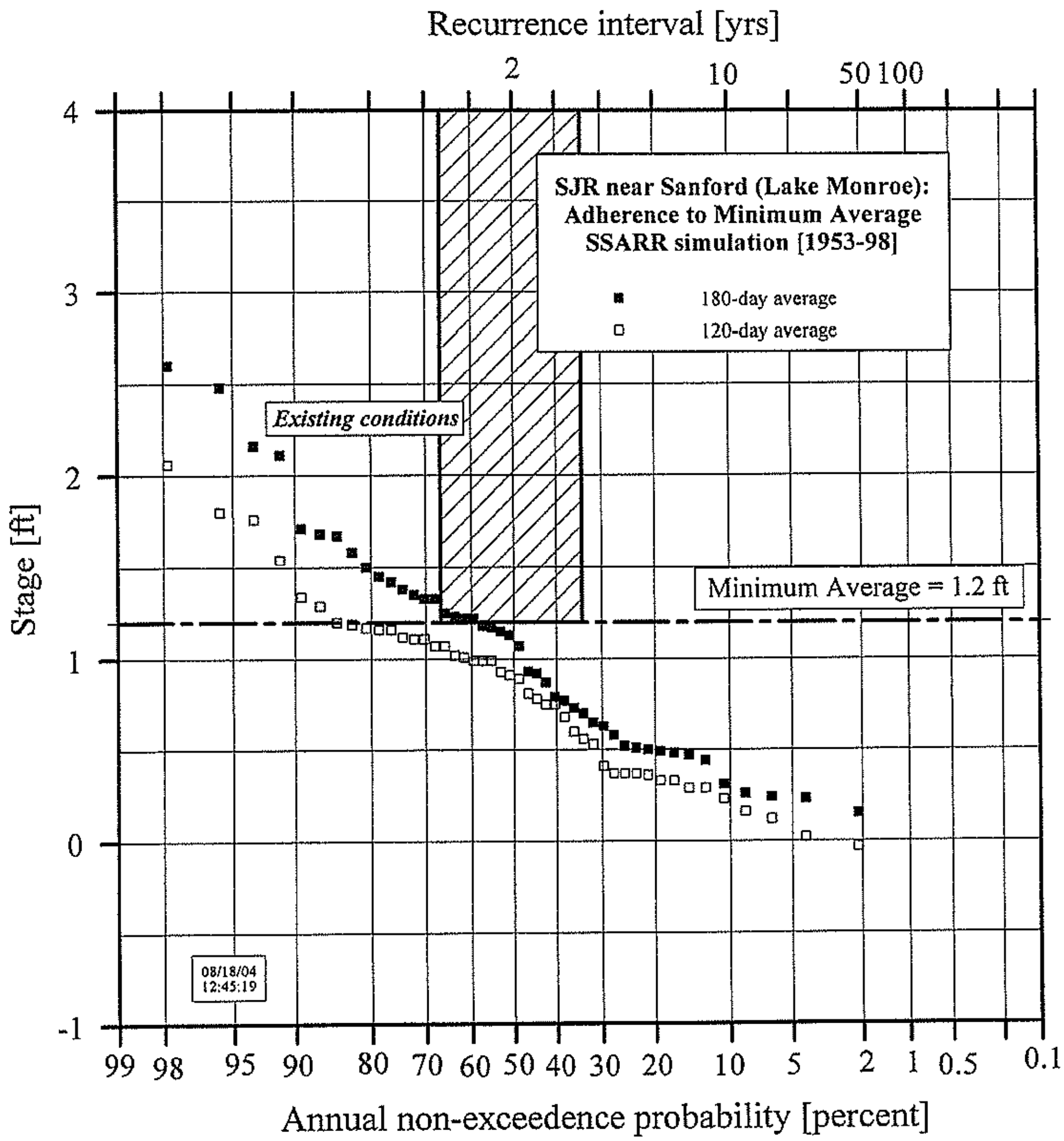


Figure 2 Lake Monroe MA: existing conditions

Source: Robison, 2002.

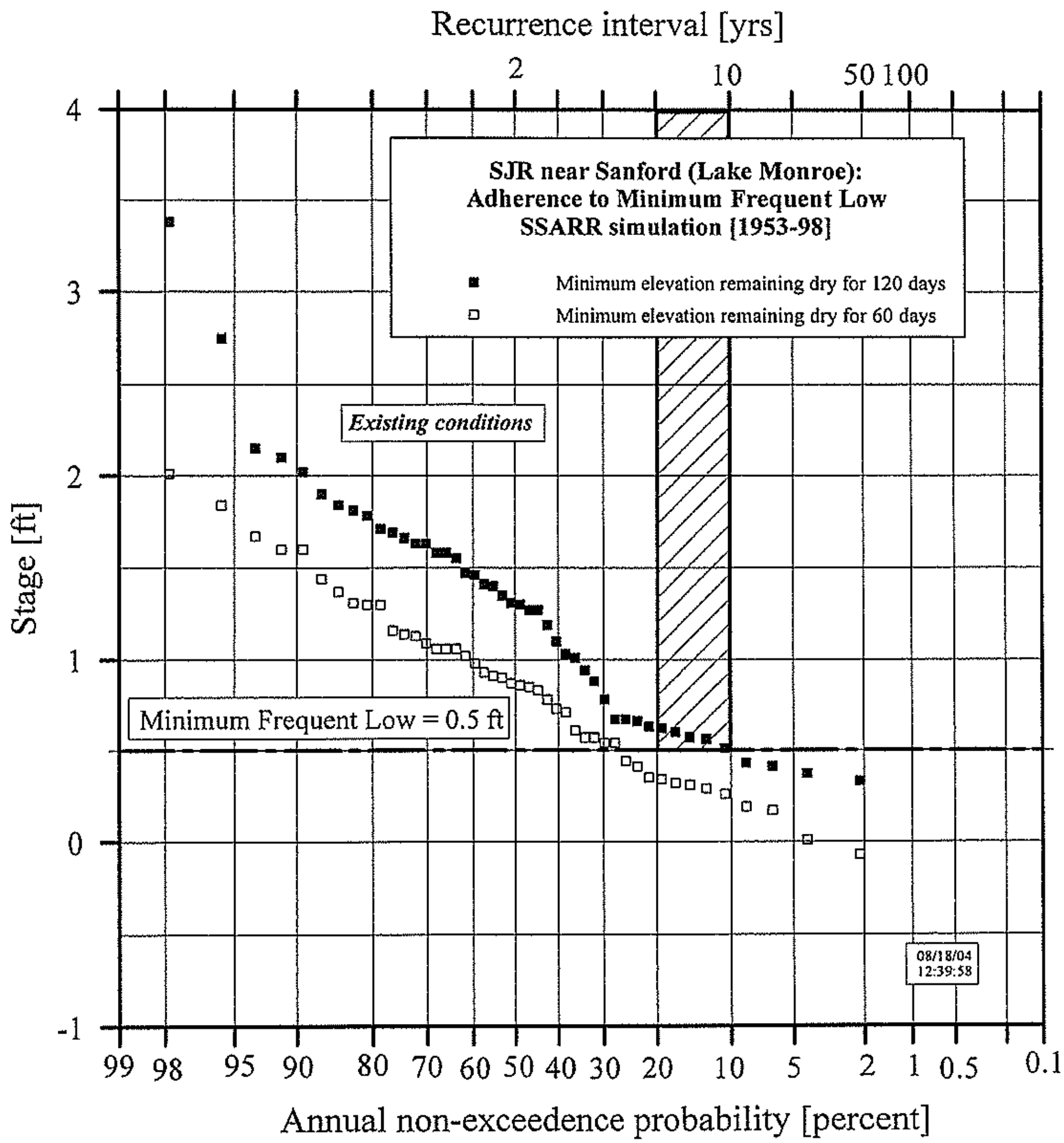


Figure 3 Lake Monroe MFL: existing conditions

Source: Robison, 2002.

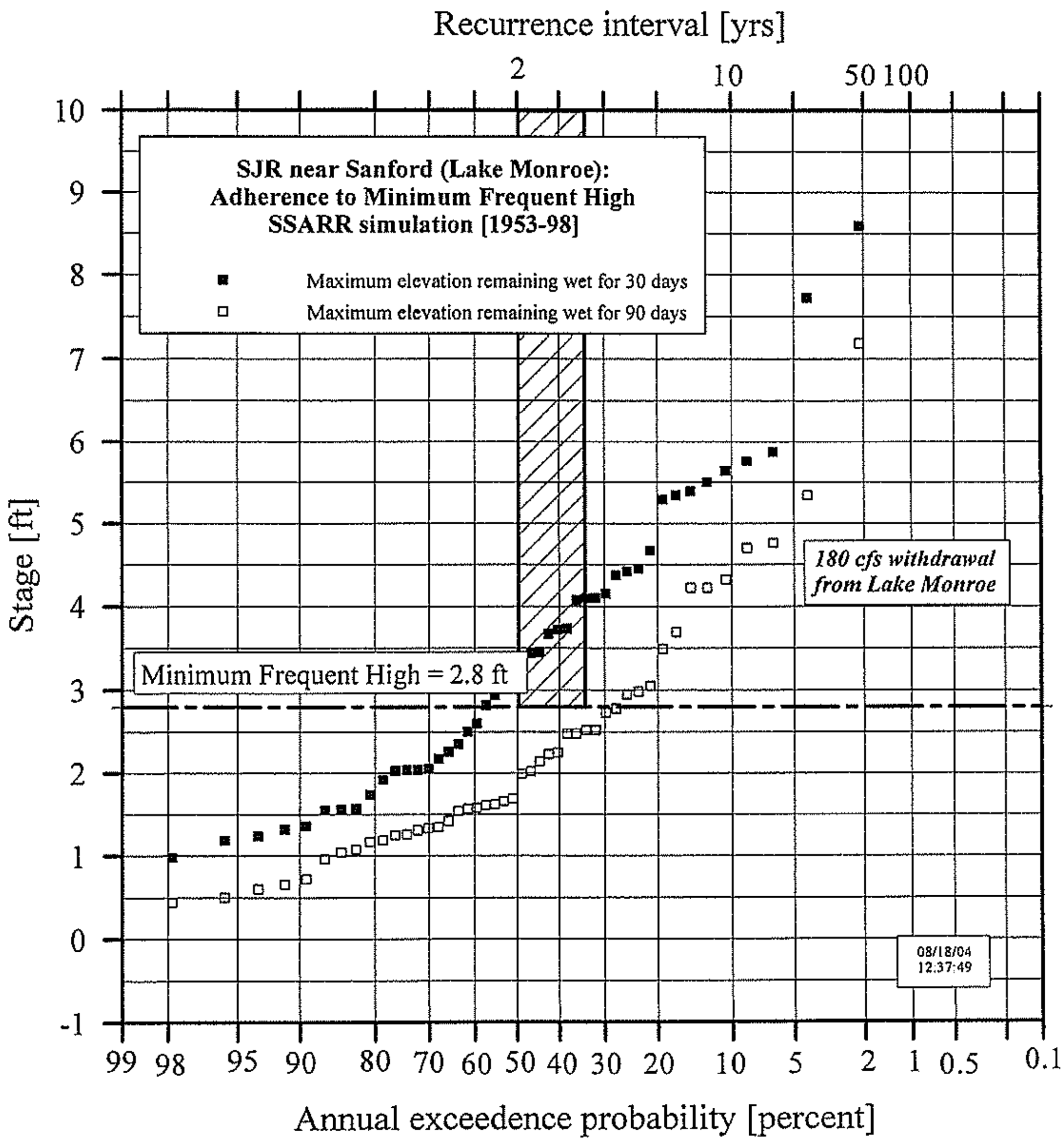


Figure 4 Lake Monroe MFH: 180 cfs withdrawal from Lake Monroe

Source: Robison, 2002.

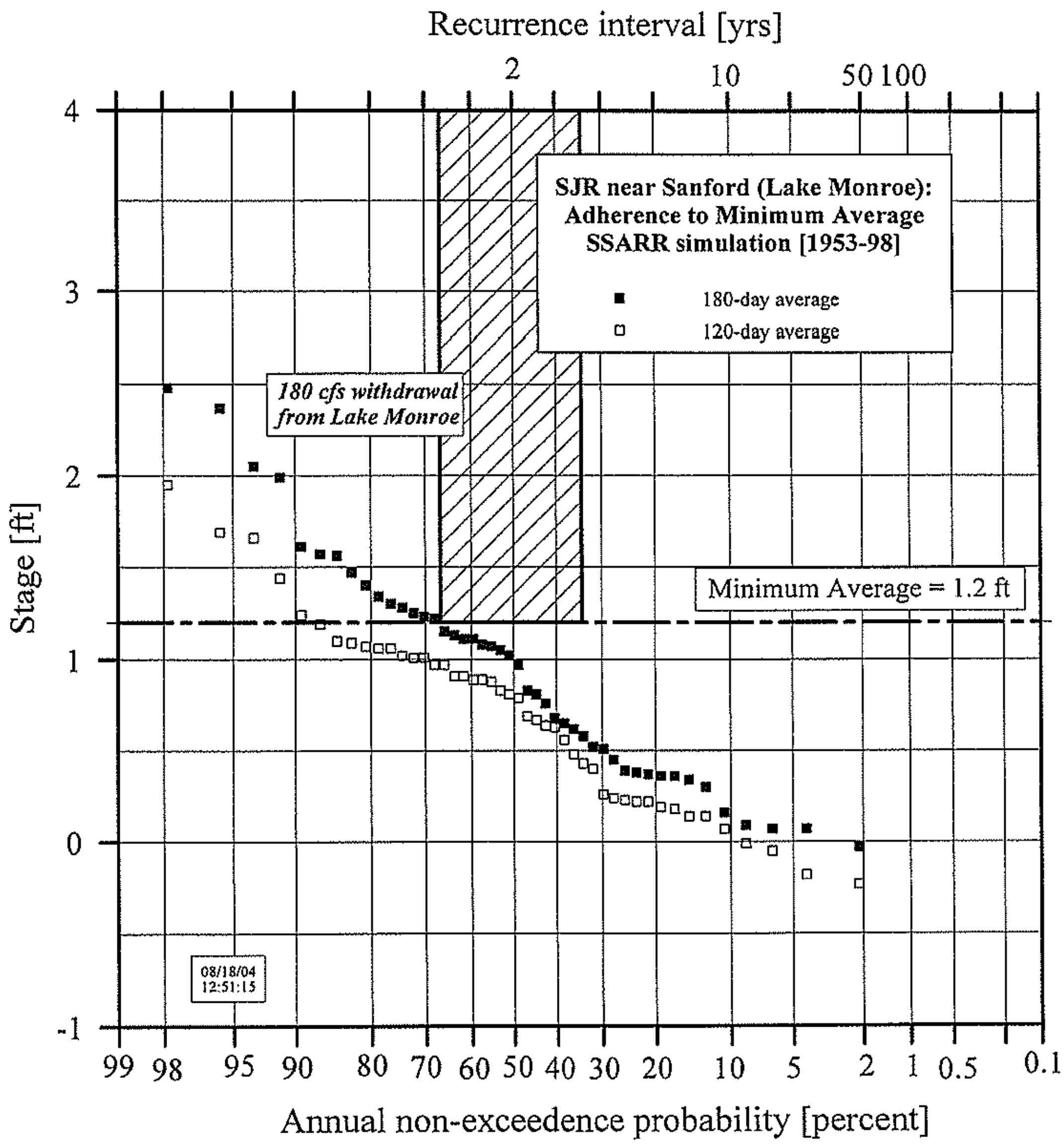


Figure 5 Lake Monroe MA: 180 cfs withdrawal from Lake Monroe

Source: Robison, 2002.

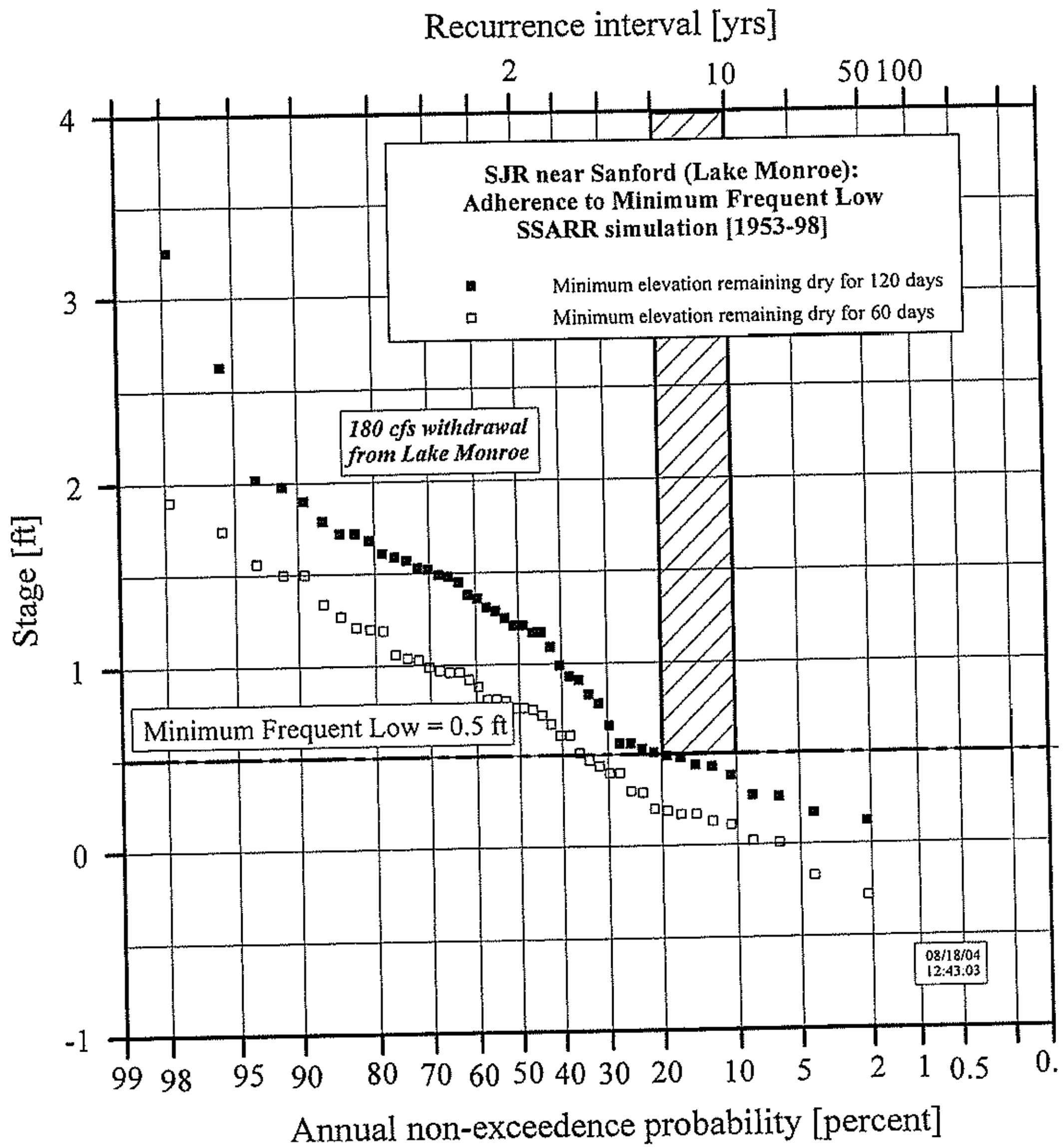


Figure 6 Lake Monroe MFL: 180 cfs withdrawal from Lake Monroe

Source: Robison, 2002.

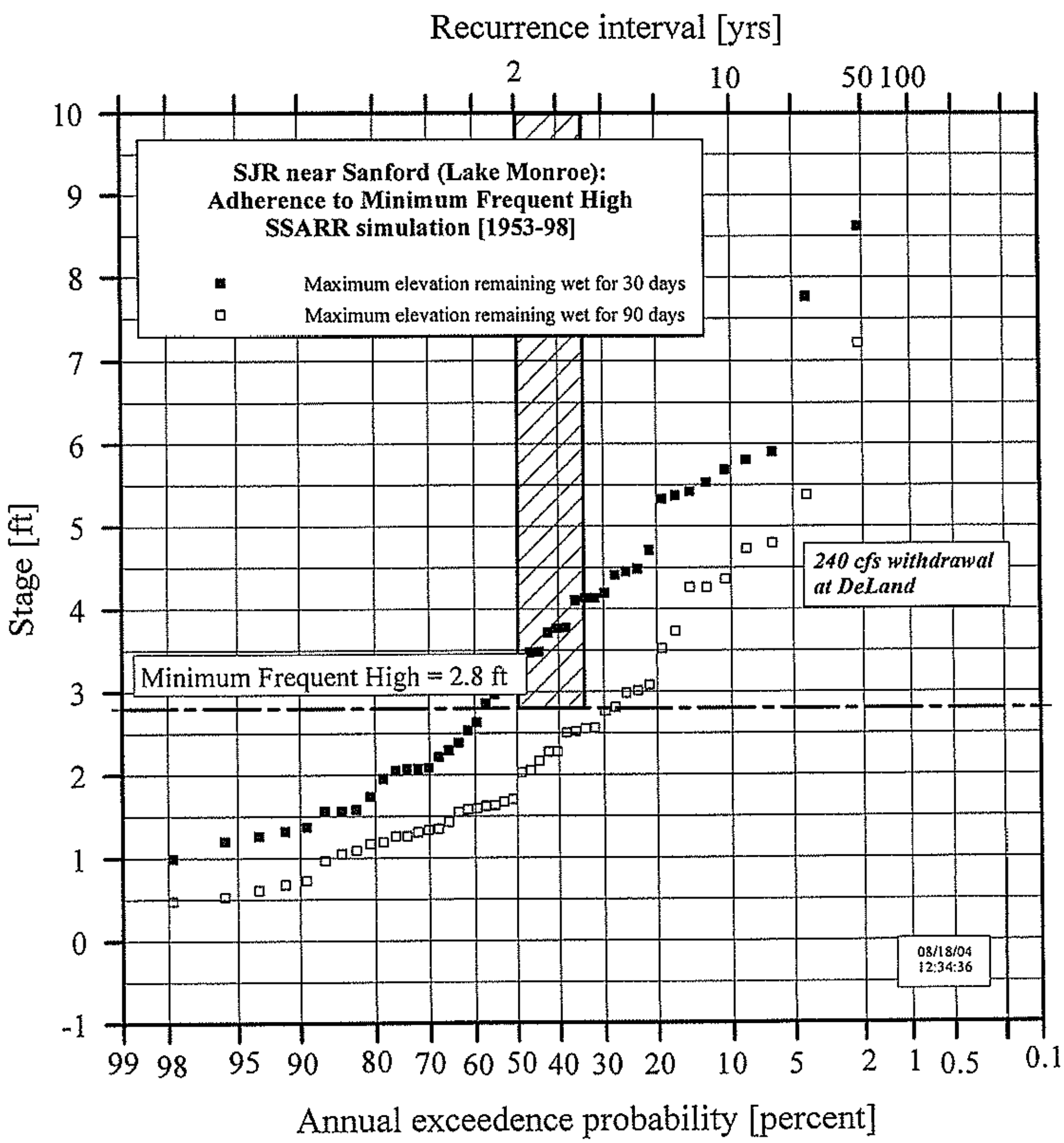


Figure 7 Lake Monroe MFH: 240 cfs withdrawal at DeLand

Source: Robison, 2002.

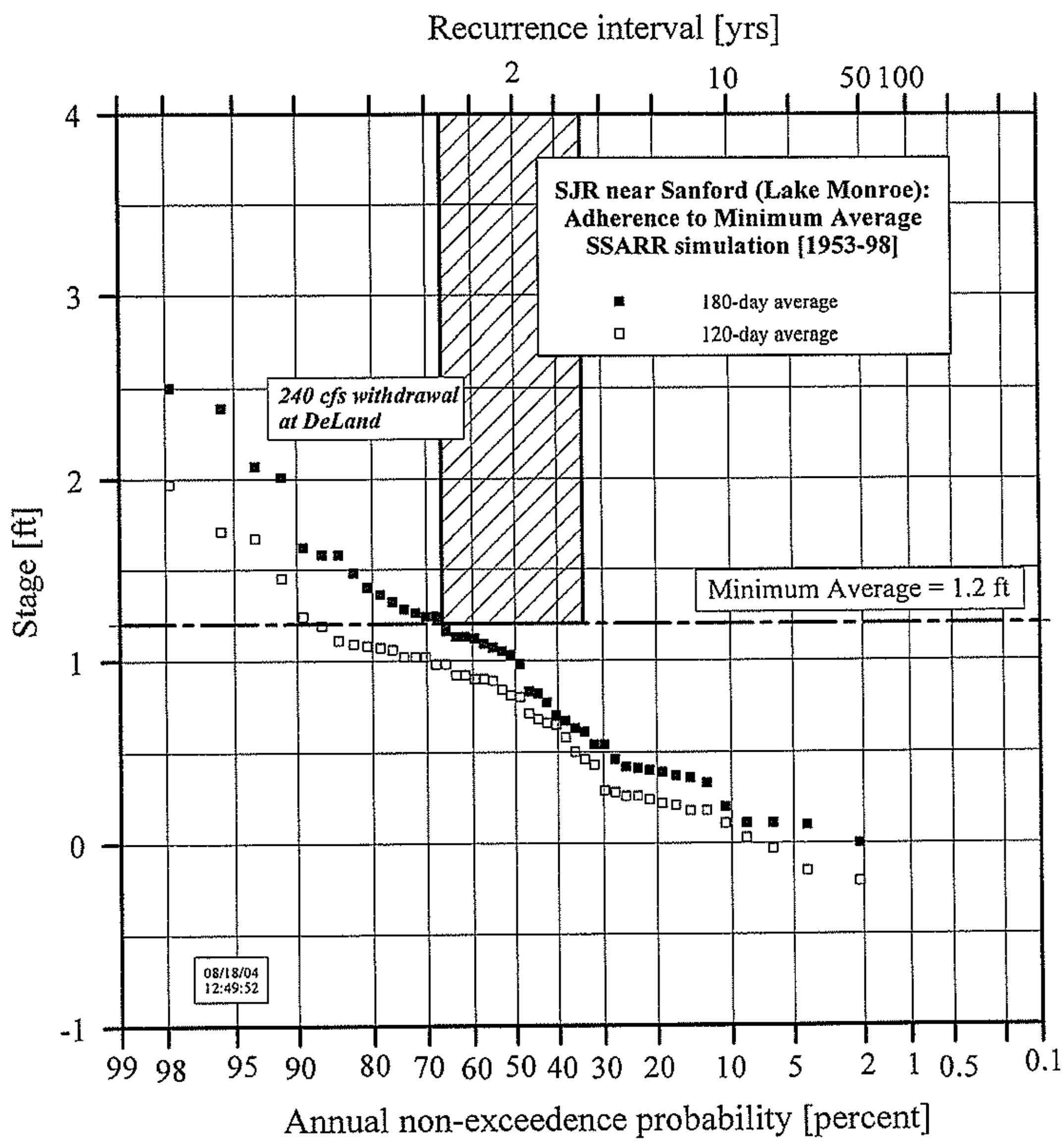


Figure 8 Lake Monroe MA: 240 cfs withdrawal at DeLand

Source: Robison, 2002.

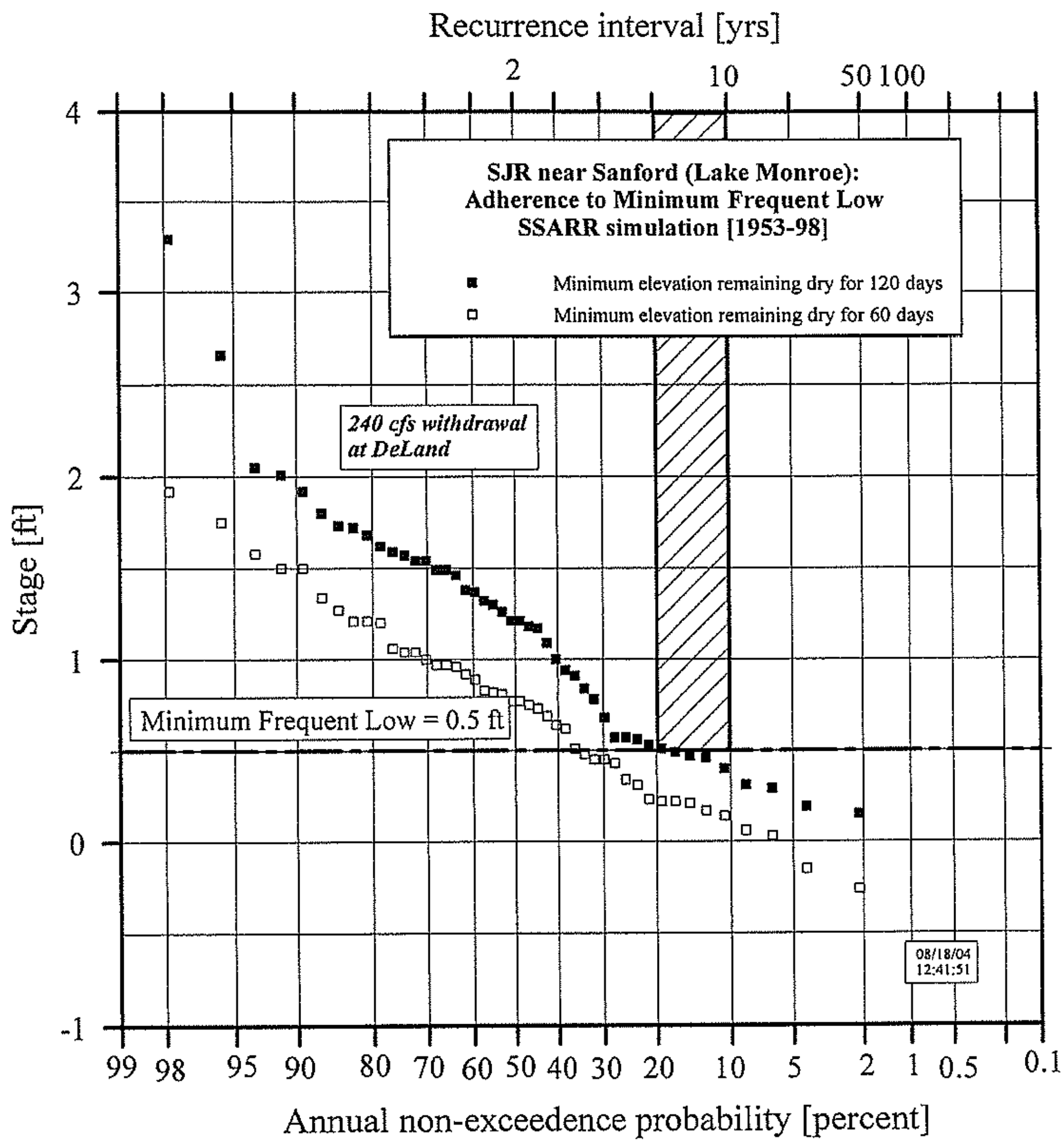


Figure 9 Lake Monroe MFL: 240 cfs withdrawal at DeLand

Source: Robison, 2002.

APPENDIX C—CUMULATIVE FREQUENCY ANALYSES OF DAILY AVERAGE SALINITY AT SELECTED LOCATIONS IN THE LOWER ST. JOHNS RIVER

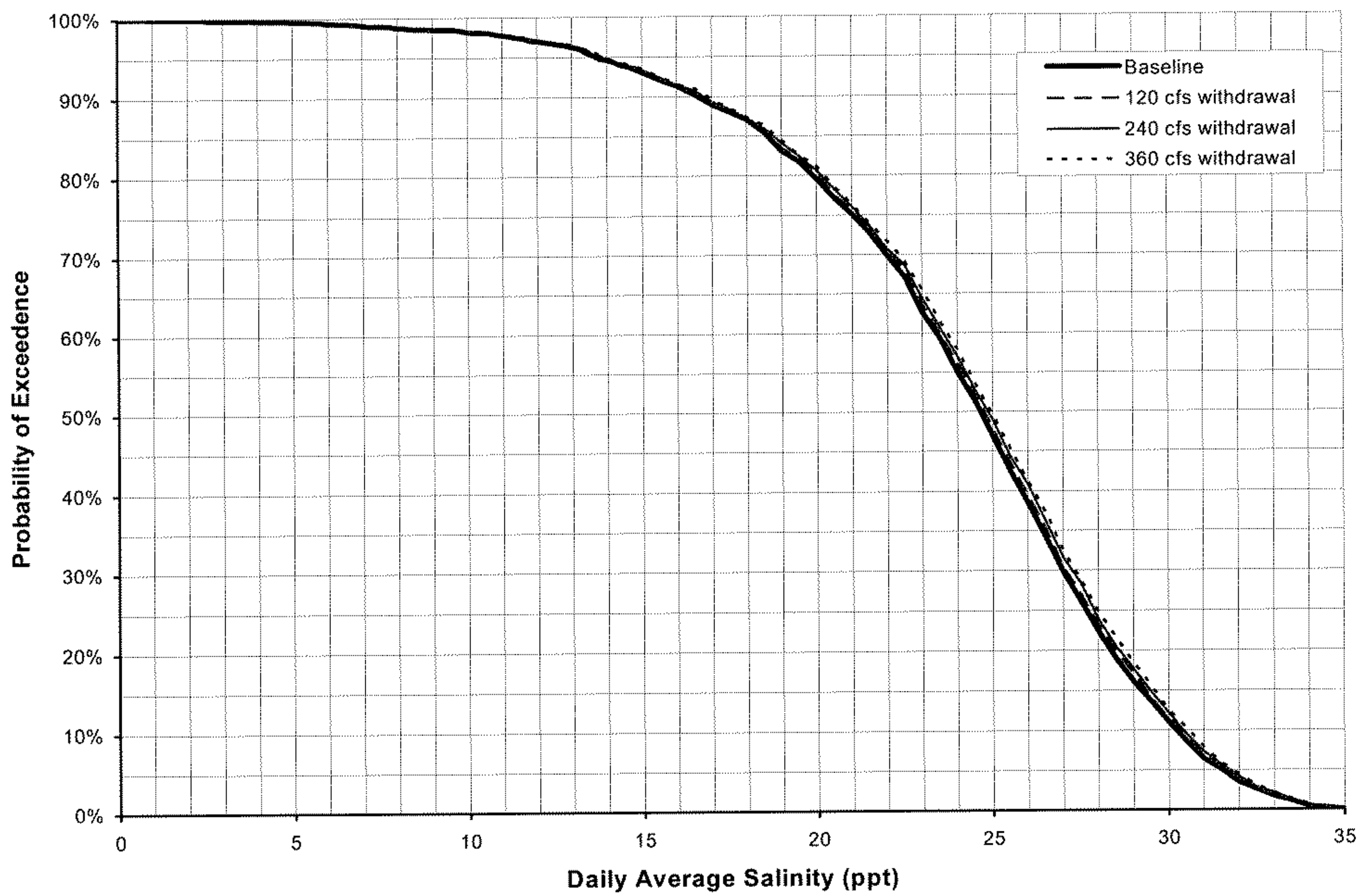


FIGURE C-1.

CUMULATIVE FREQUENCY OF DAILY AVERAGE SALINITY NEAR BLOUNT ISLAND

Source: ECT, 2004.

ECT
Environmental Consulting & Technology, Inc.

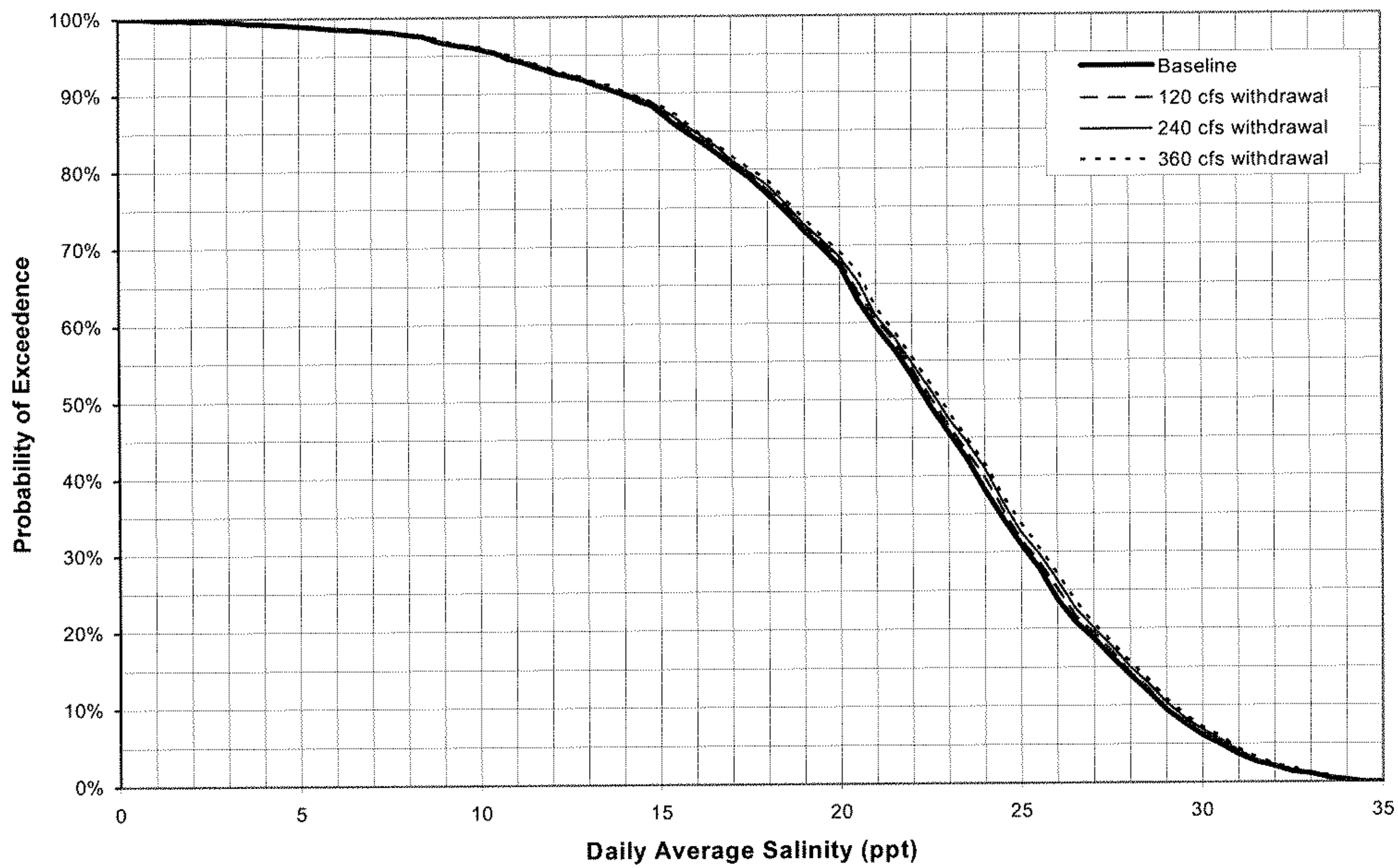


FIGURE C-2.

CUMULATIVE FREQUENCY OF DAILY AVERAGE SALINITY NEAR DAMES POINT

Source: ECT, 2004.

ECT
Environmental Consulting & Technology, Inc.

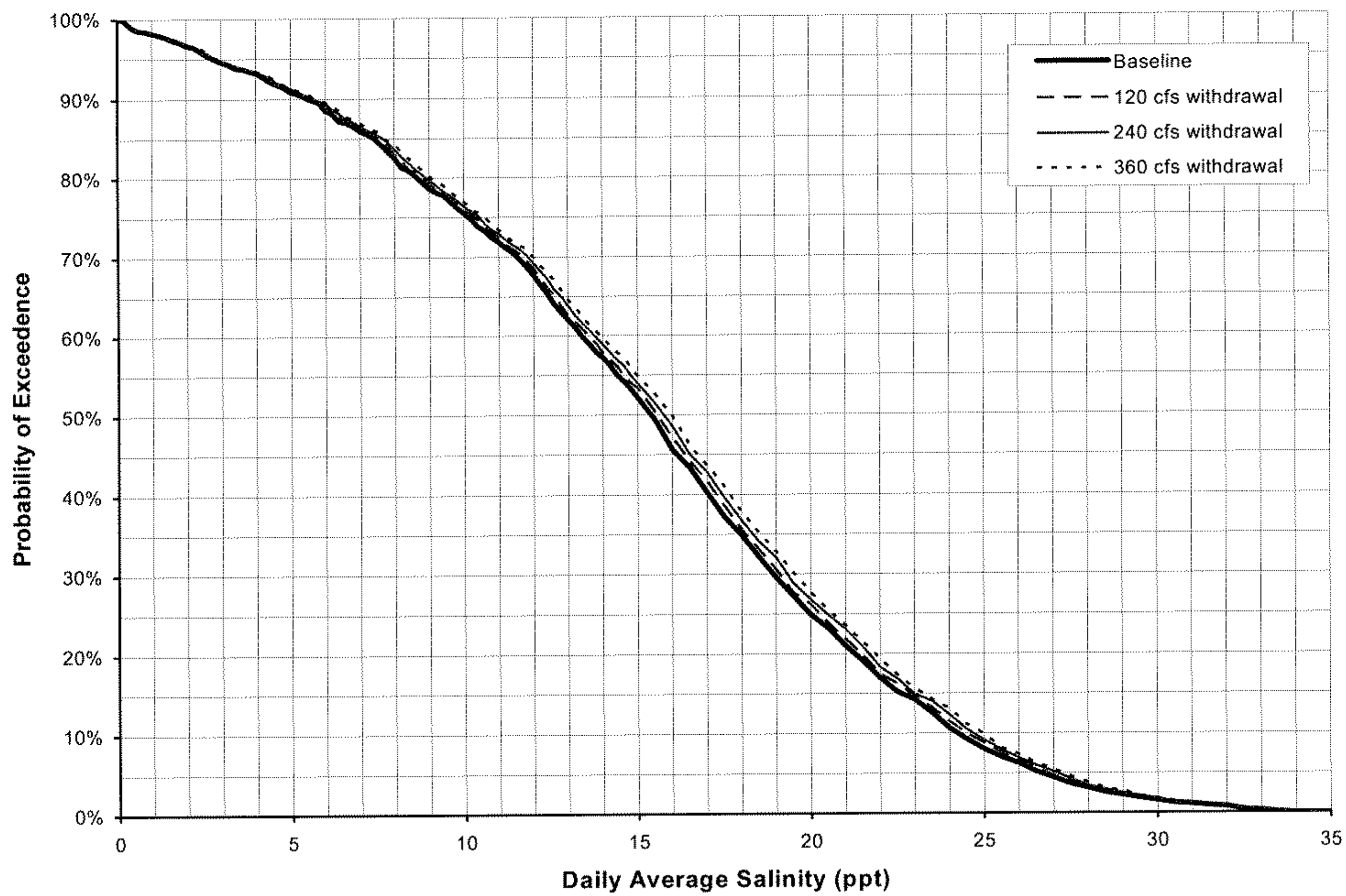


FIGURE C-3.

CUMULATIVE FREQUENCY OF DAILY AVERAGE SALINITY NEAR DRUMMOND POINT

Source: ECT, 2004.

Environmental Consulting & Technology, Inc.

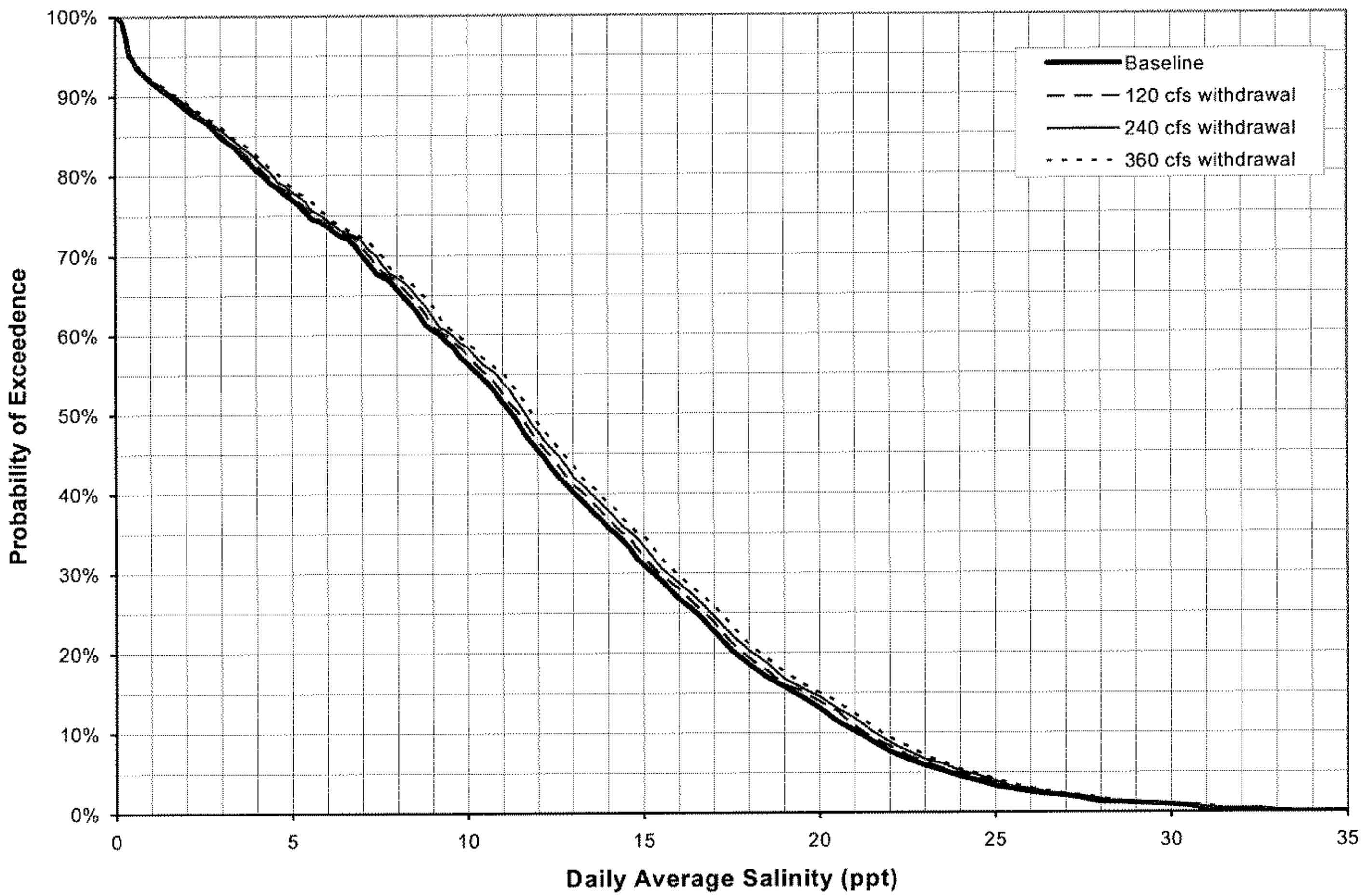


FIGURE C-4.

CUMULATIVE FREQUENCY OF DAILY AVERAGE SALINITY NEAR JACKSONVILLE UNIVERSITY

Source: ECT, 2004.

ECT
Environmental Consulting & Technology, Inc.

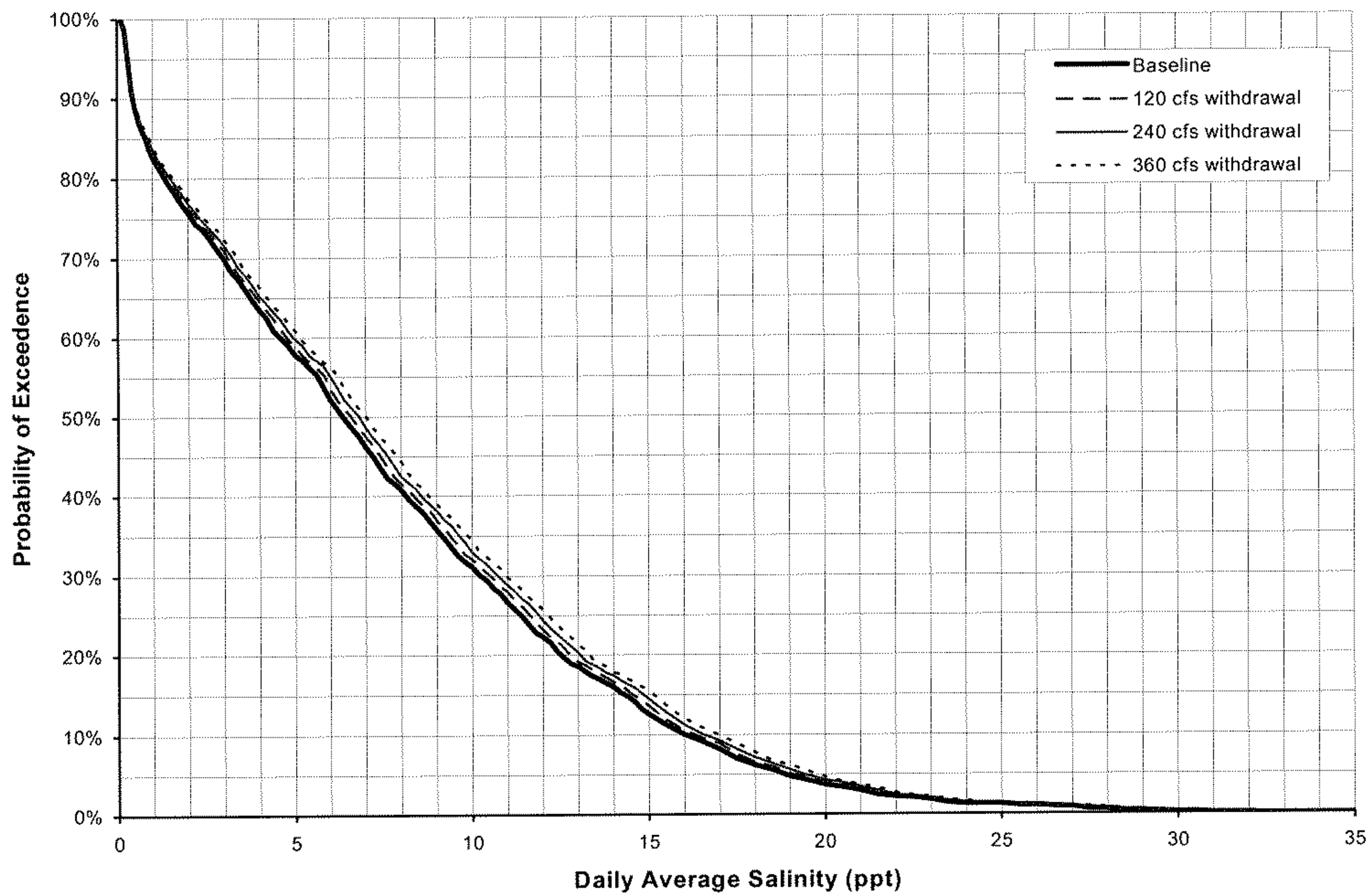


FIGURE C-5.

CUMULATIVE FREQUENCY OF DAILY AVERAGE SALINITY AT ACOSTA BRIDGE

Source: ECT, 2004.

ECT Environmental Consulting & Technology, Inc.

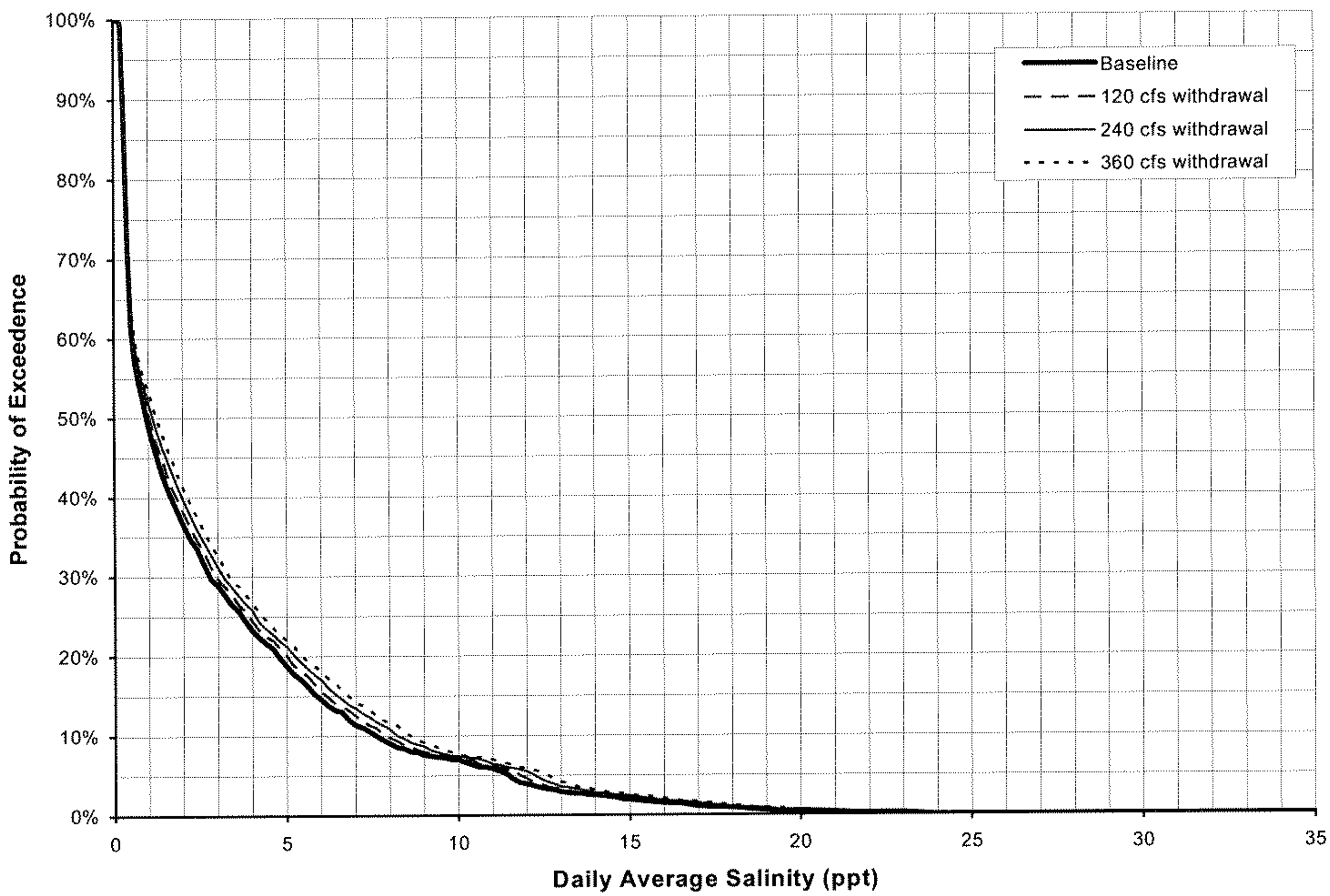


FIGURE C-6.

CUMULATIVE FREQUENCY OF DAILY AVERAGE SALINITY
AT BUCKMAN BRIDGE
Source: ECT, 2004.

ECT
Environmental Consulting & Technology, Inc.

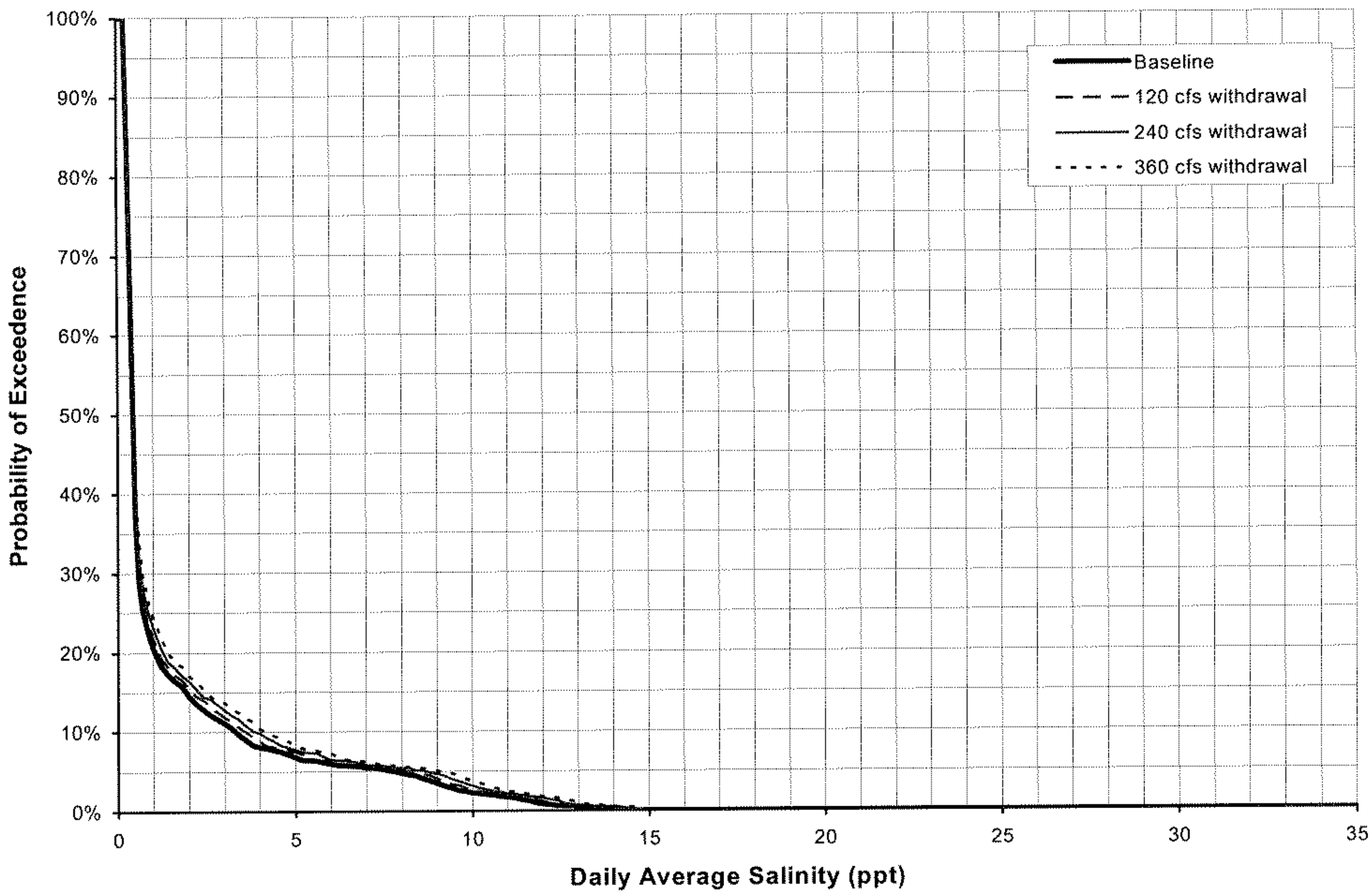


FIGURE C-7.

CUMULATIVE FREQUENCY OF DAILY AVERAGE SALINITY AT HIBERNIA POINT

Source: ECT, 2004.

Environmental Consulting & Technology, Inc.

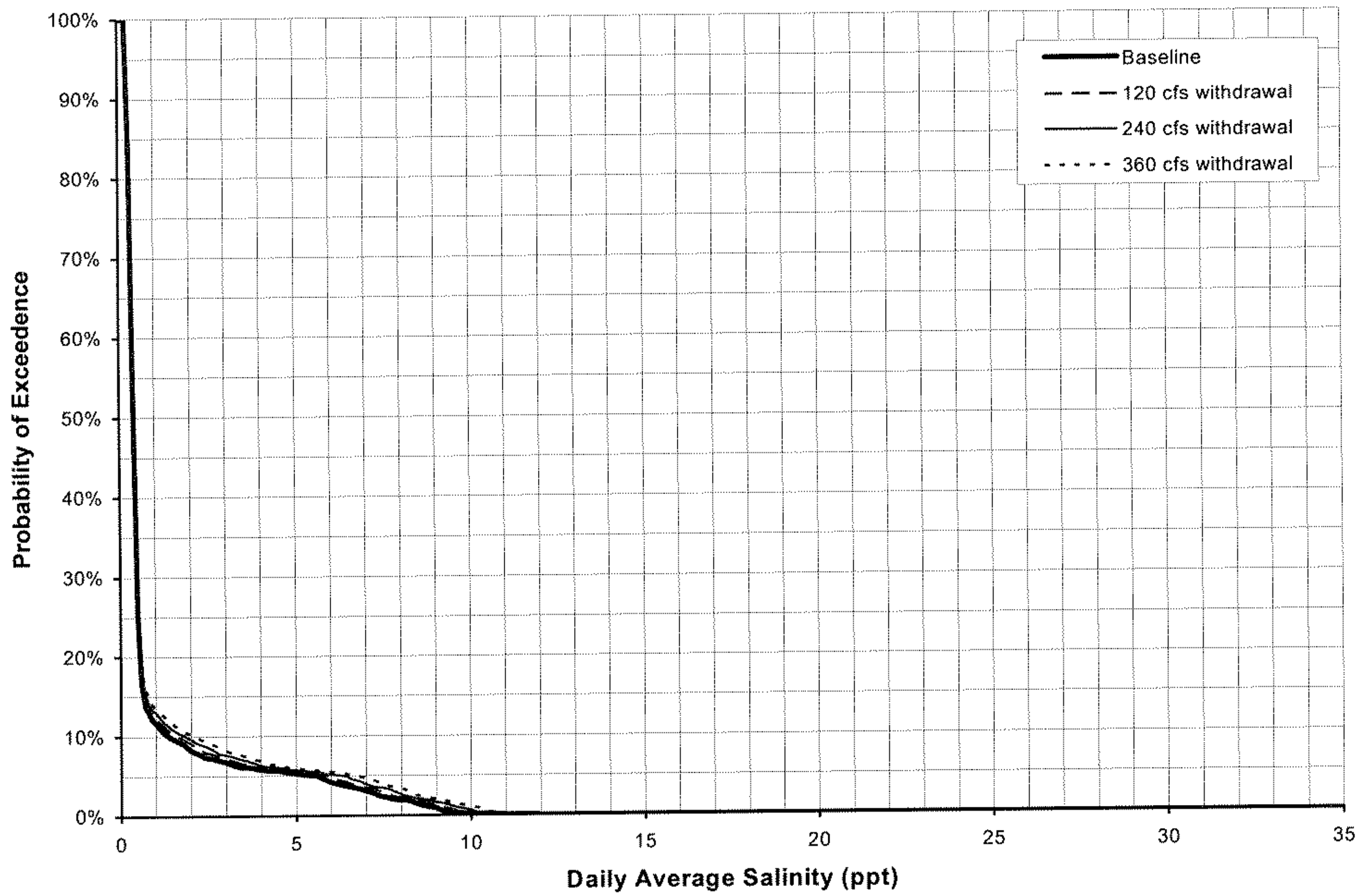


FIGURE C-8.

CUMULATIVE FREQUENCY OF DAILY AVERAGE SALINITY NEAR GREEN COVE SPRINGS

Source: ECT, 2004.

ECT

Environmental Consulting & Technology, Inc.

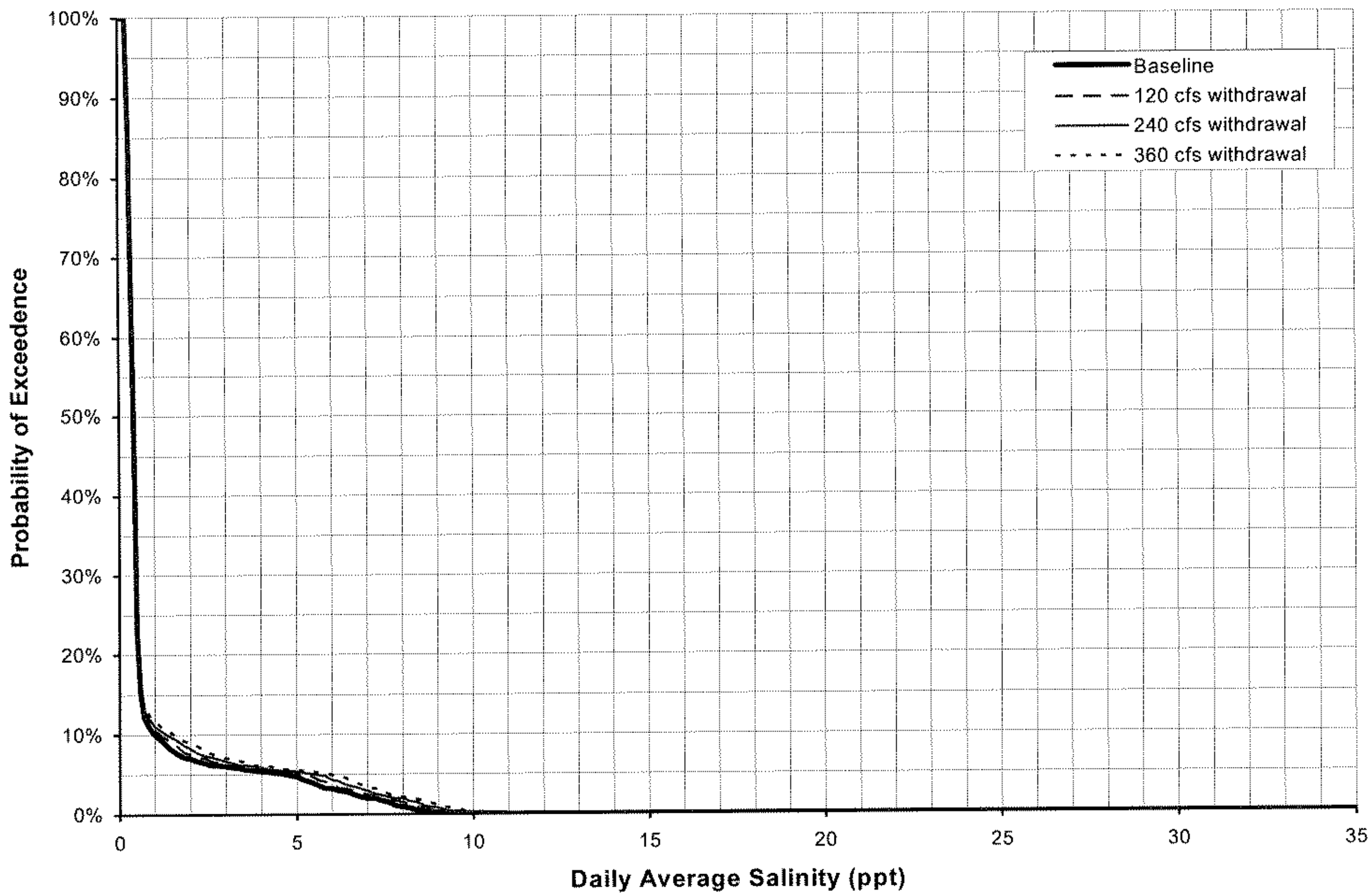


FIGURE C-9.

CUMULATIVE FREQUENCY OF DAILY AVERAGE SALINITY AT SHANDS BRIDGE

Source: ECT, 2004.

ECT
Environmental Consulting & Technology, Inc.

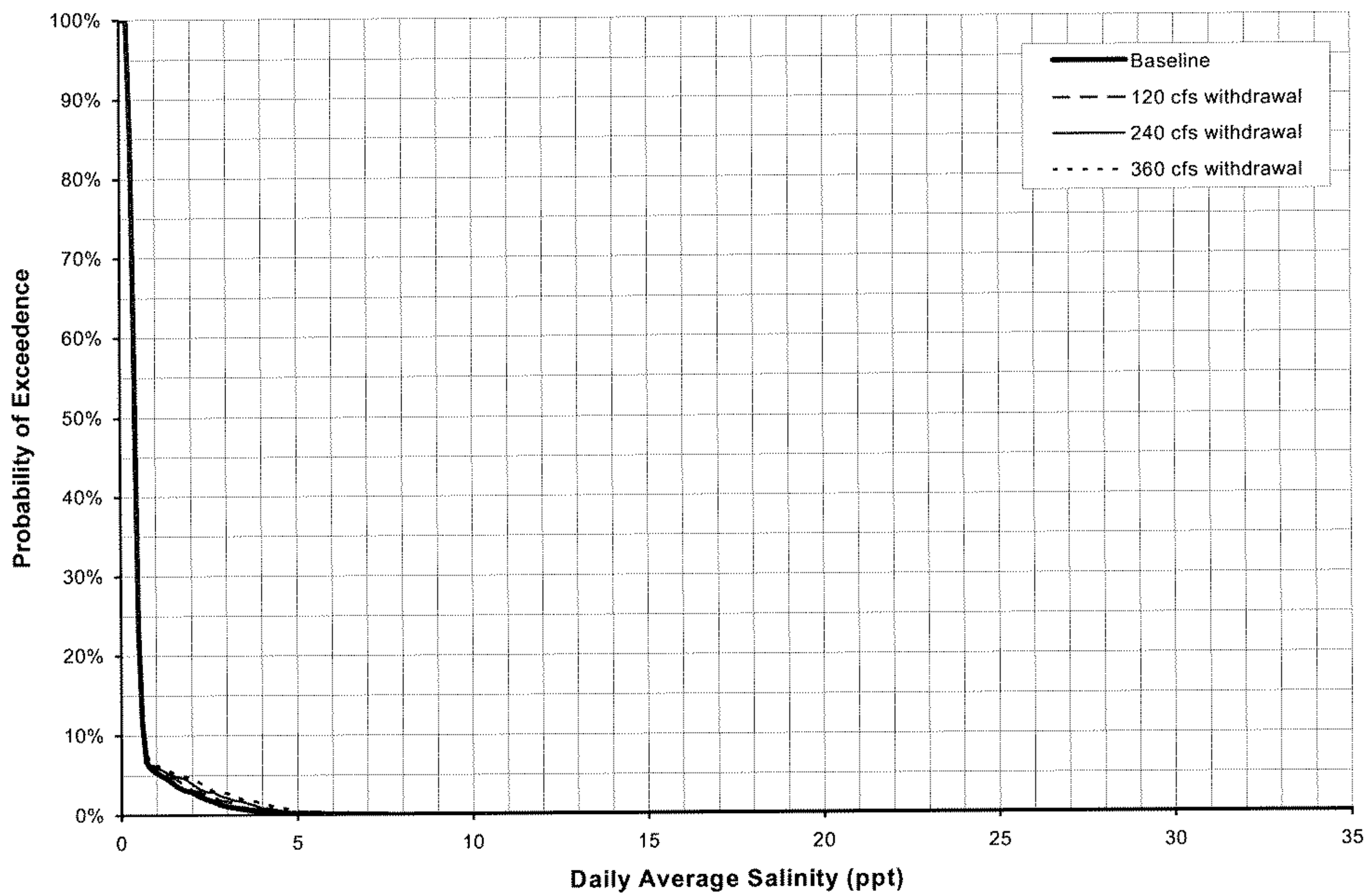


FIGURE C-10.

CUMULATIVE FREQUENCY OF DAILY AVERAGE SALINITY
NEAR WEST TOCOI

Source: ECT, 2004.

ECT
Environmental Consulting & Technology, Inc.

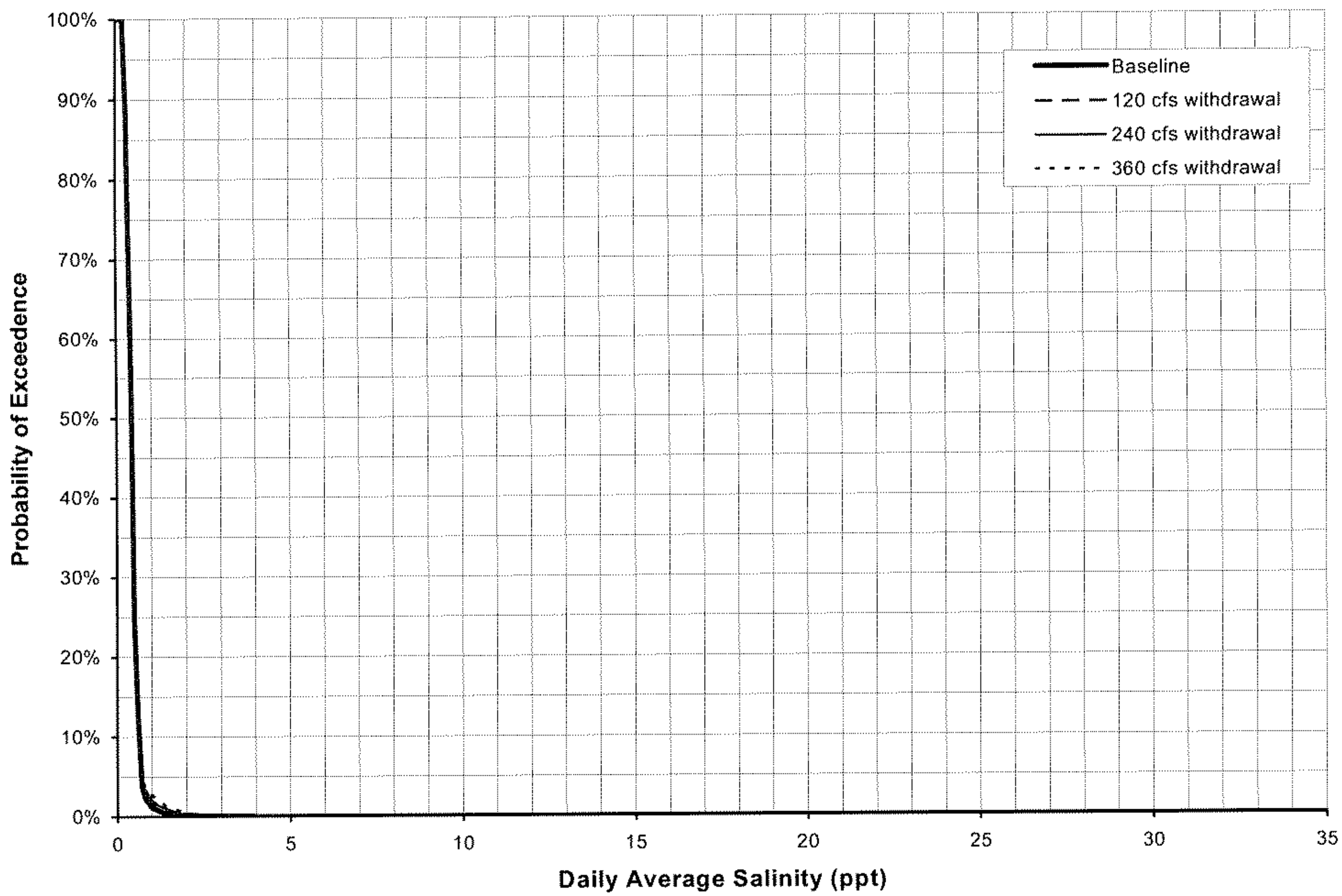


FIGURE C-11.

CUMULATIVE FREQUENCY OF DAILY AVERAGE SALINITY NEAR FEDERAL POINT

Source: ECT, 2004.

Environmental Consulting & Technology, Inc.

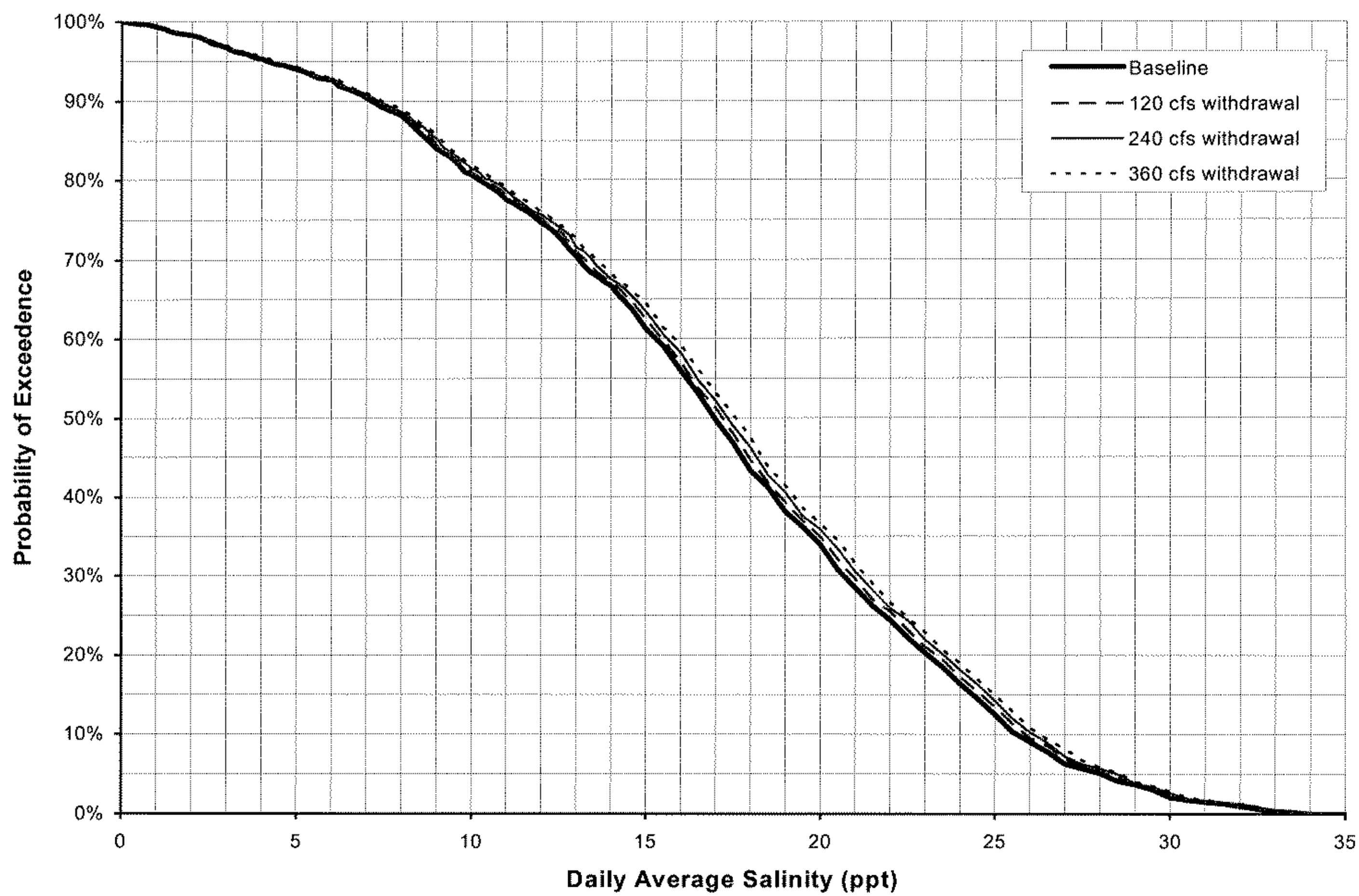


FIGURE C-12.

CUMULATIVE FREQUENCY OF DAILY AVERAGE SALINITY AT MILL COVE

Source: ECT, 2004.

ECT

Environmental Consulting & Technology, Inc.

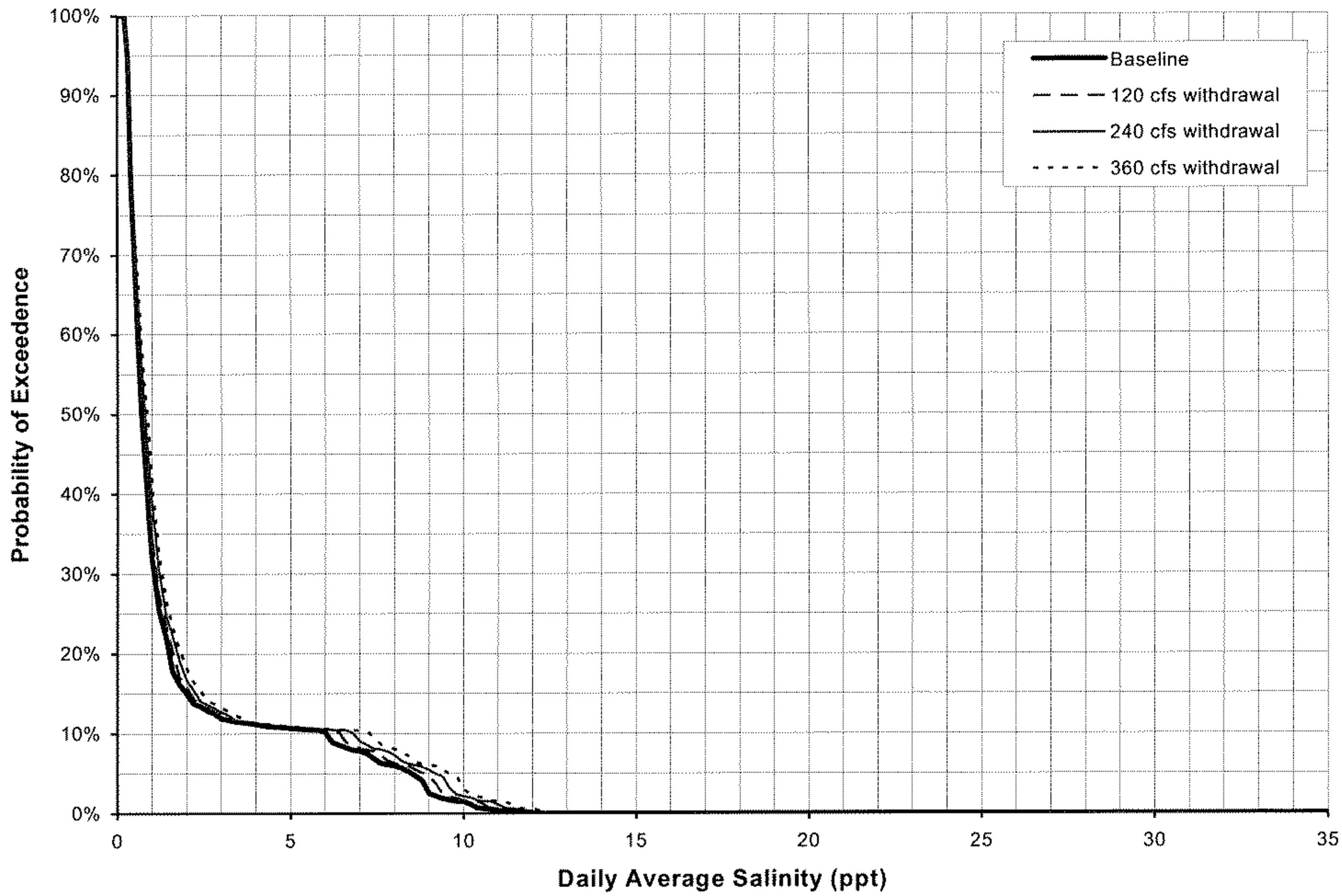


FIGURE C-13.

CUMULATIVE FREQUENCY OF DAILY AVERAGE SALINITY AT DOCTORS LAKE

Source: ECT, 2004.

ECT
Environmental Consulting & Technology, Inc.

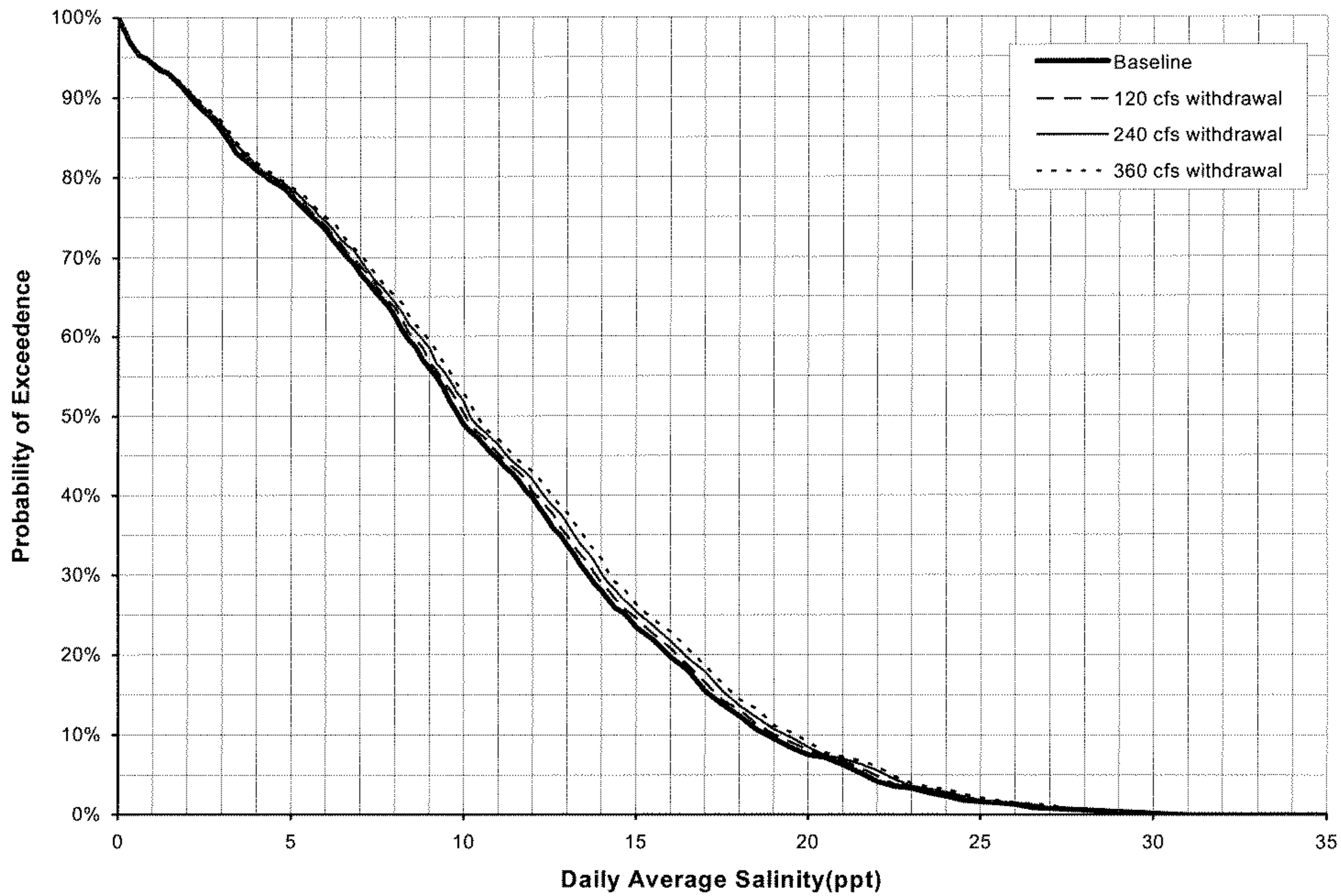


FIGURE C-14.

CUMULATIVE FREQUENCY OF DAILY AVERAGE SALINITY
AT TROUT RIVER

Source: ECT, 2004.

ECT
Environmental Consulting & Technology, Inc.

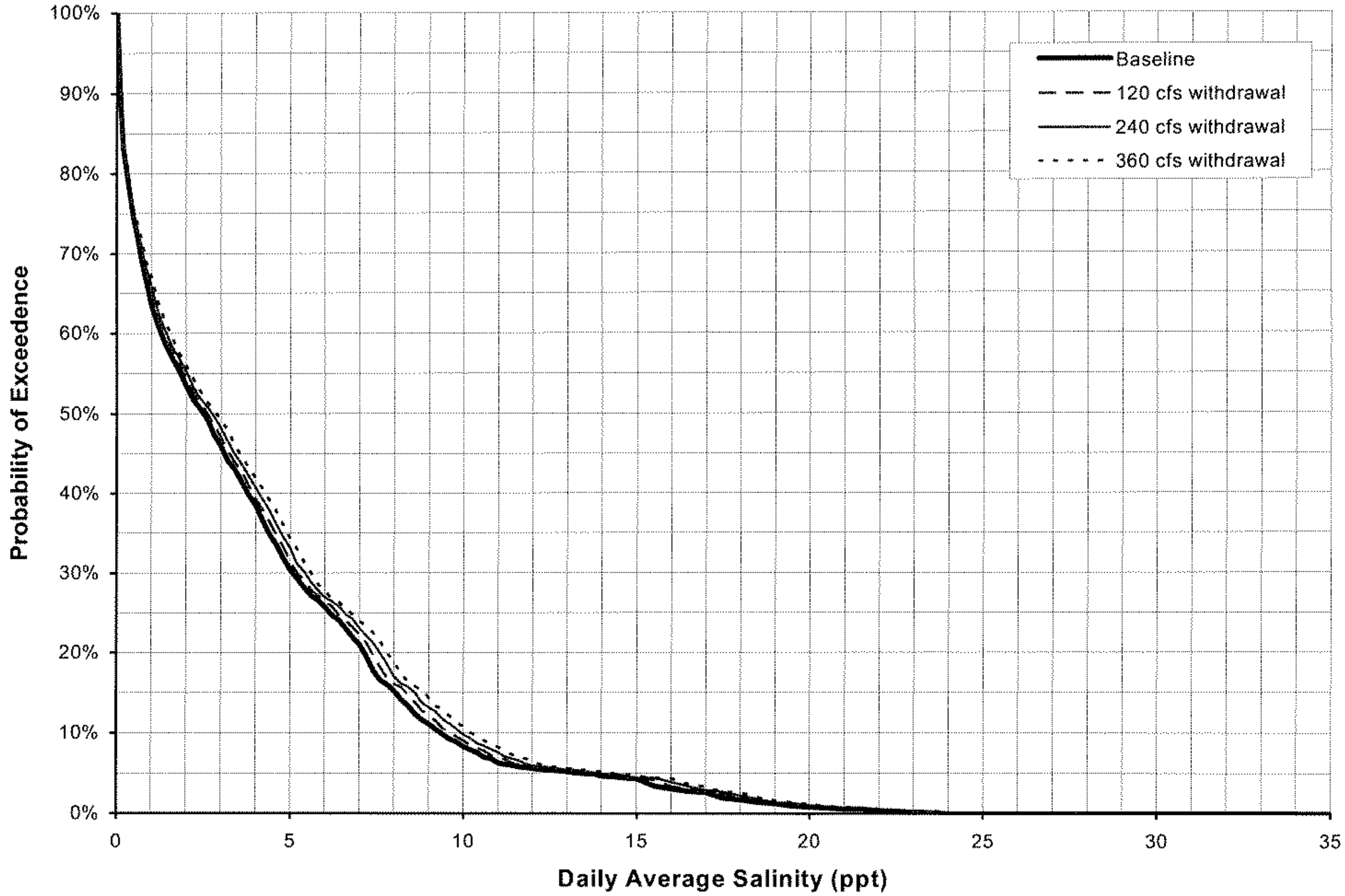


FIGURE C-15.

CUMULATIVE FREQUENCY OF DAILY AVERAGE SALINITY AT ORTEGA RIVER

Source: ECT, 2004.

ECT
Environmental Consulting & Technology, Inc.

APPENDIX D—WATER QUALITY DATA

Table D-1. Water Quality Data at the Center of Lake Monroe (1991 through 2005)

Parameter	Unit	Mean	Standard Deviation	Maximum	Minimum	Median	90th Percentile	No. of Values
Chlorophyll *a*	µg/L	26.64	27.78	130.93	1.01	17.88	63.08	42
Chlorophyll *a* , Corrected	µg/L	28.70	41.92	254.83	1	15.2	67.66	61
Conductance	umhos/cm	933.7	411.3	2,450.0	374.2	821.5	1,596.5	116
Dissolved Oxygen	mg/L	6.77	1.95	10.33	0.5	6.905	9.27	116
Fecal Coliform	#/100mL	15.35	24.85	120	1	5	30	71
Nitrite + Nitrate	mg/L	0.05	0.05	0.233	0.001	0.021	0.111	70
Nitrogen, Kjeldahl	mg/L	1.51	0.51	3.94	0.93	1.38	2.01	71
Nitrogen, Total	mg/L	1.56	0.51	3.95	0.98	1.43	2.04	70
Orthophosphate, as P	mg/L	0.03	0.02	0.092	0.003	0.021	0.046	50
Oxygen Percent Saturation	%	77.1	17.0	110.0	5.7	80.4	95.5	85
pH	s.u.	7.62	0.77	9.83	6.01	7.41	8.73	115
Phosphorus, Total	mg/L	0.08	0.03	0.184	0.02	0.075	0.127	68
Salinity	ppt	0.57	0.59	5.88	0.19	0.45	0.89	98
Secchi Depth	meter	0.73	0.20	1.3	0.2	0.7	0.9	92
Total Suspended Solids	mg/L	10.21	9.36	50	0	7.4	21.3	68
Turbidity	NTU	3.71	2.67	11.6	0.5	2.9	7.32	65
Water Temperature	°C	23.62	5.01	30.96	13.61	24.21	29.60	116

Note: Data include Stations SJ10 and VC-048.

Source: ECT, 2006.

Table D-2. Water Quality Data at Station EAST-1 in Lake Monroe (1991 through 2005)

Parameter	Unit	Mean	Standard Deviation	Maximum	Minimum	Median	90th Percentile	No. of Values
Chlorophyll *a*	µg/L	24.27	20.53	87	5	23	33.6	15
Nitrogen, Total	mg/L	1.72	0.23	2.04	1.31	1.7	2.02	15
Phosphorus, Total	mg/L	0.115	0.057	0.227	0.049	0.099	0.211	15
Secchi Depth	meter	0.54	0.09	0.70	0.46	0.50	0.61	12

Source: ECT, 2006.

Table D-3. Water Quality Data near Channel Marker 4 in Lake Monroe (1991 through 2005)

Parameter	Unit	Mean	Standard Deviation	Maximum	Minimum	Median	90th Percentile	No. of Values
Chlorophyll *a*	µg/L	22.53	25.65	142.58	1	13.5	45.54	43
Chlorophyll *a* , Corrected	µg/L	24.04	33.59	159.74	1	11.1	50.04	61
Conductance	umhos/cm	973.7	512.9	2,673.0	366.7	784.0	1,732.4	79
Dissolved Oxygen	mg/L	5.65	2.43	11.66	0.08	5.33	8.70	79
Fecal Coliform	#/100mL	40.93	53.71	305	4	20.5	112.5	70
Nitrite + Nitrate	mg/L	0.04	0.04	0.214	0.004	0.029	0.116	72
Nitrogen, Kjeldahl	mg/L	1.53	0.55	3.91	0.92	1.41	2.15	72
Nitrogen, Total	mg/L	1.57	0.54	3.92	0.97	1.47	2.16	72
Orthophosphate, as P	mg/L	0.03	0.03	0.108	0.007	0.027	0.07	50
Oxygen Percent Saturation	%	61.6	20.4	111.6	12.9	61.1	86.7	46
pH	s.u.	7.31	0.77	9.76	6.02	7.16	8.31	78
Phosphorus, Total	mg/L	0.089	0.038	0.200	0.020	0.080	0.137	70
Salinity	ppt	0.52	0.28	1.44	0.18	0.47	0.9	73
Secchi Depth	meter	0.70	0.19	1.1	0.3	0.7	0.9	73
Total Suspended Solids	mg/L	12.68	15.65	82.5	0.6	7	29.8	65
Turbidity	NTU	4.04	3.33	18	0.7	3.1	9.15	66
Water Temperature	°C	23.71	5.04	31.27	13.14	23.91	30.41	80

Note: Data include Staions SJ09 and VC047

Source: ECT, 2006.

Table D-4. Summary Statistics for Water Quality near US 17-92 near Lake Monroe (1991 through 2005)

Parameter	Unit	Mean	Standard Deviation	Maximum	Minimum	Median	90th Percentile	No. of Values
Alkalinity	mg/L	66.55	19.23	101.41	32.43	70.85	88.01	24
Chloride	mg/L	293.7	121.1	579.9	81	297.5	447.5	96
Chlorophyll *a*	µg/L	31.18	29.51	158.19	0.05	26.33	64.04	100
Chlorophyll *a* , Corrected	µg/L	35.96	36.88	162.54	1.26	28.06	70.82	48
Color	PCU	119.3	93.2	500	10	80	240	96
Conductance	umhos/cm	1,191.5	482.3	2,380.0	23.0	1,228.0	1,768.0	127
Dissolved Oxygen	mg/L	7.15	2.34	13.8	1.7	7.19	9.89	127
Dissolved Solids	mg/L	736	278	1,400	108	744	1,070	96
Fecal Coliform	#/100mL	31.94	98.35	585	0	10	47	35
Hardness	mg/L	252.79	78.09	407	81	249.5	345.5	24
Nitrite + Nitrate	mg/L	0.06	0.08	0.29	0	0.01	0.18	104
Nitrogen, Ammonia	mg/L	0.08	0.11	0.81	0.002	0.04	0.205	96
Nitrogen, Kjeldahl	mg/L	1.67	0.50	3.37	0.61	1.59	2.23	86
Orthophosphate, as P	mg/L	0.04	0.05	0.22	0.005	0.02	0.092	129
pH	s.u.	7.77	0.75	9.6	6.2	7.78	8.8	127
Phosphorus, Total	mg/L	0.089	0.051	0.380	0.010	0.080	0.140	133
Salinity	ppt	0.57	0.25	1.23	0.19	0.57	0.84	39
Secchi Depth	meter	0.60	0.16	1.1	0.3	0.6	0.7	52
Sulfate	mg/L	89.76	50.64	200	7.9	94.5	159	72
Total Organic Carbon	mg/L	19.26	5.66	33	5.5	20	25.01	69
Total Suspended Solids	mg/L	15.76	21.56	152	0.5	10	28	149
Turbidity	NTU	5.40	5.44	45	0.8	4.12	9.2	125
Water Temperature	°C	24.82	5.14	32.3	10.1	25.66	30.48	127

Note: Data include Stations USGS0223450, VC-050, and 2001003

Source: ECT, 2006.

Table D-5. Water Quality Data at Station LKMON in Lake Monroe (1991 through 2005)

Parameter	Unit	Mean	Standard Deviation	Maximum	Minimum	Median	90th Percentile	No. of Values
Alkalinity	mg/L	109.7	86.4	236.5	44.5	78.9	192.2	4
Chloride	mg/L	288.5	133.8	408.5	111.8	316.9	398.1	4
Chlorophyll *a*	µg/L	59.58	54.85	134.37	6.04	48.96	112.66	4
Chlorophyll *a* , Corrected	µg/L	54.94	52.74	128.43	5.28	43.03	105.77	4
Conductance	umhos/cm	1,017	160	1,130	904	1,017	1,107	2
Dissolved Oxygen	mg/L	6.81	4.53	10.01	3.61	6.81	9.37	2
Nitrite + Nitrate	mg/L	0.01	0.01	0.023	0.003	0.0065	0.0185	4
Nitrogen, Ammonia	mg/L	0.03	0.01	0.04	0.013	0.0245	0.0355	4
Nitrogen, Kjeldahl	mg/L	2.27	1.61	4.41	0.668	2.007	3.84	4
Orthophosphate, as P	mg/L	0.04	0.03	0.065	0.011	0.04	0.0641	4
pH	s.u.	8.28	1.15	9.09	7.46	8.28	8.93	2
Phosphorus, Total	mg/L	0.09	0.07	0.177	0.016	0.075	0.151	4
Secchi Depth	meter	0.24		0.24	0.24	0.24	0.24	1
Sulfate	mg/L	92.1	35.0	135.7	59.9	86.4	126.4	4
Total Suspended Solids	mg/L	25.25	35.37	78	5	9	58.5	4
Turbidity	NTU	12.88	13.45	32.7	3.3	7.75	25.71	4
Water Temperature	°C	30.21	0.86	30.82	29.6	30.21	30.70	2

Source: ECT, 2006.

Table D-6. Water Quality Data at Station LMCWF near Lake Monroe (1991 through 2005)

Parameter	Unit	Mean	Standard Deviation	Maximum	Minimum	Median	90th Percentile	No. of Values
Alkalinity	mg/L	133.92	19.72	180	106	130	155.2	12
Chloride	mg/L	53.68	14.42	77.9	30.2	54.4	74.27	12
Color	PCU	74.17	22.24	100	35	77.5	100	12
Conductance	umhos/cm	464.3	80.9	631.0	318.0	469.3	532.3	12
Dissolved Oxygen	mg/L	6.21	1.38	8.56	3.4	6.14	7.48	12
Dissolved Solids	mg/L	280.9	54.0	370	195	278	354.2	12
Hardness	mg/L	174.50	21.87	218	133	173	198.5	12
Nitrite + Nitrate	mg/L	0.20	0.09	0.392	0.11	0.173	0.335	12
Nitrogen, Ammonia	mg/L	0.09	0.04	0.166	0.045	0.088	0.145	12
Nitrogen, Kjeldahl	mg/L	0.67	0.23	1.19	0.35	0.66	0.89	12
Orthophosphate, as P	mg/L	0.15	0.03	0.221	0.098	0.144	0.182	12
pH	s.u.	7.44	0.18	7.77	7.23	7.405	7.61	12
Phosphorus, Total	mg/L	0.20	0.06	0.306	0.122	0.175	0.289	12
Secchi Depth	meter	0.40	0.12	0.58	0.24	0.36	0.52	12
Sulfate	mg/L	22.19	6.16	31.7	9.8	24.35	25.87	12
Total Organic Carbon	mg/L	12.99	1.90	16.7	10.8	12.6	15.84	12
Total Suspended Solids	mg/L	3.92	3.15	11	1	3	8.6	12
Turbidity	NTU	4.68	1.71	8.9	2.6	4.25	5.97	12
Water Temperature	°C	22.74	4.25	26.58	14.3	23.48	26.47	12

Source: ECT, 2006.

Table D-7. Water Quality Data at Station SJRDPP in Lake Monroe (1991 through 2005)

Parameter	Unit	Mean	Standard Deviation	Maximum	Minimum	Median	90th Percentile	No. of Values
Alkalinity	mg/L	48.63	15.61	98.7	27	47.1	63.1	41
Chloride	mg/L	191.73	96.5	442	81.4	175	338	41
Chlorophyll *a*	µg/L	7.43	7.45	31.9	0.4	5.6	16.7	41
Chlorophyll *a* , Corrected	µg/L	7.15	7.32	31.9	0.4	5	16.1	41
Color	PCU	181.95	83.29	400	40	175	250	41
Conductance	umhos/cm	795	375	1,791	296	648	1,268	41
Dissolved Oxygen	mg/L	6.91	1.72	9.86	3.52	6.96	9.3	41
Dissolved Solids	mg/L	474.4	190.7	950	235	430	745	41
Hardness	mg/L	145.2	58.6	293.8	70.9	134	240.8	41
Nitrite + Nitrate	mg/L	0.07	0.07	0.216	0	0.055	0.167	35
Nitrogen, Ammonia	mg/L	0.04	0.05	0.234	0	0.029	0.108	35
Nitrogen, Kjeldahl	mg/L	1.22	0.23	1.8	0.7	1.18	1.49	39
Orthophosphate, as P	mg/L	0.05	0.03	0.115	0.011	0.047	0.082	37
pH	s.u.	7.51	0.52	9.28	6.6	7.46	8.13	41
Phosphorus, Total	mg/L	0.10	0.05	0.333	0.04	0.091	0.131	39
Secchi Depth	meter	0.57	0.23	1.72	0.24	0.52	0.72	41
Sulfate	mg/L	51.33	33.54	132	13.6	39.2	98.8	41
Total Organic Carbon	mg/L	24.76	4.02	32.4	10.6	24.9	28.62	39
Total Suspended Solids	mg/L	5.39	4.28	16	0	4	11	41
Turbidity	NTU	3.65	2.22	8.9	1	2.7	7	41
Water Temperature	°C	23.39	5.78	32.1	13.52	24.15	29.78	41

Source: ECT, 2006.

Table D-8. Water Quality Data at Station SJR415 near Lake Monroe (1991 through 2005)

Parameter	Unit	Mean	Standard Deviation	Maximum	Minimum	Median	90th Percentile	No. of Values
Alkalinity	mg/L	46.96	10.64	68.2	26.9	46.3	58.82	42
Chloride	mg/L	207.2	114.6	468	78.8	159.5	400.7	42
Chlorophyll *a*	µg/L	8.94	9.21	48.7	0.4	5.15	18.1	42
Chlorophyll *a* , Corrected	µg/L	7.84	8.75	48.7	0	4.45	15.5	42
Color	PCU	194.0	93.9	400	60	175	318	42
Conductance	umhos/cm	857	433	1,835	332	699	1,602	42
Dissolved Oxygen	mg/L	6.06	2.28	10.69	1.12	6.325	8.617	42
Dissolved Solids	mg/L	499.7	234.6	1030	199	410.5	885.5	42
Hardness	mg/L	152.8	66.0	296.4	69.3	135.3	270.4	42
Nitrite + Nitrate	mg/L	0.05	0.05	0.189	0	0.043	0.111	39
Nitrogen, Ammonia	mg/L	0.03	0.02	0.08	0	0.027	0.062	39
Nitrogen, Kjeldahl	mg/L	1.28	0.27	1.96	0.83	1.30	1.63	42
Orthophosphate, as P	mg/L	0.04	0.03	0.154	0.011	0.03	0.075	39
pH	s.u.	7.42	0.65	8.92	6	7.16	8.42	42
Phosphorus, Total	mg/L	0.09	0.04	0.232	0.012	0.089	0.128	42
Secchi Depth	meter	0.50	0.16	0.98	0.25	0.47	0.676	42
Sulfate	mg/L	52.80	39.69	137	7	34.9	119.9	42
Total Organic Carbon	mg/L	26.65	4.09	34.2	17.2	26.85	31.58	42
Total Suspended Solids	mg/L	7.17	5.53	27	0	6	13.9	42
Turbidity	NTU	4.43	3.39	15	1.2	3.45	8.67	42
Water Temperature	°C	24.07	5.33	31.32	13.08	25.45	30.52	42

Source: ECT, 2006.

Table D-9. Water Quality Data at Station OWNE in Lake Monroe (1991 through 2005)

Parameter	Unit	Mean	Standard Deviation	Maximum	Minimum	Median	90th Percentile	No. of Values
Alkalinity	mg/L	44.51	11.62	68.4	17.2	43.2	56.98	28
Chloride	mg/L	192.2	113.3	454	75	146	374.4	28
Chlorophyll *a*	µg/L	11.09	16.69	83.4	1	4.65	23.45	28
Color	PCU	185.36	85.74	400	70	160	259	28
Conductance	umhos/cm	810	456	1797	330	624	1526	28
Dissolved Oxygen	mg/L	6.79	1.90	9.9	3.3	6.735	9.29	28
Dissolved Solids	mg/L	466.0	253.3	1030	58	363.5	866	28
Hardness	mg/L	142.6	69.6	309.8	72.8	113.2	254.8	28
Nitrite + Nitrate	mg/L	0.05	0.06	0.195	0.002	0.025	0.151	28
Nitrogen, Ammonia	mg/L	0.03	0.04	0.175	0.001	0.012	0.077	28
Nitrogen, Kjeldahl	mg/L	1.28	0.24	2.2	0.82	1.23	1.502	28
Nitrogen, Total	mg/L	1.33	0.26	2.20	0.84	1.27	1.56	26
Orthophosphate, as P	mg/L	0.03	0.03	0.11	0.002	0.017	0.074	50
pH	s.u.	7.26	0.65	8.65	6.24	7.145	8.152	28
Phosphorus, Total	mg/L	0.09	0.06	0.326	0.036	0.077	0.132	28
Secchi Depth	meter	0.45	0.09	0.6	0.25	0.445	0.56	28
Sulfate	mg/L	51.09	43.14	145	12.4	29.35	124.4	28
Total Organic Carbon	mg/L	25.55	3.12	32.1	20.5	25.35	29.63	28
Total Suspended Solids	mg/L	6.59	6.70	34	1	5	10.9	28
Water Temperature	°C	22.82	5.62	30.19	12.58	23.49	29.03	28

Source: ECT, 2006.

Table D-10. Water Quality Data at Station OWS in Lake Monroe (1991 through 2005)

Parameter	Unit	Mean	Standard Deviation	Maximum	Minimum	Median	90th Percentile	No. of Values
Alkalinity	mg/L	46.77	10.17	67.6	28.9	48.15	59.53	28
Chloride	mg/L	209.51	136.49	662	79.2	176.5	373.3	28
Chlorophyll *a*	µg/L	12.83	15.17	70.6	1	7.8	27.63	28
Color	PCU	177.86	79.58	400	60	167.5	259	28
Conductance	umhos/cm	832.49	456.19	1834	295.4	684.7	1496.4	28
Dissolved Oxygen	mg/L	6.96	2.10	9.64	2.2	7.22	9.233	28
Dissolved Solids	mg/L	479.8	238.9	1030	219	397	820.3	28
Hardness	mg/L	147.02	68.17	310.3	69.1	131.3	252.5	28
Nitrite + Nitrate	mg/L	0.05	0.05	0.174	0.001	0.03	0.131	27
Nitrogen, Ammonia	mg/L	0.04	0.06	0.276	0	0.013	0.088	27
Nitrogen, Kjeldahl	mg/L	1.33	0.22	1.99	0.95	1.3	1.56	28
Nitrogen, Total	mg/L	1.38	0.22	1.99	0.96	1.35	1.55	25
Orthophosphate, as P	mg/L	0.04	0.03	0.12	0.004	0.025	0.098	51
pH	s.u.	7.54	0.67	8.98	6.39	7.40	8.57	28
Phosphorus, Total	mg/L	0.10	0.06	0.331	0.044	0.086	0.165	28
Secchi Depth	meter	0.44	0.12	0.72	0.26	0.42	0.6	28
Sulfate	mg/L	50.69	38.33	130	13.1	30.95	114.3	28
Total Organic Carbon	mg/L	25.70	2.87	31	19.8	25.3	28.89	28
Total Suspended Solids	mg/L	7.70	5.97	23	2	5	16	28
Water Temperature	°C	22.73	5.47	30.11	12.57	23.27	28.93	28

Source: ECT, 2006.

Table D-11. Water Quality Data at Station SJ11 in Lake Monroe (1991 through 2005)

Parameter	Unit	Mean	Standard Deviation	Maximum	Minimum	Median	90th Percentile	No. of Values
Chlorophyll *a*	µg/L	29.16	33.10	161.31	1.46	16.71	71.99	36
Chlorophyll *a* , Corrected	µg/L	21.21	25.08	101.84	1.00	11.64	48.63	36
Conductance	umhos/cm	870.7	379.3	1,890.0	1.4	834.0	1,473.4	84
Dissolved Oxygen	mg/L	6.97	1.58	9.89	2.34	6.72	9.03	84
Fecal Coliform	#/100mL	28.78	111.37	675.00	5.00	5.00	17.00	37
Nitrite + Nitrate	mg/L	0.07	0.10	0.37	0.001	0.02	0.15	37
Nitrogen, Kjeldahl	mg/L	1.35	0.44	2.99	0.20	1.25	1.88	37
Nitrogen, Total	mg/L	1.42	0.44	3.01	0.22	1.33	1.89	37
Orthophosphate, as P	mg/L	0.023	0.017	0.072	0.003	0.018	0.048	37
Oxygen Percent Saturation	%	79.7	14.0	108.9	30.8	81.9	93.7	84
pH	s.u.	7.66	0.71	9.80	5.99	7.49	8.56	84
Phosphorus, Total	mg/L	0.076	0.033	0.195	0.044	0.063	0.112	35
Salinity	ppt	0.48	0.22	1.00	0.20	0.40	0.80	72
Secchi Depth	meter	0.77	0.15	1.00	0.40	0.80	0.90	51
Total Suspended Solids	mg/L	10.80	9.50	42.20	0.50	7.55	19.20	36
Turbidity	NTU	3.58	2.60	12.00	0.90	2.80	7.40	36
Water Temperature	°C	23.38	5.07	30.98	13.73	23.88	29.94	84

Source: ECT, 2006.

Table D-12. Summary Statistics for Water Quality Data at Station VC049 In Lake Monroe (1991 through 2005)

Parameter	Unit	Mean	Standard Deviation	Maximum	Minimum	Median	90th Percentile	No. of Values
Chlorophyll *a*	µg/L	22.15	2.90	24.2	20.1	22.15	23.79	2
Chlorophyll *a* , Corrected	µg/L	41.05	44.77	168.42	1.5	21.8	91.1	21
Conductance	umhos/cm	1,217.3	535.0	2,271.0	16.8	1,265.0	1,679.4	22
Dissolved Oxygen	mg/L	7.49	2.19	10.44	2.25	7.23	9.96	22
Fecal Coliform	#/100mL	6.32	3.27	15	5	5	11	19
Nitrite + Nitrate	mg/L	0.05	0.07	0.22	0.003	0.01	0.1559	20
Nitrogen, Kjeldahl	mg/L	1.82	0.80	4.49	1.18	1.52	2.65	20
Nitrogen, Total	mg/L	1.87	0.79	4.51	1.19	1.55	2.66	20
pH	s.u.	7.90	0.81	9.35	6.52	7.96	8.84	21
Phosphorus, Total	mg/L	0.092	0.043	0.189	0.02	0.088	0.153	20
Salinity	ppt	0.68	0.26	1.22	0.24	0.69	0.89	22
Secchi Depth	meter	0.59	0.20	0.9	0.06	0.6	0.8	21
Total Suspended Solids	mg/L	14.24	12.94	50	1.2	11.15	29.07	18
Water Temperature	°C	22.86	5.18	30.42	14.09	22.40	29.74	22

Source: ECT, 2006.

Table D-13. Water Quality Data near Channel Marker 10 in Lake Monroe (1991 through 2005)

Parameter	Unit	Mean	Standard Deviation	Maximum	Minimum	Median	90th Percentile	No. of Values
Chlorophyll *a*	µg/L	28.79	32.23	161.31	1.46	17.81	71.307	38
Chlorophyll *a* , Corrected	µg/L	28.52	34.68	168.42	1	15.63	68.184	57
Conductance	umhos/cm	942.6	436.9	2,271.0	1.4	845.6	1,602.0	106
Dissolved Oxygen	mg/L	7.07	1.73	10.44	2.25	6.75	9.29	106
Fecal Coliform	#/100mL	21.16	90.76	675	5	5	15	56
Nitrite + Nitrate	mg/L	0.06	0.09	0.371	0.001	0.02	0.149	57
Nitrogen, Kjeldahl	mg/L	1.52	0.63	4.49	0.2	1.34	2.00	57
Nitrogen, Total	mg/L	1.58	0.62	4.51	0.22	1.44	2.01	57
Orthophosphate, as P	mg/L	0.02	0.02	0.072	0.003	0.018	0.05	37
Oxygen Percent Saturation	%	79.7	14.0	108.9	30.8	81.9	93.7	84
pH	s.u.	7.71	0.73	9.8	5.99	7.57	8.66	105
Phosphorus, Total	mg/L	0.082	0.038	0.195	0.020	0.071	0.120	55
Salinity	ppt	0.53	0.24	1.22	0.2	0.45	0.874	94
Secchi Depth	meter	0.72	0.18	1	0.06	0.7	0.9	72
Total Suspended Solids	mg/L	11.95	10.77	50	0.5	8.15	22.42	54
Turbidity	NTU	3.58	2.60	12	0.9	2.8	7.4	36
Water Temperature	°C	23.28	5.07	30.98	13.73	23.595	29.94	106

Note: Data include Staions SJ11 and VC049

Source: ECT, 2006.

Table D-14. Summary Statistics for Water Quality Data at Station EAST2 In Lake Monroe (1991 through 2005)

Parameter	Unit	Mean	Standard Deviation	Maximum	Minimum	Median	90th Percentile	No. of Values
Chlorophyll *a*	µg/L	24.47	28.92	119	4	20	39.4	15
Nitrogen, Total	mg/L	1.71	0.24	2.04	1.35	1.63	2.04	15
Phosphorus, Total	mg/L	0.108	0.067	0.252	0.043	0.086	0.227	15
Secchi Depth	meter	0.53	0.09	0.70	0.40	0.55	0.61	12

Source: ECT, 2006.

Table D-15. Summary Statistics for Water Quality Data at Station EAST3 In Lake Monroe (1991 through 2005)

Parameter	Unit	Mean	Standard Deviation	Maximum	Minimum	Median	90th Percentile	No. of Values
Chlorophyll *a*	µg/L	27.60	24.43	83	5	18	63.6	15
Nitrogen, Total	mg/L	1.73	0.30	2.21	1.32	1.69	2.16	14
Phosphorus, Total	mg/L	0.103	0.070	0.265	0.039	0.084	0.214	14
Secchi Depth	meter	0.50	0.08	0.61	0.40	0.50	0.60	12

Source: ECT, 2006.

Table D-16. Summary Statistics for Water Quality Data at Station WEST1 In Lake Monroe (1991 through 2005)

Parameter	Unit	Mean	Standard Deviation	Maximum	Minimum	Median	90th Percentile	No. of Values
Chlorophyll *a*	µg/L	13.86	19.05	61	1	5	44.2	29
Nitrogen, Total	mg/L	1.50	0.51	3.19	0.81	1.34	2.22	31
Phosphorus, Total	mg/L	0.080	0.037	0.185	0.035	0.074	0.13	31
Secchi Depth	meter	0.63	0.26	1.22	0.305	0.61	1.07	29

Source: ECT, 2006.

Table D-17. Summary Statistics for Water Quality Data at Station WEST2 In Lake Monroe (1991 through 2005)

Parameter	Unit	Mean	Standard Deviation	Maximum	Minimum	Median	90th Percentile	No. of Values
Chlorophyll *a*	µg/L	14.52	20.12	79	1	7	41.2	29
Nitrogen, Total	mg/L	1.56	0.53	3.41	0.75	1.38	2.07	31
Phosphorus, Total	mg/L	0.083	0.037	0.186	0.033	0.073	0.133	31
Secchi Depth	meter	0.62	0.24	1.22	0.305	0.61	0.93	30

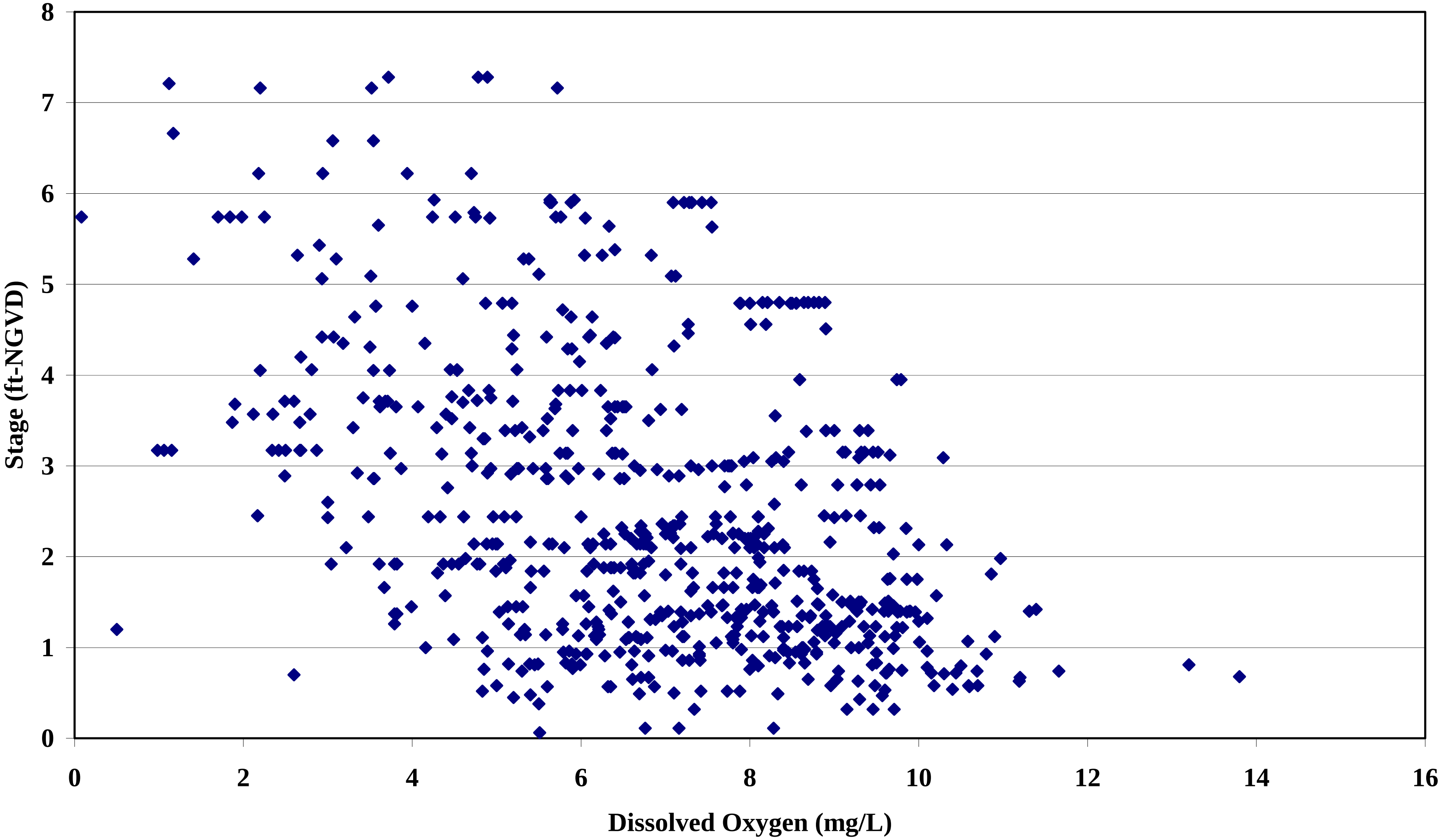
Source: ECT, 2006.

Table D-18. Summary Statistics for Water Quality Data at Station WEST3 In Lake Monroe (1991 through 2005)

Parameter	Unit	Mean	Standard Deviation	Maximum	Minimum	Median	90th Percentile	No. of Values
Chlorophyll *a*	µg/L	17.07	22.29	78	1	6	45.6	29
Nitrogen, Total	mg/L	1.55	0.54	3.23	0.94	1.39	2.17	31
Phosphorus, Total	mg/L	0.081	0.036	0.175	0.022	0.077	0.12	31
Secchi Depth	meter	0.62	0.25	1.22	0.305	0.61	0.93	30

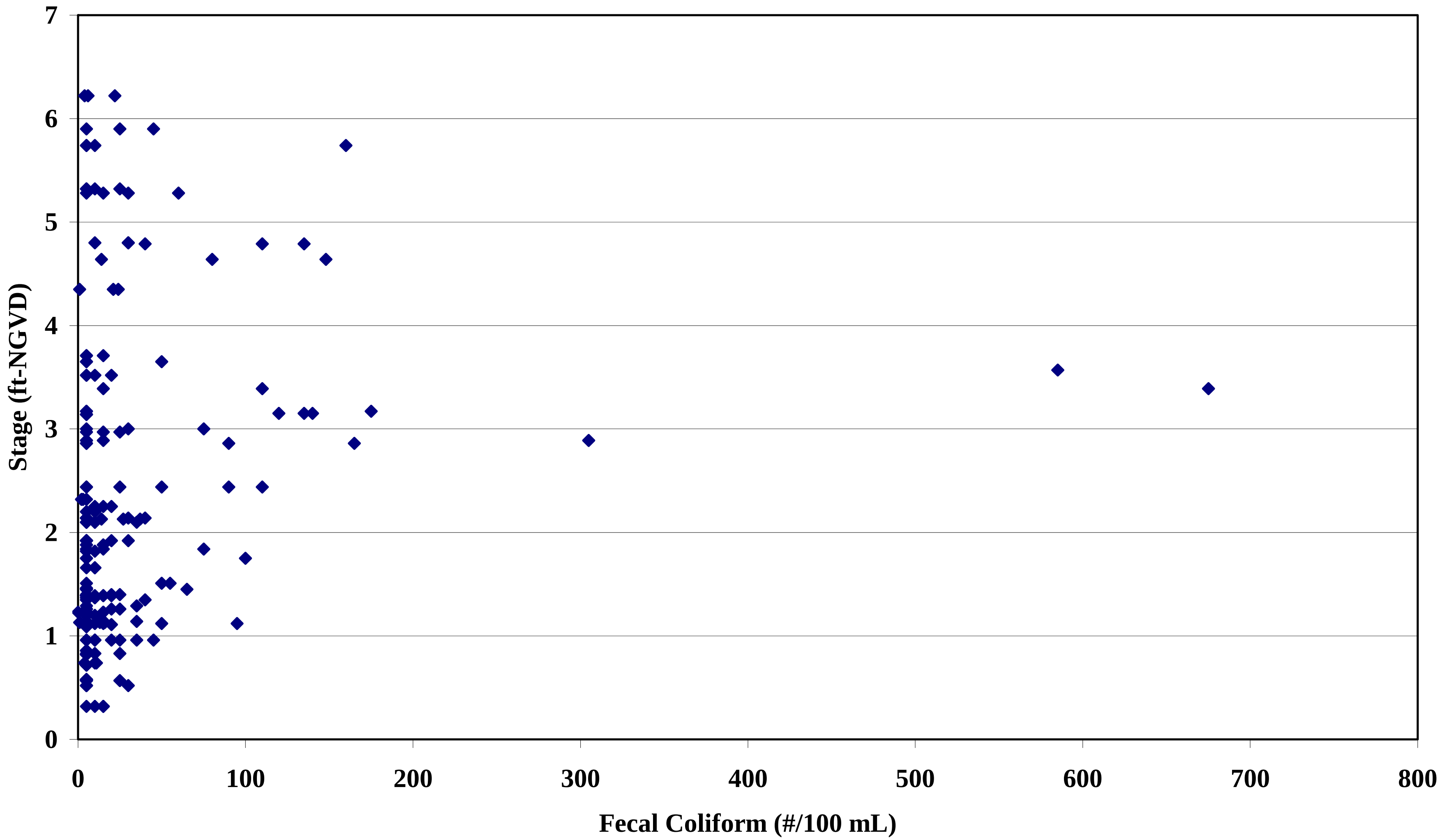
Source: ECT, 2006.

Figure D-1. Dissolved Oxygen vs. Stage
(ALL data, 1991-2005)



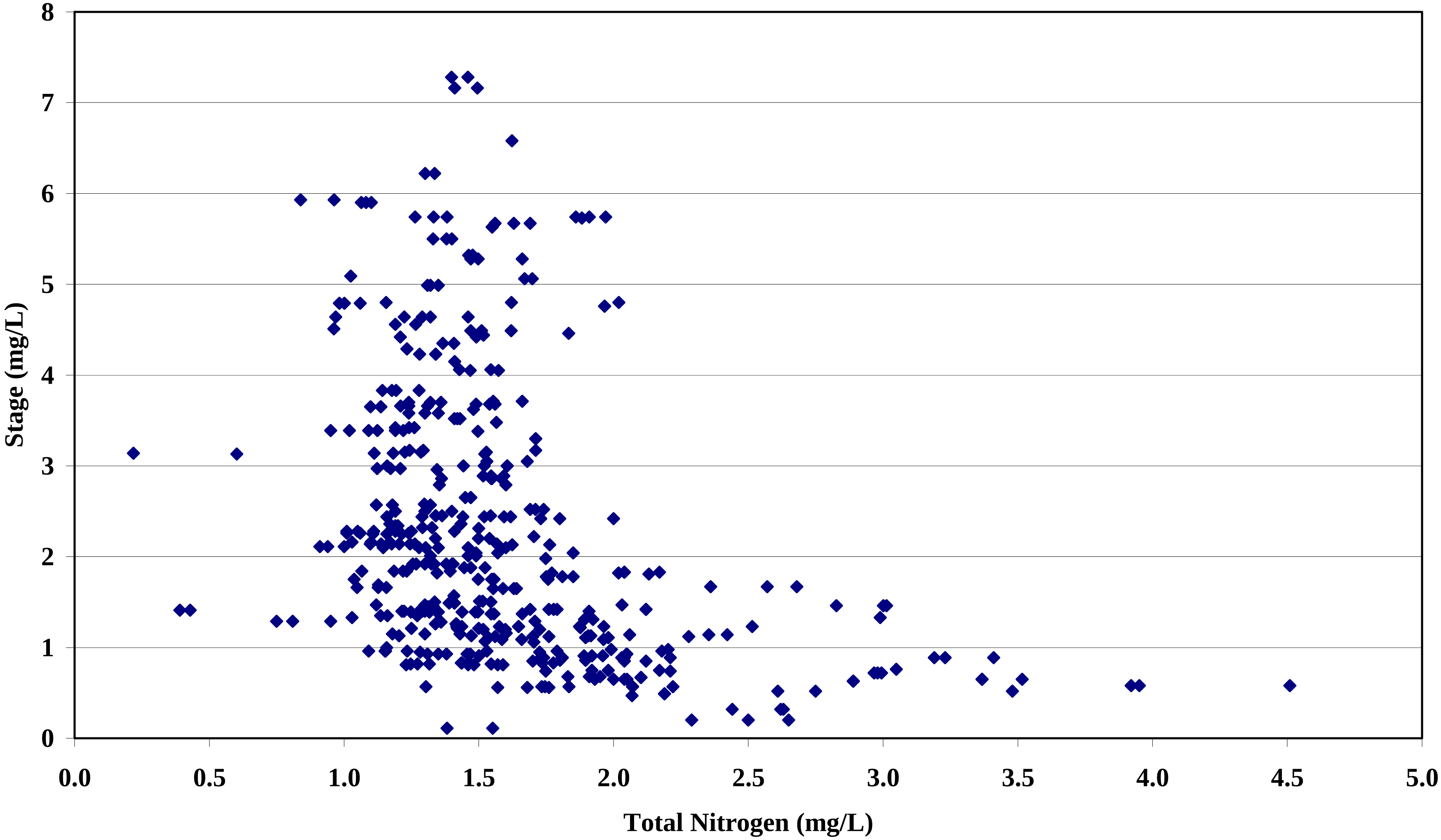
Source: ECT, 2006.

Figure D-2. Fecal Coliform vs. Stage
(ALL data, 1991-2005)



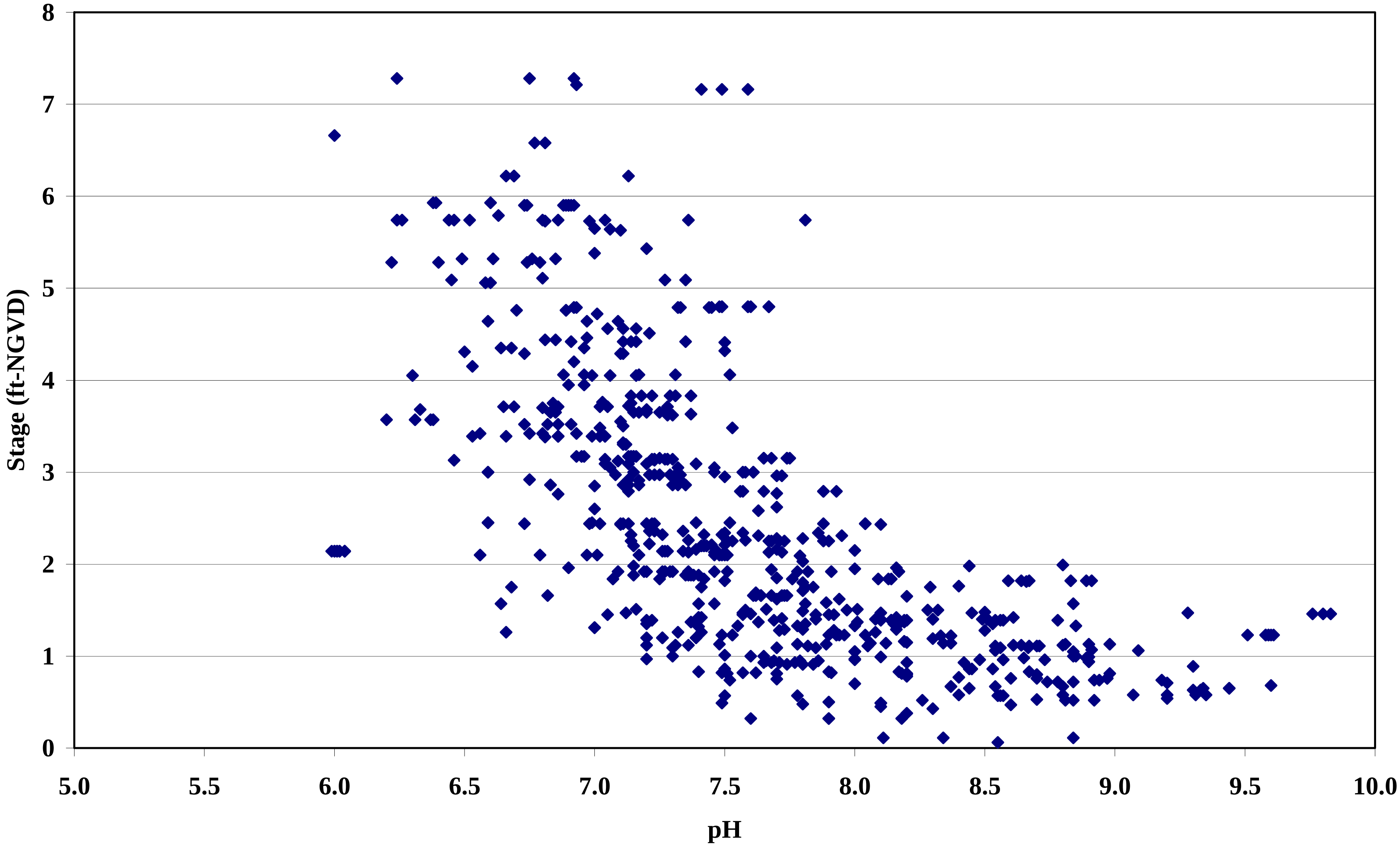
Source: ECT, 2006.

Figure D-3. Total Nitrogen vs. Stage
(ALL data, 1991-2005)



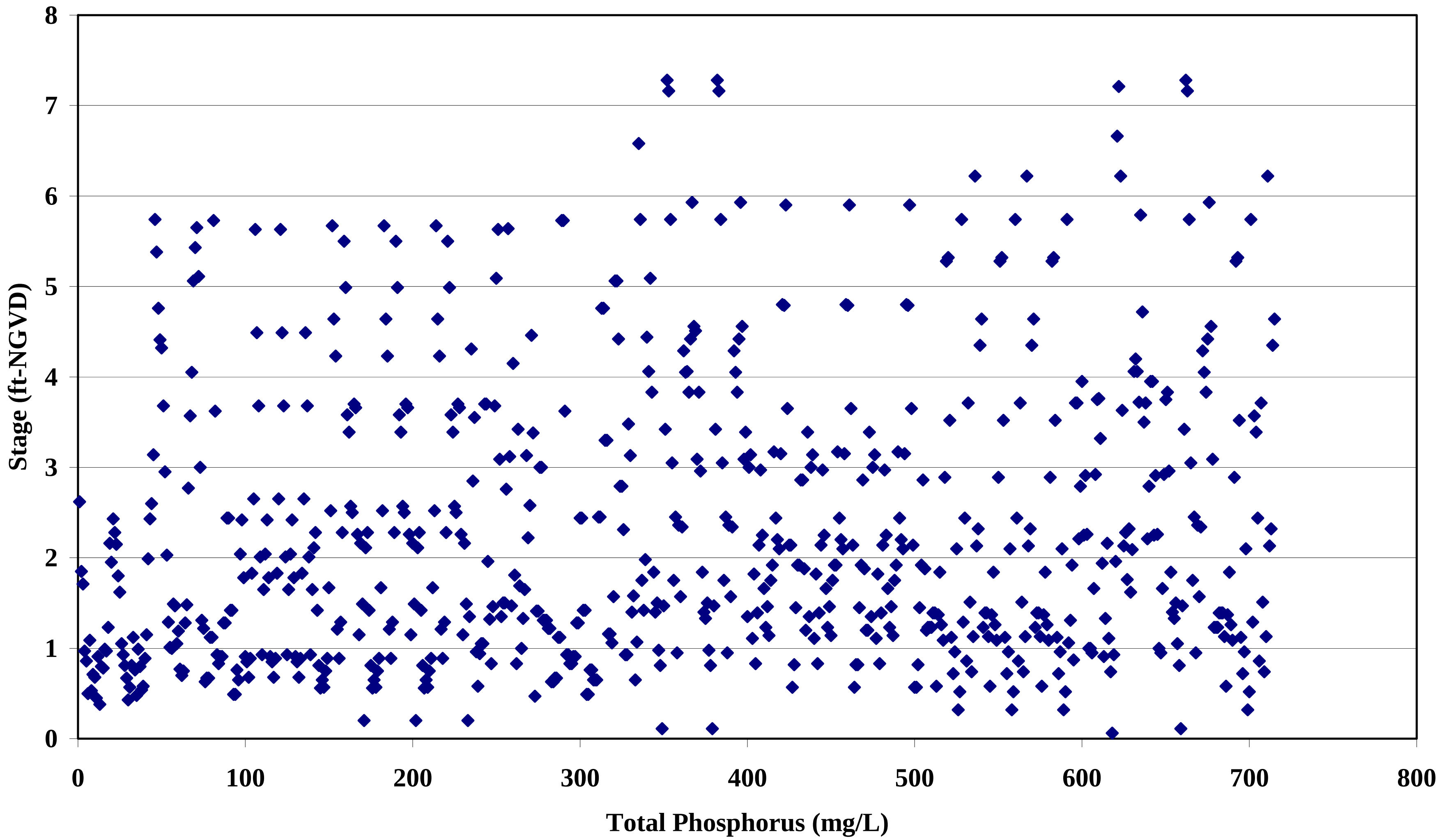
Source: ECT, 2006.

Figure D-4. pH vs. Stage
(ALL data, 1991-2005)



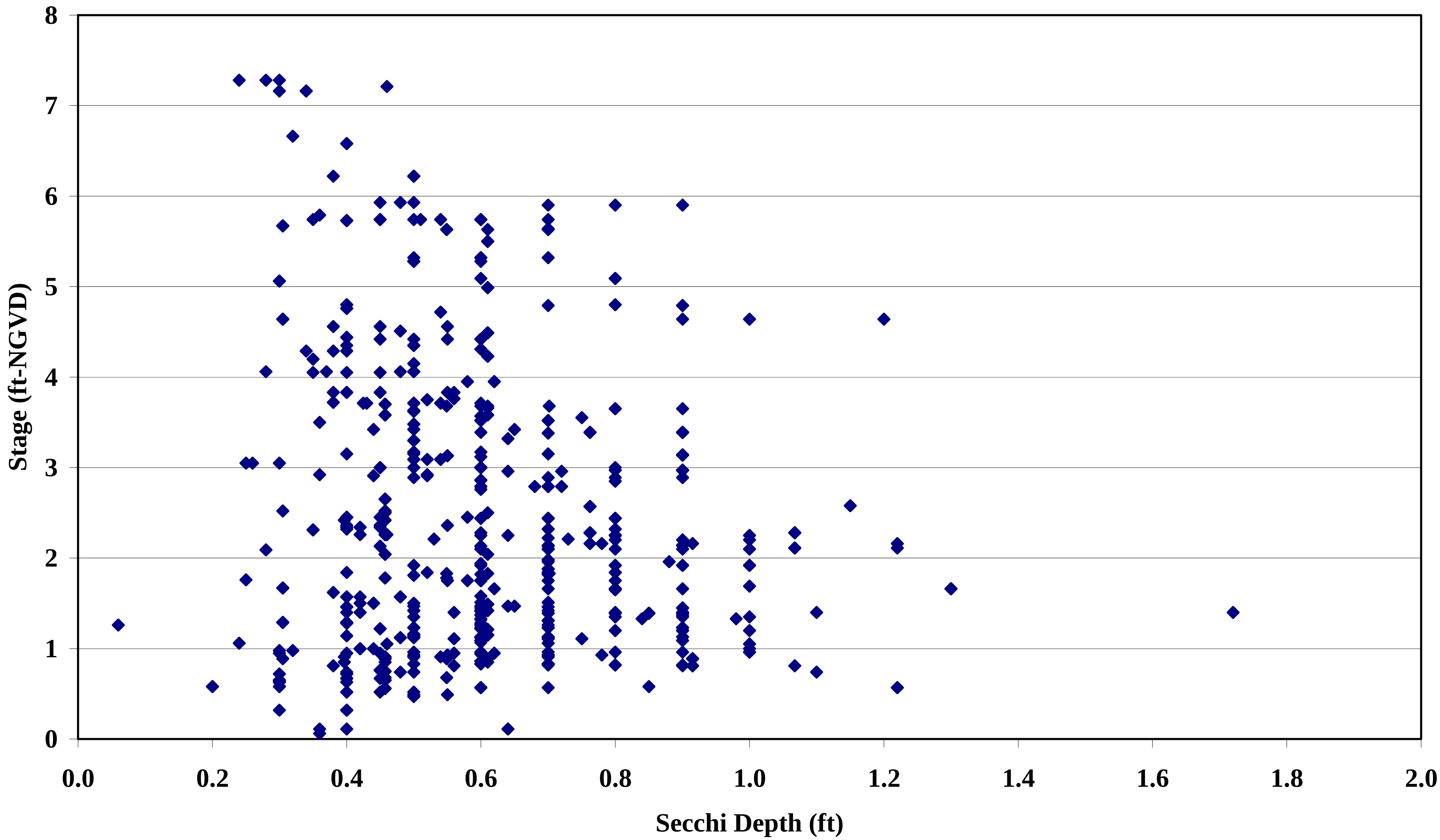
Source: ECT, 2006.

Figure D-5. Total Phosphorus vs. Stage
(ALL data, 1991-2005)



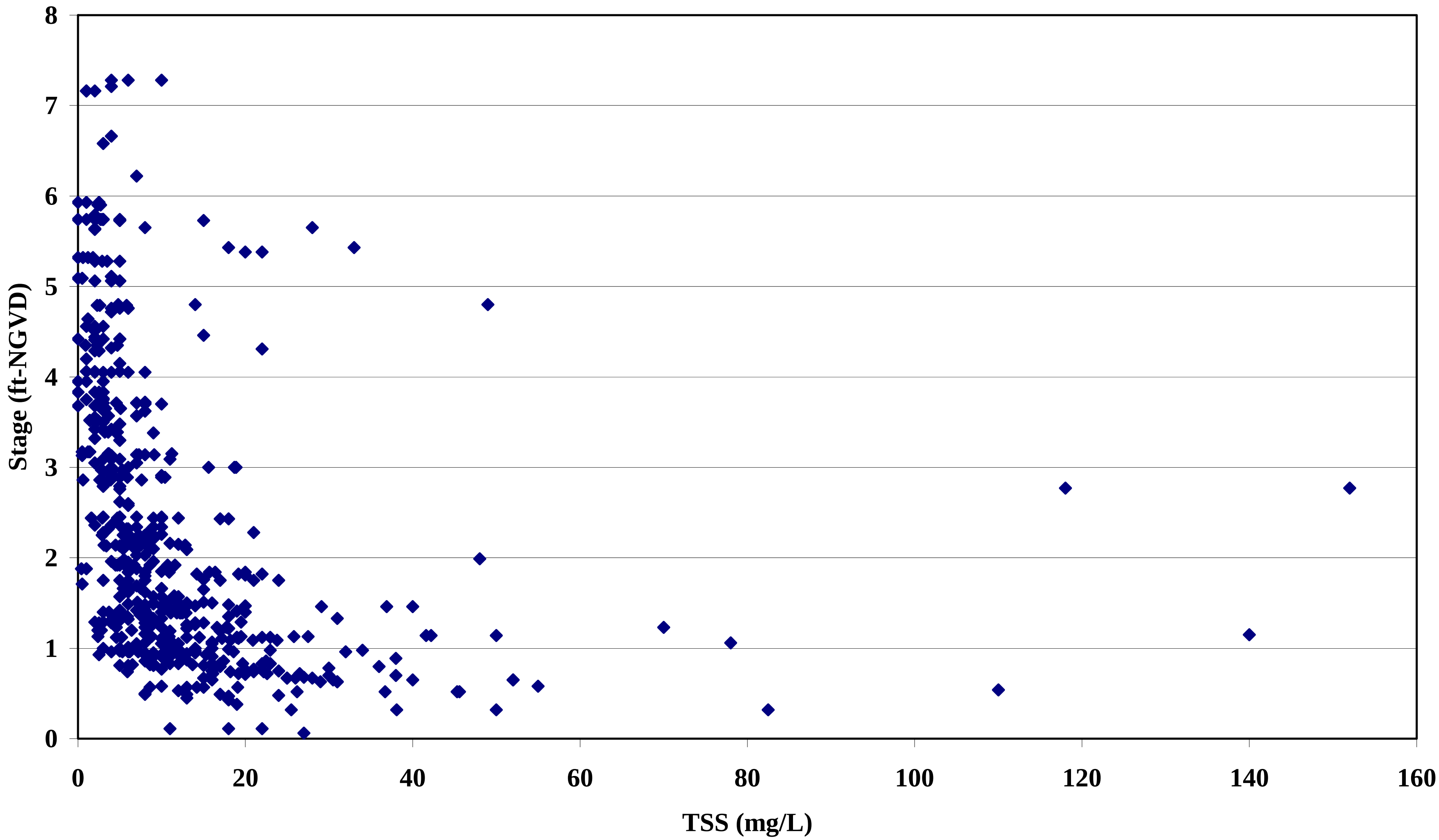
Source: ECT, 2006.

Figure D-6. Secchi Depth vs. Stage
(ALL data, 1991-2005)



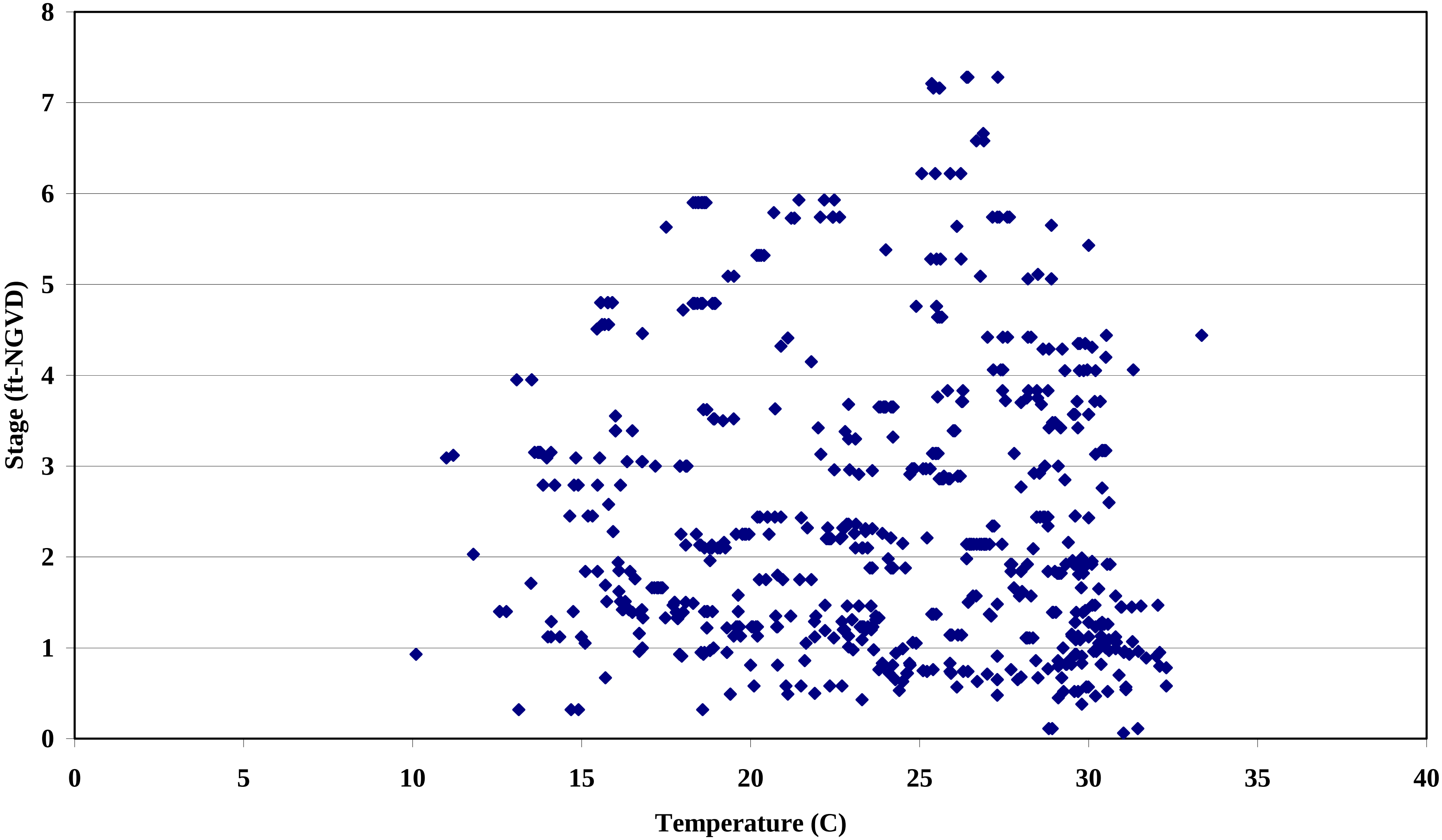
Source: ECT, 2006.

Figure D-7. Total Suspended Solids vs. Stage
(ALL data, 1991-2005)



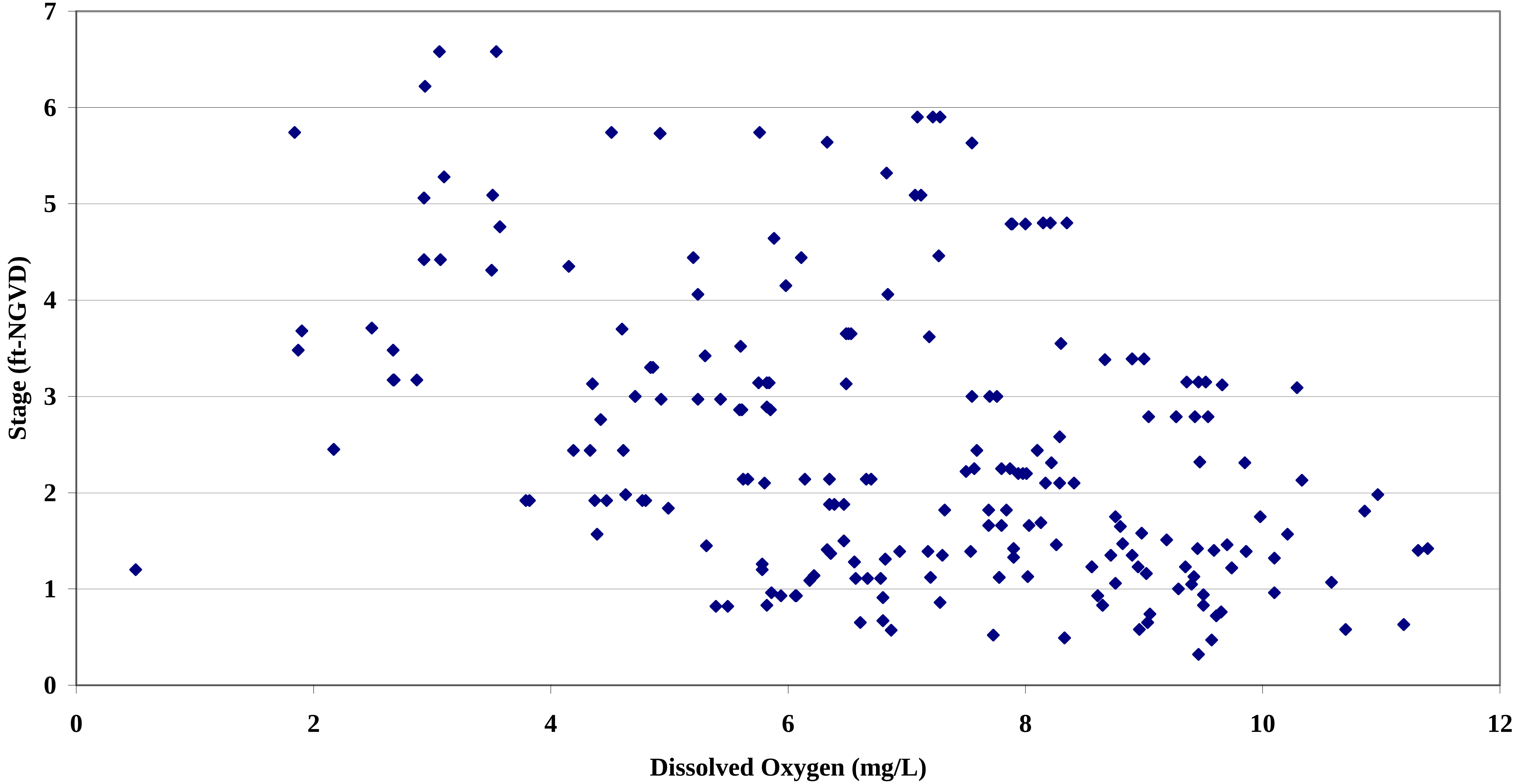
Source: ECT, 2006.

Figure D-8. Temperature vs. Stage
(ALL data, 1991-2005)



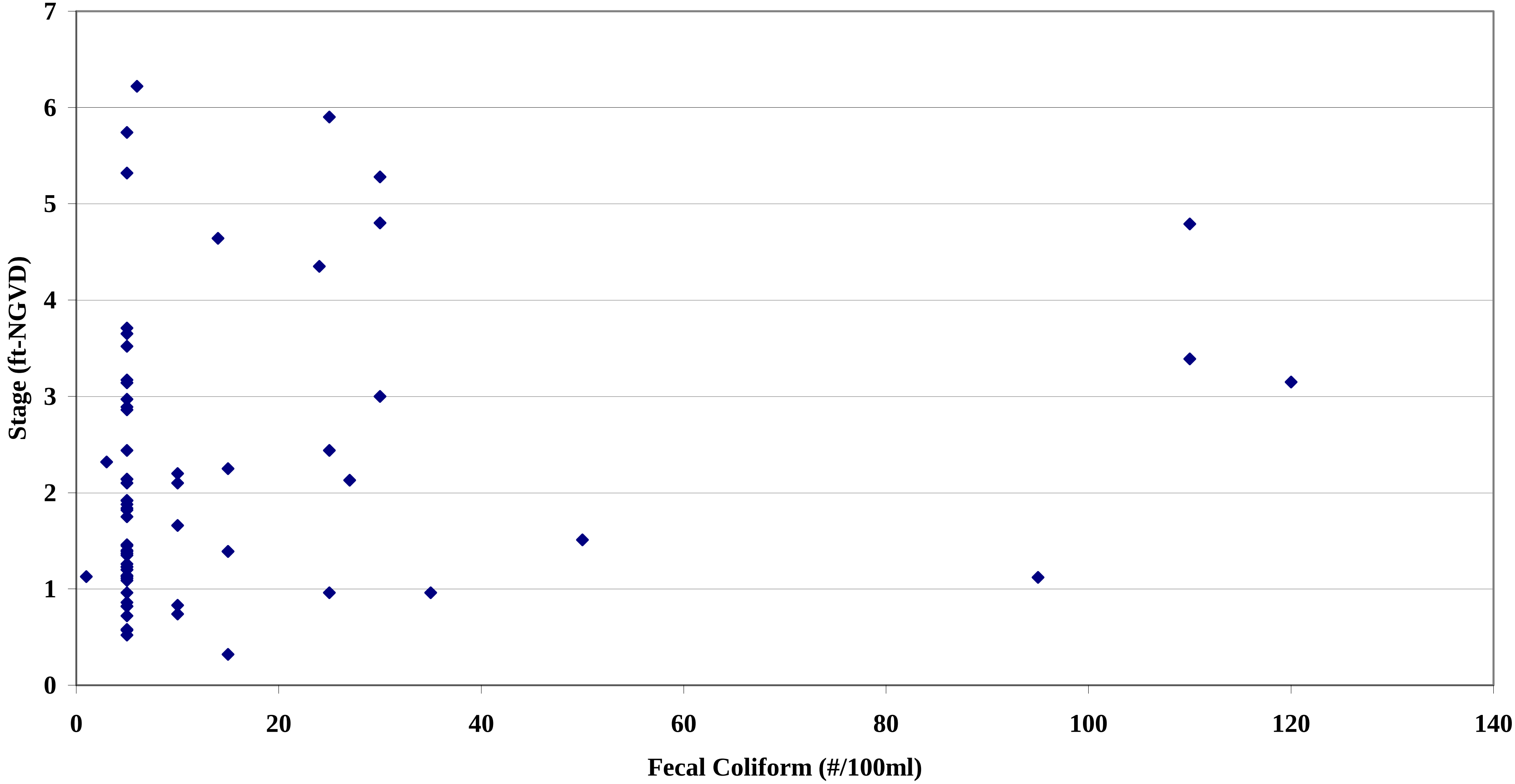
Source: ECT, 2006.

Figure D-9. Dissolved Oxygen vs. Stage
(LMAC, 1991-2005)



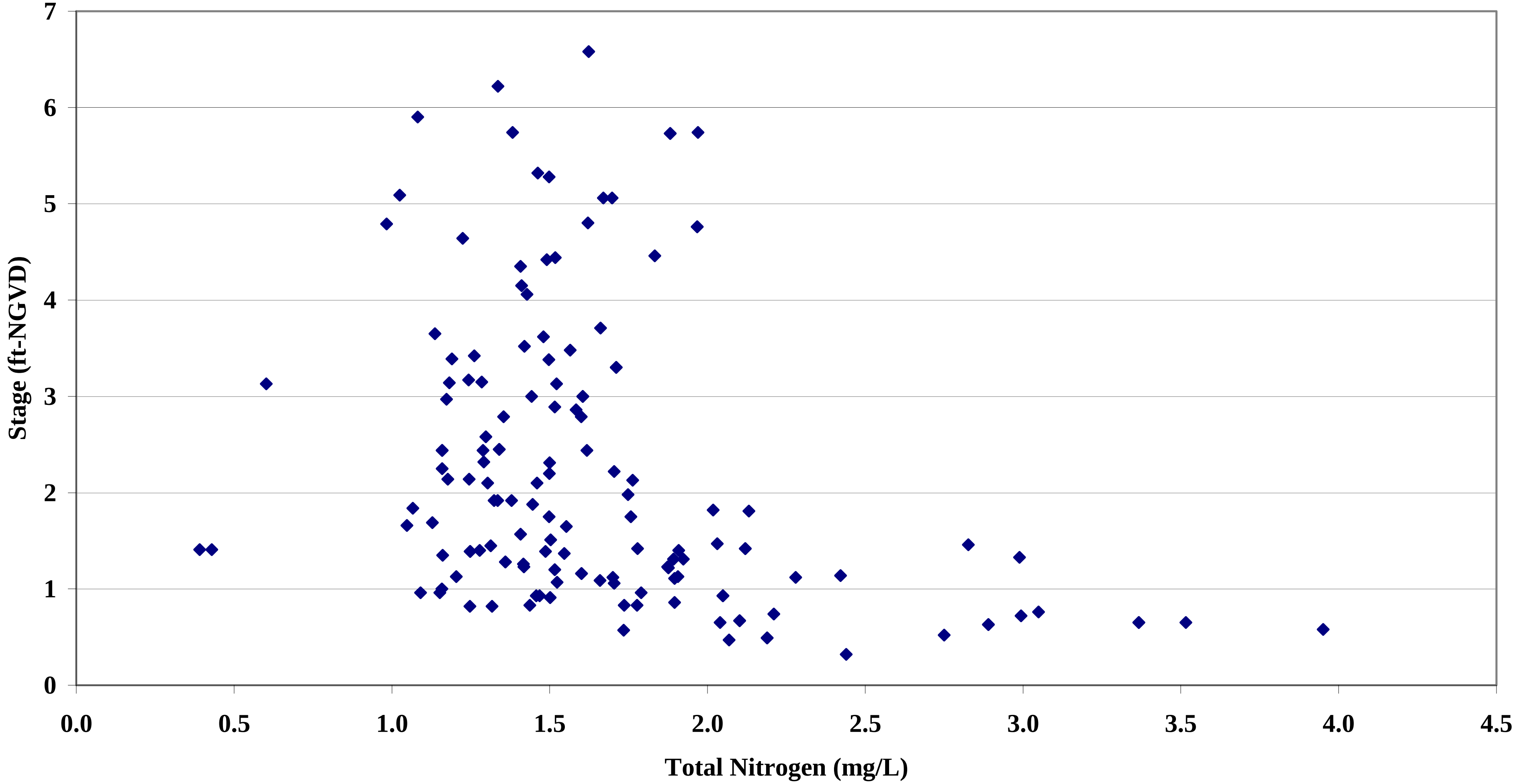
Source: ECT, 2006.

Figure D-10. Fecal Coliform vs. Stage
(LMAC, 1991-2005)



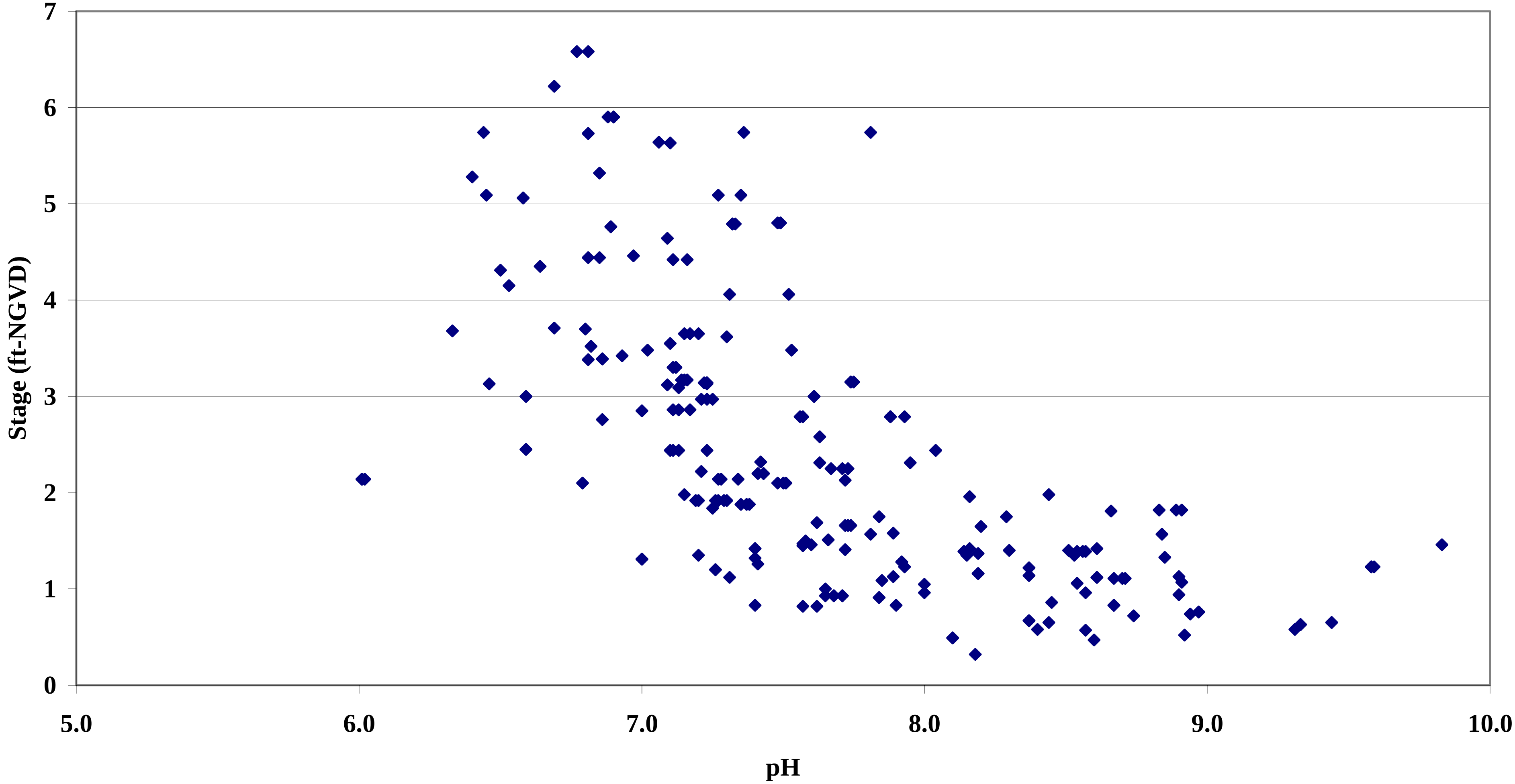
Source: ECT, 2006.

Figure D-11. Total Nitrogen vs. Stage
(LMAC, 1991-2005)



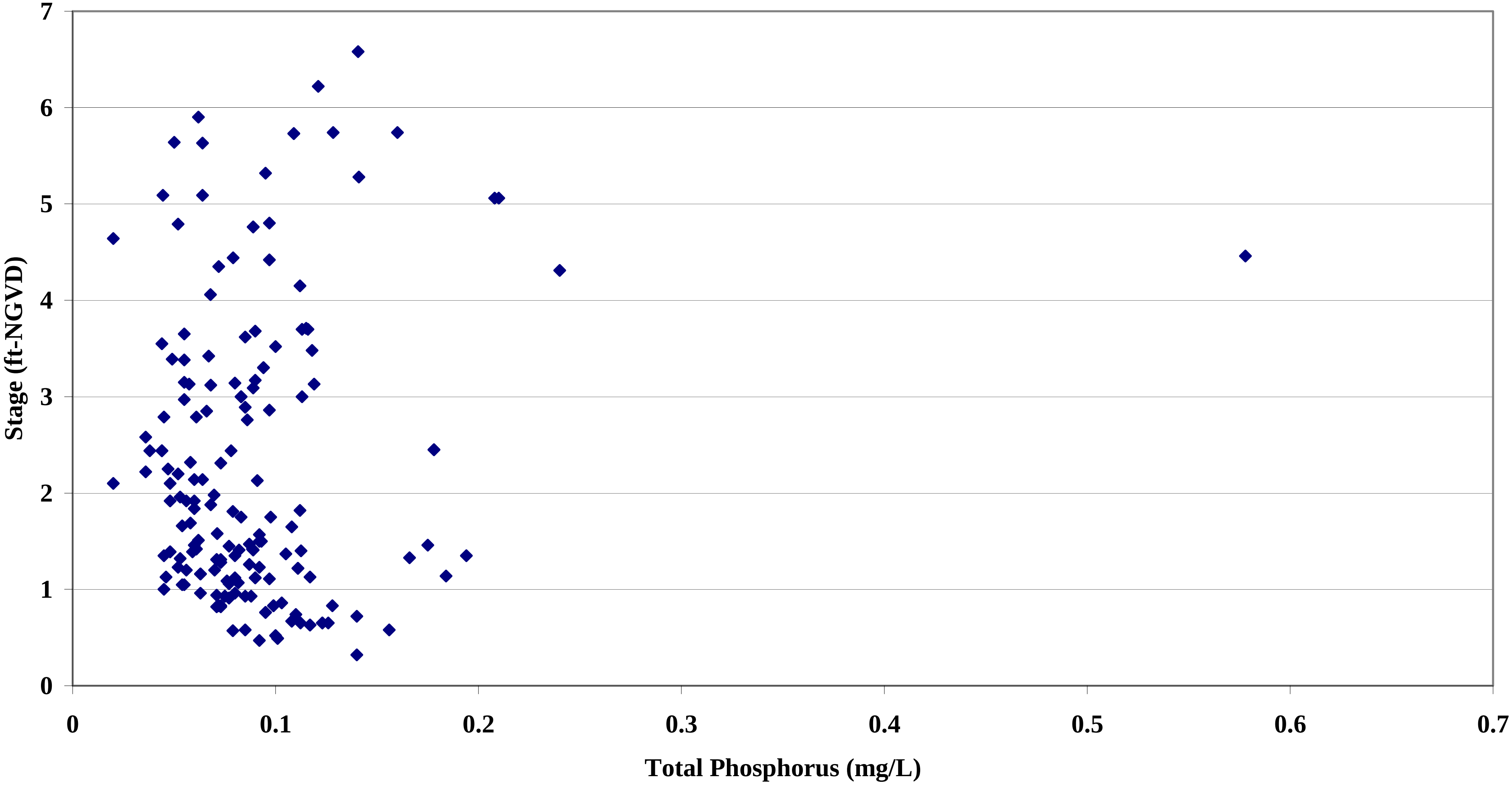
Source: ECT, 2006.

Figure D-12. pH vs. Stage
(LMAC Data, 1991-2005)



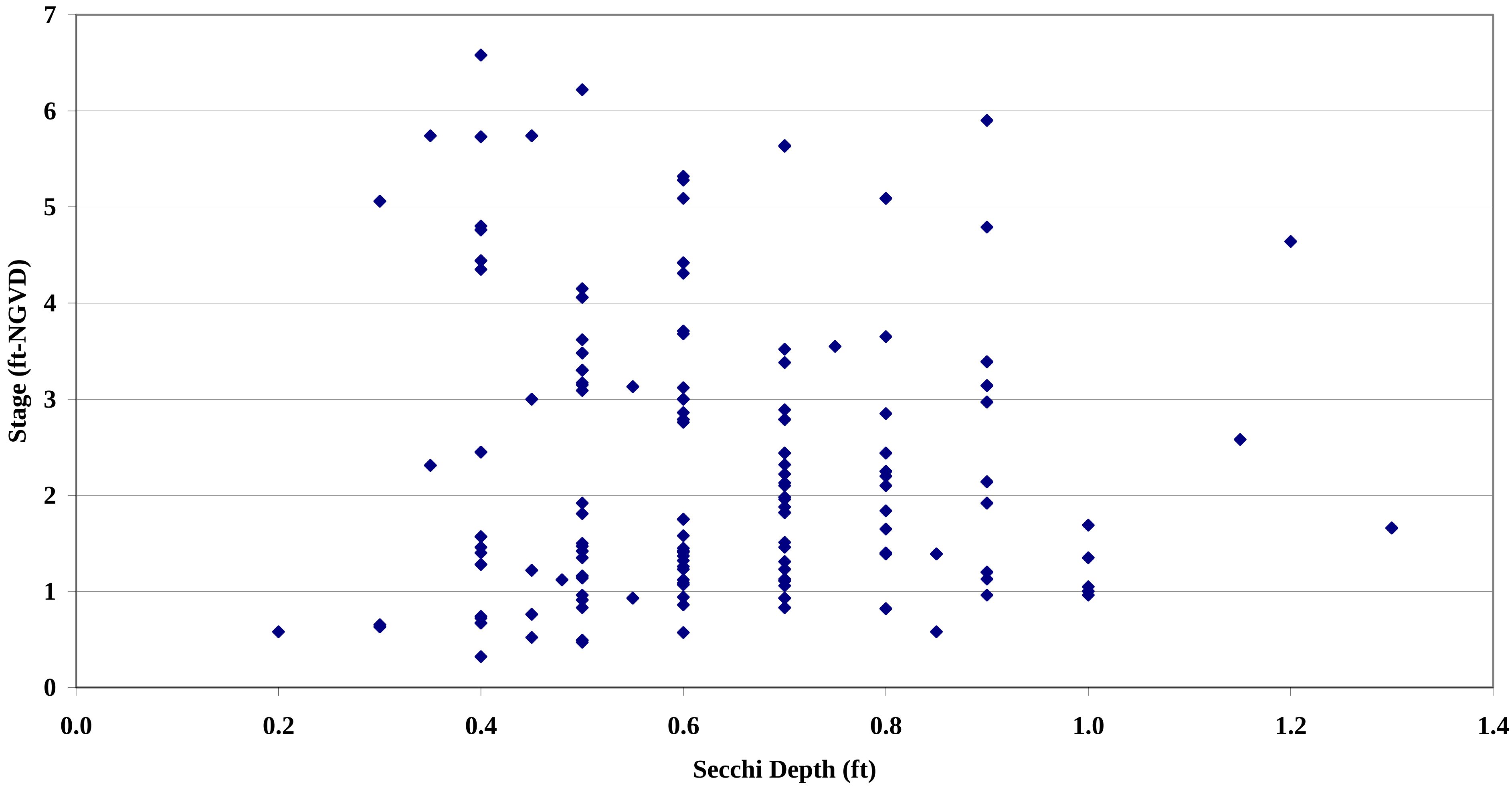
Source: ECT, 2006.

Figure D-13. Total Phosphorus vs. Stage
(LMAC, 1991-2005)



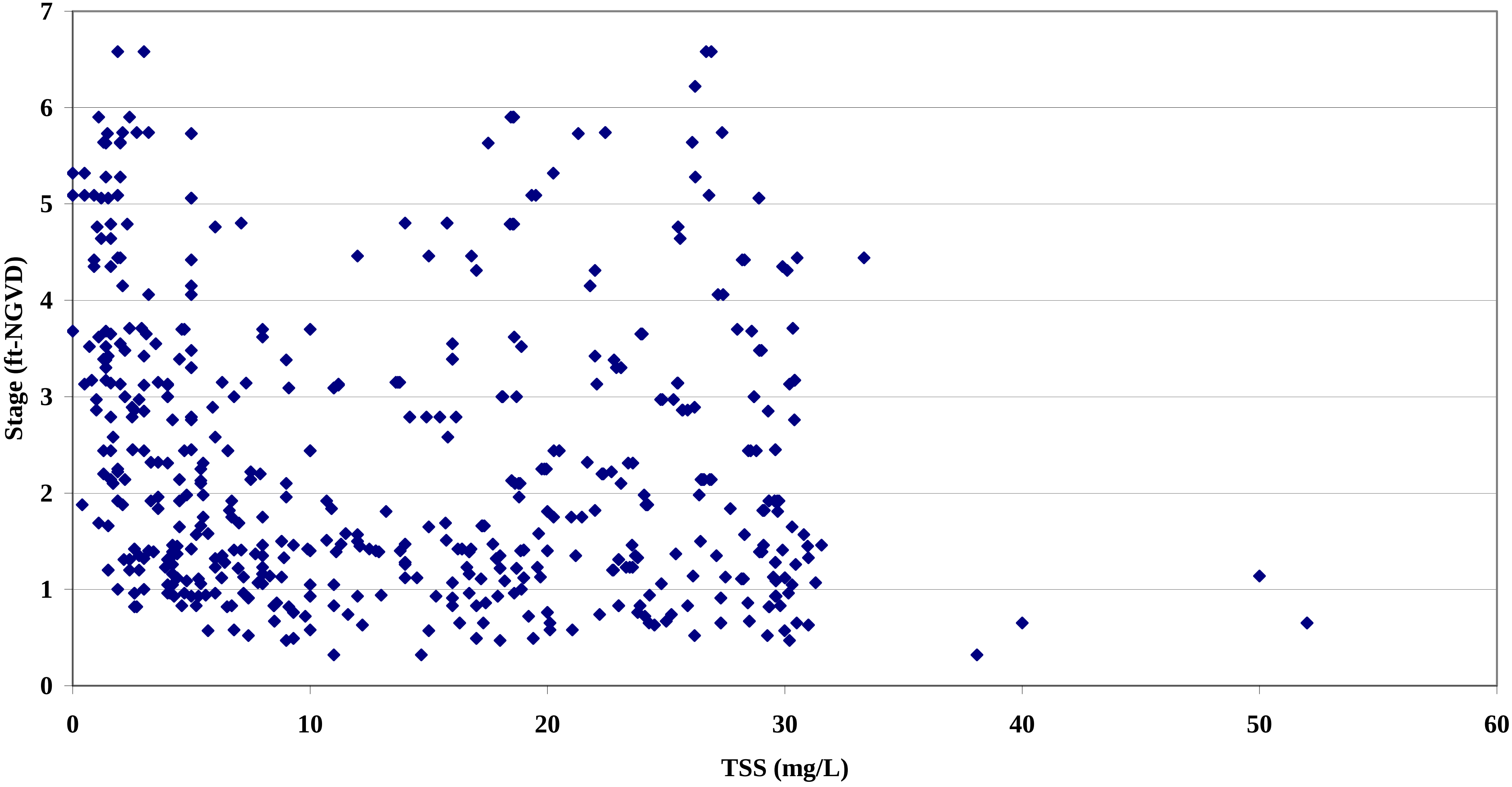
Source: ECT, 2006.

Figure D-14. Secchi Depth vs. Stage
(LMAC, 1991-2005)



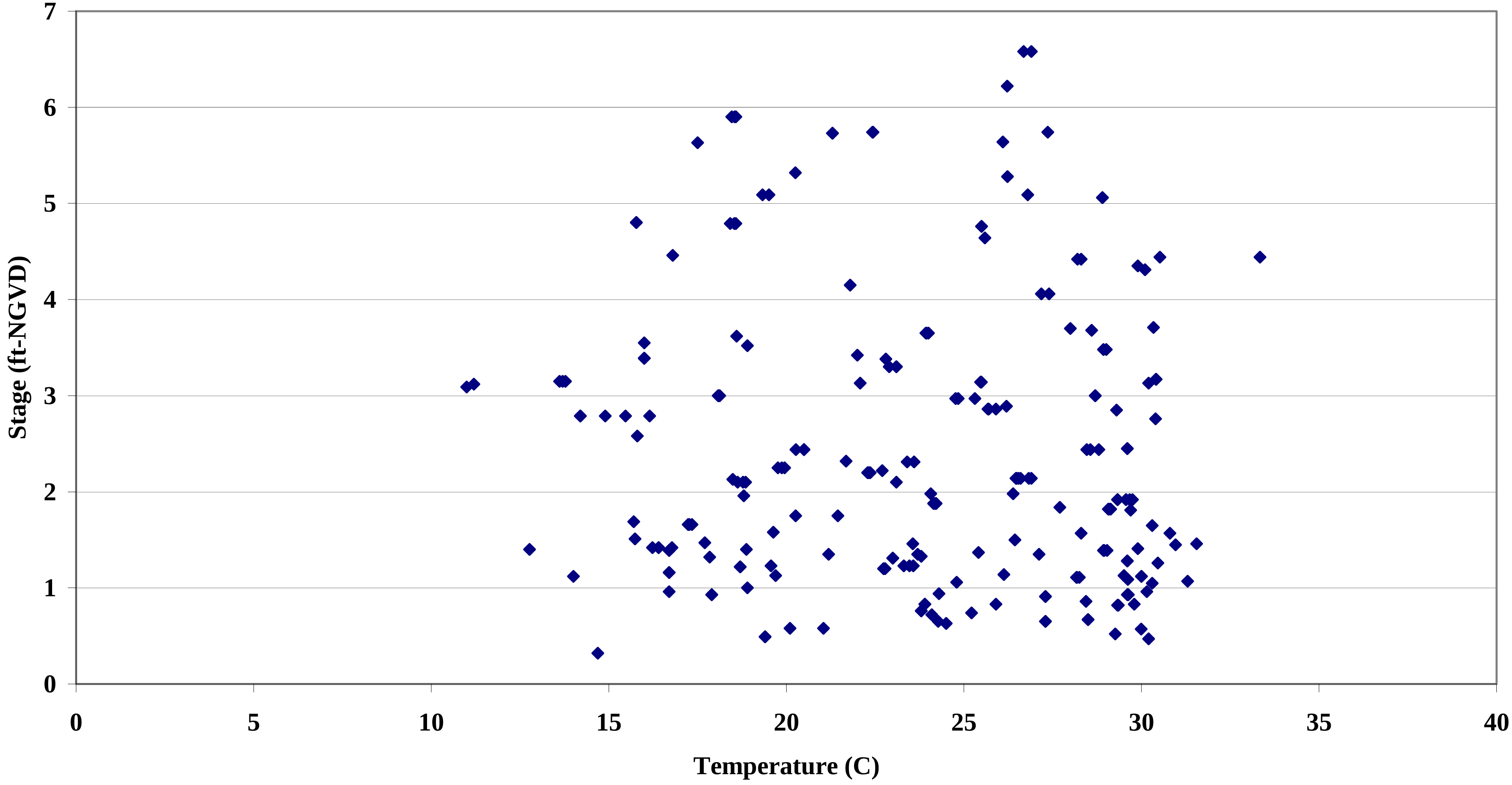
Source: ECT, 2006.

Figure D-15. Total Suspended Solids vs. Stage
(LMAC, 1991-2005)



Source: ECT, 2006.

Figure D-16. Temperature vs. Stage
(LMAC, 1991-2005)



Source: ECT, 2006.