St. Johns River
Water Supply Impact Study

February 14, 2012

St. Johns River Water Management District

floridaswater.com

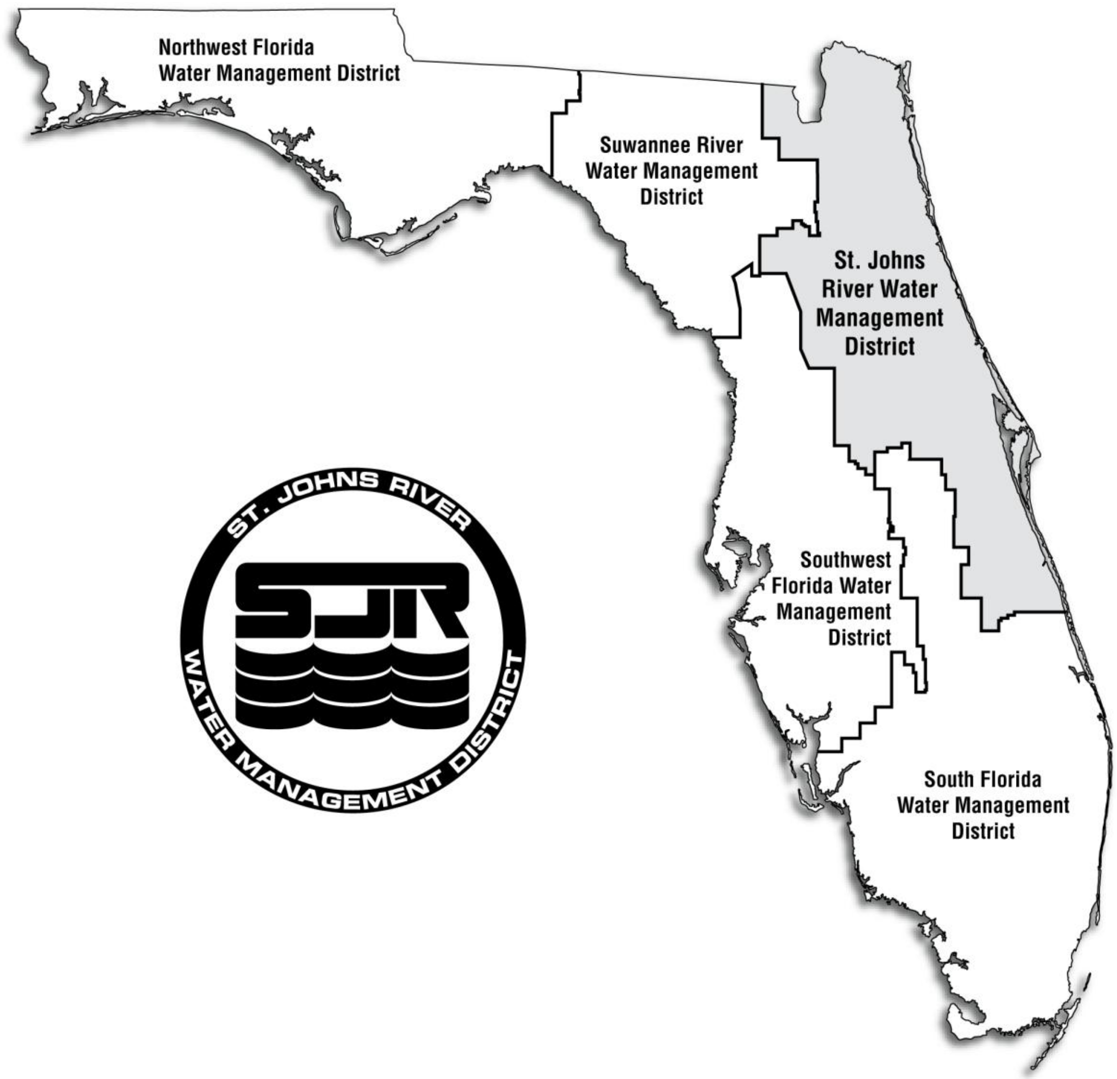
TECHNICAL PUBLICATION SJ2012-1

ST. JOHNS RIVER WATER SUPPLY IMPACT STUDY

Editors:

Edgar F. Lowe, Ph.D
Lawrence E. Battoe, Ph.D.
Hal Wilkening, P.E.
Michael Cullum,P.E.
Tom Bartol, P.E

St. Johns River Water Management District
Palatka, Florida
2012



The St. Johns River Water Management District was created in 1972 by passage of the Florida Water Resources Act, which created five regional water management districts. The St. Johns District includes all or part of 18 counties in northeast and east-central Florida. Its mission is to preserve and manage the region's water resources, focusing on core missions of water supply, flood protection, water quality and natural systems protection and improvement. In its daily operations, the District conducts research, collects data, manages land, restores and protects water above and below the ground, and preserves natural areas.

This document is published to disseminate information collected by the District in pursuit of its mission. Electronic copies are available at *floridaswater.com/technicalreports* or by calling the District at the number below.

Scientific Reference Center
St. Johns River Water Management District
4049 Reid Street/P.O. Box 1429
Palatka, FL 32178-1429 (32177 for street deliveries)
(386) 329-450

CHAPTER AUTHORS

Chapter 1.
Executive Summary
Edgar F. Lowe, Ph.D
Hal Wilkening, P.E.
Michael Cullum,P.E.
Tom Bartol, P.E.

Chapter 2.
Comprehensive Integrated Assessment
Edgar Lowe, Ph.D.
Larry Battoe, Ph.D.
Pete Sucsy, Ph.D.
Dean Dobberfuhl, Ph.D.
Michael Cullum, M.E., P.E.
Tim Cera, M.E., P.E.
John Higman, M.S.
Mike Coveney, Ph.D.
Donna Curtis B.S.
Lawrence Keenan, Ph.D.
Palmer Kinser, B.S.
Robert Mattson, M.S.
Steve Miller, M.S.

Chapter 3.
Watershed Hydrology
Tim Cera, P.E.
Dale Smith, P.E.
Michael G. Cullum, P.E.
Marc Adkins, P.E.
Joseph Amoah, Ph.D., P.E.
David Clapp
Robert Freeman, P.E.
Matt Hafner
Xiaoqing (Shaw) Huang, Ph.D.
Yanbing Jia, Ph.D., P.E.
Tom Jobes
Liang-Tsi Maria Mao, Ph.D., P.E.

Chapter 4.
Groundwater Hydrology
Getachew Belaineh, Ph.D.
Joseph Stewart, P.E.
Peter Sucsy, Ph.D.
Louis H. Motz, Ph.D., P.E.
Kijin Park, Ph.D.
Shahrokh Rouhani, Ph.D., P.E.
Michael Cullum, P.E.

Chapter 5.
River Hydrodynamics Calibration
Peter Sucsy, Ph.D.
Ed Carter
David Christian, P.E.
Michael Cullum, P.E.
Kijin Park, Ph.D.
Joseph Stewart, P.E.
Yanfeng Zhang, Ph.D., P.E.

Chapter 6.
River Hydrodynamics Results
Peter Sucsy, Ph.D.
Kijin Park, Ph.D.
Getachew Belaineh, Ph.D., P.H.
Ed Carter
David Christian, P.E.
Michael Cullum, P.E.
Joseph Stewart, P.E.
Yanfeng Zhang, Ph.D., P.E.

Chapter 7.
Biogeochemistry
Lawrence W. Keenan, Ph.D.
Edgar F. Lowe, Ph.D.
Ed J. Dunne, Ph.D.
Angelique M. K. Bochnak, Ph.D.
K. Ramesh Reddy, Ph.D.
Alan L. Wright, Ph.D.
Jian Di

Chapter 8.
Plankton
Michael F. Coveney
John C. Hendrickson
Erich R. Marzolf
Rolland S. Fulton

Jian J. Di
Clifford P. Neubauer
Dean R. Dobberfuhl
Greeneville B. Hall
Hans W. Paerl
Edward J. Phlips

Chapter 9.
Submersed Aquatic Vegetation
Dean Dobberfuhl, Ph.D.
Bob Chamberlain
Sonny Hall, Ph.D.
Chuck Jacoby, Ph.D.
Rob Mattson
Lori Morris
Jodi Slater
Ken Moore, Ph.D.
Bob Virnstein, Ph.D.

Chapter 10.
Wetland Vegetation
Palmer Kinser
Sandra Fox
Lawrence Keenan, Ph.D.
Aisa Ceric
Fay Baird
Peter Sucsy, Ph.D.
William Wise, Ph.D., P.E.
Clay Montague, Ph.D.

Chapter 11.
Benthic Macroinvertebrates
Robert A. Mattson, CEP, CSE
Kenneth W. Cummins, Ph.D.
Richard W. Merritt, Ph.D.
Paul A. Montagna, Ph.D.
Terry Palmer
Jane Mace
Jodi Slater
Charles Jacoby, Ph.D.

Chapter 12.
Fish
Steven J. Miller
Ronald E. Brockmeyer, Jr.
Wendy Tweedale
Jonathan Shenker, Ph.D.
Lawrence W. Keenan, Ph.D.
Susan Connors
Edgar F. Lowe, Ph.D.
Jan Miller
Charles Jacoby, Ph.D.
Lori McCloud

Chapter 13.
Floodplain Wildlife
Donna Curtis

STAFF CONTRIBUTORS

Marc Adkins
Joseph Amoah
Fay Baird
Tom Bartol
Larry Battoe
Getachew Belaineh
Angelique Bochnak
Ronald Brockmeyer
Ed Carter
Tim Cera
Aisa Ceric
Robert Chamberlain
David Christian
David Clapp
Susan Connors
Michael Coveney
Michael Cullum
Donna Curtis
Jian Di
Dean Dobberfuhl
Edmond Dunne
Sandra Fox
Robert Freeman
Matt Hafner
Greenville Hall
John Hendrickson
John Higman
Xiaoqing Huang
Charles Jacoby
Yanbing Jia
Tom Jobes
Lawrence Keenan
Palmer Kinser
Edgar Lowe
Jane Mace
Maria Mao
Robert Mattson
Lori McCloud
Jan Miller
Steven J. Miller
Kijin Park
Jodi Slater
Dale Smith
Joseph Stewart
Peter Sucsy
Wendy Tweedale
Hal Wilkening
Yanfeng Zhang

CONSULTANTS

Kenneth W. Cummins, Ph.D., Sr. Advisory Scientist and Adjunct Professor, California Cooperative Fishery Research Unit, Fisheries Biology Department, Humboldt State University, Arcata, Calif.

Richard W. Merritt, Professor and Chair, Department of Entomology, Michigan State University, East Lansing, Mich.

Paul A. Montagna, Professor and Endowed Chair for Ecosystems Studies and Modeling, Harte Research Institute for Gulf of Mexico Studies, Texas A&M University, Corpus Christi, Tex.

Clay Montague, Associate Professor Emeritus, Howard T. Odum Center for Wetlands, Department of Environmental Engineering Sciences, University of Florida, Gainesville, Fla.

Ken Moore, Professor of Marine Science, Virginia Institute of Marine Science, School of Marine Science, The College of William and Mary, Gloucester Point, Va.

Hans Paerl, William R. Kenan Professor of Marine and Environmental Sciences, Institute of Marine Sciences, University of North Carolina at Chapel Hill, Morehead City, N.C.

Terry Palmer, Research Associate, Harte Research Institute for Gulf of Mexico Studies, Texas A&M University, Corpus Christi, Tex.

Ed Phlips, Professor, Department of Fisheries and Aquatic Sciences, University of Florida, Gainesville, Fla.

K. Ramesh Reddy, Professor and Chair, Department of Soil and Water Science, University of Florida, Gainesville, Fla.

Shahrokh Rouhani, Ph.D., Newfields, Inc., Atlanta, Ga.

Jonathan Shenker, Director, Sportfish Research Institute, Department of Biological Sciences, Florida Institute of Technology, Melbourne, Fla.

Robert Virnstein, Ph.D., Seagrass Ecosystem Analysis, East Palatka, Fla.

William Wise, Associate Professor, Department of Environmental Engineering, University of Florida, Gainesville, Fla.

Alan L. Wright, Assistant Professor, University of Florida Everglades Research and Education Center, Belle Glade, Fla.

NATIONAL RESEARCH COUNCIL (NRC) COMMITTEE REVIEWERS

Patrick L. Brezonik, Chair, University of Minnesota, Minneapolis

M. Siobhan Fennessy, Kenyon College, Gambier, Ohio

Ben R. Hodges, University of Texas, Austin

James R. Karr, University of Washington, Seattle

Mark S. Peterson, University of Southern Mississippi, Ocean Springs

James L. Pinckney, University of South Carolina, Columbia

Jorge I. Restrepo, Florida Atlantic University, Boca Raton

Roland C. Steiner, Washington Suburban Sanitary Commission, Laurel Maryland

J. Court Stevenson, University of Maryland, Cambridge

NRC STAFF

Laura J. Ehlers, Study Director

Stephanie E. Johnson, Interim Study Director (February 2009–June 2009)

Michael J. Stoever, Project Assistant

CHAPTER 1. EXECUTIVE SUMMARY

by

Edgar Lowe, Ph.D.
Hal Wilkening, P.E.
Michael Cullum, P.E.
Tom Bartol, P.E.

St. Johns River Water Management District
Palatka, Florida
2012

LIST OF FIGURES AND TABLES

FIGURES

TABLES

This page intentionally left blank.

1. BACKGROUND

Florida's outstanding water resources are among its most valuable assets. The state's average annual rainfall of 53 inches is much higher than the national average of 30 inches and is exceeded within the United States only by Alabama (Henry, 1998). Florida's groundwater resources exceed those of any other state, with an estimated volume greater than a thousand trillion gallons (10^{15} gallons) of freshwater — about one-fifth the volume of water in the five Great Lakes (Berndt et al., 1998). Due to its watery wealth, Florida is exceptionally rich in aquatic and wetland ecosystems, including approximately 7,800 lakes (Brenner et al., 1990), 1,700 rivers and streams (Nordlie, 1990), vast areas of wetland (Ewel, 1990), more than 700 artesian springs (Scott et al., 2004), and extensive coastal lagoons and estuaries. These ecosystems provide valuable goods and services that support the state's economy and enhance the quality of life for all Florida residents.

An overarching goal of Florida's water policy is to realize the beneficial use of water resources, ensuring their sustainability and providing water for all reasonable-beneficial uses and for natural systems (Figure 1–1). To achieve this goal, the direct benefits of human water uses must be balanced against the indirect benefits provided by natural systems. Striking an appropriate balance requires development of a sound scientific understanding of the water requirements of natural systems. This is one of the primary roles of scientific research in water management.

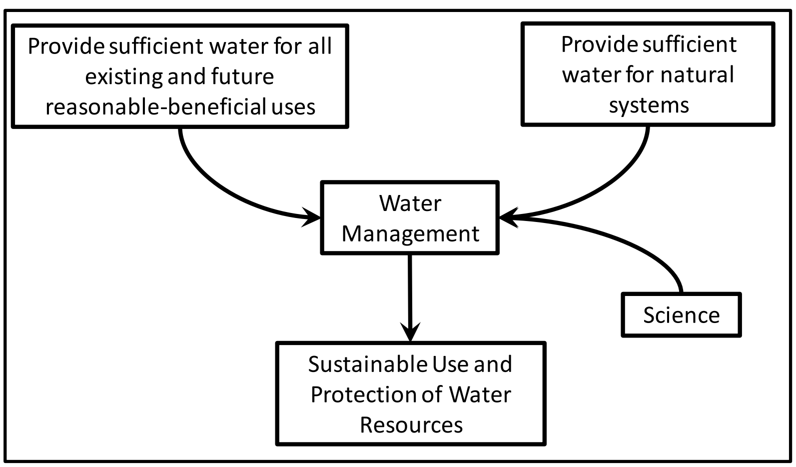


Figure 1–1. An overarching goal of Florida's water policy is to provide sufficient water for all reasonable-beneficial uses and for natural systems. Sound science is required to determine the water requirements of natural systems.

2. Reason for the Water Supply Impact Study (WSIS)

The South Florida Water Management District (SFWMD), Southwest Florida Water Management District (SWFWMD), and St. Johns River Water Management District (SJRWMD) jointly recognized the potential for harm to water resources in central Florida associated with continued reliance on groundwater to meet the growing need of human water consumption. In 2007, all of the districts adopted Consumptive Use Permit rule provisions that limit the amount of water that can be obtained in a permit to the quantity needed to supply projected water demand in 2013, in order to prevent harm to water resources and natural systems of the region. Further, the three districts agreed that alternative water supplies (AWS) would be needed to meet water demands above the 2013 level. Within SJRWMD, two potential alternative sources of water are the St. Johns River and its major tributary, the Ocklawaha River. Earlier work indicated that the St. Johns River could provide as much as 155 million gallons per day (mgd) without suffering ecological harm (Robison, 2004). In addition, as much as 107 mgd could be available from the Ocklawaha River (Hall, 2005).

To ensure a sound scientific basis for future decisions regarding use of these surface water supplies, the SJRWMD Governing Board initiated the Water Supply Impact Study (WSIS) in 2007. The goal of the WSIS was to provide a comprehensive and scientifically rigorous analysis of the potential environmental effects to the St. Johns River associated with annual average surface water withdrawals as high as 262 mgd (155 mgd from the St. Johns River and 107 mgd from the Ocklawaha River).

3. Staffing and Scope of WSIS

The WSIS staff consisted of 81 scientists and engineers, including 24 scientists from outside SJRWMD, many of whom have international standing in their areas of expertise. To ensure the scientific integrity of the work, the Board approved a multiyear contract with the National Academies, providing for external peer review of the work by the National Research Council (NRC).

The scope of the study was broad. To address the diversity of potential environmental effects, project personnel were organized into eight work groups: (1) hydrologic and hydrodynamic modeling, (2) biogeochemistry, (3) plankton, (4) submersed aquatic vegetation, (5) wetland vegetation, (6) benthic macroinvertebrates, (7) fish, and (8) wetland wildlife. These groups covered the complete riverine ecosystem from the mouth to the headwaters, from the channel to the upland border of the floodplain, and from bottom habitats through the water column. The study did not evaluate potential in-stream effects on the Ocklawaha River due to a separate project (a minimum flows and levels analysis) that would consider these.

For the WSIS, we evaluated the effects of water withdrawals. Other factors such as increased pollutant loadings and channel dredging can also affect ecological attributes. Other programs, such as the development of Total Maximum Daily Loads for pollutants or the U.S. Army Corps of Engineers environmental analysis of channel dredging effects will address these other factors.

4. Study Methods

4.1 Data and Models

The WSIS work groups used extensive data sets on the hydrology, water quality, and biology of the St. Johns River in developing predictive computer models. These models simulated the effects of withdrawing water from the St. Johns River and from the Ocklawaha River. The modeled withdrawals were from four locations (Figure 1–2). The work groups assessed the effects of withdrawals by quantifying the changes from a baseline condition (1995 condition of the watershed; rainfall and evapotranspiration as from 1995 through 2005) for key aspects of hydrology and water quality. Changes in these factors were then used as inputs to models that quantified the consequent changes in key ecological attributes.

4.2 Scenarios

The work groups evaluated many different combinations of water withdrawals rates, land use conditions, sea level, and status of regional water projects in the upper reaches of the St. Johns River. These scenarios were used to elucidate the interactions among the effects of water withdrawals and the effects of changes in watershed conditions and sea level. Three scenarios had special significance because they represented the conditions that could exist when water withdrawals occur. These forecast scenarios modeled the effects of future land use conditions (estimated 2030 land use), future sea level (estimated 2030 sea level = 1995 sea level plus 14 cm), and completion of the Upper St. Johns River Basin regional water projects. The forecast scenarios approximate the conditions that could exist when water withdrawals feasibly could occur (Table 1-1).

Table 1–1. Baseline and forecast scenarios. The forecast scenarios represent the conditions that would exist when additional withdrawals could feasibly occur.

Scenario	Withdrawal Rate (mgd)	Land Use Condition	USJRB Projects Condition	Sea Level
Baseline	0	1995	1995, incomplete	1995
Forecast	77.5	2030	Completed	95+14 cm
Forecast	155	2030	Completed	95+14 cm
Forecast	262	2030	Completed	95 +14 cm

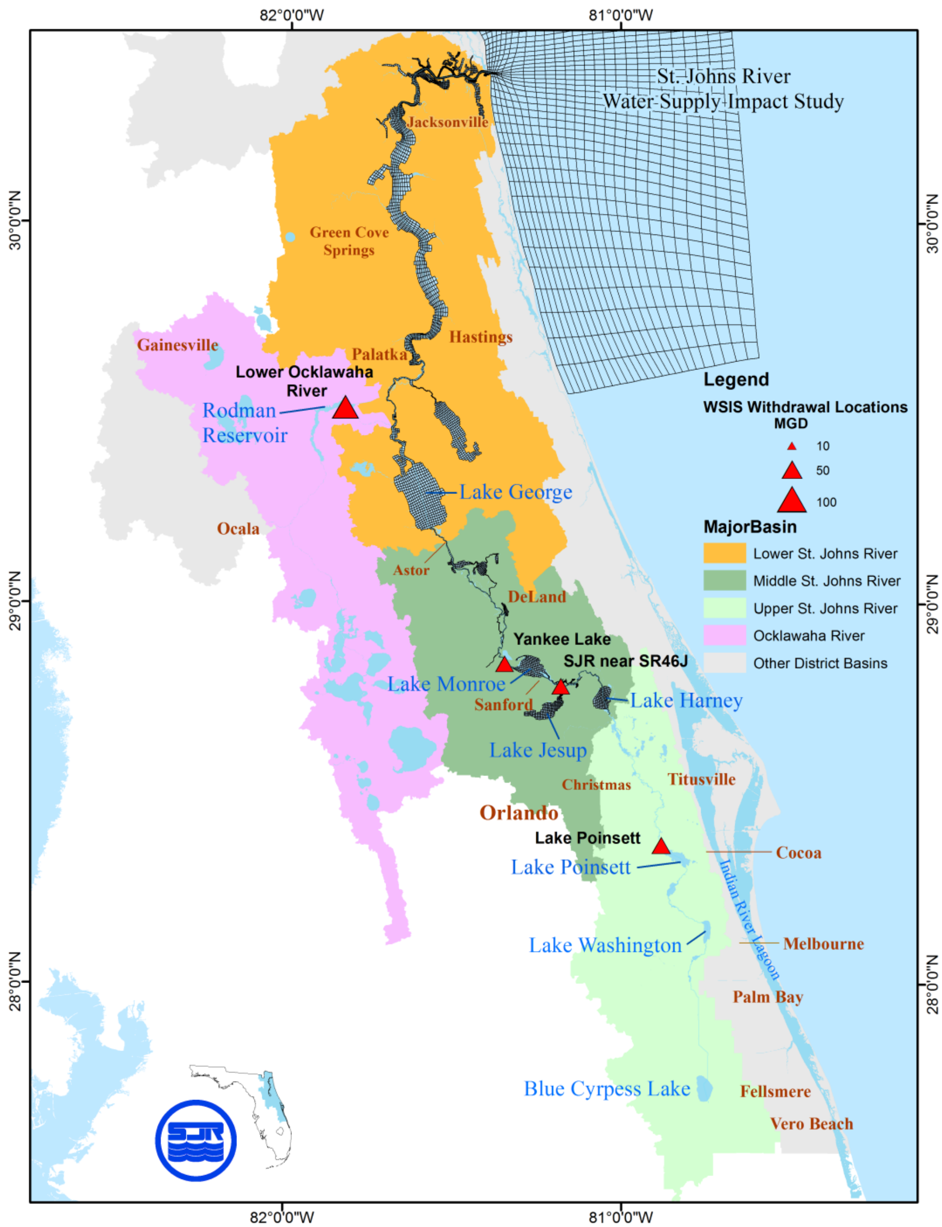


Figure 1–2. Modeled water withdrawal locations.

The environmental work groups evaluated the importance of the environmental effects of withdrawals by using these five categories: (1) extreme, (2) major, (3) moderate, (4) minor, and (5) negligible (Table 1–2). Evaluations considered the strength, persistence, and diversity (i.e., how many environmental attributes would be affected) of the effect.

Because the river is not ecologically uniform, we divided the river into nine segments, based on geomorphology, hydrology, hydrodynamics, water quality, soils, and floodplain communities (Figure 1–3). The environmental work groups considered the potential for effects in each of these segments.

Table 1–2. Scale for evaluation of the level of ecological importance of an effect.

Level of Effect	Criteria
Extreme	Effect is persistent, strong, and highly diverse; significant change in natural resource values.
Major	Effect is persistent and strong, but not highly diverse; significant change in natural resource values.
Moderate	Effect is ephemeral or weak or is limited to minor species, no significant change in natural resource values.
Minor	Effect is ephemeral and weak; no significant change in any ecosystem attribute.
Negligible	No appreciable change in any ecosystem attribute.

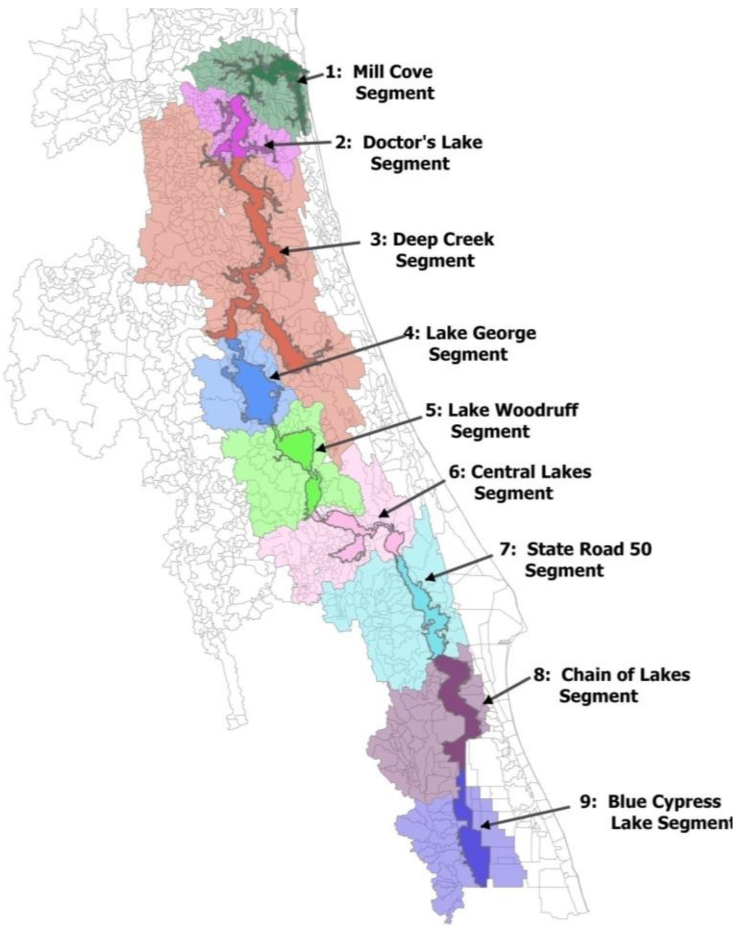


Figure 1–3. The river segments used for the WSIS. Segment 9 and the southern portion of segment 8 (south of the Lake Washington weir) are hydrologically isolated from the withdrawal sites and, consequently, were not part of the analysis.

5. Major Findings

Under The Most Likely Scenario Of Surface Water Withdrawals, An Appreciable Quantity Of Surface Water May Be Safely Withdrawn From The St. Johns River With Minimal To Negligible Environmental Effects.

5.1.1 Minor and Negligible Effects

For three ecological components; plankton, submersed aquatic vegetation, and the biogeochemistry of organic wetland soils; there is little potential for effects from water withdrawals. Under all of the conditions modeled, effects for these groups would be negligible to minor for all areas of the river.

5.1.2 Moderate Effects

In the scenarios with conditions that could exist when withdrawals occur, moderate environmental effects would occur only with the highest level of water withdrawal modeled. Withdrawal at the highest rate modeled (262 mgd; 107 mgd from the Ocklawaha River and 155 mgd from the St. Johns River) would lead to moderate effects in the estuary, river segments 1 and 2. The effects would alter the spatial distributions of wetland vegetation and the relative abundances and distributions of fish and floodplain wildlife species. At lower rates of water withdrawal (155 mgd and 77.5 mgd), all effects on the ecological attributes of the entire river that we examined would be negligible or minor.

The WSIS work groups also tested extreme conditions represented by unrealistic scenarios with 1995 sea level and 1995 land uses. Moderate effects would be more widespread under such conditions, but even under these extreme scenarios, no major effects would occur if entrainment and impingement were avoided through design, location, and operation of intakes.

5.1.3 Major Effects

For river herring populations in the upper reach of the river, there is the potential for major effects from entrainment and impingement of planktonic life stages. The magnitude of these effects would vary in proportion to the rate of water withdrawal and the densities of planktonic life stages of river herrings in the source water. Entrainment and impingement of planktonic life stages could be avoided, however, through proper location, design, and operation of water intake structures.

Sea level rise, land use changes, and completion of regional water projects in the Upper St. Johns River Basin project would reduce or eliminate the effects of water withdrawals.

The effects of sea level rise, additional runoff resulting from land development associated with future land use, and completion of several Upper St. Johns River Basin regional restoration projects would serve to offset water level and flow reductions that may be associated with surface water withdrawals (Figure 1–4). These ameliorating effects either are in progress or anticipated to occur concurrently with the need for future surface water withdrawals.

Intensification of land uses would increase runoff and river flows. Sea level rise will cause saline water to move farther upstream and will raise water levels in the lower and middle reaches.

Completion of a major water project in the upper reaches of the river (the Upper St. Johns River Basin Project [USRBP]) will return to the river water previously diverted to coastal waters. Consequently, the USRBP will increase low flow rates, especially in the upper reaches of the river. The combined effects of these future conditions will be sufficient to override effects from the withdrawals.

The environmental sensitivity of the river to water withdrawals varies significantly along the river's length.

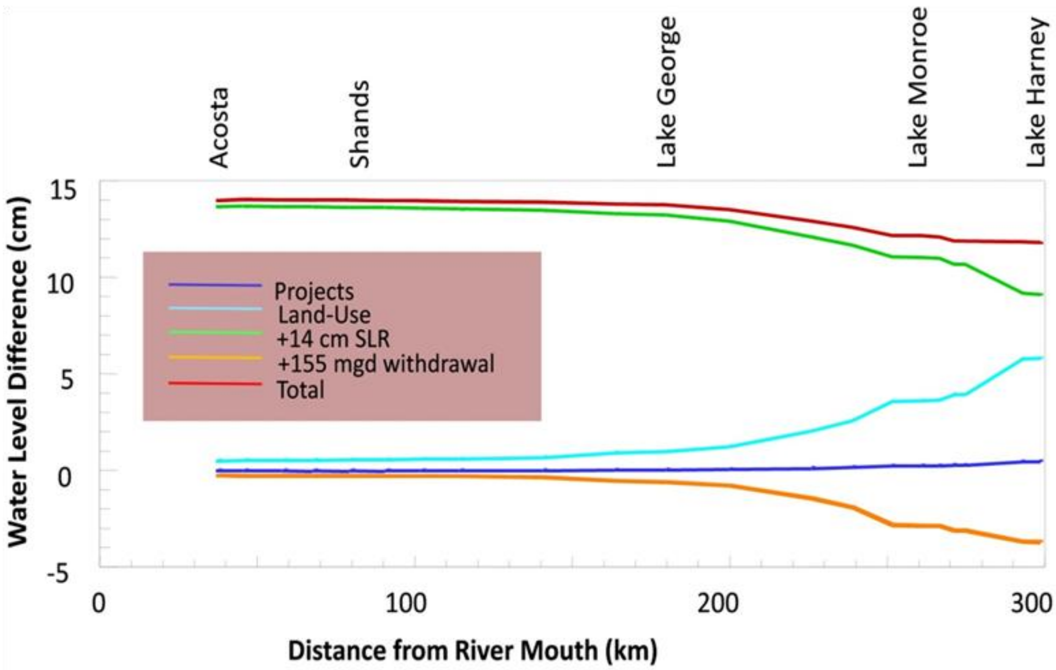


Figure 1–4. Effects of separate factors on water levels in the lower 300 km of the St. Johns River. The difference shown is the change from the baseline condition (1995–2005).

5.3.1 WATER LEVEL EFFECTS

Ecological effects caused by changes in water levels could only occur in the upper reaches of the river (Figure 1–5). Water level changes over the lower 300 km of the river (segments 1–5) would be small because in these segments, the control of water level is dominated by sea level, not discharge, when discharge is below the median discharge. Under these conditions, changes in discharge have little effect on water level. Ocean influences extend far up the river because of the river's low hydraulic slope. In addition, the river's bottom slope does not drive river discharge in this reach since bottom elevations are below mean sea level to Lake Harney (Figure 1–6). Even if there were no freshwater flow into the St. Johns River at all, the mainstem river and connected lakes of the lower and middle St. Johns River and Lake George would be inundated from ocean water.

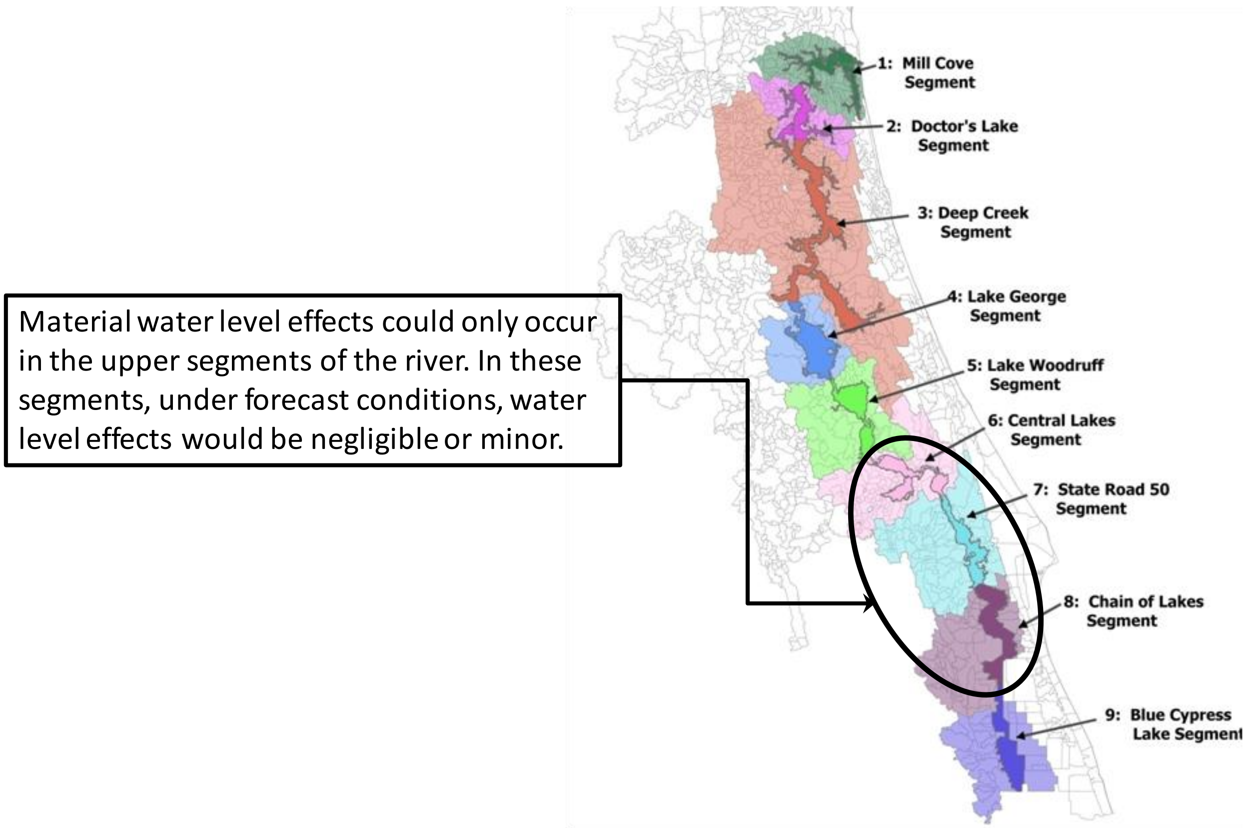


Figure 1–5. Area where ecological effects due to changes in water level could occur.

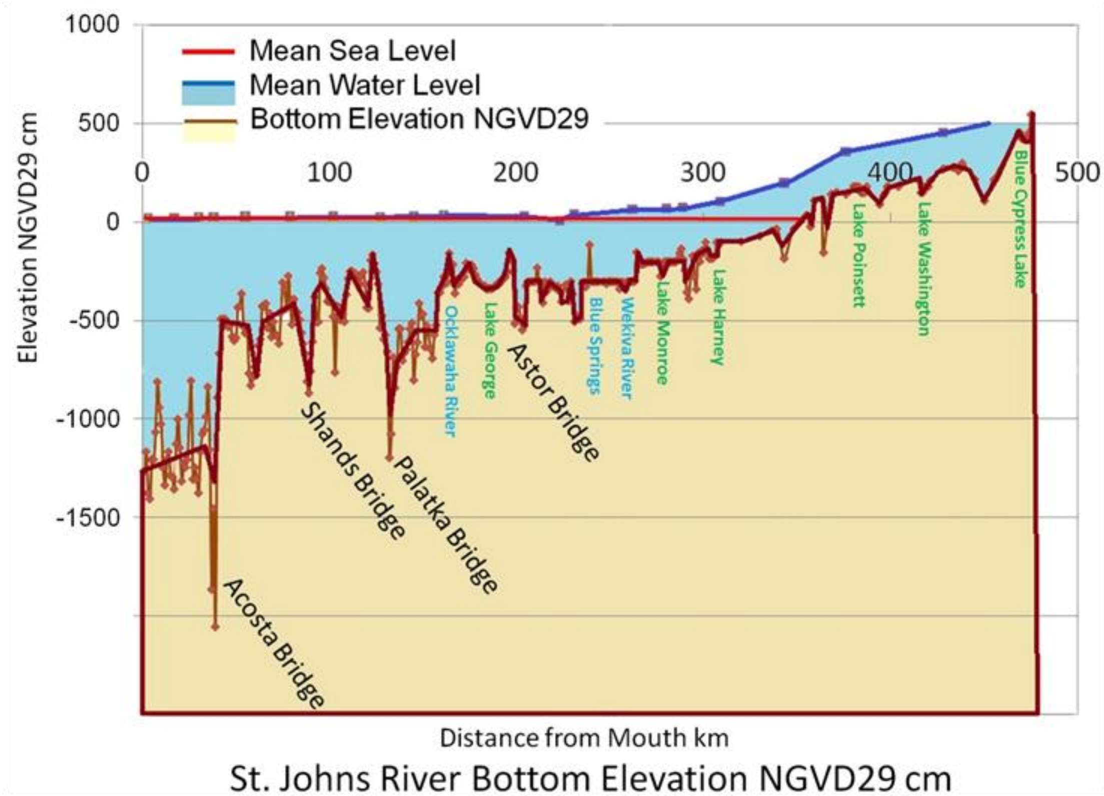


Figure 1–6. Bottom elevation of the St. Johns River, mean sea level, and mean water level.

6. CAVEATS

6.1 DISCHARGE AND SALINITY EFFECTS

Material salinity and discharge effects would be limited to the lower reaches of the river (Figures 1–7 and 1–8). Freshwater discharge is a source of dilution for ocean salinities, and the intersection of preferred salinity zones with preferred habitats can affect the relative abundance of fish species in the lower reach of the river. With the exception of the highest level of withdrawal modeled (262 mgd), however, all discharge and salinity effects would negligible or minor.

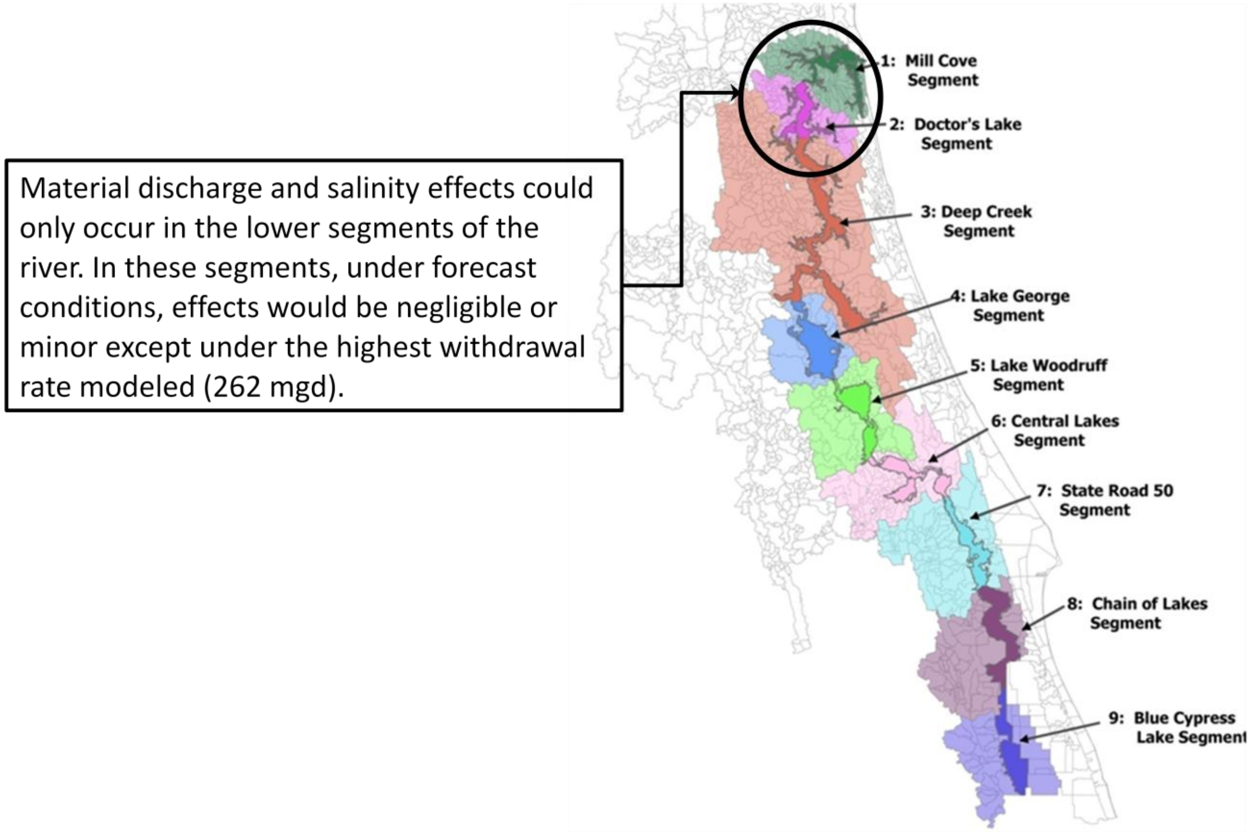


Figure 1–7. Area where ecological effects due to changes in discharge and salinity could occur.

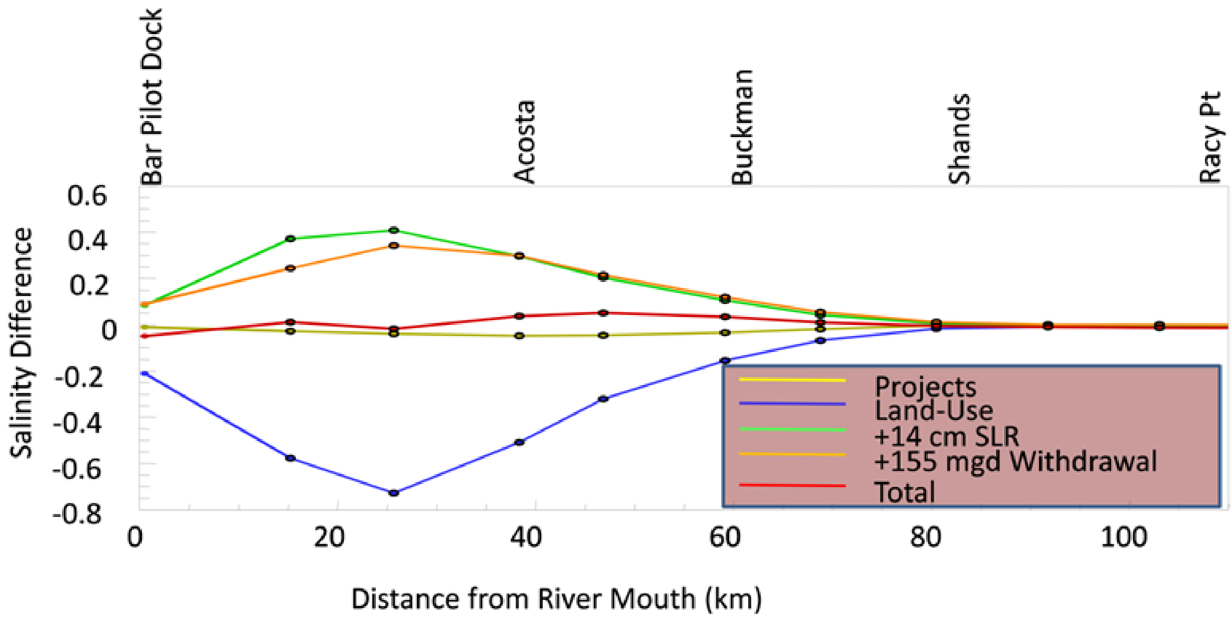


Figure 1–8. The effects of water withdrawals on salinity would become immaterial within the first 80 km of the lower reach of the river.

6.2 Residence Time

Residence time effects would be negligible or minor in all areas of the river.

6.3 Uncertainty

Each work group also assessed the scientific uncertainty associated with their findings. In scenarios where hydroecological models were required to evaluate the potential for ecological effects, the overall uncertainty included that associated with both the hydrology and hydrodynamics (H&H) models and the hydroecology (HE) models. In forecast scenarios where H&H modeling predicted an overall increase in river discharges and water levels, the uncertainty associated with potential ecological effects attributable to withdrawals is largely that uncertainty inherent in the H&H models.

6.4 SUMMARY OF LEVELS OF EFFECTS

If direct and indirect entrainment and impingement is avoided through appropriate location, design, and operation of intake structures, then none of the hydroecological effects would be more than moderate. Under forecast conditions, all hydroecological effects would be negligible or minor, with the exception of effects in the estuary (river segments 1 and 2) at the highest level of withdrawal modeled (262 mgd).

6.5 CAVEATS

These findings apply to the specific conditions considered by the WSIS. For the sake of brevity and clarity, they were expressed as if they would occur if water withdrawals begin under the modeled conditions. It should be noted however that the realized effects of a water withdrawal would depend upon the specific conditions of the withdrawal (e.g., existing land use, sea level, status of upper basin regional water projects, rate of withdrawal, location of intakes, temporal pattern of withdrawals, withdrawal constraints related to river flow, design of intake structures, etc.), which could vary significantly from those considered in the WSIS. Furthermore, there is some level of inherent scientific uncertainty associated with any scientific forecast. How closely the predicted effects match the realized effects will depend upon the veracity of the suite of predictive models.

7. Other Important Factors

7.1 Increased Surface Water Runoff

Although increases in runoff associated with the intensification of land uses would significantly reduce the effects of water withdrawals, they could increase pollutant loadings. This important factor was not evaluated by the WSIS, and this limitation was a concern raised by the National Research Council during peer review. WSIS staff agreed that the potential increase in pollutant loadings is an important consideration; however, the purpose of the WSIS was to evaluate the potential effects directly linked to surface water withdrawals. The potential effects of increased loadings due to land development will need to be addressed through other programs, such as development of Total Maximum Daily Loads and Pollutant Load Reduction Goals, and the operation of regional water projects for water quality improvements.

7.2 Channel Dredging

Deepening or widening of the navigation channel connecting the river mouth to major ports in Jacksonville could have a significant effect on salinities in the lower St. Johns River. While the channel improvement project is not the direct responsibility of SJRWMD, the U.S. Army Corps of Engineers is using the hydrodynamic models developed during the WSIS to perform a detailed potential impact analyses for the project. The data and hydroecological models developed in the WSIS can be used to evaluate the potential effects of associated changes in salinity on submersed aquatic vegetation, benthic macroinvertebrates, and fish in the estuary.

8. WSIS Applications

The WSIS significantly advanced our understanding of the hydrology, hydrodynamics, and ecology of the St. Johns River. The predictive models and scientific understanding produced by the study will enhance our ability to make sound management decisions. The primary product of the WSIS is a suite of hydrologic, hydrodynamic, and hydroecological models. These models will be used in the evaluation of specific proposals for surface water use, in the formulation of water resource planning, and in the management of regional water projects. The WSIS models also provide a strong foundation for building a comprehensive river model that includes other important environmental factors, such as pollutant loadings.

SJRWMD recognizes that there is scientific uncertainty in the predictive capabilities of the models developed during the WSIS. Since future water withdrawals would most likely occur incrementally over time, this uncertainty can be addressed by employing a feedback loop, using monitoring data, to verify predictive tools developed in this study and to make refinements when needed (adaptive management).

The tools developed during the WSIS, including hydrology and hydrodynamic models and numerous environmental assessment tools, are now available for use in evaluating future Consumptive Use Permit applications and surface water withdrawal planning proposals. These "state-of-the-art science" tools will allow SJRWMD to comprehensively evaluate surface water withdrawal proposals to ensure that environmental harm does not occur in the St. Johns River system as a result of future surface water withdrawals.

REFERENCES CITED

Berndt, M.P., E.T. Oaksford, and G.L. Mahon, 1998. Groundwater. Chapter 3 in Fernald, E.A. and E.D. Purdum (eds.). Water Resources Atlas of Florida. Institute of Science and Public Affairs, Florida State University, Tallahassee, Fla., 312 pp.

Brenner, M., M.W. Binford, E.S. Deevey, 1990. Lakes. Chapter 11 in Myers, R.L. and J.J. Ewel (eds.), Ecosystems of Florida. University of Central Florida Press, Orlando, Fla., 765 pp.

Ewel, K.C., 1990. Swamps. Chapter 9 in Myers, R.L. and J.J. Ewel (eds.), Ecosystems of Florida. University of Central Florida Press, Orlando, Fla., 765 pp.

Hall, G. 2005. Ocklawaha River Water Allocation Study. Technical Publication SJ2005-1. St. Johns River Water Management District, Palatka, Fla.

Henry, J.A., 1998. Weather and Climate. Chapter 2 in Fernald, E.A. and E.D. Purdum (eds.). Water Resources Atlas of Florida. Institute of Science and Public Affairs, Florida State University, Tallahassee, Fla., 312 pp.

Nordlie, F.G., 1990. Rivers and Springs. Chapter 12 in Myers, R. L. and J. J. Ewel (eds.), Ecosystems of Florida. University of Central Florida Press, Orlando, Fla., 765 pp.

Robison, C.P. 2004. Middle St. Johns River Minimum Flows and Levels Hydrologic Methods Report. Technical Publication SJ2004-2. St. Johns River Water Management District, Palatka, Fla.

Scott, T.M., G.H. Means, R.P. Meegan, R.C. Means, S.B. Upchurch, R.E. Copeland, et al. 2004. Springs of Florida. Florida Geological Survey Bulletin No. 66. 377 pp, CD.