TECHNICAL PUBLICATION SJ2005-1

OCKLAWAHA RIVER WATER ALLOCATION STUDY

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Edited by
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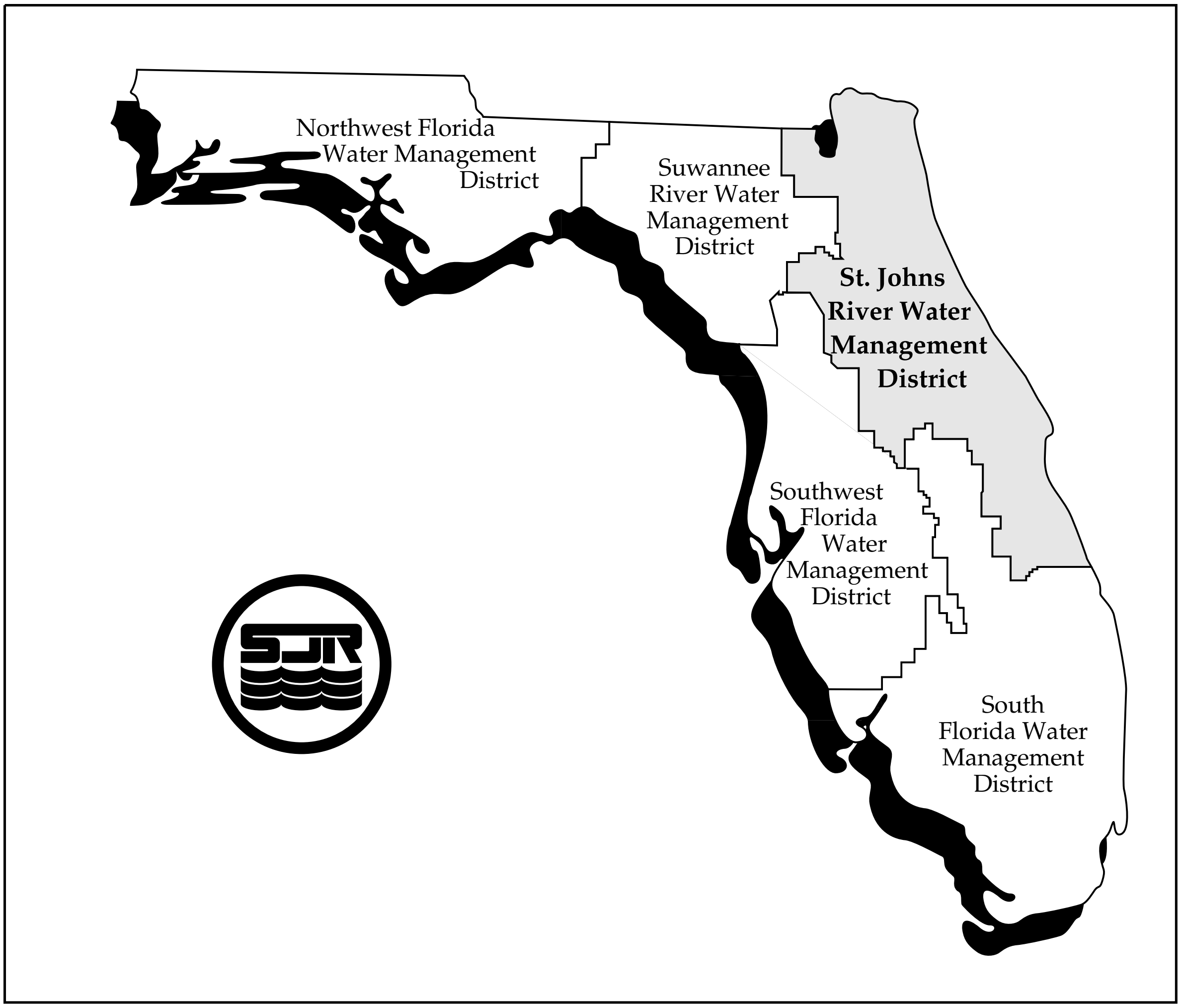
St. Johns River Water Management District
Palatka, Florida

2005



The St. Johns River Water Management District (SJRWMD) was created by the Florida Legislature in 1972 to be one of five water management districts in Florida. It includes all or part of 18 counties in northeast Florida. The mission of SJRWMD is to ensure the sustainable use and protection of water resources for the benefit of the people of the District and the state of Florida. SJRWMD accomplishes its mission through regulation; applied research; assistance to federal, state, and local governments; operation and maintenance of water control works; and land acquisition and management.

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EXECUTIVE SUMMARY

The 1994 Florida Legislature included the following language in the general appropriations bill for surface water improvement and management:

> From funds provided in Specific Appropriation 2082 for the St. Johns Water Management District, the district shall conduct an Oklawaha River Water Allocation Study, to be submitted to the Legislature on or before June 30, 1995. Said study shall recommend water use allocations between human consumptive needs and natural systems needs.

The St. Johns River Water Management District (SJRWMD) performed the water allocation study reported in this document in response to this directive. The water allocation study was originally prepared for submittal to the Florida Legislature in 1995, but was not published by SJRWMD. Subsequent interest in the possible development of the lower Ocklawaha River as a source of water supply to meet projected future water demands prompted the publication of this document. Due to editorial changes, this document differs somewhat from the original, but the data and analysis presented here remain unaltered.

The information contained in this document describes the methods and assumptions; the data; the evaluation and results of the effects of the consumptive use withdrawals on groundwater, surface water, and the aquatic and wetland communities; and the recommendations for the Ocklawaha River Basin (ORB). In addition, the availability of water from the lower Ocklawaha River (LOR) subbasin for human consumptive use was evaluated. The report also includes analyses of the quantity of water available for use, the environmental impacts to aquatic and wetland communities as a result of surface water withdrawals, and a cost comparison of transporting LOR water versus locally treating water by using the reverse osmosis process.

WATER ALLOCATION STUDY

The general method employed in this study was to quantify the impacts that predicted increases in ground and surface water withdrawals, if implemented, would have on water levels and flows in the major surface water bodies and courses of the ORB. These changes in hydrologic conditions were then used to predict the degree of ecological impacts to the plant species composition (structure) and biological functions of the aquatic and wetland communities in the floodplain. The withdrawal analyses were separated into groundwater and surface water categories. The hydrologic analyses were conducted in two phases. Phase 1 used groundwater flow models to determine the potential impact of groundwater withdrawals on spring flows. Phase 2 used computer hydrologic simulation models to determine the potential impact of these changes in spring flows on streamflows and lake levels. The impact assessment used these model-predicted changes in flows and levels to evaluate the potential impact on specific natural communities.

HYDROLOGIC COMPUTER SIMULATIONS

Groundwater

Groundwater withdrawals are projected to increase by 2010. Public supply, commercial/industrial, and agricultural categories account for the largest projections in groundwater withdrawals. These withdrawals are projected to lower the elevation of the potentiometric surface of the surficial and Floridan aquifer systems throughout the ORB. The most significant decreases are projected to occur in the upper Ocklawaha River (UOR) subbasin, as a result of projected increases in water use for public supply in Lake, Orange, Seminole, Marion, and Sumter counties. Most of this area has been designated as a priority water resource caution area because there is a likelihood of harm to native vegetation, reduced discharge from springs, or reduced quality of groundwater because of projected 2010 consumptive uses (Vergara 1994).

If the projected water use increases are realized, the resultant lowering of the elevation of the potentiometric surface of the Floridan aquifer system would reduce spring discharges throughout the ORB. The percentage reductions in spring discharges from eight springs ranged from 5.45% to 70.0%. The maximum spring discharge reduction is projected to be approximately 58.5 cubic feet per second (cfs) (-7%) at Silver Springs, in Marion County, and the minimum reduction is projected to be <0.1 cfs (-8%) at Magnesia Spring, in Alachua County. Springs are important to the base flow of surface waters, particularly in the dry season. Therefore, these projected declines in spring discharges have the potential to negatively impact the surface water hydrology and ultimately the aquatic and wetland-dependent biota.

Surface Water

Long-term streamflow (stage and discharge) data are necessary for performing various analyses (hydrologic and environmental) to determine the water availability in the ORB. These data are required for the existing conditions as well as for the projected 2010 conditions. Because the physical features of the basin have changed markedly over the past 100 years, computer simulation models were used to generate data to reflect the present basin hydrology and the projected 2010 conditions.

Five computer simulations were used. Simulation 1 (Existing hydrologic conditions) was based on existing land use, current lake regulation schedules, current spring flows, and current elevation of the potentiometric surface of the Floridan aquifer system (in the case of Orange Lake). Simulation 2 (Existing-2010 hydrologic conditions) was based on no significant changes in the land use or surface water withdrawals from major lakes and streams for 2010 and significant increases in groundwater withdrawals projected for 2010. This increase in groundwater withdrawals would result in a decrease in spring discharges in the ORB. The simulations for 2010 conditions provide stages and discharges for various locations under the reduced spring flow and aquifer potentiometric surface conditions. Simulation 3 (Proposed hydrologic conditions) was based on a modified surface water level regulation schedule for Rodman Reservoir. The modified regulation criteria were aimed at maintaining the reservoir, to the degree possible, at 18.00 feet National Geodetic Vertical Datum (ft NGVD) while maintaining discharge out of the reservoir at or above minimum desirable levels for downstream conditions. The existing regulation schedules were maintained at all other water control structures within the ORB. Simulation 4 (Proposed-2010 hydrologic conditions) was based on conditions used in Simulations 2 and 3. Simulation 5 (Full Restoration-2010 hydrologic conditions) was based on the removal of Rodman Dam, complete restoration of the historical Ocklawaha River channel, and the conditions of Simulation 2 .

NATURAL SYSTEM IMPACT ASSESSMENT

The impacts of the model-predicted changes were evaluated for the following subbasins: the upper Ocklawaha River, the lower Ocklawaha River, and Orange Creek.

In the UOR subbasin, the current regulation schedules (developed for flood control and recreational boating) for the chain of lakes produce insufficient water levels to protect the ecological functions and structure of the wetland communities. The hydraulic alterations associated with these regulation schedules have modified the natural hydrology of the lakes, which has resulted in structural and functional changes to the floodplain wetlands. By 2010, the projected increases in groundwater withdrawals in the UOR subbasin, if they occur, would further exacerbate the environmental impacts caused by the current lake regulation schedules. Surface water levels in Lake Apopka would be the most affected by the predicted increases in groundwater withdrawals. Relatively minor reductions in the water levels of Lakes Harris, Dora, Beauclair, Eustis, and Griffin are also predicted.

The UOR subbasin has been identified as a priority water resource caution area because the impacts of projected groundwater demands exceed the impact criteria limits to natural systems, to groundwater quality, or to existing legal users of water, established in association with SJRWMD Water Supply Needs and Sources Assessment (Vergara 1994). Because of these factors, new consumptive use permit (CUP) applications in this area should be reviewed carefully to determine the impact on the natural community. SJRWMD will develop alternative strategies for water supply.

In the LOR subbasin, the impacts of model-predicted changes were evaluated at the following locations: Silver Springs and along the Silver River, Eureka Dam on the Ocklawaha River, Rodman Reservoir, and Riverside Landing on the Ocklawaha River.

At Silver Springs and along the Silver River, the average 2010 spring discharge is expected to decrease by 58.47 cfs (37.8 million gallons per day [mgd]) because of the predicted increases in groundwater withdrawals, if these withdrawals are realized. This reduction represents a 7% decrease in average flow. The direct ecological impacts of reduced flow to the flora and fauna of the Silver River cannot be quantified at this time.

The flow from Silver Springs supplies a large volume of water to the LOR. More important, these discharges contribute significantly to the base flow of the river during dry periods. Removal of surface water directly from the spring run or a further reduction in spring discharge due to increases in groundwater use may significantly harm the ecology of downstream reaches of the Ocklawaha River.

Impacts of consumptive uses on the natural community around Silver Springs and the Silver River are not quantifiable at the present time.

However, new CUPs in this area should be reviewed carefully to determine their impact on the natural community. Although the LOR subbasin is not identified as a water resource caution area, SJRWMD should develop alternative strategies for water supply.

At Eureka Dam, projected increases in groundwater usage, if realized, would lower spring discharges between the Silver River and Eureka Dam. The predicted 2010 decreases in groundwater discharges, however, would only weakly affect the hydrologic conditions in this river reach. The hydrologic changes predicted to occur at this river reach appear insignificant, and no impacts to the wetland plant communities in the floodplain or in-stream biota are expected.

At Rodman Reservoir, hydrologic computer simulations included a proposed modification of the existing water level and discharge regulation schedule, with the intent to more closely match the historical downstream stage-discharge relationship. This modified schedule should simulate a more gradual reduction in downstream flows and stages, a decrease in the rate of decline in water levels downstream, and a rise downstream in low water levels by approximately 0.33 ft. The 2010 groundwater use is not expected to cause significant hydrologic, hydraulic, or environmental impacts. If the decision is made to maintain Rodman Reservoir, the surface water regulation schedule for Rodman Dam should be modified to provide a downstream hydrologic regime that more closely approximates the pre-reservoir conditions and to provide more gradual changes in downstream water levels.

At Riverside Landing (located approximately 1 mile downstream from Rodman Dam), flows and water levels are dependent upon surface water discharges from Rodman Reservoir. The regulation schedule at the reservoir discharge structure has a strong effect on this part of the river reach. Changes in the gate opening are made to maintain critical water levels in the reservoir. The effect on the Ocklawaha River at Riverside Landing is most pronounced under low-flow conditions. The hydrologic changes predicted along this river reach due to projected 2010 increased groundwater withdrawals are considered negligible. No additional impacts to the wetland plant communities in the floodplain or in-stream biota of the Ocklawaha River are expected.

A comparison of water level durations produced by the Existing and Proposed hydrologic conditions indicated no major differences in the water levels achieved downstream of the reservoir at Riverside Landing. However, the Proposed-2010 hydrologic conditions produced a more gradual reduction in downstream stages, and low water stages were improved by approximately 0.33 ft over the stages produced by the Existing conditions.

In the Orange Creek subbasin, hydraulic features (such as weirs) have altered the natural hydrology of the lakes, the streams, and Paynes Prairie. This alteration resulted in ecological degradation and negative economic impacts. However, the hydrologic changes predicted to occur in the Orange Creek subbasin due to projected 2010 increased groundwater withdrawals are considered insignificant, and no additional ecological or economic impacts are expected.

SUMMARY

Groundwater withdrawals are projected to increase by 2010. This increase, if realized, would lower the elevation of the potentiometric surfaces of the surficial and Floridan aquifer systems throughout the ORB. This would cause a general reduction in spring discharges.

The most significant decreases in the elevation of the potentiometric surface of the Floridan aquifer in response to projected increases in groundwater withdrawals are predicted to occur in the UOR subbasin. Surface water levels in Lake Apopka would be the most affected, with only relatively minor reductions in the surface water levels predicted for Lakes Dora, Beauclair, Harris, Eustis, and Griffin. These decreases in lake levels in the UOR subbasin will further exacerbate the environmental impacts caused by the current lake regulation schedules.

The hydrologic changes due to projected 2010 increased groundwater withdrawals predicted to occur elsewhere in the ORB are considered negligible. No impacts to the wetland plant communities in the floodplain or in-stream biota are expected.

WATER AVAILABILITY STUDY

As part of the water use allocation study, SJRWMD evaluated the availability of water from the LOR subbasin for human consumptive use, that is, as a source of drinking water. The results are presented in two parts: a quantitative evaluation and an economic evaluation.

QUANTITATIVE EVALUATION

This evaluation examined the quantity of surface water that could be removed from the LOR subbasin without causing unacceptable environmental impacts to wetland plant communities in Rodman Reservoir and the downstream floodplain (safe yield). The evaluation was based on existing policies, rules, and procedures. The hydrologic model used was the same one used to evaluate the water use allocation simulations for the entire ORB. Computer model simulations of the Existing-2010 conditions, Proposed-2010 conditions, and Full Restoration-2010 conditions were used to evaluate the impacts of withdrawing 0, 165, 250, and 330 cfs of water.

Lower Ocklawaha River With Rodman Reservoir

The most significant effect of the withdrawals on Rodman Reservoir was a marked increase in the range of surface water fluctuations due to a lowering of low water levels. The magnitude of this lowering increased with the size of the withdrawal (i.e., 0, 165, 250, and 330 cfs). The area of the reservoir bottom exposed by the drawdown conditions increased markedly with the size of the withdrawal.

A 3–4-ft range of water level fluctuation is not unusual for many Florida lakes and is often desirable to consolidate and compact sediments and allow re-seeding of emergent aquatic vegetation. The timing of the low water events, however, is especially critical in Rodman Reservoir. Water levels should not be significantly lowered in Rodman Reservoir during the summer months when hydrilla covers the water surface and fills the water column. Reduced water levels and heavy hydrilla coverage in the summer months increase the possibility of a fish kill.

An analysis of average monthly water levels in Rodman Reservoir with withdrawals of 0, 165, 250, and 330 cfs shows that water levels would not be reduced significantly during the summer months by a withdrawal of 165 cfs. However, during low-water years, average monthly water levels during the summer months would be significantly reduced by withdrawals of 250, and 330 cfs. Thus, these higher withdrawals could lead to large fish kills in Rodman Reservoir. The regulation schedule used in the Proposed-2010 conditions produced lower water levels than did the Existing-2010 conditions for all withdrawal levels. Modifying the regulation schedules in 2010 would have an even greater potential to cause fish kills.

A comparison of stage-duration curves for Riverside Landing for the four surface water withdrawal rates showed the same general trends for both the Existing and Proposed-2010 conditions. There were no major differences in the actual water levels achieved downstream of Rodman Reservoir; however, the duration of the stages decreased with increasing levels of withdrawal. Minimum water levels declined with the level of withdrawal. Minimum water levels simulated under the Proposed-2010 conditions were 0.08–0.33 ft higher than the corresponding levels simulated under the Existing-2010 conditions. The width of the river channel experiencing altered hydrology was $\leq$5 ft.

The impact on downstream flows of these four levels of withdrawal from Rodman Reservoir was assessed to predict impacts on migratory fishes during the winter months when they move upstream. Flows would be reduced significantly during the winter months by 165-, 250-, or 330-cfs withdrawals from Rodman Reservoir. However, without fish passage facilities, the ecological significance of these impacts is minor. If fish passage facilities were constructed on either the canal or dam outlets from Rodman Reservoir, then these winter month discharge reductions may become ecologically significant. There are no data available, however, to ascertain the relationship between migratory fish movement and reproduction and flow rate for the Ocklawaha River.

Lower Ocklawaha River With Rodman Reservoir Removed

A comparison of the stage-duration curves for the three simulations (Existing conditions for 2010, Proposed conditions for 2010, and Full Restoration for 2010) clearly indicates the improved hydrologic conditions at Riverside Landing which would result from restoration. The largest differences in water levels occurred at the lowest floodplain elevations. The minimum level without withdrawal (0 cfs) was 2.80 ft. The minimum level declined to 2.13, 1.70, and 1.23 ft for the 165-, 250-, and 330-cfs withdrawals, respectively.

The duration of flooding of the mean elevation of the hardwood swamp also decreased as the level of the withdrawal increased. The duration of flooding shifted from approximately 86% without withdrawal (0 cfs) to 77%, 72%, and 65% for the 165-, 250-, and 330-cfs withdrawals, respectively. The elevations of the floodplain that would experience the 86% inundation frequency changed rather markedly. These changes in stage duration (86% to 65%), even at the highest water withdrawal (330 cfs), probably will not alter the structure and ecological functions of the mixed hardwood swamp community in the floodplain for this reach of the Ocklawaha River.

Determination of Safe Yield

The determination of safe yield for withdrawing water from the LOR subbasin for human consumptive use was based on the following assumptions:

- Water level regulation schedules for upstream lakes did not change.
- Groundwater withdrawals equaled the 2010 predictions.
- Surface water withdrawals upstream of Rodman Reservoir did not increase.
- The existing surface water management plan for Rodman Reservoir was maintained (i.e., stabilized water levels for aquatic weed control and sport fisheries management).

Allocating consumptive uses only from the downstream reaches of the Ocklawaha River has the advantage of potentially maximizing water availability, because the withdrawals are at the point of maximum surface water volume for the ORB. A given withdrawal in the LOR subbasin represents a smaller proportion of the total river flow than it does upstream. Changes to the hydrologic regime of the ORB and environmental impacts to aquatic dependent biota would be less downstream (LOR subbasin) than upstream (UOR subbasin).

- A safe yield of $\leq$165 cfs (106.6 mgd) could be withdrawn from either Rodman Reservoir (as it is currently operated) or the river channel in 2010 without causing unacceptable environmental harm. Water availability from the LOR subbasin is relatively insensitive to retention of Rodman Reservoir under current operating conditions. The reservoir could likely be operated differently to optimize environmental and water supply benefits.

A more accurate assessment of water availability can be determined only after minimum flows and levels are established and incorporated into a basinwide surface water management plan which addresses the water supply potential of the LOR under different reservoir management options and river restoration strategies.

ECONOMIC EVALUATION

The economic evaluation was limited to a comparison of the estimated costs associated with transporting various quantities of water from the LOR subbasin various distances or locally treating water with reverse osmosis. This comparison indicated that it may be feasible to use water from the LOR subbasin by transporting it up to 50 miles. Beyond this distance, consideration should be given to treating water of lesser quality where it is withdrawn, using reverse osmosis to meet the use demands and water quality standards.

CONTENTS

FIGURES

TABLES

INTRODUCTION, by Greeneville Hall and Marion Ritter

The Florida Legislature created the Cross Florida Greenbelt State Recreation and Conservation Area with the enactment of Chapter 90-328, Laws of Florida. This legislation required a specific boundary determination be made by a management plan study process. The Governor and the Cabinet approved a management plan on December 15, 1992, which was submitted to the Florida Legislature for approval. The Legislature passed House Bill 1751 on April 2, 1993, which included directives regarding the management plan. One of these directives required that prior to a final determination of the disposition of the canal works impounding the Ocklawaha River at the Rodman Reservoir being made, the Department of Natural Resources shall study the efficacy, both environmental and economic, of complete restoration of the Ocklawaha River, partial restoration of the river, total retention of the Rodman Reservoir, and partial retention of the reservoir. These studies have been completed. Additionally, the 1994 Legislature included the following language in the Surface Water Improvement and Management (SWIM) appropriation bill:

> From funds provided in Specific Appropriation 2082 for the St. Johns Water Management District, the district shall conduct an Oklawaha River Water Allocation Study, to be submitted to the Legislature on or before June 30, 1995. Said study shall recommend water use allocations between human consumptive needs and natural systems needs.

The St. Johns River Water Management District (SJRWMD) performed the water allocation study reported in this document in response to this directive. The water allocation study was originally prepared for submittal to the Florida Legislature in 1995, but was not published by SJRWMD. Subsequent interest in the possible development of the lower Ocklawaha River as a source of water supply to meet projected future water demands prompted the publication of this document. Due to editorial changes, this document differs somewhat from the original, but the data and analysis presented here remain unaltered.

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River Basin (ORB). In addition, the availability of water from the lower Ocklawaha River (LOR) subbasin for human consumptive use was evaluated. This report also includes analyses of the quantity of water available for use, the environmental impacts to aquatic and wetland communities as a result of surface water withdrawals, and a cost comparison of transporting LOR water versus locally treating water by using the reverse osmosis process.

The general methods employed in this study were to quantify the impacts that predicted increases in ground and surface water withdrawals would, if implemented, have on water levels and flows in the major surface water bodies and courses of the ORB. These changes in hydrologic conditions were then used to predict the degree of ecological impacts to the plant species composition (structure) and biological functions of the aquatic and floodplain wetland communities. The basic methods for this type of analysis were formulated in the SJRWMD document *Water Supply Needs and Sources Assessment* (Vergara 1994) and the Minimum Flows and Levels Project. The study area has been defined as the area within the hydrologic basin boundaries of the ORB. The application of modeling techniques also required the delineation of the interior subbasin boundaries.

Basin Description

The ORB is a major surface water basin near the center of peninsular Florida (Figure 1). The ORB has an area of 2,116 square miles and extends for 130 miles from its headwaters in the Green Swamp to the St. Johns River north of Lake George. The river system can be broken into four major subbasins based upon hydrologic boundaries: (1) the upper Ocklawaha River subbasin, (2) the lower Ocklawaha River subbasin, (3) the Florida Ridge subbasin, and (4) the Orange Creek subbasin (Figure 1). Only three of these basins are included in the study reported in this document: the Upper Ocklawaha River subbasin, excluding the Palatlakaha River; the Lower Ocklawaha River subbasin; and the Orange Creek subbasin.

Upper Ocklawaha River Subbasin

The upper Ocklawaha River (UOR) subbasin is located in Sumter, Lake, Orange, and Marion counties. The basin encompasses 1,042 square miles, extending from Lake Apopka to State Road (SR) 40 near Ocala (Figure 2).

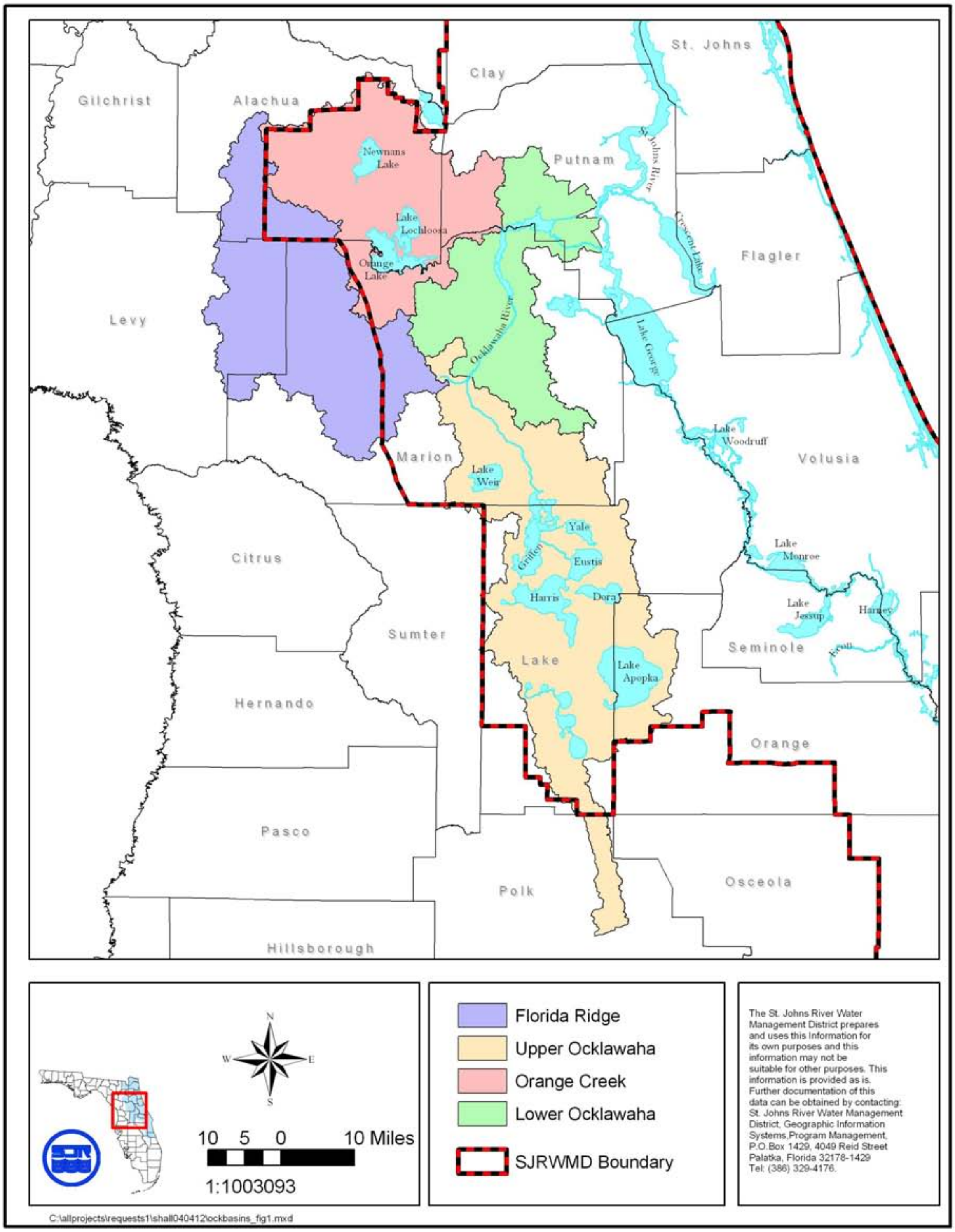


Figure 1. The major subbasins of the Ocklawaha River Basin

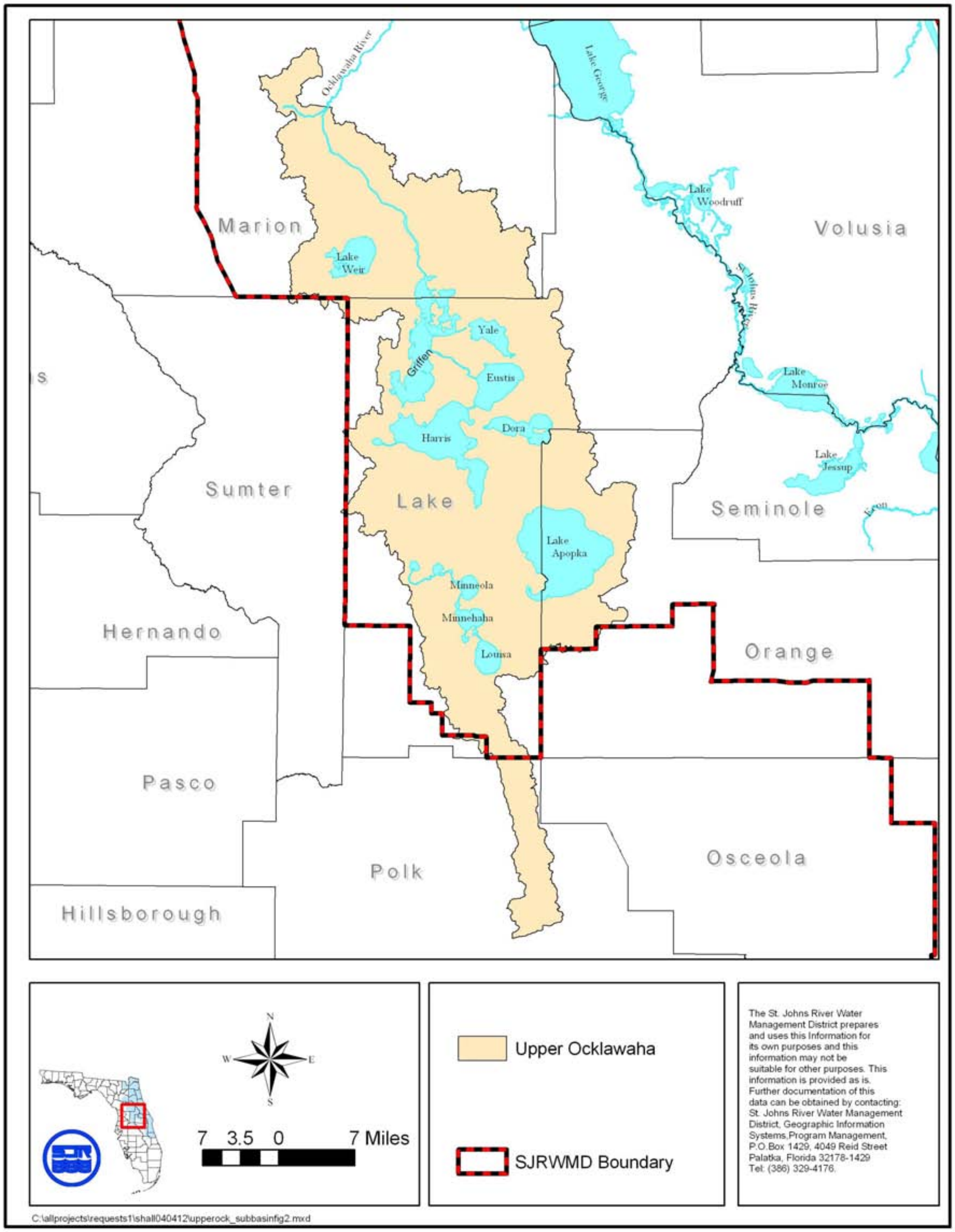


Figure 2. The upper Ocklawaha River subbasin

Flow in the UOR originates from the Green Swamp-Palatlakaha River and Lake Apopka. Virtually all of the surface water flow is regulated by water control structures. These structures have dampened the natural periodic fluctuations in lake stages and stream discharges. As a result, the lakes function hydrologically as managed reservoirs rather than natural water bodies. Most areas of this basin were designated as priority water resource caution areas because there is a likelihood of harm to native vegetation, unacceptable reductions in discharge from springs, or unacceptable changes in groundwater quality if projected 2010 consumptive uses are realized (Vergara 1994).

The UOR can be partitioned at the Burrell water control structure into northern and southern regions. The southern region includes several interconnected lakes which comprise the Ocklawaha Chain of Lakes. The northern region of the UOR is a lake and riverine system. Surface water inflow occurs from upstream drainage through Haines Creek, Lake Yale, Lake Weir and Marshall Swamp, and the Silver River. From Lake Griffin, water flows northward through the J.D. Young Canal (C-231) to the Moss Bluff water control structure, which controls water levels in Lake Griffin. Most of the river between Lake Griffin and SR 40 has been channelized. Flow has been altered from the natural river course into canals for most of this reach, and much of the floodplain has been converted to farmland.

The UOR subbasin is primarily within the Central Lakes Subdivision of the Central Lake District Physiographic Province (Brooks 1982). The Central Lakes Subdivision is a large lowland area between the Mount Dora Ridge on the east and the Ocala Uplift District on the west. In many areas, the valley floor intersects the potentiometric surface of the Floridan aquifer, resulting in large spring discharges and spring-fed lakes. As a result, surface waters receive a considerable portion of their total water budget from groundwater (Canfield 1981). In addition, surface inflows for the region generally originate in calcareous, nutrient-rich soils. Consequently, the lakes of the region, with few exceptions, are naturally eutrophic hardwater lakes. Although the lakes are naturally eutrophic, urbanization and intensive agricultural practices have substantially increased the surface water loading rate of nutrients. Therefore, eutrophication has increased to detrimental levels and recreational, aesthetic, and commercial values have declined.

Orange Creek Subbasin

The Orange Creek subbasin encompasses approximately 600 square miles in Marion, Alachua, and Putnam counties in north-central Florida and is a major tributary of the lower Ocklawaha River (Figures 1 and 3). Orange Lake, Lochloosa Lake, Newnans Lake, and Paynes Prairie are the major surface waters within the basin (Figure 3) and are recognized for their considerable ecological and economical value (Gottgens and Montague 1987, 1988; SJRWMD 1993).

Paynes Prairie and Orange and Lochloosa lakes have been designated as Outstanding Florida Waters. Economic and recreational values center around the reputation of the major lakes as excellent sport fisheries. Paynes Prairie also provides passive recreation. Orange Creek has traditionally attracted many sportsmen, naturalists, and tourists annually. Paynes Prairie State Preserve is registered as a National Natural Landmark by the U.S. Department of the Interior.

Orange Creek is located within the Northern Peninsula Slopes and Northern Peninsula Plains of the Ocala Uplift District, described as an area of karst topography characterized by shallow, flat-bottomed lakes, irregular drainage patterns, sinkholes, and other solution features (Sellards 1910; Brooks 1982). The geomorphology of the Orange Creek subbasin is dominated by ancient marine deposits of phosphate-rich sands, clays, and limestones (Pirkle and Brooks 1959) that are exposed in the central and eastern parts of the drainage basin. As a result, the lakes, the wetlands, and many upland areas are naturally nutrient-enriched and highly eutrophic.

Orange Creek is divided into six surface water drainage subbasins: Hogtown Creek, Newnans Lake, Paynes Prairie, Lochloosa Lake, Orange Lake, and Orange Creek (Figure 3). With the exception of the Hogtown Creek and Paynes Prairie subbasins, which are closed watersheds, all of the subbasins contribute runoff to Orange Creek, a tributary of the Ocklawaha River. The direction of flow within the watershed is from Newnans Lake into Paynes Prairie and Orange Lake, Lochloosa Lake into Orange Lake, and Orange Lake into Orange Creek.

There are four principal water control structures within Orange Creek. A fixed-crest weir is located at the outlet of Orange Lake, Newnans Lake has an adjustable weir, and gated culverts control water flow at the Prairie

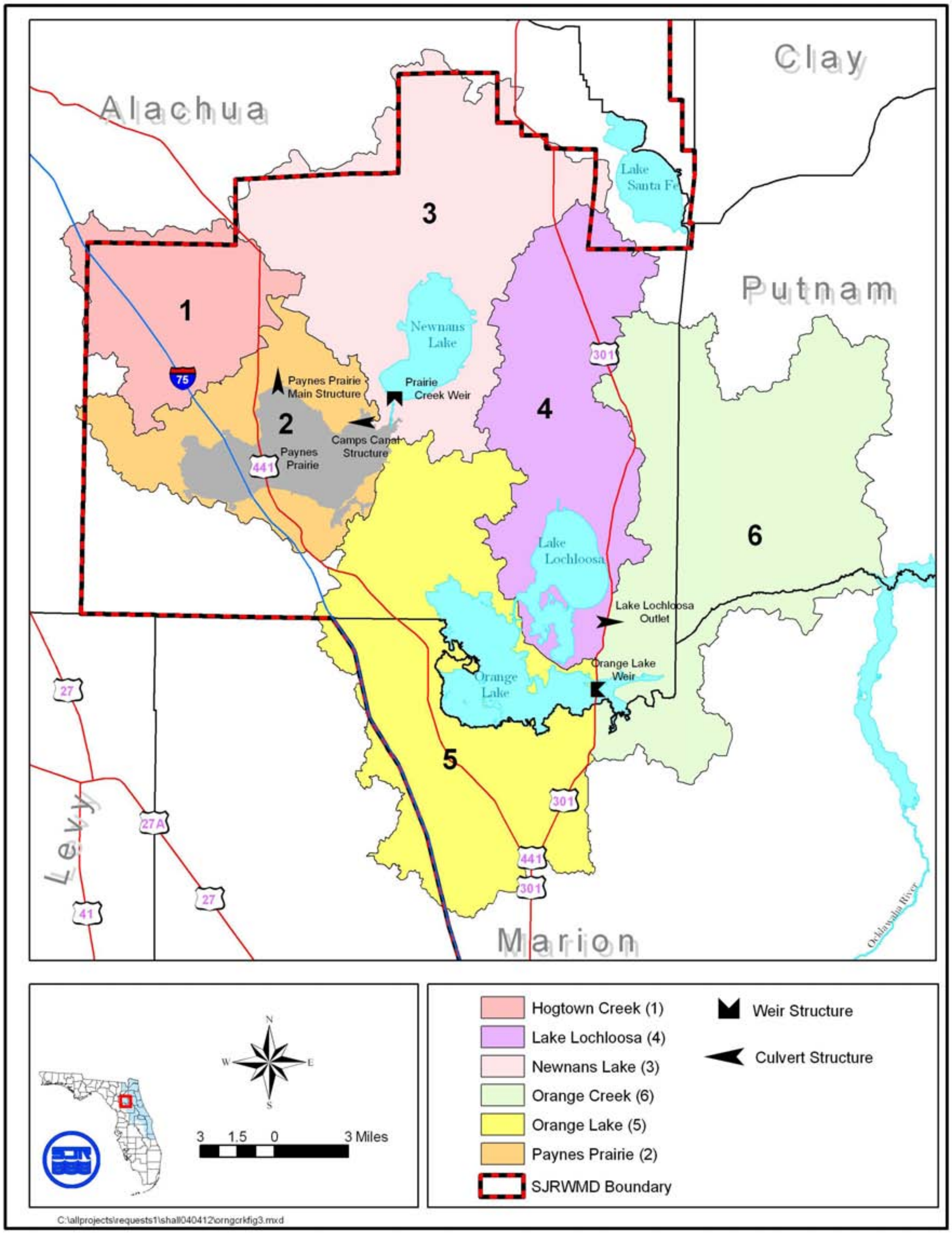


Figure 3. The major subbasins of the Orange Creek Basin

Creek / Camps Canal structure and the Alachua Sink within Paynes Prairie (Figure 3). Currently, all of the water control structures are operational except for the Newnans Lake weir; the stoplogs were permanently removed during 1991 to increase lake level fluctuation.

During the 1970s, the state of Florida purchased Paynes Prairie and the Florida Department of Environmental Protection (FDEP) began restoration efforts. Many excavated channels and drainage canal systems have been constructed within Paynes Prairie. Camps Canal is perhaps the most notable. The original purpose of this canal was to dewater Paynes Prairie to create rangeland. This canal system was constructed during the 1920s and diverted the flow of Prairie Creek from Paynes Prairie into the River Styx and ultimately to Orange Lake (Figure 3). In addition, canals and levees were constructed within Paynes Prairie to convey runoff to the Alachua Sink and to a currently inactive pump station that discharged to Camps Canal.

Lower Ocklawaha River Subbasin

The lower Ocklawaha River (LOR) subbasin encompasses an area of approximately 472 square miles in Putnam and Marion counties (Figure 4). This subbasin occurs downstream from SR 40, near Ocala, to the St. Johns River north of Lake George. Silver Springs, the Silver River, and Orange Creek are major tributaries to this portion of the Ocklawaha River. Silver Springs accounts for approximately 80% of the baseflow of the Ocklawaha River in this basin. The Rodman Reservoir (Lake Ocklawaha), located near the mouth of the Ocklawaha River, is the main surface water body within this reach of the ORB. The primary surface water inflows to the reservoir are the Orange Creek drainage basin and practically the entire Ocklawaha River.

Rodman Reservoir extends from Eureka Dam to Rodman Dam, with a surface area of approximately 9,000 acres (Figure 4). The reservoir was created in 1968 by impounding the lower Ocklawaha River as a part of the now deauthorized Cross-Florida Barge Canal project (CFBCP). The CFBCP was initiated in 1964; however, further work on the project was suspended by the president of the United States in January 1971 for environmental reasons. The U.S. Army Corps of Engineers recommended termination of the project in February 1977, and the U.S. Congress passed a bill in October 1990 that was signed into law, deauthorizing the project. The reservoir was filled during the fall of 1968 to a height of 20 feet National Geodetic Vertical Datum (ft NGVD) and was subsequently lowered to 18 ft NGVD by the end of 1970. Except for

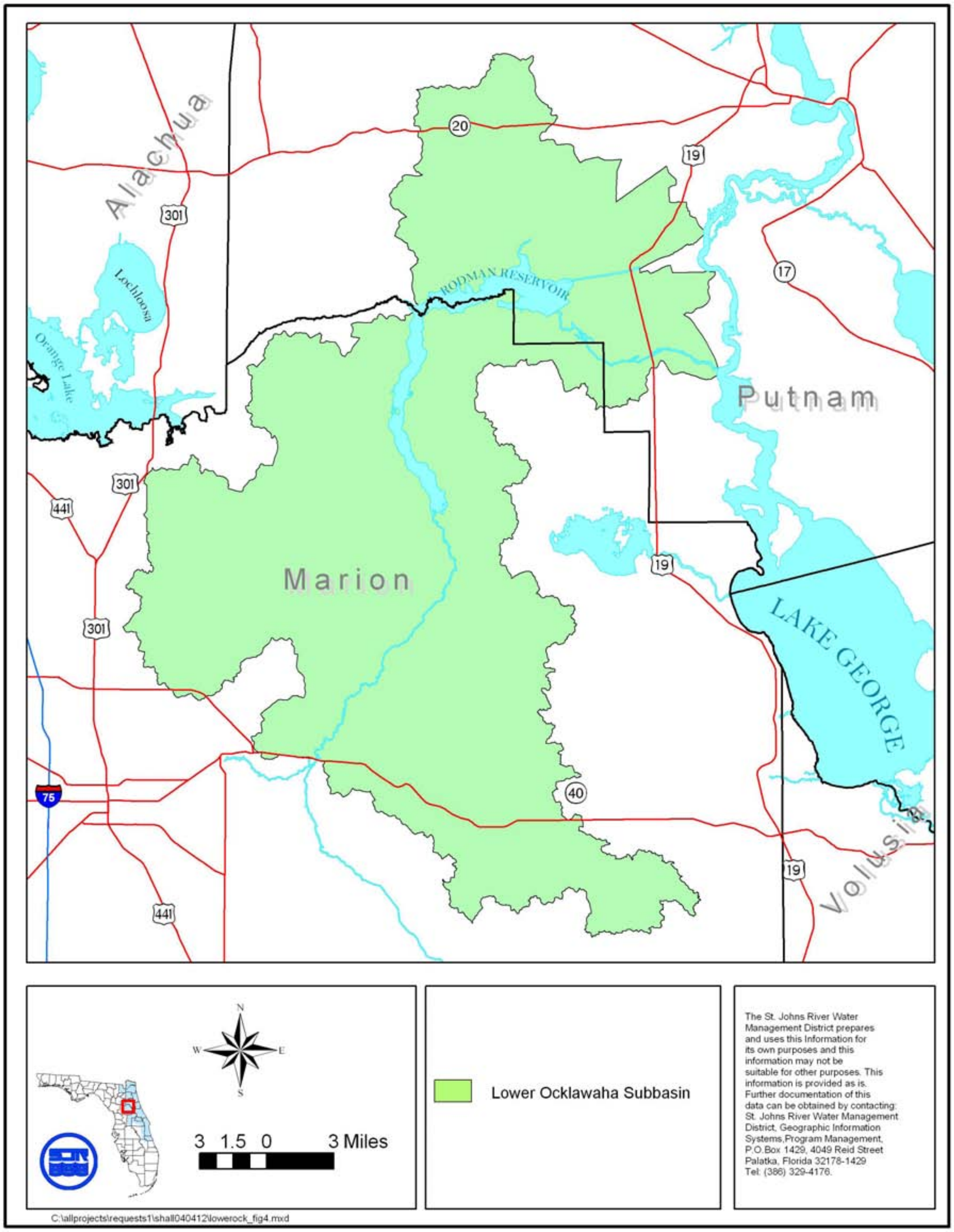


Figure 4. The lower Ocklawaha River subbasin

periodic brief partial drawdowns, the average reservoir water level has been maintained at 18 ft NGVD.

The river floodplain in the southern reaches of the LOB lies primarily within the Ocklawaha Valley of the Ocala Uplift District (Brooks 1982). This is a lowland (flatwoods and swamplands) area between the xeric terrain of the Ocala Scrub paleo-sand-dune field of the Central Lake District on the east, and the Anthony Hills of the Ocala Uplift District on the west. The northern reaches of the LOB occur in the St. Johns Offset (flatwoods and swamplands), between the xeric ridges of the Interlachen Sand Hills to the north and the Ocala Scrub to the south, all of the Central Lake District. In many areas, the valley floor intersects the potentiometric surface of the Floridan aquifer, resulting in springs and spring-fed lakes. As a result, surface waters receive a considerable portion of their total water budget from nutrient-rich groundwater (Canfield 1981).

METHODS

The time allowed for this assessment was short, and therefore only existing information was used. The project schedule precluded site visits or the collection of additional data. The following sections describe the surveying, engineering, and environmental methods used to perform the hydrologic modeling, calculations, and analyses for this study.

WATER ALLOCATION STUDY

The general method employed in this study was to quantify the impacts that predicted increases in ground and surface water withdrawals would have on water levels and flows in the major surface water bodies and courses of the ORB. These changes in hydrologic conditions were then used to predict the degree of ecological impacts to the plant species composition (structure) and biological functions of the aquatic and wetland communities in the floodplain. The withdrawal analyses were separated into groundwater and surface water categories. The hydrologic analyses were conducted in two phases. Phase 1 used groundwater flow models to determine the impact of groundwater withdrawals on spring flows. Phase 2 used computer hydrologic simulation models to determine the impact of these changes in spring flows on streamflows and lake levels. The impact assessment used these model-predicted changes in flows and levels to evaluate the impact on specific natural communities.

DATA NEEDS

The objective of this segment of the study was to define the existing and projected (year 2010) ground and surface water uses within the ORB. Existing SJRWMD databases were used to obtain this information. The analyses required the separation of these needs into those obtained from groundwater and those obtained from surface water.

The groundwater hydrologic analyses used data and models previously developed as a part of the *Water Supply Needs and Sources Assessment* (Vergara 1994). The water use needs were inventoried for the year 1990 and were projected to 2010 for three categories: public supply, agricultural irrigation self-supply, and recreation self-supply. The database for 1990 was obtained from an SJRWMD staff report. Projections of future needs for 2010 were based on historical trends, local government comprehensive plans, and direct communications with federal and state agencies, water users, and publicly and privately owned public water supply utilities. This information database was used in the development of numerical groundwater flow models designed to assess the potential impact of future withdrawals.

The primary source of the existing surface water use data was the SJRWMD consumptive use permitting database. Information on owner, number of pumps, location of the pumps, the quantity pumped, the source, and the source surface area were obtained for each permitted use in the study area. The major use categories were agricultural, golf course, and sand mining. No significant change in agricultural surface water use to 2010 was expected (Lynne, Kiker et al. 1992). Sand mining is considered a non-consumptive use, with the water being returned to the source. No increased use was projected for 2010. Golf course use was projected to increase by 2010. The quantity was estimated by county; however, it was not possible to determine the exact location of the use within the county. Reclaimed water and stormwater retention ponds are expected to provide a major portion of the golf course irrigation water in the future. The impact of this future use will have to be examined on a site-by-site basis. Although the impact was not evaluated in this study, the quantity increase by county was furnished.

The assessment of surface water availability from Rodman Reservoir utilized information from SJRWMD data files and public/private water utilities.

HYDROLOGIC ANALYSES

The hydrologic analyses were conducted in several phases. Because of the analytical techniques used, the evaluations were separated into the categories of groundwater use and surface water use. Using the methods developed in Vergara 1994 and the groundwater use data developed for that study, the projected impacts of these withdrawals on spring flows in the study area were determined. The results of this analysis were used as input data in the hydrologic modeling effort conducted to determine the impact on streamflows and lake stages resulting from these changes in spring flows. The changes in flows and stages were related to specific locations having significant relevance to impacts on the plant species composition (structure) and biological functions of the aquatic and floodplain wetland communities. For human surface water use, the existing water use and the 2010 water use were determined. Where there was an increase in 2010 use of surface water, the impact on the natural community was evaluated.

Groundwater Analyses, by Ching-tzu Huang

The groundwater analyses were divided into two phases. Phase one identified the springs which contributed significant spring discharges to the Ocklawaha River. Phase two quantified how spring discharges in the ORB would be impacted by projected 2010 increases in groundwater withdrawals if these withdrawals are implemented. Eight spring sites in three counties within the ORB were evaluated.

No proposed groundwater model simulations were conducted for this study. The spring discharge reductions for Apopka Spring, Blue Springs, and Holiday Spring were those reported by Vergara (1994). The Floridan aquifer water levels for 1988 and 2010 were determined from composite potentiometric maps presented in Vergara 1994. The 1977 predevelopment potentiometric surface of the Floridan aquifer was used to determine the spring pool elevations. The reduction in spring discharge between 1988 and 2010 was determined by multiplying the spring conductance coefficient with the head difference between the 1988 and 2010 composite potentiometric surface elevations of the Floridan aquifer. The 1988 spring discharge was estimated by multiplying the spring conductance coefficient by the head difference between the 1988 mean potentiometric surface elevation and the spring pool surface elevation. The ratio between the calculated spring discharge reduction and the 1988 spring discharge was calculated to represent the percentage change between 1988 and 2010.

The groundwater flow model results presented in Vergara 1994 indicated a potential for springflow reductions associated with projected increased water supply demands by 2010. The projected spring discharge reductions are the result of projected declines in the potentiometric surface in the Floridan aquifer caused by the predicted increase in groundwater demand. The potential impacts on Apopka Spring, Blue Springs, and Holiday Spring in Lake County were calculated using the Wekiva River Basin regional groundwater flow model (GeoTrans 1992). The spring discharge for these springs was assessed and reported in Vergara 1994. The spring discharge reductions for the remaining five springs within the ORB were calculated with the method described below.

Spring discharge rates are totally dependent on spring discharge conductance and the head difference between the spring pool surface elevations and the elevations of the potentiometric surface of the Floridan aquifer. Generally, the spring discharge rates can be calculated with the following equation:

$$Q = C * (H - H_P) \quad \textbf{(1)}$$

where

Q = spring discharge rate (ft^3 / d)
C = spring conductance coefficient (ft^2 / d)
H = elevation of the potentiometric surface in the Floridan aquifer (ft)
H_p = spring pool elevation (ft)

The definition of hydraulic and hydrologic variables used in Equation 1 are briefly described as follows. The spring pool elevation is the altitude of the spring pool surface. Because no spring pool elevation data are available for the eight spring sites in the ORB, it was decided that the earliest predevelopment 1977 potentiometric surface elevations of the Floridan aquifer coincident with the springs would be used as the assumed spring pool elevations. The potentiometric surface elevations of the Floridan aquifer based on the 1988 average pumping rates and the projected 2010 groundwater withdrawal were determined using model results presented in Vergara 1994. The results of the simulated potentiometric surfaces of the Floridan aquifer based on various regional numerical and analytical groundwater flow models were integrated, and the composite elevations of the potentiometric surface for 1988 and 2010 were produced. The composite 1988 and 2010 potentiometric surface elevations were then used to estimate the head values in the Floridan aquifer. Spring conductance is usually determined by dividing spring discharge by the head differential between the spring pool and the head in the Floridan aquifer. Due to the lack of spring discharge and head difference data, no spring conductance values could be calculated in this study. However, the lack of spring conductance values will not affect spring discharge percentage change calculations. The reasons for this are discussed in the following section.

The physical parameters contained in the formula used to evaluate the spring discharge reduction percentage between the average 1988 and the projected 2010 spring discharges are defined as

$$P(\%) = \frac{Q_{2010} - Q_{1988}}{Q_{1988}} \quad \textbf{(2)}$$

where

P(%) = relative change in spring discharge between 1988 and 2010
Q_{2010} = 2010 spring discharge rate (ft^3 / day)
Q_{1988} = 1988 spring discharge rate (ft^3 / day)

Equation 2 may be simplified by substituting potentiometric elevations of the Floridan aquifer for spring discharge, Q, using Equation 1. The simplified spring discharge change percentage equation can be expressed as

$$P(\%) = \frac{H_{2010} - H_{1988}}{H_{1988} - H_P} \quad \textbf{(3)}$$

where

P(%) = relative change in spring discharge between 1988 and 2010
H_{2010} = the 2010 composite potentiometric surface elevation (ft NGVD)
Q_{1988} = the 1988 composite potentiometric surface elevation (ft NGVD)
H_p = spring pool elevation (ft)

The spring conductance term was eliminated from the denominator and the numerator of the spring discharge percentage Equation 2. Therefore, an actual value of the spring conductance was not required for spring discharge percentage change calculations. The variable, the head difference between 1988 and 2010 in Equation 3, was directly calculated from the composite potentiometric surface elevations resulting from the simulated 1988 and 2010 pumping scenarios.

Streamflow Analyses, by Donthamsetti Rao, Apurba Borah, Awes Karama, and Price Robison

Streamflow and / or stage analyses were performed for the following locations in the ORB:

- Lake Apopka
- Lakes Eustis / Harris / Dora
- Lake Griffin

- Ocklawaha River near Conner
- Ocklawaha River near the Orange Creek confluence
- Ocklawaha River at the Rodman Dam
- Orange Creek subbasin

The analyses were performed for the Existing and predicted 2010 increases in groundwater withdrawals. The required data were generated by hydrologic simulation.

Hydrologic Simulations. Long-term streamflow (stage and discharge) data are necessary for performing various analyses (hydrologic and environmental) to determine the water availability in the ORB. These data are required for the current conditions as well as the projected 2010 conditions. The U.S. Geological Survey monitored stage and discharge for the locations mentioned above. However, because the physical features of the basin have changed markedly over the past 100 years, it was necessary to rely on data generated by computer simulation models, to reflect the present basin hydrology, and also the projected 2010 conditions. The models used for this purpose were developed by SJRWMD and extensively used for several studies of the basin (e.g., for establishing optimal lake fluctuations and evaluation of various alternatives for the Rodman Reservoir). A brief description of the models and some model applications can be found in Borah et al. 1992 and Robison et al. 1995. For the present evaluations, simulations are performed by dividing the basin into eight segments:

1. Lake Apopka Basin
2. “Superpond”—Lakes Dora, Eustis, and Harris
3. Lake Griffin to the Ocklawaha River near Conner
4. Ocklawaha River near Conner to Rodman Dam
5. Newnans Lake Basin
6. Paynes Prairie Basin
7. Orange / Lochloosa Basin
8. Orange Creek subbasin

Five hydrologic computer simulations were used. These are described in the following sections.

<u>Simulation 1—Existing Conditions</u>. Simulations for the Existing conditions consider existing land use, current lake regulation schedules, current spring flows, and the current potentiometric surface of the Floridan aquifer (in the case of Orange Lake). The environmental analyses extensively use the

streamflow and stage data generated by the hydrologic simulations. The majority of the hydrologic modeling results are presented in the environmental assessment section of this document.

Simulation 2—2010 Conditions. No significant changes are projected either in the land use or in surface water withdrawals for 2010. Groundwater withdrawals, however, are projected to be substantially greater for 2010, which would result in a decrease in spring discharges in the basin. This reduction in spring discharges would decrease the surface water levels and/or discharges at various locations along the Ocklawaha River. In the case of Orange Lake, the amount of seepage loss to the Floridan aquifer depends on the difference between the potentiometric surface of the aquifer beneath the lake and the lake surface elevation. Typically, a declining potentiometric surface increases this difference, resulting in greater seepage loss from the lake to the aquifer. To evaluate the long-term effect of the reductions in spring discharges and increased seepage on the surface water flows and levels in the ORB, hydrologic simulations are performed. These simulations provide stages and discharges for various locations under the reduced springflow and potentiometric surface conditions.

Simulation 3—Proposed Conditions. Simulations for Rodman Reservoir and Riverside Landing (located approximately 1 mile downstream from Rodman Dam) included a modified surface water level regulation schedule for Rodman Reservoir. The modified regulation criteria were aimed at maintaining the reservoir, to the degree possible, at 18.0 ft NGVD while maintaining discharge out of the reservoir at or above minimum desirable levels for downstream conditions. Additionally, the reservoir was operated so that discharges from the reservoir at the 90% stage exceedance probability equals that expected for the Full Restoration alternative. The existing regulation schedules were maintained at all other water control structures within the basin.

Simulation 4—Proposed-2010 Conditions. This hydrologic modeling alternative included the basin modifications for the 2010 and Proposed conditions listed above.

Simulation 5—Full Restoration-2010 Conditions. This modeling alternative assumed removal of the Rodman Dam and complete restoration of the historical Ocklawaha River channel and the basin conditions for the 2010 alternative listed above.

NATURAL SYSTEM IMPACT ASSESSMENT, by Greeneville Hall and Clifford Neubauer

Existing floodplain elevation transects within each of the major water bodies were used to typify and determine the elevation ranges for wetland plant communities. These transects were generally (1) perpendicular to the shore / bank of the water body or water course, (2) relatively undisturbed, (3) representative of the general vegetative conditions of the floodplains, and (4) extended from the open water or wetland areas, landward to upland areas. Elevations were determined by professional survey firms under contract or by SJRWMD survey crews. Traditional survey traverse methods were used, and elevations were referenced to NGVD 29. The location of these transects are shown in Figures 5–11.

The range and mean elevations of the floodplain vegetation communities were compared to the existing and predicted stage duration analyses, range of water level fluctuation (the difference between the minimum and maximum water levels), and mean period of record high and low stage frequency analyses for selected durations (number of consecutive days a water level was equaled or exceeded) for each major water body. Additional information used as important factors to assess water availability included (1) *Water Supply Needs and Sources Assessment* (Vergara 1994), (2) Soil Conservation Service soils maps, and (3) literature on endangered or listed species in major springs in the basin.

Consideration of impacts to smaller lakes and wetland resources present at higher elevations within the basin were not included in this assessment because of time constraints.

WATER AVAILABILITY STUDY, by Greeneville Hall and Marion Ritter

This evaluation was divided into two phases: a quantitative hydrologic evaluation and an economic analysis of transporting water. The first phase examined the quantity of surface water that could be removed from the LOR (Rodman Dam area) without causing unacceptable environmental impacts. It estimated the safe yield from surface waters available for consumptive uses. The hydrologic model included the predicted 2010 changes in surface water

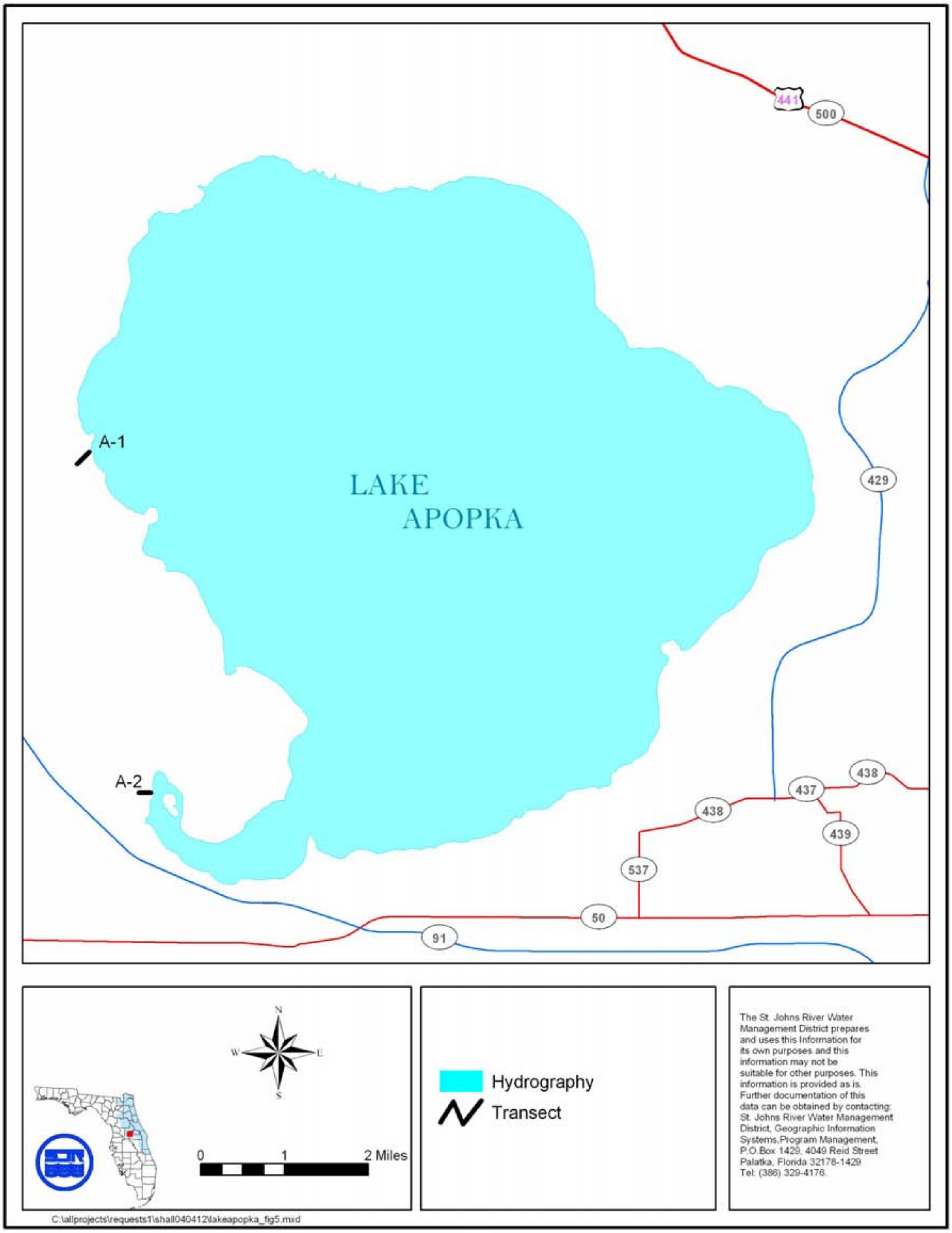


Figure 5. Location of elevation/vegetation transects at Lake Apopka

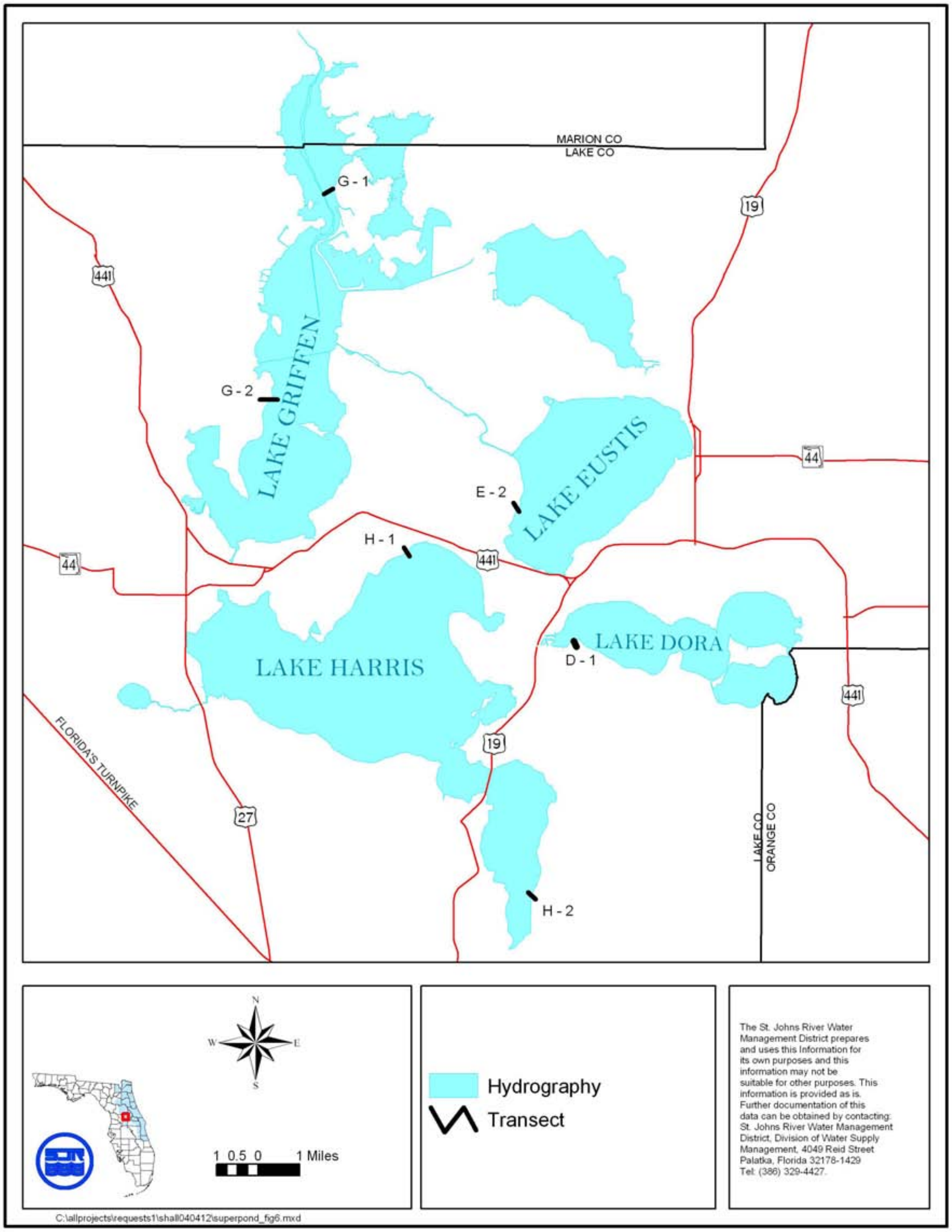


Figure 6. Location of elevation/vegetation transects at "Superpond" (Lakes Dora, Harris, and Eustis) and Lake Griffin

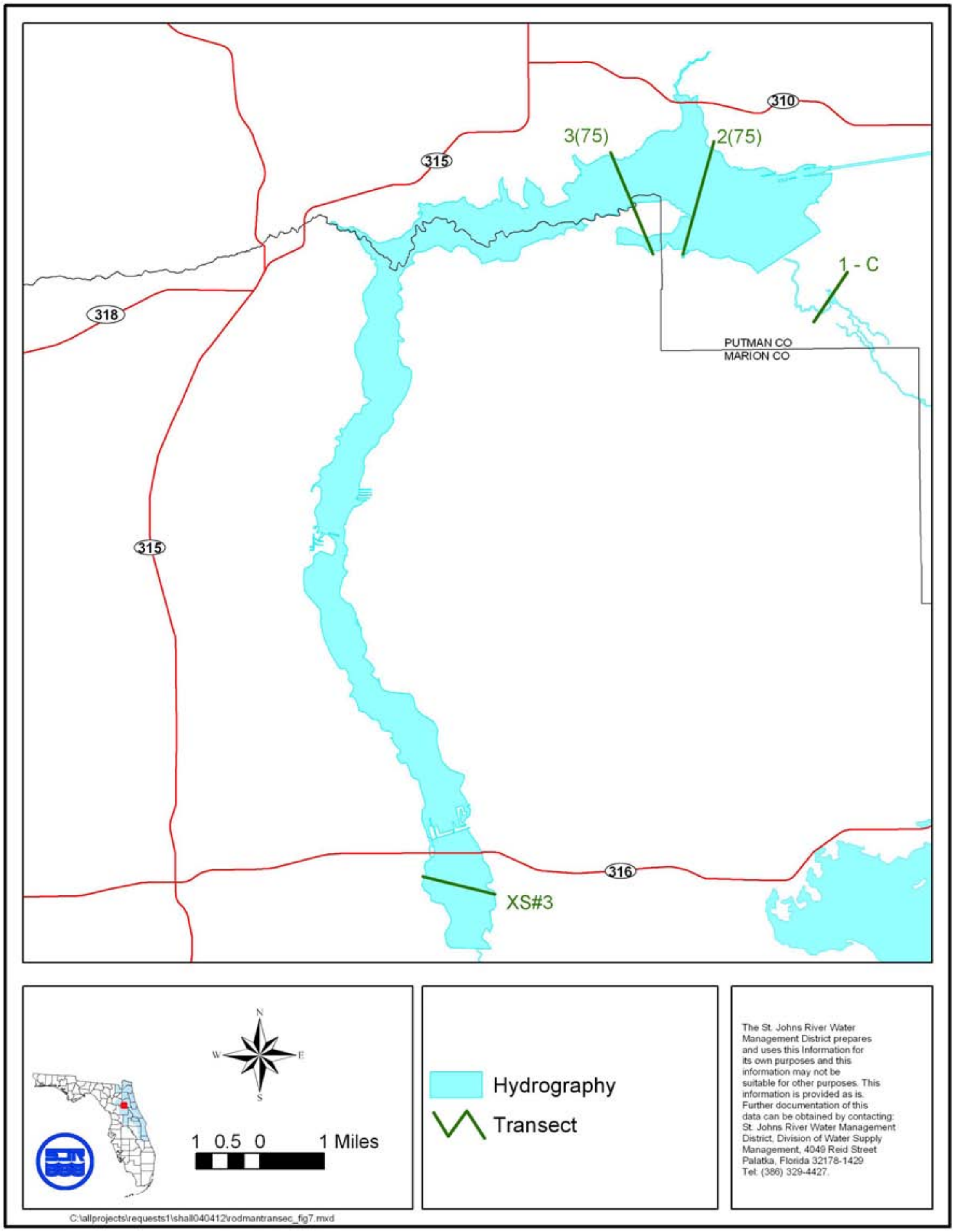


Figure 7. Location of elevation/vegetation transects at Rodman Reservoir

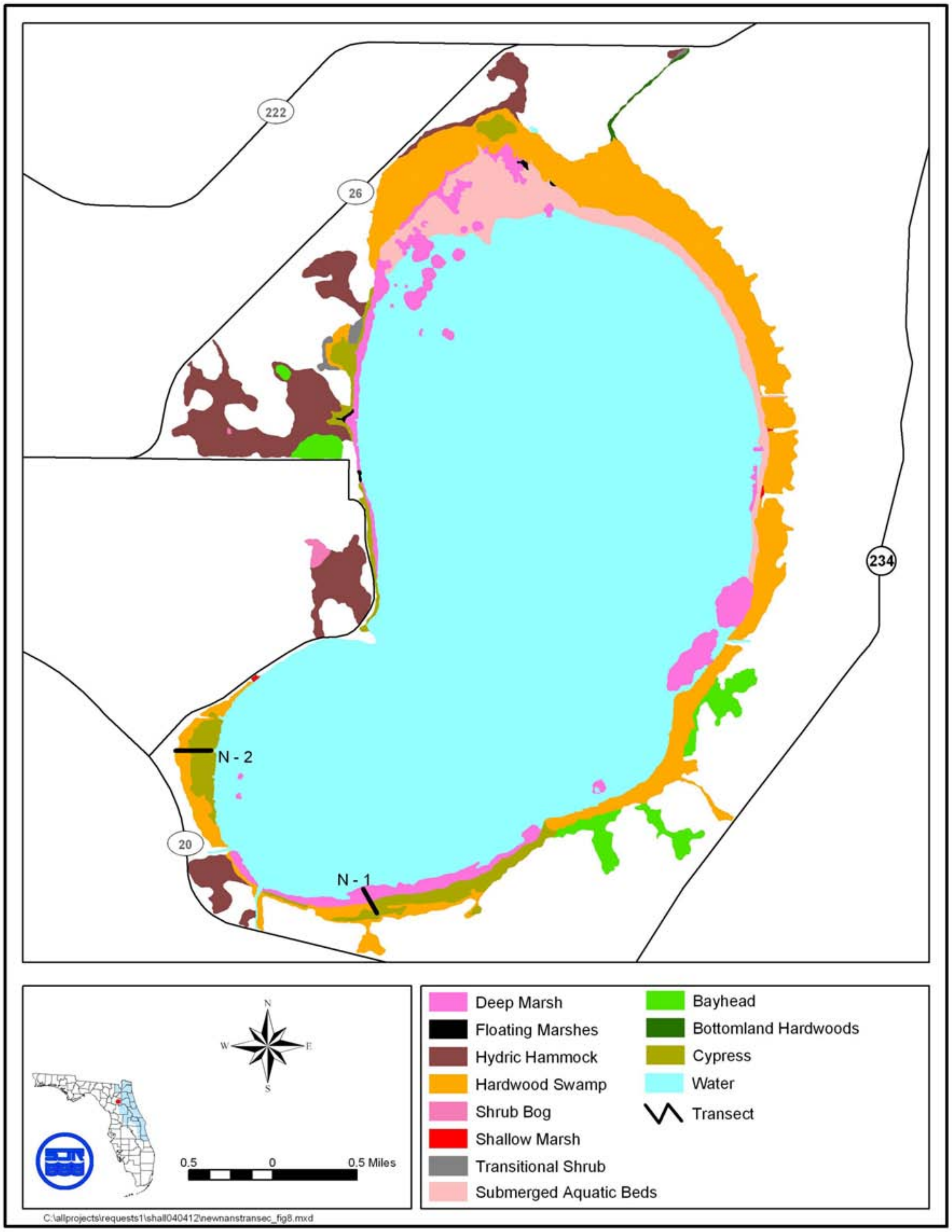


Figure 8. Location of elevation/vegetation transects at Newnans Lake

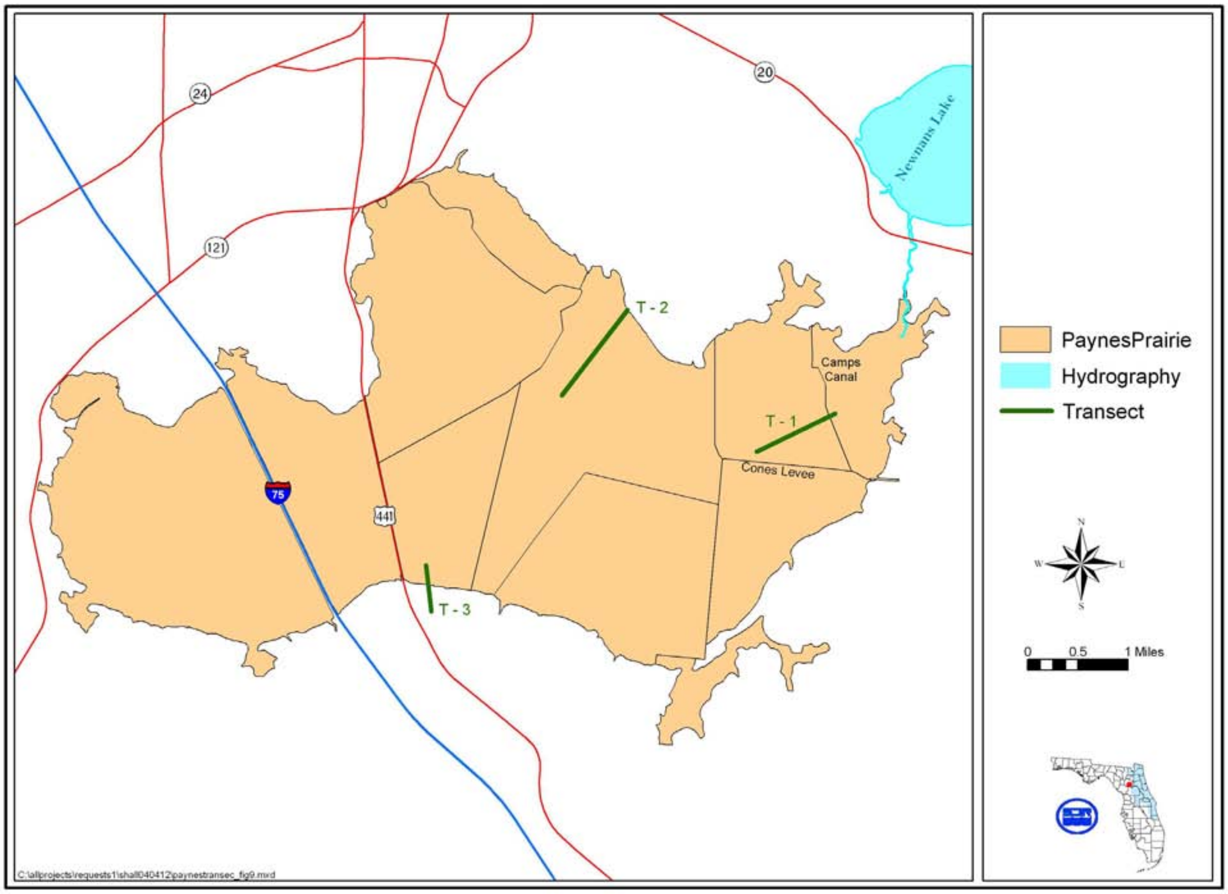


Figure 9. Location of elevation/vegetation transects at Paynes Prairie

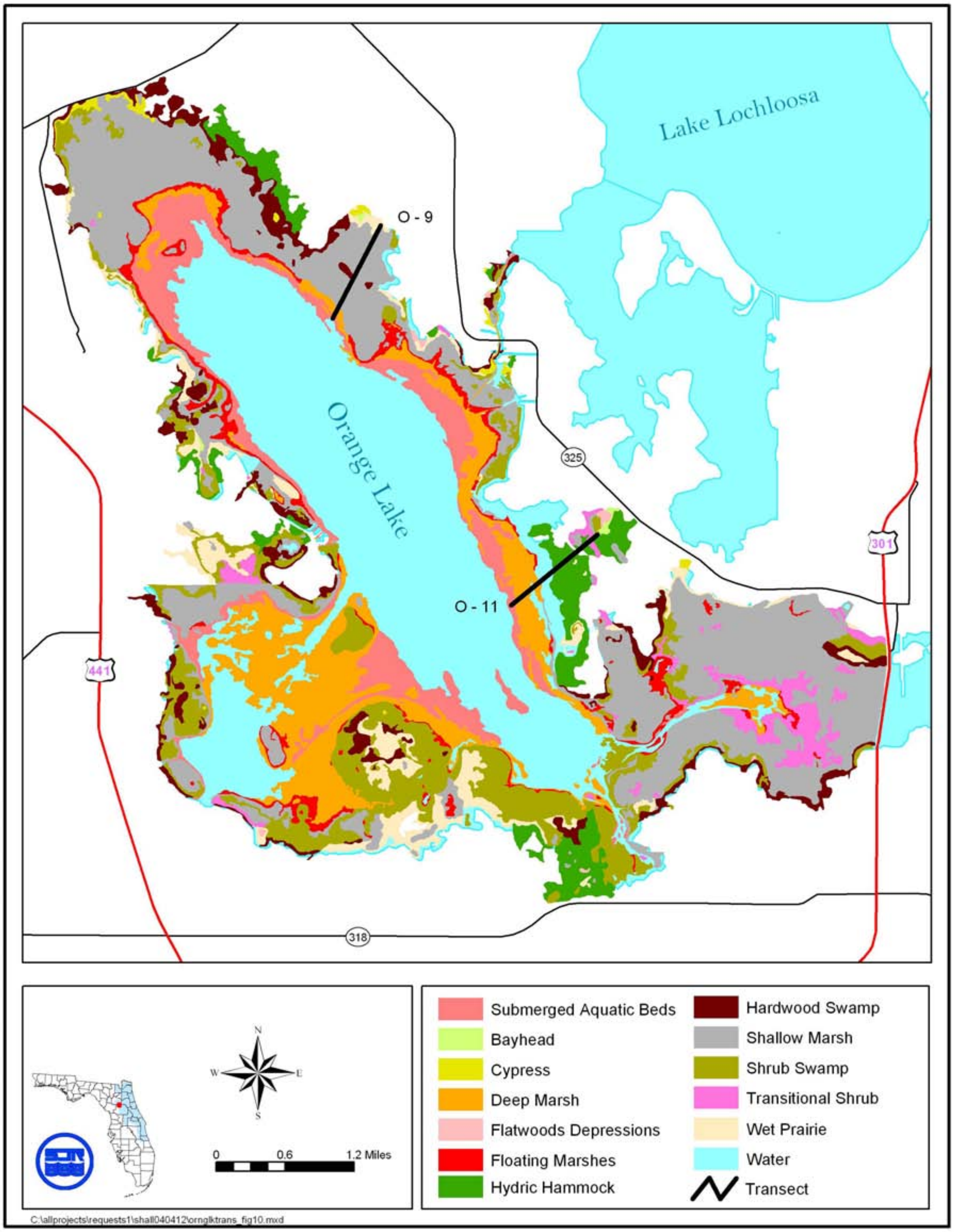


Figure 10. Location of elevation/vegetation transects at Orange Lake

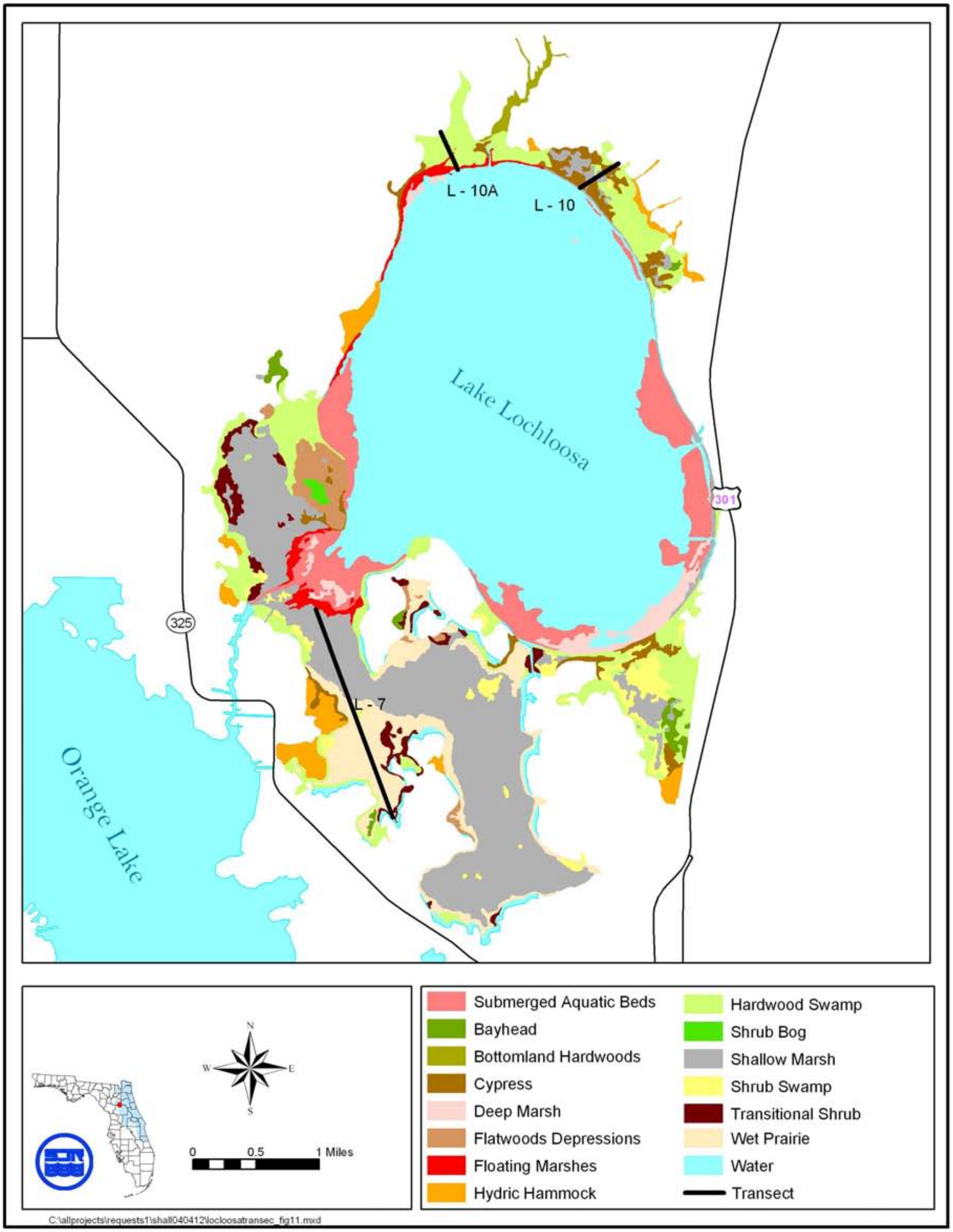


Figure 11. Location of elevation/vegetation transects at Lake Lochloosa

hydrology resulting from projected increased groundwater withdrawals. Four surface water withdrawals (0, 165, 250, and 330 cubic feet per second [cfs]) were simulated for the following surface water management alternatives: (1) Existing-2010 hydrologic conditions, (2) Proposed-2010 hydrologic conditions, and (3) Full Restoration-2010 hydrologic conditions (removal of Rodman Reservoir). The second phase compared the cost of transporting water various distances to the cost of utilizing water of lesser quality available in the locality and providing a treatment such as reverse osmosis to meet use demands and water quality standards.

RESULTS

WATER ALLOCATION STUDY

Groundwater, by Ching-tzu Huang

Groundwater uses within the ORB are predicted to increase significantly by 2010 (Vergara 1994). Public supply/commercial industrial and agriculture uses account for the largest groundwater withdrawals. The predicted increase in groundwater withdrawals by 2010, if realized, would lower the potentiometric levels of the surficial and Floridan aquifer systems throughout the basin. However, the most significant projected decreases have been identified for the UOR subbasin as a result of projected increases in groundwater withdrawals associated with public supply water use in Orange, Lake, Sumter, and Marion counties.

The following sections describe the locations and characteristics of major springs identified within the ORB and the quantitative assessment of potential spring discharge reductions due to predicted increased groundwater withdrawals by 2010. The potential spring discharge reduction impacts were determined based upon the projected future groundwater withdrawals from the ORB. Though these projected future water withdrawals may not actually occur, the potential of spring discharge reductions are evident if no remedial actions are taken. The primary purpose of the SJRWMD water supply needs and sources assessment (Vergara 1994) was to identify potential unacceptable decreases in spring flow to support efforts to avoid such unacceptable impacts.

The results of the spring discharge reduction percentages for eight springs in the ORB are summarized in Table 1. The projected potential percentage reductions in spring flows ranged from 5.4% to 70.0%. The maximum spring discharge reduction was 58.5 cfs (-7%) at Silver Springs in Marion County, and the minimum reduction was <0.1 cfs (-8%) at Magnesia Spring in Alachua County.

Description of Springs in Alachua County

Glen Springs. Glen Springs is located in the northwest part of the city of Gainesville at latitude 294027 north and longitude 822050 west (Figure 12). The spring run flows in a southeastward direction into Hogtown Creek in the

Table 1. Springs contributing significant discharges to the Ocklawaha River

Spring	Location		Floridan Aquifer 1988 (ft NGVD)	Floridan Aquifer 2010 (ft NGVD)	Spring Pool (ft NGVD)	Average Discharge (cfs)	Projected Discharge (cfs)	Discharge Change (%)
	Latitude	Longitude						
Glen Springs	29 40 27	82 20 50	38.6	38.4	N/A	0.4	0.4	N/A
Magnesia Spring	29 34 58	82 09 00	76.3	75.9	72.0	0.8	0.7	-7.9
Orange Spring	29 30 38	81 56 38	63.5	62.9	54.0	7.6	7.2	-5.4
Silver Springs	29 12 57	82 03 15	45.0	44.8	42.0	820.0	761.5	-7.1
Bugg Spring	28 45 07	81 54 06	75.0	73.8	70.0	14.5	11.1	-23.5
Blue Springs	28 44 55	81 49 41	71.0	67.5	65.0	3.0	0.9	-70.0
Holiday Springs	28 43 54	81 49 05	71.9	68.5	65.0	3.6	1.6	-56.3
Apopka Spring	28 34 00	81 40 51	68.2	67.6	67.0	36.0	21.3	-40.8

Note: cfs = cubic feet per second
ft NGVD = feet National Geodetic Vertical Datum
NA = not applicable

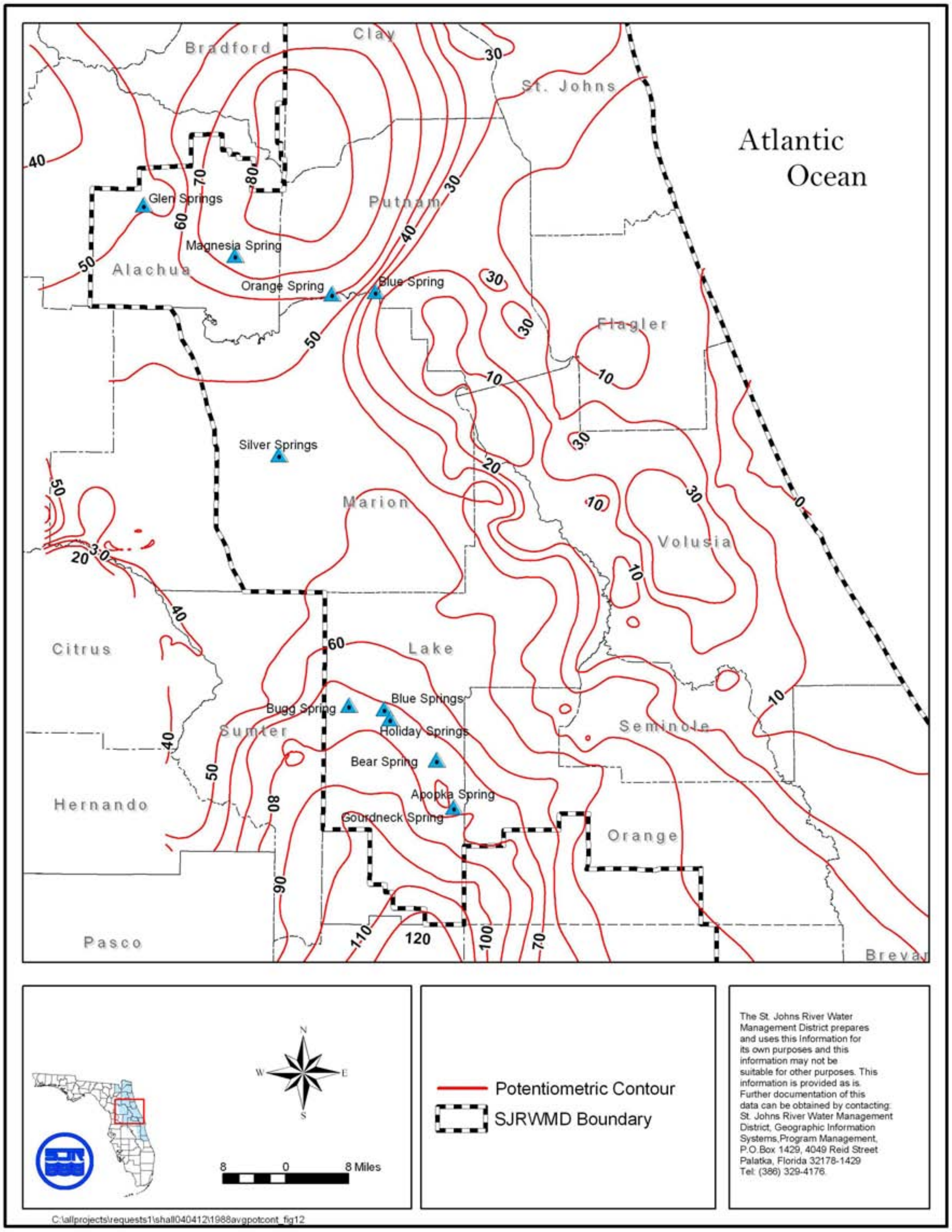


Figure 12. Location of major springs within the Ocklawaha River Basin

northwest end of the ORB. Glen Springs is enclosed by a concrete wall which directs the flow of water into two concrete swimming pools built downstream from the springs. The water flows through the pools, then down a ravine to Hogtown Creek. Because of the location of the spring, there is some question as to whether the source of water for this spring is the Floridan aquifer. Because no spring pool elevation data at Glen Springs are available, an estimation of the sources of spring flow was first developed and used to predict the spring pool elevation. The assumptions used to estimate spring pool elevation at Glen Springs are as follows. The land surface elevation, using the SJRWMD geographic information system (GIS) database, is about 159 ft NGVD. The spring pool at Glen Springs is located in a depressed area. It is estimated that the spring pool elevation is probably higher than 100 ft NGVD but less than the land surface elevation. The potentiometric surface elevations of the Floridan aquifer for 1988 and 2010 model simulations at Glen Springs were 38.58 and 38.40 ft NGVD, respectively. The potential effect of predicted groundwater withdrawal from the Floridan aquifer on Glen Springs discharge was, therefore, insignificant (Table 1).

Magnesia Spring. Magnesia Spring is located approximately 4 miles west of the town of Hawthorne at latitude 293458 north and longitude 820900 west (Figure 12). The spring discharges into Lochloosa Creek, which flows into Lochloosa Lake. The spring is enclosed by a concrete wall, and a control gate allows flow from a surface outlet into an open ditch. The spring run flows eastward and southward to Lochloosa Creek. The base of the spring pool is a clayey sandy material. The spring discharges from two holes at the base of the pool (Rosenau et al. 1977). Clark et al. (1964) stated that this spring seems to discharge from the Floridan aquifer. The average discharge, based on 5 years measured data, is 0.79 cfs (511,330 gallons per day [gpd]). Magnesia Spring is a privately owned low-flow, fourth-magnitude spring.

Based on a 1977 potentiometric elevation map, the spring pool elevation at Magnesia Spring was estimated to be 72 ft NGVD. The potentiometric elevations of the Floridan aquifer for 1988 and 2010 at Magnesia Spring were 76.27 and 75.93 ft NGVD (SJRWMD GIS database). The head difference in the Floridan aquifer between 1988 and 2010 was 0.34 ft. The ratio between the projected spring discharge reduction and the 1988 spring discharge at Magnesia Spring was calculated to be 7.88%.

Description of Springs in Marion County

Orange Spring. Orange Spring is located at the northern edge of the town of Orange Springs at latitude 293038 north and longitude 815638 west (Figure 12). The spring discharges to Orange Creek and flows about 2 miles to the Ocklawaha River. Orange Spring is bordered by a concrete wall which is about 2 ft above the surface of the water. The discharge to Orange Creek is through a weir in the concrete wall on the north end of the pool. The visible part of the bottom of the pool is mostly white sand. The measured spring discharge on September 11, 1972, was 7.59 cfs (4,905,200 gpd). Orange Spring is a third-magnitude spring and is privately owned (Rosenau et al. 1977).

Based on a 1977 potentiometric elevation map, the spring pool elevation at Orange Spring was estimated to be 54 ft NGVD. The potentiometric elevations of the Floridan aquifer for 1988 and 2010 at Orange Spring were 63.45 and 62.94 ft NGVD (SJRWMD GIS database). The projected head difference in the Floridan aquifer between 1988 and 2010 was 0.51 ft. The projected average 2010 spring discharge at Orange Spring was calculated to be 5.45% less than the 1988 spring discharge.

Silver Springs. Silver Springs is located at the western edge of the Ocklawaha River valley at latitude 291244 north and longitude 820315 west (Figure 12). It is located at the headwaters of the Silver River and flows through the eastward winding river about 5 miles to the Ocklawaha River. The primary spring is located at the head pool, and several smaller springs are located in the river bed or in the sides of the river. The flow at Silver Springs is supplied through a large connecting system of solution channels. The maximum and minimum recorded spring discharges are 1,290 cfs (833,690,880 gpd) and 539 cfs (348,340,600 gpd). The average spring discharge, based on measured data from October 1932 through September 1974, was 820 cfs (529,943,000 gpd). Silver Springs is a first-magnitude spring and the largest spring in SJRWMD (Rosenau et al. 1977).

Based on a 1977 potentiometric elevation map, the spring pool elevation at Silver Springs was estimated to be 42 ft NGVD. The potentiometric elevations of the Floridan aquifer for 1988 and 2010 at Silver Springs were 45.00 and 44.79 ft NGVD (SJRWMD GIS database). The projected head difference in the Floridan aquifer between 1988 and 2010 was 0.21 ft. The projected average 2010 spring discharge at Silver Springs was calculated to be 7.13% less than the 1988 spring discharge.

Description of Springs in Lake County

Bugg Spring. Bugg Spring is located approximately one-half mile northwest of Okahumpka at latitude 284507 north and longitude 815406 west (Figure 12). The spring flows about 1 mile into Helena Run. Helena Run then flows in a eastward direction about 1.2 miles into Lake Harris. The spring is leased by the Navy from a private owner and is used as an underwater research facility. This spring is not open to the public. The average discharge rate is 14.5 cfs (9,370,950 gpd), based on 6 years of measured discharge data. Bugg Spring is a second-magnitude spring (Rosenau et al. 1977).

Based on a 1977 potentiometric elevation map, the spring pool elevation at Bugg Spring was estimated to be 70 ft NGVD. The potentiometric elevations of the Floridan aquifer for 1988 and 2010 at Bugg Spring were 75.01 and 73.83 ft NGVD (SJRWMD GIS database). The projected head difference in the Floridan aquifer between 1988 and 2010 was 1.18 ft. The projected 2010 spring discharge at Bugg Spring was calculated to be 23.55% less than the 1988 spring discharge.

Blue Springs. Blue Springs is located on the southeast shore of Lake Harris at latitude 284455 north and longitude 814941 west (Figure 12). The spring is enclosed by a concrete retaining wall that forms a swimming pool, with a natural sandy bottom. The spring is used as a swimming and recreational facility by local residents. The pool discharges through a weir in the retaining wall and flows into a run that forms a lagoon which drains into the southeast end of Lake Harris. The spring is privately owned and not open to the public. The discharge rate measured on March 30, 1972, was 3.04 cfs (1,964,670 gpd). Blue Springs is a third-magnitude spring (Rosenau et al. 1977).

The spring pool elevation at Blue Springs was estimated to be 65 ft NGVD (GeoTrans 1992). The projected spring reduction percentage (1988 to 2010) at Blue Springs was evaluated and reported in Vergara 1994. The average projected 2010 spring discharge was reported as 70.0% less than the 1988 median spring discharge.

Holiday Springs. Holiday Springs is located at Yalaha near the southern shore of Lake Harris at latitude 284354 north and longitude 814905 west (Figure 12). The water from the spring flows in a northward direction down a gently meandering run about one-quarter mile to Lake Harris. The owner of the spring uses the water for domestic use, to fill a private swimming pool, and for freeze protection of fernery growth. The average discharge rate is 3.90

cfs (2,520,460 gpd), based on 5 years of measured discharge data. Holiday Springs is a third-magnitude spring (Rosenau et al. 1977).

The spring pool elevation at Holiday Springs was estimated to be 65 ft NGVD (GeoTrans 1992). The projected spring reduction percentage (1988 to 2010) at Holiday Springs was evaluated and reported in Vergara 1994. The average projected 2010 spring discharge was reported as 56.3% less than the 1988 median spring discharge at Holiday Springs.

Apopka Spring. Apopka Spring, which is also known as Gourdneck Spring, is located near the southwest edge of Lake Apopka at latitude 283400 north and longitude 814051 west (Figure 12). The flow from the spring moves eastward down a run to the "Gourd Neck," which is a narrow arm of Lake Apopka that curves northwestward from the southwest tip of the main body of the lake. The spring has no particular uses (Rosenau et al. 1977). The discharge rate measured on May 4, 1971, was 38.40 cfs (3,317,760 gpd). Apopka Spring is a second-magnitude spring.

The spring pool elevation at Apopka Spring was estimated to be 67 ft NGVD (GeoTrans 1992). The projected spring reduction percentage at Apopka Spring was evaluated and reported in Vergara 1994. The projected 2010 spring discharge was reported as 40.8% less than the 1988 median spring discharge at Apopka Spring.

Streamflow

The results of the streamflow analyses, relating the changes in spring flows to changes in streamflow and lake levels, have been incorporated into the Natural System Impact Assessment and are discussed as a part of that section.

Surface Water, by Cynthia Moore and Marion Ritter

The surface water analysis was limited to an examination of the water use associated with water removed directly from the surface water source and the resulting determination of no unacceptable impact on the natural community as a result of that water use.

The primary source of existing water use data was the SJRWMD consumptive use permitting database. The information is stored in different files in the database, depending upon the major water use category of the permit holder.

The major distinction is made between public supply and commercial/industrial uses and all other uses, of which the largest is agricultural. Information on the owner, the product produced, the amount of permitted water use in million gallons per year (mgy), and the location in longitude/latitude of pumps and the source of the surface water was obtained for each "permitted" use falling within the basin boundaries. Permitted surface water was used for the following purposes: agricultural irrigation of citrus, vegetables, pasture, horticulture, nursery, and landscape; sand mining; and irrigation of golf courses.

Vergara (1994) determined the existing water use from SJRWMD databases, information from users, and studies performed for SJRWMD by the University of Florida. These studies presented data by county rather than by hydrologic units such as river basin boundaries. In the case of commercial and industrial water uses, the data were obtained from water utility service units, and the individual permits contained map reference locations; therefore, it was possible to associate them with specific basin boundaries. These water utility service units provided projections of their future 2010 water use, and it was possible to associate these data with the ORB. In the case of agriculture and golf course irrigation, the future projected information is available at the county level only.

Public supply/commercial industrial users obtain the major amount of their water from groundwater (Table 2). However, commercial/industrial users in Lake, Polk,[1] and Putnam counties utilize surface water as a source of supply, but no significant increase is projected through 2010.

There is agricultural surface water use in Lake, Marion, Orange, and Polk counties. Based on information contained in a study by Lynne, Kiker et al. (1992), Alachua, Polk, and Putnam counties show insignificant or no increases in agricultural acreage under cultivation in 2010 when compared with the 1995 acreage under cultivation. With the introduction of best management practices, ground and surface water use is projected to decrease in these counties. This study also projected the agricultural acreage under cultivation to increase in Marion, Orange, and Lake counties by 2010. Of the total amount of agricultural water used in Marion and Orange counties in 1995, surface water represents 13% of the total agricultural water use in Marion County and 68% of the total agricultural water use in Orange County.

[1]As of July 1, 2003, the portion of the St. Johns River Water Management District that was in Polk County became part of the Southwest Florida Water Management District.

Table 2. Permitted 1995 and projected 2010 water use within the Ocklawaha River Basin, in million gallons per year. The projected 2010 golf course use in the basin was not available.

Type Use	Groundwater Use			Surface Water Use		
	1995	2010	% Increase	1995	2010	% Increase
Alachua County						
PS/CI	9,313.197	11,536.097	24.0	0.000	0.000	0.0
Ag	1,207.760	1,207.760	0.0	0.000	0.000	0.0
Other	412.30	412.230	0.0	0.000	0.000	0.0
Golf	500.100	(625.123)	(25.0)	0.000	0.000	0.0
Total	11,433.287	(13,781.212)	(21.0)	0.000	0.000	0.0
Lake County						
PS/CI	18,421.314	23,526.784	28.0	34.500	34.500	0.0
Ag	23,129.704	27,669.704	20.	4,764.450	4,764.450	0.0
Other	159.070	159.070	0.0	0.000	0.000	0.0
Golf	628.969	(1,195.041)	(9.0)	421.955	(797.495)	(89.0)
Total	42,339.057	(52,550.599)	(24.0)	5,220.910	(5,596.445)	(07.2)
Marion County						
PS/CI	2,548.586	2,548.586	0.0	0.000	0.000	0.0
Ag	4,549.944	4,549.944	0.0	573.110	573.110	0.0
Other	4.830	4.830	0.0	0.000	0.000	0.0
Golf	130.820	(217.161)	(66.0)	0.000	0.000	0.0
Total	7,234.180	(7,320.521)	(01.2)	573.110	573.110	0.0
Orange County						
PS/CI	4,953.166	9,733.336	97.0	0.000	0.000	0.0
Ag	6,986.15	6,986.15	0.0	10,238.470	10,238.470	0.0
Other	0.000	0.000	0.0	0.000	0.000	0.0
Golf	409.300	(720.368)	(76.0)	8.085	(14.800)	(83.0)
Total	12,349.081	(17,443.319)	(41.0)	10,246.555	(10,253.270)	(0)
Polk County						
PS/CI	992.818	992.818	0.0	238.000	238.000	0.0
Ag	2,441.404	2,441.404	0.0	17.610	17.610	0.0
Other	0.000	0.000	0.0	0.000	0.000	0.0
Golf	30.700	(30.70)	0.0	0.000	0.000	0.0
Total	3,464.922	(3,464.922)	0.0	255.610	255.610	0.0
Putnam County						
PS/CI	653.792	708.552	8.0	273.700	273.700	0.0
Ag	22.620	22.620	0.0	0.000	0.000	0.0
Other	0.000	0.000	0.0	0.000	0.000	0.0
Golf	0.000	0.000	0.0	0.000	0.000	0.0
Total	676.412	731.172	8.0	273.700	278.700	0.0

Note: PS/CI = public supply/commercial industrial
Ag = agricultural
Other = nursery, power production, recreation, etc.
Golf = golf course

Numbers in ( ) represent total county percent increases in Table 4 applied to the existing values "within the Ocklawaha River Basin"

This percentage by county is projected to remain the same in 2010. With the introduction of best management practices, surface water use in both Marion and Orange counties is supposed to be approximately the same as the 1995 agricultural use. In Lake County, surface water represents approximately 22% of the total existing agricultural water use in the county. This water is obtained from isolated lakes and impoundments not connected to the Ocklawaha River system. Contacts with the Cooperative Extension Service in Lake County confirmed that the major future agricultural water supply is projected to be obtained from groundwater. In those limited cases where it is projected that new surface water will be used, it is projected that it will be obtained from similar sources to that of the existing use, and the impacts of its withdrawal will require a site-by-site evaluation as each site is proposed for future use.

A separate study by Lynne, Moore et al. (1992) was undertaken to examine golf course water use. The information in the study is available at the county level only, and a specific determination of the impacts in the ORB is not readily accomplished. Existing and projected 2010 golf course water use is shown in Tables 3 and 4. As is evident by the tables, golf course water use represents a very small use in terms of overall water use. A large part of the future golf course use is projected to be obtained from on-site retention ponds and reuse water obtained from wastewater treatment plants located in the course development area. The future projected water use data do not specifically locate each use, and the impacts of these withdrawals will require a site-by-site evaluation as each site is proposed for use.

Table 3. Total county golf course water use, in millions of gallons per year

County	1990 Water Use			2010 Water Use			Percent of Total	
	Surface	Ground	Total	Surface	Ground	Total	Percent Including Surface	Percent Including Ground
Alachua	40.150	664.300	704.450	54.750	832.200	886.950	2	24
Lake	379.600	507.350	886.950	715.400	963.600	1,679.000	38	51
Marion	266.450	423.400	689.850	419.750	697.150	1,116.900	22	40
Orange	193.450	1,032.950	1,226.400	354.050	1,817.700	2,171.750	13	64
Polk	0.000	0.000	0.000	0.000	0.000	0.000	0	0
Putnam	0.000	113.150	113.150	0.000	156.950	156.950	0	39
Total	879.650	2,741.170	3,620.800	1,543.950	4,467.600	6,011.550	18	63

Table 4. Percent increase in golf course water use between 1990 and 2010, in million gallons per day

County	Surface Water Use				Groundwater Use			
	1990	2010	Difference	% Increase	1990	2010	Difference	% Increase
Alachua	40.150	54.750	14.6	36	664.300	832.200	167.90	25
Lake	379.600	715.400	335.8	89	507.350	963.600	456.25	90
Marion	266.450	419.750	153.3	58	423.400	697.150	273.75	66
Orange	193.450	354.050	160.6	83	1,032.950	1,817.700	784.75	76
Polk	0.000	0.000	0.0	0.	0.000	0.000	0.00	0
Putman	0.000	0.000	0.0	0	113.150	156.950	43.80	38
Total	879.650	1,543.950	664.3	75	2,741.170	4,467.600	1,726.45	48

Based on this analysis, no conflict is projected to exist between the human consumptive surface water use and the natural community surface water use during the period extending to 2010. For those incidents where increased consumptive use is projected, the site-by-site evaluations should provide adequate resolution for any negative impacts to the natural community.

Natural System Impact Assessment, by Greeneville Hall and Clifford Neubauer

Aquatic, wetland, and estuarine communities exist and are maintained by specific physical, chemical, and hydrologic requirements. The plant and animal species which inhabit these communities in Florida have adapted and evolved to the “historical” physical, chemical, and hydrologic conditions. Therefore, although Florida receives generally greater than 50 inches of rainfall on average per year, a significant portion of the annual precipitation is required to protect and maintain aquatic, wetland, and estuarine communities. Sufficient changes to these requirements will result in changes to the biological structure and functions of these systems. Estuaries require freshwater inflows of sufficient quantity and quality, as well as timing, to maintain the proper ranges of water salinities and to protect the structure and functions of these communities. Lotic (stream) and lentic (lake) aquatic systems require sufficient water flows and / or levels; significant reductions to a hydrologic regime may cause open-water habitat to become herbaceous or woody wetlands.

Wetland communities generally exist along an elevation gradient between permanently flooded, open-water areas of lakes or rivers, to upland areas which are generally not inundated or saturated by water. Wetlands may exist because of seepage of water from higher elevations or higher potentiometric surfaces near springs, or be maintained by inundation and overflow from aquatic systems. Wetland plant and animal species are adapted to periods of wet and dry and require water depths of sufficient duration and return intervals to exist as viable communities. Therefore, during any evaluation of the water availability for human uses (groundwater and surface water withdrawals, diversion projects, water discharge regulation schedules, etc.), the potential environmental impacts to the biota of the floodplains must be assessed.

A water assessment for the ORB should focus upon the water quality and quantity needs of the aquatic and wetland communities because large aquatic and wetland areas exist in the basin. Providing for the hydrologic requirements of these aquatic and wetland systems should result in a release of surface water of proper quantity and quality to protect the estuary system of the lower St. Johns River.

The accuracy of these assessments is dependent upon (1) the knowledge of the hydrologic requirements of aquatic and wetland species and communities, (2) the types and quantity of field data from the area being assessed, and (3) the quality of predictive modeling tools. The knowledge base of hydrologic requirements of aquatic and wetland species is considered limited at this time. Improved understanding of the water requirements of Florida's ecosystems, coupled with improved predictive computer models (including data required to calibrate and verify these models), and better understanding of surface and groundwater interactions will result in more accurate estimates of water availability in the future.

The results of the natural system impact assessment are discussed in the following categories: (1) upper Ocklawaha River subbasin, (2) lower Ocklawaha River subbasin, and (3) Orange Creek subbasin.

Upper Ocklawaha River Subbasin

The UOR subbasin has three major water control structures. The regulation schedules for these structures have reduced the range of water level fluctuation by attenuating high and low water levels during wet and dry periods, respectively. The regulation schedules have also altered the timing of high and low water events; drawdown conditions occur during the rainy mid-summer months to reduce flood damage potential.

Analysis of historic and recent aerial photography and vegetation/elevation transect data on the floodplains of the major lakes of the subbasin indicated that wetland community structure and, therefore, functions, have changed under the existing surface water regulation schedules for the lakes. For example, marsh areas dominated by saw grass (*Cladium jamaicense*), present in the early 1940s, have changed to mixed hardwood swamp or maple swamp (*Acer rubrum*) because high water stages of the lakes have been truncated (high water levels are not allowed to occur because of flood control considerations) and because the lake has received excessive loads of phosphorus and nitrogen. A transition from marsh to swamp communities is expected when hydroperiod regimes are truncated by reducing maximum water levels for flood control purposes.

The reduction in hydroperiods is evident in Table 5 where the mean elevation of the hardwood swamp communities along transects at Lakes Apopka and Harris are inundated <2.5% of the time. Knochenmus (1967) indicated that the upland tree line elevation corresponded to approximately the 5% inundation exceedance level of a duration analysis from eight Florida lakes. The "old" swamp communities at these lakes are expected to shift toward hydric or mesic hammock, while the new maple swamp will become mixed hardwood swamp and is expected to replace sawgrass marsh communities. Reduction in the frequency of fire or a long-term drought may be other reasons why this observed community shift has occurred.

Table 5. Hydrologic conditions within major plant communities present along transects at Lake Apopka, "Superpond," and Lake Griffin

Location	Plant Community	Elevation		Inundation Frequency (%) by Hydrologic Conditions		
		Mean (feet)	Range (feet)	Existing	2010	Change*
Lake Apopka	Mesic hammock	72.2	68.5–74.8	0.0	0.0	0.0
	Hydric hammock	68.8	67.9–71.1	0.0	0.0	0.0
	Hardwood swamp	67.7	67.2–68.1	0.5	0.2	-0.3
Superpond	Mesic hammock	66.5	62.9–68.7	0.0	0.0	0.0
	Hardwood swamp	63.9	61.7–64.9	1.9	1.4	-0.5
	Cypress swamp	62.5	59.4–64.1	86.7	81.6	-5.1
	Shallow marsh	62.5	61.8–62.9	86.7	81.6	-5.1
Lake Griffin	Mesic hammock	63.6	59.1–67.9	0.0	0.0	0.0
	Hydric hammock	60.2	59.3–61.1	0.0	0.0	0.0
	Shrub swamp	58.4	57.6–59.3	65.4	63.6	-1.8
	Shallow marsh	58.2	57.8–58.2	73.8	72.0	-1.8

*Represents the difference in inundation frequency between the Existing and 2010 conditions

Marsh communities have not become established down-slope of the newly extended swamp communities because the floodplain is so steep-sided at the wetland / open-water boundary and because the lower water stages of the lakes have been truncated (low water levels have not been allowed to occur except during infrequent drawdowns). Additionally, many wetland plant species cannot become established unless “drawdown conditions,” which occur during drought periods, expose sediments to the atmosphere and allow seeds to germinate and become established. The current reservoir regulation schedule does not allow extreme low water levels to be achieved, which may prevent wetland plant seed germination and seedling establishment.

The projected increases in groundwater withdrawals by 2010 within the UOR subbasin are predicted to further lower stages within the major lakes of the basin. Surface water levels in Lake Apopka would be the most affected by the predicted increases in groundwater withdrawals. Noticeable shifts in water level durations were predicted to occur (Figure 13). The greatest changes in stage duration occurred on those portions of the floodplain which experienced long periods of inundation (>50%). An approximately 0.5-ft decrease in the elevation that corresponded to the 60th percentile of stage exceedance (inundated for 60% of the period of record), an inundation duration that typically corresponds to the mean elevation of emergent wetland, was predicted (Figure 13). The elevations corresponding to the 90th percentile duration were lowered by approximately 1 ft. Similarly, the recurrence and duration of inundation at any given floodplain elevation decreased. The changes were most consequential on the lower elevations of the floodplain.

Relatively minor reductions in the hydrologic regimes of the “Superpond” (Lakes Dora, Harris, and Eustis) and Lake Griffin were predicted (Table 5; Figures 14 and 15). The greatest changes in inundation frequency occurred on those portions of the floodplain which experienced long periods of inundation (>50%). However, the magnitude of these changes was generally less than 0.2 ft (Figures 14 and 15). Similarly, the stages predicted to meet selected recurrence intervals (how often an event occurred) and durations decreased; however, the changes were relatively small (<0.1 ft).

The overall effect on the hydrologic conditions in each of the major lakes was to further decrease the range of surface water fluctuation, and the frequency and duration that many of the floodplain wetland communities will be inundated.

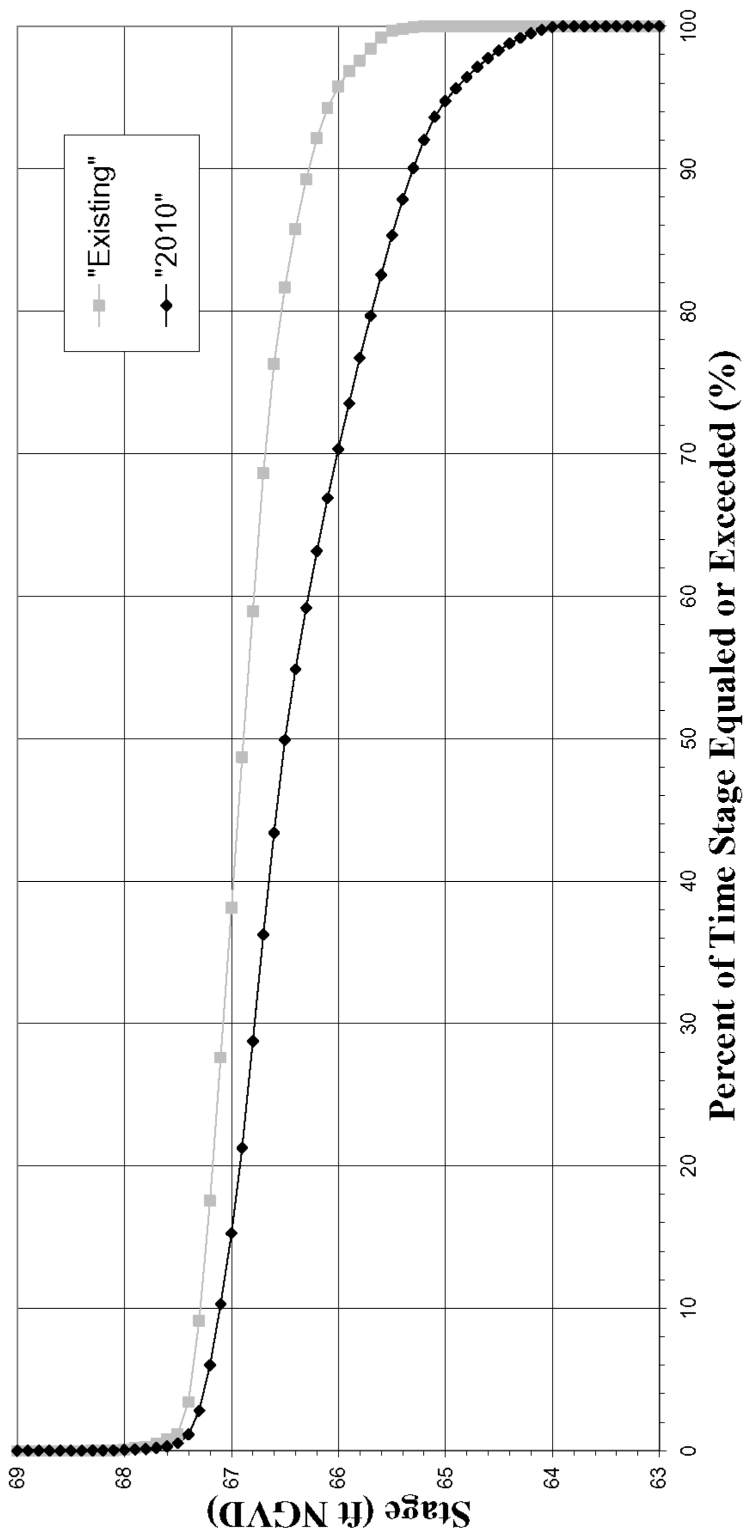


Figure 13. Stage duration analyses for Lake Apopka—Existing and 2010 hydrologic conditions

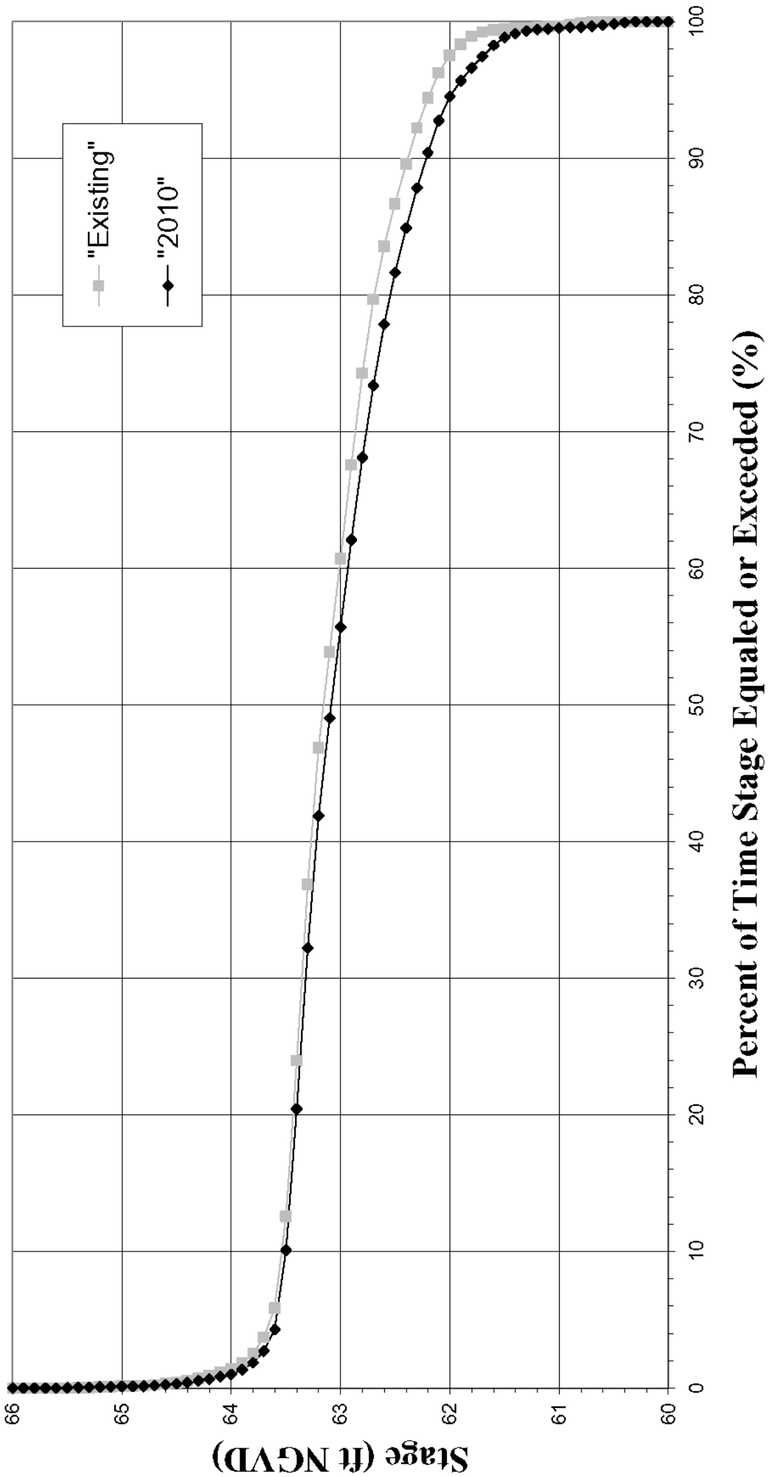


Figure 14. Stage duration analyses for "Superpond" (Lakes Dora, Harris, and Eustis)—Existing and 2010 hydrologic conditions

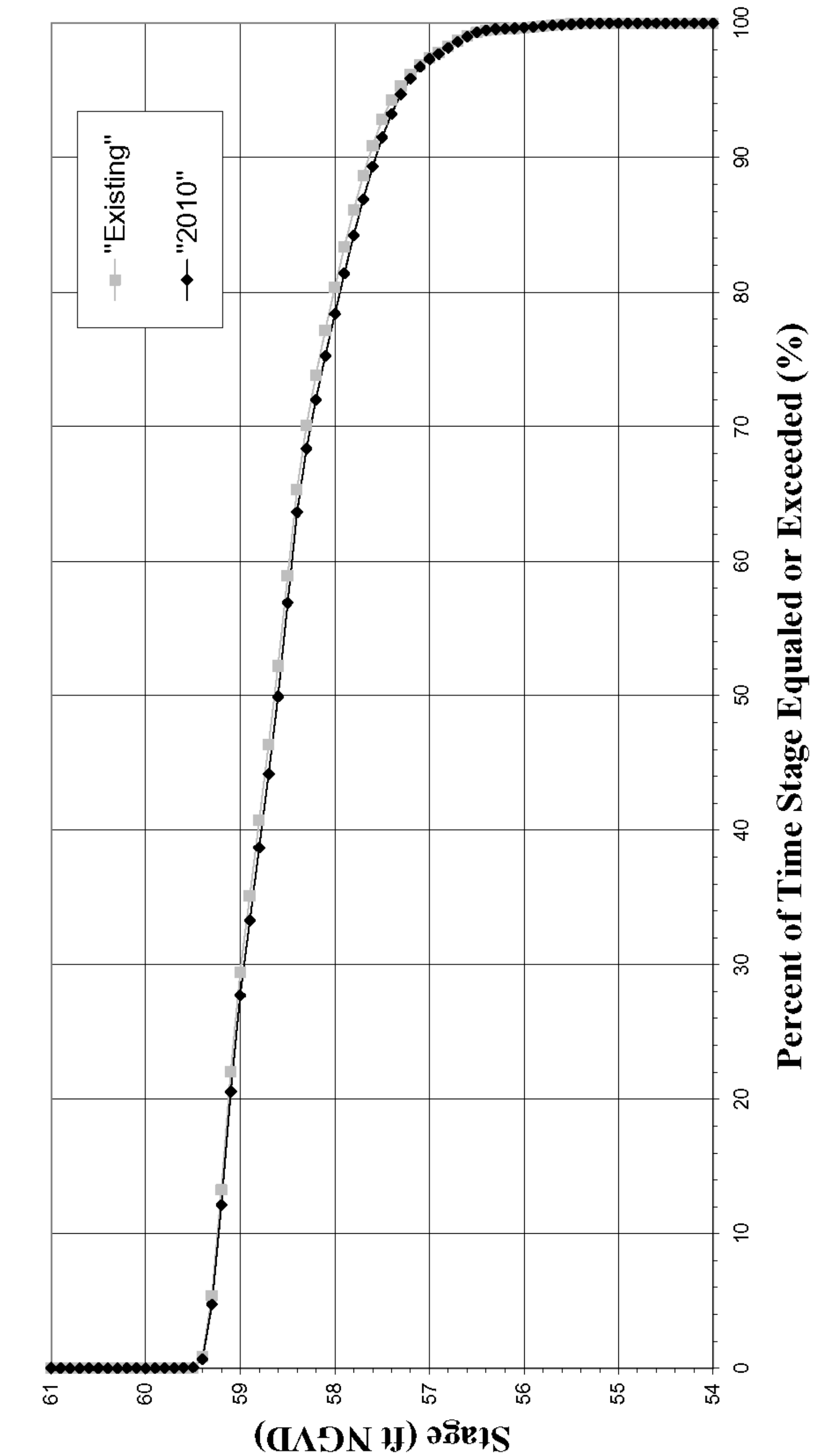


Figure 15. Stage duration analyses for Lake Griffin—Existing and 2010 hydrologic conditions

Lower Ocklawaha River Subbasin

Silver Springs and Silver River. An extensive study of Silver Springs and the upper Silver River was conducted by Odum (1957). The monograph includes a description of the Silver Springs community, estimates of community production and metabolism, water quality (nitrogen, phosphorus, oxygen, carbon dioxide, and hardness), and a community energy budget. The article mentions the potential of impacts to spring flows because of groundwater withdrawals for human consumptive use. Odum wrote in 1957: “A long history of permanency is of course no guarantee of a future, for when industry and large municipalities locate nearby, large springs cease flow as demands on the artesian groundwater lower the table. This has already happened at Kissingen Springs, Polk County, Florida and Palma Ceia Springs, Hillsborough County, Florida.”

The average spring discharge is predicted to decrease by 58.5 cfs, or 37.8 million gallons per day (mgd), by 2010 (Table 2). This represents a 7% decrease in average flow. The direct ecological impacts of reduced flow to the flora and fauna of the Silver River cannot be quantified at this time. No unique animal or plant species have been identified for Silver Springs. However, Odum (1957) does reference the possibility of distinct “races” among the hydrobiidae (small freshwater snails, Gastropoda). However, the reduction in flow may reduce fixed organic carbon inputs to the Ocklawaha River from Silver Springs and the Silver River. Odum (1957) estimated the primary production at Silver Springs and the upper Silver River at 6,390 grams / square meter / year (gm / m^2 / yr) (57,100 lb / acre / year) and that 766.8 gm / m^2 / yr (68.52 lb / acre / yr) of this production was carried downstream as organic matter in the form of seston (particulate organic matter).

Ocklawaha River at Eureka Dam. River flows and stages at Eureka Dam and downstream are dependent upon upstream inflows. Increases in groundwater usage were predicted to lower spring discharges in this reach, and Silver Springs contributes significantly to the base flow of this reach of the Ocklawaha River. Comparisons of the surface water stage duration analyses for the Existing conditions and the predicted 2010 hydrologic conditions at Eureka Dam showed no consequential changes (Figure 16), nor did frequency analyses (selected durations of mean period of record high and low water levels). The range of surface water fluctuation was predicted to be 0.7 ft lower for 2010. While this is not an insignificant change, the potential impacts to the floodplain wetland communities are negligible. The greatest reduction in inundation frequency occurs at the highest floodplain elevations

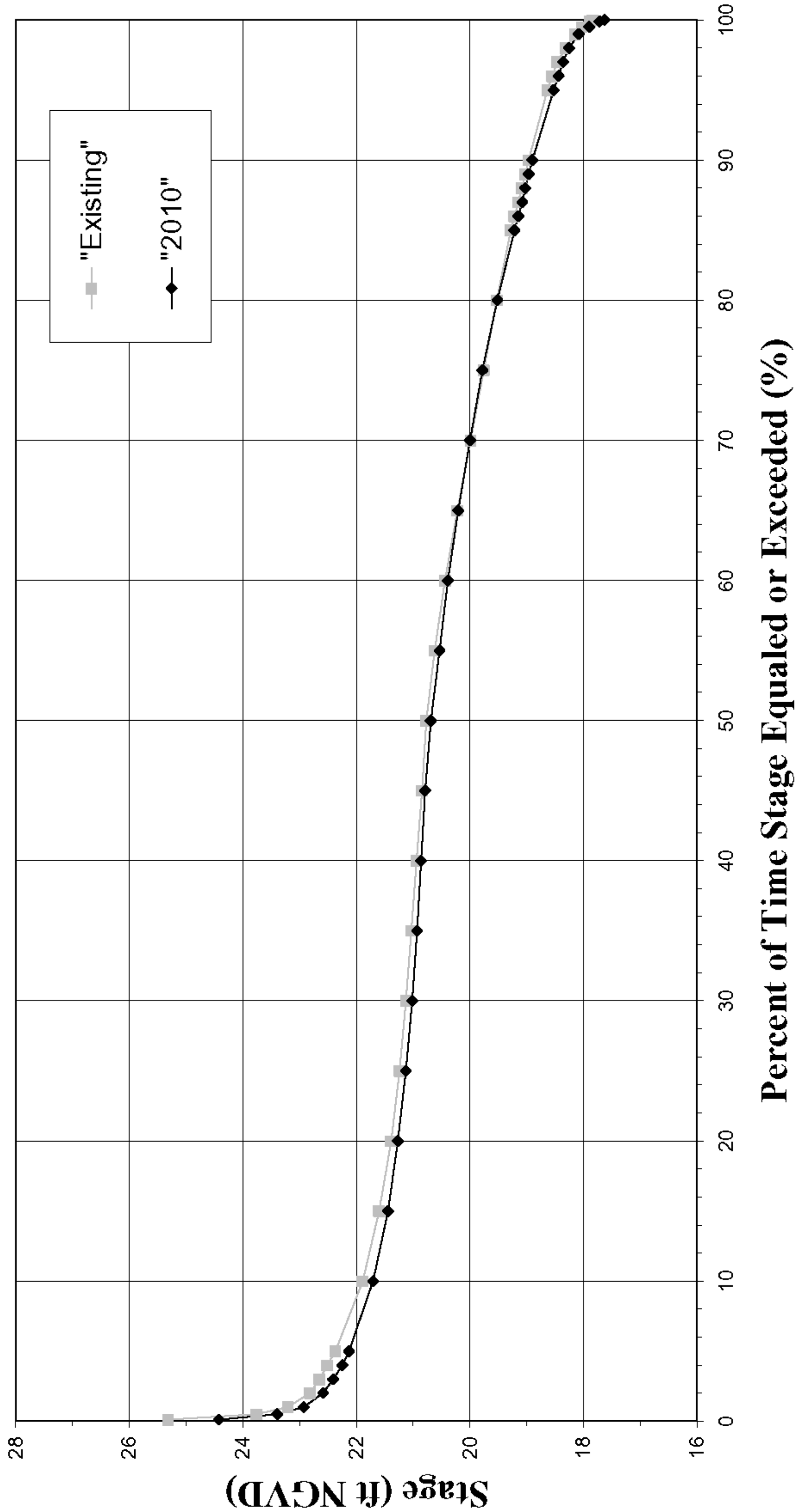


Figure 16. Stage duration analyses for the Ocklawaha River at Eureka Dam—Existing and 2010 hydrologic conditions

(21–23 ft NGVD; Figure 16). This elevation range also corresponds to that portion of the floodplain with the steepest elevation gradient and, therefore, the acreage of affected wetlands is relatively small. Also, wetland plant communities on this portion of the floodplain are maintained by high flow / stage events (floods) and possible seepage flow from the surficial aquifer.

A graphical representation of the floodplain elevation transect (XS#3) at Eureka Dam is shown in Figure 17, and indicates the general locations of the primary floodplain plant communities. The mean elevations of plant communities are summarized in Table 6, as are the existing and predicted 2010 water level durations for each of these elevations. Comparisons of stage duration analyses for the mean elevations of plant communities at Eureka Dam for the two time periods indicated small changes in the periods of inundation (Table 6). The greatest differences in the stage duration curves for the two time periods was at the higher floodplain elevations (hydric hammock community, 21.5–25.3 ft NGVD). However, the inundation frequency of the mean elevation of the hydric hammock community was predicted to change by less than 1% (Table 6). The 5% decrease in inundation frequency for the mean elevation of the mixed hardwood swamp community for 2010 corresponded to less than a 0.1-ft change in elevation at the 30th inundation percentile (Figure 16). These hydrologic changes are negligible, and no impacts to the wetland plant communities in this reach of the basin are expected.

Rodman Reservoir. A comparison of the surface water stage duration data for the Existing and Proposed reservoir water level regulation schedules indicated negligible differences between the two management alternatives (Figure 18). The results of mean period of record high and low stage frequency analyses showed small ($\leq$0.05 ft) differences in stage for selected durations (Table 7). In addition, the inundation frequency for the mean elevation of the wetland zone was identical for each management alternative (Table 6). These findings indicated that the hydrologic regimes produced by these two management alternatives in Rodman Reservoir were essentially indistinguishable.

The surface water stage duration analyses for the Existing and predicted 2010 and the Proposed-2010 hydrologic conditions at Rodman showed relatively small differences (Figure 19). The predicted mean period of record high and low stage frequency analyses for selected durations differed by $\leq$0.05 ft.

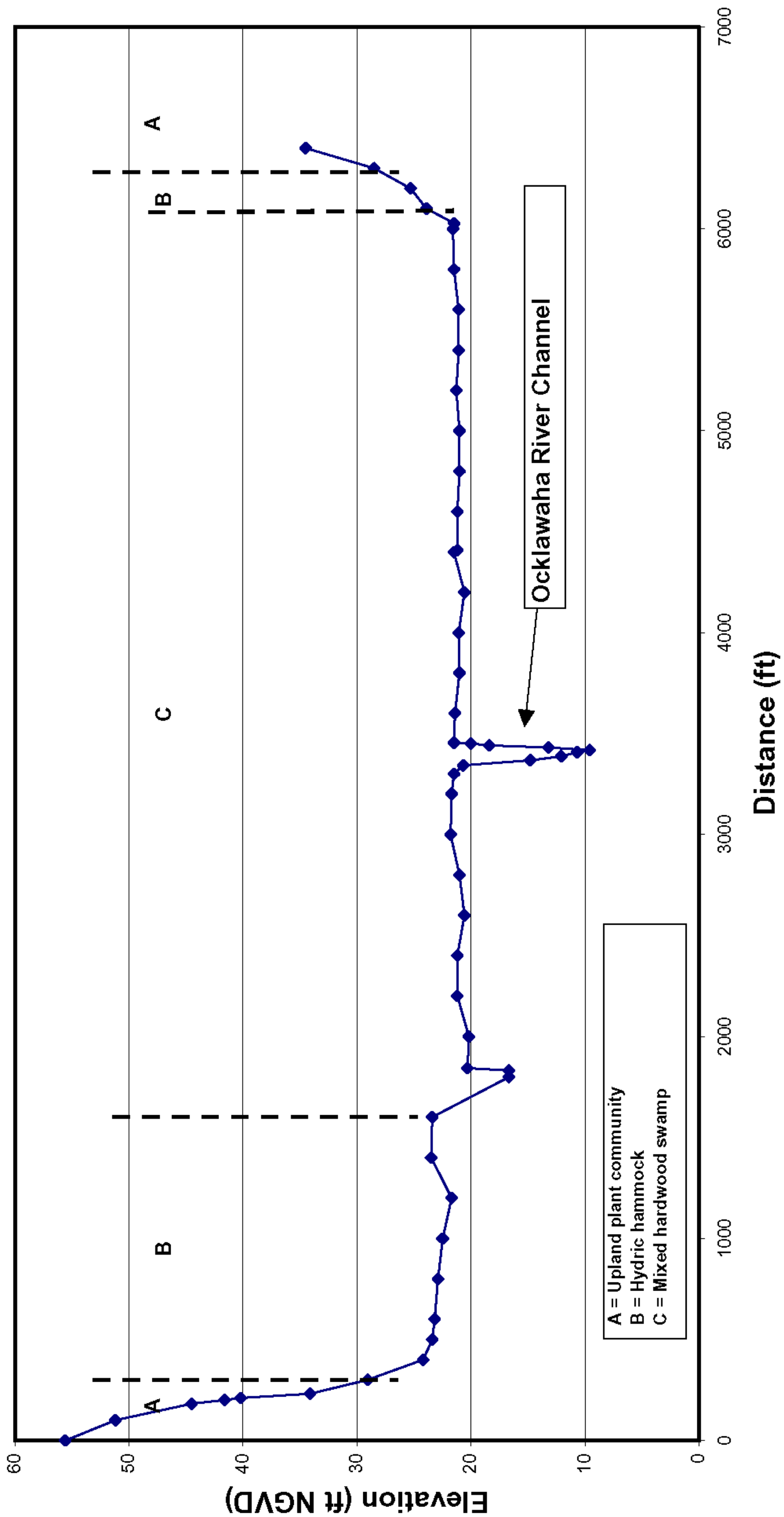


Figure 17. Elevation/vegetation transect of the Ocklawaha River at Eureka Dam

Table 6. Hydrologic conditions within major wetland vegetation communities in the Ocklawaha River Basin. Values in parentheses represent differences in the inundation frequency between the Existing and the other hydrologic conditions.

Location	Plant Community	Elevation		Water Level Inundation Frequency (%) by Hydrologic Conditions			
		Mean (feet)	Range (feet)	Existing	Proposed	2010	Proposed-2010
Eureka Dam	Mixed hardwood swamp	21.1	20.0–21.5	31.5	—	27.0 (-4.5)	—
	Hydric hammock	23.1	21.5–25.3	1.3	—	0.8 (-5.0)	—
Rodman Reservoir	Wetland zone	18.2	17.9–18.5	60.0	57.5 (-2.5)	35.0 (-25.0)	55.0 (-5.0)
Riverside Landing	Mixed hardwood swamp	4.0	3.1–6.1	88.2	83.0 (-5.2)	87.2 (-1.0)	78.0 (-10.2)
	Hydric hammock	7.1	6.1–8.3	3.3	3.3 (0)	2.3 (-1.0)	2.3 (-1.0)

Note: — = no data

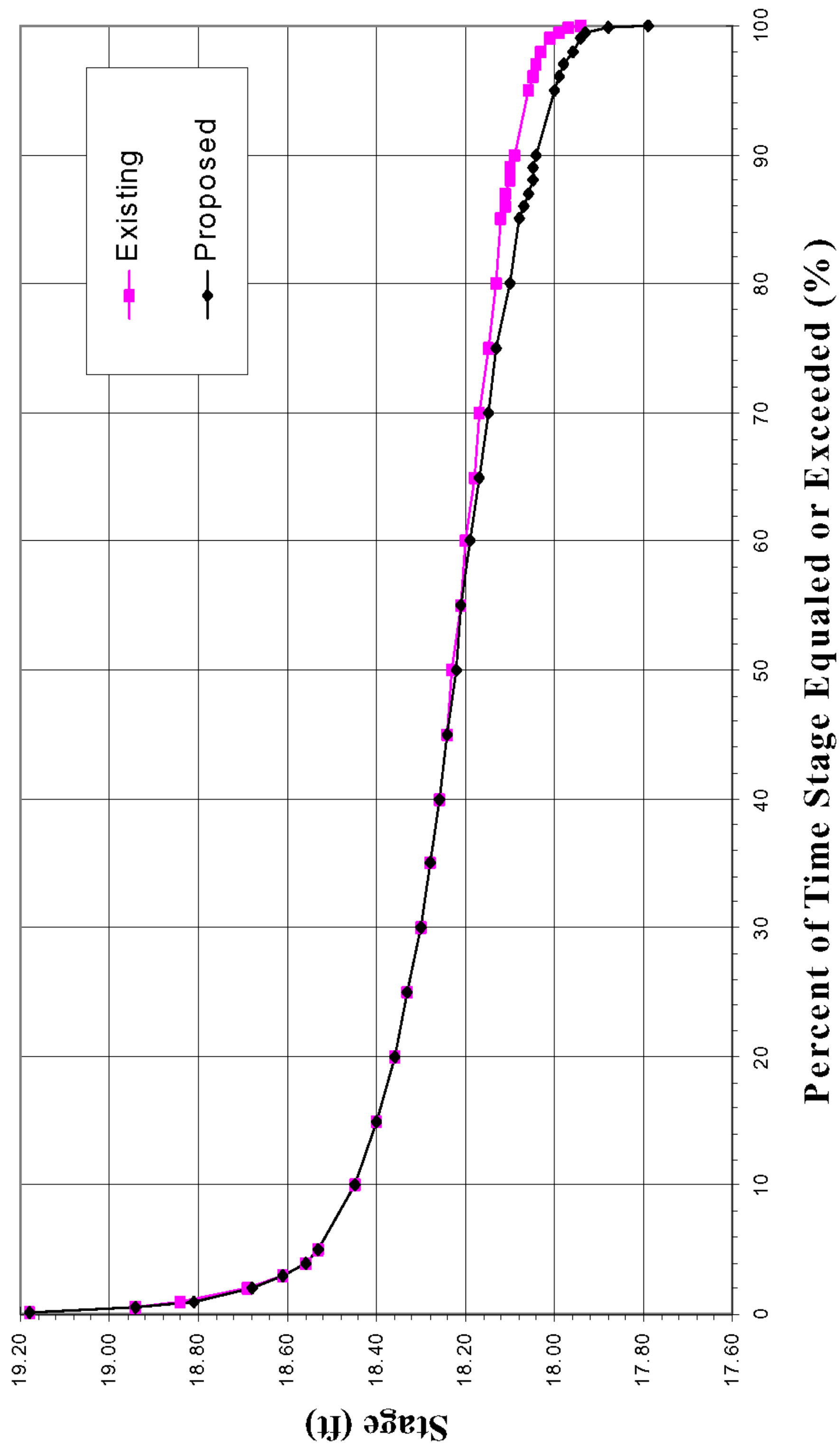


Figure 18. Stage duration analyses for Rodman Reservoir—Existing and Proposed hydrologic conditions

Table 7. Results from frequency analysis for various water management alternatives at Rodman Reservoir and Riverside Landing

Location	Conditions	Mean High Stage Duration (days)																	
		1		7		14		30		60		120		183		274		365	
		Level	Delta	Level	Delta	Level	Delta	Level	Delta	Level	Delta	Level	Delta	Level	Delta	Level	Delta	Level	Delta
Rodman	Existing	18.86	—	18.68	—	18.60	—	18.49	—	18.40	—	18.34	—	18.31	—	18.28	—	18.26	—
	Proposed	18.85	–0.01	18.68	0.00	18.60	0.00	18.49	0.00	18.40	0.00	18.34	0.00	18.30	–0.01	18.27	–0.01	18.24	–0.02
	E-2010	18.82	–0.04	18.66	–0.02	18.59	–0.01	18.46	–0.03	18.37	–0.03	18.29	–0.05	18.24	–0.07	18.20	–0.08	18.17	–0.09
	P-2010	18.84	–0.02	18.67	–0.01	18.59	–0.01	18.48	–0.01	18.40	0.00	18.33	–0.01	18.29	–0.02	18.26	–0.02	18.23	–0.03
Riverside	Existing	8.01	—	7.32	—	7.00	—	6.45	—	6.01	—	5.65	—	5.38	—	5.17	—	4.99	—
	Proposed	8.00	–0.01	7.33	0.01	7.00	0.00	6.46	0.01	6.02	0.01	5.67	0.02	5.40	0.02	5.20	0.03	5.03	0.04
	E-2010	7.88	–0.13	7.29	–0.03	7.00	0.00	6.48	0.03	6.04	0.03	5.67	0.02	5.39	0.01	5.15	–0.02	4.95	–0.04
	P-2010	7.93	–0.08	7.30	–0.02	6.98	–0.02	6.44	–0.01	6.00	–0.01	5.64	–0.01	5.37	–0.01	5.15	–0.02	4.96	–0.03

Location	Conditions	Mean Low Stage Duration (days)																	
		1		7		14		30		60		120		183		274		365	
		Level	Delta	Level	Delta	Level	Delta	Level	Delta	Level	Delta	Level	Delta	Level	Delta	Level	Delta	Level	Delta
Rodman	Existing	18.03	—	18.10	—	18.11	—	18.13	—	18.15	—	18.18	—	18.21	—	18.23	—	18.26	—
	Proposed	18.01	–0.02	18.05	–0.05	18.06	–0.05	18.08	–0.05	18.11	–0.04	18.15	–0.03	18.18	–0.03	18.21	–0.02	18.24	–0.02
	E-2010	17.92	–0.11	17.98	–0.12	18.00	–0.11	18.01	–0.12	18.04	–0.11	18.08	–0.10	18.11	–0.10	18.14	–0.09	18.17	–0.09
	P-2010	17.92	–0.11	17.98	–0.12	18.00	–0.11	18.01	–0.12	18.04	–0.11	18.08	–0.10	18.11	–0.10	18.14	–0.09	18.17	–0.09
Riverside	Existing	2.62	—	3.51	—	3.63	—	3.80	—	4.04	—	4.34	—	4.58	—	4.77	—	4.99	—
	Proposed	3.34	0.72	3.69	0.18	3.77	0.14	3.91	0.11	4.12	0.08	4.41	0.07	4.64	0.06	4.82	0.05	5.03	0.04
	E-2010	2.84	0.22	3.40	–0.11	3.51	–0.12	3.67	–0.13	3.93	–0.11	4.28	–0.06	4.50	–0.08	4.72	–0.05	4.95	–0.04
	P-2010	3.26	0.64	3.57	0.06	3.65	0.02	3.78	–0.02	4.01	–0.03	4.33	–0.01	4.54	–0.04	4.73	–0.04	4.96	–0.03

Note: — = not applicable

*The ‘Delta’ column represents the difference between the Existing and the Proposed, Existing-2010, and Proposed-2010 hydrologic conditions (E=Existing, P=Proposed)

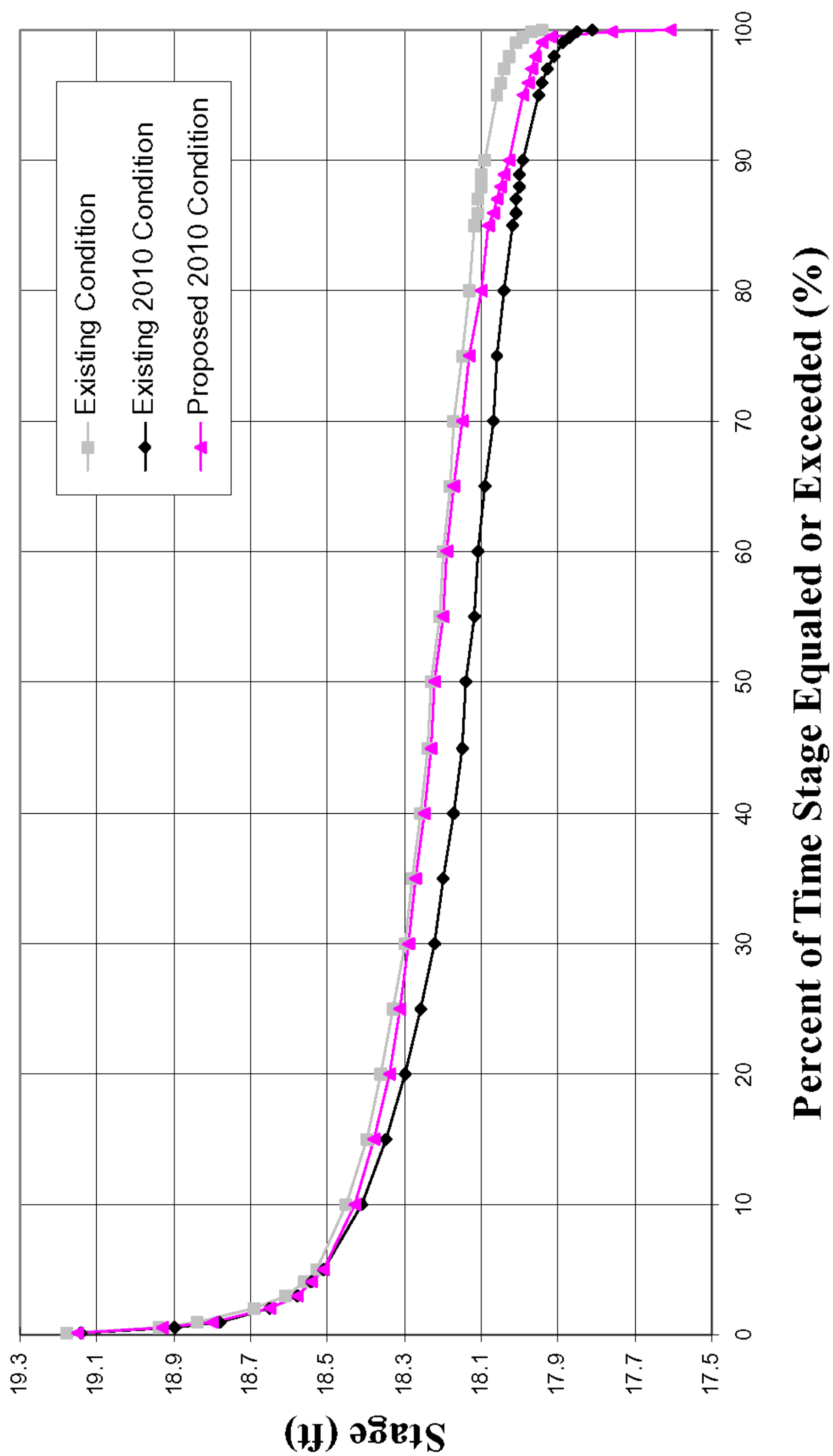


Figure 19. Stage duration analyses for Rodman Reservoir—Existing, Existing-2010, and Proposed-2010 hydrologic conditions

The range of surface water fluctuation showed negligible differences between the different hydrologic conditions (Figure 19). Graphical representations of floodplain elevation transects at Rodman Reservoir are shown in Figures 20 and 21, and indicate the general locations of the wetland plant communities (wetland zone). The mean elevation and range of the wetland zone are summarized in Table 6, as are the Existing, Proposed, Existing-2010 and Proposed-2010 water level durations for this elevation. Comparisons of stage duration for the mean elevation of the wetland zone (18.2 ft NGVD) for the Existing and Existing-2010 conditions showed a 25% reduction in the predicted inundation frequency. However, this reduction in inundation frequency corresponded to approximately a 0.1-ft decrease in elevation at the 60th stage duration percentile (Figure 19). The greatest differences between the stage duration curves occurred at the lower elevations (17.9 to 18.3 ft NGVD), however, the actual vertical differences were relatively small. There was less than a 0.2-ft difference in elevation between the data graphs at any given stage duration percentile (Figure 19).

Comparing the Existing and Proposed-2010 hydrologic conditions indicated negligible changes in inundation frequencies (Figure 19). The difference in the inundation frequency for the mean elevation of the wetland zone (18.2 ft NGVD) for these hydrologic conditions was 5.0% (Table 6). This reduction in inundation frequency corresponded to a less than 0.1-ft difference in elevation from the Existing condition at the 60th stage duration percentile (Figure 19). These hydrologic changes were negligible and indicated that there will be no significant hydrologic/hydraulic impacts caused by the predicted increases in groundwater withdrawals within the region.

Ocklawaha River at Riverside Landing. River flows and stages at Riverside Landing are dependent upon surface water discharges from Rodman Reservoir. The regulation schedule at the reservoir discharge structure has a significant effect on the stage/duration relationship for this river reach. The stage duration graph appears “stair-stepped” because the operation of the structure is not gradual (Figure 22). Rather, changes in the gate opening are made in response to the attainment of critical water levels in the reservoir. The effect is most pronounced under low-flow conditions (see the 80th to 90th percentiles, Figure 22). The Proposed water management alternative provides greater surface water discharges during low water periods than the Existing conditions (reservoir pool ≤18 ft NGVD; Figure 22). Therefore, the discharge duration curves for these two conditions were identical except for discharges

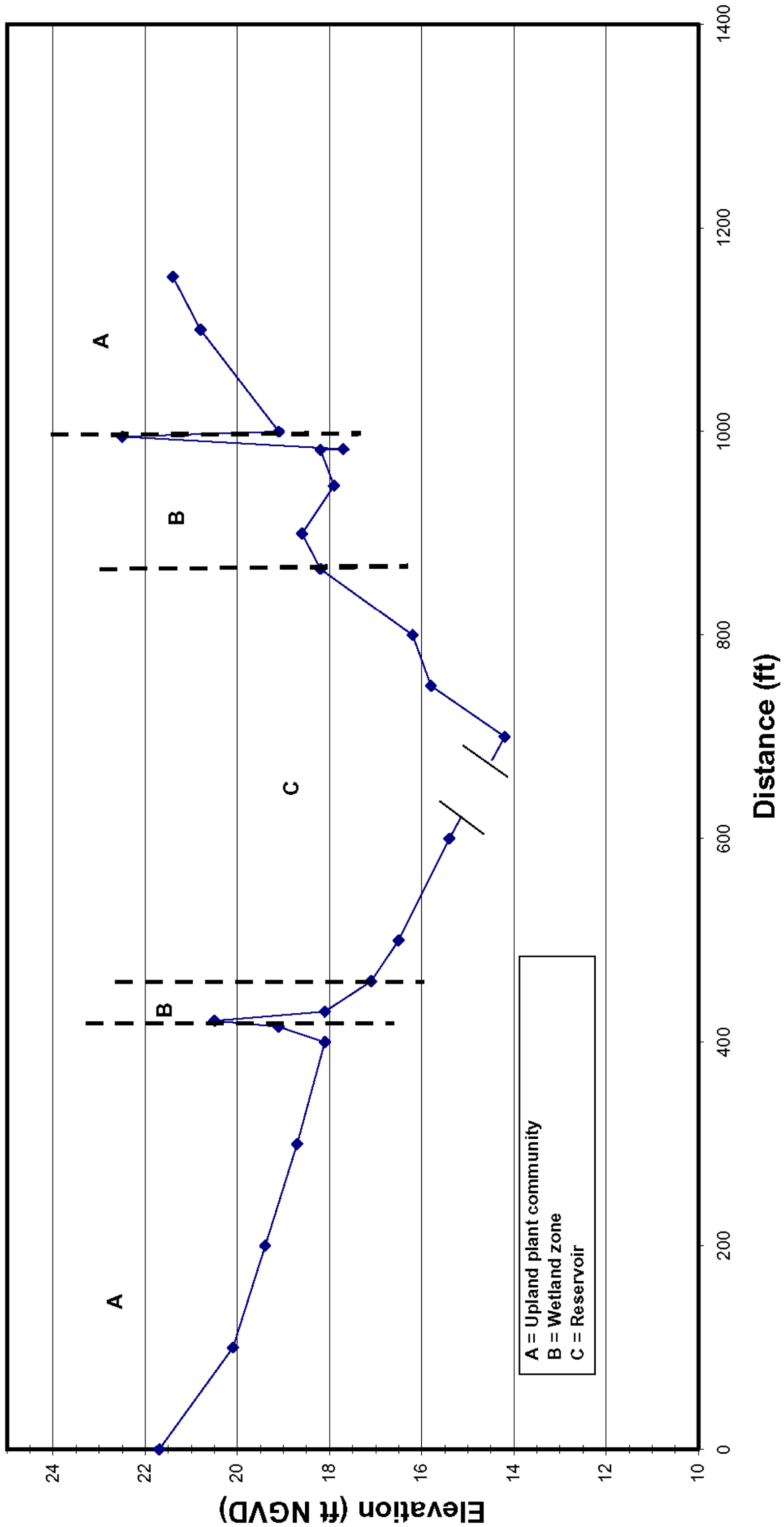


Figure 20. Elevation/vegetation transect 2(75) at Rodman Reservoir

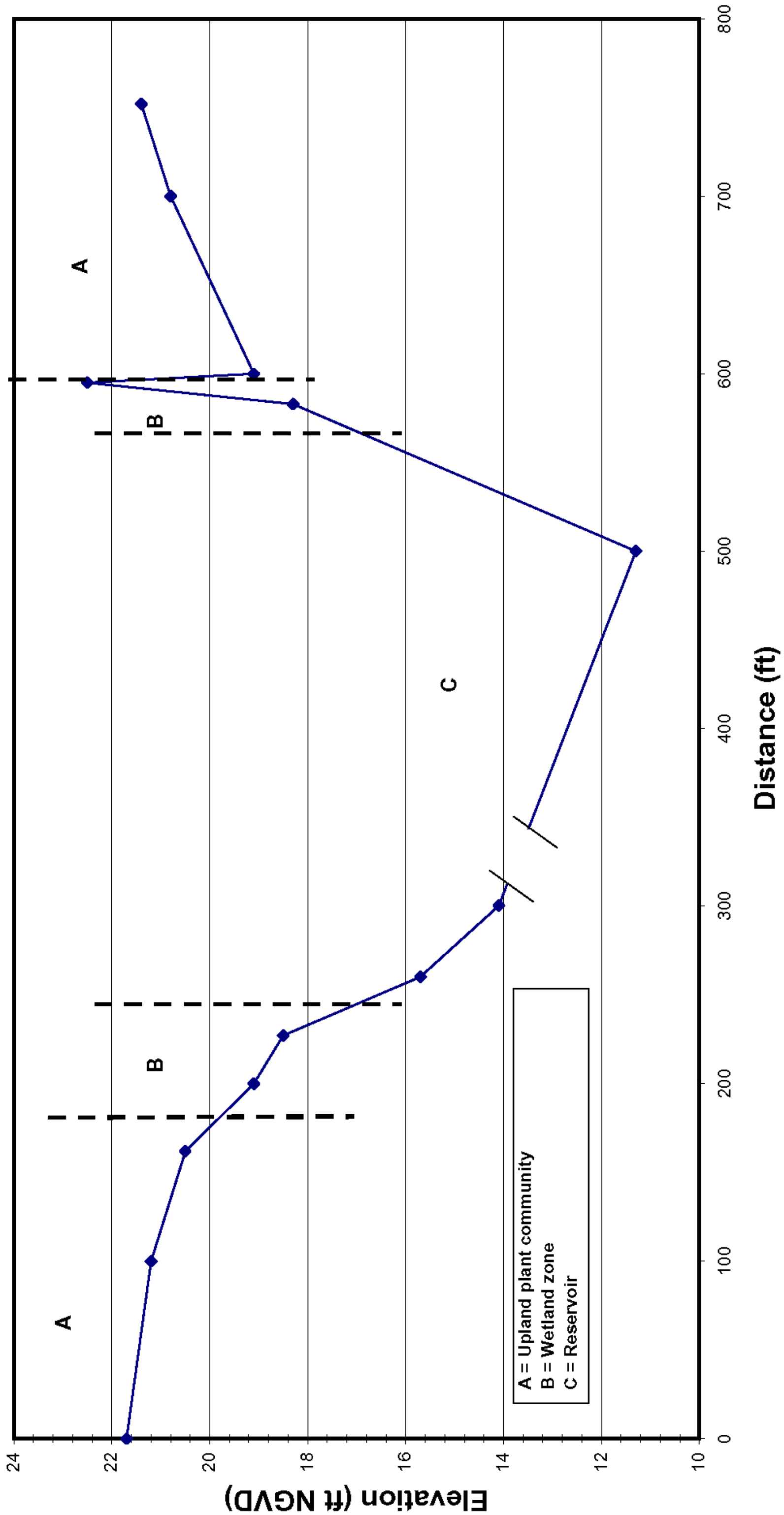


Figure 21. Elevation/vegetation transect 3(75) at Rodman Reservoir

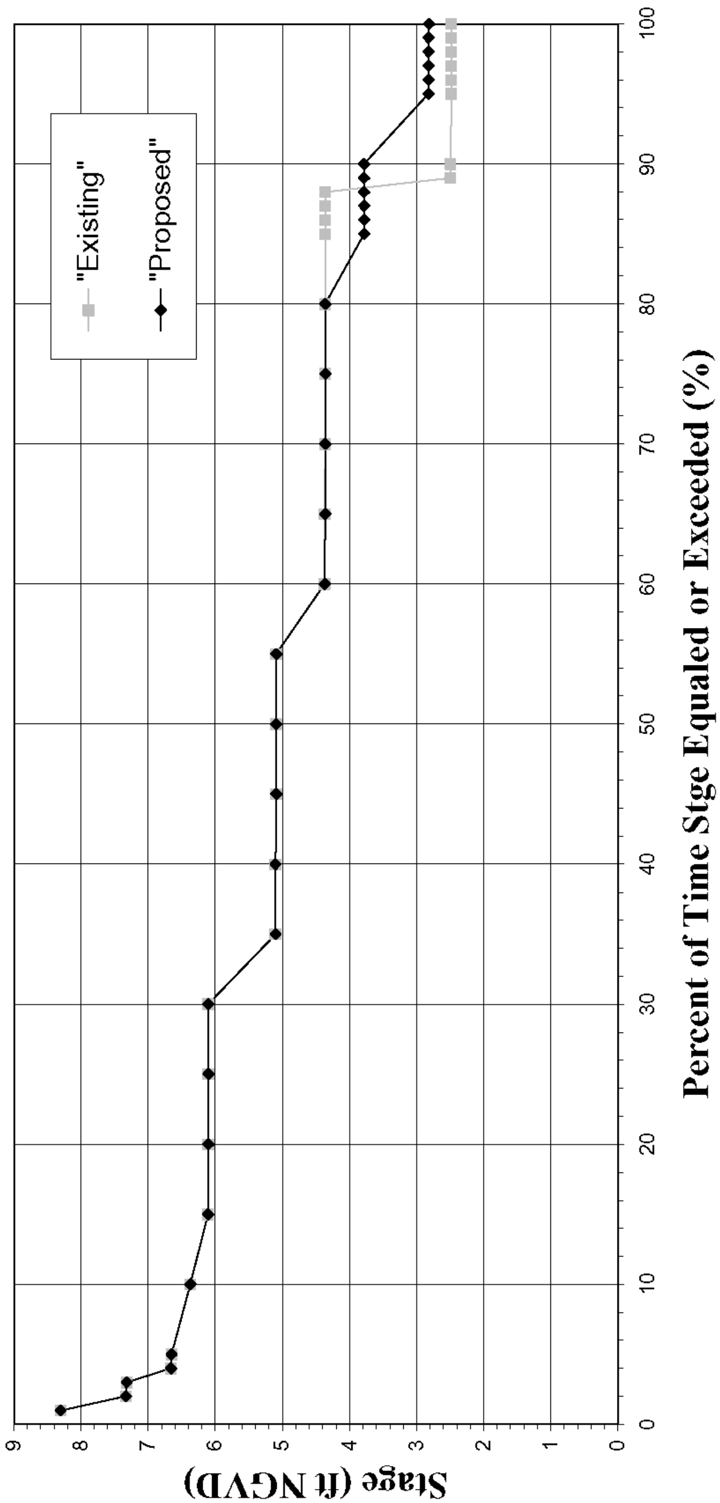


Figure 22. Stage duration analyses for the Ocklawaha River at Riverside Landing—Existing and Proposed hydrologic conditions

below 1,500 cfs (80th to 90th percentile; Figure 23). The Proposed reservoir regulation schedule provides a more gradual transition between stages downstream of the reservoir.

A comparison of the stage duration data for Existing and Proposed hydrologic conditions indicated no major differences in the stages achieved downstream of the reservoir. However, the length of time (duration) that certain stages were held constant decreased (see 25th to 30th and 50th to 60th percent duration levels; Figure 22). These changes represent approximately a 5% reduction in inundation frequencies. The magnitude of the shift in water levels remained constant between the two management alternatives (Figure 22). The most significant difference in the stage duration relationships for the management options occurred between the 70th and 100th percent duration levels (Figure 22). The Existing operation schedule calls for discharges to be reduced instantaneously from approximately 1,130 cfs to 530 cfs (a 53% change; Figure 23) when stages in the reservoir reach approximately 18 ft NGVD. The effect is a rather rapid dewatering of the floodplain swamp, as stages drop from approximately 4.4 to 2.5 ft NGVD (Figure 22). The predicted mean period of record high and low stage frequency analyses for selected durations differed by $\leq$0.05 ft. The range of surface water fluctuation showed negligible differences between the different hydrologic conditions (Figure 22).

The operating schedule for the Proposed management alternative produces a more gradual reduction in downstream flows/stages and the rate of stage recession on the downstream floodplain is slowed (Figure 23). Discharges are reduced from 1,130 to 900 cfs when reservoir stages reach approximately 18.12 ft NGVD, and further reduced from 900 to 600 cfs when reservoir stages reach 18 ft NGVD. Downstream low water stages are improved by approximately 0.33 ft (2.49 to 2.82 ft NGVD; Figure 22) over the Existing structure operation schedule.

The reservoir water level regulation schedules for the Existing and Existing-2010 conditions were identical. The results of mean period of record high and low stage frequency analyses showed relatively small differences ($\leq$0.2 ft) in the predicted mean stage for selected stage durations (Table 7). Comparisons of the surface water stage duration analyses for these two conditions were similar. Differences in the stage/duration relationships occurred at the 20th to 30th and 80th to 90th percentiles (Figure 24). The shift that occurs between the

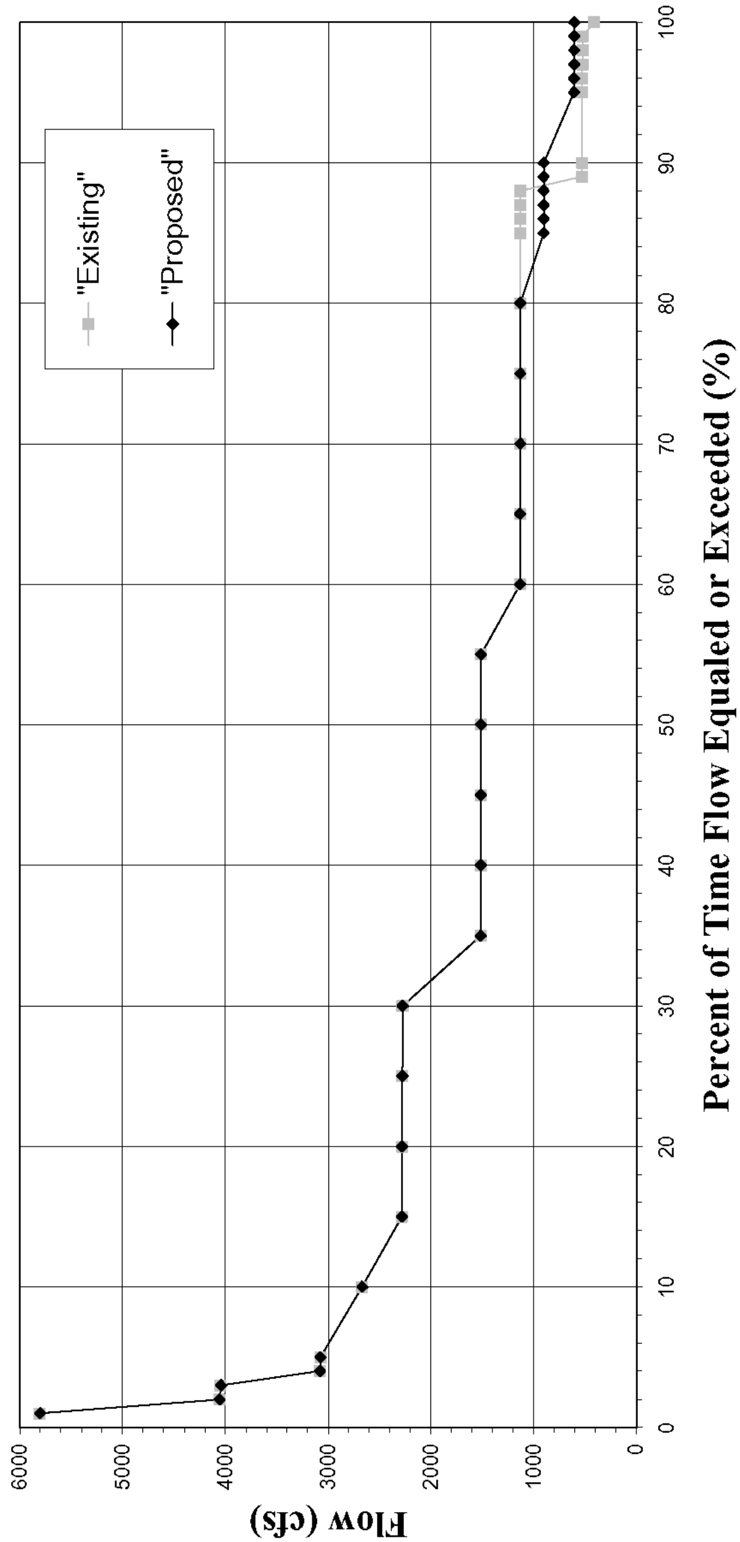


Figure 23. Discharge duration analyses for Rodman Reservoir—Existing and Proposed hydrologic conditions

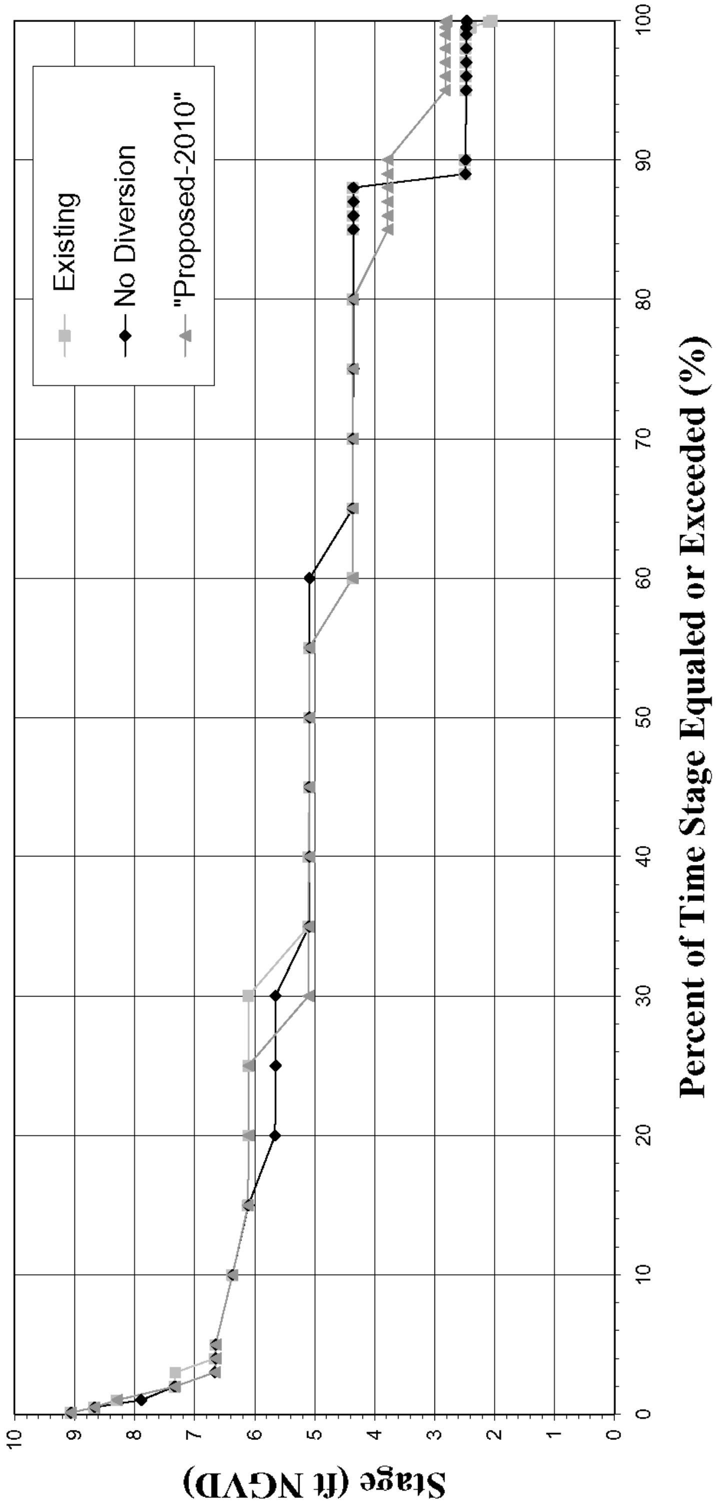


Figure 24. Stage duration analyses for the Ocklawaha River at Riverside Landing—Existing, Proposed, and Proposed-2010 hydrologic conditions

80th and 90th percentiles is small, representing a difference of approximately 1.0% (88–87%). The corresponding differences in elevations at the 88th stage duration percentile were negligible (≤0.01 ft, 4.36–4.35 ft).

The differences at the 20th to 30th percentile were more pronounced. As an example, the inundation frequency for the elevation 6.1 ft NGVD changed from 30% (Existing) to 15% (2010). This change in duration represented approximately a 0.5-ft change in elevation at the 30th percentile. The 6.1-ft NGVD elevation is significant because it corresponds to the transitions area (ecotone) between the mixed hardwood swamp and hydric hammock wetland plant communities (Table 6). However, this ecotone occurs at that point on the floodplain with the steepest elevation gradient, and, therefore, the acreage of wetlands that will experience a decline in inundation frequency is relatively small (a 10–20-ft-wide band, based on the elevation transect information; Figure 25).

As previously stated, the reservoir regulation schedules for the Existing and Proposed-2010 hydrologic conditions were identical, except that the Proposed water management alternative provides more water downstream during low water periods (reservoir stages ≤18 ft NGVD; Figure 24). Therefore, the discharge duration curves for these two conditions were identical, except where discharges were below 1,500 cfs (80th to 90th percentile; Figure 26). This provided more gradual transition between stages downstream of the reservoir. Comparisons of the stage duration curves for the Existing-2010 and Proposed-2010 conditions indicated similar trends. Minor differences in stage duration occurred between the 20th to 30th and 50th to 60th percent duration levels (Figure 24). The stage duration curves differed by approximately 5% at these points on the curves. The magnitude of the changes in river stage were identical to the Existing conditions (approximately 1.0 ft for the 25th to 30th percentile, and 0.7 ft for the 55th to 50th percentiles; Figure 24). The most pronounced differences in the stage duration curves occurred between the 75th and 100th percentiles. The operating schedule for the Proposed-2010 alternative produced a more gradual reduction in downstream stages, essentially identical to the Proposed regulation schedule. Discharges were reduced from 1,130 to 900 cfs when reservoir stages reach approximately 18.12 ft NGVD, and were further reduced from 900 to 600 cfs when reservoir stages reach approximately 18.0 ft NGVD. Downstream low water stages were improved by approximately 0.33 ft (2.49 to 2.82 ft NGVD; Figure 24) over the stages produced by the Existing structure operation schedule. It appears that the increased groundwater withdrawals within the region have very little effect on river stages and flows at this location in the basin.

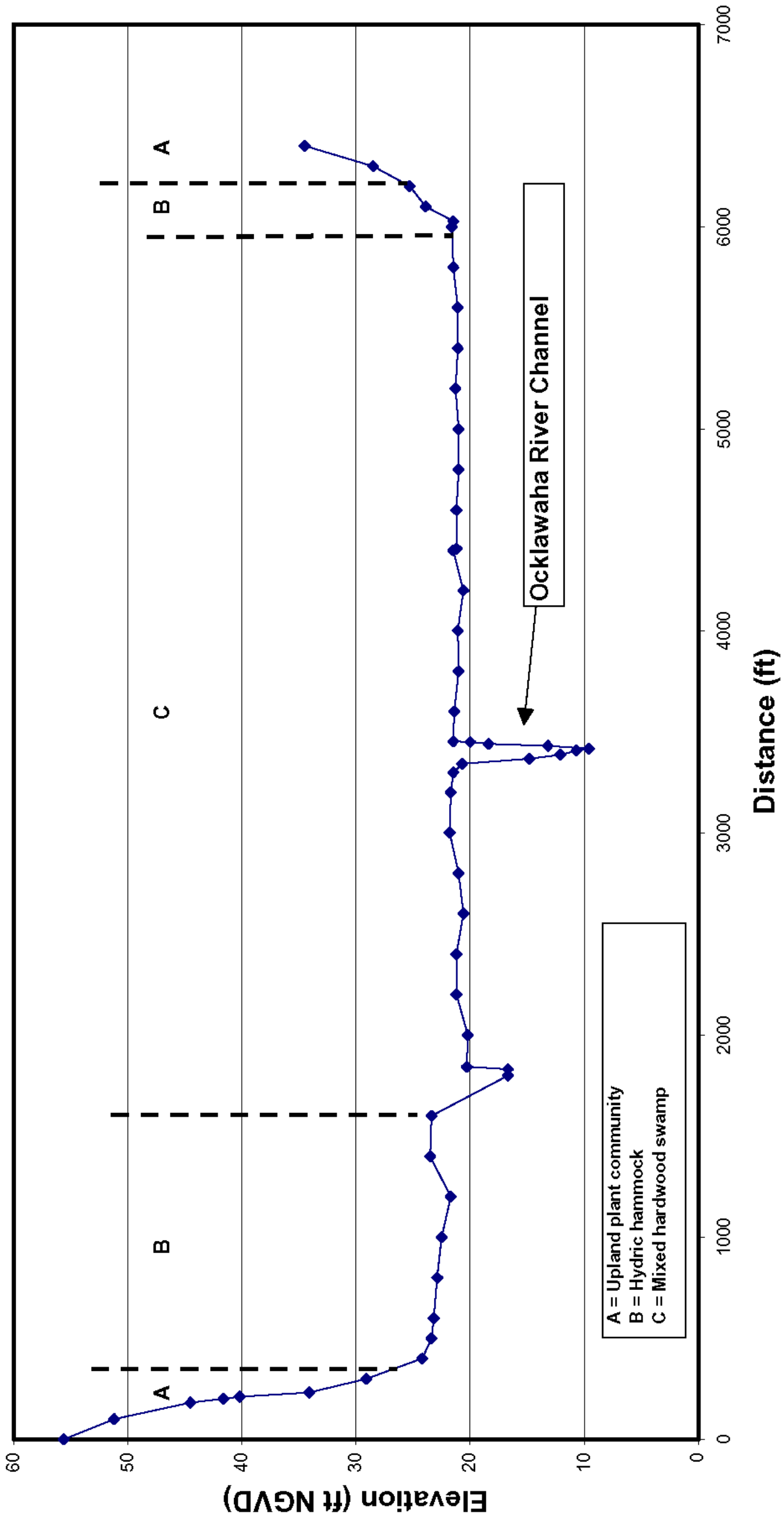


Figure 25. Elevation/vegetation transect I-C, the Ocklawaha River at Riverside Landing

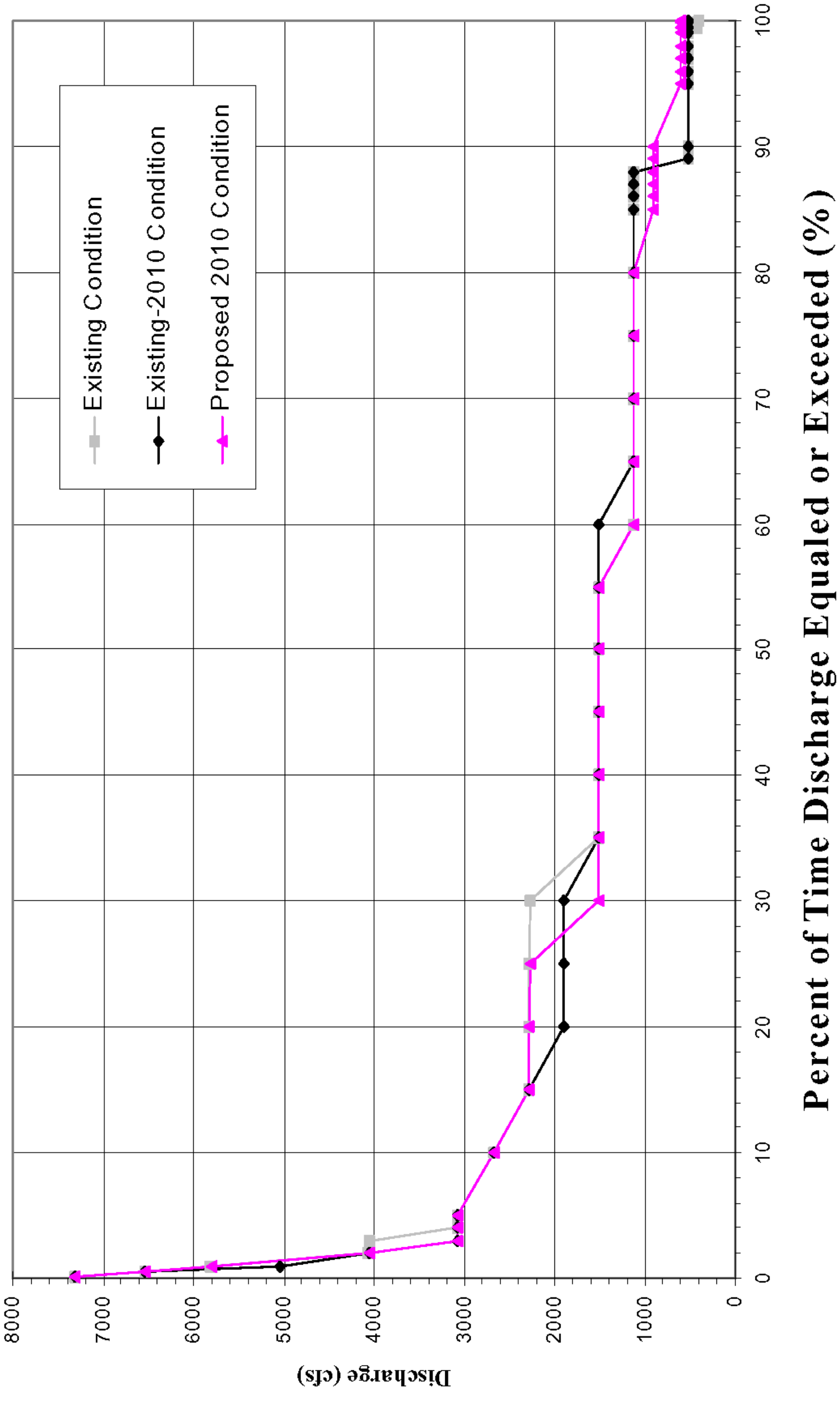


Figure 26. Discharge duration analyses for Rodman Reservoir—Existing, Proposed, and Proposed-2010 hydrologic conditions

A graphical representation of the floodplain elevation transect at Riverside is shown in Figure 25 and indicates the general locations of the primary floodplain plant communities. The mean elevations of plant communities are summarized in Table 6, as are the Existing, Proposed, Existing-2010, and Proposed-2010 water level durations for each of these elevations. Comparisons of stage duration analyses for the mean elevations of plant communities at Riverside for these different conditions indicated small changes in the periods of inundation (Table 6). The inundation frequency for the mean elevation of the mixed hardwood swamp community shifted from 88.2% under Existing to 78% for the Proposed-2010. While this represented a 10.2% decrease in duration, it corresponded to only a 0.2-ft change in elevation (4.0 to 3.8 ft NGVD) at the 88th stage duration percentile. The elevation transect data for this river reach (Figure 25) indicated that the spatial extent of changes in inundation frequency was limited to a 5–30-ft-wide zone along the river channel. These hydrologic changes are insignificant, and no impacts to the wetland plant communities in this reach of the basin are expected.

Orange Creek Subbasin

Major lakes and Paynes Prairie. A review of the existing and projected (year 2010) surface and groundwater usage within the Orange Creek subbasin indicated that groundwater will remain the primary source of water for consumptive uses (Table 2). Only one permitted surface water withdrawal was identified from the major lakes and streams of the basin. Approximately 33 million gallons per year, or 6% of the total surface water withdrawals for Marion County, are permitted from Orange Lake. The actual usage was undetermined. No increase in surface water withdrawals was predicted for 2010 (Table 2; Vergara 1994).

Groundwater uses within the Orange Creek subbasin were predicted to increase markedly by 2010 (Tables 3 and 4). However, no significant lowering of the potentiometric surface of the Floridan aquifer was predicted due to the increased withdrawals (Vergara 1994). This was verified by the relatively minor reductions in flow predicted to occur at springs within the basin (Glen, Magnesia, and Orange springs), as previously reported (Table 1).

The incorporation of these anticipated surface and groundwater withdrawals into the computer model simulations of surface water levels for the Orange Creek subbasin indicates no predicted major changes in the duration, frequency of high and low stage events, or fluctuation ranges of water levels or flows within the major lakes of the basin, Orange Creek, and Paynes Prairie. Comparisons of the Existing and Existing-2010 surface water level duration analyses and the ranges of water level fluctuation for Newnans Lake and Paynes Prairie indicated no changes (Figures 27 and 28). However, stage duration and frequency analyses for Orange and Lochloosa lakes showed slight but negligible (hundredths of feet) changes between the two time periods (Figures 29 and 30). Only Lake Lochloosa was predicted to experience a slight increase (0.2 ft NGVD) in the range of water level fluctuation by 2010 (Figure 30). Graphical representations of elevation transects for each major lake and Paynes Prairie are shown in Figures 31–34, and indicate the general locations of the primary floodplain plant communities. The mean elevations of plant communities are summarized in Table 8, as are the Existing and Existing-2010 water level durations for each of these elevations. The percent of time that the mean elevations of major plant communities of Newnans Lake and Paynes Prairie are expected to be inundated were unchanged for the two time periods (Table 8). Similar analyses for Lakes Orange and Lochloosa indicated extremely small changes in the inundation frequencies for the mean elevations of plant communities (Table 8).

Orange Creek. Comparisons of the existing and predicted 2010 stage and flow durations for Orange Creek at Orange Springs indicated negligible changes to the flow regime because of increased groundwater usage in the basin (Figures 35 and 36).

No biological or elevation data regarding the floodplain wetland communities of Orange Creek were available to allow a comparison to the predicted hydrologic conditions. However, because the changes in the flow regime were predicted to be very slight, the existing relationships between biotic communities and hydrology are expected to be unchanged.

WATER AVAILABILITY STUDY, by Greeneville Hall, Awes Karama, Clifford Neubauer, and Donthamsetti Rao

Quantitative Evaluation

This evaluation examined and quantified the amount of surface water that could be removed for human consumptive uses from the LOR subbasin without causing unacceptable environmental impacts. The hydrologic simulations included the predicted 2010 changes in surface water hydrology resulting from increased groundwater withdrawals. Four surface water withdrawals (0, 165, 250, and 330 cfs) were simulated for the following

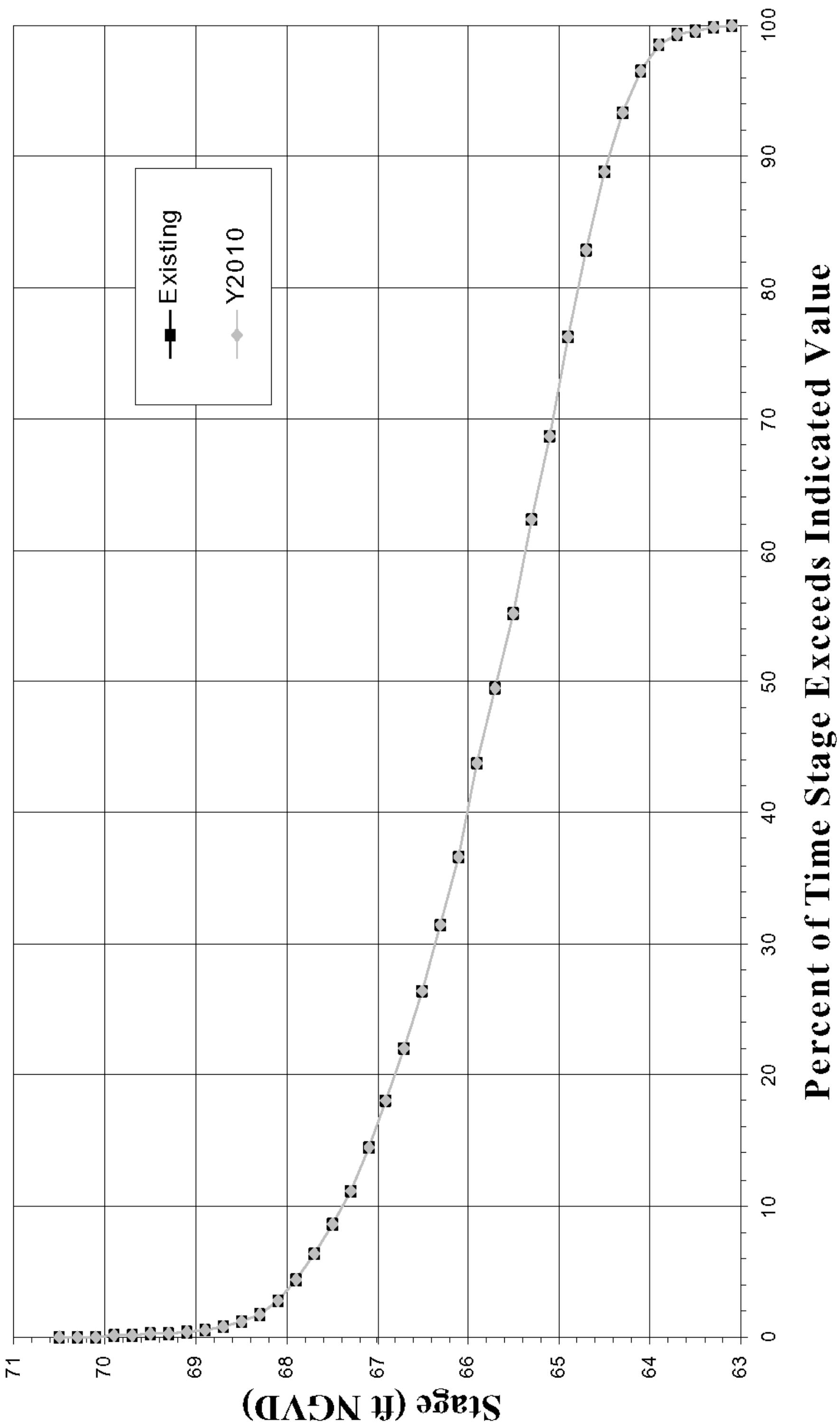


Figure 27. Stage duration analyses for Newnans Lake—Existing and 2010 hydrologic conditions

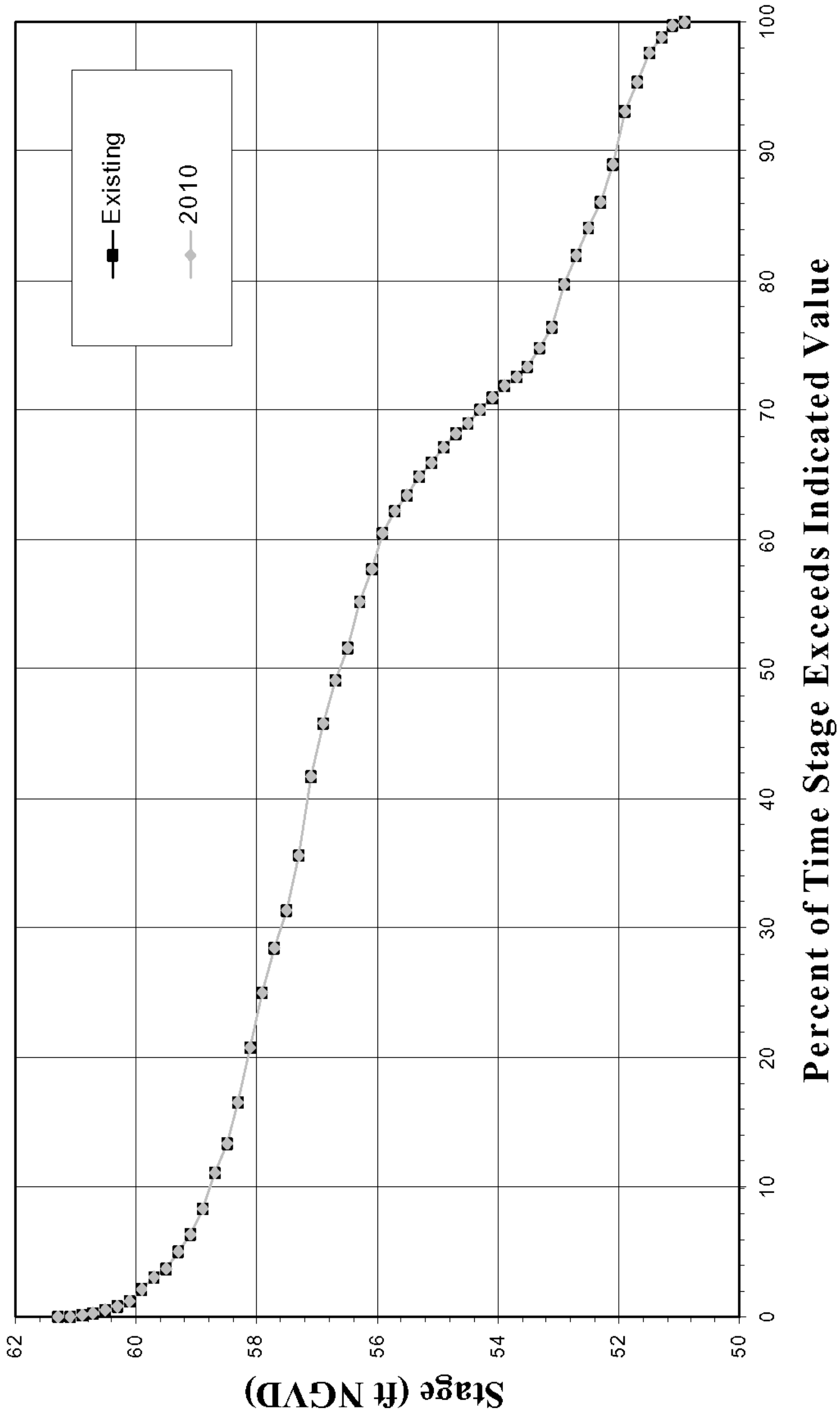


Figure 28. Stage duration analyses for Paynes Prairie—Existing and 2010 hydrologic conditions

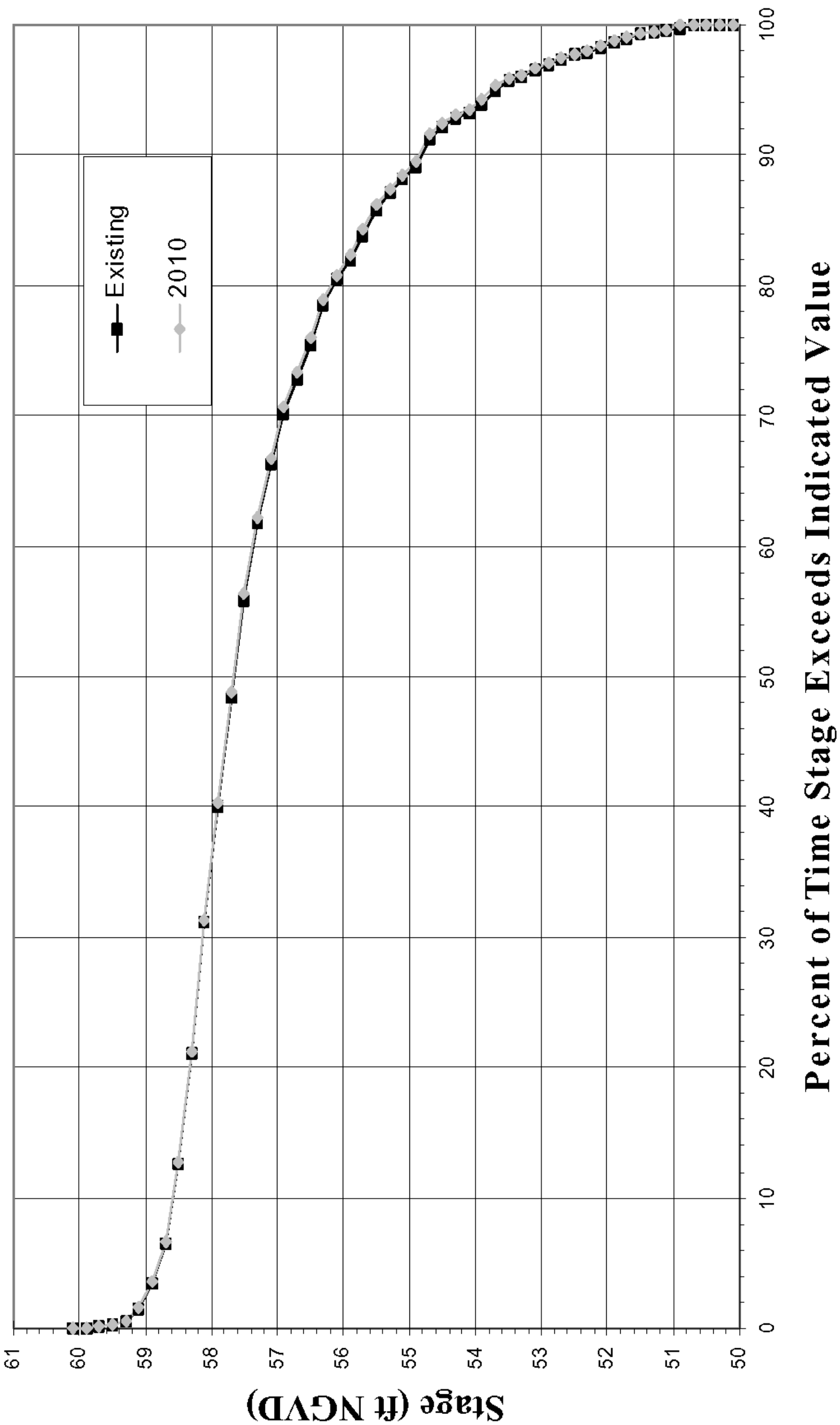


Figure 29. Stage duration analyses for Orange Lake—Existing and 2010 hydrologic conditions

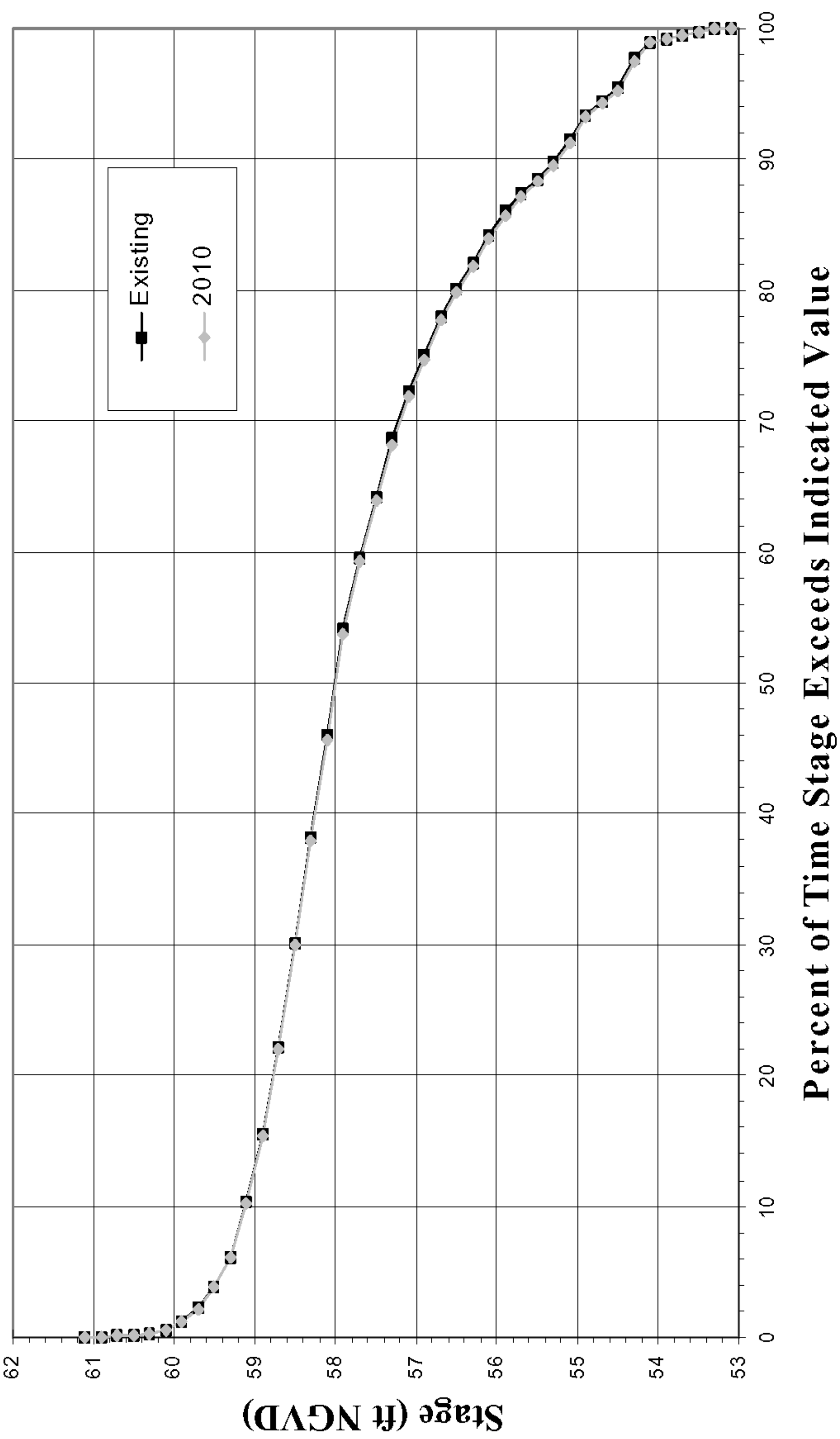
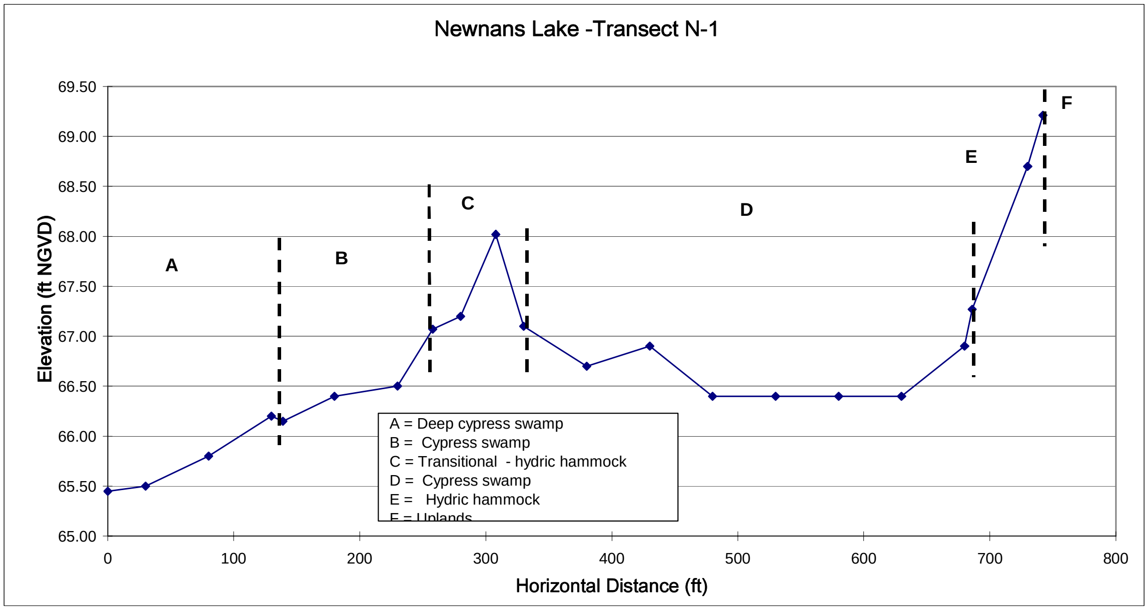


Figure 30. Stage duration analyses for Lake Lochloosa—Existing and 2010 hydrologic conditions



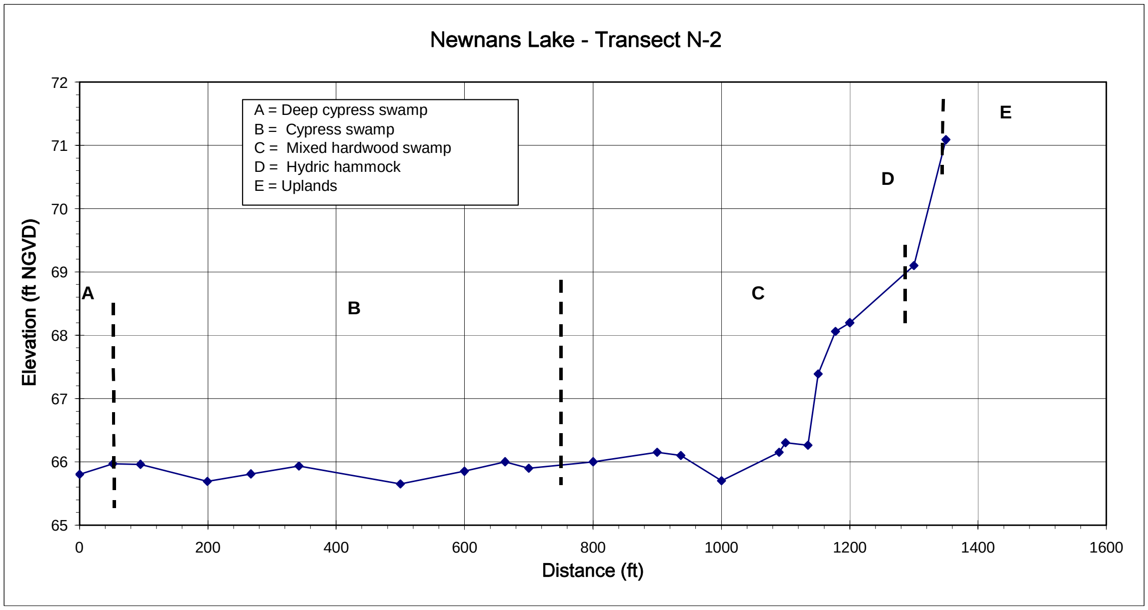
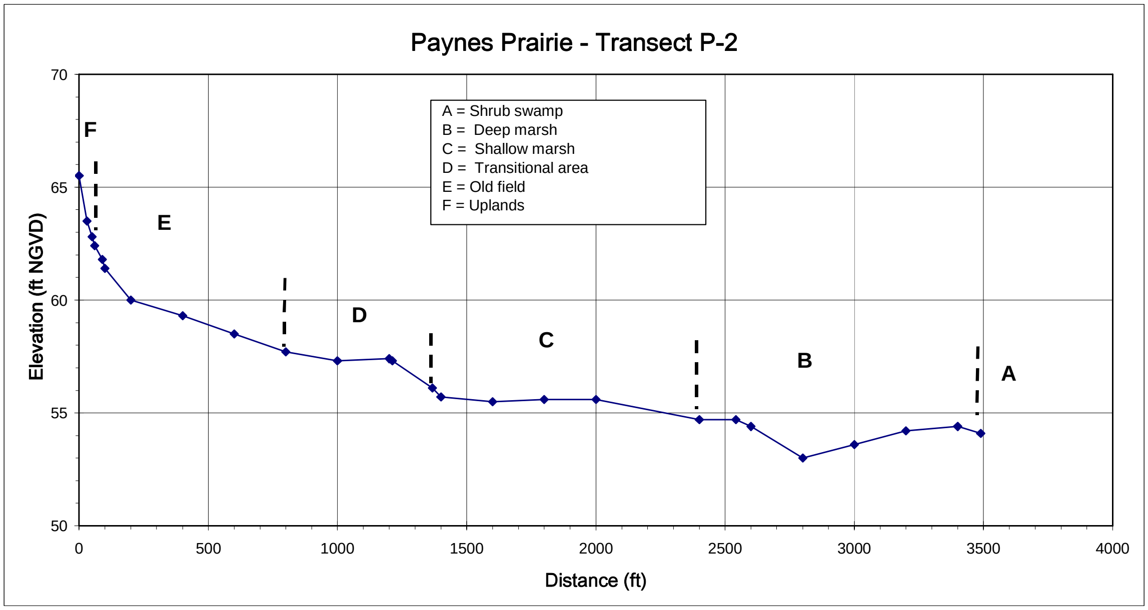


Figure 31. Elevation/vegetation transects at Newnans Lake



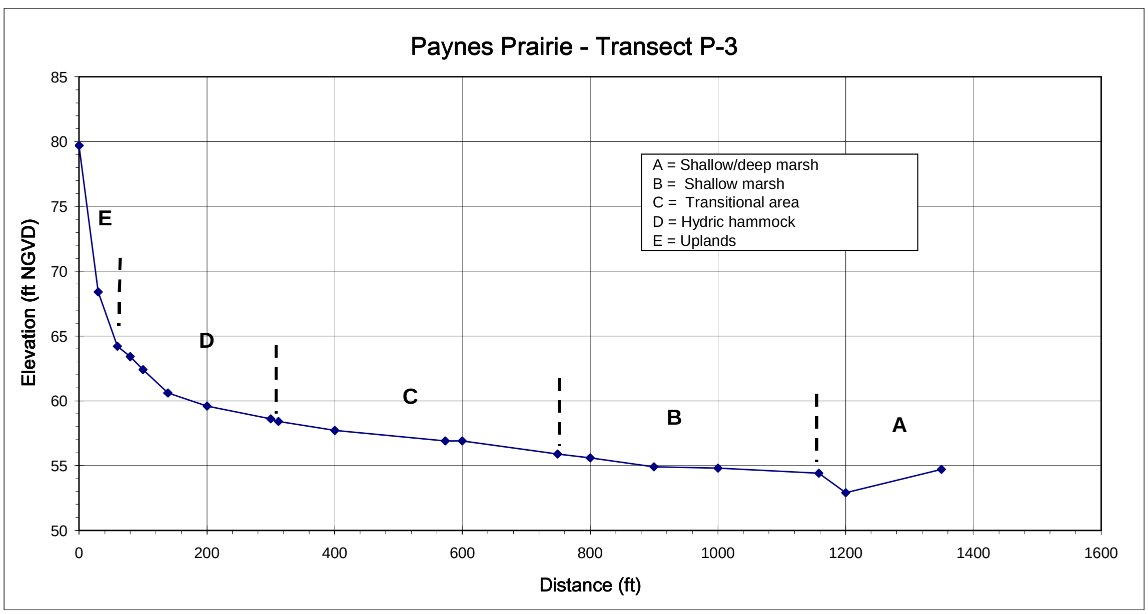
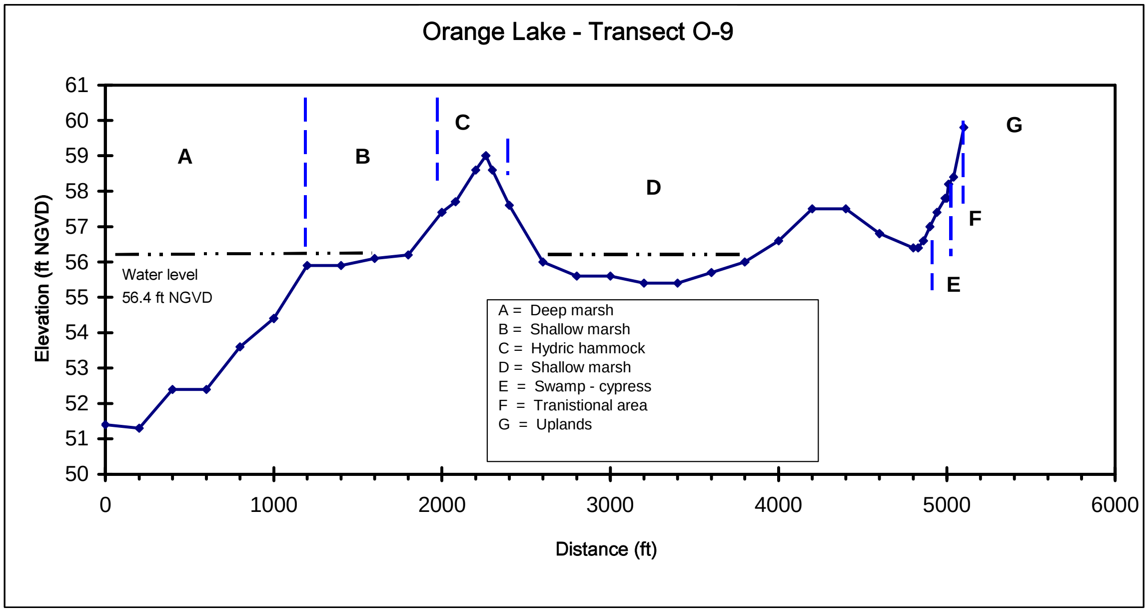


Figure 32. Elevation/vegetation transects at Paynes Prairie



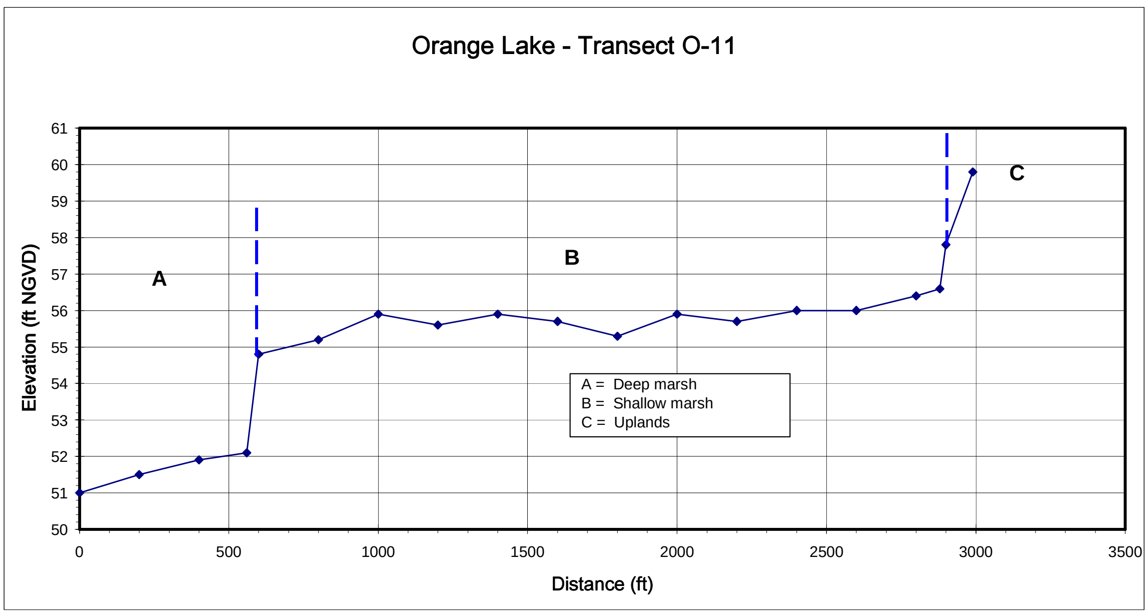
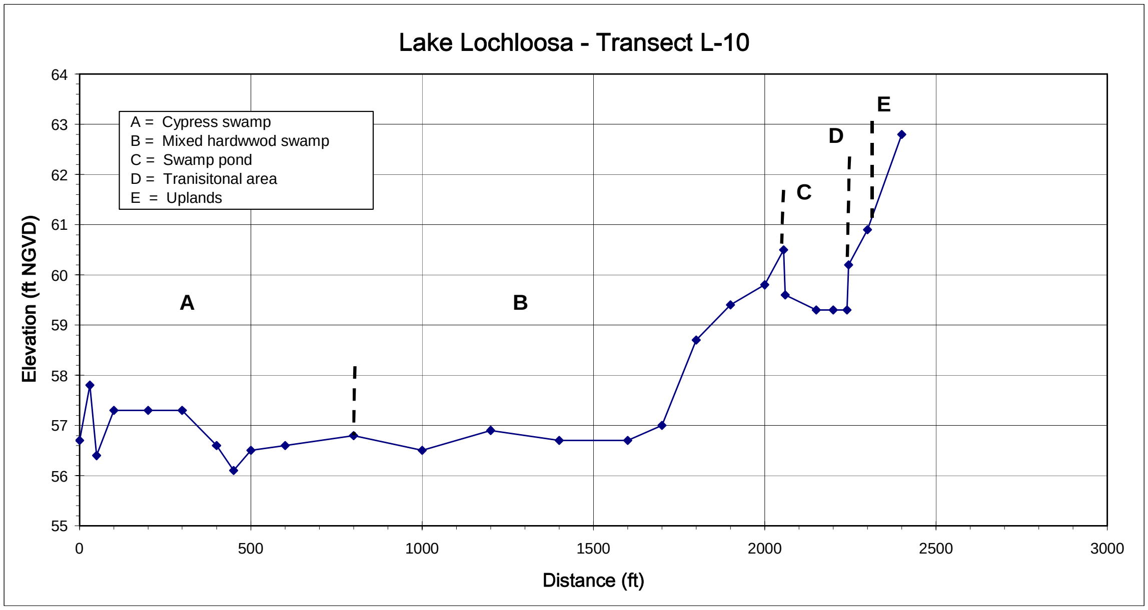


Figure 33. Elevation/vegetation transects at Orange Lake



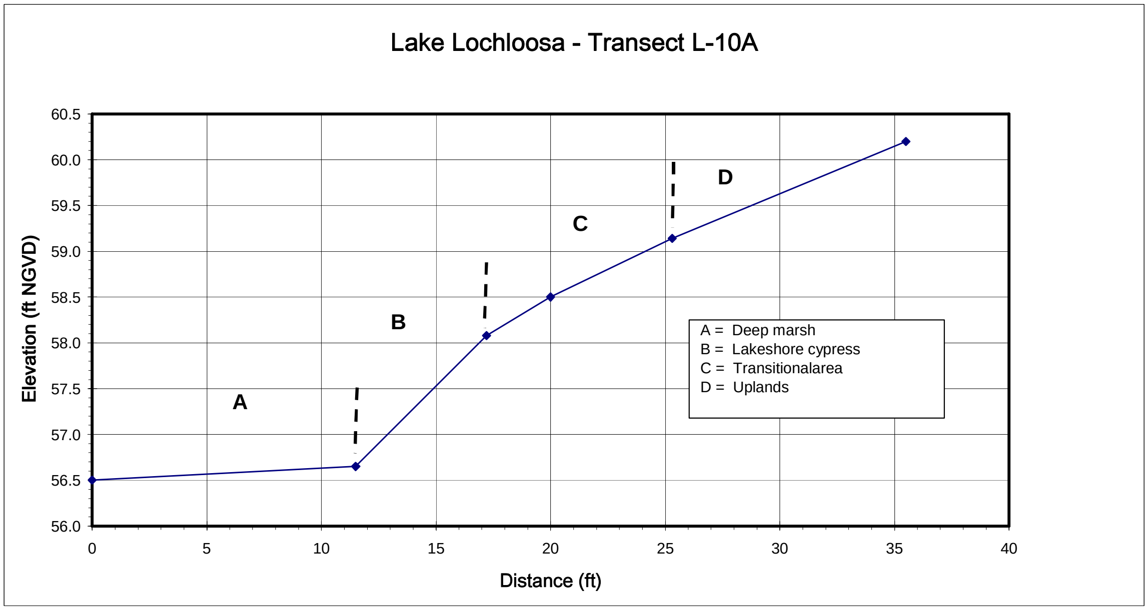


Figure 34. Elevation/vegetation transects at Lake Lochloosa

Table 8. Hydrologic conditions within major plant communities along transects in the Orange Creek Basin*

Location	Plant Community	Elevation		Water Level Inundation Frequency (%) by Hydrologic Conditions		
		Mean (feet)	Range (feet)	Existing	2010	Change (%)
Newnans Lake	Deep marsh	64.0	—	98.6	98.6	0.0
	Cypress swamp	65.7	(65.4–66.1)	49.4	49.4	0.0
	Mixed hardwood swamp	66.5	(66.1–66.9)	26.4	26.4	0.0
	Hydric hammock	67.5	(66.9–68.7)	8.6	8.6	0.0
	Mesic woods	68.6	—	1.0	1.0	0.0
Orange Lake	Deep marsh	53.0	(51.5–56.0)	96.9	96.8	-0.2
	Shallow marsh	56.2	(56.0–57.7)	79.8	79.6	-0.5
	Cypress swamp	57.4	(56.4–58.4)	59.3	58.8	0.0
	Wet prairie	59.0	(57.7–59.0)	2.5	2.5	0.0
	Mesic forest	59.2	(59.0–59.5)	1.0	1.0	0.0
Lake Lochloosa	Shallow marsh	56.8	(57.4–56.2)	76.6	76.2	-0.4
	Cypress swamp	57.0	(56.5–57.2)	73.7	73.3	-0.2
	Mixed hardwood swamp	58.3	(56.7–60.2)	38.2	38.0	-0.1
	Wet prairie	59.1	(57.5–59.2)	10.4	10.3	0.0
Paynes Prairie	Shrub swamp	54.2	—	70.6	70.6	0.0
	Deep marsh	54.2	(54.4–55.9)	70.6	70.6	0.0
	Shallow marsh	54.2	(54.4–55.9)	70.6	70.6	0.0
	Wet prairie	56.7	(55.9–58.4)	49.1	49.1	0.0
	Mesic forest	62.8	(58.4–65.2)	0.0	0.0	0.0

Note: — = not available

*The 'Change' column represents the difference in inundation frequency between the Existing and 2010 conditions

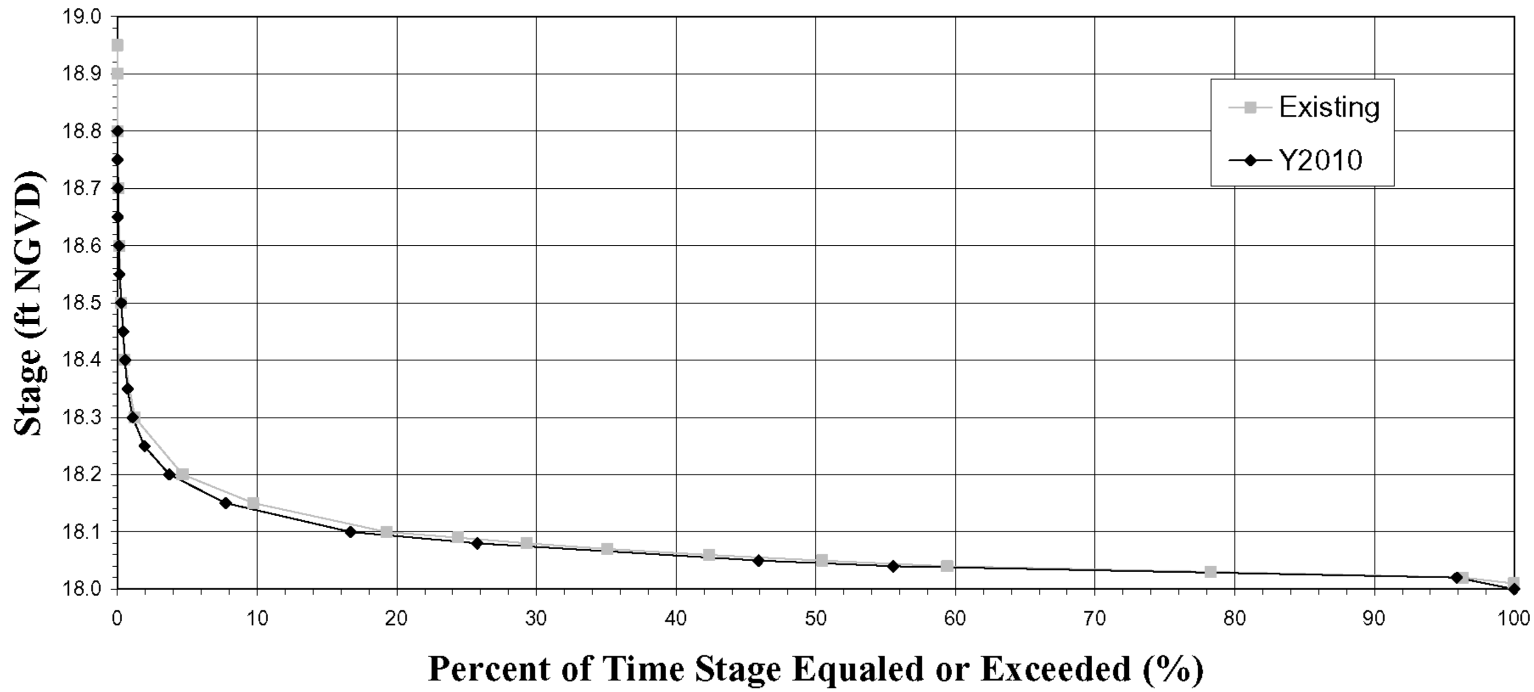


Figure 35. Stage duration analyses for the Ocklawaha River confluence with Orange Creek—Existing and 2010 hydrologic conditions

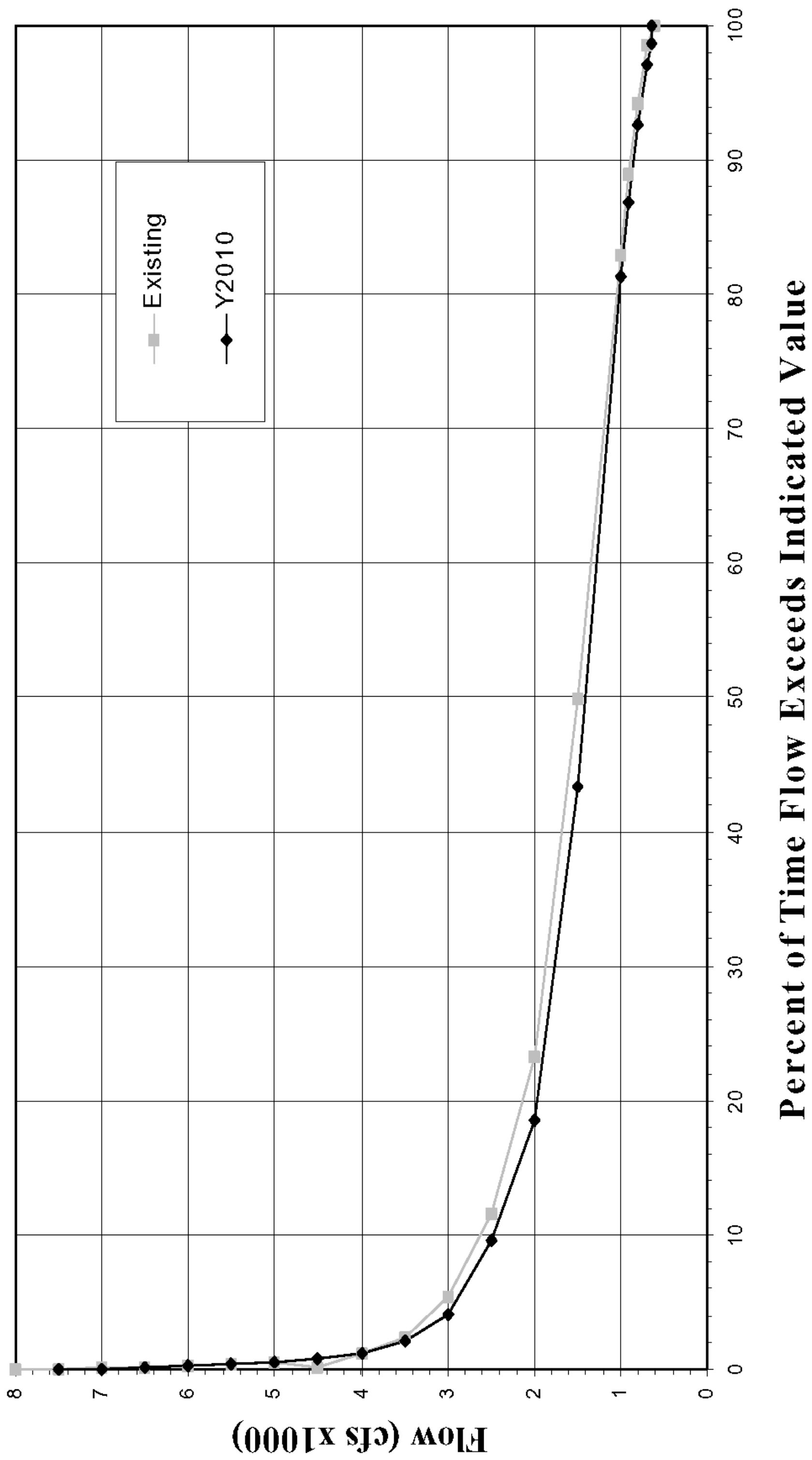


Figure 36. Discharge duration analyses for the Ocklawaha River confluence with Orange Creek—Existing and 2010 hydrologic conditions

surface water management alternatives: (1) Existing-2010 hydrologic conditions, (2) Proposed-2010 hydrologic conditions, and (3) Full Restoration-2010 hydrologic conditions (removal of Rodman Reservoir). The predicted impacts to the wetland communities of the reservoir and the downstream river floodplain at Riverside Landing are discussed below.

Existing-2010 Hydrologic Conditions

This evaluation assessed the environmental impacts to wetland plant communities in Rodman Reservoir and on the floodplain downstream of the dam (Riverside Landing), resulting from surface water withdrawals directly from the reservoir. The hydrologic simulation utilized the Existing reservoir regulation schedule, and the predicted 2010 surface water hydrologic/ hydraulic conditions caused by increased ground/surface water usage.

Rodman Reservoir. The distributions of stage data (stage duration curves) for Rodman Reservoir predicted for the four surface water withdrawal rates showed remarkable similarity (Figure 37). The curves differed by less than 0.1 ft up to the 80th stage duration percentile (approximately 18.0 ft NGVD). The curves diverged at floodplain elevations below 18 ft NGVD, and the duration curves for the 250- and 330-cfs withdrawals exhibited the greatest differences from the “zero” withdrawal condition. The results of mean period of record high and low stage frequency analyses showed relatively small differences ($\leq \pm$ 0.2 ft) in the predicted mean stage for selected durations (number of consecutive days) between the “zero” withdrawal and the 165- and 250-cfs withdrawals (Table 9). However, the changes in the mean period of record low stage for the 330-cfs withdrawal differed by as much as 0.8 ft (Table 9).

A graphical representation of the floodplain elevation transects at Rodman is shown in Figures 20 and 21, and indicates the general location of the primary floodplain plant communities (wetland zone). The mean elevation of the wetland plant zone is summarized in Table 10, as are the water level durations predicted to correspond to this elevation for each withdrawal. Comparisons of stage duration analyses for the mean elevation of the wetland zone (18.2 ft NGVD) indicated small changes in the frequency of inundation (Table 10). The inundation frequency for the mean elevation of the wetland zone shifted from 35% for the Existing-2010 condition, to 26%, 23%, and 21% for the 165-, 250-, and 330-cfs withdrawals, respectively. While these differences represent a 9–14% decrease in inundation frequency, they

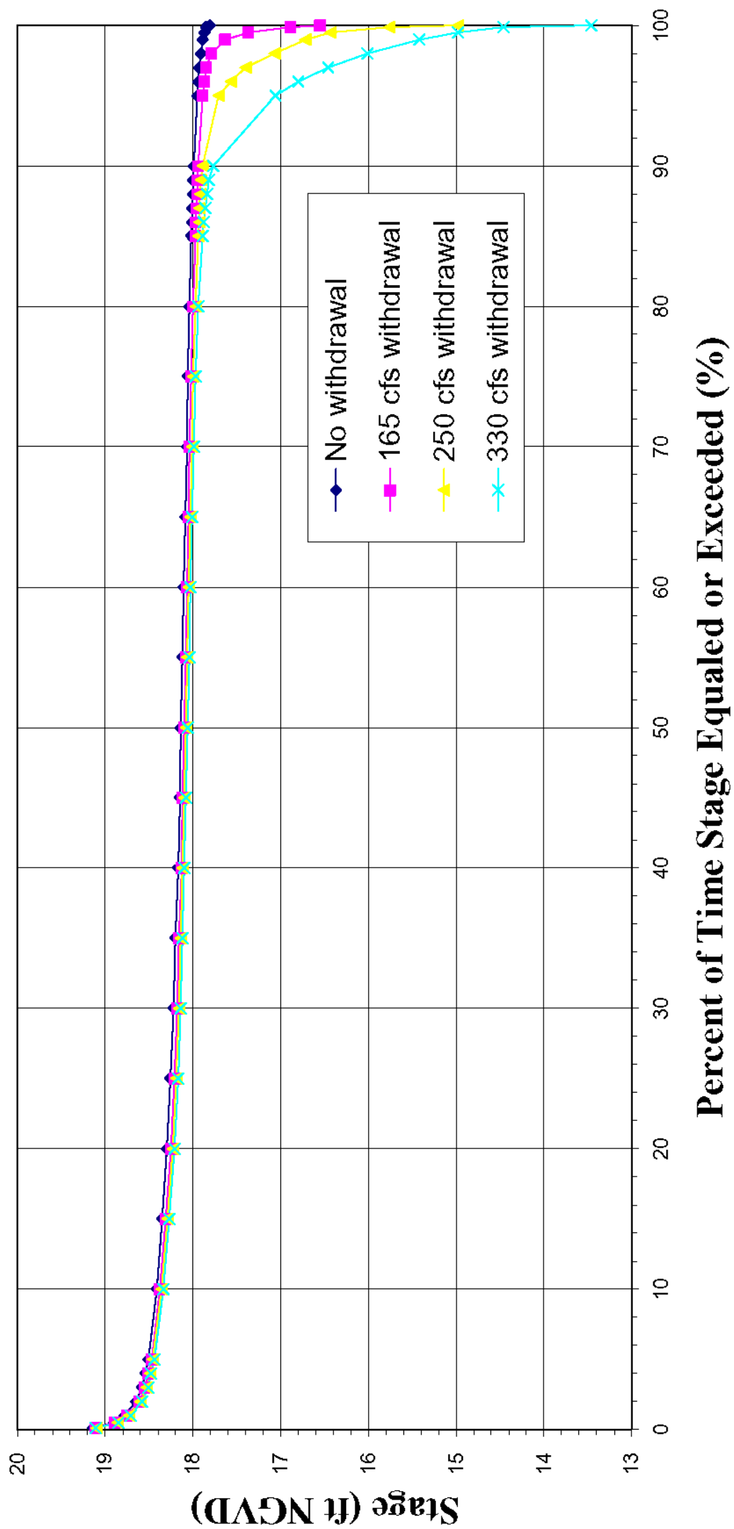


Figure 37. Stage duration analyses for Rodman Reservoir—Existing-2010 hydrologic conditions with 0-, 165-, 250-, and 330-cubic feet per second withdrawals

Table 9. Results from frequency analyses for various 2010 withdrawal alternatives at Rodman Reservoir and Riverside Landing*

Location	Conditions	Mean High Stage Duration (days)																	
		1		7		14		30		60		120		183		274		365	
		Level	Delta	Level	Delta	Level	Delta	Level	Delta	Level	Delta	Level	Delta	Level	Delta	Level	Delta	Level	Delta
Rodman	E-2010	18.82	—	18.66	—	18.59	—	18.46	—	18.37	—	18.29	—	18.24	—	18.20	—	18.17	—
	E-2010-165	18.79	–0.03	18.63	–0.03	18.56	–0.03	18.43	–0.03	18.33	–0.04	18.25	–0.04	18.20	–0.04	18.16	–0.04	18.13	–0.04
	E-2010-250	18.77	–0.05	18.61	–0.05	18.54	–0.05	18.41	–0.05	18.31	–0.06	18.23	–0.06	18.18	–0.06	18.12	–0.08	18.07	–0.10
	E-2010-330	18.76	–0.06	18.60	–0.06	18.52	–0.07	18.49	–0.07	18.29	–0.08	18.21	–0.08	18.15	–0.09	18.07	–0.13	18.98	–0.19
	P-2010	18.84	—	18.67	—	18.59	—	18.48	—	18.40	—	18.33	—	18.29	—	18.26	—	18.23	—
	P-2010-165	18.81	–0.03	18.64	–0.03	18.57	–0.02	18.45	–0.03	18.37	–0.03	18.30	–0.03	18.25	–0.04	18.20	–0.06	18.15	–0.08
	P-2010-250	18.79	–0.05	18.62	–0.05	18.55	–0.04	18.44	–0.04	18.35	–0.05	18.28	–0.05	18.22	–0.07	18.14	–0.12	18.05	–0.18
	P-2010-330	18.77	–0.07	18.61	–0.06	18.54	–0.05	18.42	–0.06	18.33	–0.07	18.25	–0.08	18.18	–0.11	18.05	–0.21	18.90	–0.33
Riverside	E-2010	7.88	—	7.29	—	7.00	—	6.48	—	6.04	—	5.67	—	5.39	—	5.15	—	4.95	—
	E-2010-165	7.77	–0.11	7.18	–0.11	6.88	–0.12	6.33	–0.15	5.85	–0.19	5.43	–0.24	5.12	–0.27	4.85	–0.30	4.63	–0.32
	E-2010-250	7.73	–0.15	7.12	–0.17	6.82	–0.18	6.25	–0.23	5.73	–0.31	5.30	–0.37	4.96	–0.43	4.68	–0.47	4.44	–0.51
	E-2010-330	7.60	–0.28	7.06	–0.23	6.74	–0.26	6.16	–0.32	5.62	–0.42	5.16	–0.51	4.80	–0.59	4.51	–0.64	4.26	–0.69
	P-2010	7.93	—	7.30	—	6.98	—	6.44	—	6.00	—	5.64	—	5.37	—	5.51	—	4.96	—
	P-2010-165	7.81	–0.12	7.19	–0.11	6.86	–0.12	6.29	–0.15	5.81	–0.19	5.41	–0.23	5.11	–0.26	4.86	–0.29	4.65	–0.29
	P-2010-250	7.79	–0.14	7.12	–0.18	6.79	–0.19	6.20	–0.24	5.70	–0.30	5.28	–0.36	4.96	–0.41	4.70	–0.45	4.48	–0.48
	P-2010-330	7.63	–0.30	7.06	–0.24	6.72	–0.26	6.12	–0.32	5.59	–0.41	5.15	–0.49	4.81	–0.56	4.54	–0.61	4.31	–0.65
	R-2010	7.38	—	7.25	—	7.02	—	7.53	—	6.10	—	5.75	—	5.47	—	5.25	—	5.07	—
	R-2010-165	7.27	–0.11	7.15	–0.10	6.91	–0.11	6.38	–0.15	5.91	–0.19	5.52	–0.23	5.22	–0.25	4.96	–0.29	4.76	–0.31
	R-2010-250	7.21	–0.17	7.09	–0.16	6.84	–0.18	6.30	–0.23	5.81	–0.29	5.40	–0.35	5.07	–0.35	4.80	–0.45	4.59	–0.48
	R-2010-330	7.16	–0.22	7.03	–0.22	6.78	–0.24	6.22	–0.31	5.70	–0.40	5.27	–0.48	4.93	–0.54	4.63	–0.62	4.41	–0.66

Table 9—*Continued*

Location	Conditions	Mean Low Stage Duration (days)																	
		1		7		14		30		60		120		183		274		365	
		Level	Delta	Level	Delta	Level	Delta	Level	Delta	Level	Delta	Level	Delta	Level	Delta	Level	Delta	Level	Delta
Rodman	E-2010	17.92	—	17.98	—	18.00	—	18.01	—	18.04	—	18.08	—	18.11	—	18.14	—	18.17	—
	E-2010-165	17.79	−0.13	17.85	−0.13	17.87	−0.13	17.91	−0.10	17.96	−0.08	18.01	−0.07	18.05	−0.06	18.09	−0.05	18.13	−0.04
	E-2010-250	17.57	−0.35	17.61	−0.37	17.68	−0.32	17.78	−0.23	17.90	−0.14	17.97	−0.11	18.02	−0.09	18.09	−0.05	18.13	−0.04
	E-2010-330	17.11	−0.81	17.17	−0.81	17.22	−0.78	17.33	−0.68	17.50	−0.54	17.70	−0.38	17.81	−0.30	17.91	−0.23	17.98	−0.19
	P-2010	17.92	—	17.98	—	18.00	—	18.01	—	18.04	—	18.08	—	18.11	—	18.14	—	18.17	—
	P-2010-165	17.62	−0.30	17.65	−0.33	17.69	−0.31	17.76	−0.25	17.87	−0.17	17.98	−0.10	18.05	−0.06	18.10	−0.04	18.15	−0.02
	P-2010-250	17.18	−0.74	17.22	−0.76	17.27	−0.73	17.39	−0.62	17.56	−0.48	17.77	−0.31	17.88	−0.23	17.98	−0.16	18.05	−0.12
	P-2010-330	16.57	−1.35	16.62	−1.36	16.69	−1.31	16.86	−1.15	17.12	−0.92	17.44	−0.64	17.62	−0.49	17.79	−0.35	17.90	−0.27
Riverside	E-2010	2.84	—	3.40	—	3.51	—	3.67	—	3.93	—	4.28	—	4.50	—	4.72	—	4.95	—
	E-2010-165	2.56	−0.28	2.99	−0.41	3.09	−0.42	3.23	−0.44	3.49	−0.44	3.87	−0.41	4.12	−0.38	4.36	−0.36	4.63	−0.32
	E-2010-250	2.43	−0.41	2.80	−0.60	2.89	−0.62	3.01	−0.66	3.26	−0.67	3.65	−0.63	3.91	−0.59	4.16	−0.56	4.44	−0.51
	E-2010-330	2.40	−0.44	2.67	−0.73	2.73	−0.78	2.84	−0.83	3.07	−0.86	3.45	−0.42	3.71	−0.41	3.96	−0.40	4.26	−0.69
	P-2010	3.26	—	3.57	—	3.65	—	3.78	—	4.01	—	4.33	—	4.54	—	4.73	—	4.96	—
	P-2010-165	3.03	−0.23	3.21	−0.36	3.27	−0.38	3.38	−0.40	3.60	−0.41	3.94	−0.39	4.02	−0.52	4.40	−0.33	4.65	−0.31
	P-2010-250	2.91	−0.35	3.03	−0.54	3.09	−0.56	3.19	−0.59	3.40	−0.61	3.74	−0.59	3.98	−0.56	4.21	−0.52	4.48	−0.48
	P-2010-330	2.78	−0.48	2.89	−0.68	2.93	−0.72	3.02	−0.76	3.21	−0.80	3.55	−0.78	3.80	−0.74	4.03	−0.70	4.31	−0.65
	R-2010	3.70	—	3.74	—	3.80	—	3.92	—	4.15	—	4.46	—	4.66	—	4.85	—	5.07	—
	R-2010-165	3.19	−0.51	3.23	−0.51	3.30	−0.50	3.44	−0.48	3.70	−0.45	4.06	−0.40	4.29	−0.37	4.51	−0.34	4.76	−0.31
	R-2010-250	2.89	−0.81	2.94	−0.80	3.01	−0.79	3.16	−0.76	3.45	−0.70	3.83	−0.63	4.08	−0.58	4.32	−0.53	4.59	−0.48
	R-2010-330	2.57	−1.13	2.63	−1.11	2.71	−1.09	2.85	−1.07	3.19	−0.96	3.59	−0.87	3.86	−0.80	4.12	−0.73	4.41	−0.66

Note: — = not applicable

*The Delta column represents the difference between the mean water level for the 'zero' withdrawal conditions and the mean water levels for the 165-, 250-, and 330-cubic feet per second withdrawals for the Existing-2010 and Full Restoration-2010 hydrologic conditions (E=Existing, P=Proposed, R=Full Restoration)

Table 10. Hydrologic conditions within major plant communities at Rodman Reservoir and Riverside Landing for Existing-2020

Location	Plant Community	Elevation		Inundation Frequency (%) by Level of Withdrawal			
		Mean (feet)	Range (feet)	0 cfs	165 cfs	250 cfs	330 cfs
Rodman Reservoir	Wetland zone	18.2	17.9–18.5	35.0	26.0	23.0	21.0
Riverside Landing	Mixed hardwood swamp	4.0	3.1–6.1	88.2	76.0	71.0	66.0
	Hydric hammock	7.1	6.1–8.3	2.3	2.3	1.6	1.6

Note: cfs = cubic feet per second

corresponded to less than a 0.1-ft change in elevation at the 60th percentile (Figure 37). These hydrologic changes were insignificant, and no additional impacts to the wetland plant communities in this reach of the basin were expected.

The most significant effect of the withdrawals to the reservoir was a marked increase in the range of surface water fluctuation. This was due primarily to a lowering of the minimum pool elevation, as more of the reservoir bottom was exposed, as the amount of the withdrawal increased (Figure 37). The upper elevation range for each of the withdrawals was similar, because these elevations are influenced primarily by flood flow events, and did not vary more than 0.04 ft (Figure 37). The lowest elevation exposed by the “zero” withdrawal was 17.81 ft NGVD. The 165-cfs withdrawal exposed the 16.55 ft NGVD contour (-1.26 ft below the “zero” condition) with an exposure zone of approximately 15–55 ft. The 250-cfs withdrawal exposed the 14.98 ft NGVD contour (-2.83 ft below “zero” condition) and affected a littoral zone area of 45–180 ft. The 330-cfs withdrawal exposed the 13.46 ft NGVD contour (-4.35 ft below the “zero” condition) and the exposure zone was approximately 95–260 ft wide.

A 3–4-ft range of water level fluctuation is not unusual for many Florida lakes (Motz et al. 1982) and is often desirable to consolidate and compact sediments (e.g., the Harris Chain of Lakes in the Upper Ocklawaha River subbasin) and allow re-seeding of emergent aquatic vegetation.

The timing of the low water events, however, is especially critical in Rodman Reservoir. Hydrilla expands during the growing season in Rodman Reservoir and usually covers the water surface in all but the deeper areas of the reservoir during the summer. In August 1994, SJRWMD increased water levels to around 18.5 ft NGVD to alleviate the impacts hydrilla has on oxygen exchange between the water column and the atmosphere. This action was taken to decrease the possibility of a summer fish kill on Rodman Reservoir. The relevance of this with respect to consumptive use withdrawals from Rodman is that water levels should not be significantly lowered during the summer months when hydrilla covers the water surface and fills the water column.

An analysis of average monthly water levels in Rodman Reservoir with 0-, 165-, 250-, and 330-cfs consumptive use withdrawals shows that water levels are not significantly reduced during the summer months (Table 11). However, average monthly water levels in Rodman Reservoir during the summer months of low-water years would be significantly reduced by the 250- and 330-cfs consumptive use withdrawals (Table 12) and could lead to large fish kills in Rodman under those conditions.

Table 11. Effects of consumptive use withdrawals from Rodman Reservoir on reservoir water levels during all years

CUP Withdrawal (cfs)	All Months		Summer Months	
	Level (feet)	Difference*	Level (feet)	Difference
0	18.23	a	18.27	a
165	18.16	a, b	18.23	a
250	18.07	b	18.15	a
330	17.91	c	18.03	a

Note: cfs = cubic feet per second
CUP = consumptive use permit

*CUPs with more than one letter are statistically significantly different from one another ($P < 0.05$—the significance probability. There is less than a 5% chance that the means for the different levels [feet] are not significantly different).

Table 12. Effects of consumptive use withdrawals from Rodman Reservoir on reservoir water levels during low-water years*

CUP Withdrawal (cfs)	All Months		Summer Months	
	Level (feet)	Difference	Level (feet)	Difference
0	18.04	a	18.08	a
165	17.58	a	17.86	a
250	16.79	b	17.35	b
330	15.45	c	15.75	c

Note: cfs = cubic feet per second
CUP = consumptive use permit

*A low-water year for a particular month is defined as any year during the 1933–1992-year modeling period when the average water level in the reservoir for that month fell below 17.0 feet National Geodetic Vertical Datum for any of the four CUP alternatives.

Riverside Landing. A comparison of stage duration curves for Riverside Landing predicted for the four surface water withdrawal rates showed remarkable similarities (Figure 38). There were no major differences in the actual water levels achieved downstream of the reservoir; however, the duration of the stages decreased with increasing level of withdrawal (see the 20th to 35th, 35th to 65th, and 65th to 90th percentiles; Figure 38). The 20th to 35th percentile (5–6 ft NGVD) experienced a 5–10% decrease in duration frequency for the withdrawals and a drop in elevation of 0.57 ft, and the hydrology was altered on a 5–10-ft-wide floodplain zone. The 35th to 65th percentile (4–5 ft NGVD) experienced a 15–25% decrease in inundation frequency and a drop of 0.73 ft; hydrology was altered on a 10–20-ft-wide floodplain zone. These ranges of inundation frequency are tempered by high flow events and are less affected by increases in withdrawal volumes. Additionally, the volume of the river flow is so large at these points on the stage duration curve, that the effects of withdrawals are minimal. The 65th to 90th percentile represents the lower floodplain elevations (2–5 ft NGVD) and corresponds to a 3,900-ft-wide floodplain zone (Figure 38). This portion of the floodplain experienced a 13–23% decrease in inundation frequency and a drop in stage of 1.88 ft for all management options. The lowest elevations achieved (100th percentile) for the different water withdrawals varied from 2.09 to 2.46 ft NGVD, or a range of 0.1 to 0.4 ft below the “zero” withdrawal level. The width of the river channel experiencing an altered hydrology was ≤5 ft.

A graphical representation of the floodplain elevation transect at Riverside is shown in Figure 25 and indicates the general location of the primary floodplain plant communities. The mean elevation of the wetland plant communities is summarized in Table 10, as are the water level durations predicted to correspond to these elevations for each withdrawal. The inundation frequencies for the mean elevation of the hardwood swamp (4.0 ft NGVD) decreased as the level of the withdrawal increased (Table 10). The inundation frequency for the mean elevation of the swamp community shifted from approximately 88% for the Existing-2010 condition, to 76%, 71%, and 66% for the 165-, 250-, and 330-cfs withdrawals, respectively. While these differences represent a 12–22% decrease in inundation frequency, no change in elevation occurred (Figure 38). The hydrologic alterations to the hydric hammock community were negligible for all levels of surface water withdrawal (Table 10).

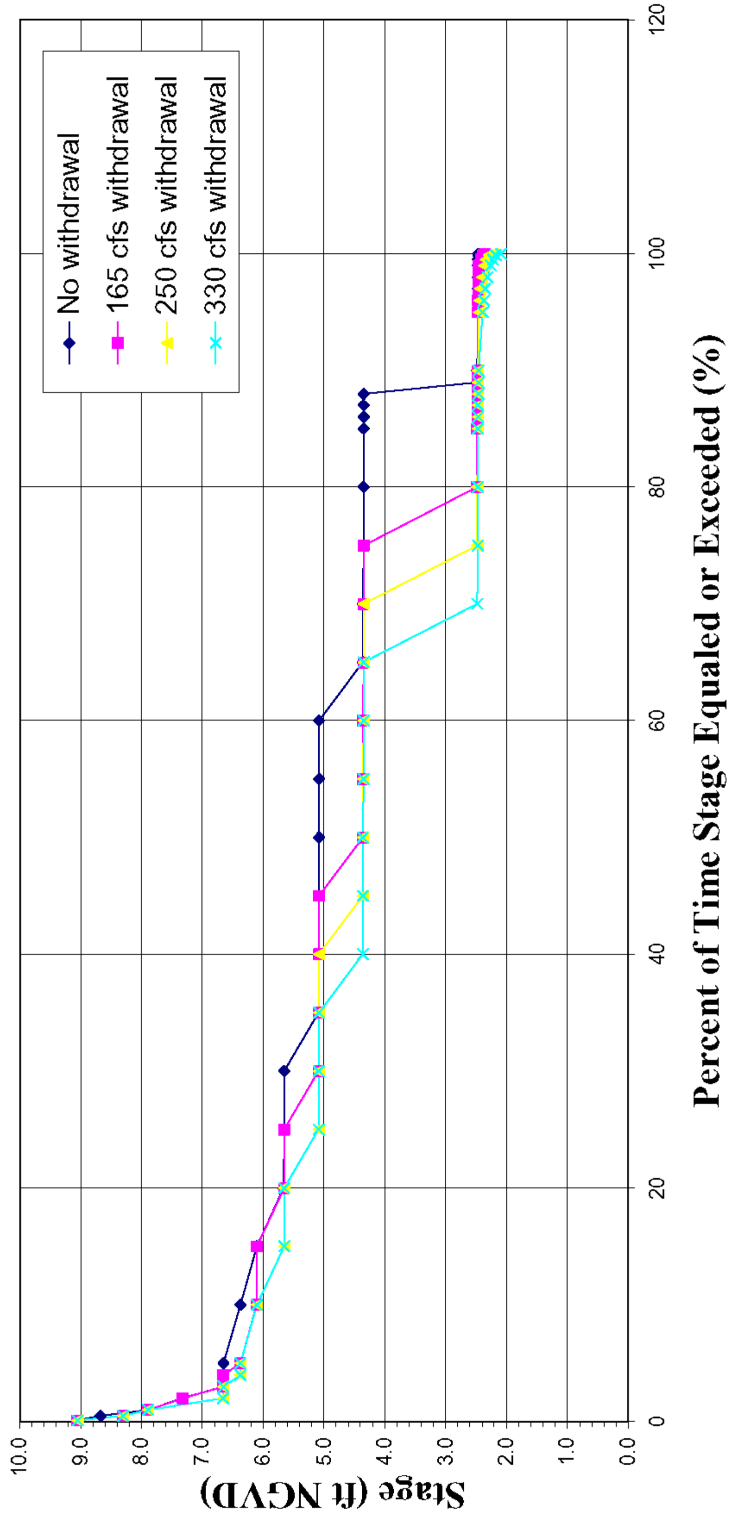


Figure 38. Stage duration analyses for Riverside Landing—Existing-2010 hydrologic conditions with 0-, 165-, 250-, and 330-cubic feet per second withdrawals

The impact of these four consumptive use withdrawals from Rodman Reservoir on downstream discharge volumes to the Ocklawaha River was assessed to predict impacts on migratory fishes that might occur during the winter months when they move upstream. Discharge volumes to the Ocklawaha River would be expected to be significantly reduced during the winter months by 165-, 250-, or 330-cfs withdrawals from Rodman Reservoir (Tables 13 and 14). However, with the dam in place, the ecological significance of these impacts is minor unless fish passage facilities are provided. If fish passage facilities are constructed on either the canal or dam outlets from Rodman Reservoir, then these winter month discharge reductions may be ecologically significant. There are no data available, however, to ascertain the relationship between migratory fish movement and reproduction with river discharges for the Ocklawaha River.

Table 13. Effects of consumptive use withdrawals from Rodman Reservoir on discharges through Rodman Dam to Ocklawaha River levels during all years

CUP Withdrawal (cfs)	All Months		Winter Months	
	Discharge (cfs)	Difference*	Discharge (cfs)	Difference*
0	1673.8	a	1582.4	a
165	1509.1	a, b	1418.2	b
250	1424.5	b	1334.0	b, c
330	1345.1	b	1256.3	c

Note: cfs = cubic feet per second
CUP = consumptive use permit

*CUPs with more than one letter are statistically significantly different from one another ($P < 0.05$—the significance probability. There is less than a 5% chance that the means for the different levels [feet] are not significantly different).

Table 14. Effects of consumptive use withdrawals from Rodman Reservoir on discharges through Rodman Dam to Ocklawaha River levels during low-water years*

CUP Withdrawal (cfs)	All Months		Winter Months	
	Discharge (cfs)	Difference	Discharge (cfs)	Difference†
0	1,105.9	a	1,110.8	a
165	926.2	b	911.2	b
250	841.4	c	826.3	b, c
330	765.0	c	755.1	c

Note: cfs = cubic feet per second
CUP = consumptive use permit

*A low-water year for a particular month is defined as any year during the 1933–1992-year modeling period when the discharge through Rodman Dam to the Ocklawaha River fell below 1,000 cfs during that month for any of the four CUP alternatives.

†CUPs with more than one letter are statistically significantly different from one another (P < 0.05—the significance probability. There is less than a 5% chance that the means for the different levels [feet] are not significantly different).

Proposed-2010 Hydrologic Conditions

Rodman Reservoir. The hydrologic regimes for the Proposed-2010 and Existing-2010 management alternatives were similar. Only slight differences in minimum and maximum stages and durations were observed. The trends in the stage duration data predicted for the four surface water withdrawals for the Proposed-2010 conditions were quite similar (Figure 39). The curves differed by less than 0.2 ft up to the 80th stage duration percentile (approximately 18.0 ft NGVD). The curves diverged at floodplain elevations below 18 ft NGVD, and the duration curves for the 250- and 330-cfs withdrawals exhibited the greatest differences from the "zero" withdrawal condition. The results of mean period of record high and low stage frequency analyses showed relatively small (≤0.3 ft) differences in the predicted mean stage for selected durations between the "zero" withdrawal and the 165- and 250-cfs withdrawals (Table 9). However, the changes in the mean period of record low stages for selected durations for the 330-cfs withdrawal differed by as much as 1.4 ft (Table 9).

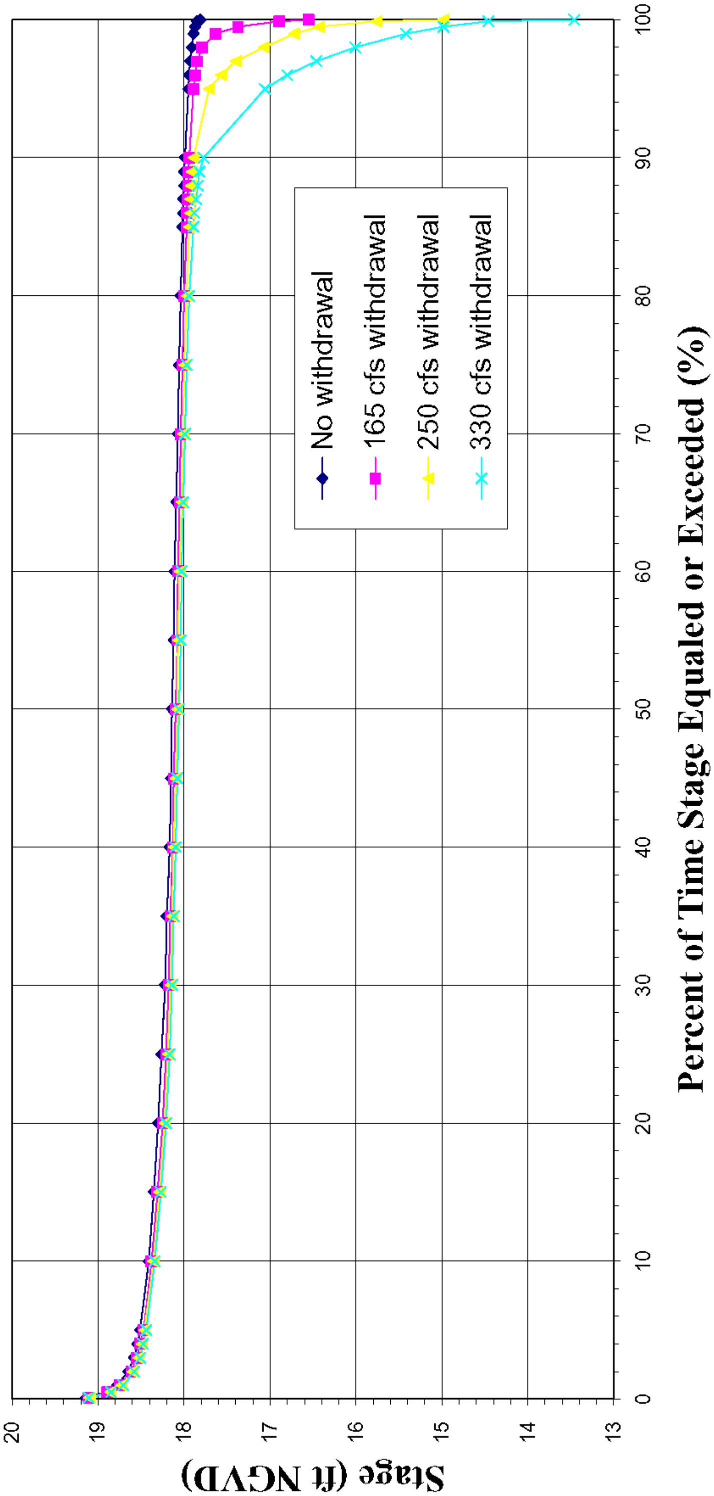


Figure 39. Stage duration analyses for Rodman Reservoir—Proposed-2010 hydrologic conditions with 0-, 165-, 250-, and 330-cubic feet per second withdrawals

A graphical representation of the floodplain elevation transects at Rodman is shown in Figures 20 and 21, and indicates the general location of the primary floodplain plant communities (wetland zone). The mean elevation of the wetland plant zone is summarized in Table 15, as are the water level durations predicted to correspond to this elevation for each withdrawal. The mean elevation of the wetland zone (18.2 ft NGVD) was inundated 55% of the time for the Proposed-2010 condition, but the inundation frequency was reduced to 42.5%, 37.5%, and 32.5% for the 165-, 250-, and 330-cfs withdrawals, respectively. While these differences represent a 12.5–17.5% decrease in the inundation frequency, they corresponded to a ≤0.1-ft change in elevation at the 55th stage duration percentile (Figure 39). These hydrologic changes were negligible, and no additional impacts to the wetland plant communities in this reach of the basin were expected.

The range of surface water fluctuation was increased over the Existing-2010 hydrologic conditions for all levels of withdrawal (Figures 37 and 39). The maximum reservoir water level for each of the withdrawals was similar, and did not vary more than ±0.02 ft. However, surface water withdrawals increased the exposure of lower floodplain elevations and enhanced the range of reservoir fluctuation. The magnitude of the increase in the fluctuation range increased with the size of the withdrawal (Figure 39). The lowest elevation exposed by the “zero” withdrawal was 17.61 ft NGVD. The 165-cfs withdrawal exposed the 15.23 ft NGVD contour (-2.38 ft below the “zero” condition) with an exposure zone of approximately 25–165 ft. The 250-cfs withdrawal exposed the 13.64 ft NGVD contour (-3.97 ft below “zero” condition) and exposed a littoral zone of 43–260 ft. The 330-cfs withdrawal exposed the 11.936 ft NGVD contour (-5.68 ft below the “zero” condition) and the exposure zone was approximately 61–350 ft wide.

As with the Existing-2010 hydrologic conditions, the timing of low water events is critical for proper reservoir management. Because the Proposed-2010 hydrologic conditions produced lower minimum water levels than the Existing-2010 conditions, for all withdrawal levels, it has the potential to exacerbate poor water quality conditions and increase the likelihood of fish kills.

Riverside Landing. The stage duration curves for the Proposed-2010 and Existing-2010 management alternatives were very similar through the 50th percentile (Figures 38 and 40). Differences occurred at the higher durations (lower floodplain elevations) and were due to changes in the low-flow

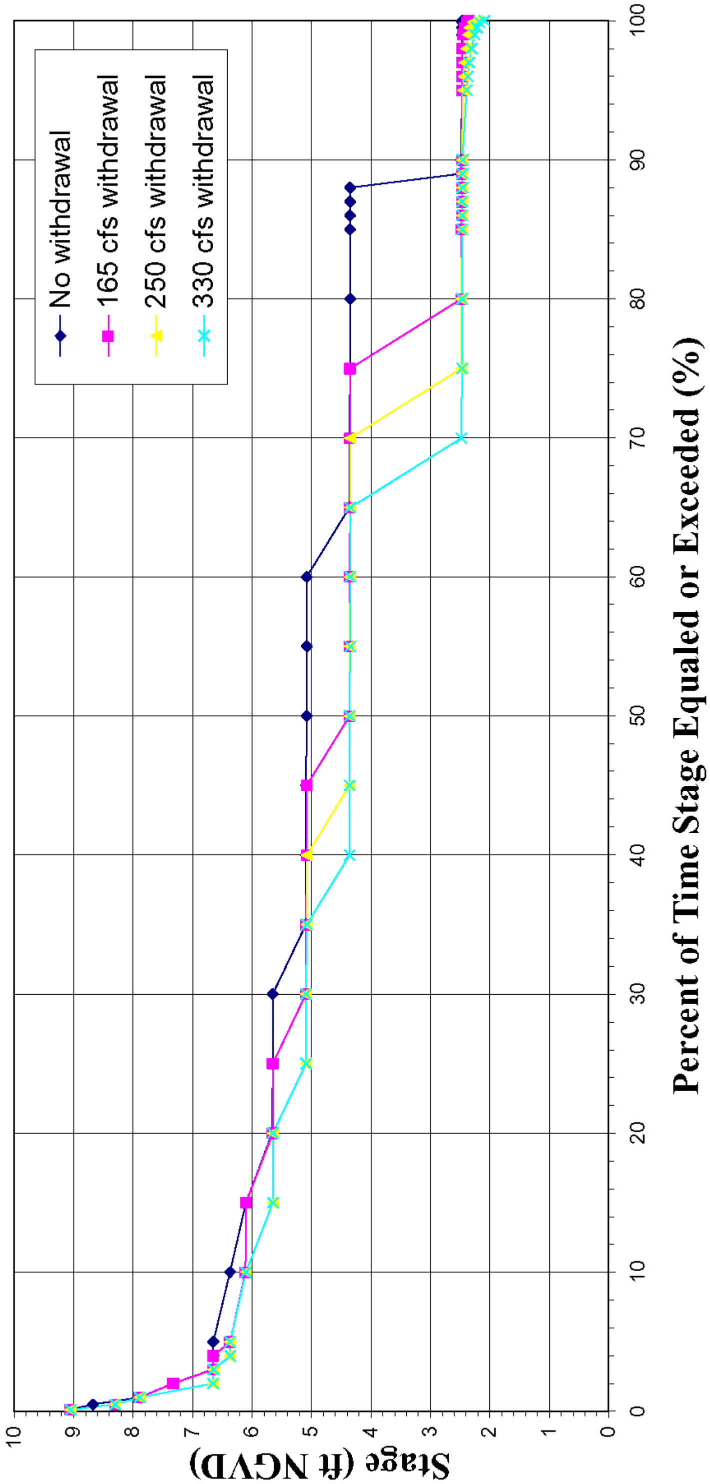


Figure 40. Stage duration analyses for the Ocklawaha River at Riverside Landing—Proposed-2010 hydrologic conditions with 0-, 165-, 250-, and 330-cubic feet per second withdrawals

discharge schedule for the Proposed-2010 conditions (80th to 90th duration percentiles; Figures 41 and 42). The results are a more gradual transition between stages downstream of the reservoir.

A comparison of stage duration curves for Riverside Landing predicted for the four surface water withdrawal rates showed the same general trends as for the Existing-2010 conditions (Figures 38 and 40). There were no major differences in the actual water levels achieved downstream of the reservoir; however, the duration of the stages decreased with increasing level of withdrawal (see the 20th to 35th, 35th to 65th, and 65th to 90th percentiles; Figure 40). The 20th to 35th percentile (5–6 ft NGVD) experienced a 5–10% decrease in inundation frequencies for the withdrawals and a drop in elevation of 1.01 ft predicted to occur over a 5–10-ft-wide floodplain zone. The 35th to 60th percentile (4–5 ft NGVD) experienced a 15–25% decrease in the inundation frequencies and a drop of 0.73 ft predicted to occur on a 10–20-ft-wide floodplain zone. These ranges of inundation frequency are tempered by high-flow events and less affected by increases in withdrawal volumes. Additionally, the volume of the river flow is so large at these points on the stage duration curve that the effects of withdrawals are minimized. The 65th to 90th percentile represents the lower floodplain elevations (3–5 ft NGVD) and corresponds to a 3,900-ft-wide floodplain zone (Figure 40). This portion of the floodplain experienced a 10–25% decrease in inundation frequency and a drop in stage of 0.58 ft for all management options. The lowest elevations achieved (100th percentile) for the different water withdrawals varied from 2.17 to 2.79 ft NGVD. These elevations were 0.08–0.33 ft higher than the corresponding levels under the Existing-2010 alternative. The width of the river channel experiencing altered hydrology is ≤5 ft.

A graphical representation of the floodplain elevation transect at Riverside Landing is shown in Figure 25 and indicates the general location of the primary floodplain plant communities. The mean elevations of the wetland plant communities are summarized in Table 15, as are the water level durations predicted to correspond to these elevations for each withdrawal. The inundation frequency for the mean elevation of the mixed hardwood swamp (4.0 ft NGVD) decreased as the level of the withdrawal increased (Table 15). The inundation frequency for the 4.0-ft NGVD elevation shifted from approximately 83% for the “zero” withdrawal to 73%, 63.0%, and 58% for the 165-, 250-, and 330-cfs withdrawals, respectively. While these differences represent a 10–25% decrease in inundation frequency, no change

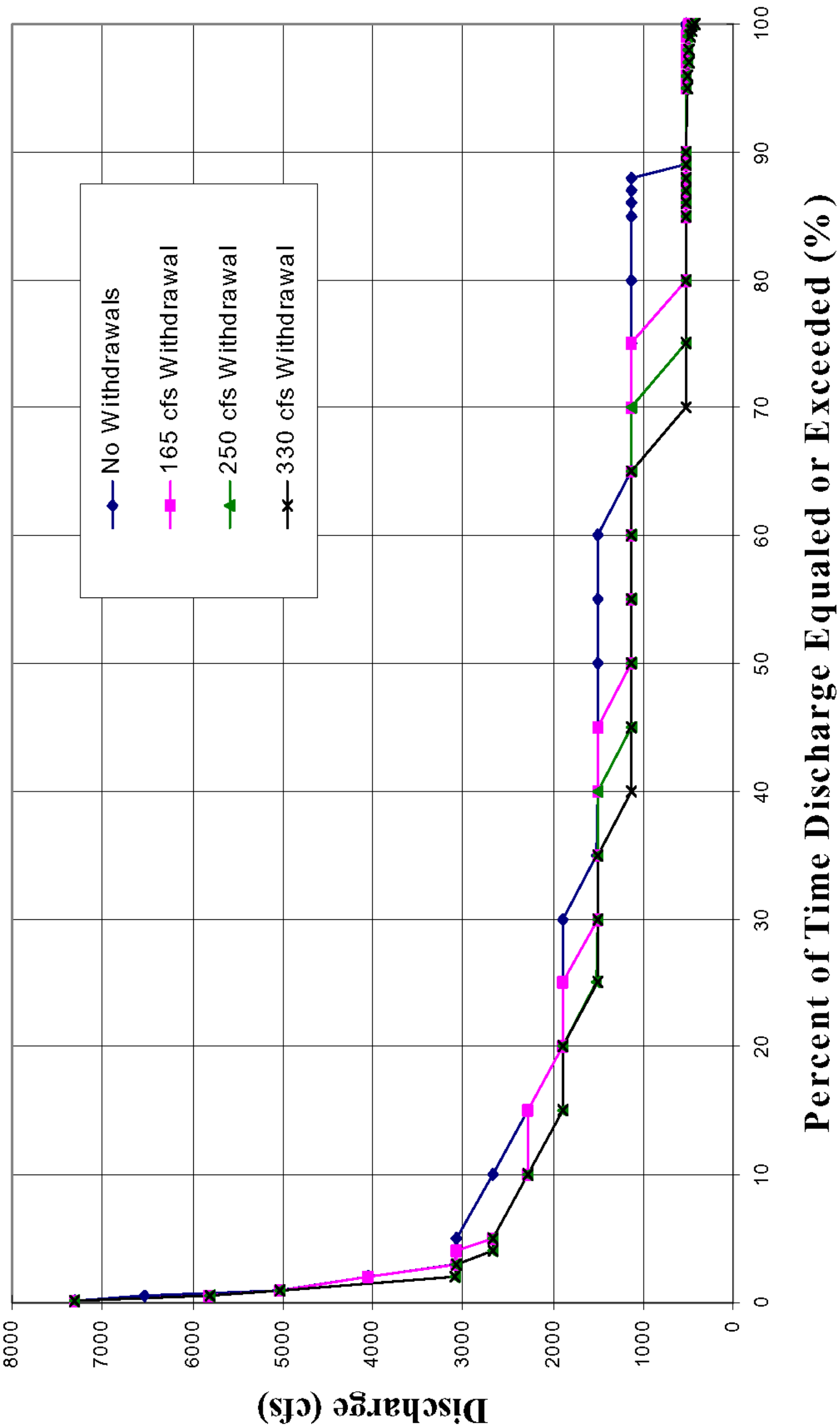


Figure 41. Discharge duration analyses for Rodman Dam—Existing-2010 hydrologic conditions with 0-, 165-, 250-, and 330-cubic feet per second withdrawals

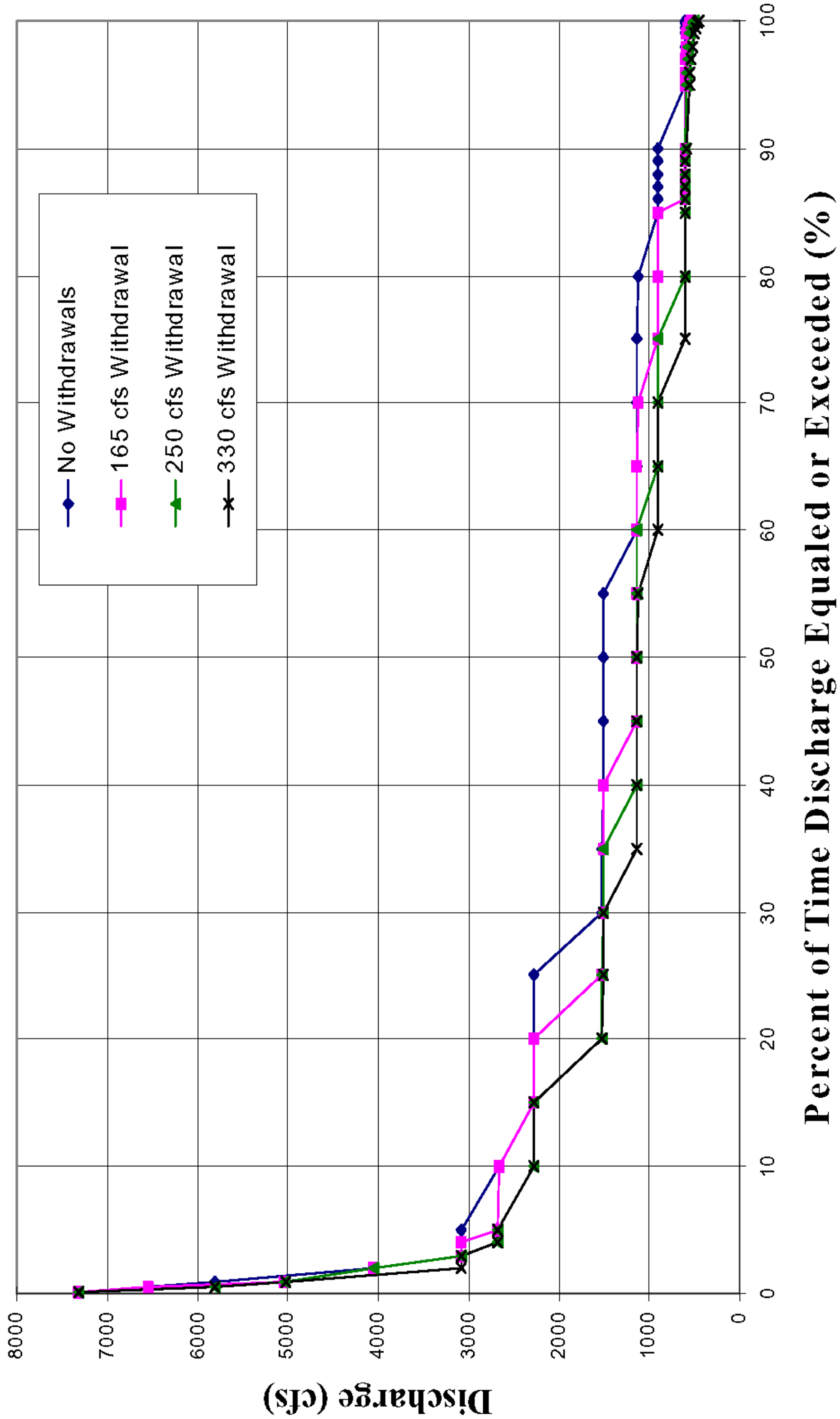


Figure 42. Discharge duration analyses for Rodman Dam—Proposed-2010 hydrologic conditions with 0-, 165-, 250-, and 330-cubic feet per second withdrawals

in elevation occurred (Figure 40). The hydrologic alterations to the hydric hammock community were negligible for all levels of surface water withdrawal (Table 15).

Full Restoration-2010 Hydrologic Conditions

Rodman Reservoir. Comparisons for Rodman Reservoir are impracticable for this alternative. No environmental information was available near the Rodman Dam to allow an evaluation of this restoration alternative.

Riverside Landing. A comparison of the stage duration curves for the Existing-2010, Proposed-2010 and Full Restoration-2010 alternatives clearly indicates the improved hydrologic conditions that would result from restoration (Figure 43). Between the 90th and 95th percentile, the stage duration curves were comparable for the Full Restoration-2010 and Proposed-2010 management alternatives. The most obvious improvement is the smooth transition between stages which will provide more gradual stage recession rates on the floodplain.

The effects of withdrawals from the river channel near the current site of the Rodman Dam on the stage duration relationships at Riverside Landing are displayed in Figure 44. The general trends are similar to the previous evaluations; the inundation frequency decreased with increasing level of withdrawal. The largest differences in inundation frequency occurred at the lowest floodplain elevations, approximately 1.0–4.0 ft NGVD. The minimum river stage for the “zero” withdrawal was 2.80 ft NGVD, a level essentially identical to the Proposed-2010 management alternative (Figure 43). The minimum river stage declined to 2.13, 1.70, and 1.23 ft NGVD for the 165-, 250-, and 330-cfs withdrawals, respectively (Figure 44). Minimum river stages for the Full Restoration-2010 alternative for the 165-, 250-, and 330-cfs withdrawals, respectively, were 0.41, 0.66, and 0.94 ft lower than the Proposed-2010 conditions. Apparently, this is due to the absence of the low-flow augmentation capability provided by the reservoir basin.

A graphical representation of the floodplain elevation transect at Riverside Landing is shown in Figure 25 and indicates the general location of the primary floodplain plant communities. The mean elevations of the wetland plant communities are summarized in Table 15, as are the water level durations predicted to correspond to these elevations for each withdrawal. The inundation frequency for the mean elevation of the hardwood swamp (4.0 ft NGVD) decreased as the level of the withdrawal increased (Table 16).

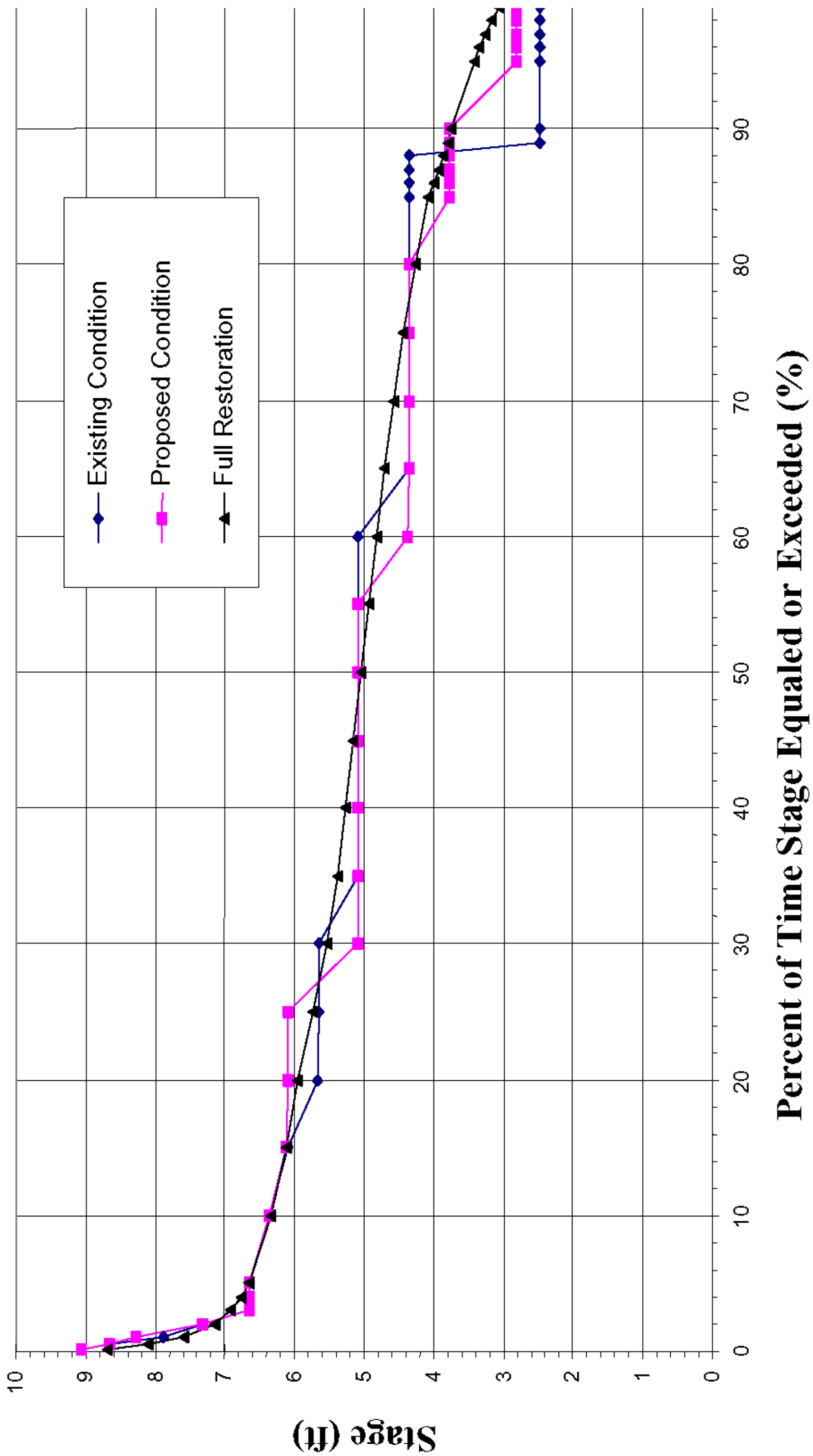


Figure 43. Stage duration analyses for Riverside Landing—Existing-2010, Proposed-2010, and Full Restoration-2010 hydrologic conditions

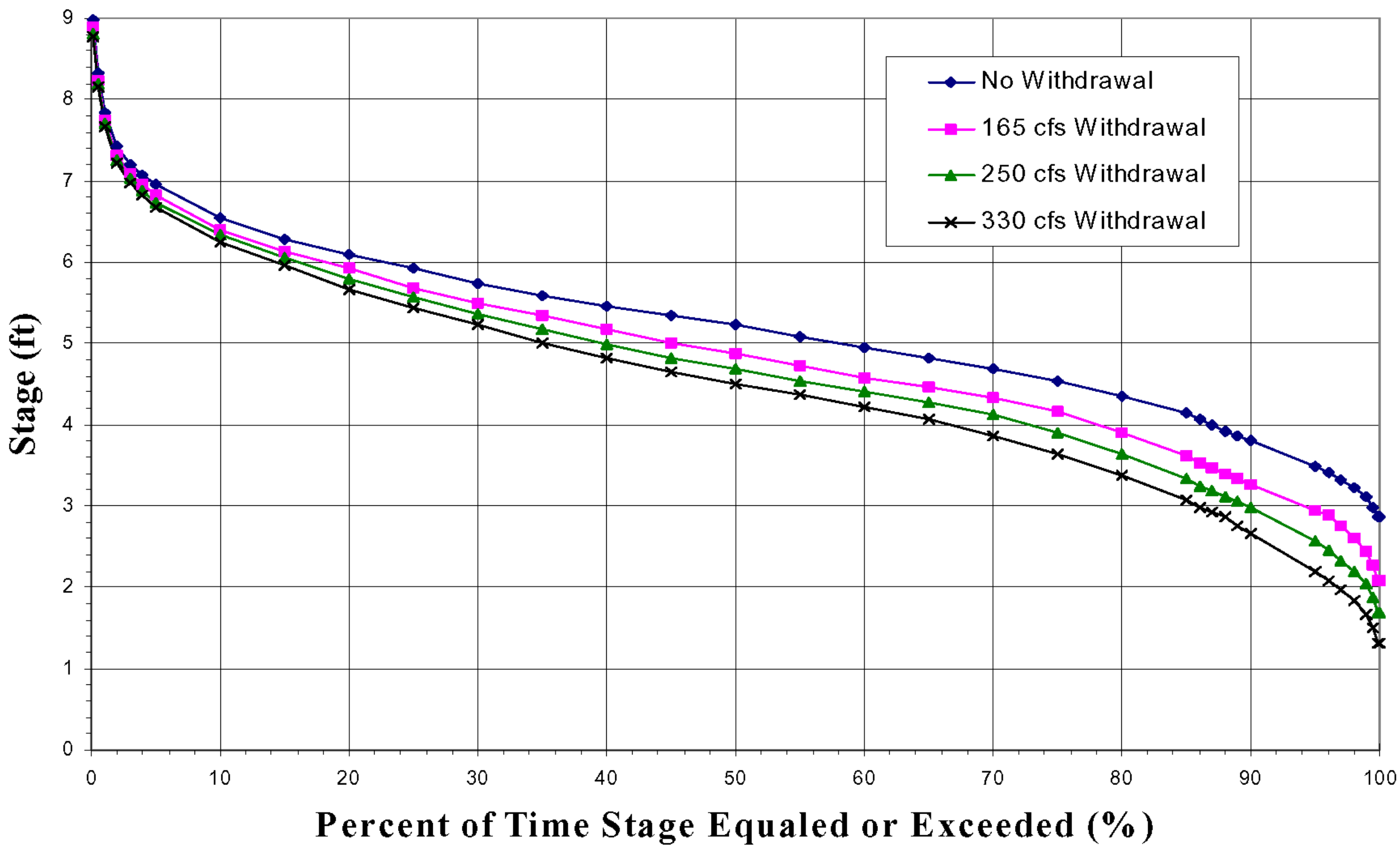


Figure 44. Stage duration analyses for Riverside Landing—Full Restoration-2010 hydrologic conditions with 0-, 165-, 250-, and 330-cubic feet per second withdrawals

Table 15. Hydrologic conditions within major wetland plant communities at Rodman Reservoir and Riverside Landing for Proposed-2010

Location	Plant Community	Elevation		Inundation Frequency (%) by Level of Withdrawal			
		Mean (feet)	Range (feet)	0 cfs	165 cfs	250 cfs	330 cfs
Rodman Reservoir	Wetland zone	18.2	17.9–8.5	55.0	42.5	37.5	32.5
Riverside Landing	Mixed hardwood swamp	4.0	3.1–6.1	83.0	73.0	63.0	58.0
	Hydric hammock	7.1	6.1–8.3	2.3	2.3	2.3	1.6

Note: cfs = cubic feet per second

Table 16. Hydrologic conditions within major plant communities present at Riverside Landing for Full Restoration-2010

Location	Plant Community	Elevation		Inundation Frequency (%) by Level of Withdrawal			
		Mean (feet)	Range (feet)	0 cfs	165 cfs	250 cfs	330 cfs
Riverside Landing	Mixed hardwood swamp	4.0	3.1–6.1	83.0	77.0	71.0	65.0
	Hydric hammock	7.1	6.1–8.3	2.2	1.8	1.6	1.6

Note: cfs = cubic feet per second

The inundation frequency for the 4.0-ft NGVD elevation shifted from approximately 86% for the "zero" withdrawal to 77%, 71%, and 65% for the 165-, 250-, and 330-cfs withdrawals, respectively. The elevations of the floodplain that would experience the 86% inundation frequency changed rather markedly (Figure 44). The differences between the "zero" withdrawal and the 165, 250, and 330 cfs were -0.54, -0.81, and -1.07 ft, respectively. However, these changes in inundation frequency (86 to 65%), even at the highest water withdrawal, will not alter the structure and ecological functions of the floodplain mixed hardwood swamp community or the hydric hammock community in this reach of the river.

Economic Evaluation, by Marion Ritter and Don Smith

The economic evaluation was limited to a comparison of the estimated costs associated with transporting various quantities of water from the LOR subbasin various distances with the estimated costs of treating locally derived water with reverse osmosis (RO) technology. These estimates were average approximations of costs and provide information for use in judgments associated with very general comparisons. Costs associated with lands and rights-of-way, and special crossings over highways, waterways, and other obstructions, were difficult to estimate without more specific routing determinations. A factor of 50% (research and development, 10%; overhead, 10%; contingencies, 15%; and land and rights-of-way, 15%) has been estimated to allow for these type items associated with the transport of water to off-site locations (Tables 17 and 18).

Transporting water to off-site locations up to 50 miles from the Rodman Reservoir location may compare favorably with the cost of treating water using the RO method. The costs for transporting water 50 miles ranged from $516 per mgd to $1,140 per mgd. An estimate of costs, using existing water treatment plants, to treat the water to improve the quality to that of the RO water produced in the transport area would add a minimum of $500 per mgd to the cost. Production costs for RO water were based on the review of a number of cost analyses prepared for journal publications and presentations at professional seminars, and the review of several actual plant projected budgets. The plant production capacities ranged from 1.0 mgd to 14.0 mgd, with the costs varying from $0.75 per 1,000 gallons to $2.50 per 1,000 gallons. The average cost was $1.22 / 1,000 gallons. The development of a supply source will increase this value to between $1.50 / 1,000 gallons and $1.70 / 1,000 gallons, which makes the cost of RO water $1,600 per mgd ($1.60 / 1,000 gallons, the average of these two values).

The number of variables associated with analyzing production costs made it difficult to compute a cost applicable to a general situation. A more detailed design description will be required for comparing specific sites. However this analysis indicated that it may be feasible to utilize LOR water by transporting it up to 50 miles. Beyond 50 miles, consideration should be given to using water of lesser quality available in the locality and providing a treatment such as RO to meet the use demands and water quality standards.

Table 17. Unit costs for transporting water from the lower Ocklawaha River subbasin to off-site locations

Capacity		Transmission Cost				
		Cost/Mile		Cost/mgd/Mile		
cfs	mgd	Capital Cost, Initial ($)	O&M Cost, Annual ($)	Capital Cost ($)	O&M Cost ($)	Total ($)
10	6.5	423,800	18,300	15.06	7.74	22.80
25	16.2	777,500	20,500	11.05	3.47	14.52
50	32.3	1,042,200	58,100	7.41	4.92	12.33
100	64.6	2,014,700	118,800	7.16	5.04	12.20
200	129.3	3,040,100	280,300	5.40	5.94	11.34
300	193.9	5,653,600	256,300	6.70	3.62	10.32

Note: Values are based on capital and O&M costs estimated by SJRWMD staff. The capital cost estimate includes 10% engineering and design cost, 10% supervision and administrative cost, 15% contingency allowance, and 15% for lands, rights-of-way, and easements. The estimate assumes a straight corridor. The discount rate is 7½%, and the project life is 30 years.

Table 18. Examples of estimated costs to transport water from the lower Ocklawaha River subbasin

Capacity		Capital/O&M Cost/mgd/Mile* ($)	Miles Pumped	Total Capita/O&M* Cost ($)	Treatment Cost ($)	Total Transmission and Treatment Cost ($)
cfs	mgd					
Example 1—50 Miles From Reservoir Site						
10	6.5	22.80	50	1,140.00	500.00	1,640.00
25	16.2	14.52	50	726.00	500.00	1,226.00
50	32.3	12.33	50	616.00	500.00	1,116.00
100	64.6	12.20	50	610.00	500.00	1,110.00
200	129.3	11.34	50	567.00	500.00	1,067.00
300	193.9	10.32	50	516.00	500.00	1,016.00
Example 2—100 Miles From Reservoir Site						
10	6.5	22.80	100	2,280.00	500.00	2,780.00
25	16.2	14.52	100	1,452.00	500.00	1,952.00
50	32.3	12.33	100	1,233.00	500.00	1,733.00
100	64.6	12.20	100	1,220.00	500.00	1,720.00
200	129.3	11.34	100	1,304.00	500.00	1,634.00
300	193.9	10.32	100	1,032.00	500.00	1,532.00
Example 3—150 Miles From Reservoir Site (approximate distance to Tampa)						
10	6.5	22.80	150	3,420.00	500.00	3,920.00
25	16.2	14.52	150	2,178.00	500.00	2,678.00
50	32.3	12.33	150	1,849.00	500.00	2,349.00
100	64.6	12.20	150	1,830.00	500.00	2,330.00
200	129.3	11.34	150	1,701.00	500.00	2,201.00
300	193.9	10.32	150	1,548.00	500.00	2,048.00
Example 4—239 Miles From Reservoir Site (approximate distance to West Palm Beach)						
10	6.5	22.80	239	5,449.00	500.00	5,949.00
25	16.2	14.52	239	3,470.00	500.00	3,970.00
50	32.3	12.33	239	2,946.00	500.00	3,446.00
100	64.6	12.20	239	2,915.00	500.00	3,415.00
200	129.3	11.34	239	2,710.00	500.00	3,210.00
300	193.9	10.32	239	2,466.00	500.00	2,966.00

*Values are based on capital and O&M costs estimated by SJRWMD staff. The capital cost estimate includes 10% engineering and design cost, 10% supervision and administrative cost, 15% contingency allowance, and 15% for lands, rights-of-way, and easements. The estimate assumes a straight corridor. Treatment costs assume use of existing treatment plants.

SUMMARY AND RECOMMENDATIONS

The following section summarizes the evaluations and results of the consumptive use withdrawal effects on groundwater, surface water, and the aquatic and wetland communities, and presents the recommendations associated with the findings of this assessment.

WATER ALLOCATION STUDY

Surface and Groundwater Consumptive Uses, by Ching-tzu Huang, Cynthia Moore, and Donthamsetti Rao

A water supply needs and sources study has predicted that there will be no increase in surface water withdrawals from the major lakes and streams of the basin by 2010 (Vergara 1994). Based on the information examined during this study, no conflict will exist between the human consumptive surface water use demands and the natural community surface water use demands to 2010. For those incidents where increased human consumptive use is projected, the site-by-site evaluations should provide adequate resolution for any negative impacts to the natural community.

Groundwater uses within the ORB were predicted to increase significantly by 2010 (Vergara 1994). Public supply, commercial/industrial, and agricultural uses are projected to account for the largest future groundwater withdrawals. These groundwater withdrawals are projected to lower the potentiometric levels of the surficial and Floridan aquifers throughout the basin. The most significant decreases will occur in the UOR subbasin as a result of projected increases in water use for public supply in Lake, Orange, Sumter, and Marion counties. Most areas of this basin have been designated as priority water resource caution areas (Vergara 1994) because there is a likelihood of harm to native vegetation, unacceptable impacts to discharge from springs, or unacceptable changes in groundwater quality because of projected 2010 consumptive uses.

The lowering of the potentiometric level of aquifers will reduce spring discharges throughout the ORB. Flow assessments of eight springs indicate there will be large spatial differences with regard to flow reduction. The percentage reductions in spring flows range from 5.4% to 70.0% (Table 1). The maximum spring discharge reduction will be 58.5 cfs (-7%) at Silver Springs in Marion County, and the minimum reduction will be <0.1 cfs (-8%) at

Magnesia Spring in Alachua County. Springs make important contributions to the base flow (dry season) of surface waters. Therefore, these declines in spring discharges have the potential to negatively impact the surface water hydrology and ultimately the aquatic- and wetland-dependent biota.

For those incidents where increased human consumptive use is expected, it is anticipated that site-by-site evaluations of groundwater withdrawals will be needed to prevent negative impacts to the natural communities.

Natural System Impact Assessment, by Greeneville Hall, Clifford Neubauer, and John Schuman

Upper Ocklawaha River Subbasin

The current regulation schedules for the Upper Ocklawaha River Chain of Lakes, which were developed to provide a balance between the project purposes of flood control and recreational boating, have resulted in insufficient water levels (with appropriate return intervals and durations) to protect the structure and ecological functions of the associated wetland communities. These hydraulic alterations to the basin have modified the natural hydrology of the lakes, resulting in structural and functional changes to the floodplain wetlands. A regulation schedule that results in an increased range of water level fluctuation with appropriate seasonal highs and lows is being investigated by SJRWMD as a means of improving these conditions.

The projected increases in groundwater withdrawals in the UOR by 2010 were predicted to further exacerbate the environmental impacts caused by the current lake regulation schedules. Surface water levels in Lake Apopka would be the most affected by the predicted increases in groundwater withdrawals. Fairly marked shifts in water level durations were predicted to occur (Figure 13). The greatest changes in inundation frequency occurred on those portions of the floodplain which experienced long periods of inundation (>50%).

Relatively minor reductions in the hydrologic regimes of the “Superpond” (Lakes Dora, Beauclair, Harris, and Eustis) and Lake Griffin were predicted (Figures 14 and 15). The greatest changes in inundation frequency occurred on those portions of the floodplain which experienced long periods of inundation (>50%). However, the magnitude of these changes was generally less than 0.2 ft (Figures 14 and 15).

The UOR subbasin has been identified as a priority water resource caution area (Vergara 1994). Within these areas, the impacts of projected groundwater demands exceed the impact criteria limits for natural systems, for groundwater quality, or to existing legal users of water. Because of these factors, new human consumptive water use permit applications in this area should be carefully reviewed to determine their impact on the natural community.

In designated water resource caution areas, such as the UOR, SJRWMD proposes in the *Water Supply Needs and Sources Assessment 1994* (Vergara 1994) to develop alternative strategies for water supply. The purpose of these alternative strategies is to identify courses of action to remediate water resource problems that have become critical and to prevent water resource problems that are projected to become critical as a result of projected increases in water use by 2010. These courses of remedial or preventative action will be developed based on economic, environmental, and technical feasibility analyses.

Lower Ocklawaha River Subbasin

Silver Springs and Silver River. Because of the predicted increases in groundwater withdrawals, the average 2010 spring discharge was predicted to decrease by 58.5 cfs (37.8 mgd; Table 2). This represents a 7% decrease in average flow. The direct ecological impacts of reduced flow to the flora and fauna of the Silver River cannot be quantified at this time. However, the reduction in flow may reduce fixed organic carbon inputs to the Ocklawaha River from Silver Springs and the Silver River. Odum (1957) estimated the primary production at Silver Springs and the upper Silver River at 6,390 $gm/m^2/year$ (57,100 lb/acre/year) and that 766.8 $gm/m^2/yr$ (68.52 lb/acre/yr) of this production was carried downstream as organic matter in the form of seston (particulate organic matter).

No unique animal or plant species have been identified for Silver Springs. However, Odum (1957) does reference the possibility of distinct “races” among the hydrobiidae (small freshwater snails, Gastropoda).

The flows from Silver Springs supply a large volume of water to the lower Ocklawaha River. More important, these discharges contribute significantly to the base flow (dry period) of the river. Removal of surface water directly from the spring run or a further reduction in spring discharges below predicted 2010 levels, due to increased groundwater use, may significantly impact downstream reaches. Allocating consumptive uses from the downstream areas of the basin (i.e., Rodman area) instead of from the Silver River would maximize water availability while minimizing the potential environmental impacts to the main-stem of the river.

Although impacts of human consumptive uses on the natural community are not quantifiable at the present time, new human consumptive water use permit applications in this area should be carefully reviewed to determine their impact on the natural community. As with the case of the UOR subbasin, this area should be included in the SJRWMD development of "alternative strategies for water supply program."

Ocklawaha River at Eureka Dam. Increases in groundwater usage were predicted to lower spring discharges in this reach between the Silver River and Eureka Dam. The Silver River contributes significantly to the base flow (dry period) of this reach, and further reductions in spring discharges below those predicted for 2010 or the direct removal of surface water for consumptive uses from the spring run may cause consequential hydrologic or environmental impacts. However, comparisons of the Existing and 2010 surface water hydrology (inundation frequencies and range of fluctuation) at Eureka Dam indicated that the predicted 2010 decreases in groundwater discharges had little effect on the hydrologic conditions in this river reach.

The periods of inundation of the mean elevations of plant communities at Eureka Dam for the Existing and 2010 hydrologic conditions showed small but inconsequential changes, and changes in base flow water levels were negligible. The hydrologic changes predicted to occur at this river reach due to increased groundwater withdrawals were considered to be negligible, and no additional impacts to the floodplain wetland plant communities or in-stream biota were expected.

Rodman Reservoir. Hydrologic computer simulations for Rodman Reservoir included a modification of the existing water level / discharge regulation schedule, with the intent to more closely match the historical downstream discharge / stage relationship. This Proposed management alternative produced a more gradual reduction in downstream flows / stages and the rate of stage recession on the downstream floodplain was slowed (Figure 23). Downstream low water stages were improved by approximately 0.33 ft over the Existing structure operation schedule.

Comparing the Existing, Existing-2010, and Proposed hydrologic conditions for Rodman Reservoir indicated negligible changes in inundation frequency, the range of surface water fluctuation, or the frequencies and durations of high or low water events. These findings indicated that the hydrologic regimes produced by the Existing, Existing-2010, and Proposed groundwater conditions in Rodman Reservoir were essentially indistinguishable. No additional hydrologic / hydraulic or environmental impacts were expected to occur as a result of the predicted 2010 increases in regional groundwater withdrawals.

It is recommended that, if the decision is made to maintain Rodman Reservoir, the existing surface water regulation schedule for Rodman Dam should be evaluated and modified to provide a downstream hydrologic regime that more closely approximates the pre-reservoir conditions and provides a more gradual transition between downstream stages.

Ocklawaha River at Riverside Landing. River flows and stages at Riverside Landing are dependent upon surface water discharges from Rodman Reservoir. The regulation schedule at the reservoir discharge structure has a significant effect on the stage / duration relationship for this river reach. The stage duration graph appears “stair-stepped” because the operation of the structure is not gradual (Figures 22 and 24). Rather, changes in the gate opening are made in response to the attainment of critical water levels in the reservoir. The effect is most pronounced under low-flow conditions (see the 80th to 90th percentiles, Figures 22 and 24).

A comparison of the stage duration data for the Existing and Proposed hydrologic conditions indicated no major differences in the stages achieved downstream of the reservoir. However, the inundation frequency decreased (see 25th to 30th and 50th to 60th percentile duration levels; Figure 22). The magnitude of the shift in water levels, relative to the changes in inundation frequency, remained constant between the two management alternatives. The most pronounced differences in the stage duration curves occurred between the 75th to 100th percentiles. The operating schedule for the Proposed-2010 alternative produced a more gradual reduction in downstream stages, and low water stages were improved by approximately 0.33 ft (2.49 to 2.82 ft NGVD; Figure 25) over the stages produced by the Existing structure operation schedule.

The stage duration analyses for the mean elevations of plant communities at Riverside Landing for these different conditions indicated small changes in the periods of inundation (Table 6). The inundation frequency for the mean elevation of the mixed hardwood swamp community shifted from 88.2% under Existing to 78% for the Proposed-2010. While this represented a 10.2% decrease in duration, it corresponded to only a 0.2-ft change in elevation (4.0 to 3.8 ft NGVD) at the 88th stage duration percentile. The spatial extent of changes in inundation frequency was limited to a 5–30-ft-wide floodplain zone.

The hydrologic changes predicted to occur at this river reach due to 2010 increased groundwater withdrawals were considered to be negligible, and no additional impacts to the floodplain wetland plant communities or in-stream biota of this river reach would be expected.

Orange Creek Subbasin

Pre-existing hydraulic alterations to the basin have modified the natural hydrology of the lakes, the streams, and Paynes Prairie, resulting in ecological degradation and economic impacts. However, the hydrologic changes predicted to occur in the Orange Creek subbasin due to 2010 increased groundwater withdrawals were considered insignificant, and no additional ecological or economic impacts would be expected.

Water Availability Study

Quantitative Evaluation, by Greeneville Hall, Awes Karama, and Donthamsetti Rao

This evaluation examined and quantified the amount of surface water that could be removed for human consumptive uses from the LOR subbasin without causing unacceptable environmental impacts. The hydrologic simulations included the predicted 2010 changes in surface water hydrology resulting from increased groundwater withdrawals. Four surface water withdrawals (0, 165, 250, and 330 cfs) were simulated for the following: (1) Existing-2010 hydrologic conditions, (2) Proposed-2010 hydrologic conditions, and (3) Full Restoration-2010 hydrologic conditions (removal of Rodman Reservoir).

The findings and recommendations of this assessment are summarized below, first, as LOR with Rodman Reservoir and second, as LOR with Rodman Reservoir removed (Full Restoration).

Lower Ocklawaha River With Rodman Reservoir

Rodman Reservoir. Stage duration curves for Rodman Reservoir predicted for the four surface water withdrawal rates showed remarkable similarity between the Existing and Proposed reservoir regulation schedules (Figures 38 and 40). The curves diverged at floodplain elevations below 18 ft NGVD, and the duration curves for the 250- and 330-cfs withdrawals exhibited the greatest differences from the “zero” withdrawal condition. The inundation frequency for the mean elevation of the wetland zone (18.2 ft NGVD) were decreased by approximately 5–22% for the different withdrawal levels, relative to the “zero” withdrawal level for the Existing-2010 and Proposed-2010 hydrologic conditions. However, these shifts in inundation frequency corresponded to a <0.1-ft change in elevation. The spatial extent of changes in inundation frequency were limited to a ≤10-ft-wide zone along the littoral zone of the reservoir for both the Existing and Proposed water management alternatives.

The most significant effect of the withdrawals to the reservoir was a marked increase in the range of surface water fluctuation. This was due primarily to a lowering of the minimum pool elevation, as more of the reservoir bottom was exposed, as the amount of the withdrawal increased (Figure 37). The upper elevation range for each of the withdrawals was similar, because these elevations are influenced primarily by flood flow events and did not vary more than 0.04 ft (Figure 37).

A 3–4 ft range of water level fluctuation is not unusual for many Florida lakes and is often desirable to consolidate and compact sediments and allow re-seeding of emergent aquatic vegetation. The timing of the low water events, however, is especially critical in Rodman Reservoir. Hydrilla expands during the growing season in the reservoir and usually covers the water surface in all but the deeper areas of the basin. In August 1994, SJRWMD increased water levels to around 18.5 ft NGVD to alleviate the impacts hydrilla had on oxygen exchange between the water column and the atmosphere. This action was taken to decrease the possibility of a summer fish kill in Rodman Reservoir. The relevance of this with respect to consumptive use withdrawals from Rodman is that water levels should not be significantly lowered during the summer months when hydrilla covers the water’s surface and fills the water column.

An analysis of average monthly water levels in Rodman Reservoir with withdrawals of 0, 165, 250, and 330 cfs shows that water levels would not be significantly reduced during the summer months by a withdrawal of 165 cfs (Table 11). However, during low-water years, average monthly water levels during the summer months would be significantly reduced by withdrawals of 250 and 330 cfs (Table 12). Thus, these higher withdrawals could lead to large fish kills in Rodman. The Proposed regulation schedule produced lower water levels than did the Existing schedule for all withdrawal levels and, therefore, it has even greater potential to cause fish kills.

Riverside Landing. A comparison of stage duration curves for Riverside Landing predicted for the four surface water withdrawal rates showed the same general trends for both the Existing-2010 and Proposed-2010 hydrologic conditions (Figures 38 and 40). There were no major differences in the actual water levels achieved downstream of the reservoir; however, the duration of the stages decreased with increasing level of withdrawal. Minimum water levels declined with the level of withdrawal. Minimum water levels for the Proposed-2010 conditions were 0.08–0.33 ft higher than the corresponding levels under the Existing-2010 alternative. The width of the river channel experiencing altered hydrology was ≤5 ft.

The inundation frequency for the mean elevation of the mixed hardwood swamp (4.0 ft NGVD) decreased as the level of the withdrawal increased for the Existing-2010 and Proposed-2010 water management alternatives (Tables 10 and 15). However, there was no change in the corresponding elevations. The hydrologic alterations to the hydric hammock community were negligible for all levels of surface water withdrawal for both water management alternatives.

The impact on downstream flows of these four levels of withdrawal from Rodman Reservoir was assessed to predict impacts on migratory fishes during the winter months when they move upstream. Flows would be significantly reduced during the winter months by 165-, 250-, or 330-cfs withdrawals from Rodman Reservoir (Tables 13 and 14). However, without fish passage facilities, the ecological significance of these impacts is minor. If fish passage facilities were constructed on either the canal or dam outlets from Rodman Reservoir, then these winter month discharge reductions may become ecologically significant. There are no data available, however, to ascertain the relationship between migratory fish movement and reproduction and flow rate for the Ocklawaha River.

Lower Ocklawaha River With Rodman Reservoir Removed

Rodman Reservoir. Comparisons for Rodman Reservoir are impracticable for this alternative. No environmental information was available near the Rodman Dam to allow an evaluation of this restoration alternative.

Riverside Landing. A comparison of the stage duration curves for the Existing-2010, Proposed-2010, and Full Restoration-2010 alternatives clearly indicates the improved hydrologic conditions that would result from restoration (Figure 43). The general trends were similar to the previous evaluations. The largest differences in water levels occurred at the lowest floodplain elevations, approximately 1.0–4.0 ft NGVD. The minimum level without withdrawal was 2.80 ft NGVD, a level essentially identical to the Proposed-2010 management alternative (Figures 40 and 43). The minimum level declined to 2.13, 1.70, and 1.23 ft NGVD for the 165-, 250-, and 330-cfs withdrawals, respectively (Figure 43). These levels are 0.41, 0.66, and 0.94 ft lower than those expected for the Proposed-2010 conditions. Apparently, this would result from the absence of the low-flow augmentation capability provided by the reservoir.

The duration of flooding of the mean elevation of the hardwood swamp (4.0 ft NGVD) also decreased as the level of the withdrawal increased (Table 16). The duration of flooding for the 4.0 ft NGVD elevation shifted from approximately 86% without withdrawal to 77%, 72%, and 65% for the 165, 250-, and 330-cfs withdrawals, respectively. The elevations of the floodplain that would experience the 86% inundation frequency changed rather markedly (Figure 44). These changes in inundation frequency (86%–65%), even at the highest water withdrawal, will not alter the structure and ecological functions of the floodplain mixed hardwood swamp community in this reach of the river. These inundation frequencies were well within the ranges reported by other researchers for bottomland hardwood swamps of the Southeast (51–100%, seasonally to semipermanently inundated; Wharton et al. 1982).

Determination of Safe Yield

The determination of safe yield for withdrawing water from the LOR subbasin for human consumptive use was based on the following assumptions:

- No changes to the water level regulation schedules for upstream lakes

- Groundwater withdrawals equaling the 2010 predictions of spring discharge reduction within the basin
- No increases above present levels in surface water withdrawals upstream of Rodman Reservoir
- Maintaining the existing surface water management plan for Rodman Reservoir (i.e., stabilized water levels for aquatic weed control and sport fisheries management)

Allocating consumptive uses only from the downstream reaches of the river has the advantage of potentially maximizing water availability, because the withdrawals are at the point of maximum surface water volume for the river system. A given withdrawal there would represent a smaller proportion of the total river flow than it would upstream; consequently, changes to the hydrologic regime of the river/floodplain and to the aquatic-dependent biota would be less than upstream.

Based on the ecological and hydrologic evaluations in this report, a safe yield of $\leq$165 cfs (106.6 million gallons/day) could be withdrawn from either the Rodman Reservoir or the river channel (under Full Restoration-2010) without causing unacceptable environmental harm.

The quantitative evaluation of available water indicated that water availability from the LOR is relatively insensitive to retention of the reservoir under current operating conditions. The reservoir could likely be operated differently to optimize environmental and water supply benefits. However, it appears that if maintaining Rodman Reservoir as a viable recreational sport fishery and aquatic ecosystem is the management objective, then more water may be available from the river system under the Full Restoration-2010 management alternative than would be available if the reservoir is retained. The reasons for this conclusion are as follows:

- The floodplain swamp community has lower water requirements as compared to the aquatic communities of the reservoir. Even fairly large changes in the frequency of flooding of the floodplain swamp during drought periods will not unacceptably harm its biological structure and functions.

- Management issues (i.e., aquatic plant growth and the maintenance of a sport fishery) restrict the range of surface water level fluctuation that is acceptable for Rodman Reservoir. This study determined that average monthly water levels in the reservoir during the summer months of dry years would be significantly reduced by the 250- and 330-cfs consumptive use withdrawals and could stimulate growth of hydrilla. Such conditions have resulted in low dissolved oxygen concentrations in the reservoir water column and have historically caused large fish kills.

- A more accurate assessment of water availability can be completed only after minimum flows and levels are established for the major water bodies of the basin, implemented, and incorporated into a basinwide surface water management plan, which addresses the water supply potential of the LOR under different reservoir management options and river restoration strategies.

Economic Evaluation, by Marion Ritter and Don Smith

The economic evaluation was limited to a comparison of the estimated costs associated with transporting various quantities of water from the LOR subbasin and pumped various distances with the estimated costs of treating locally derived water with reverse osmosis technology. The number of variables associated with analyzing production costs made it difficult to compute a cost applicable to a general situation. A more detailed design description was necessary for comparing specific sites. However, this analysis indicated that it may be feasible to utilize water from the LOR subbasin by transporting it up to 50 miles. Beyond 50 miles, consideration should be given to utilizing water of lesser quality available in the locality, and a treatment such as reverse osmosis should be provided to meet the use demands and water quality standards.

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