TECHNICAL PUBLICATION SJ2008-3

MINIMUM LEVELS REEVALUATION: FOR LAKE GRANDIN PUTNAM COUNTY, FLORIDA

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MINIMUM LEVELS REEVALUATION FOR LAKE GRANDIN PUTNAM COUNTY, FLORIDA

by

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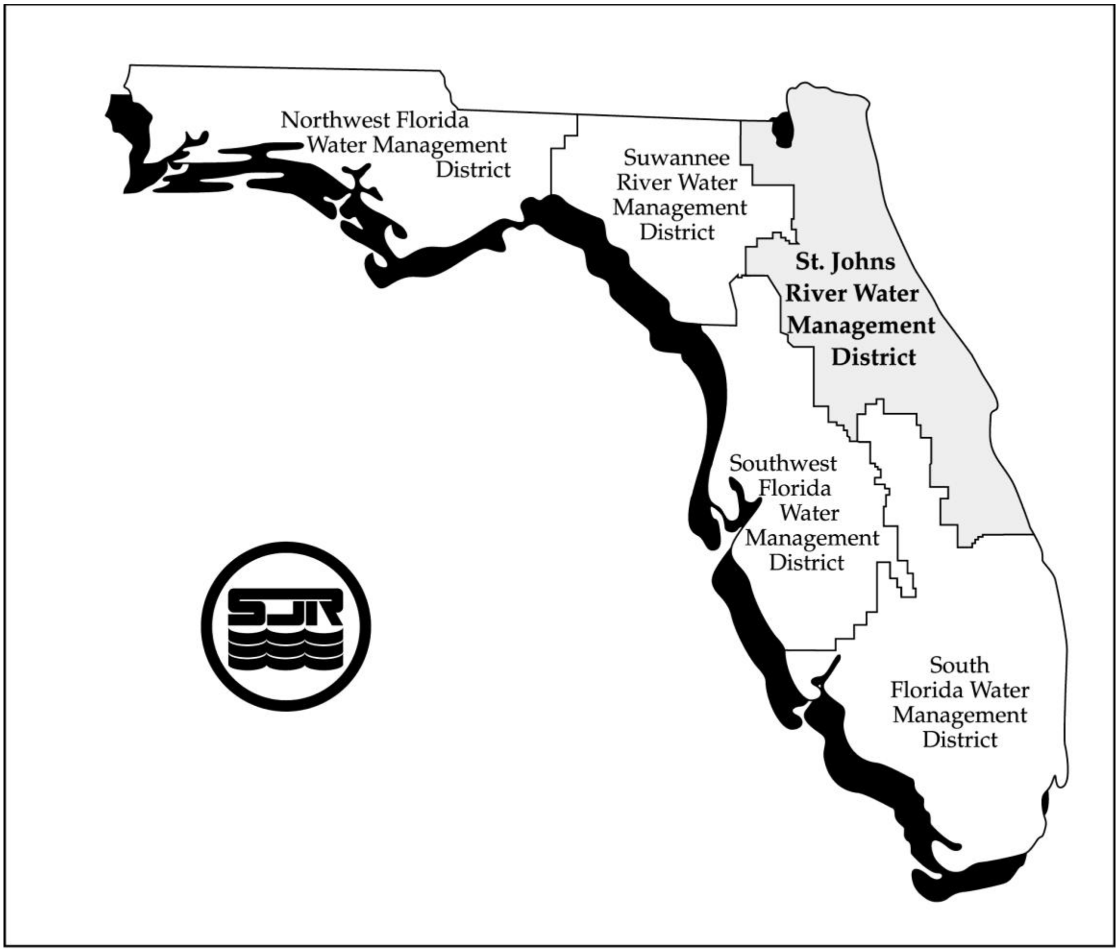
2008



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

This report describes the St. Johns River Water Management District's (SJRWMD's) minimum flows and levels (MFLs) reevaluation for Lake Grandin in Putnam County, Florida. The SJRWMD Governing Board adopted minimum levels for Lake Grandin in 1996 (Neubauer 1995). MFLs are reviewed periodically and revised as needed (Section 373.0421(3), *Florida Statutes* [F.S.]). Recent completion of a hydrologic model for Lake Grandin (Price Robison, SJRWMD, pers. com. 2007; CDM 2005) indicated that the adopted minimum frequent high, minimum average, and the minimum frequent low levels were not being met under 2002 water use and most recent land use conditions. Consequently, a reevaluation of the adopted Lake Grandin MFLs was performed based upon the current SJRWMD multiple MFLs method (SJRWMD 2006; Neubauer et al. 2007a). The MFLs reevaluation described in this document has resulted in the recommendation to modify the adopted MFLs for Lake Grandin (Table ES-1).

Table ES-1. Adopted and recommended minimum surface water levels for Lake Grandin, Putnam County, Florida

	Adopted				Recommended		
Minimum Level	Level (ft NGVD)	Duration (days)	Return Interval (years)	Hydroperiod Category	Level (ft NGVD)	Duration (days)	Return Interval (years)
Frequent high (FH)	81.8	None	None	Seasonally flooded	81.5	30	2
Minimum average (MA)	81.3	None	None	Typically saturated	None	None	None
Frequent low (FL)	80.1	None	None	Semi-permanently flooded	78.6	120	5

ft NGVD = feet National Geodetic Vertical Datum

The minimum frequent high (FH) and minimum frequent low (FL) levels were reevaluated for Lake Grandin. The minimum average (MA) level was not reevaluated because sandhill lakes (such as Lake Grandin) have a tendency to remain at high or low water levels with little time at the minimum average level. CH2M HILL (2005) presents a conceptual model of sandhill lakes and states that "… sandhill upland lakes are astatic, because they appear to lack a mean around which the system is organized" and that "… critical system behaviors of sandhill lakes may be related most strongly to high and low water levels corresponding to drought cycles and multidecadal climate cycles." Because of the nature of sandhill lakes to fluctuate dramatically

(CH2M HILL 2005), the lack of stable/seasonally flooded vegetation communities, and the absence of organic soils, a minimum average level is not recommended for Lake Grandin.

Fieldwork for the original (adopted) determination of minimum levels was performed in 1995 (Neubauer 1995). The recommended FH level (81.5 ft National Geodetic Vertical Datum [NGVD]) for Lake Grandin is 0.3 ft lower than the adopted level, because a different criterion was used. The adopted FH level (81.8 ft NGVD) for Lake Grandin corresponds to the average elevation of mixed swamp at Transect XS-1 (Neubauer 1995). The recommended FH level (81.5 ft NGVD) equals the mean of the minimum elevations of the two transitional shrub communities on two transects as determined in 2005.

The recommended FL level (78.6 ft NGVD) for Lake Grandin is 1.5 ft lower than the adopted level (80.1 ft NGVD), because a different FL level criterion was used. In 1995, the FL was based on two factors (Neubauer 1995): (1) the water level is maintained within 1.7 ft of the average elevation of the seasonally flooded mixed swamp, a criterion used at other lakes and derived from interpretation of Putnam County and Volusia County soil surveys; and (2) 80.1 ft NGVD was the average elevation of the maidencane-dominated portion of the littoral zone at Transect XS-2. The adopted lake level would be about 0.6 ft below the willow swamp and the emergent marsh/aquatic bed would be flooded, on average, to a depth of 0.4 feet at Transect XS-1. The recommended FL level (78.6 ft NGVD) equals the mean of the mean elevations of the deep marsh communities on two transects as determined in 2005.

The hydrologic model for Lake Grandin was calibrated for 2002 conditions. These conditions included the most recent land use information and groundwater levels consistent with 2002 regional water use. Based on hydrologic model results, SJRWMD concludes that the recommended MFLs for Lake Grandin are protected under 2002 conditions. To determine if changes in groundwater use allocations subsequent to 2002 would cause lake levels to fall below the recommended MFLs for Lake Grandin, the existing Lake Grandin hydrologic model should be run using Floridan aquifer potentiometric level declines that reflect these changes in water use allocations.

The recommended MFLs for Lake Grandin are intended to protect the lake from significant harm. MFLs provide technical support to SJRWMD's regional water supply planning (Section 373.0361, F.S.), consumptive use permitting (Chapter 40C-2, *Florida Administrative Code* [*F.A.C.*]), and environmental resource permitting programs (Chapter 40C-4, *F.A.C.*).

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INTRODUCTION

This report describes the St. Johns River Water Management District's (SJRWMD's) minimum flows and levels (MFLs) reevaluation for Lake Grandin in Putnam County, Florida. The SJRWMD Governing Board adopted minimum levels for Lake Grandin in 1996 (Neubauer 1995, Appendix A). MFLs are reviewed periodically and revised as needed (Section 373.0421(3), *Florida Statutes* [F.S.]). Recent completion of a hydrologic model for Lake Grandin (Price Robison, SJRWMD, pers. com. 2007; CDM 2005) indicated that the adopted minimum frequent high, minimum average, and minimum frequent low levels were not being met under 2002 water use and most recent land use conditions. Consequently, a reevaluation of the adopted Lake Grandin MFLs was performed based upon the current MFLs method (SJRWMD 2006, Neubauer et al. 2007a).

MFLS PROGRAM OVERVIEW

SJRWMD's MFLs program, based on the requirements of Section 373.042 and Section 373.0421, F.S., develops recommended MFLs for lakes, streams and rivers, wetlands, springs, and aquifers. Furthermore, the MFLs program is subject to the provisions of Chapter 40C-8, *Florida Administrative Code* (*F.A.C.*) and provides technical support to SJRWMD's regional water supply planning (Section 373.0361, F.S.), consumptive use permitting (Chapter 40C-2, *F.A.C.*), and environmental resource permitting (Chapter 40C-4, *F.A.C.*) programs.

Based on the provisions of Rule 40C-8.011(3), *F.A.C.*, "… the Governing Board shall use the best information and methods available to establish limits which prevent significant harm to the water resources or ecology." Significant harm, or the environmental effects resulting from the reduction of long-term water levels and/or flows below MFLs, is prohibited by Section 373.042(1a)(1b), F.S. Additionally, MFLs should be expressed as multiple flows or levels defining a minimum hydrologic regime, to the extent practical and necessary to establish the limit beyond which further withdrawals would be significantly harmful to the water resources or the ecology of the area (Rule 62-40.473(2), *F.A.C.*).

Factors to Be Considered When Determining MFLs

According to Rule 62-40.473, *F.A.C.*, in establishing MFLs pursuant to Section 373.042 and Section 373.0421, F.S., consideration shall be given to natural seasonal fluctuations in water flows or levels, nonconsumptive uses, and environmental values associated with coastal, estuarine, riverine, spring, aquatic, and wetlands ecology, including:

- Recreation in and on the water (Rule 62.40.473(1)(a), *F.A.C.*)

- Fish and wildlife habitats and the passage of fish (Rule 62.40.473(1)(b), *F.A.C.*)
- Estuarine resources (Rule 62.40.473(1)(c), *F.A.C.*)
- Transfer of detrital material (Rule 62.40.473(1)(d), *F.A.C.*)
- Maintenance of freshwater storage and supply (Rule 62.40.473(1)(e), *F.A.C.*)
- Aesthetic and scenic attributes (Rule 62.40.473(1)(f), *F.A.C.*)
- Filtration and absorption of nutrients and other pollutants (Rule 62.40.473(1)(g), *F.A.C.*)
- Sediment loads (Rule 62.40.473(1)(h), *F.A.C.*)
- Water quality (Rule 62.40.473(1)(i), *F.A.C.*)
- Navigation (Rule 62.40.473(1)(j), *F.A.C.*)

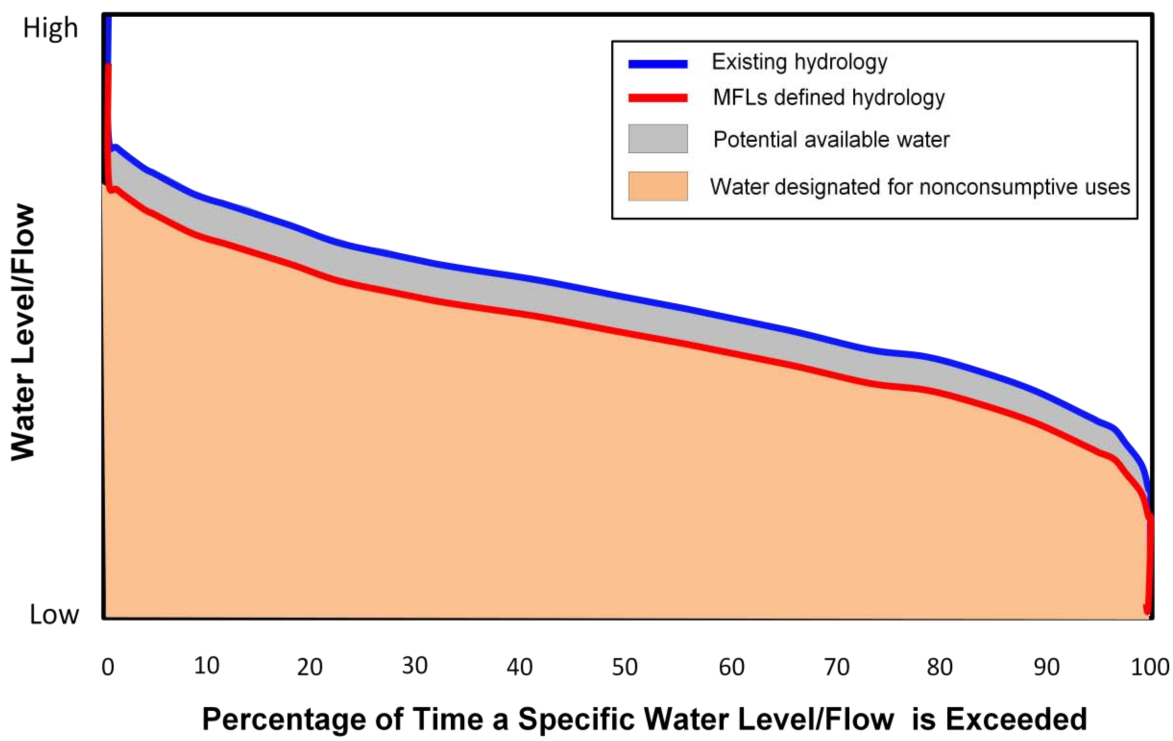
In addition to these factors, based on Section 373.0421(1), F.S., the following considerations are also required.

"When establishing minimum flows and levels pursuant to Section 373.042, the department or Governing Board shall consider changes and structural alterations to watersheds, surface waters, and aquifers and the effects such changes or alterations have had, and the constraints such changes or alterations have placed, on the hydrology of an affected watershed, surface water, or aquifer, provided that nothing in this paragraph shall allow significant harm as provided by Section 373.042(1) caused by withdrawals."

Hydrology

The MFLs designate an environmentally protective hydrologic regime (i.e., hydrologic conditions that prevent significant ecological harm) and identify levels and/or flows above which water may be available for use. MFLs define the frequency and duration of high-, average-, and low water events necessary to protect relevant water resource values criteria, and indicators that prevent significant harm to aquatic and wetland habitats. Three MFLs are usually defined for each system—minimum frequent high, minimum average, and minimum frequent low—flows and/or water levels. If deemed necessary, minimum infrequent high and/or minimum infrequent low flows and/or water levels are also defined. The MFLs represent hydrologic statistics composed of three components: a magnitude (a water level and/or flow), duration (days), and a frequency or return interval (years). SJRWMD historically synthesized the continuous duration and frequency components of the MFLs into seven discrete hydroperiod categories to facilitate MFLs determinations for lakes and wetlands. However, for MFLs associated with reevaluations of established MFLs and MFLs for water bodies for which MFLs have not been previously established, these hydroperiod categories are now being replaced with specific duration and return interval values.

MFLs are water levels and/or flows that primarily serve as hydrologic constraints for water supply development, but may also apply in environmental resource permitting (Figure 1). MFLs take into account the ability of wetlands and aquatic communities to adjust to changes in the return intervals of high- and low water events. Therefore, MFLs allow for an acceptable level of change to occur relative to the existing hydrologic conditions (gray-shaded area, Figure 1). However, when use of water resources shifts the hydrologic conditions below that defined by the MFLs, significant ecological harm occurs.



The existing hydrology curve represents the current river stage or flow regime.
The MFLs-defined hydrology curve represents the new river stage or flow regime, which provides for the potentially available water (gray-shaded area).

Figure 1. Hypothetical percentage exceedence curves for existing and MFLs-defined hydrologic conditions

As it applies to wetland and aquatic communities, significant harm is a function of changes in the frequencies of water level and/or flow events of defined duration, causing impairment or loss of ecological structures and functions. Significant harm can be prevented if water withdrawals do not cumulatively alter the hydrology beyond the minimum hydrologic regime defined by the MFLs.

MFLs apply to decisions affecting permit applications, declarations of water shortages, and assessments of water supply sources. Surface water and groundwater computer simulation models are used to evaluate existing and/or proposed consumptive uses to determine if these uses are causing, or will cause, water levels or flows to fall below established MFLs. Actual or projected instances where water levels fall below established MFLs require the SJRWMD Governing Board to develop recovery or prevention strategies (Section 373.0421(2), F.S.). MFLs are to be reviewed periodically and revised as needed (Section 373.0421(3), F.S.).

LAKE GRANDIN GENERAL INFORMATION

Lake Grandin is located about 3 miles north of Interlachen, Florida (Figure 2). The lake has an area of about 360 acres as estimated from the Putnam Hall (U.S. Geological Survey [USGS] quadrangle map, scale 1:24,0000, lake elevation not given), and is within the Interlachen Hills physiographic division of the Central Lakes District (Neubauer 1995). The recharge category is low at 0–4 in./yr (Boniol et al. 1993 as cited in Neubauer 1995).

Lake Grandin has a drainage area of 3.71 square miles and a surface water outlet to Etonia Creek to the north through a canal (USGS 1993 as cited in Neubauer 1995). The extensive canal system, constructed before 1943, drains Lake Grandin, Boyds and Orange Grove (not delimited, about 4,400 ft due north of Boyds Lake) lakes, and the marshes north of these lakes (Figure 2). The controlling elevation of the canal system is unknown; however, recorded lake levels have rarely exceeded 82.4 ft NGVD. Another canal connects Lake Grandin to Clearwater Lake to the south. This canal is navigable and is used frequently by residents to access either lake. The highest elevation in the canal channel was measured at 77.8 ft NGVD, with more typical high points near 77.2 ft NGVD.

Lake Grandin is a sandhill lake. Sandhill lakes are typically sinkhole features in sandy landscapes and lack significant accumulations of organic matter (JEA 2006a). Water levels can fluctuate dramatically. Lake Grandin is surrounded by residential development to the east and south, while the northwest and western lakeshore consists of a mixture of forested and nonforested wetlands (Figure 3 and Figure 4).

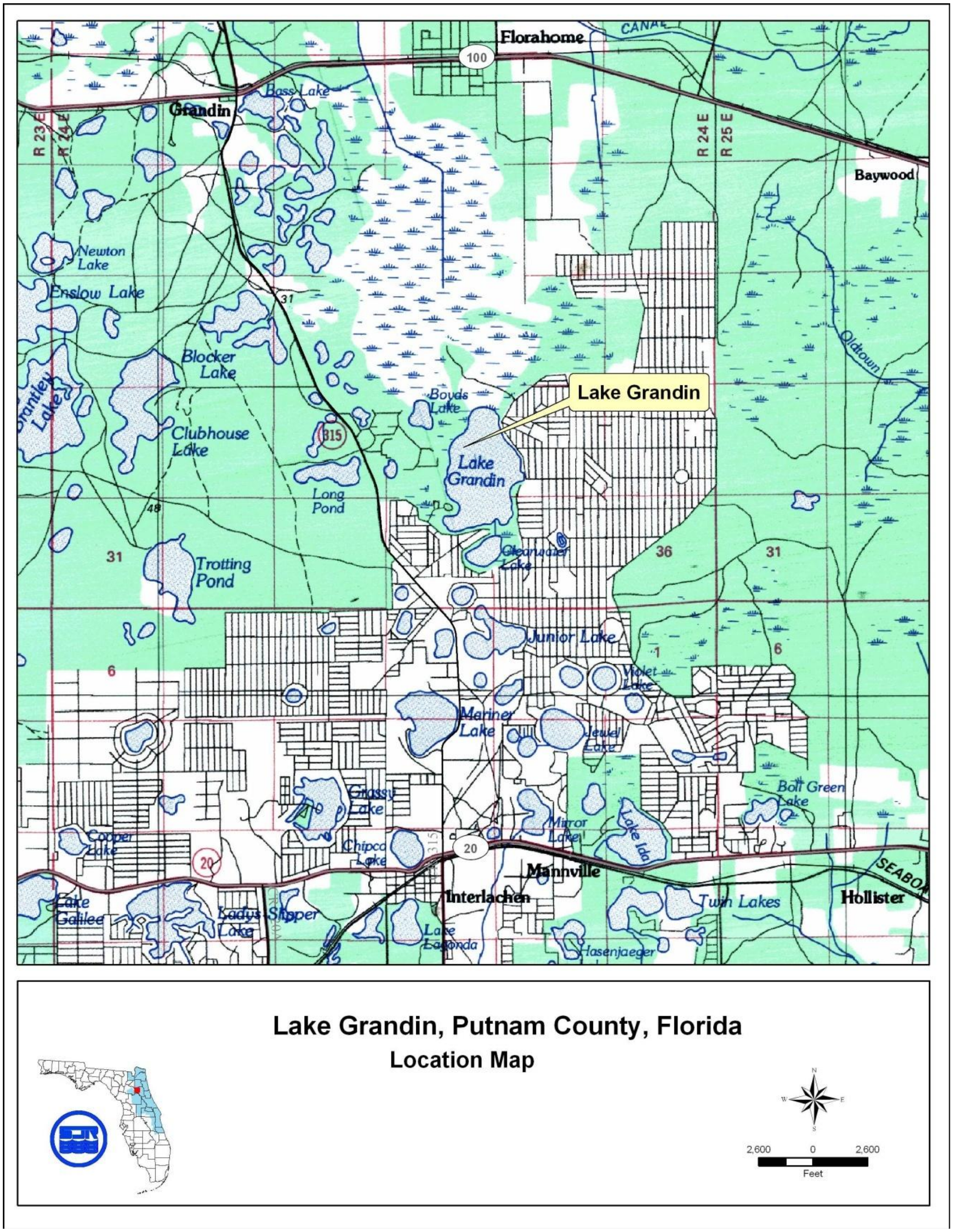


Figure 2. Lake Grandin, Putnam County, Florida, location map

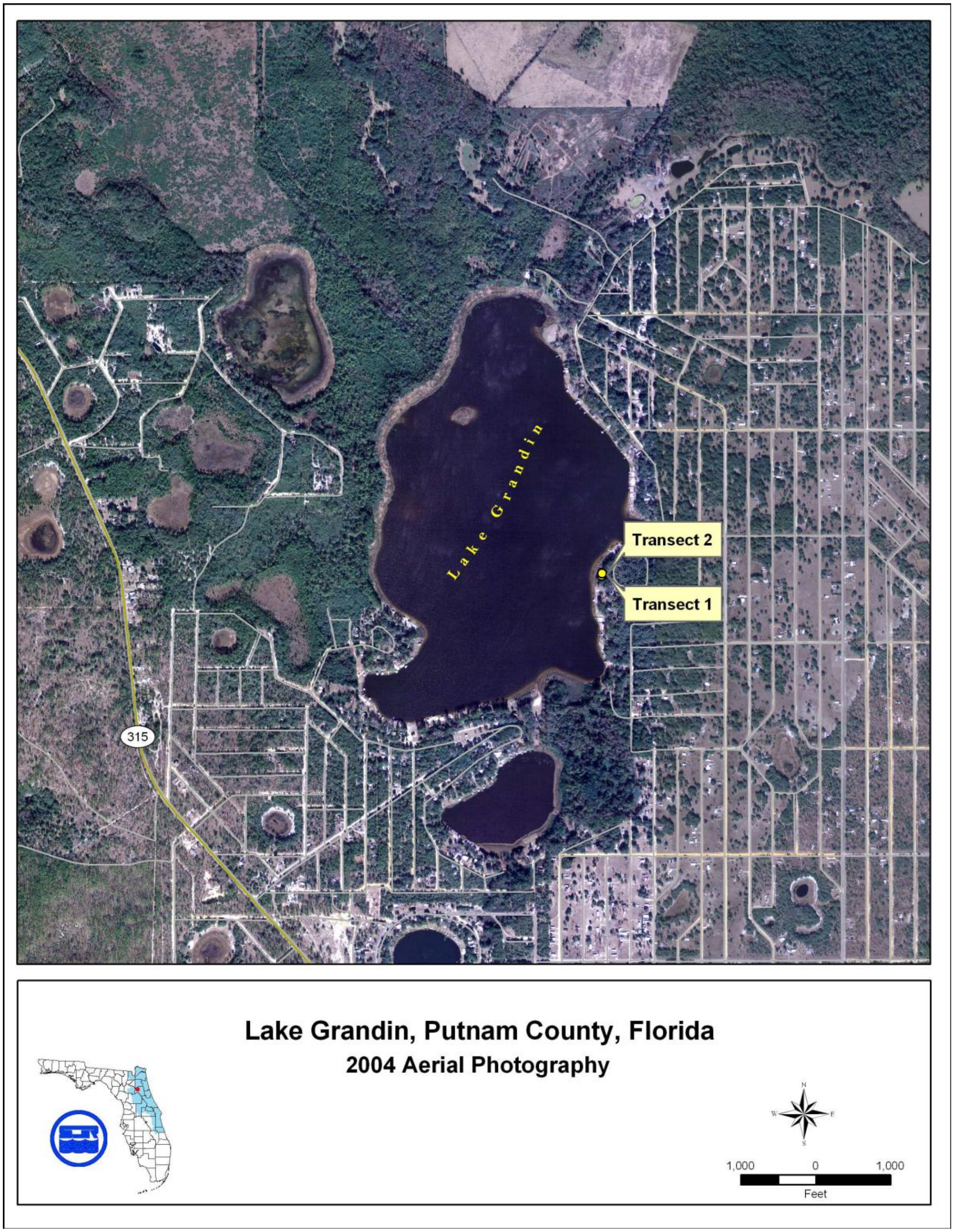


Figure 3. 2004 aerial photo of Lake Grandin area, Putnam County, Florida

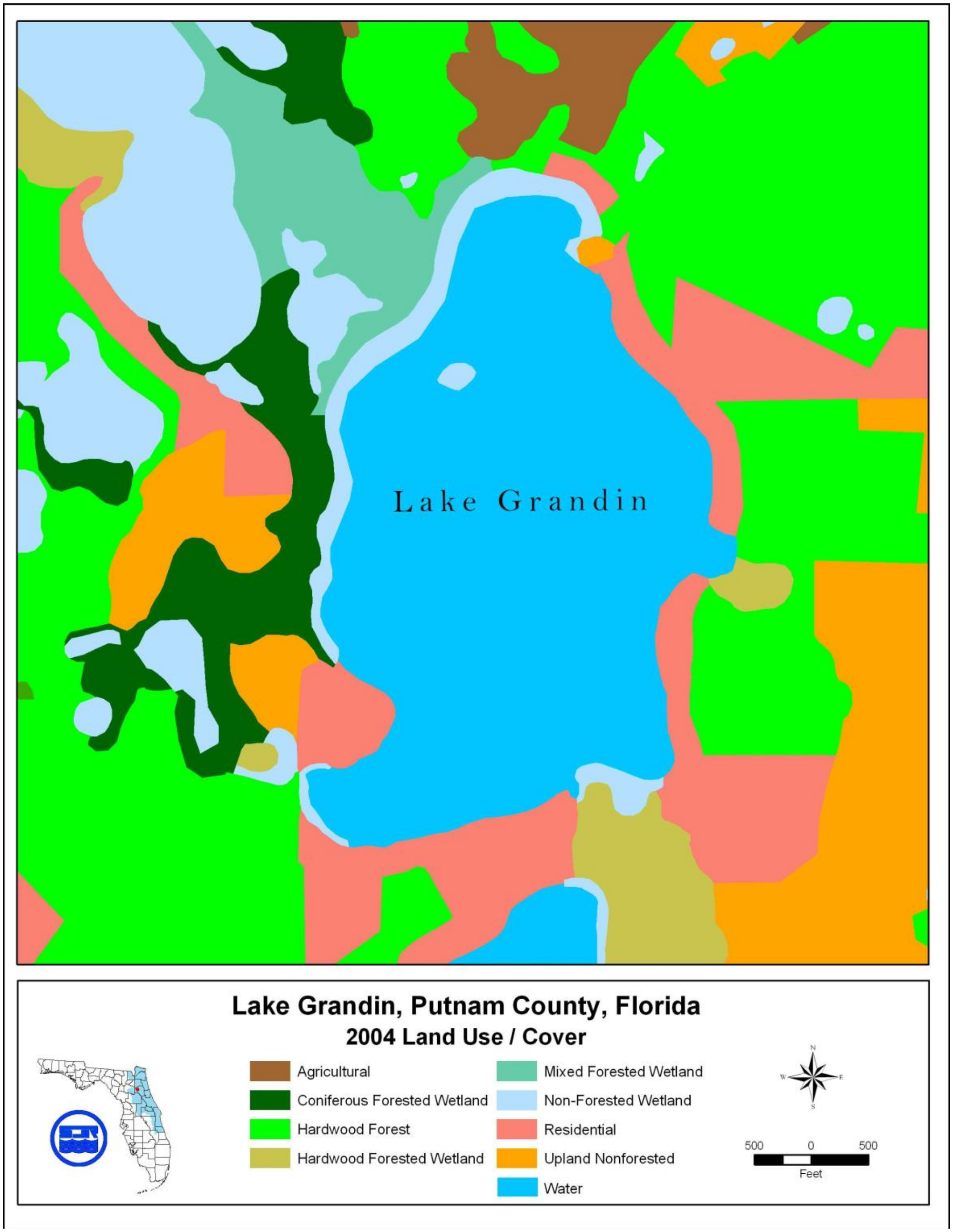


Figure 4. 2004 land use/cover in vicinity of Lake Grandin, Putnam County, Florida

Hydrology

Hydrologic data for Lake Grandin (CDM 2005) including: rainfall, hydrologic simulation program-FORTRAN (HSPF) model simulated stages, observed Lake Grandin stage, and estimated Upper Floridan aquifer (UFA) water levels; the adopted minimum frequent high and minimum frequent low levels are presented in Figure 5. Rainfall data from gauges around the Lake Grandin area were used because local rainfall data was only available from 1991 to 2002. Based on the composite rainfall data set, average rainfall from 1960 to 2003 is estimated to be 52.1 in. per year, ranging from 33.8 in. to 76.9 in. Observed stage data is available from July 1957 to October 2004; however, daily stage measurements were limited to May 1991–September 1996 and July 1957–October 1960. During other periods, observations were sporadic. Lake levels ranged from 82.8 ft to 76.1 ft NGVD during the period-of-record. Before 1990, lake stages were between 80 ft and 83 ft NGVD; however, after 1990, lake stages ranged from 76 ft to 82 ft NGVD. Estimated UFA water levels were determined by using several wells with different periods-of-record near Lake Grandin.

Mapped Soils

Many soils series were mapped in the vicinity of Lake Grandin. Hoontoon and Samsula are the prominent hydric soils adjacent to the lake (Figure 6), surrounding the vast majority of the water body.

The Hontoon series consists of deep, very poorly drained, rapidly permeable organic soils that occur in freshwater swamps and marshes (NRCS USDA 2007a). Native vegetation includes loblolly bay, maple, gum, and scattered cypress trees, with a ground cover of greenbriers, ferns, and other aquatic plants. Slash pine with a ground cover of osmunda fern is found in a few areas.

The Samsula series consists of very deep, very poorly drained, rapidly permeable soils that occur in swamps, poorly defined drainageways and floodplains (NRCS USDA 2007b). Natural vegetation includes loblolly bay with scattered cypress, maple, gum, and pine trees with a ground cover of greenbriers, ferns, and other aquatic plants.

Mapped Wetlands

Three wetland communities occur in the immediate vicinity of Lake Grandin (Figure 7) as classified by the SJRWMD Wetlands Vegetation Classification System (Kinser 1996). The vegetation and hydroperiod descriptions for these wetland communities are summarized in Table 1.

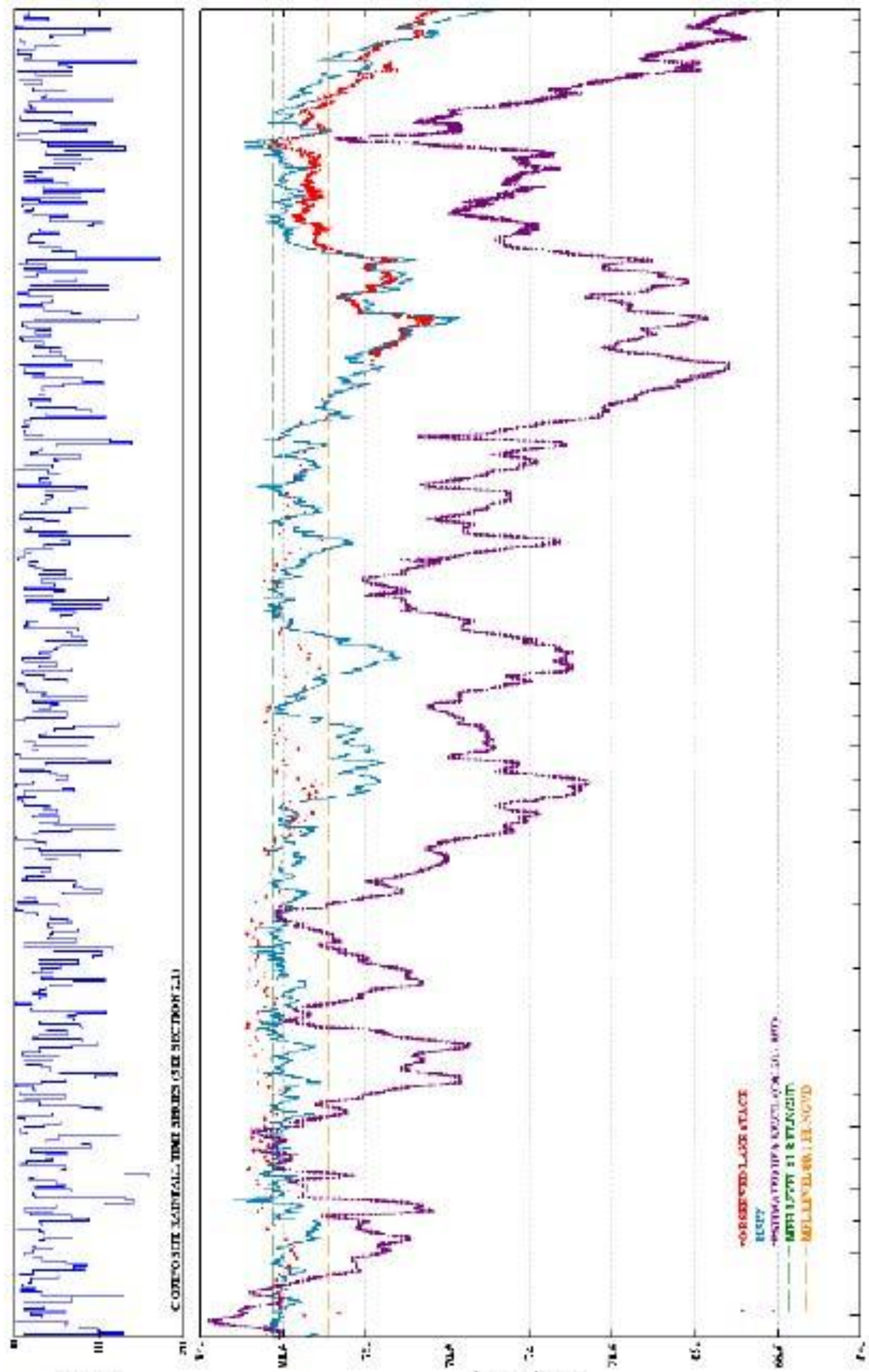


Figure 5. Lake Grandin, Putnam County, Florida, hydrologic data (CDM 2005)

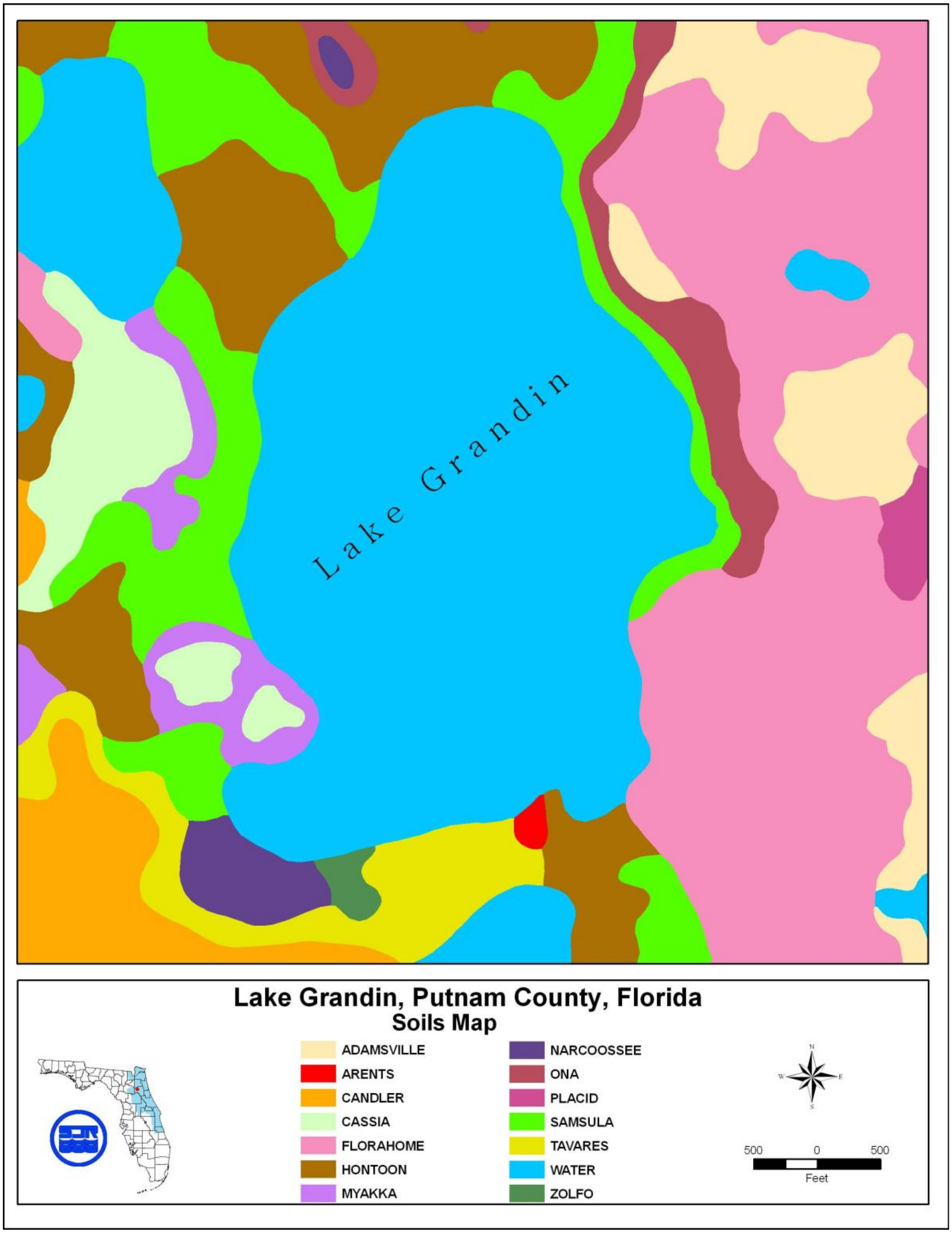


Figure 6. Soils in vicinity of Lake Grandin, Putnam County, Florida

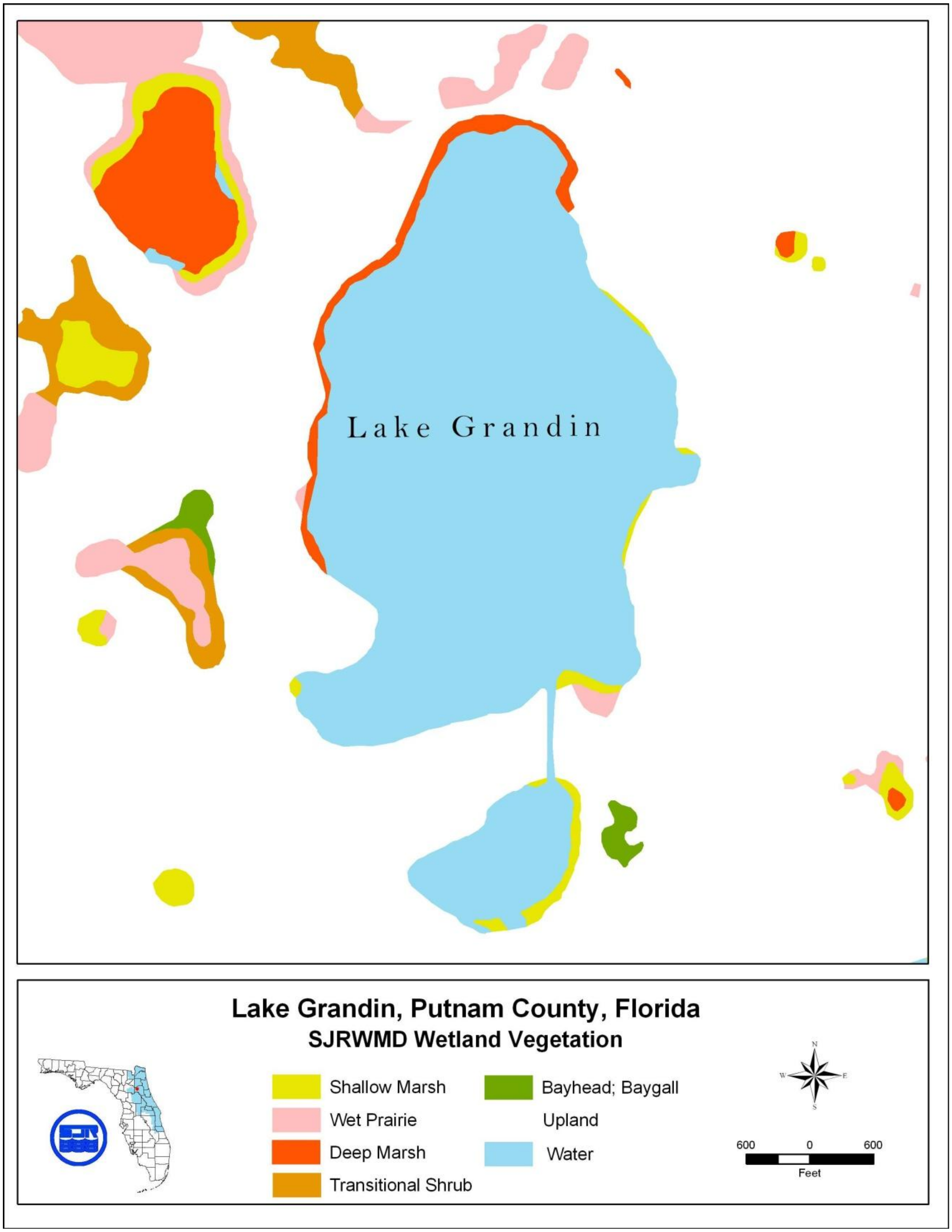


Figure 7. Wetlands in vicinity of Lake Grandin, Putnam County, Florida

Table 1. SJRWMD wetlands classification system for wetland communities in the immediate vicinity of Lake Grandin, Putnam County, Florida

Vegetation Description	Hydroperiod Description
Deep marsh	Semipermanently to permanently flooded
Shallow marsh	Lengthy seasonal inundation
Wet prairie	Relatively short inundation period, but prolonged soil saturation

METHODS

MFLs determinations incorporate biologic, soils, and topographic data collected in the field with information from the scientific literature to develop recommended MFLs. This section describes the MFLs methodology and assumptions used in the minimum levels reevaluation process for Lake Grandin, including field procedures such as site selection and field data collection, data analyses, and levels determination criteria. The SJRWMD general MFLs methodology is described more completely in the (draft) Minimum Flows and Levels Methods Manual (SJRWMD 2006).

FIELD TRANSECT SITE SELECTION

Many factors are considered in the selection of field transect sites. Transects are fixed sample lines across a river, lake, or wetland floodplain. Transects usually extend from open water to uplands. Elevation, soils, and vegetation are sampled along transects in order to characterize the influence of surface water flooding on the distribution of soils and plant communities. Field site selection began with the implementation of a site history survey and data search. All relevant available existing information was identified and assembled through data searches of SJRWMD library documents, project record files, the hydrologic database, and the SJRWMD Division of Surveying Services files. The data collected may have included the following:

- On-site and regional vegetation surveys and maps
- Aerial photography (existing and historical)
- Remote sensing (vegetation, land use, etc.) and topographic maps
- Soil surveys, maps and descriptions
- Hydrologic data (hydrographs and stage duration curves)
- Environmental, engineering, or hydrologic reports
- Topographic survey profiles
- Occurrence records of rare and endangered flora and fauna

These data were reviewed to familiarize the investigator with site characteristics, locate important basin features that needed to be evaluated, and assess prospective sampling locations. Copies of this information were organized and placed in permanent MFLs files for future reference and archiving.

Potential transect locations at Lake Grandin were initially identified from maps of wetlands, soils, and topography. Specific transect site selection goals included:

- Establishing transects at sites where multiple wetland communities of the most commonly occurring types were traversed.
- Selecting multiple transect locations with common wetland communities among them.
- Establishing transects that traverse unique wetland communities.

Transect characteristics were subsequently field-verified to ensure that the transect locations contained representative wetland communities, hydric soils, and reasonable upland access. These goals help to ensure ecosystem protection of commonly occurring wetland ecosystems at Lake Grandin. Individual transect site selection criterion for Lake Grandin are described in the Results and Discussion section.

FIELD DATA COLLECTION

The field data collection procedure for determining MFLs involved gathering information and sampling elevation, soils, and vegetation data along fixed transects, across a hydrologic gradient. Transects were established in areas where there are changes in vegetation and soil, and the hydrologic gradient was marked (SJRWMD 2006). The main purpose in using transects in these situations, where the change in vegetation and soils is clearly directional, was to describe maximum variations over the shortest distance in the minimum time (Martin and Coker 1992).

Site Survey

Once a transect location was established, vegetation was trimmed along the transect to allow a line-of-sight. A measuring tape was then laid out along the length of the transect. Elevation measurements were recorded at varying interval lengths (5 ft, 10 ft, 20 ft) to adequately characterize the topography and transect features. In addition, elevations were measured at obvious elevation changes, vegetation community changes, soil changes, high water marks, and at bases of trees.

Soil Sampling Procedures

Detailed soil profiles were described along each transect to gain an understanding of past and present hydrologic, geologic, and anthropogenic processes that have occurred, resulting in the observed transect soil features. Soil profiles were described following standard Natural Resources Conservation Service (NRCS) procedures (USDA, NRCS 2002). Each soil horizon (unique layer) was generally described with respect to texture, thickness, Munsell Color (Kollmorgen Corp. 1992), structure, consistency, boundary, and the presence of roots. The primary soil criteria considered during an MFLs determination are the presence and depth of organic soils as well as the extent of hydric soils observed along the field transects (SJRWMD 2006). The draft Minimum Flows Levels Methods Manual (SJRWMD 2006) documents additional soil sampling procedures.

Vegetation Sampling Procedures

SJRWMD has wetland maps developed from aerial photography utilizing a unique wetland classification system. SJRWMD's Wetlands Vegetation Classification System (Kinser 1996) was used to standardize the names of wetland plant communities in MFLs fieldwork and in developing reports documenting the MFLs determination.

The spatial extent of plant communities or transition zones (i.e., ecotones) between plant communities was determined using reasonable scientific judgment. Reasonable scientific judgment involves the ability to collect and analyze information using technical knowledge and personal skills and experience to serve as a basis for decision making (Gilbert et al. 1995). In this case, such judgment was based upon field observations of relative abundance of dominant plant species, occurrence and distribution of soils and hydric soil indicators, and changes in land slope or elevation along the hydrologic gradient. Plant communities and transition zones were delineated along a specialized line transect called a belt transect. A belt transect is a line transect with width (belt width). It is essentially a widening of the line transect to form a long, thin, rectangular plot divided into smaller sampling areas called quadrats that correspond to the spatial extent of plant communities or transitions between plant communities (Figure 8). The transect belt width will vary depending upon the type of plant community to be sampled (SJRWMD 2006). For example, a belt width of 10 ft (5 ft on each side of the transect line) may suffice for sampling herbaceous plant communities of a floodplain marsh. However, a belt width of 50 ft (25 ft on each side of the line) may be required to adequately represent a forested community (e.g., hardwood swamp, Figure 8).

Plants were identified and the percent cover of plant species was estimated if they occurred within the established belt width for the plant community under evaluation (quadrat). Percent cover is defined as the vertical projection of the crown or shoot area of a plant to the ground surface and is expressed as a percentage of the quadrat area. Percent cover as a measure of plant distribution is often considered as being of greater ecological significance than density, largely because percent cover gives a better measure of plant biomass than the number of individuals. The canopies of the plants inside the quadrat will often overlap each other, so the total percent cover of plants in a single quadrat will frequently sum to more than 100% (SJRWMD 2006). Percent cover was estimated visually using cover classes (ranges of percent cover). The cover class and percent cover ranges are a variant of the Daubenmire method (Mueller-Dombois and Ellenberg 1974) and summarized in the SJRWMD (draft)

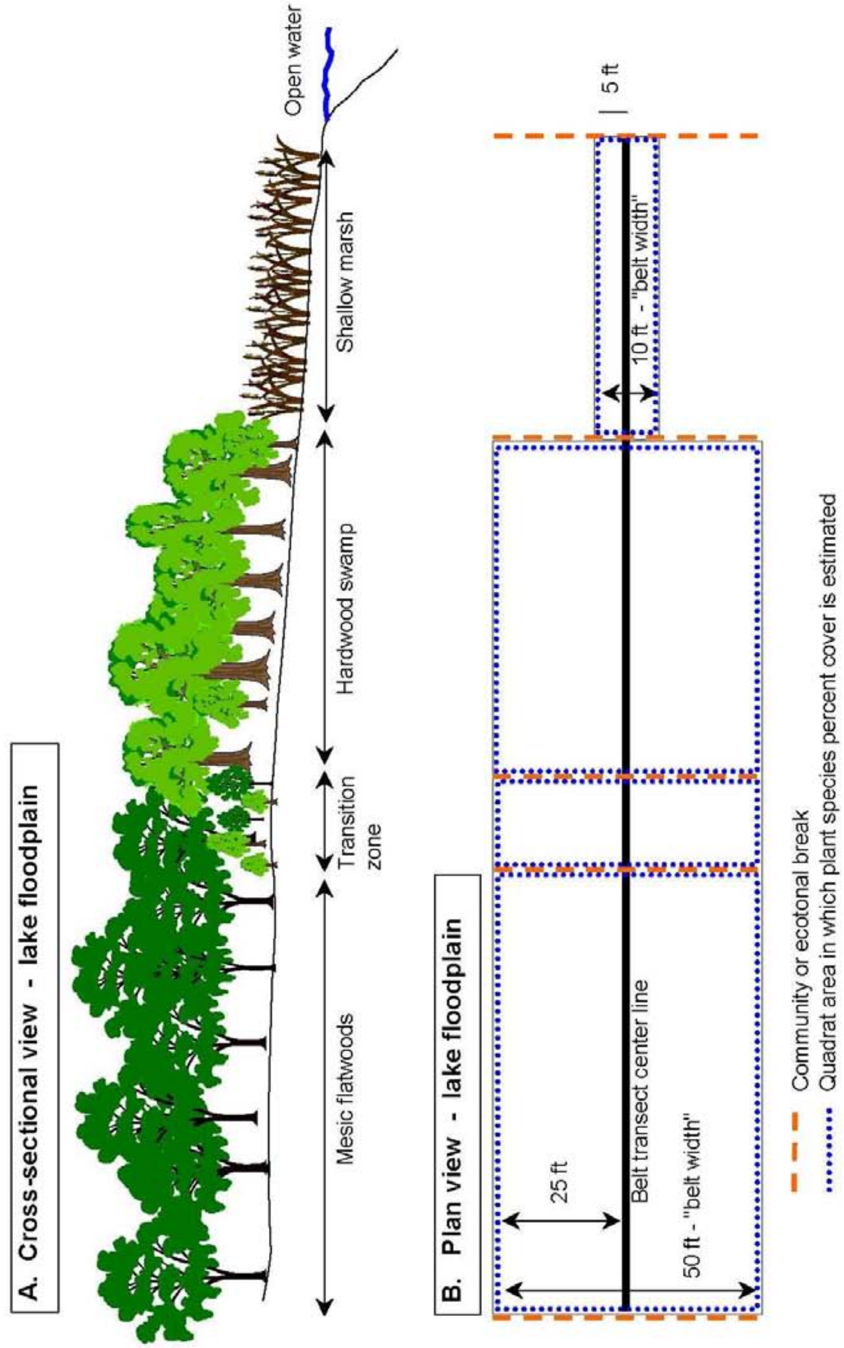


Figure 8. Example of belt transect through forested and herbaceous plant communities

Minimum Flows and Levels Methods Manual (SJRWMD 2006). Plant species, plant communities and percent cover data were recorded on field vegetation data sheets The data sheets are formatted to facilitate data collection in the field and, also, computer transcription.

Surface Water Inundation/Dewatering Signatures (SWIDS)

Frequency analysis of long-term stage data or modeled stage data was utilized to provide probabilities of flooding/dewatering events of a set duration (i.e., SWIDS) for wetland plant communities and organic soils. The probabilities were interpreted as return intervals (Gordon et al. 1992). For example, if a 30-day flooding event of an elevation of interest (e.g., maximum elevation of shallow marsh) had a probability of exceedence of 33%, then the event is interpreted as occurring approximately 33 in 100 years or a 1:3 year return interval, on average. This approach enables like plant communities or soils indicators from systems at different elevations to be compared and results in quantitative hydrologic signatures of specific elevations (e.g., mean-, minimum-, and maximum elevation of a vegetation community; Neubauer et al. 2004, Neubauer et al. 2007b).

Quantitatively defining the hydrologic signatures of vegetation communities provides a hydrologic range for each vegetation community, with a transition to a drier community on one side of the range and a transition to a wetter community on the other side. These hydrologic signatures provide a target for MFLs determinations based on vegetation communities and an estimate of how much the return interval of a flooding or dewatering event can be shifted and still maintain a vegetation community within its observed hydrologic range.

DATA ANALYSIS

The primary data analysis for information collected at Lake Grandin consisted of performing basic statistical analyses on the surveyed elevation data, in a computer spreadsheet file. Vegetation and soils information collected along transects were incorporated with the elevation data. Descriptive statistics were calculated for the elevations of the vegetation communities and specific hydric soil indicators.

Transect elevation data were also graphed to illustrate the elevation profile between the open water and upland community. Location of vegetation communities along the transect, together with a list of dominant species, statistical results, and soils information, were labeled on the graph. Specific transect elevation data from Lake Grandin may be found in the Results and Discussion section of this document.

CONSIDERATION OF ENVIRONMENTAL VALUES IDENTIFIED IN RULE 62-40.473, *F.A.C.*

In establishing MFLs for water bodies pursuant to Section 373.042 and Section 373.0421, F.S., SJRWMD identifies the environmental value or values most sensitive to long-term changes in the hydrology of each water body/course. SJRWMD then typically defines the minimum number of flood events and maximum number of dewatering events that would still protect the most sensitive environmental value or values. For example, for water bodies/courses for which the most sensitive environmental values may be wetlands and organic substrates, recommended MFLs would reflect the number of flooding or dewatering events that allow for no net loss of wetlands and organic substrates. By protecting the most sensitive environmental value or values for each water body/course, the 10 environmental values identified in Rule 62-40.473, *F.A.C.*, are considered to be protected.

SJRWMD uses the following working definitions when considering these 10 environmental values:

1. Recreation in and on the water—The active use of water resources and associated natural systems for personal activity and enjoyment. These legal water sports and activities may include, but are not limited to swimming, scuba diving, water skiing, boating, fishing, and hunting.
2. Fish and wildlife habitat and the passage of fish—Aquatic and wetland environments required by fish and wildlife, including endangered, endemic, listed, regionally rare, recreationally or commercially important, or keystone species; to live, grow, and migrate. These environments include hydrologic magnitudes, frequencies and durations sufficient to support the life cycles of wetland and wetland-dependent species.
3. Estuarine resources—Coastal systems and their associated natural resources that depend on the habitat where oceanic salt water meets freshwater. These highly productive aquatic systems have properties that usually fluctuate between those of marine and freshwater habitats.
4. Transfer of detrital material—The movement by surface water of loose organic material and associated biota.
5. Maintenance of freshwater storage and supply—The protection of an amount of freshwater supply for permitted users at the time of MFLs determinations.
6. Aesthetic and scenic attributes—Those features of a natural or modified waterscape usually associated with passive uses such as bird-watching, sightseeing, hiking, photography, contemplation, painting and other forms of relaxation that usually result in human emotional responses of well-being and contentment.

7. Filtration and absorption of nutrients and other pollutants—The reduction in concentration of nutrients and other pollutants through the process of filtration and absorption (i.e., removal of suspended and dissolved materials) as these substances move through the water column, soil or substrate, and associated organisms.
8. Sediment loads—The transport of inorganic material, suspended in water, which may settle or rise. These processes are often dependent upon the volume and velocity of surface water moving through the system.
9. Water quality—The chemical and physical properties of the aqueous phase (i.e., water) of a water body (lentic) or a watercourse (lotic) not included in definition number 7 (i.e., nutrients and other pollutants).
10. Navigation—The safe passage of watercraft (e.g., boats and ships), which is dependent upon adequate water depth and width.

CONSIDERATION OF BASIN ALTERATIONS IN ESTABLISHING MFLS

Based on the provisions of Section 373.0421(1)(a), F.S., SJRWMD, when establishing MFLs, considers changes and structural alterations to watersheds, surface waters, and aquifers and the effects such changes or alterations have had, and the constraints such changes and alterations have placed, on the hydrology of an affected watershed, surface water, or aquifer. However, when considering such changes and alterations, SJRWMD cannot allow harm caused by withdrawals. To accomplish this, SJRWMD reviews and evaluates available information, and makes site visits to ascertain the following information concerning the subject watershed, surface water body, or aquifer.

- The nature of changes and structural alterations that have occurred.
- The effects the identified changes and alterations have had.
- The constraints the changes and alterations have placed on the hydrology.

SJRWMD develops hydrologic models that address existing structural features and uses these models to consider the effects these changes have had on the long-term hydrology of water bodies for which recommended MFLs are being developed.

SJRWMD considers that the existing hydrologic condition, which is used to calibrate and verify the models, reflects the changes and structural alterations that have occurred in addition to changes that are the result of groundwater and surface water withdrawals existing at the time of model development. This consideration may also apply to vegetation and soils conditions if the changes, structural alterations, and water withdrawals have been sufficiently large to affect vegetation and soils and have been in place for a sufficiently long period to allow vegetation and soils to respond to the altered hydrology. However, the condition of vegetation and soils may not reflect the long-term existing hydrologic condition if the changes, structural alterations, and water withdrawals are relatively recent. This is because vegetation and soil conditions do not respond to all hydrologic changes nor respond instantaneously to changes in hydrology that are sufficiently large to cause such change. SJRWMD typically develops recommended MFLs based on the vegetation and soils conditions that exist at the time fieldwork is being performed to support the development of these recommended MFLs.

SJRWMD also provides for the collection and evaluation of additional data subsequent to the establishment of MFLs. SJRWMD uses this data collection and evaluation as the basis of determining if the MFLs are protecting the water resources or if the MFLs are appropriately set. If SJRWMD determines, based on modeling and this data collection and evaluation process, that MFLs have not been appropriately set, SJRWMD can establish revised MFLs.

If SJRWMD determines that recommended MFLs cannot be met under post-change hydrologic conditions due to existing structural alterations, SJRWMD may consider whether feasible structural or nonstructural changes, such as changes in the operating schedules of water control structures, can be accomplished such that the recommended MFLs can be met. In such cases, SJRWMD may identify a recovery strategy that includes feasible structural or nonstructural changes.

MFLs Compliance Assessment

A hydrologic model for Lake Grandin was developed to provide a means of assessing whether the recommended MFLs are achieved under specific water use and land use conditions (CDM 2005). This hydrologic model was calibrated for 2002 conditions. These conditions included the most recent land use information and groundwater levels consistent with 2002 regional water use.

An explanation of the use of this hydrologic model and applicable SJRWMD regional groundwater flow model to assess whether water levels are likely to fall below MFLs under specific water use and land use conditions is presented in Appendix B. This appendix also includes an introduction to the use of hydrologic statistics in the SJRWMD MFLs program.

RESULTS AND DISCUSSION

Fieldwork for the original (adopted) determination of minimum levels was performed in 1995 (Neubauer 1995). Elevation data were collected from: (1) water depths at various locations in the lake littoral zone; (2) one transect (XS-1) traversing a marsh, willow swamp, mixed swamp, and bay swamp; (3) one transect (XS-2) from the littoral zone to a low pine flatwood; and (4) one transect (XS-3) from the littoral zone through hydric and mesic hammocks to a live oak hammock.

To reevaluate the minimum levels for Lake Grandin, elevation, soils, and vegetation field data were obtained from two transect locations (Figure 3) in 2005. This section describes the data collected, the primary level determination criteria, and concludes with a description of the minimum level recommendations for Lake Grandin.

FIELD DATA COLLECTION—TRANSECT 1

Transect 1, located on the southeast shore of Lake Grandin (Figure 3), extended 95 ft in a westerly direction from the uplands edge to the floating pickerel weed edge. Figure 9 depicts the elevation ranges and dominant plant species for each major plant community and community portion. Table 2 presents a complete list of plant species observed on Transect.

The major plant communities and community portions occurring along Transect 1 were the uplands edge, transitional shrub, shallow marsh, deep marsh and floating pickerel weed edge. The uplands edge was located at station 10 ft and corresponded to 82.48 ft NGVD. The community portion is dominated by slash pine. The transitional shrub community was located between stations 10 ft and 24 ft and corresponded to 82.48 ft and 81.36 ft NGVD, respectively. The community is dominated by wax myrtle. The shallow marsh community was located between stations 24 ft and 60 ft and corresponded to 81.36 ft and 79.25 ft NGVD, respectively. The community is dominated by invading slash pine, some up to 6–8 ft tall, that probably colonized during the 2000 drought. The deep marsh community was located between stations 60 ft and 85 ft and corresponded to 79.30 ft and 77.76 ft NGVD, respectively. The community is dominated by rush fuirena. The floating pickerel weed edge was located at station greater than 85 ft. The community is dominated by floating pickerel weed. Table 2 lists the plant species observed, common names, *Florida Wetlands Delineation Manual* (FWDM, Gilbert et al. 1995) wetland indicator status, and plant communities with species occurrence for Transect 1.

No muck was present along Transect 1 (JEA 2006b).

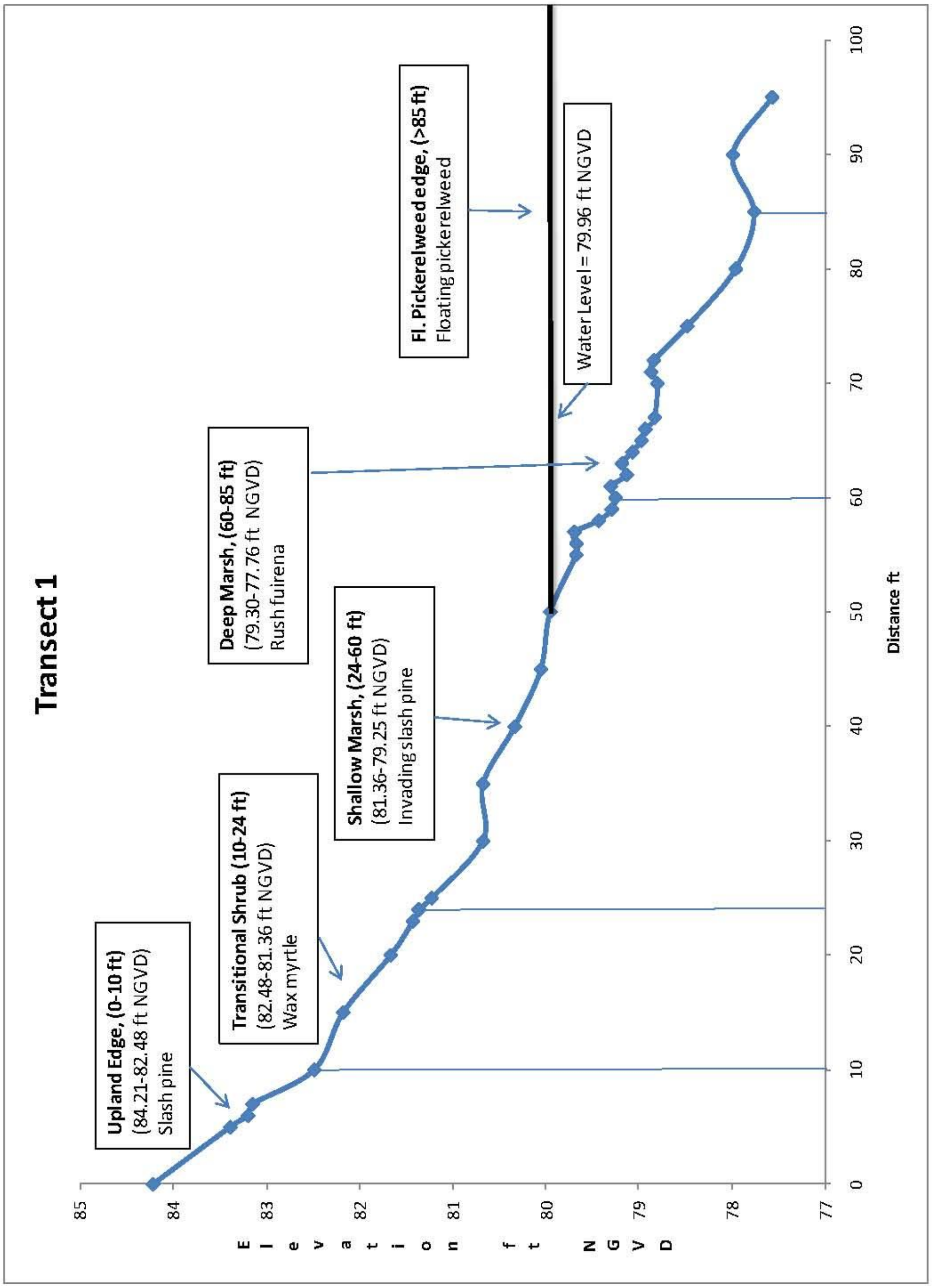


Figure 9. Transect 1 elevation and environmental features, Lake Grandin, Putnam County, Fla.

Table 2. Plant species, common names, FWDM wetland indicator status (drier to wetter), and plant communities or community edge (drier to wetter) with species occurrence for Transect 1 at Lake Grandin, Putnam County, Florida

Plant Species	Common Name	FWDM*	Plant Community or Community Edge				
			Upland Edge 0–10 ft NGVD	Trans. Shrub 10–24 ft NGVD	Shallow Marsh 24–60 ft NGVD	Deep Marsh 60–85 ft NGVD	Float. Pick. Weed Edge >85 ft NGVD
Pinus elliottii	Slash pine	UPL	X				
Pinus elliottii (invader)	Slash pine	UPL			X	X	
Smilax sp.	Greenbrier	**UPL**	X				
Vitis rotundifolia	Muscadine grape	**UPL**	X	X	X		
Lachnanthes caroliniana	Bloodroot	FAC			X		
Myrica cerifera	Wax myrtle	FAC	X	X		X	
Paspalum urvillei	Vasey grass	FAC				X	
Acer rubrum	Red maple	FACW				X	
Centella asiatica	Coinwort	FACW			X		
Gordonia lasianthus	Loblolly bay	FACW			X		
Liquidambar styraciflua	Sweetgum	FACW	X		X	X	
Quercus laurifolia	Laurel oak	FACW	X				
Quercus nigra	Water oak	FACW	X		X		
Woodwardia virginica	Virginia chain fern	FACW			X		
Alternanthera philoxeroides	Alligator weed	OBL				X	
Fuirena scirpoidea	Rush fuirena	OBL			X	X	
Ilex cassine	Dahoon holly	OBL	X	X	X		
Magnolia virginiana	Sweetbay	OBL			X		
Persea palustris	Swamp bay	OBL	X		X		
Pontederia cordata	Pickerelweed	OBL				X	X
Andropogon sp.	Bluestem grass	-			X		
Cyperus sp.	Sedge	-			X	X	
Hydrocotyle sp.	Water pennywort	-			X	X	
Juncus sp.	Rush	-				X	

Note: *Wetland indicator status for species not listed are in bold and assumed to be upland

ft NGVD = feet National Geodetic Vertical Datum

FIELD DATA COLLECTION—TRANSECT 2

Transect 2, located on the southeast shore of Lake Grandin (Figure 3), is about 100 ft north of Transect 1. Transect 2 extended 90 ft in a westerly direction from the uplands edge to the floating pickerel weed edge. Figure 10 depicts the elevation ranges and dominant plant species for each major plant community and community portion. Table 3 presents a complete list of plant species observed on Transect 2.

The major plant communities and community portions occurring along Transect 2 were the uplands edge, transitional shrub, shallow marsh, deep marsh and floating pickerel weed edge. The uplands edge was located at station 10 ft and corresponded to 82.25 ft NGVD. The community portion is dominated by water oak. The transitional shrub community was located between stations 10 ft and 21 ft and corresponded to 82.25 ft and 81.59 ft NGVD, respectively. The community is dominated by wax myrtle. The shallow marsh community was located between stations 21 ft and 65 ft and corresponded to 81.59 ft and 79.14 ft NGVD, respectively. The community is dominated by invading slash pine, some up to 6 ft and 8 ft tall, that probably colonized during the 2000 drought. The deep marsh community was located between stations 65 ft and 85 ft and corresponded to 79.14 ft and 77.66 ft NGVD, respectively. The community is dominated by rush fuirena. The floating pickerel weed edge was located at station greater than 85 ft. The community is dominated by floating pickerel weed. Table 3 lists the plant species observed, common names, *Florida Wetlands Delineation Manual* (FWDM, Gilbert et al. 1995) wetland indicator status, and plant communities with species occurrence for Transect 2.

No hydric soil indicators or muck were present along Transect 2 (JEA 2006b).

Table 4 describes important elevations on Transect 1 and 2 considered when determining minimum levels for Lake Grandin.

STRUCTURAL ALTERATIONS AND OTHER CHANGES

Lake Grandin has a drainage area of 3.71 square miles and a surface water outlet to Etonia Creek to the north through a canal (USGS 1993 as cited in Neubauer 1995). The extensive canal system, constructed before 1943, drains Lake Grandin, Boyds and Orange Grove (not delimited, about 4,400 ft due north of Boyds Lake) lakes, and the marshes north of these lakes (Figure 2). The controlling elevation of the canal system is unknown; however, recorded lake levels have rarely exceeded 82.4 ft NGVD. Another canal connects Lake Grandin to Clearwater Lake to the south. This canal is navigable and used frequently by residents to access either lake. The highest elevation in the canal channel was measured at 77.8 ft NGVD, more typical high points were near 77.2 ft NGVD.

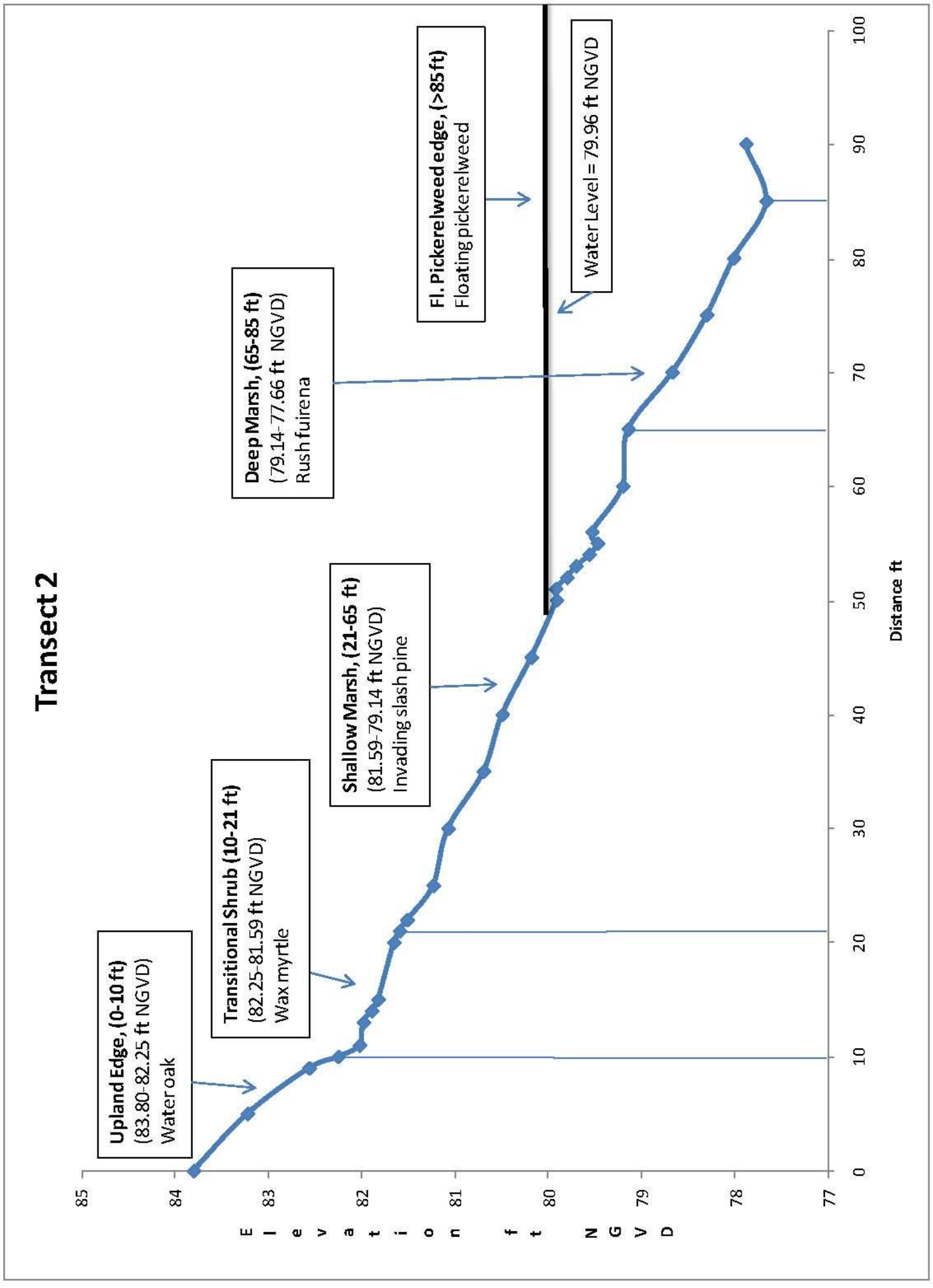


Figure 10. Transect 2 elevation and environmental features, Lake Grandin, Putnam County, Fla.

Table 3. Plant species, common names, FWDM wetland indicator status (drier to wetter), and plant communities or community edge (drier to wetter) with species occurrence for Transect 2 at Lake Grandin, Putnam County, Florida

Plant Species	Common Name	FWDM*	Plant Community or Community Edge				
			Upland Edge 0–10 ft NGVD	Trans. Shrub 10–21 ft NGVD	Shallow Marsh 21–65 ft NGVD	Deep Marsh 65–85 ft NGVD	Float. Pick. Weed Edge >85 ft
Dicanthelium portoricense	Panic grass	**UPL**			X		
Magnolia grandiflora	Bull magnolia	**UPL**	X				
Pinus elliottii (invader)	Slash pine	UPL			X		
Smilax sp.	Greenbrier	**UPL**	X				
Vitis rotundifolia	Muscadine grape	**UPL**		X	X		
Lachnanthes caroliniana	Bloodroot	FAC			X		
Myrica cerifera	Wax myrtle	FAC		X	X		
Acer rubrum	Red maple	FACW			X		
Gordonia lasianthus	Loblolly bay	FACW		X	X		
Liquidambar styraciflua	Sweetgum	FACW	X	X	X		
Osmunda cinnamomea	Cinnamon fern	FACW	X				
Quercus nigra	Water oak	FACW	X	X			
Vaccinium corymbosum	Highbush blueberry	FACW	X				
Woodwardia virginica	Virginia chain fern	FACW			X		
Alternanthera philoxeroides	Alligator weed	OBL			X		
Cephalanthus occidentalis	Buttonbush	OBL			X		
Eichhornia crassipes	Water hyacinth	OBL			X		
Fuirena scirpoidea	Rush fuirena	OBL			X	X	
Ilex cassine	Dahoon holly	OBL		X	X		
Juncus effusus	Soft rush	OBL			X	X	
Limnobium spongia	Frog's-bit	OBL				X	
Ludwigia peruviana	Primrose willow	OBL				X	
Persea palustris	Swamp bay	OBL	X	X			
Pontederia cordata	Pickerelweed	OBL				X	X
Andropogon sp.	Bluestem grass	-			X		

Table 3—*continued*

Plant Species	Common Name	FWDM*	Plant Community or Community Edge				
			Upland Edge 0–10 ft NGVD	Trans. Shrub 10–21 ft NGVD	Shallow Marsh 21–65 ft NGVD	Deep Marsh 65–85 ft NGVD	Float. Pick. Weed Edge >85 ft
Cyperus sp.	Sedge	-			X		
Hydrocotyle sp.	Water pennywort	-			X	X	
Juncus sp.	Rush	-				X	
Polygonum sp.	Smartweed	-			X		

Note: *Wetland indicator status for species not listed are in bold and assumed to be upland

ft NGVD = feet National Geodetic Vertical Datum

Table 4. Elevation summary statistics of important features measured at Lake Grandin

Location	*Feature*	N	Mean	Max	Min
Transect 1	Uplands edge	5	-	84.21	82.48
Transect 1	Transitional shrub community	5	81.82	82.48	81.36
Transect 1	Shallow marsh community	13	80.10	81.36	79.25
Transect 1	Deep marsh community	14	78.81	79.30	77.76
Transect 1	Floating pickerelweed edge	3	-	77.99	77.57
Transect 2	Uplands edge	4	-	83.80	82.25
Transect 2	Transitional shrub community	7	81.89	82.25	81.59
Transect 2	Shallow marsh community	16	80.19	81.59	79.14
Transect 2	Deep marsh community	5	78.37	79.14	77.66
Transect 2	Floating pickerelweed edge	2	-	77.88	77.66
Transects 1 and 2	Mean of transitional shrub communities	2	81.86	-	-
Transects 1 and 2	Mean of minimum of transitional shrub communities	2	81.48	-	-
Transects 1 and 2	Mean of shallow marsh communities	2	80.15	-	-
Transects 1 and 2	Mean of minimum of shallow marsh communities	2	79.20	-	-
Transects 1 and 2	Mean of deep marsh communities	2	78.59	-	-
Transects 1 and 2	Mean of minimum of deep marsh communities	2	77.71	-	-

N = the number of elevations surveyed at each vegetation community

Assuming a controlling elevation of 77.8 ft for the canal and a minimum of 1.5 ft water depth for boat clearance, lake levels at or below 79.3 ft (77.8 + 1.5 = 79.3) could hinder boat traffic through the Grandin–Clearwater canal. Lake levels below 79.3 ft occur during extreme droughts (Figure 5).

CDM (2005) delineated a Lake Grandin tributary area based on 1:24,000 USGS quadrangle map and year 2000 aerial photographs. CDM then used the 1995 land use coverage to quantify land use distribution around the lake. Based on this coverage, the tributary area (not including open water) consisted of low-density residential (1,143.0 acres), 66 %; wetland (185.3 acres), 11 %; medium-density residential (144.7 acres), 8%; upland forest (104.9 acres), 6%; open land (101.7 acres), 6%; rangeland (36.4 acres), 2%; and agricultural (25.8 acres), 1% (Table 5).

Table 5. Land use distribution excluding the lakes (modified from CDM 2005)

Land Use Area	Area (in ac)	Percent
Low-density residential	1143.0	66
Wetland	185.3	11
Medium-density residential	144.7	8
Upland forest	104.9	6
Open land	101.7	6
Rangeland	36.4	2
Agricultural	25.8	1
Total	1741.8	100

The open-water area of Lakes Grandin and Clearwater was estimated to be 359 acres at a stage of 80 ft NGVD (CDM 2005).

Based on this information and using typical percentages of impervious areas for land use categories, CDM (2005) estimated a tributary area of about 2,100 acres (3.3 square miles) that includes 1,591 acres (76%) of pervious area, 359 acres (17%) of open water and 150 acres (7%) of impervious area. Impervious surfaces allow for quicker runoff during rainfall events, causing water levels to rise more quickly. However, the small amount of impervious surfaces within the tributary area probably has little effect on lake levels, and hydrologic modeling shows that the MFLs were protected under existing conditions (2002), long-term hydrology.

Fieldwork performed in 2005 indicated that the condition of the soils and vegetation around the lake did not appear to be in transition because of anthropogenic changes. Rather, vegetation changes appeared to be influenced by the late-1990s to early 2000s drought, as evidenced by the invasion of upland slash pine in shallow marsh areas (Figures 9 and 10). Typical shallow marsh vegetation will be reestablished as water levels return to normal.

MINIMUM LEVELS DETERMINATION CRITERIA

The minimum frequent high (FH) and minimum frequent low (FL) levels were reevaluated for Lake Grandin. The minimum average (MA) level was not reevaluated because sandhill lakes (such as Lake Grandin) typically remain at high or low water levels with little time at the minimum average level. CH2M HILL (2005) presents a conceptual model of sandhill lakes and states that "… sandhill upland lakes are astatic, because they appear to lack a mean around which the system is organized" and that "… critical system behaviors of sandhill lakes may be related most strongly to high and low water levels corresponding to drought cycles and multidecadal climate cycles." Because of the nature of sandhill lakes to fluctuate dramatically (CH2M HILL 2005), the lack of stable/seasonally flooded vegetation communities, and the absence of organic soils, a minimum average level is not recommended for Lake Grandin.

Two minimum levels with associated durations and return intervals are recommended. Brief descriptions of the criteria used to determine these minimum levels, as well as the important ecological structures and functions protected by these minimum levels, are provided below.

Criteria vary depending upon the level being determined and the on-site wetland community characteristics. For example, the primary criterion for a level may be the average or extreme (high or low) elevation associated with a vegetation community or soil indicator based on the scientific literature and hydrologic data.

Vegetation communities occur along a continuum from dry (upland) to wet (open water) and were used along with published literature concerning the hydrology and functions of individual communities to determine the recommended minimum levels.

The minimum levels are also supported by current surface water inundation/ dewatering signatures (SWIDS, Neubauer et al. 2004, Neubauer et al. 2007b). SWIDS quantitatively define the hydrologic range for wetland vegetation communities. These hydrologic signatures provide a target for MFLs determinations, based on vegetation communities, and provide an estimate of how much the return interval of a flooding or dewatering event can be shifted and still maintain a vegetation community within its observed hydrologic range.

MINIMUM LEVELS REEVALUATION FOR LAKE GRANDIN

Minimum Frequent High (FH) Level

The recommended FH level for Lake Grandin is 81.5 ft NGVD with an associated flooding duration of 30 continuous days and a return interval of once every 2 years (i.e., 50 flooding events in 100 years), on average. The FH level is defined as "… a chronically high surface water level or flow with an associated frequency and duration that allows for inundation of the floodplain at a depth and duration sufficient to maintain wetlands functions" (Rule 40C-8.021(7), *F.A.C.*).

The recommended FH elevation component is equivalent to the mean of the minimum elevations of the two transitional shrub communities on Transect 1 and Transect 2 (81.36 ft and 81.59 ft NGVD, respectively, Table 4, Figures 9 and 10). The transitional shrub communities had very similar minimum elevations for both occurrences.

The recommended FH duration component (30 days continuously exceeded) represents a sufficiently long-enough period to protect the structure of seasonally flooded wetland plant communities. This duration also allows for sufficient time for fish and other aquatic biota to feed, reproduce, and use the available habitat for refuge.

The recommended FH return interval (2 years) occurs in the driest quartile of the 30-day return intervals observed for transitional shrub minimum elevations (Figure 11). That is, the recommended FH level is supported by current SWIDS analysis of the minimum elevation of transitional shrub communities. SWIDS analysis of 16 transitional shrub systems (Figure 11) indicates this elevation could flood for 30 continuous days with an approximate return interval of 2 years (i.e., 50 flooding events in 100 years), on average (Neubauer et al. 2004, Neubauer et al. 2007b). The return interval associated with the FH level (2 years) is drier than the median of the hydrologic range observed for the minimum elevation of transitional shrub communities at other systems. This allows for some hydrologic shift in the number of these flood events, while maintaining a natural hydrologic signature that is within the hydrologic range for the minimum elevation of transitional shrub communities.

The recommended FH level for Lake Grandin occurs under 2002 conditions for a duration of 30 continuous days approximately once every 1.7 years (59 out of 100 years), on average, based upon HSPF (hydrologic simulation program-FORTRAN) model simulation (CDM 2005, Figure 12). Therefore, the recommended FH level for Lake Grandin allows for nine fewer, 30-continuous-day flooding events in 100 years of the 81.5 ft NGVD elevation than would be expected under the 2002 hydrologic

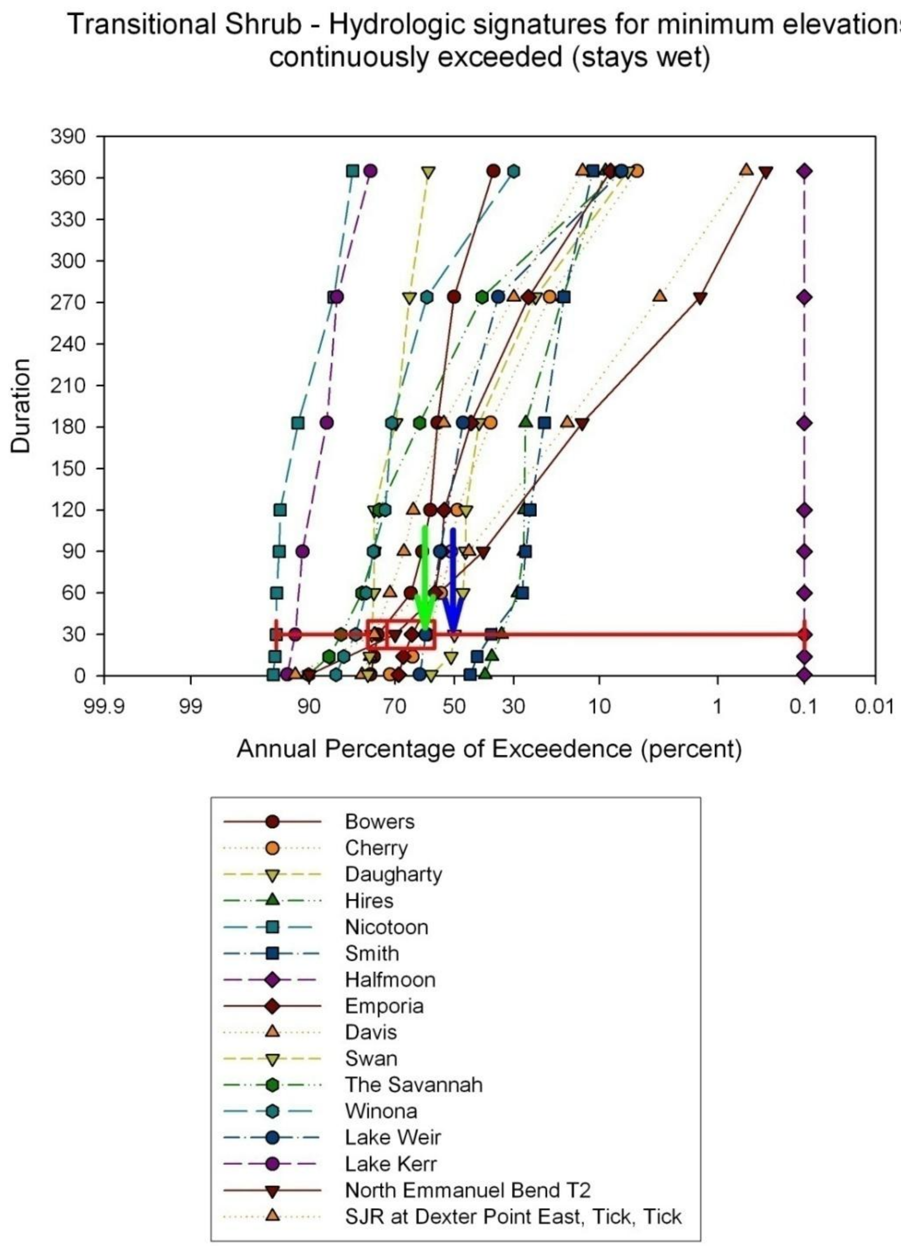


Figure 11. Surface water inundation/dewatering signatures (SWIDS) for minimum elevations of transitional shrub communities

(blue arrow = recommended FH, green arrow = 2002 existing conditions)

conditions. This duration/return interval shows that the hydrologic requirements of the recommended FH level are met under 2002 hydrologic conditions and that this recommended FH level would allow for some consumptive use in addition to that which existed under 2002 conditions (Figure 12).

The recommended FH elevation component, 81.5 ft NGVD, provides about 1.35 ft of water over the mean elevation of the shallow marsh communities on Transect 1 and Transect 2 (80.15 ft NGVD, Table 4). The longer duration and more frequent inundation in the shallow marsh communities are sufficient to support the obligate and facultative wetland plant species within and the spatial extent and functions of the shallow marsh communities. This level also allows sufficient water depths for fish and other aquatic organisms to feed and spawn on the lake floodplain. Bain (1990) and Poff et al. (1997) have reported that connecting the lake and floodplain are extremely important to animal productivity. Similar benefits likely result from flooding the shallow marsh communities at Lake Grandin. As water levels rise, the amount of habitat available to aquatic organisms increases greatly as large areas of the floodplain are inundated (Light et al. 1998).

The life cycles of many fishes are related to seasonal water level fluctuations, particularly the annual flood pattern (Guillory 1979). The floodplain provides feeding and spawning habitat (Guillory 1979; Ross and Baker 1983) and refugia for juvenile fishes (Finger and Stewart 1987). The FH water level component will be exceeded during wet years and may not occur during dry years; most fish and other aquatic fauna are adapted to year-to-year variations of the natural hydrologic regime.

An appropriate normal high water level is necessary to maintain the structure and function of the wetlands at Lake Grandin. High water levels of this duration and frequency protect the vegetation and structure, and the ecological functions of the hydric soils within the transitional wetland communities at Lake Grandin. Schneider and Sharitz (1986) reported that short-term flooding events are important to the redistribution of plant seeds within aquatic habitats. The species composition and structural development of floodplain plant communities are influenced by the timing and duration of floods occurring during the growing season (Huffman 1980). Floods affect reproductive success as well as plant growth. The resulting anaerobic soil conditions within the wetland communities favor hydrophytic vegetation, tolerant of longer periods of soil saturation, and eliminates upland plant species that have invaded during low water events.

Inundation of the floodplain is also necessary for the exchange of particulate organic matter and nutrients (McArthur 1989). Flooding events redistribute and concentrate organic particulates (i.e., decomposing plant and animal parts, seeds, etc.) across the floodplain (Junk et al. 1989). This organic matter is assimilated by bacteria and invertebrate populations (Cuffney 1988), which, in turn, serve as food for larger fauna.

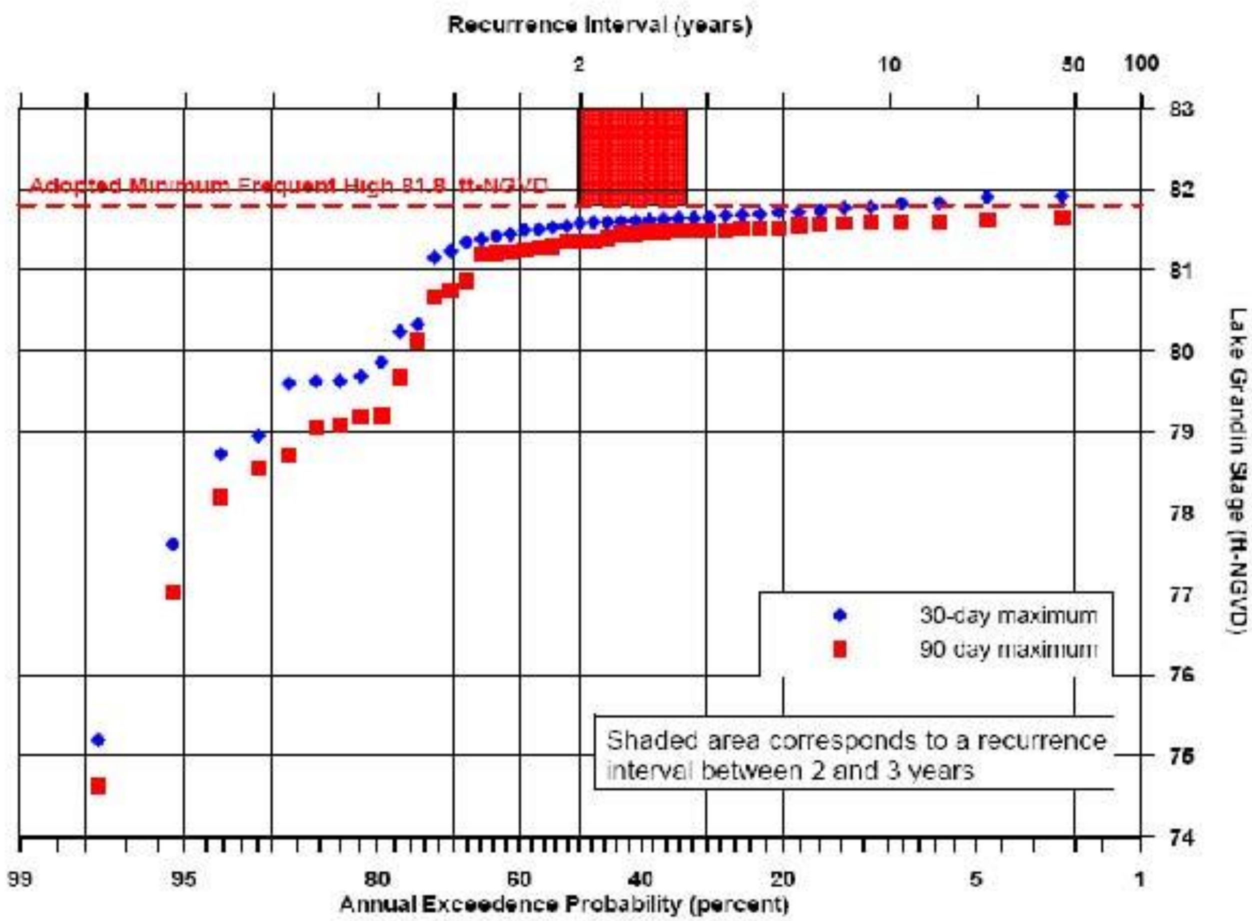


Figure 12. Modeled frequency analysis for the adopted minimum frequent high (FH) level (CDM 2005), Lake Grandin, Putnam County, Florida

Minimum Frequent Low (FL) Level

The recommended FL level for Lake Grandin is 78.6 ft NGVD with an associated duration of 120 days and return interval of once every 5 years (i.e., 20 dewatering events in 100 years), on average. The FL level is defined as "… a chronically low surface water level or flow that generally occurs only during periods of reduced rainfall. This level is intended to prevent deleterious effects to the composition and structure of the floodplain soils, the species composition and structure of floodplain and instream biotic communities, and the linkage of aquatic and floodplain food webs" (Rule 40C-8.021(10), *F.A.C.*). The FL level represents a low lake stage that generally occurs during moderate droughts and results in dewatered wetlands with ecological benefits (see below).

The recommended FL elevation component is equivalent to the mean of the mean elevations of the deep marsh communities on Transect 1 and Transect 2 (78.81 ft and 78.37 ft NGVD, respectively, Table 4). The deep marsh communities had very similar mean elevations for both occurrences.

The recommended FL duration component (120 days continuously not exceeded) represents a sufficiently long-enough period to protect the structure of seasonally flooded wetland plant communities. This duration allows for sufficient time for periodic dewatering of seasonally flooded wetlands to allow for seed germination of wetland plants (e.g., *Taxodium sp*.) that require saturated but not inundated substrates. Further, this duration allows for sufficient time for plants to grow sufficiently tall to survive post-drought, higher water conditions. Additionally, such drawdowns enable wading birds to feed and allow access to the floodplain resources by wildlife species that usually inhabit upland plant communities (Harris and Gosselink 1990).

The recommended FL return interval (5 years) is supported by current SWIDS analysis for mean deep marsh elevations (Neubauer et al. 2004, Neubauer et al. 2007b) and corresponds to a return interval somewhat drier than the median observed at 20 other lake systems (Figure 13). This level allows dewatering of the shallow marsh minimum elevations for 120 days every 5 years (i.e., 20 dewatering events in 100 years), on average, over the long term.

The recommended FL level for Lake Grandin occurs under 2002 conditions for a duration of 120 continuous days once in 7.7 years (13 out of 100 years), on average, based upon HSPF model simulation (CDM 2005, Figure 14). The recommended FL level would result in a change in the return interval of this mild drought event from an event that historically occurred, on average, every 7.7 years (13 out of 100 years) to an event which would occur, on average, every 5 years (20 times in 100 years), while maintaining a 120-day duration at a stage of 78.6 ft NGVD. This duration and return interval shows that the hydrologic requirements of the recommended FL level are met under 2002 hydrologic conditions (Figure 14).

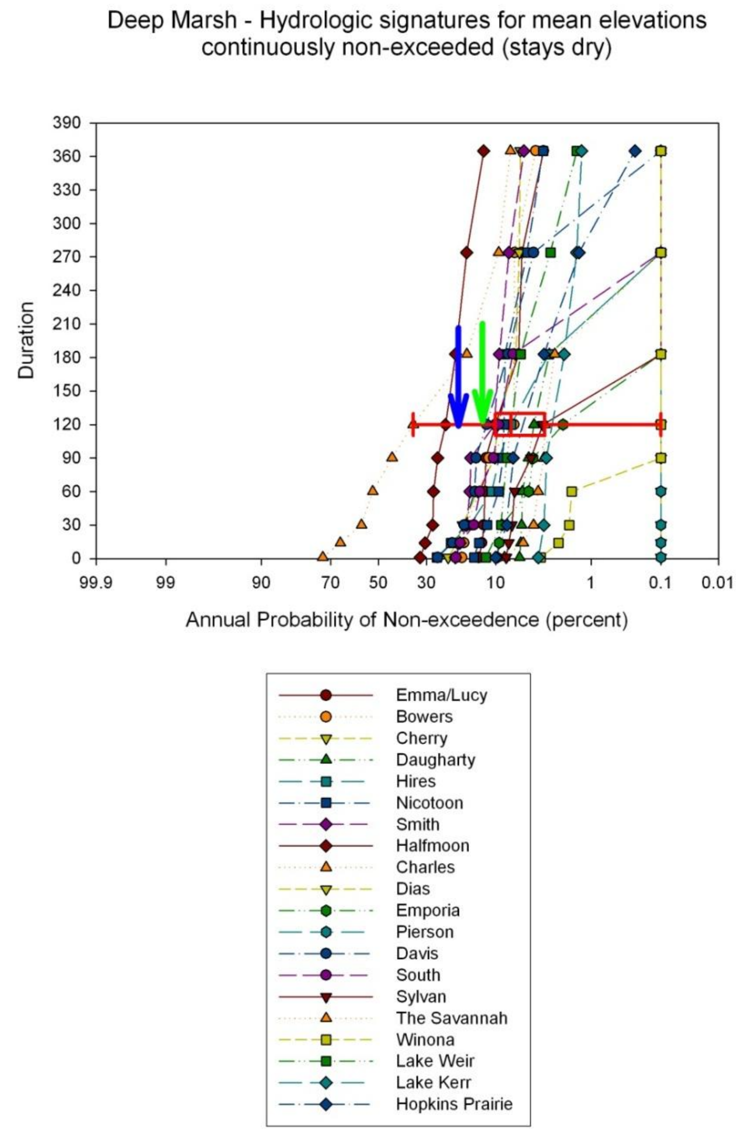


Figure 13. Surface water inundation/dewatering signatures (SWIDS) for mean elevations of deep marsh communities

(blue arrow = recommended FL, green arrow = 2002 existing conditions)

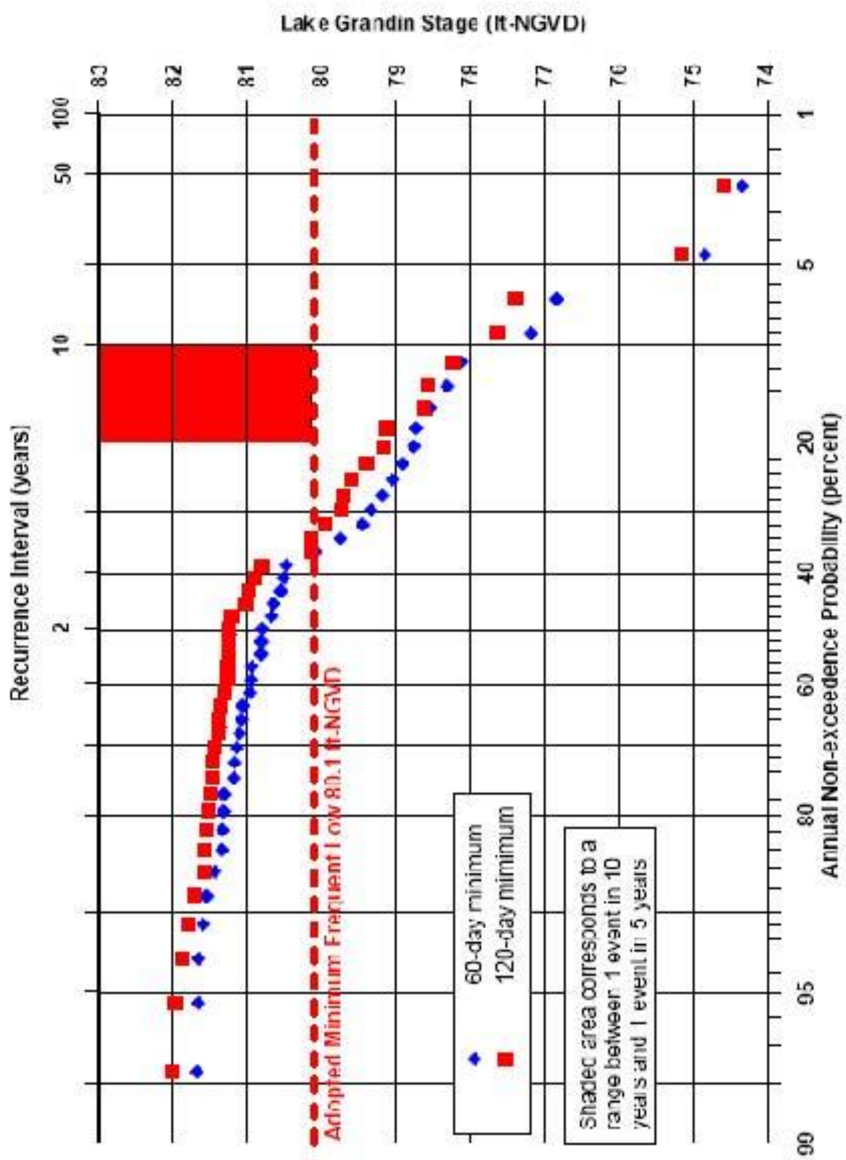


Figure 14. Modeled frequency analysis for the adopted minimum frequent low (FL) level (CDM 2005), Lake Grandin, Putnam County, Florida

Return intervals for both the recommended FL level (5 years) and 2002 hydrologic conditions (7.7 years) occur in the driest quartile of 120-day return intervals observed for mean elevation of deep marsh (Figure 13). However, the FL level return interval has a drier hydrologic signature than for 2002 hydrologic conditions, allowing more dewatering events to occur in 100 years.

Dewatering the floodplain is a natural consequence of drought and has ecological benefits. Drawdown conditions enable seeds of emergent wetland plants to germinate from the seed banks of the floodplain. The seeds of many wetland plant species require exposed soils to germinate (Van der Valk 1981). Exposing the floodplain of Lake Grandin for suitable durations should maintain the locations of floodplain communities. Upland plant species are able to invade the floodplain and become established during low water events. When these species die in response to rising water, their biomass becomes a significant substrate for bacterial and fungal growth, which becomes a critical food source for invertebrate collector-gathering and collector-filtering guilds (Cuffney 1988).

The recommended FL level component of 78.6 ft NGVD allows complete dewatering of the shallow marsh at Lake Grandin, but maintains flooded conditions across the bottom half of the deep marsh communities (Table 4, and Figure 9, Figure 10), which is important refugia for small fish, amphibians, and small reptiles.

Low water levels also allow for the decomposition and/or the compaction of flocculent organic sediments. Aerobic microbial breakdown of the sediment begins with receding water levels, releasing nutrients, thereby stimulating primary production. Sunlight also heats, dries, and compacts sediment into firm substrates. Normally upon reflooding, conditions are improved for fish nesting and foraging since the marsh surface has consolidated, structural cover has increased, and forage resources (terrestrial and aquatic invertebrates) are abundant (Kushlan and Kushlan 1979; Merritt and Cummins 1984).

The FL level supports protection of the accumulated organic matter in low-lying soils by preventing its loss and the associated negative effects. Sandhill lakes typically do not have large quantities of organic matter, so even minor losses could significantly impact heterotrophic production, water quality, and ecosystem health (JEA 2006a). The FL level supports: (1) turnover and storage of nutrients in the ecosystem, which provides the energy source of organic matter for detrital food chain; and (2) prevention of carbon loss, keeping organic soil features near existing conditions elevations. Oxygen is readily depleted by the action of microorganisms in saturated soil (JEA 2006a). As a result, organic matter accumulates as breakdown by microorganisms is slowed by lack of oxygen. Organic matter is a well-documented source and sink for many important nutrients such as carbon, nitrogen, and phosphorus (JEA 2006a).

CONCLUSIONS AND RECOMMENDATIONS

The intent of the establishment of minimum levels for Lake Grandin in Putnam County, Florida, is to protect the aquatic and wetland ecosystems from significant harm caused by the consumptive use of water. Additionally, the MFLs provide technical support to SJRWMD's regional water supply planning (Section 373.0361, F.S.), consumptive use permitting (Chapter 40C-2, *F.A.C.*), and environmental resource permitting programs (Chapter 40C-4, *F.A.C.*).

Recent completion of a hydrologic model for Lake Grandin (Price Robison, SJRWMD, pers. com. 2007; CDM 2005) indicated that the adopted minimum frequent high (FH), minimum average (MA), and minimum frequent low (FL) levels were not being met under 2002 water use and most recent land use conditions. Consequently, a reevaluation of the adopted Lake Grandin MFLs was performed based upon the current minimum flows and levels (MFLs) methodology.

The FH and FL levels were reevaluated for Lake Grandin. The MA level was not reevaluated because sandhill lakes (such as Lake Grandin) have a tendency to remain at high or low water levels with little time at the minimum average level. CH2M HILL (2005) presents a conceptual model of sandhill lakes and states that "… sandhill upland lakes are astatic, because they appear to lack a mean around which the system is organized" and that "… critical system behaviors of sandhill lakes may be related most strongly to high and low water levels corresponding to drought cycles and multidecadal climate cycles." Because of the nature of sandhill lakes to fluctuate dramatically (CH2M HILL 2005), the lack of stable/seasonally flooded vegetation communities, and the absence of organic soils, an MA level is not recommended for Lake Grandin.

The SJRWMD multiple MFLs method (SJRWMD 2006; Neubauer et al. 2007a) was applied to determine the MFLs recommended in this document. MFLs determinations are based on evaluations of topographic, soils, and vegetation data collected within plant communities associated with the water body, together with information collected from other aquatic ecosystems and from the scientific literature. The MFLs reevaluation has resulted in the recommendation to modify the adopted MFLs for Lake Grandin (Table 6) based on current SJRWMD MFLs methodology and criteria (SJRWMD 2006).

The recommended FH level (81.5 ft NGVD) for Lake Grandin is 0.3 ft lower than the adopted level because a different criterion was used. The adopted FH level (81.8 ft NGVD) for Lake Grandin corresponds to the average elevation of mixed swamp at Transect XS-1 (Neubauer 1995). The recommended FH level, based upon new research involving surface water inundation/dewatering signatures (SWIDS) and frequency analysis, equals the mean minimum elevations of the two transitional shrub communities on Transect 1 and Transect 2, as determined in 2005.

Table 6. Adopted and recommended minimum surface water levels for Lake Grandin, Putnam County, Florida

	Adopted				Recommended		
Minimum Level	Level (ft NGVD)	Duration (days)	Return Interval (years)	Hydroperiod Category	Level (ft NGVD)	Duration (days)	Return Interval (years)
Frequent high (FH)	81.8	None	None	Seasonally flooded	81.5	30	2
Minimum average (MA)	81.3	None	None	Typically saturated	None	None	None
Frequent low (FL)	80.1	None	None	Semi-permanently flooded	78.6	120	5

ft NGVD = feet National Geodetic Vertical Datum

The recommended FL level (78.6 ft NGVD) for Lake Grandin is 1.5 ft lower than the adopted level (80.1 ft NGVD) because a different criterion was used. The adopted FL was based on two factors (Neubauer 1995): (1) the water level is maintained within 1.7 ft of the average elevation of the seasonally flooded mixed swamp, a criterion used at other lakes and derived from interpretation of Putnam and Volusia county soil surveys; and (2) 80.1 ft NGVD was the average elevation of the maidencane dominated portion of the littoral zone at Transect XS-2. The adopted lake level would be about 0.6 ft below the willow swamp and the emergent marsh/aquatic bed would be flooded, on average, to a depth of 0.4 feet at Transect XS-1.

The recommended FL level, based upon new research involving SWIDS and frequency analysis, equals the mean of the mean elevations of the deep marsh communities on Transect 1 and Transect 2, as determined in 2005.

The hydrologic model for Lake Grandin was calibrated for 2002 conditions. These conditions included the most recent land use information and groundwater levels consistent with 2002 regional water use. Based on hydrologic model results (CDM 2005; Robison, pers. com. 2007), SJRWMD concludes that the recommended MFLs for Lake Grandin are protected under 2002 conditions. To determine if changes in groundwater use allocations subsequent to 2002 would cause lake levels to fall below the recommended MFLs for Lake Grandin, the existing Lake Grandin hydrologic model should be run using Floridan aquifer potentiometric level declines that reflect these changes in water use allocation.

SJRWMD concludes that the recommended MFLs for Lake Grandin are protected under 2002 conditions, based on long-term hydrologic model simulations (CDM 2005; Robison, pers. com. 2007). Results presented in this report are preliminary and will not become effective unless the recommended MFLs are adopted by SJRWMD Governing Board rule. Periodic reassessment of these levels should be conducted to determine if these levels are being achieved and if they are adequate to prevent significant harm from occurring at Lake Grandin. Reassessments should include analysis of period-of-record stage data and periodic monitoring of the vegetation communities and the soil water table at the Lake Grandin transects to ensure these areas are protected.

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APPENDIX A—MINIMUM SURFACE WATER LEVELS FOR LAKE GRANDIN, SEPTEMBER 1995

MEMORANDUM **Putnam 93-1358**

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DATE: September 1, 1995

TO: Jeff Elledge, Director JE
Resource Management Department

THROUGH: for Charles A. Padera, Director CAP
Water Resources Department

FOR Edgar F. Lowe, Ph.D., Director GBH
Environmental Sciences Division

G.B. (Sonny) Hall, Ph.D., Technical Program Manager
Environmental Sciences Division GBH

for Clifford P. Neubauer, Ph.D., Supervising Environmental Specialist
Environmental Sciences Division GBH

FROM: Ric Hupalo, Environmental Specialist IV R.H.
Environmental Sciences Division

RE: Minimum Surface Water Levels determined for Lake Grandin, Putnam County
(Project # 01-43-5140-DIST-10009)

The purpose of this memorandum is to forward recommended minimum lake levels and hydroperiod categories (Table 1) determined for Lake Grandin to the Resource Management Department.

Table 1. Recommended minimum lake levels for Lake Grandin. Terminology is defined in 40C-8.021, F.A.C.

MINIMUM LEVEL	ELEVATION (ft NGVD)	HYDROPERIOD CATEGORY
Minimum Frequent High Level	81.8	Seasonally Flooded
Minimum Average Level	81.3	Typically Saturated
Minimum Frequent Low Level	80.1	Semipermanently Flooded

Lake Grandin was selected for investigation to comply with the Minimum Flows and Levels Sierra Club settlement. The 354 acre lake is located 3 miles north of Interlachen and one-half mile east of County Road 315 (Figure 1). Field work was conducted on the lake on August 3 and 10, 1995 when lake levels were 80.82 and 80.95 ft NGVD, respectively.

Hydrology and Lake Morphometry

Lake Grandin is within the Interlachen Hills Physiographic Division of the Central Lakes District. A direct hydraulic connection to the Floridan aquifer exists in this physiographic division and lakes are at or slightly above the potentiometric surface of the Floridan aquifer. However, more detailed information (Boniol et al. 1993) places the lake in a low (0-4 in/yr) recharge category. The rapid recovery of lake levels from the 1989-91 drought and the relative stability of water levels prior to the drought support the low recharge classification (Figure 2). There are no Consumptive Use Permit allocations from the lake or from wells adjacent to the lake (personal communication, Daniel Hornsby).

Lake Grandin has a drainage area of 3.71 mi^2 and a surface water outlet to Etonia Creek through a canal (USGS 1993). The extensive canal system was constructed prior to 1943 and drains Lake Grandin, Boyd's and Orange Grove lakes, and the marshes north of these lakes (Figure 3). The controlling elevation of the canal system is not known, however, recorded lake levels have rarely exceeded 82.4 ft NGVD. Another canal connects Lake Grandin to Clearwater Lake. This canal is navigable and is frequently used by residents to access either lake. The highest elevation in the canal channel was measured at 77.8 ft NGVD, more typical high points were near 77.2 ft NGVD.

A recording fathometer was used to determine elevations of the lake bottom. Depths were collected along two profiles on north-south and east-west bearings (Figure 1). Typically, the lake was approximately 10 feet deep, indicating the bottom is near 71 ft NGVD. The maximum recorded depth was 11 feet. Along the western shore the lake remained shallow (4-8 ft at 80.8 ft NGVD) for a considerable distance from shore.

A record of lake levels exists from July 1957 at USGS Station 02244950. Daily values were recorded from July 1957-October 1960 and monthly to bi-monthly there after. The District staff gage record has daily readings from May 1991 to present. These stage data are shown in Figure 2. The lake was recovering from low levels in 1957 when the period of record began. Record keeping at Lake Grandin probably was initiated in response to the 1956 drought. Pirkle and Brooks (1959), citing a Florida Water Resources Study Commission report, state that in many sections of the state water levels in 1956 were the lowest on record due to a prolonged rainfall deficit.

The fluctuation range for the period of record is 5.77 feet. Prior to the 1989-91 drought, the fluctuation range of Lake Grandin was ranked 11 of 121 Florida lakes, meaning that, 91 % of the lakes fluctuated more than Lake Grandin (Motz et al. 1991). The lowest recorded lake level from 1957 to 1995 was 77.01 ft NGVD (Aug. 3, 1992). The highest recorded lake level occurred on Oct. 8, 1960 and was 82.78 ft NGVD. Descriptive statistics were calculated after converting periods of daily lake level readings to monthly means. This was to prevent approximately six years of daily values (mostly from periods of low levels) from excessively weighting the descriptive statistics of the 38 year period. Peak stages may not have been recorded since much of the record is from bi-monthly readings. The 20th, 60th and 80th percentiles of exceedance are 81.98, 81.27 and 80.42 ft NGVD, respectively (Figure 4). The mean and median lake levels were 81.08 and 81.47 ft NGVD, respectively. The mean stage is less than the median stage because the value of the mean is more affected by the extremely low stages that occurred during the recent drought. The small standard deviation (1.21 feet) indicates that the lake typically has a relatively small fluctuation range. A hydrologic model for Lake Grandin is not available.

Hydric Soils

Hydric soils fringe about two-thirds of the lake (Figure 5). Hydric soils were described as Samsula muck (MUID 27) and Hontoon muck (MUID 30) by the Putnam County Soil Survey (SCS 1990). These mucks occur in depressions and are formed in moderately thick beds of hydrophytic, nonwoody plant remains. Both soils have a high water table at or above the soil surface (+2.0-1.0 ft) except during extended dry periods. However, SCS (1990 p. 40) notes large areas of Hontoon muck near Florahome have been drained and are used for agriculture. Both soils are prone to subsidence and oxidation and should be saturated when not cultivated (SCS 1990). MUID 27 and 30 polygons adjacent to Lake Grandin total 1137 acres (SJRWMD GIS soil coverage).

Wetlands and Littoral Zone Vegetation

Wetlands adjacent to the lake were classified by the U.S. Fish and Wildlife Service Wetland Inventory (now U.S. Biological Service, USBS) in 1987 with 1983 CIR aerial photography (Figure 6). The wetland types are: Palustrine Emergent Persistent / Aquatic Bed Rooted Vascular Semipermanently Flooded (PEM1/AB3F); Palustrine Forested Broad-Leaved Deciduous Seasonally Flooded (PFO1C); Palustrine Forested Broad-leaved Evergreen and Broad-Leaved Deciduous Seasonally Flooded (PFO3/1C and 1/3C); and Palustrine Forested Needle-Leaved Evergreen Temporarily Flooded (PFO4A). Generally, emergent vegetation occurs in a band less than 100 feet wide and to a depth of approximately 4 feet (76.8 ft NGVD). Common plant species are southern smartweed, frog's-bit, pickeralweed, water hyacinth, bag-grass, and southern cutgrass.

Elevation data were collected from: 1) water depths at various locations in the lake littoral zone; 2) one transect (XS-1) traversing a marsh, willow swamp, mixed swamp, and bay swamp; 3) one transect (XS-2) from the littoral zone to a low pine flatwood and; 4) one transect (XS-3) from the littoral zone through hydric and mesic hammocks to a live oak hammock. The forested wetland traversed by XS-1 was classified as PFO3/1C by USBS. However, this area is primarily bay swamp with high abundance of bays, water oak, laurel oak, and cinnamon fern. The other transects (XS-2,3) did not traverse any wetlands which were classified by USBS. The transect locations are shown in Figure 1 and the elevations of the plant communities, with some common plants, are plotted in Figure 7. Elevation data for the plant communities and other significant features are summarized below in Table 2. Scientific names for plant species are provided in Table 3.

The recommended minimum levels for Lake Grandin are based upon consideration of elevation transects conducted by ES staff and Surveying staff (Lee Amon), information contained in the SCS soil survey and the USBS Wetland Inventory. Three levels with corresponding hydroperiod categories are recommended. A short description of the functions of each minimum level and some of the related data used in the determination follows.

Table 2. Elevation Summary from survey at Lake Grandin. Unit is ft NGVD.

Location	Feature	Spot	Mean	Median	Max	Min
XS-3	Live oaks	88.0				
XS-3	Mesic hammock		85.6	85.2	88.0	84.0
Shoreline	Top of dock decks, n=12		83.8	83.9	84.6	82.9
XS-2	Low pine flatwood		83.2	83.1	83.5	82.5
XS-1	Bay swamp		82.6	82.7	82.9	82.1
XS-3	Mixed deciduous and bay swamp		82.4	82.3	83.5	81.4
XS-1	Mixed swamp		81.8	81.9	82.1	81.5
XS-2	Shoreline shrub zone		81.4	81.3	81.9	80.9
XS-3	Shoreline	81.4				
XS-1	Willow swamp		80.7	80.5	81.5	80.3
XS-2	Littoral maidencane zone		80.1	80.0	80.9	79.4
XS-1	Emergent marsh		79.7	79.7	81.3	79.4
Canal	Lake Grandin to Clearwater Lake		76.9	77.0	77.8	75.8
Shoreline	Waterward dock piling, n=12		76.6	76.9	77.8	74.5

MINIMUM FREQUENT HIGH LEVEL

The recommended Minimum Frequent High Level is 81.8 ft NGVD with an associated hydroperiod category of Seasonally Flooded. This water level and hydroperiod category maintains the spatial extent of marshes and mixed swamp. This water level floods to the average elevation of mixed swamp at XS-1. Signs of deep flooding, such as tussocks on the royal fern and tree water lines were not evident in the mixed swamp at XS-1. The stage record indicates that the outlet canal prevents the forested wetlands from deep flooding, water levels rarely (<5%) exceed 82.4 ft NGVD. The water level 81.8 ft NGVD was exceeded by approximately 30% of the monthly mean and bi-monthly stage observations from the period of record (Figure 4). Water depths typically associated with seasonal ponding of Hontoon muck no longer occur in the bay swamps due to the drainage canal. The high abundance of water oak, sweet gum, and laurel oak observed in the bay swamp is probably due to the reduced hydroperiod. The recommended Minimum Frequent High water level provides seasonal saturation for the bay swamps since, the lake level will be less than a foot below the soil surface. A lake level of 81.8 ft NGVD is two feet below the average dock deck height (Table 2).

MINIMUM AVERAGE LEVEL

The recommended Minimum Average Level is 81.3 ft NGVD with an associated hydroperiod category of Typically Saturated. The recommended minimum average level was based on the median elevation of the shoreline shrub zone (81.3 ft NGVD) at XS-2 and consideration of the 60th percentile of exceedance (81.27 ft NGVD). The recommended water level minimizes the potential encroachment of facultative woody shrub species (e.g., dahoon holly and wax myrtle) into the emergent littoral zone. The upper littoral zone has relatively little slope, thus it is susceptible to extensive physiognomic changes. Woody species predominate above 81 ft NGVD; the woody shrub shoreline at XS-2 and XS-3 began at 81-81.4 ft NGVD. Invasion of the littoral zone by shrubs and trees did occur during the recent drought, and now many of these plants are succumbing to higher water levels. The emergent marsh/aquatic bed at XS-1 would have an average water depth of 1.6 ft NGVD. The recommended Minimum Average level will also likely maintain saturated soils in the mixed swamps, since the lake level will be within 0.3-0.9 ft of the ground surface.

The average lake level for the 1957-95 period was 81.08 ft NGVD. The median, and 60th percentiles of exceedance were 81.47 and 81.27 ft NGVD, respectively. Maintaining long-term and dry-season saturation of the bay swamp community does not seem attainable with the existing outfall. The bay swamp we surveyed had a mean elevation of 82.6 ft NGVD and is located on Hontoon and Samsula mucks. These muck soils typically have a high water table at or above the soil surface except during extended dry periods (SCS 1990). The reduced hydroperiod would explain the abundance of mature water oak, sweet gum, and slash pine, and lack of royal fern observed in the bay swamps.

The canal connecting Lake Grandin to Clearwater Lake will have water depths, on average, of 4.3 feet, and a minimum depth of 3.4 feet. The water depth at the average elevation of waterward dock pilings is 4.6 feet.

MINIMUM FREQUENT LOW LEVEL

The recommended Minimum Frequent Low level is 80.1 ft NGVD with an associated hydroperiod category of Semipermanently Flooded. This level recognizes that occasional drawdown conditions are necessary to stimulate decomposition and promote seed germination. The rationale for this minimum level are: 1) the water level is maintained within 1.7 ft of the average elevation of the seasonally flooded mixed swamp, a criterion used at other lakes and derived from interpretation of Putnam and Volusia county soil surveys; 2) 80.1 ft NGVD was the average elevation of the maidencane dominated portion of the littoral zone at XS-2. The lake level would be about 0.6 ft below the willow swamp and the emergent marsh/aquatic bed would be flooded, on average, to a depth of 0.4 feet at XS-1. The emergent marsh/aquatic bed would have near ideal water levels for foraging wading birds. Great Egrets need water depths less than 0.8 ft and the small herons need depths less than 0.5 ft to forage efficiently when water levels are receding (Bancroft et al. 1990, p. 139).

Dock decks, on average, are 3.7 ft above the lake surface and the water depth is 3.5 ft at the waterward piling. The canal connecting Lake Grandin and Clearwater Lake would have water depths >2.3 feet. The lake level 80.1 ft NGVD was exceeded by 83% of the stages (monthly means and bi-monthly readings). For comparison, one standard deviation below the mean lake level is 79.87 ft NGVD.

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Please call me (ext. 4338), Cliff Neubauer (4343), or Jane Mace (4389) if you wish to discuss these minimum levels or hydroperiod definitions.

RH:bs

attachments

c:	Wayne Flowers	Hal Wilkening	Larry Battoe	Tommy Walters
	Larry Fayard	Jane Mace	Sandy McGee	David Clapp
	Price Robison	Bob Freeman	Chris Sweazy	MFL-REG

Putnam Hall and Baywood USGS Topoquads Figure 1

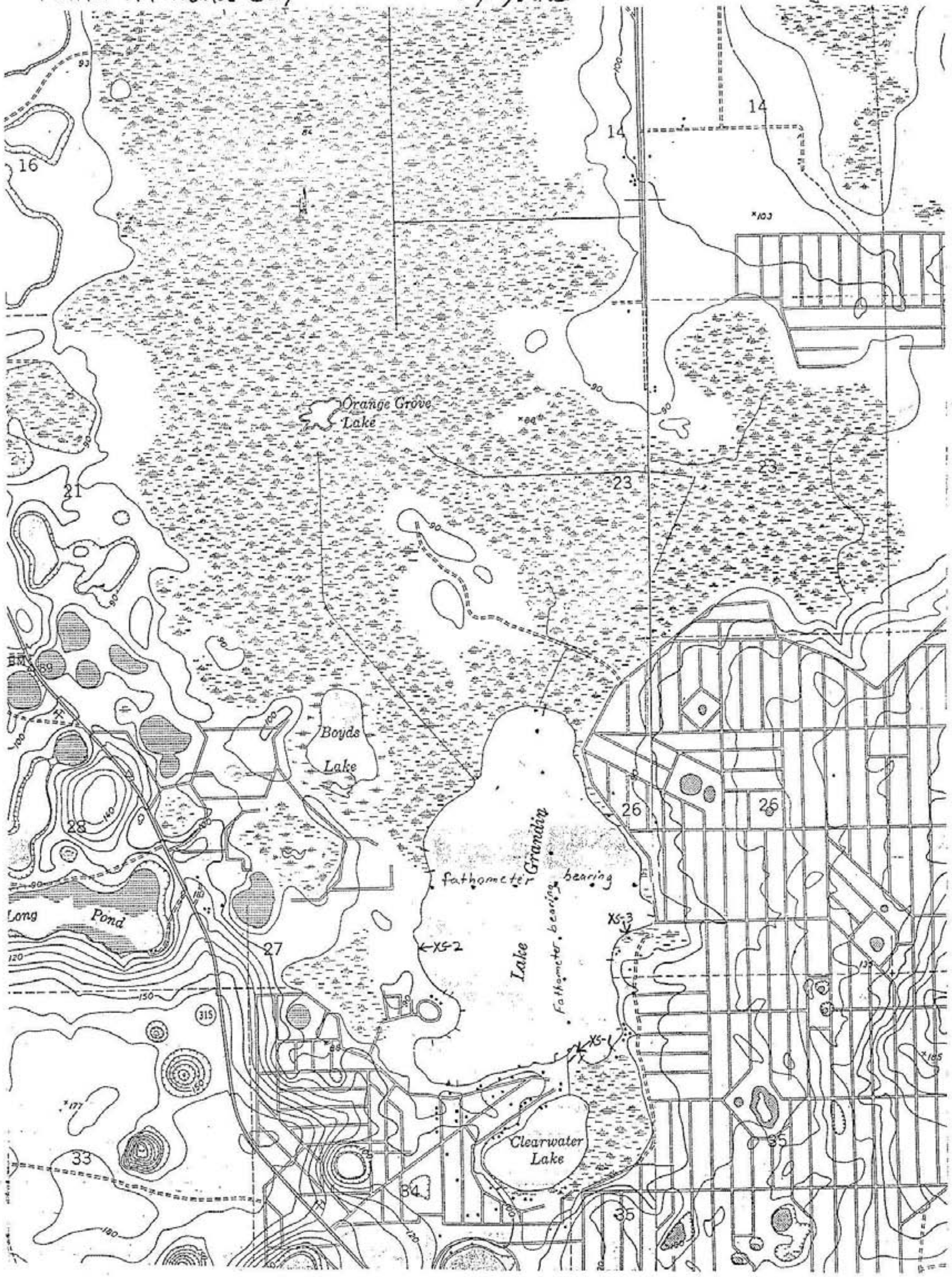

Figure 2

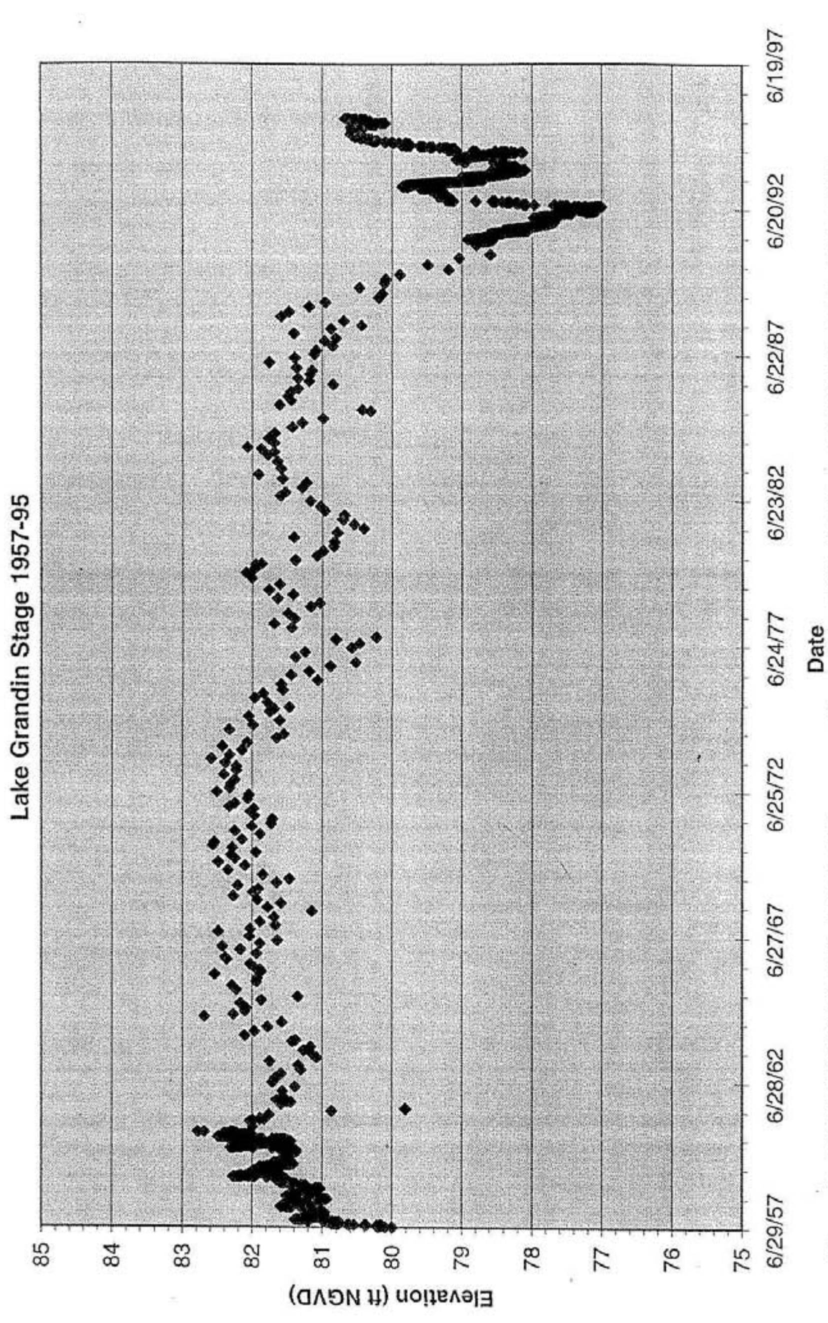

Figure 2. USGS 02244950 (daily 7/57-10/60, approx. bi-monthly 10/60-1991) and SJRWMD (daily 5/91-1995).

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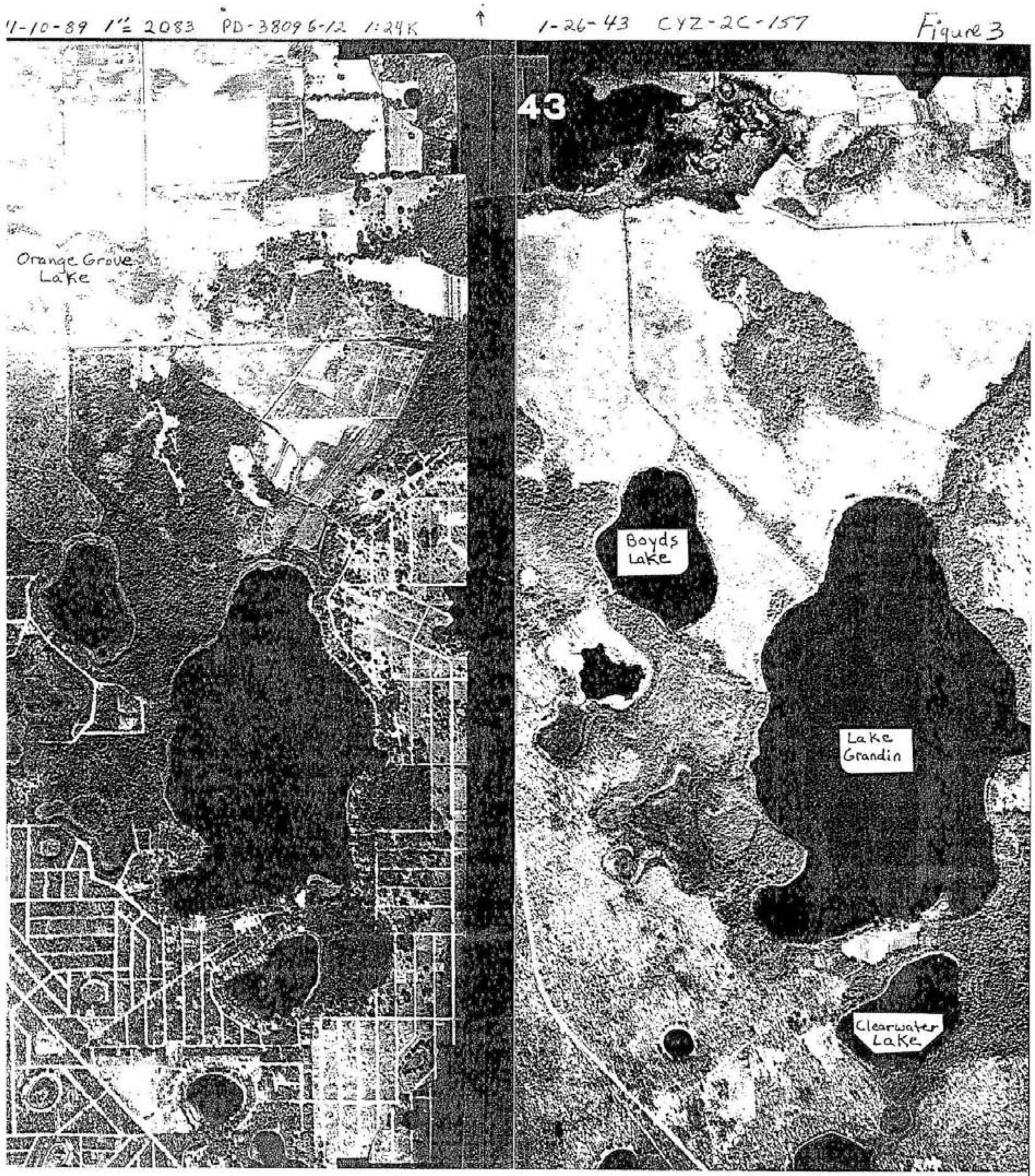
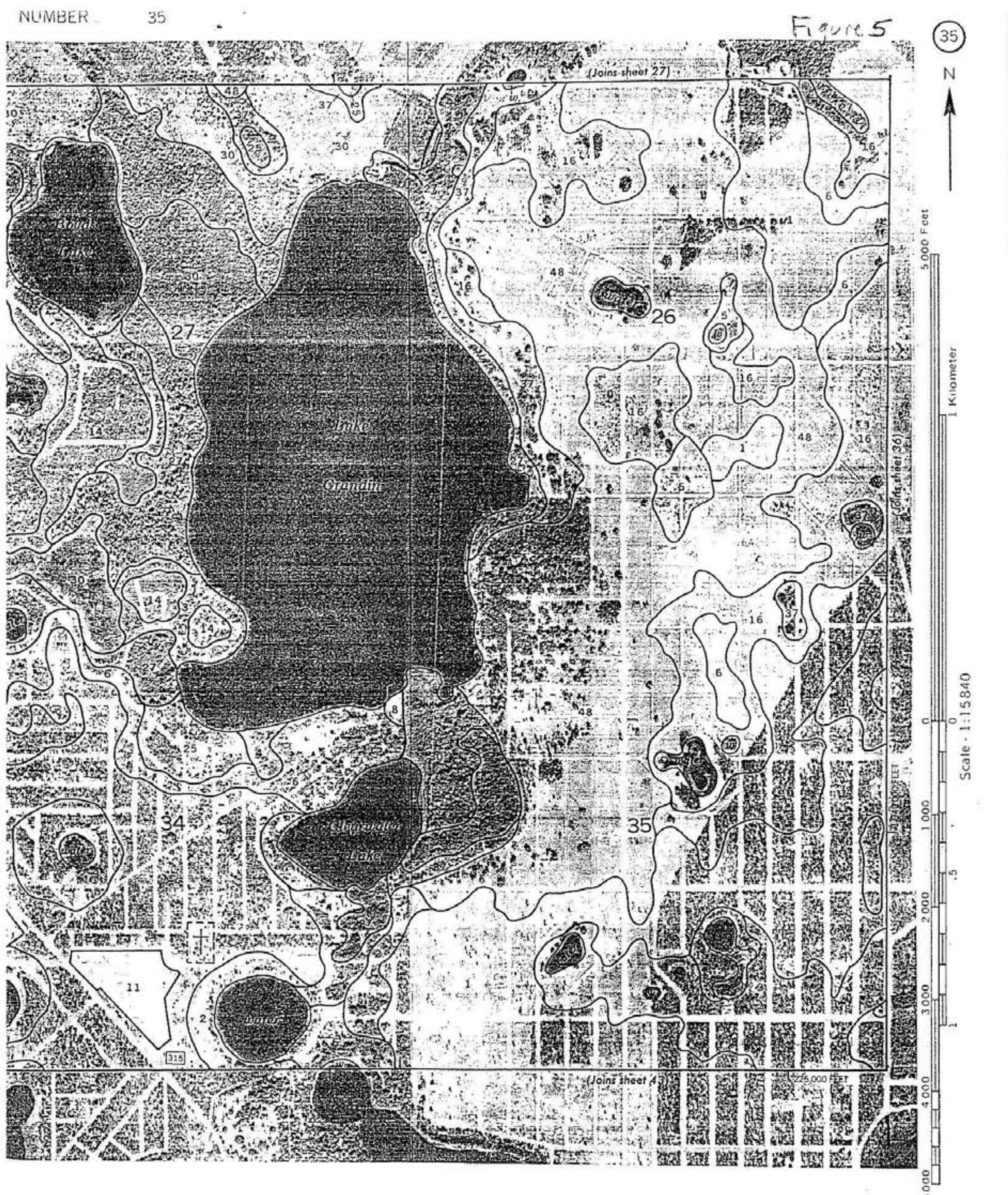


Figure 3. Comparative photos from 1989 and 1943 of the area near Lake Grandin. The canal from Lake Grandin to Etonia Creek and the marsh drainage system were in place in 1943, although the canal to Clearwater Lake did not exist. Several other notable features are: area lakes had larger areas of open water in 1943; some karsts were marshes in 1943 and 1989; woody cover in wetlands and uplands is greater in 1989.


NUMBER 35
Figure 5
35
N
(Joins sheet 27)
Lake
Grandin
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Clearwater
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Scale - 1:15 840
315

Putnam Hall and Baywood USGS - Wetland Maps

Figure 6

Figure 7

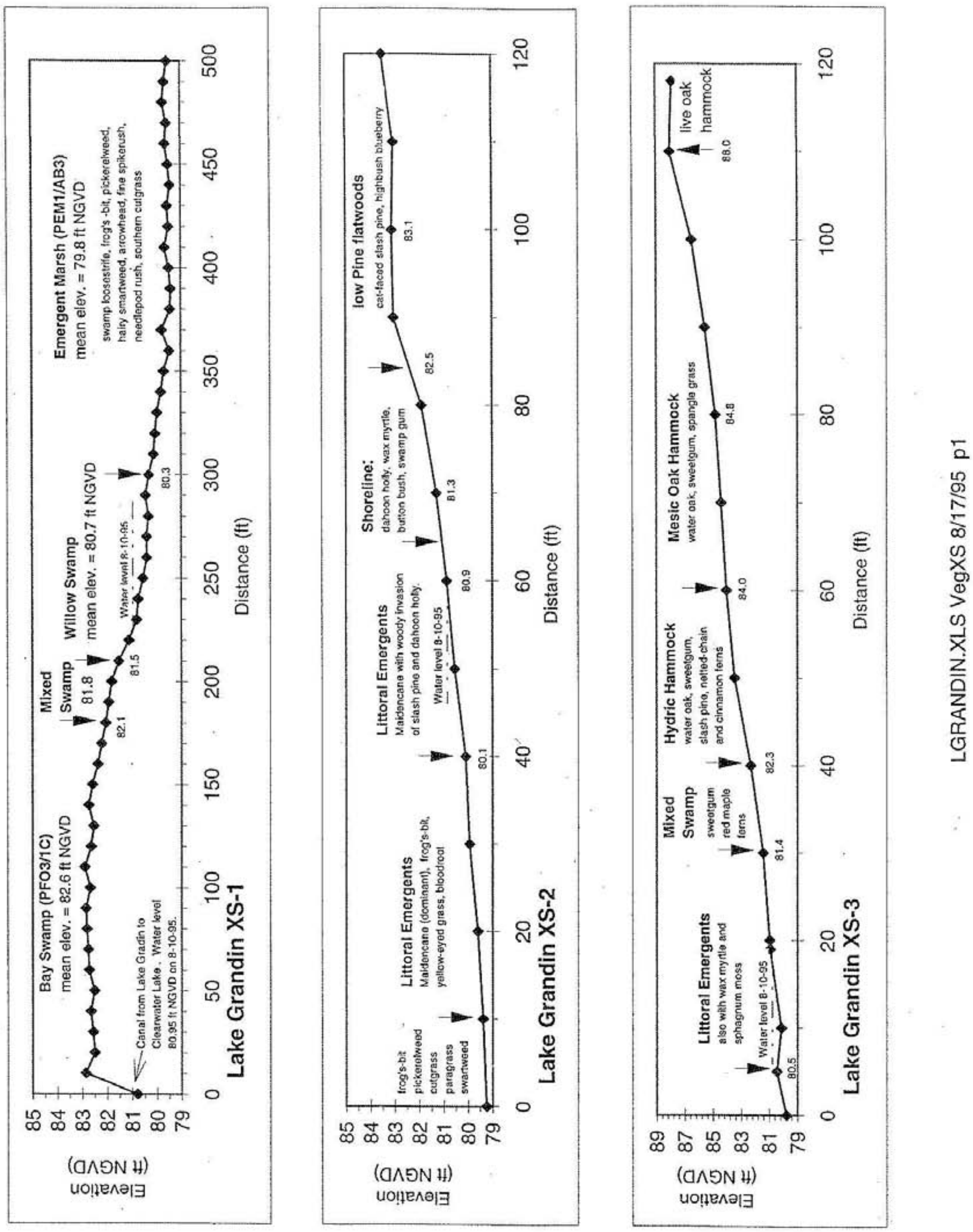
Lake Grandin XS-1
Bay Swamp (PFO3/1C) mean elev. = 82.6 ft NGVD
Canal from Lake Gradin to Clearwater Lake. Water level 80.95 ft NGVD on 8-10-95.
Mixed Swamp 81.8
82.1
81.5
Willow Swamp mean elev. = 80.7 ft NGVD
Water level 8-10-95
80.3
Emergent Marsh (PEM1/AB3) mean elev. = 79.8 ft NGVD
swamp loosestrife, frog's-bit, pickerelweed, hairy smartweed, arrowhead, fine spikerush, needlepod rush, southern cutgrass
Elevation (ft NGVD)
Distance (ft)
Lake Grandin XS-2
frog's-bit
pickerelweed
cutgrass
paragrass
smartweed
Littoral Emergents
Maidencane (dominant), frog's-bit, yellow-eyed grass, bloodroot
80.1
Littoral Emergents
Maidencane with woody invasion of slash pine and dahoon holly.
Water level 8-10-95
80.9
Shoreline:
dahoon holly, wax myrtle, button bush, swamp gum
81.3
82.5
low Pine flatwoods
cat-faced slash pine, highbush blueberry
83.1
Elevation (ft NGVD)
Distance (ft)
Lake Grandin XS-3
Littoral Emergents
also with wax myrtle and sphagnum moss
Water level 8-10-95
80.5
Mixed Swamp
sweetgum
red maple
ferns
81.4
82.3
Hydric Hammock
water oak, sweetgum, slash pine, netted-chain and cinnamon ferns
84.0
Mesic Oak Hammock
water oak, sweetgum, spangle grass
84.8
88.0
live oak hammock
Elevation (ft NGVD)
Distance (ft)
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Table 3. Plant species observed at Lake Grandin.

SPECIES	COMMON NAME	CATG
Acer rubrum	red maple	FAC
Boehmeria cylidrica	smallspike false-nettle	FACW+
Centella asiatica	coinwort	FACW
Cephalanthus occidentalis	buttonbush	OBL
Colocasia esculenta	wild taro	OBL
Decodon verticillatus	swamp loosestrife	OBL DRA
Eichhornia crassipes	water hyacinth	OBL
Eliocharis sp.	spikerush	OBL
Gordonia lasianthus	loblolly bay	FACW
Hydrocotyl umbellata	umbrella pennywort	OBL
Ilex cassine	dahoon holly	FACW
Itea virginica	virginia sweetspire	FACW+
Juncus scirpoides	needlepod rush	FACW+
Lachnanthes caroliniana	bloodroot	OBL
Leersia hexandra	southern cutgrass	OBL
Limnobium spongia	frog's-bit	OBL
Liquidambar styraciflua	sweetgum	FAC+
Ludwigia peruviana	primrose willow	OBL
Lyonia lucida	fetterbush	FACW
Magnolia grandiflora	bull magnolia	FAC+
Myrica cerifera	wax myrtle	FAC+
Nyssa biflora	swamp blackgum	OBL
Osmunda cinnamomea	cinnamon fern	FACW+
Osmunda regalis	royal fern	OBL
Panicum hemitomon	maidencane	OBL
Peltandra virginica	arrow-arum	OBL
Persea palustris	swamp bay	FACW
Pinus elliottii	slash pine	FACW
Polygonum densiflorum	southern smartweed	OBL
Polygonum hirsutum	smartweed	OBL
Pontederia cordata	pickeralweed	OBL
Quercus nigra	water oak	FAC
Quercus virginiana	live oak	UPL
Rubus betulifolius	blackberry	FAC
Sabal palmetto	cabbage palm	FAC
Sacciolepsis striata	bag-grass	OBL
Sagittaria latifolia	duck potato	OBL
Sagitttaria lancifolia	arrowhead	OBL
Salix caroliniana	coastal plain willow	OBL
Salvini rotundifolia	common salvinia	OBL
Sphagnum sp.	sphagnum	OBL
Typha latifolia	cattail	OBL
Vaccinium corymbosum	highbush blueberry	FACW
Vitis rotundifolia	muscadine grape	FAC
Woodwardia areolata	netted chain fern	OBL
Woodwardia virginica	virginia chain fern	OBL
Xyris ambigua	tall yelloweye-grass	OBL

APPENDIX B—IMPLEMENTATION OF MFLS FOR LAKE GRANDIN

Prepared by
C. Price Robison, P.E., St. Johns River Water Management District (2008)

The objective of minimum flows and levels (MFLs) is to establish limits to allowable hydrologic change in a water body or watercourse, to prevent significant harm to the water resources or ecology of an area. Hydrologic changes within a water body or watercourse may result from an increase in the consumptive use of water or the alteration of basin characteristics, such as down-cutting outlet channels or constructing outflow structures.

MFLs define a series of minimum high and low water levels and/or flows of differing frequencies and durations required to protect and maintain aquatic and wetland resources. MFLs take into account the ability of wetlands and aquatic communities to adjust to changes in hydrologic conditions. MFLs allow for an acceptable level of change to occur relative to existing hydrologic conditions, without incurring significant ecological harm to the aquatic system.

Before MFLs can be applied, the minimum hydrologic regime must be defined or characterized statistically. Resource management decisions can then be made predicated on maintaining at least these minimum hydrologic conditions as defined by the appropriate statistics.

One way to understand how changes within a watershed alter a hydrologic regime and, therefore, how the aquatic and wetland resources might be affected, is by simulating the system with a hydrologic model. Significant harm can be avoided by regulating hydrologic changes based on the comparison of statistics of the system with and without changes.

MFLs determinations are based on a concept of maintaining the duration and return periods of selected, ecologically based stages and/or flows. Thus, a water body can fall below the selected stage and/or flow, but if it does so too often and/or for too long, then the MFLs would no longer be met.

Statistical analysis of model output provides a framework to summarize the hydrologic characteristics of a water body. The St. Johns River Water Management District (SJRWMD) MFLs program relies on a type of statistical analysis referred to as frequency analysis.

Frequency analysis

As discussed previously, aquatic resources are sustained by a certain hydrologic regime. Depending on the resource in question, a selected ground elevation might need to:

- Remain wet for a certain period of time with a certain frequency.
- Remain dry for a certain period of time with a certain frequency.
- Be under a given minimum depth of water for a certain period of time with a certain frequency.

Frequency analysis estimates how often, on average, a given event will occur. If annual series data are used to generate the statistics, frequency analysis estimates the probability of a given hydrologic event happening in any given year.

A simple example illustrates some of the concepts basic to frequency analysis. A frequently used statistic with respect to water level is the yearly peak stage of a water body. If a gauge has been monitored for 10 years, then there will be 10 yearly peaks $S_1, S_2, \cdots, S_{10}$. Once sorted and ranked, these events can be written as $\hat{S}_1, \hat{S}_2, \cdots, \hat{S}_{10}$, with $\hat{S}_1$ being the highest peak. Based on this limited sample, the estimated probability of the yearly peak being greater than or equal to $\hat{S}_1$ would be:

$$P(S \geq \hat{S}_1) = \frac{1}{n} = \frac{1}{10} = 0.1; \qquad \text{(B1)}$$

the probability of the 1-day peak stage in any year being greater than $\hat{S}_2$

$$P(S \geq \hat{S}_2) = \frac{2}{10} = 0.2; \qquad \text{(B2)}$$

and so on. The probability of the stage equaling or exceeding $\hat{S}_{10}$ would be

$$P(S \geq \hat{S}_{10}) = \frac{10}{10} = 1.0. \qquad \text{(B3)}$$

Because this system of analysis precludes any peak stage from being lower than $\hat{S}_{10}$, the usual convention is to divide the stage continuum into 11 parts: nine between each of the 10 peaks, one above the highest peak, and one below the lowest peak (n – 1 + 2 = n + 1 = 11). This suggests what is known as the Weibull plotting position formula:

$$P(S \geq \hat{S}_m) = \frac{m}{n+1} \tag{B4}$$

where,

$P(S \geq \hat{S}_m) =$ probability of S equaling or exceeding $\hat{S}_m$

$m =$ rank of the event

Thus, in the example, the probability of the peak in any year equaling or exceeding $\hat{S}_1$ would be

$$P(S \geq \hat{S}_1) = \frac{1}{n+1} = \frac{1}{11} = 0.0909\ ; \tag{B5}$$

the probability of the 1-day peak stage in any year being greater than $\hat{S}_{10}$

$$P(S \geq \hat{S}_{10}) = \frac{10}{11} = 0.9091\ ; \tag{B6}$$

and so on. The probability the stage in any year is smaller than $\hat{S}_{10}$ would be

$$P(S < \hat{S}_{10}) = 1 - P(S \geq \hat{S}_{10}) = 1 - \frac{10}{11} = 1 - 0.9091 = 0.0909 \tag{B7}$$

The return period (in years) of an event, T, is defined as

$$T = \frac{1}{P} \tag{B8}$$

so the return period for $\hat{S}_1$ would be

$$T(\hat{S}_1) = \frac{1}{P(S \geq \hat{S}_1)} = \frac{1}{\frac{1}{11}} = 11 \tag{B9}$$

Said another way, $\hat{S}_1$ would be expected to be equaled or exceeded, on average, once every 11 years.

As the size of the sample increases, the probability of $\hat{S}_1$ being exceeded decreases. Thus, with n = 20,

$$P(S \geq \hat{S}_1) = \frac{1}{n+1} = \frac{1}{21} = 0.048 \tag{B10}$$

and

$$T(\hat{S}_1) = \frac{1}{P(S \geq \hat{S}_1)} = 21 \tag{B11}$$

The stage or flow characteristics of a water body can be summarized using the Weibull plotting position formula and a frequency plot. For example, Figure B1 shows a flood frequency plot generated from annual peak flow data collected at the U.S. Geological Survey (USGS) gauge on the Wekiva River.

Minimum events are treated in much the same way as maximum events, except with minimums the events are ranked from smallest to largest. Thus $\hat{S}_1$ is the smallest or lowest event in a sampling. The minimum stage or flow characteristics of a gauge or water body can be summarized using the Weibull plotting position formula and a frequency plot. For example, Figure B2 shows a drought frequency plot generated from a hydrologic simulation of the middle St. Johns River.

One of the purposes of performing this process of sorting, ranking, and plotting events is to estimate probabilities and return periods for events larger than $\hat{S}_1$, smaller than $\hat{S}_n$, or any event between sample points. There are two methods of obtaining these probabilities and return periods. The first method is to use standard statistical methods to mathematically calculate these probabilities and return periods (Figure B3). This method is beyond the scope of this appendix; the reader is referred to a standard hydrology text (Ponce 1989, Linsley et al. 1982) or the standard flood frequency analysis text, Bulletin 17B (USGS 1982).

With the second method, interpolated or extrapolated frequencies and return periods can also be obtained by the graphical method. Once the period-of-record or period-of-simulation events have been sorted and ranked, they are plotted on probability paper. Probabilities and return periods for events outside of the sampled events can be estimated by drawing a line through the points on the graph to obtain an estimated best fit (Figure B4).

Frequency analysis is also used to characterize hydrologic events of durations longer than 1 day. Frequency analysis encompasses four types of events: (1) maximum average stages or flows; (2) minimum average stages or flows; (3) maximum stages or flows continuously exceeded; and (4) minimum stages or flows continuously not exceeded.

Maximum average stages or flows. In this case, an event is defined as the maximum value for a mean stage or flow over a given number of days. For example, if the maximum yearly values for a 30-day average are of interest, the daily-value hydrograph is analyzed by using a moving 30-day average. Therefore, a 365-day hydrograph would have 336 (365 –30 + 1 = 336) different values for a 30-day average. These 336 values are searched and the highest is saved. After performing this analysis for each year of the period of record or period of simulation, the events are sorted and ranked. The analytical process is then the same as for the 1-day peaks.

Minimum average stages or flows. In this case, an event is defined as the minimum value for a mean stage or flow over a given number of days. For example, if the minimum yearly values for a 30-day average are of interest, the daily-value hydrograph is analyzed by using a moving 30-day average. Therefore, a 365-day hydrograph would have 336 (365 – 30 + 1 = 336) different values for a 30-day average. These 336 values are searched and the lowest is saved. After performing this analysis for each year of the period of record or period of simulation, the events are sorted and ranked. The process is then the same as for the 1-day low stages.

Maximum stage or flow continuously exceeded. In this case, an event is defined as the stage or flow that is exceeded continuously for a set number of days. For example, if the maximum yearly ground elevation that continuously remains under water for 60 days is of interest, the stage hydrograph of each year is analyzed by taking successive 60-day periods and determining the stage that is continuously exceeded for that period. This is repeated for 306 (365 – 60 + 1 = 306) periods of 60 days. The maximum stage in those 306 values is saved. Once that operation is performed for all years of record or of simulation, the results are sorted and ranked as for the 1-day peaks.

Minimum stage or flow continuously not exceeded. In this case, an event is defined as the stage or flow that is not exceeded continuously for a set number of days. For example, if the minimum yearly ground elevation that continuously remains dry for 60 days is of interest, the stage hydrograph of each year is analyzed by taking successive 60-day periods and determining the stage that is continuously not exceeded for that period. This is repeated for 306 (365 – 60 + 1 = 306) periods of 60 days. The minimum stage in those 306 values is saved. Once that operation is performed for all years of record or of simulation, the results are sorted and ranked as for the 1-day low stages.

In frequency analysis, it is important to identify the most extreme events occurring in any given series of years. Because high surface water levels (stages) in Florida generally occur in summer and early fall, maximum value analysis is based on a year that runs from June 1 to May 31. Conversely, because low stages tend to occur in late spring, the year for minimum events runs from October 1 to September 30.

Hydrologic statistics and their relationships to the Lake Grandin MFLs

This section describes the process used to relate long-term hydrologic statistics to the establishment of MFLs. SJRWMD has determined two recommended MFLs for Lake Grandin: (1) a minimum frequent high (FH) level; and (2) a minimum frequent low (FL) level. The FH level for this lake is used here to illustrate how long-term hydrologic statistics of a lake relate to MFLs.

Each of the two MFLs is tied to characteristic stage durations and return frequencies. For example, the ground elevation represented by the FH level is expected to remain wet continuously for a period of at least 30 days. This event is expected to occur, on average, at least once every 3 years.

The standard stage frequency analysis described previously in this appendix was performed on stage data from lake model simulations of Lake Grandin (CDM 2005). In particular, stages continuously exceeded (ground elevations remaining wet) for 30 days were determined, sorted, ranked, and plotted (Figure B5). These stages were obtained assuming that long-term groundwater withdrawals occurred at the same level at which they occurred in 2002. The ground elevation of the FH level can be superimposed on the plot (Figure B6) to demonstrate how the level is related to the pertinent hydrologic statistics. Finally, a box bounded by: (1) the FH level on the bottom; (2) a vertical line corresponding to a frequency of occurrence of once in every 2 years on the right; and (3) a vertical line corresponding to a frequency of occurrence of once in every 1.5 years on the left, is superimposed on the plot (Figure B7). Similar analyses were performed for the FL level (Figure B8). Both levels are being met under these conditions.

A summary of the recommended MFLs for Lake Grandin is shown in Table B1. Values in this table will be used as benchmarks for modeling outputs to determine if groundwater withdrawals in the vicinity of Lake Grandin will cause water levels to fall below MFLs.

Evaluation of the potential impacts of proposed increased withdrawals of water from the Floridan aquifer

This section describes the process used by SJRWMD to determine if proposed or projected increased withdrawals of water from the Floridan aquifer in the vicinity of Lake Grandin would cause water levels in the lake to fall below established MFLs. SJRWMD uses two modeling tools in this process: a regional groundwater flow model and the lake model described above. The following steps are included in the process.

1. Estimation of Floridan aquifer water level drawdown (1995 through the last year of model simulation)
2. Estimation of Floridan aquifer freeboard in the year of calibration of the lake model
3. Estimation of Floridan aquifer water level decline from 1995 to the year of calibration of the lake model
4. Estimation of Floridan aquifer water level drawdown from the year of calibration of the lake model through the last year of model simulation
5. Comparison of Floridan aquifer water level drawdown from the year of calibration of the lake model through the last year of simulation (step 4) to the year of calibration freeboard (step 2)

Step 1. Estimation of Floridan aquifer water level drawdown (1995 through the last year of model simulation)

When evaluating consumptive use permit applications for increased withdrawals of groundwater from the Floridan aquifer or when performing water supply planning evaluations, SJRWMD estimates the projected drawdown in the potentiometric surface of the Floridan aquifer in the vicinity of lakes with established MFLs. The analysis includes all existing permitted uses in addition to the proposed increased withdrawals. SJRWMD uses the appropriate regional groundwater flow model to produce these estimates. In the case of Lake Grandin, at the time of preparation of this document, SJRWMD was using the Northeastern Florida Regional Groundwater Flow Model (Birdie 2006) for this purpose. This steady-state model is calibrated to 1995 conditions; therefore, the projected drawdown in the potentiometric surface represents the estimated drawdown that would occur from 1995 to the last year of simulation. In association with consumptive use permit evaluations, the last year of simulation represents the year through which issuance of the permit is contemplated. In SJRWMD's water supply assessment and planning processes the last year of simulation represents the planning horizon year and/or other intermediate years that may represents significant water use targets.

Step 2. Estimation of Floridan aquifer freeboard in year of calibration of the lake model

As stated previously, the model simulation results depicted in Figures B7 and B8 assume long-term Floridan aquifer withdrawals at 2002 levels. Any withdrawal increases beyond 2002 would tend to lower potentiometric levels in the area and, therefore, would tend to lower lake levels in Lake Grandin. In order to determine the freeboard present at Lake Grandin from the point of view of Floridan aquifer water level drawdowns, a trial-and-error process was undertaken assuming incrementally increasing drawdowns. Drawdowns are represented by subtracting a set amount from the well hydrograph used in simulation of Lake Grandin. In the case of Lake Grandin, for a Floridan aquifer water level drawdown of 1.6 ft, the FH level would still be met (Figure B9). However, any drawdowns greater than 1.6 ft would cause water levels to fall below the established FH level. At a drawdown of 1.6 ft, the FL level would still be met (Figure B10). Therefore, future Floridan aquifer water level drawdowns beyond 2002 conditions will be limited to 1.6 ft in the Lake Grandin area.

Step 3. Estimation of Floridan aquifer water level decline from 1995 to the year of calibration of the lake model

Because the calibration years of lake models and the applicable regional groundwater flow models do not coincide, an adjustment of projected drawdown in the potentiometric surface of the Floridan aquifer in the vicinity of the lake of interest must be made for purposes of comparison to the previously described Floridan aquifer freeboard value. The adjusted value should represent the projected drawdown from the calibration year of the lake model to the final year of simulation of the applicable regional groundwater flow model.

In order to determine this adjusted value, drawdown in the potentiometric surface of the Floridan aquifer in the vicinity of a lake of interest from 1995 through the calibration year of the lake model is estimated. This estimated value is subtracted from the projected drawdown from 1995 to the final year of simulation of the applicable regional groundwater flow model to determine the adjusted value.

Estimated drawdown in the potentiometric surface of the Floridan aquifer in the vicinity of a lake of interest from 1995 through the calibration year of the lake model is calculated using one of the following approaches.

- A water use data set for the calibration year of the lake model is prepared and used in the applicable regional groundwater flow model. The resulting drawdowns represent drawdowns from 1995 to the calibration year of the lake model.

- Estimated drawdowns in the potentiometric surface from 1995 to the calibration year of the lake model are interpolated based on estimates of drawdowns projected to occur from 1995 to some simulation year beyond the lake model calibration year. This approach requires assuming a straight-line increase of the projected drawdown from 1995 to the final year of simulation and selecting the appropriate interpolated value for the period 1995 to the year of calibration for the lake model.

Step 4. Estimation of Floridan aquifer water level drawdown from the year of calibration of the lake model through the last year of model simulation

The Floridan aquifer water level drawdown from the year of calibration of the lake model through the last year of model simulation is estimated by subtracting the drawdown from 1995 through the year of calibration of the lake model (step 3) from the total drawdown (step 1).

Step 5. Comparison of Floridan aquifer water level drawdown from the year of calibration of the lake model through the last year of model simulation (step 4) to the freeboard in the year of calibration of the lake model (step 2)

If the Floridan aquifer water level drawdown from the year of calibration of the lake model through the last year of groundwater model simulation (step 4) is greater than the year of calibration of the lake model freeboard (step 2), then proposed or projected increased withdrawals through the last year of groundwater model simulation would cause water levels to fall below MFLs. If the Floridan aquifer water level drawdown from the year of calibration of the lake model through the last year of groundwater model simulation (step 4) is less than the year of calibration of the lake model freeboard (step 2), then proposed or projected increased withdrawals through the last year of groundwater model simulation would not cause water levels to fall below established MFLs.

Table B1. Summary of recommended MFLs for Lake Grandin

MFLs	Level (ft NGVD)	Duration	Series	Water Year	Statistical Type	Minimum Return Period	Maximum Return Period
Minimum frequent high (FH)	81.5	30 days	Annual	June 1–May 31	Maximum, continuously exceeded	NA	2 yrs
Minimum frequent low (FL)	78.6	120 days	Annual	Oct. 1–Sept. 30	Minimum, continuously not exceeded	5 yrs	NA

ft NGVD = feet National Geodetic Vertical Datum

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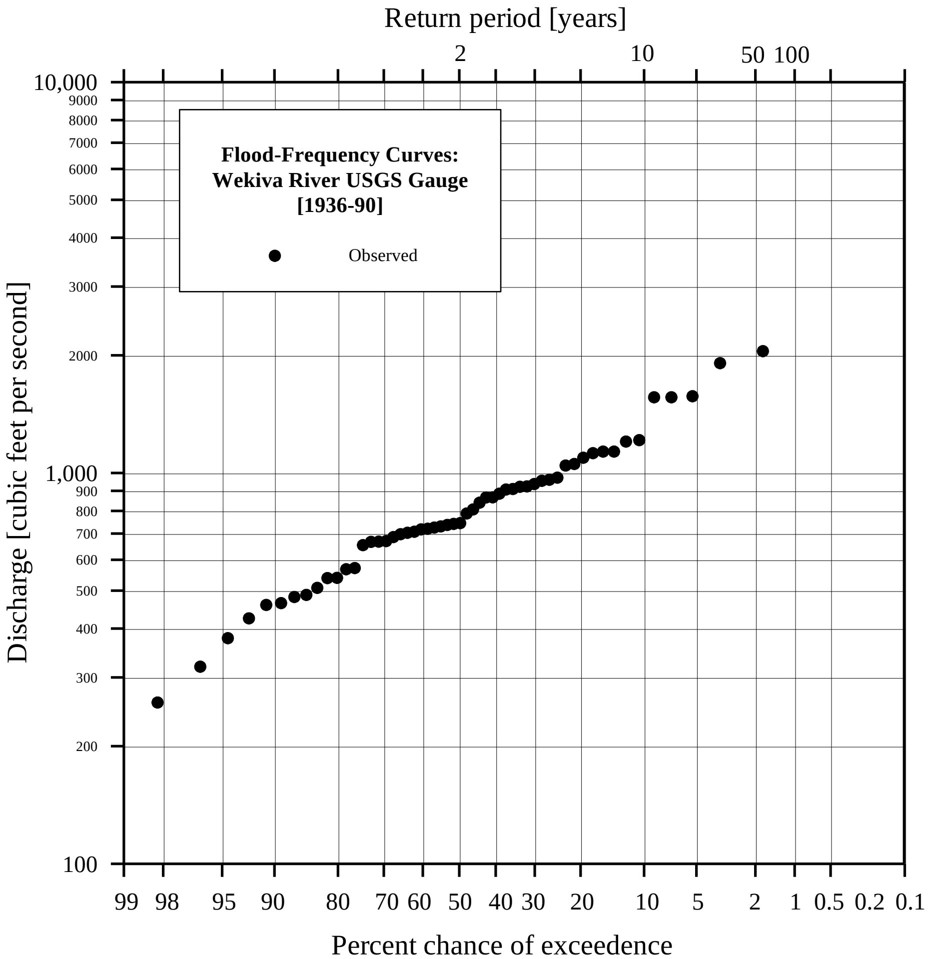

Figure B1. Flood frequencies for the Wekiva River at the USGS gauge near Sanford, Fla.; the 1–day peak flows have been sorted, ranked, and plotted according to the Weibull plotting position formula

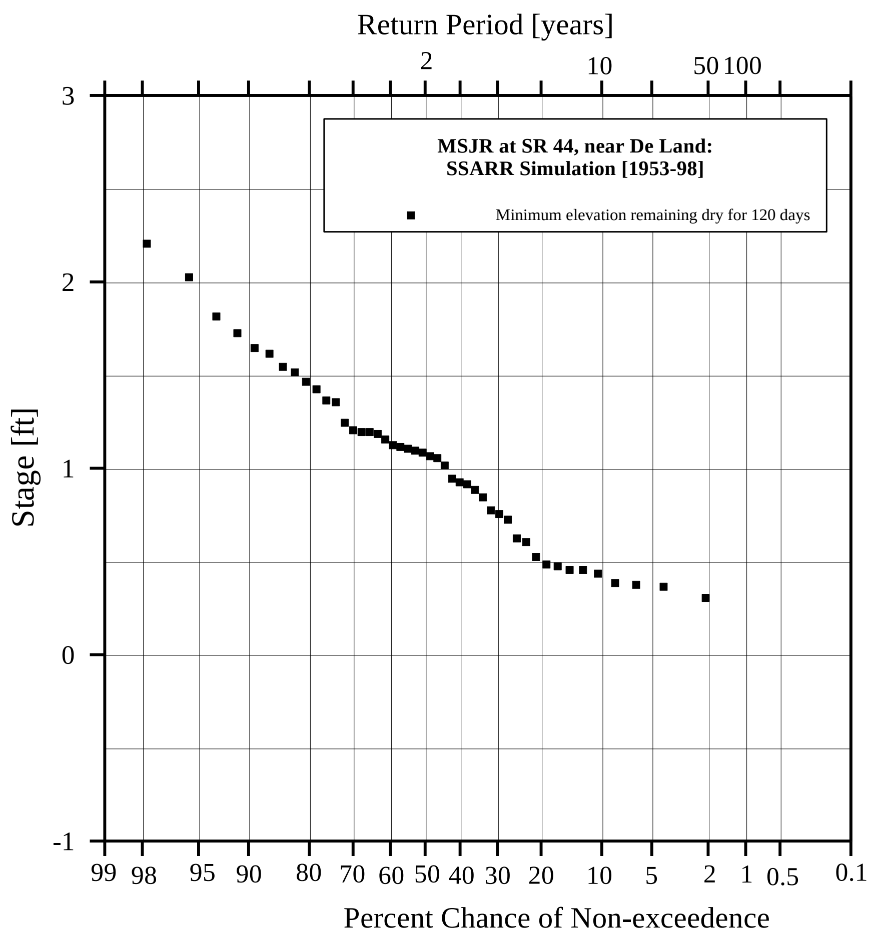

Figure B2. Drought frequencies computed using daily stages simulated by the MSJR SSARR model at SR 44, near DeLand; the minimum stages continuously not exceeded for 120 days have been sorted, ranked, and plotted according to the Weibull plotting position formula

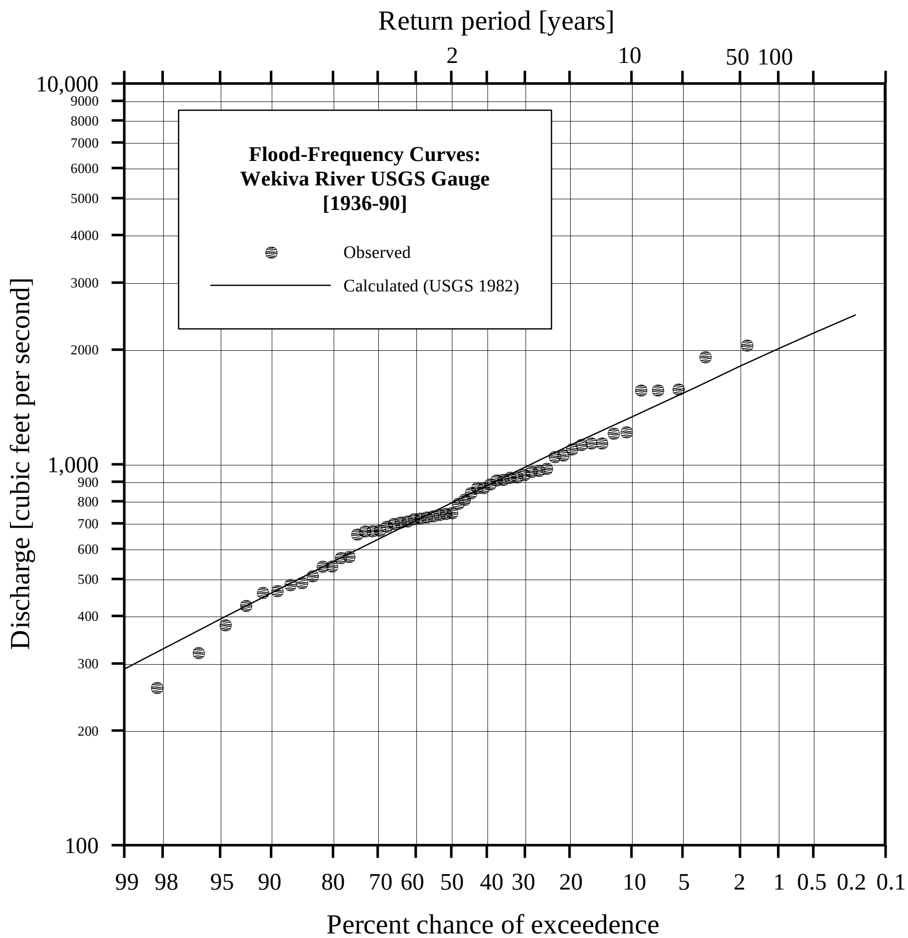

Figure B3. Flood frequencies for the Wekiva River at the USGS gauge near Sanford, Fla., fitted by standard mathematical procedure

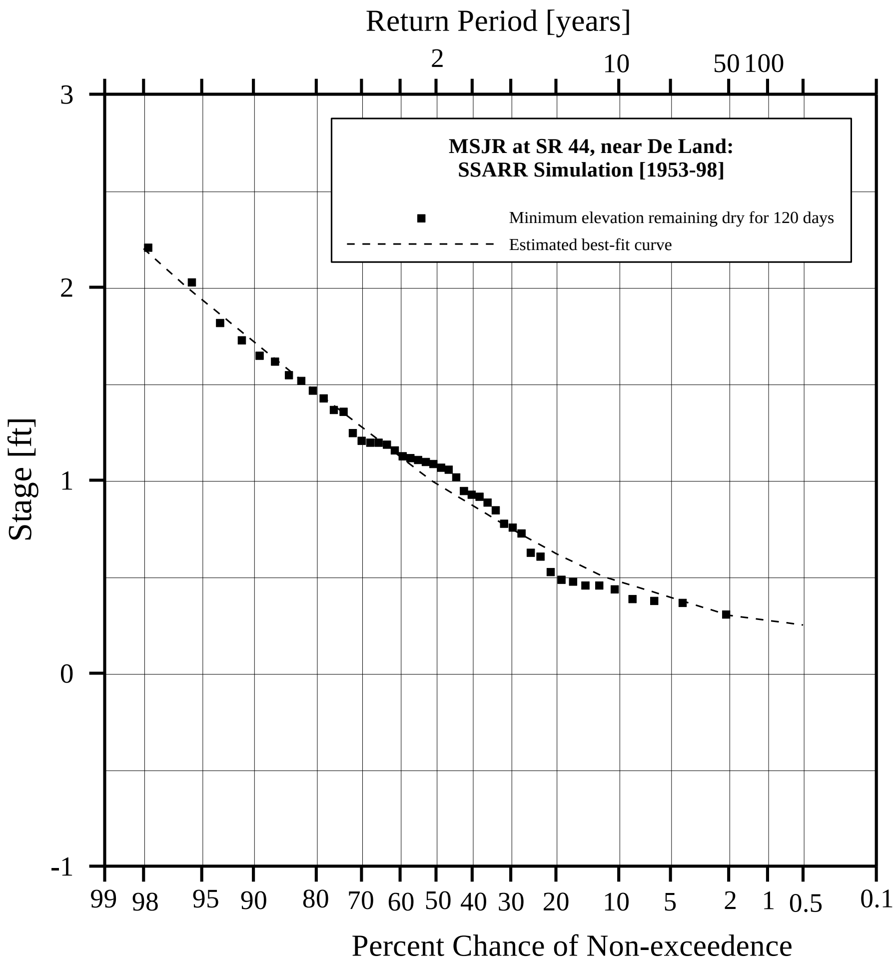

Figure B4. Drought frequencies computed using daily stages simulated by the MSJR SSARR model at SR 44, near DeLand, fitted by the graphical method

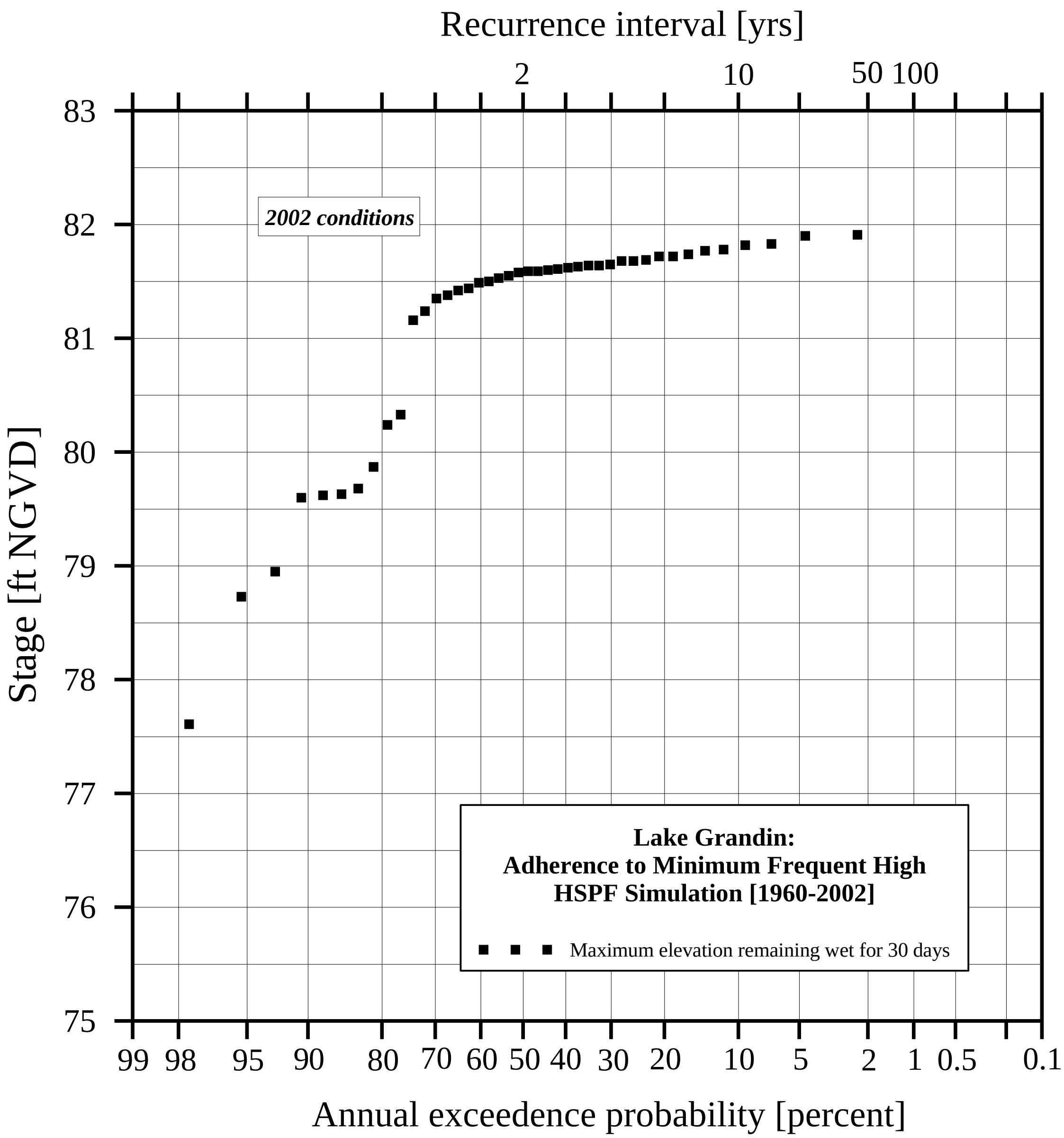

Figure B5. Flood frequencies computed using daily stages from model simulations of Lake Grandin, for elevations continuously wet for 30 days and 2002 conditions

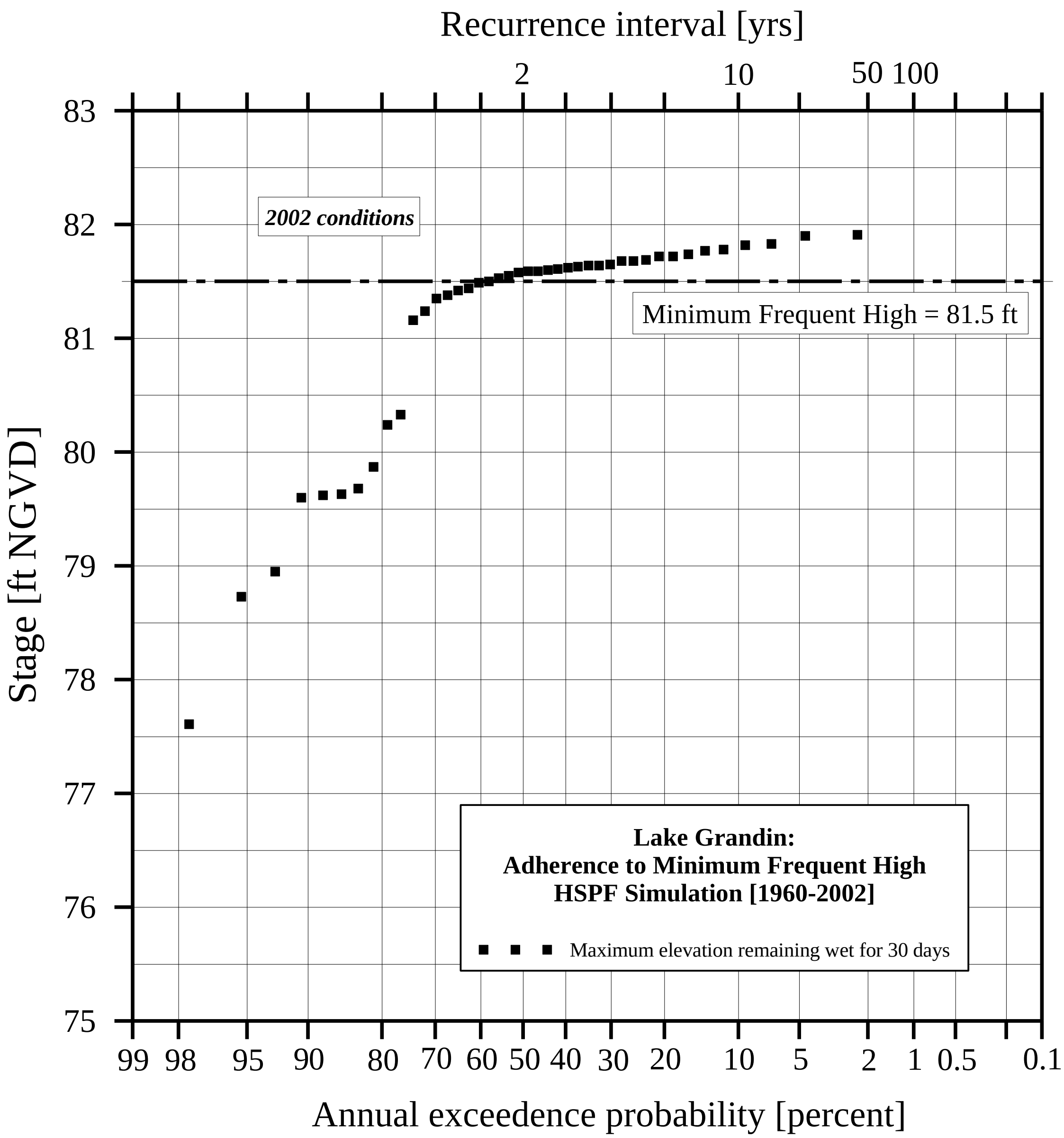

Figure B6. Flood frequencies computed using daily stages from model simulations of Lake Grandin, for elevations continuously wet for 30 days and 2002 conditions with the FH of 81.5 ft NGVD superimposed

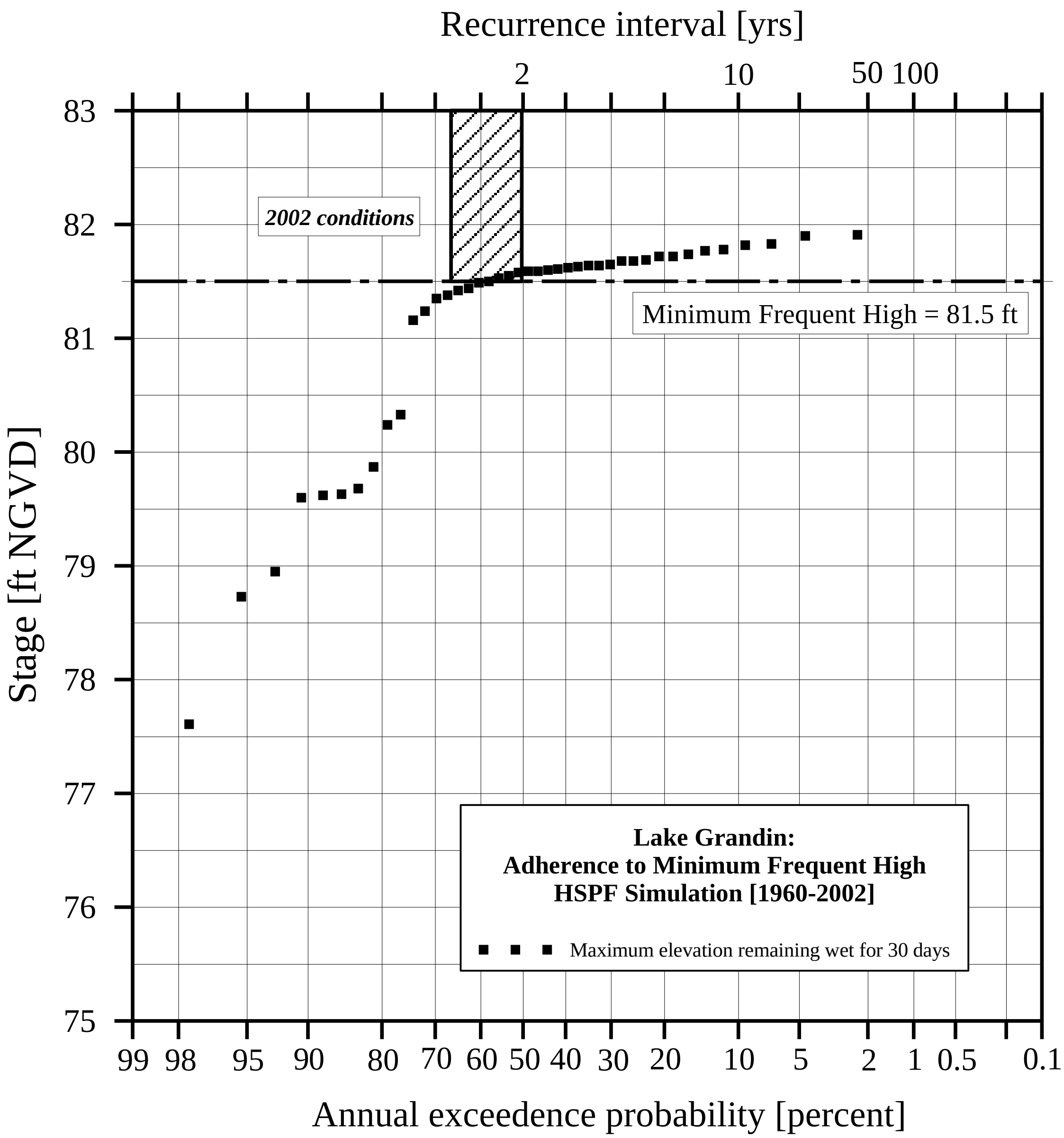

Figure B7. Flood frequencies computed using daily stages from model simulations of Lake Grandin, for elevations continuously wet for 30 days and 2002 conditions with a superimposed box bounded by: (1) the FH; (2) a vertical line corresponding to a return period of 1.5 years; and (3) a vertical line corresponding to a return period of 2 years

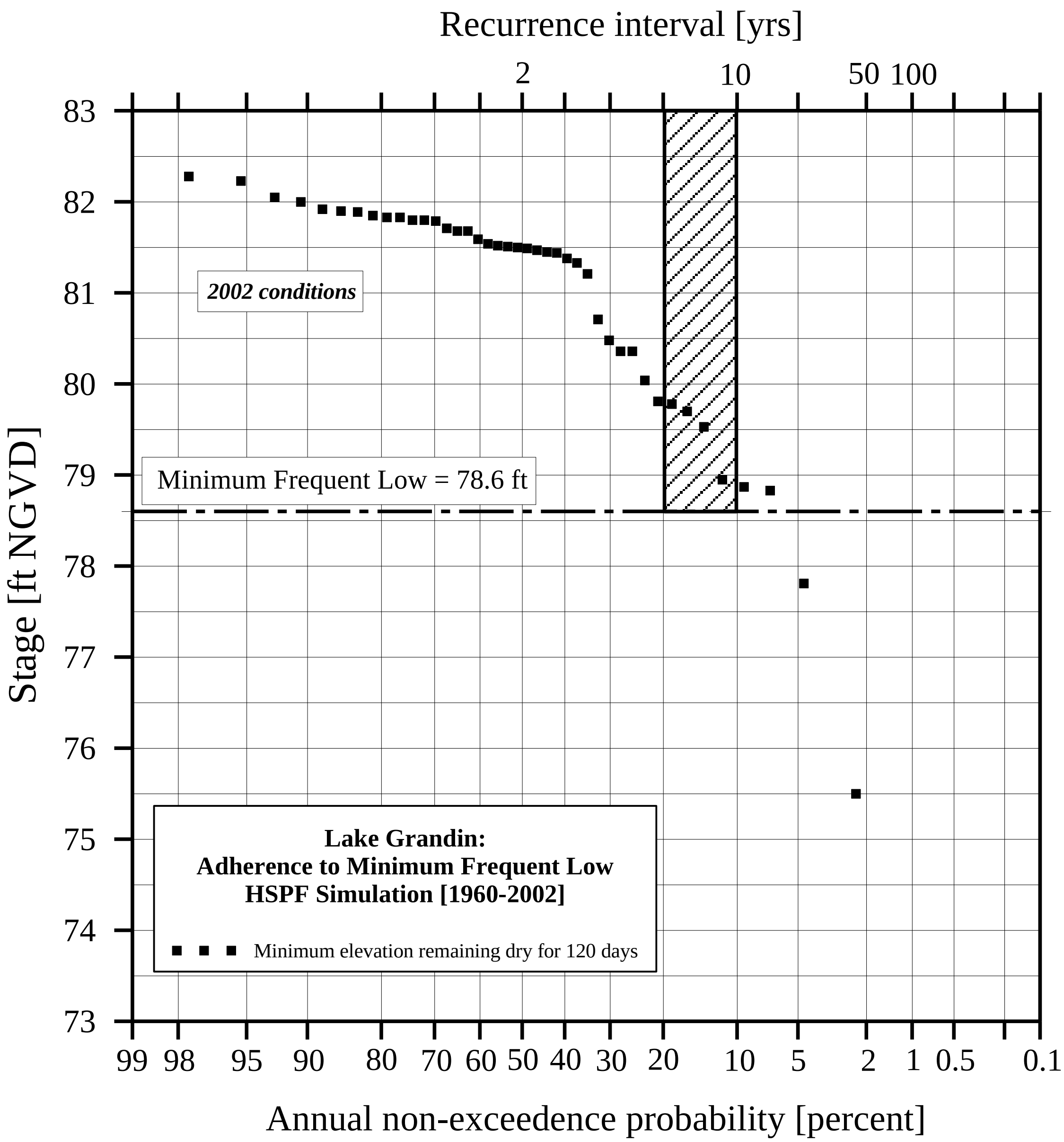

Figure B8. Drought frequencies computed using daily stages from model simulations of Lake Grandin, for the FL level and 2002 conditions

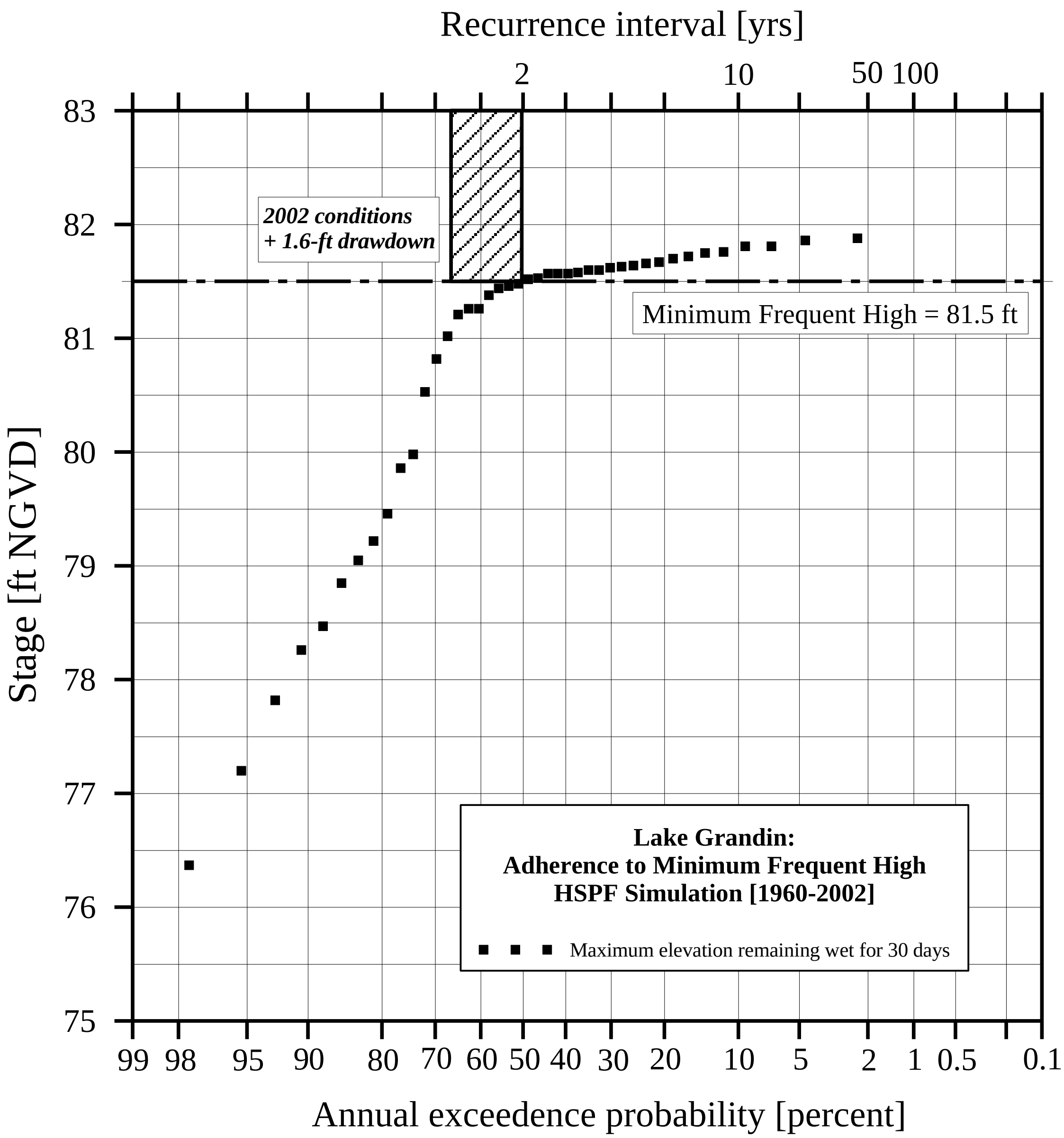

Figure B9. Drought frequencies computed using daily stages from model simulations of Lake Grandin, for the FH level and 2002 conditions plus a 1.6-ft Floridan aquifer drawdown.

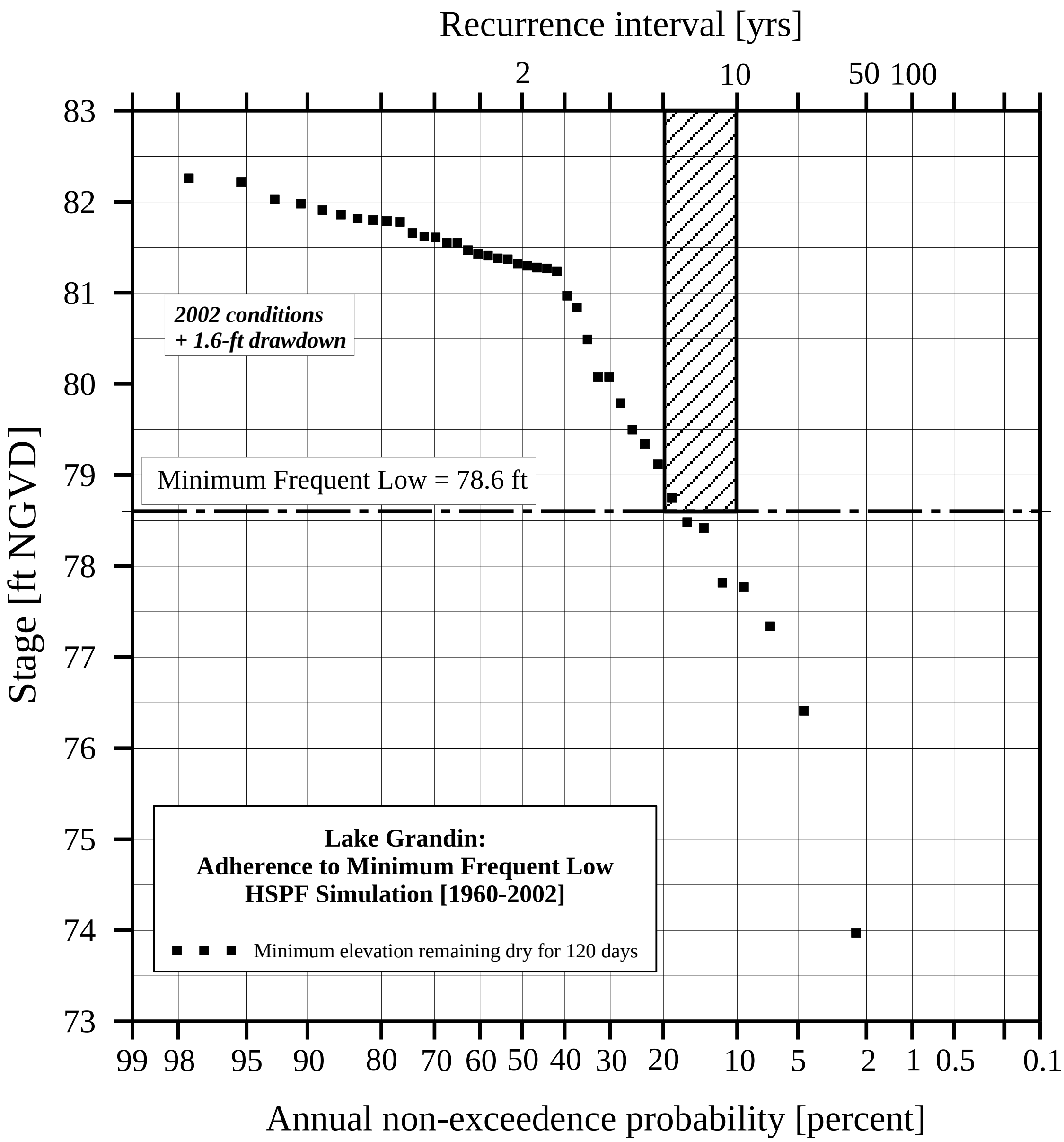

Figure B10. Flood frequencies computed using daily stages from model simulations of Lake Grandin, for the FL level and 2002 conditions plus a 1.6-ft Floridan aquifer drawdown