TECHNICAL PUBLICATION SJ2009-2

MINIMUM LEVELS REEVALUATION: LAKE DIAS, VOLUSIA COUNTY, FLORIDA

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by

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St. Johns River Water Management District
Palatka, Florida

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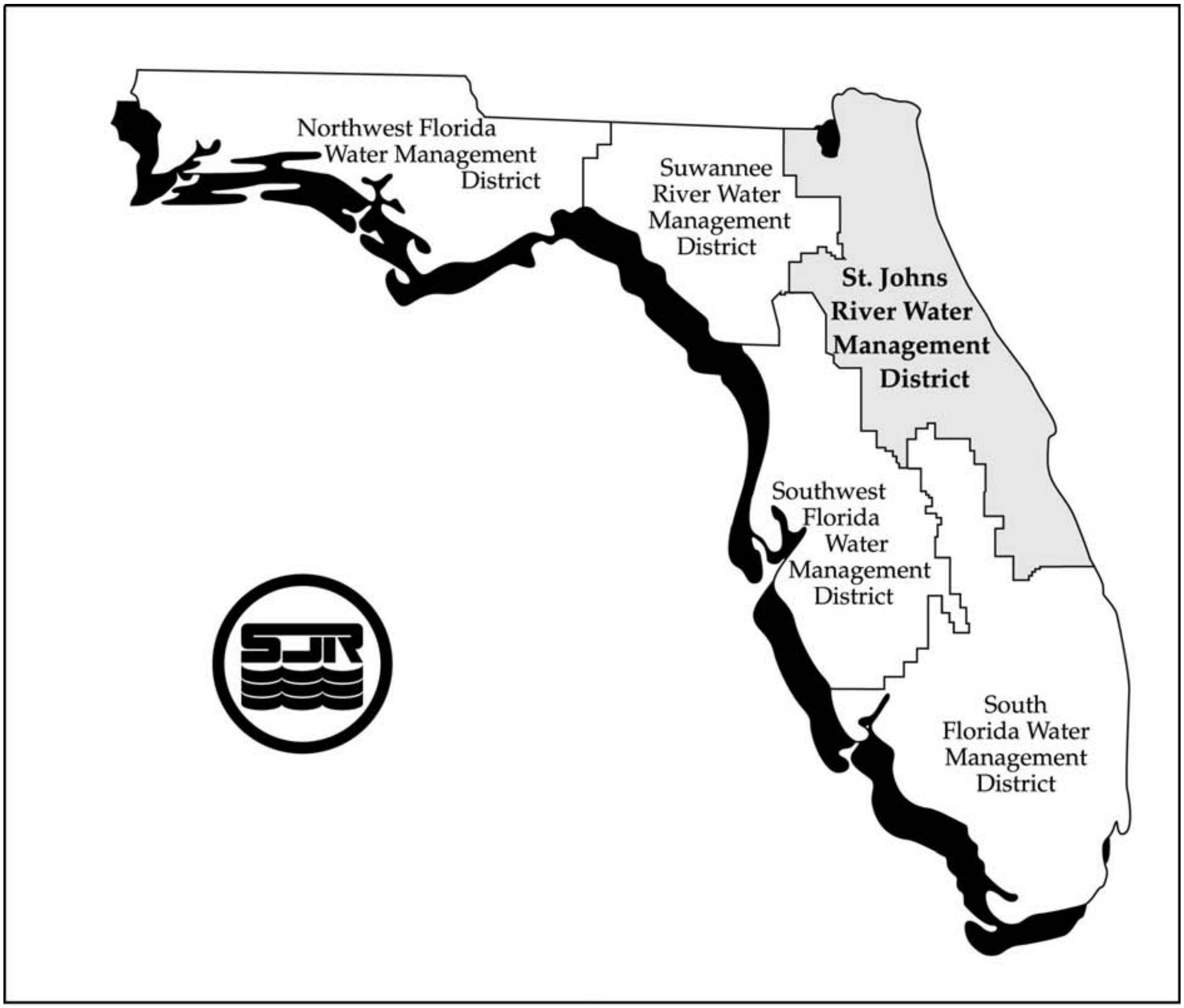

The St. Johns River Water Management District (SJRWMD) was created by the Florida Legislature in 1972 to be one of five water management districts in Florida. It includes all or part of 18 counties in northeast Florida. The mission of SJRWMD is to ensure the sustainable use and protection of water resources 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 outlines the St. Johns River Water Management District's (SJRWMD's) minimum flows and levels (MFLs) reevaluation for Lake Dias, Volusia County, Florida. The original minimum flows and levels (MFLs) determination for Lake Dias was completed in July 1997 (Neubauer 1997, Appendix A). The adopted MFLs were based upon the best available information. However, no water budget model was available. A hydrologic water budget model was developed after the MFLs were adopted. The model indicated that the adopted minimum average level was not being met. Thus, a reevaluation of all adopted MFLs for Lake Dias was performed with the most recently developed criteria and information. Adopted and newly recommended MFLs with associated hydroperiod categories, based upon best available information, are presented in Table ES-1. Hydroperiod categories and definitions are adapted from water regime modifiers developed by Cowardin et al. (1979).

The SJRWMD multiple MFLs method (SJRWMD 2006, Neubauer et. al. 2006) was used to determine the minimum lake levels. MFLs determination is based on evaluations of topographic, soils, and vegetation data collected within plant communities associated with the water body. Best available information also included the use of surface water inundation/dewatering signatures (SWIDS), recently developed by MFLs staff (Neubauer et al. 2004), that quantitatively define flooding and dewatering signatures for the minimum, mean, and maximum elevations of selected plant communities.

The recommended minimum average and minimum frequent low levels components were 0.6 foot (ft) lower than the adopted levels because organic soils occurred at slightly lower elevations than organic soils of the original MFLs determination. It is not known whether this is because of an improved soils evaluation (a soil scientist identified the soils for the reevaluation) or if the transect was located in an area that regularly drains into the lake following rain events, thus removing organic matter and resulting in reduced muck depths; subsidence did not appear to be an issue. The recommended minimum frequent high was 0.1 ft higher than the adopted level because elevations of the entire extent of hardwood swamp were measured for the reevaluation. Results presented in this report are considered recommended until the MFLs are adopted for inclusion into Chapter 40C-8, *Florida Administrative Code* (*F.A.C.).* (Table ES-1).

The hydrologic model for Lake Dias was calibrated for 2001 conditions (CDM 2003). These conditions included the most recent land use information and groundwater levels consistent with 2001 regional water use. Based on hydrologic model results, SJRWMD concludes that the recommended MFLs for Lake Dias are protected under

Table ES-1. Adopted and recommended minimum surface water levels for Lake Dias, Volusia County.

Minimum Levels	Adopted Elevation (ft NGVD) 1929 datum	Adopted Hydroperiod Categories	Recommended Elevation (ft NGVD) 1929 datum	Recommended Hydroperiod Categories	Recommended Duration	Recommended Return Interval
Minimum frequent high level	34.5	Seasonally flooded	34.6	Seasonally flooded	30 days	3 years
Minimum average level	34.1	Typically saturated	33.5	Typically saturated	183 days	1.5 years
Minimum frequent low level	32.8	Semipermanently flooded	32.2	Semipermanently flooded	120 days	5 years

ft NGVD = feet National Geodetic Vertical Datum

2001 conditions. To determine if changes in groundwater use allocations subsequent to 2001 would cause lake levels to fall below the recommended MFLs for Lake Dias, the existing Lake Dias hydrologic model should be run using Floridan aquifer potentiometric level declines that reflect these changes in water use allocation.

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PURPOSE

The original minimum flows and levels (MFLs) determination for Lake Dias, Volusia County, Florida, was completed in July 1997 (Neubauer 1997, Appendix A). The adopted MFLs were based upon the best available information. However, no water budget model was available. A hydrologic water budget model was developed after the MFLs were adopted. The model indicated that the established minimum average level was not being met. Thus, a reevaluation of all adopted MFLs for Lake Dias was performed with the most recently developed criteria and information. This report documents the MFLs reevaluation for Lake Dias.

PROGRAM OVERVIEW

The St. Johns River Water Management District (SJRWMD) MFLs program establishes MFLs for lakes, streams and rivers, wetlands, springs, and groundwater aquifers. The MFLs program is subject to rule (Chapter 40C-8, *Florida Administrative Code* [*F.A.C.*]) and provides technical support to the SJRWMD regional water supply planning process (Section 373.0361, *Florida Statutes* [F.S.]) and the consumptive use permitting program (Chapter 40C-2, *F.A.C.*). With respect to SJRWMD rule regarding MFLs, “The Governing Board shall use the best information and methods available to establish limits which prevent significant harm to the water resources or ecology” (Rule 40C-8.011(3), *F.A.C.*). Significant harm is prohibited by Section 373.042(1a)(1b), F.S. The determinations of MFLs shall give consideration to natural, seasonal fluctuations in water flows and levels, nonconsumptive uses, and environmental values associated with coastal, estuarine, riverine, spring, aquatic, and wetlands ecology (Rule 62-40.473(1), *F.A.C.*).

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 is available for reasonable–beneficial use. Reasonable–beneficial use is defined as the use of water in such quantity as is necessary for economic and efficient utilization for a purpose and in a manner that is both reasonable and consistent with the public interest (Section 373.019 (13), F.S.).

The MFLs define the frequency of high- and low water events necessary to protect biologically relevant goals, criteria, and indicators that prevent significant harm to aquatic and wetland habitats. Events are defined by the magnitude and duration components. Three MFLs are usually defined for each system—minimum frequent high (FH), minimum average (MA), and minimum frequent low (FL) flows and/or levels. The MFLs represent hydrologic statistics comprised of three components:

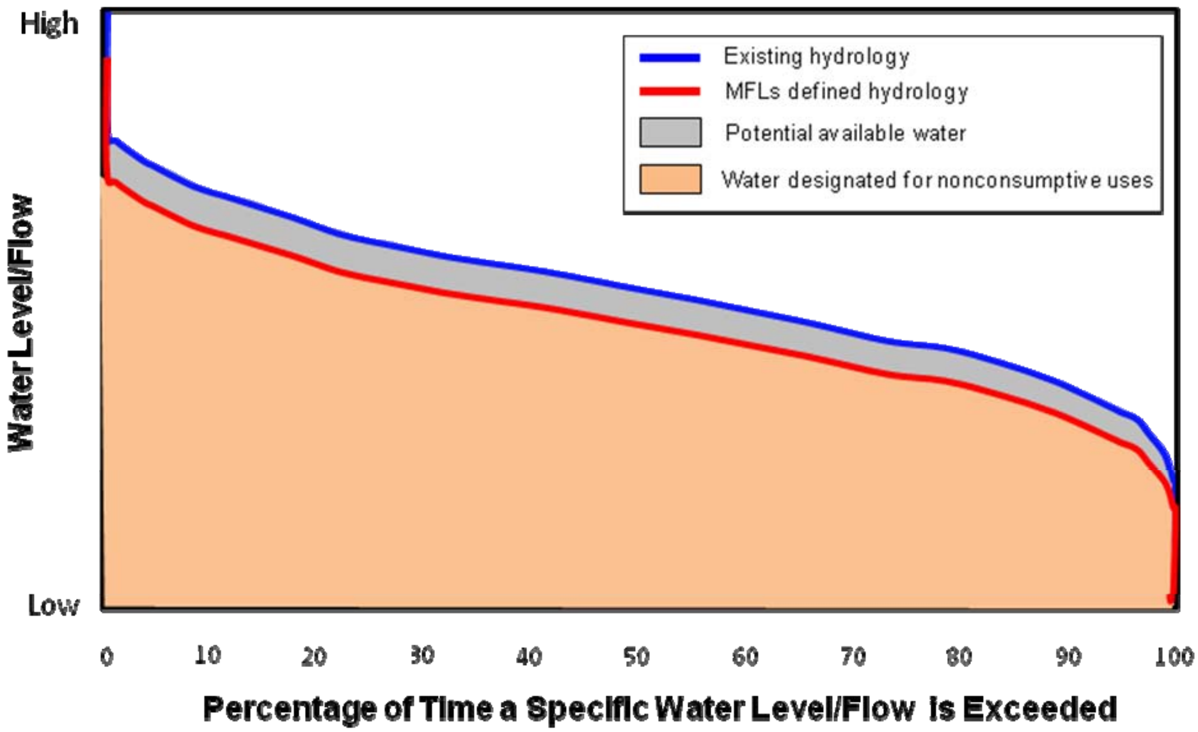
magnitude (a water level and/or flow), duration (days), and frequency or return interval (years). District staff synthesized the continuous duration and frequency components of the MFLs into seven discrete hydroperiod categories to facilitate MFLs determinations for lakes and wetlands before surface water inundation/dewatering signatures (SWIDS) were developed (Neubauer et al., 2004). The hydroperiod categories and the related frequencies and durations are defined in Rule 40C-8.021, *F.A.C.*, and summarized in Table 1.

Table 1. MFLs hydroperiod categories and approximate frequencies (i.e., on average) and durations

Hydroperiod Category	Approximate Frequency	Approximate Duration
Intermittently flooded	Once every 10 years high	Weeks to months
Temporarily flooded	Once every 5 years high	Weeks to months
Seasonally flooded	Once every 2 years high	Weeks to months
Typically saturated	Once every 2 years low	Months
Semipermanently flooded	Once every 5 to 10 years low	Months
Intermittently exposed	Once every 20 years low	Weeks to months
Permanently flooded	More extreme drought	Days to weeks

The 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 depicts two exceedence (i.e., duration) curves comparing existing long-term water level or flow duration conditions to a lowered hydrologic condition defined by MFLs. The MFLs exceedence curve, defined in this case by five MFLs, is similar to the existing hydrologic regime, although typically lower. The distance between the two curves (gray-shaded area, Figure 1) represents the water available for reasonable–beneficial uses. The area below the MFLs-defined curve (Figure 1) represents the water needed for ecosystem protection (e.g., fisheries and wetlands) or the protection of public health and safety. Although presented for illustrative purposes, exceedence curves are not sufficient when defining or implementing MFLs, because these curves result in the loss of biologically important duration, return interval, seasonality, and rate-of-change hydrologic components.

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 hydrologic 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



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

occurs (Figure 1). As it applies to wetland and aquatic communities, significant harm is a function of changes in the frequencies of high and low water events, defined by a level and/or flow and duration, causing unacceptable changes to ecological structure and functions.

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 in a cumulative and *a priori* manner and the likelihood that they might cause significant harm. Actual or projected violations of MFLs require the water management districts 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.).

BACKGROUND INFORMATION

Lake Dias is located 7.5 miles north of DeLand and 3.5 miles northeast of DeLeon Springs State Park in Volusia County, Florida (Figure 2 and Figure 3). The lake is approximately 711 acres at a stage of 35 feet (ft) National Geodetic Vertical Datum (NGVD). Lake Dias is in the Crescent City–DeLand Ridge physiographic division (4d) of the Central Lakes District. This division consists of sand hills, with summits of generally 80–100 ft elevation, and Plio-Pleistocene sand and shell resting directly upon the Floridan aquifer. The sand soils are described as very thick (Brooks 1982). The Central Lake District is described as uplifted limestone of the Floridan aquifer that lies unconformably below surficial sands. This Central Lake District is described as a sandhill karst with solution basins, a region of most active collapsed sinkhole development, and is considered a principle recharge area of the Floridan aquifer.

HYDROLOGY

Lake Dias is located in a low recharge zone (i.e., 0–4 in./year) and adjacent to higher recharge zones (up to 12 in./year), according to Boniol et al., (1993, Figure 4). The lake has one surface water outflow to Haw Creek, located on the east shore, and no perennial surface water inflows (Figure 3). Groundwater inflows originate from sand ridges surrounding the lake. This low recharge rate to the Floridan aquifer and the lake outflow to Haw Creek may explain the relatively stable surface water levels observed during the period of record.

Stage data for Lake Dias exist from April 1985 to the present (Figure 5). The data presented are daily mean water levels. Gaps in the data exist for the following periods:

11/7/87 to 11/30/87	7/22/95 to 7/26/95
9/14/89 to 10/24/89	10/15/97 to 10/17/97
2/19/91 to 4/15/91	4/4/2000 to 5/1/2000
7/22/91 to 1/28/92	1/11/01 to 2/5/02
8/3/93 to 8/31/93	5/17/02 to 8/29/02
4/19/95 to 4/24/95	5/16/03 to 6/1/03

Figure 2. Lake Dias, Volusia County, Florida, location map

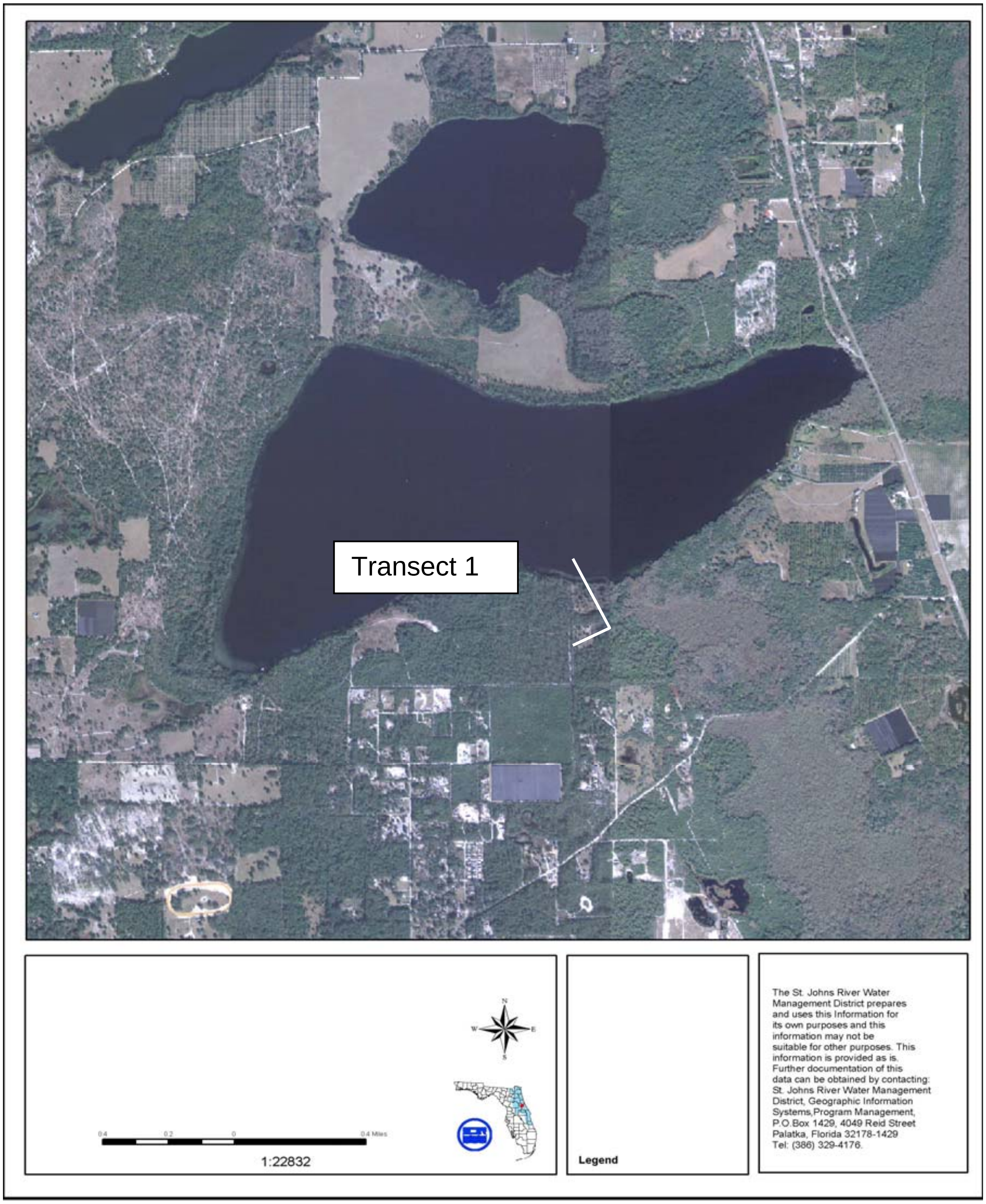


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Figure 3. Lake Dias, Volusia County, Florida, digital orthophotography quadrangle (DOQ) map, with location of Transect 1

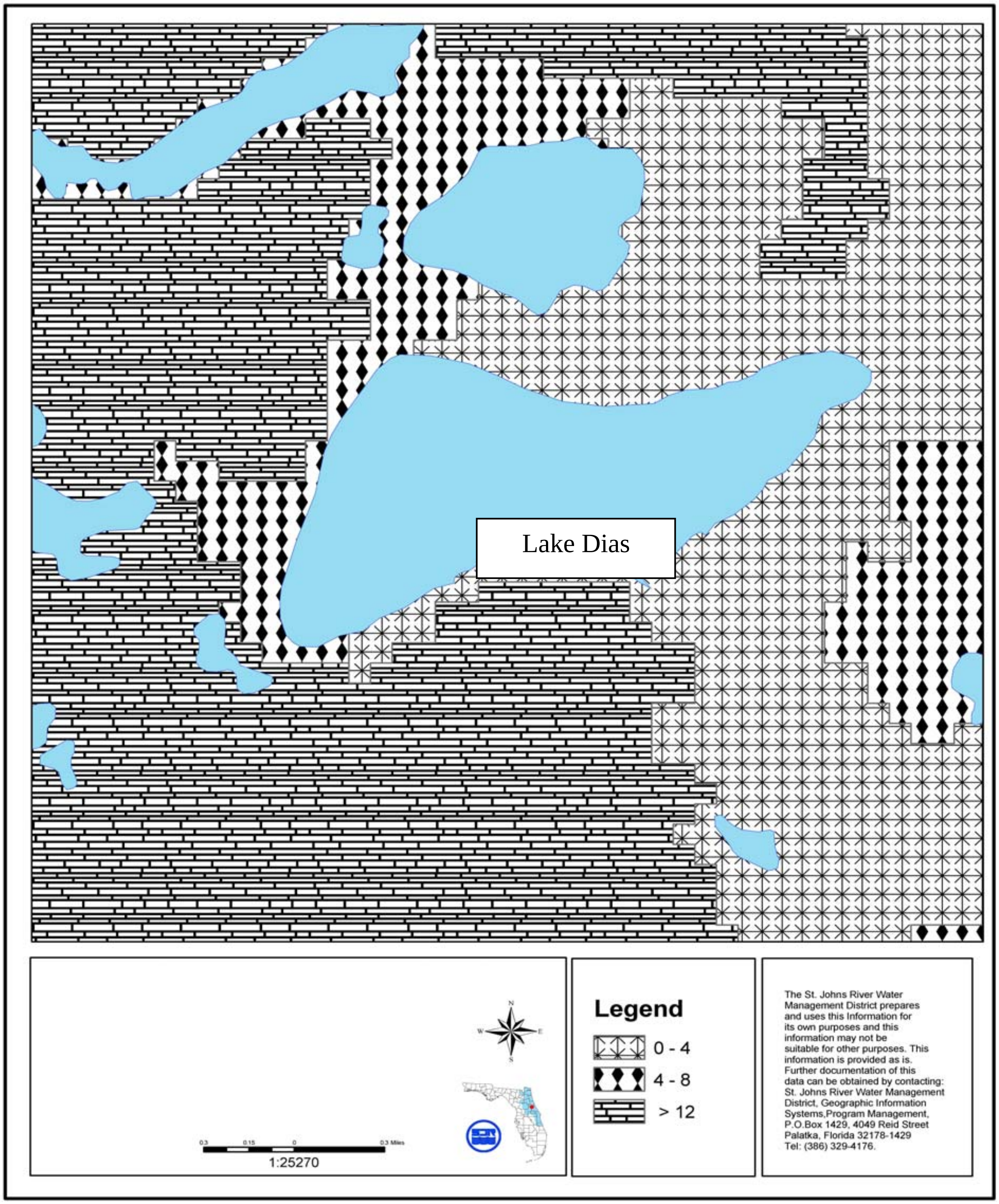

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Figure 4. Potential recharge map for Lake Dias, Volusia County, Florida

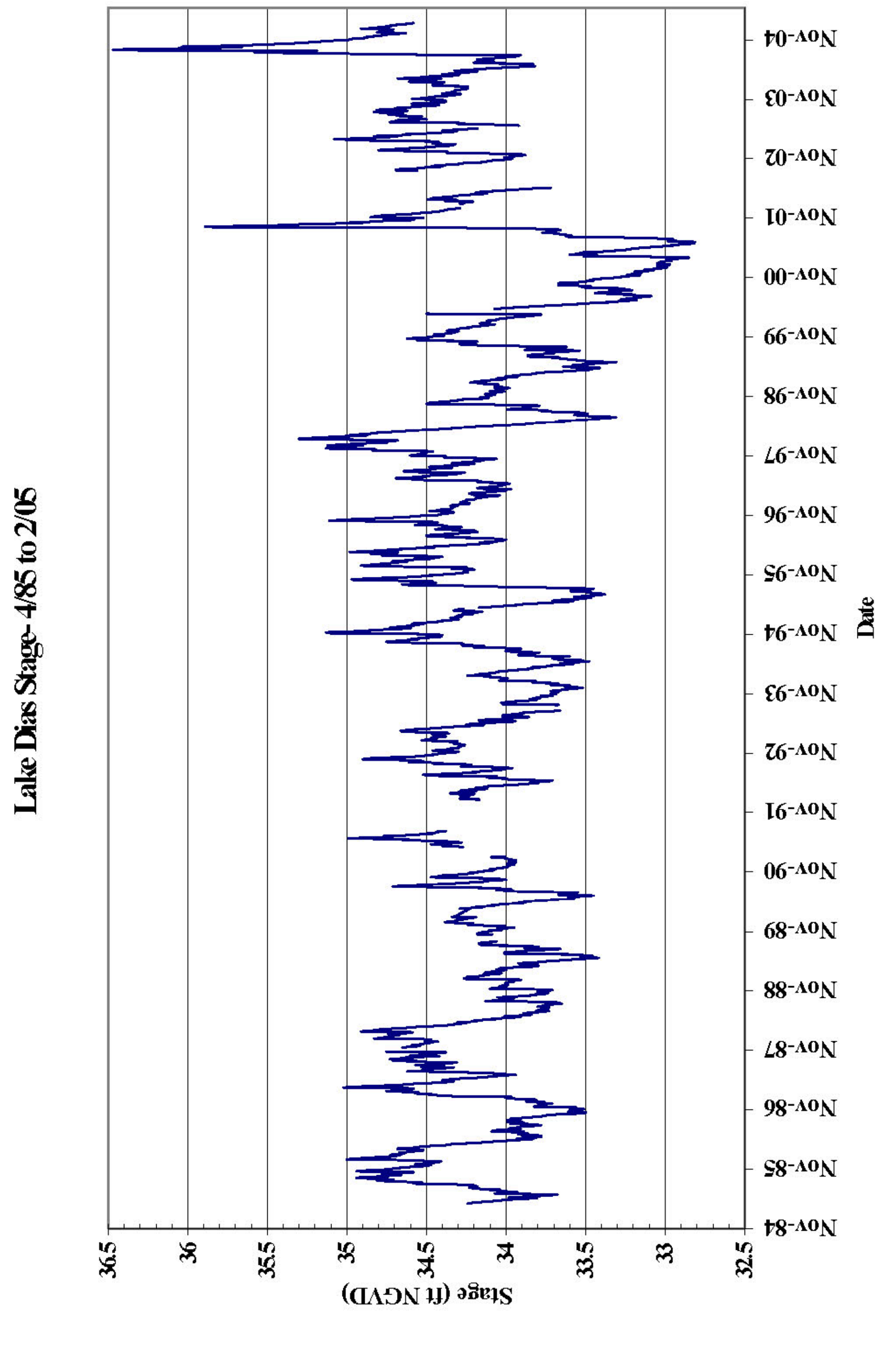

Figure 5. Hydrograph for Lake Dias, Volusia County, Florida

A stage duration curve (Figure 6), derived for the daily mean stage data, is presented. During the period of record, the lake fluctuated 3.66 ft, with a mean stage of 34.18 ft NGVD, as determined from 6,727 daily values (Table 2). The maximum and minimum stage elevations for the period of record were 36.47 ft NGVD (9/10/04) and 32.81 ft NGVD (6/16/01), respectively (Table 3). Notably, the maximum and minimum water level dates occurred during a 3.25-year period that included a severe drought and a summer when four hurricanes made landfall in Florida.

A hydrologic water budget model for the lake exists (CDM 2003). The high- and low-stage frequency analyses, based on model results for the originally adopted minimum frequent high (FH), minimum average (MA), and the minimum frequent low (FL) levels, are presented in Figures 7, 8, and 9, respectively. The modeled results indicated that the currently adopted MA (34.1 ft NGVD, typically saturated) was not being met by approximately 0.1 ft (i.e., 1.25 in.). The next most sensitive minimum level was the FH.

HYDRIC SOILS

Nine soil types were mapped immediately adjacent to Lake Dias (USDA-SCS 1980, Figure 10). Five soils were classified as hydric according to the Florida Association of Environmental Soil Scientists (2000). The hydric soils were Hontoon mucky peat (MUID #27), Immokalee fine sand (MUID #29), Myakka fine sand (MUID #32), Pompano-Placid complex (MUID #53), and Samsula muck (MUID #56). Hydric soil descriptions follow.

Hontoon mucky peat is described as very poorly drained, nearly level organic soil that occurs in freshwater swamps and marshes within the flatwoods. The surface is a 5-in.-thick, dark reddish brown mucky peat. The underlying layer is well-decomposed organic material to a depth of more than 52 in. During most years, the water table is at or above the soil surface for 6 to 9 months and within 10 in. of the soil surface for 6 months or more. Natural fertility is moderate. Natural vegetation of dense swamp hardwoods characterizes this soil. This soil requires water near the surface to prevent excessive oxidation of the organic layers.

Immokalee fine sand, described as nearly level, poorly drained sandy soil, generally occurs in broad areas in the flatwoods. The water table is within 10 in. of the soil surface for 1 to 2 months in most years and within 10 in. to 40 in. of the soil surface more than half the time. Occasionally, in very wet areas, the water table rises above

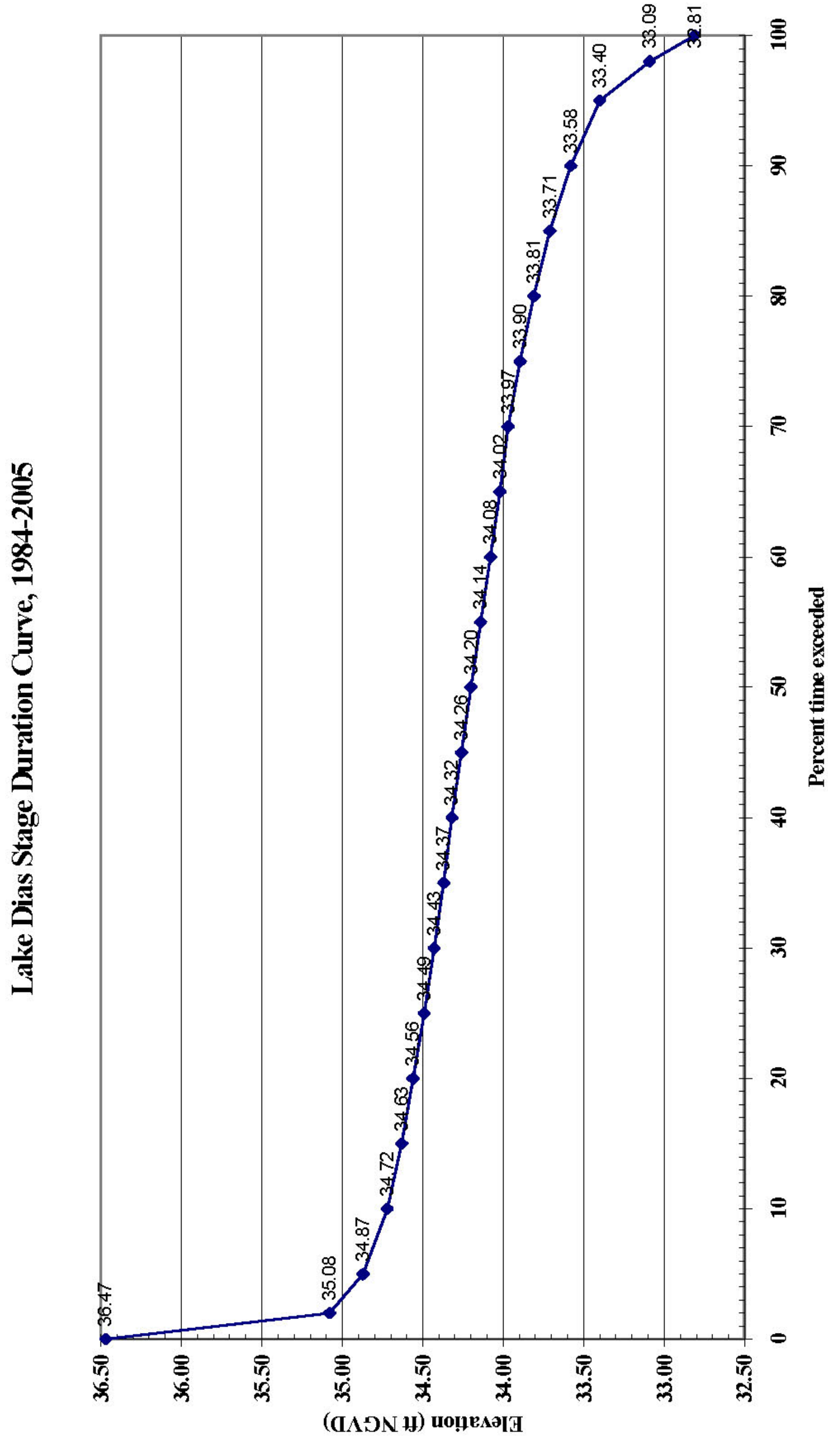

Figure 6. Lake Dias, Volusia County, Florida, stage duration curve

Table 2. Mapped wetlands: U.S. Fish and Wildlife Service, wetlands inventory map (Lake Dias quadrangle)

Wetland ID	Wetland Class/Hydroperiod Category
PEM1A	Palustrine emergent persistent, temporarily flooded
PEM1C	Palustrine emergent persistent, seasonally flooded
PEM1F	Palustrine emergent persistent, semipermanently flooded
PFO1/3C	Palustrine forested broad-leaved deciduous/broad-leaved evergreen, seasonally flooded
PFO1/3F	Palustrine forested broad-leaved deciduous/broad-leaved evergreen, semi-permanently flooded
PFO3/4C	Palustrine forested broad-leaved evergreen/needle-leaved evergreen, seasonally flooded
PFO3C	Palustrine forested broad-leaved evergreen, seasonally flooded
PFO6/3C	Palustrine forested deciduous/broad-leaved evergreen, seasonally flooded
PFO6/3F	Palustrine forested deciduous/broad-leaved evergreen, semipermanently flooded
PFO6C	Palustrine forested deciduous, seasonally flooded
PSS1/7C	Palustrine scrub-shrub broad-leaved deciduous/evergreen, seasonally flooded

the soil surface for a few days. The available water capacity is low. Permeability is moderate or moderately rapid in the subsoil and rapid in the other horizons. Natural fertility and organic matter content are low. The natural vegetation is an open forest of slash pine and longleaf pine and an understory of saw palmetto, runner oak, and pineland threeawn.

Myakka fine sand is described as nearly level, poorly drained soil in the flatwoods. Runoff is slow to very slow. The water table is within 12 in. of the soil surface from June to November and commonly within 40 in. of the soil surface the rest of the year except during extended droughts. Permeability is rapid in the surface layer and moderate in the subsoil. Infiltration is impeded by the seasonal high water table that occurs near the soil surface. The available water capacity is low. The organic matter content and natural fertility are low. The natural vegetation is the pine-palmetto type typically of the flatwoods. Slash and longleaf pine are the overstory and saw palmetto dominates the understory. Pineland threeawn is the predominant grass in the open areas.

Pomona-Placid complex is described as nearly level, poorly drained Pompano soil and very poorly drained Placid soil in depressions in the flatwoods. Pompano soil is slightly higher and surrounds the Placid soil. The Pompano soil has a water table that

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Minimum frequent high level	34.5	Seasonally flooded	34.6	30 days	3 years	Seasonally flooded
Minimum average level	34.1	Typically saturated	33.5	183 days	1.5 years	Typically saturated
Minimum frequent low level	32.8	Semipermanently flooded	32.2	120 days	5 years	Semipermanently flooded

ft NGVD = feet National Geodetic Vertical Datum

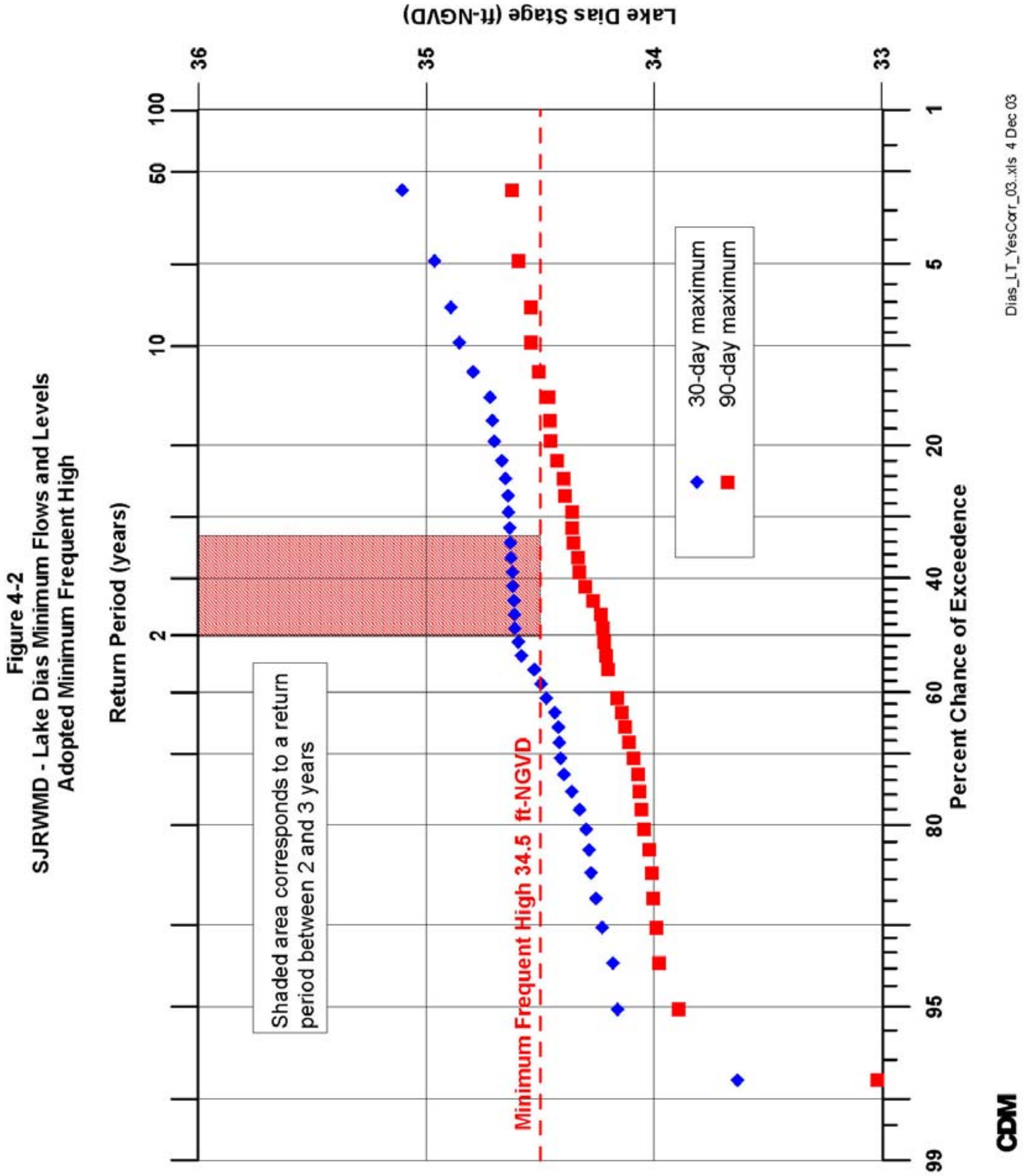

Figure 7. Lake Dias, Volusia County, Florida, stage frequency analysis results for the currently adopted FH level (CDM 2003)

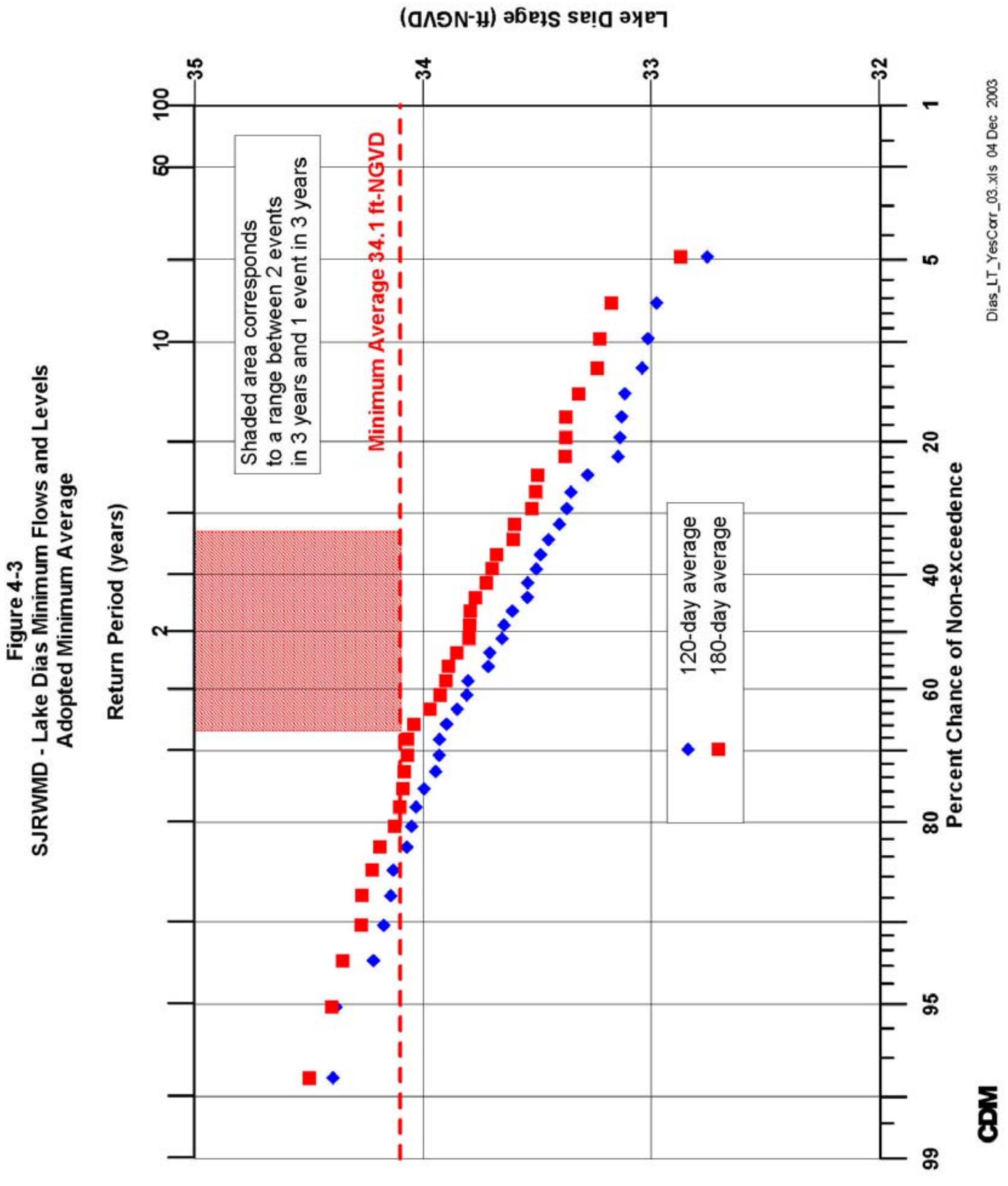

Figure 8. Lake Dias, Volusia, County, Florida, stage frequency analysis results for the currently adopted MA level (CDM 2003)

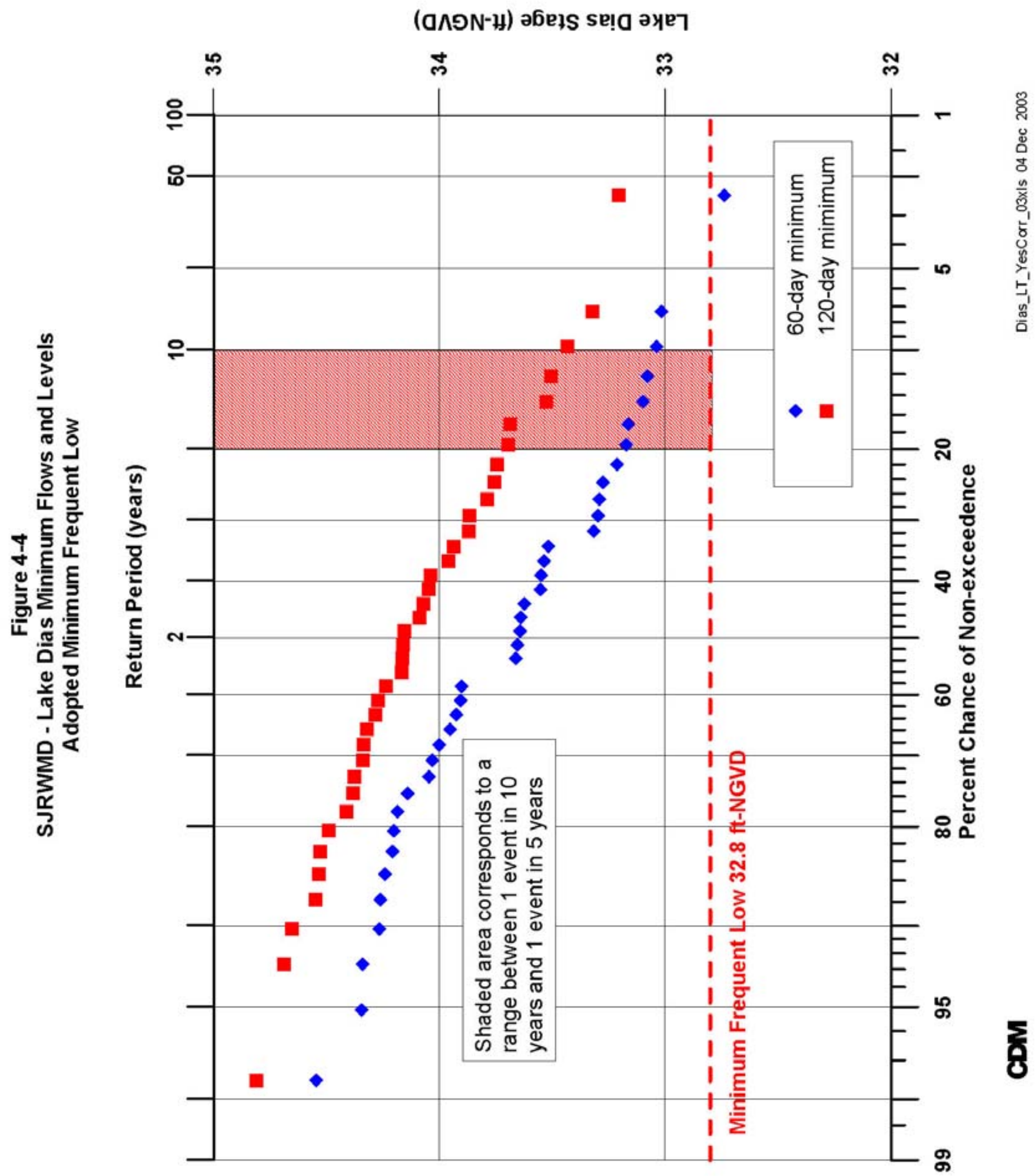

Figure 9. Lake Dias, Volusia County, Florida, stage frequency analysis results for the currently adopted FL level (CDM 2003)

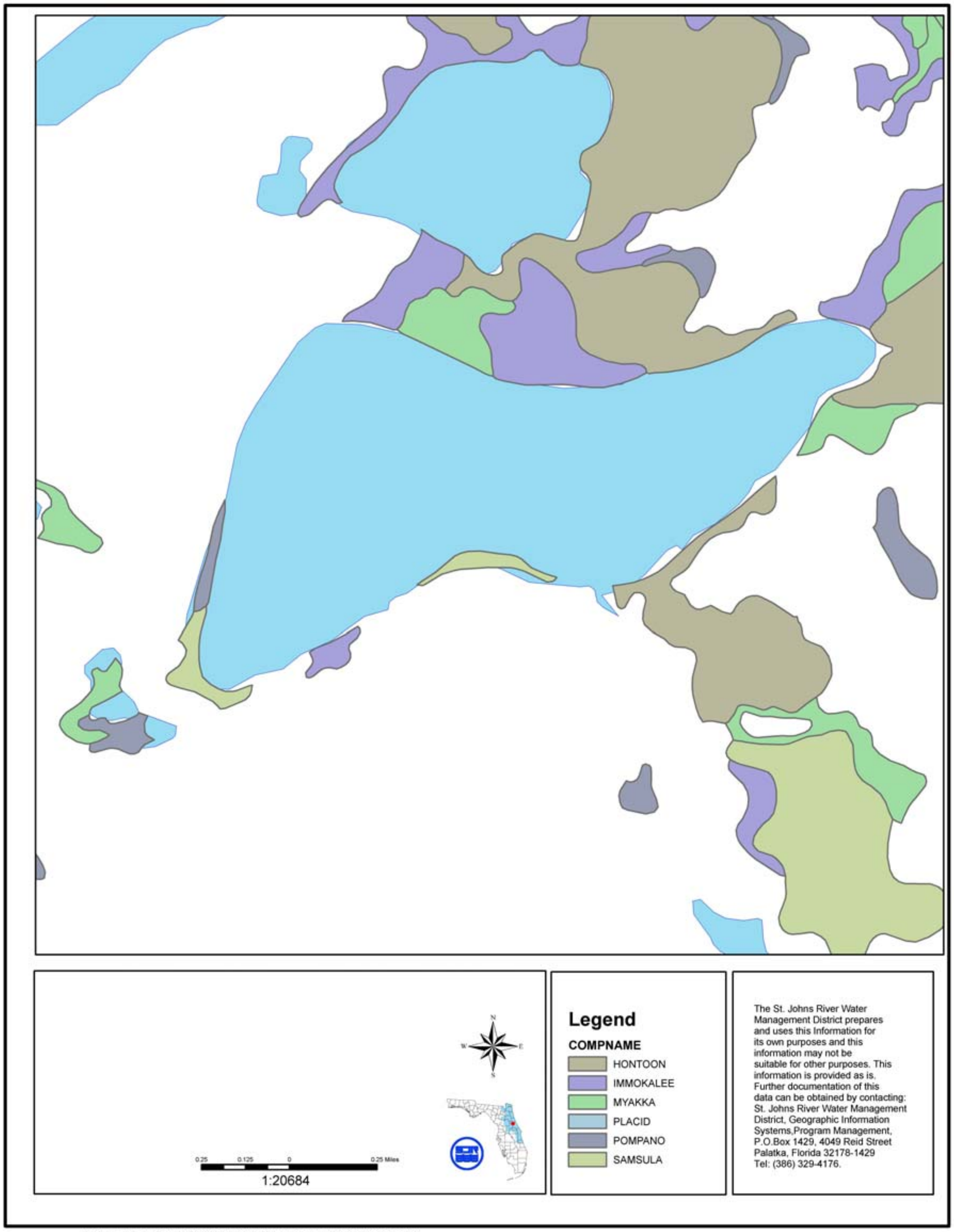

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Figure 10. Mapped hydric soils from Lake Dias, Volusia County, Florida

occurs within 6 in. of the soil surface. This soil is saturated within 10 in. of the soil surface in summer and fall. Frequently, this soil is covered with standing water during the wet season. It is low in natural fertility and organic matter content. Placid fine sand typically has a surface layer that is 11 in. of black fine sand and 4 in. of very dark gray fine sand. The Placid soil has a water table within 6 in. of the soil surface and is saturated within 10 in. of the soil surface in summer, fall, and winter. Frequently, it is covered with standing water during the wet season. It is moderate in natural fertility and organic matter content. The natural vegetation is of swamp hardwoods interspersed with slash pine and cabbage palm.

Samsula muck is described as very poorly drained, nearly level, organic soil that occurs in broad flats, small depressions, freshwater marshes, and swamps. The surface layer is about 9 in. of black muck underlain by 27 in. of dark reddish-brown muck with sand below. The water table is at or above the soil surface except during extended dry periods. Organic matter is high and fertility is moderate. The natural vegetation ranges from wetland grasses to dense swamps of cypress, various wetland hardwoods, or mixtures of these trees and longleaf pine. The soil is susceptible to oxidation and subsidence when dewatered.

WETLANDS

The U.S. Fish and Wildlife Service's National Wetlands Inventory Center map of Lake Dias quadrangles (NWIC 1987) identified 11 classes of wetlands adjacent to Lake Dias, Florida (Table 3). The wetlands located along Transect 1 used for this reevaluation were classified as PFO6/3C and PFO6/3F.

Wetland communities for this MFLs determination were classified according to the SJRWMD wetlands classification system (Kinser 1996, Figure 11).

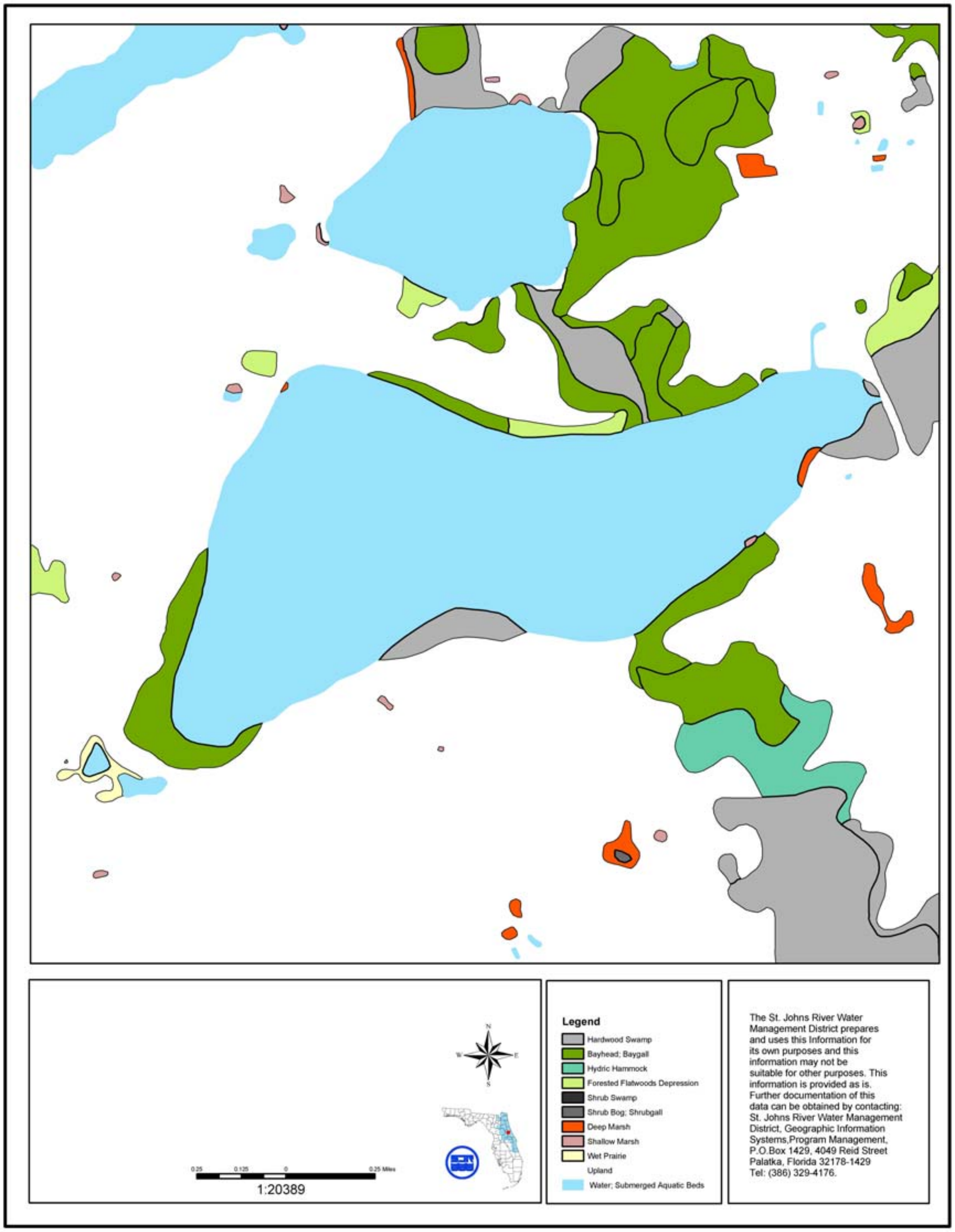

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Figure 11. Mapped wetland vegetation communities at Lake Dias, Volusia County, Florida

MFLs Methodology

Minimum flows and levels (MFLs) determinations incorporate biological, soils, and topographical data collected in the field with information from the scientific literature to develop a recommended MFLs hydrologic regime. The MFLs methodology provides a process for incorporating these factors.

This section describes the MFLs methodology and assumptions used in the minimum levels reevaluation process for Lake Dias, including field procedures such as site selection, field data collection, data analyses, and levels determination criteria. The SJRWMD general MFLs methodology is described more completely in the MFLs 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, along which, elevation, soils, and vegetation are sampled to characterize the influence of surface water flooding on the distribution of soils and plant communities.

Field site selection begins with the implementation of a site history survey and data search. All available existing information is assembled, including 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 for Lake Dias to familiarize the investigator with site characteristics and to locate important basin features that needed to be evaluated, as well as to assess prospective sampling locations.

Potential transect locations at Lake Dias 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.

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

Upon selection of a transect site at Lake Dias, vegetation was trimmed to allow a line-of-sight along the length of the transect. A measuring tape was then laid out along the length of the transect. Elevation measurements were recorded at various length intervals (5 ft, 10 ft, 20 ft, etc.) to adequately characterize the topography and transect features. Additional elevations were measured, including obvious elevation changes, vegetation community changes, soil changes, high water marks, and at bases of trees.

Soil Sampling Procedures

The primary soil criteria considered in MFLs determinations are the presence and depth of organic soils, as well as the extent of hydric soils observed along the field transects (SJRWMD 2006).

Vegetation Sampling Procedures

Vegetation sampling associated with MFLs determinations is completed with 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 12). 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 12).

Plants are identified and the percent cover of plant species is estimated if they occur 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 is estimated visually using cover classes (ranges of percent cover). The cover classes and percent cover ranges are a variant of the Daubenmire method (Mueller-Dombois and Ellenberg 1974), summarized in Table 4 (SJRWMD 2006). Plant species, plant communities, and percent cover data are recorded on field vegetation data sheets. The data sheets are formatted to facilitate data collection in the field as well as computer transcription.

Table 4. Summary of cover classes and percent cover ranges

Cover Class	Percentage Cover Range	Descriptor
0	< 1 %	Rare
1	1–10 %	Scattered
2	11–25 %	Numerous
3	26–50 %	Abundant
4	51–75 %	Co-dominant
5	> 75 %	Dominant

SURFACE WATER INUNDATION/DEWATERING SIGNATURES (SWIDS)

Frequency analysis of long-term stage data or modeled stage data is utilized to provide probabilities of flooding/dewatering events of a set duration (i.e., SWIDS) for wetland plant communities and organic soils. The probabilities are 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 similar 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).

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 that are 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 range.

DATA ANALYSIS

A computer spreadsheet file was used to perform basic statistical analysis for the information collected at Lake Dias. 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 communities. Location of vegetation communities along the transect, together with a list of dominant species, statistical results and soils information, were labeled on the graph.

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, which 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 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 Dias was developed to provide a means of assessing whether compliance with MFLs is achieved under specific water use and land use conditions (CDM 2003). This hydrologic model was calibrated for 2001 conditions. These conditions included the most recent land use information and groundwater levels consistent with 2001 regional water use.

An explanation of the use of this hydrologic model and the 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

The recommended minimum levels were derived from topographic data related to vegetation communities and the occurrence of organic soils observed on Transect 1 (Table 3). Field data were collected on May 26, June 7, and June 21, 2005. SJRWMD staff collected vegetation data, and Jones, Edmunds and Assoc. Inc. staff collected soils data. SJRWMD's Division of Surveying Services collected elevation data (Table 5). Elevations on Transect 1 were determined using a top-of-water (TOW) benchmark (TOW on June 7 was 34.82 ft NGVD) that referenced a staff gauge reading of 14.66 ft with a staff gauge elevation datum of 20.16 ft NGVD. Station numbers represent the distance measured in feet from the transect point of origin (0.0 ft). The location of Transect 1 did not coincide with the locations of the transect segments used for the original MFLs determination.

FIELD DATA COLLECTION—TRANSECT 1

Transect 1, located on the southern shore of Lake Dias (Figure 3, Transect 1 illustration is not to scale), extended 492 ft south-southeast, then west to station 644 ft from the waterward edge of deep marsh, through hardwood swamp and hydric hammock, to the upland edge (Figure 12). Figure 12 also depicts the extent of muck soils > 8 in., in depth, elevation ranges, and the dominant plant communities. The plant species found in each community, the estimated percent cover of each species, and *The Florida Wetlands Delineation Manual* (Gilbert et al. 1995) wetland indicator status are presented in Table 6.

The deep marsh, located between stations 0 and 170 (i.e., elevations 29.12 and 34.55 ft NGVD, respectively), was dominated by *Nuphar spp.* (spatterdock) with scattered *Taxodium* distichum (bald cypress) and young (< 6 in. diameter at breast height) *Fraxinus profunda* (pumpkin ash) occurred landward of station 140 (i.e., elevation 32.84 ft NGVD).

The hardwood swamp was located between stations 170 and 538 (elevation 35.79 ft NGVD) and was dominated by a canopy of *Acer rubrum* (red maple), pumpkin ash, *Liquidambar styraciflua* (sweetgum), *Taxodium ascendens* (pond cypress) and bald cypress, *Nyssa sylvatica var. biflora* (swamp tupelo) with *Cephalanthus occidentalis* (buttonbush), *Ilex cassine* (hahoon holly), *Itea virginica* (virginia sweetspire), *Osmunda cinnamomea* (cinnamon fern), *O. regalis* (royal fern), *Saururus cernuus* (lizard tail), *Woodwardia areolata* (netted chain fern), and *W. virginica* (virginia chain fern) understory.

Table 5. Elevations (ft NGVD) and statistics[1] for features measured at Lake Dias, Volusia County, Florida.

Location	Feature	N	Mean	Median	Minimum	Maximum
Lake Dias	Stage (daily values)	6,727	34.18	34.20	32.81	36.47
Stations 0-170	Deep Marsh (DM)	17	30.60	30.30	28.12	34.55
Stations 170-538	Hardwood Swamp (HS)	39	34.62	34.62	33.56	35.79
Stations 538-644	Hydric Hammock (HH)	13	35.73	35.58	35.25	36.74
Station 644	Uplands Edge	1			36.59	
Lake Shore	Waterward edge DM	20	28.48		27.40	29.30
Lake Shore	Waterward edge Cypress	9	31.28		30.80	31.60
Stations 345-445	Muck > 8 in. depth	12	33.82	33.84	33.56	34.09

ft NGVD = feet National Geodetic Vertical Datum
N = the number of elevations surveyed at each location

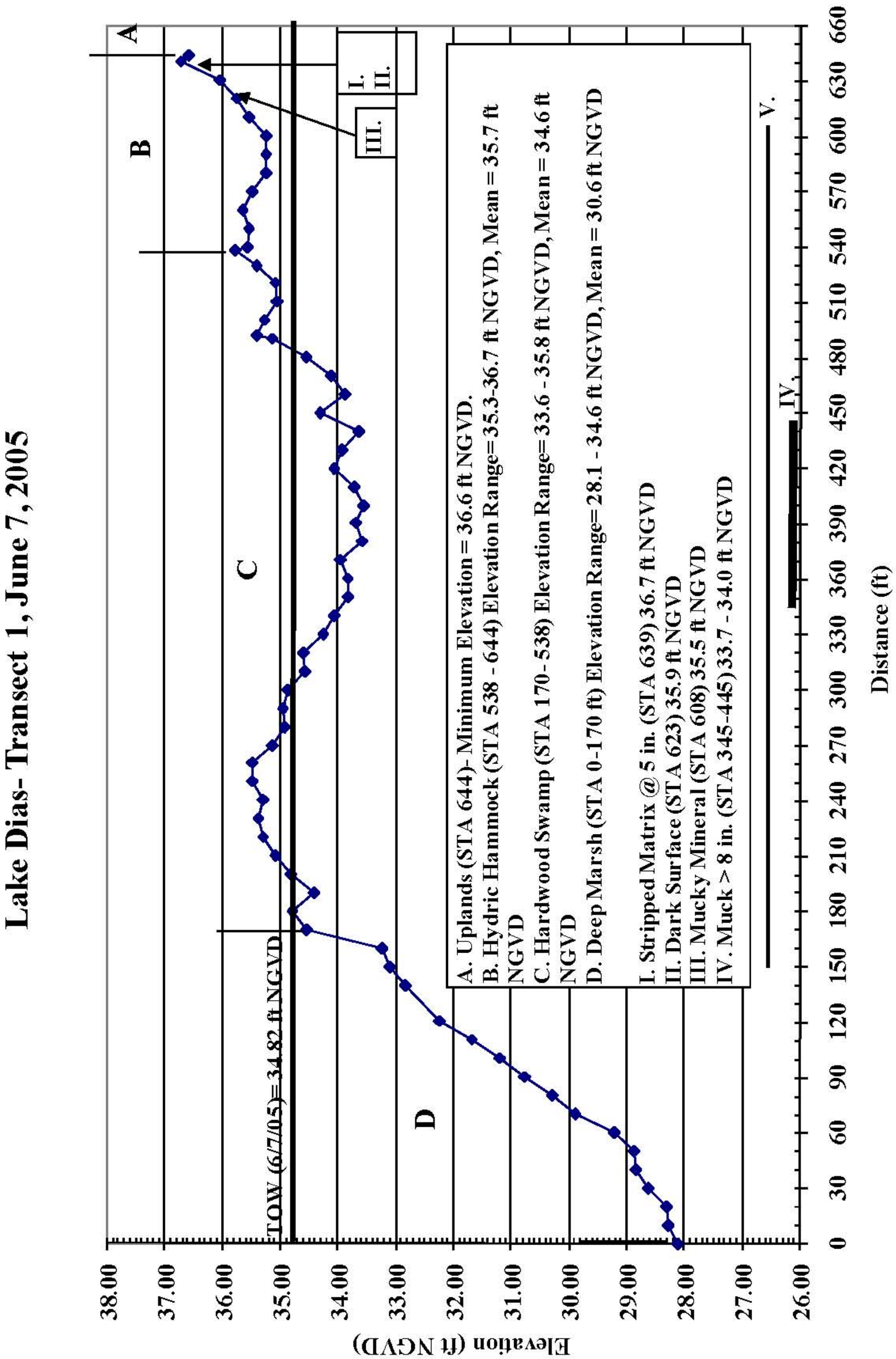

Figure 12. Lake Dias, elevation Transect 1 with vegetation and muck soils information.

Table 6. Plant species, *The Florida Wetlands Delineation Manual* wetland indicator status[2], and estimated species occurrence[3] for each plant community type occurring on Transect 1 at Lake Dias, Volusia County, Florida[1]

Species	Common Name	FLWDM*	HH	HS
Acer rubrum	Red maple	FACW	1	2
Aralia spinosa	Devil's-walking-stick	UPL	0	
Blechnum serrulatum	Sawfern blechnum	FACW		0
Boehmeria cylindrica	Smallspike false nettle	OBL		0
Callicarpa americana	Beauty-berry	UPL	0	
Cephalanthus occidentalis	Buttonbush	OBL		0
Tradescantia fluminensis	Trailing spiderwort	FAC	1	
Dichanthelium oligosanthes	Heller's witchgrass	UPL	0	0
Erechtites hieracifolia	Fireweed	FAC		0
Fraxinus profunda	Pumpkin ash	OBL	1	2
Gelsemium sempervirens	Carolina jessamine	UPL	0	
Hydrocotyle sp.	Pennywort	-		0
Ilex cassine	Dahoon holly	OBL	0	1
Itea virginica	Virginia sweetspire	OBL	0	1
Lemna obscura	Duckweed	OBL		1
Liquidambar styraciflua	Sweetgum	FACW	2	2
Magnolia virginiana	Sweetbay	OBL	1	1
Myrica cerifera	Wax myrtle	FAC		0
Nyssa sylvatica var. biflora	Tupelo, swamp	OBL		1
Osmunda cinnamomea	Cinnamon fern	FACW	2	1
Osmunda regalis	Royal fern	OBL	1	1
Parthenocissus quinquefolia	Virginia creeper	UPL	0	
Peltandra virginica	Arrow arum	OBL		0
Persea palustris	Swamp bay	OBL		0
Pinus taeda	Loblolly pine	UPL		0
Quercus laurifolia	Laurel oak	FACW	1	1
Quercus nigra	Water oak	FACW	1	0
Rubus sp.	Blackberry	FAC	1	
Sabal palmetto	Cabbage palm	FAC	2	0
Saururus cernuus	Lizard tail	OBL	2	2
Smilax laurifolia	Bamboo vine	UPL	0	
Spirodela punctata	Duckweed	OBL		1
Taxodium ascendens	Pond cypress	OBL		1
Taxodium distichum	Bald cypress	OBL		0
Toxicodendron radicans	Eastern poison ivy	UPL	1	1
Vaccinium corymbosum	Highbush blueberry	FACW	0	
Vitis rotundifolia	Muscadine grape	UPL	1	

Table 6—*Continued*

Species	Common Name	FLWDM*	HH	HS
Woodwardia areolata	Netted chain fern	OBL	2	1
Woodwardia virginica	Virginia chain fern	FACW	2	1

[1]Species and hydric designations are from Ch. 62-340.450, *F.A.C.* Species not in the rule are assumed upland (UPL) unless they are obvious aquatics; unlisted aquatic species are designated as obligates (OBL).
[2]*The Florida Wetlands Delineation Manual* (FLWDM*) wetland indicator status (Gilbert et al. 1995)
Upland (UPL)—Plants that rarely occur in wetlands, but almost always occur in uplands
Facultative (FAC)—Plants with similar likelihood of occurring in both wetlands and uplands
Facultative Wet (FACW)—Plants that typically exhibit their maximum cover in areas subject to surface water flooding and/or soil saturation, but may also occur in uplands
Obligate (OBL)—Plants that are found or achieve their greatest abundance in an area which is subject to surface water flooding and/or soil saturation; rarely uplands
[3]Species Occurrence: Aerial extent of vegetation species within each community along the transect
0 = <1%; 1 = 1–10%; 2 = 11–25%; 3 = 25–50%; 4 = 51–75%; 5 = >75%

The hydric hammock was located between stations 538 and 644 (elevation 36.59 ft NGVD) and was dominated by *Sabal palmetto* (cabbage palm), sweetgum, red maple, pumpkin ash, *Magnolia virginiana* (sweetbay), *Quercus laurifolia* (laurel oak), *Quercus nigra* (water oak), with netted chain fern, virginia chain fern, and lizard tail understory.

Uplands occurred at elevations greater than those at station 644 and were characterized as an abandoned fernery/citrus grove.

Although presence of muck soils was observed along much of the swamp and hydric hammock, muck soils > 8 in. (i.e., histic epipedon and histosols) were found between stations 345 and 445 (max elevation = 34.09 ft NGVD, mean elevation = 33.82 ft NGVD, and minimum elevation = 33.56 ft NGVD).

MINIMUM LEVELS DETERMINATION

Three minimum levels—minimum frequent high (FH), minimum average (MA), minimum frequent low (FL)—with associated hydroperiod categories are recommended to protect the structure and functions of the aquatic and wetland habitats. Additionally, specific ecological structures and functions protected by the minimum levels are also briefly discussed.

Minimum Frequent High (FH) Level

The recommended 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 function (Rule 40C-8.021(7), *F.A.C.*). Relative to the floodplain adjacent to Lake Dias, the hydroperiod category of seasonally flooded means surface water is typically present for extended periods (30 days or more) during the growing season, resulting in a predominance of submerged, or submerged and transitional, wetland species (Rule 40C-8.021(15), *F.A.C.*).

The recommended FH level for Lake Dias is 34.6 ft NGVD with an associated hydroperiod category of seasonally flooded. The FH level corresponds to the mean elevation of the hardwood swamp at Transect 1 (34.6 ft NGVD, Table 3). The stage elevation of 34.6 ft NGVD, when combined with the hydroperiod of seasonally flooded, has a duration of several weeks to several months and a return interval of every 1–2 years (Rule 40C-8.021(15), *F.A.C.*

Based upon surface water inundation/dewatering signature (SWIDS) analyses, the mean elevation of hardwood swamps from 11 different systems had the following return intervals (sorted from wettest to driest): 1.01, 1.10, 1.30, 1.32, 1.32, 1.35, 1.47, 1.52, 1.72, 3.13; and 3.13 for a 30-day flood event. The median return interval was 1.35 (i.e., 74% chance of exceedence). Additionally, the drier quartile had a return interval of 1.72 years (nearly a 2-year return interval). The driest swamps had return intervals of 3.13 (32% chance of exceedence) or nearly a 3-year return interval for a 30-day flood event. Based upon the SWIDS analyses, a 2-year to 3-year return interval for a 30-day flood of the average elevation of the hardwood swamp allows for drier conditions resulting from some water withdrawal, but does not alter the flooding hydrology beyond that characteristic of hardwood swamp, thus protecting wetlands structure and function.

The recommended FH level provides for inundation or saturation sufficient to support the obligate and facultative wetland species within the wetland communities. The level, with associated temporal component, should protect the spatial extent and functions of the seasonally flooded wetlands communities allowing sufficient water depths for fish and other aquatic organisms to feed and spawn on the floodplain of the lake. The recommended FH level of 34.6 ft NGVD provides for complete inundation of the deep marsh with 1.8 ft of water over the maximum elevation (32.8 ft NGVD at station 140) of *Nuphar* observed along Transect 1. The FH results in inundation of organic soils > 8 in., in depth (i.e., histosols and histic epipedon), located along Transect 1. The FH also results in a water table approximately 10 in. to 11 in. below the maximum elevations of muck (approximately 35.5 ft NGVD at station 250) and mucky sands, which corresponds well with the soil descriptions for Hontoon mucky peat, Immokalee fine sand, Myakka fine sand, and Pomona-Placid complex that have water tables within 10 in. to 12 in. of the soil surface for 1 to 6 months. Samsula muck is described as having water at or over the soil surface except during extended dry periods. The FH also corresponds to a water level that is 0.7 ft and 1.1 ft lower than the minimum and mean elevations of the hydric hammock community. SWIDS analyses of 10 systems showed that the minimum elevation of hydric hammock communities had a median return interval of 3 years, on average, for a 30-day flood and the mean elevation of hydric hammock communities had a median return interval of 10 years, on average, for a 30-day flood. The recommended FH corresponds to a water level that is 2 ft lower than the uplands edge, allowing for higher, but less frequent, flooding events to occur. For reference, the median return interval for a 1-day flood of the upland edge is less frequent than once every 10 years, on average (Neubauer et al., 2004).

Minimum Average (MA) Level

The recommended MA level is defined as the surface water level or flow necessary over a long period to maintain the integrity of hydric soils and wetland plant communities (Rule 40C-8.021(9), *F.A.C.*). Relative to the wetlands and hydric soils near Lake Dias, the hydroperiod category of typically saturated allows for saturated substrates for periods of one-half year during nonflooding periods of typical years and a recurrence interval, on average, of 1 to 2 years over a long-term period of record (Rule 40C-8.021(18), *F.A.C.*).

The recommended MA level for Lake Dias is 33.5 ft NGVD, with an associated hydroperiod of typically saturated. The MA level was calculated by subtracting 0.3 ft from the mean surface elevation of the histic epipedon/histosol zones described along Transect 1 (33.8 ft NGVD, Table 3). The 0.3-ft factor, based on studies by Stephens (1974), Brooks and Lowe (1984), and Hall (1987), is used to calculate the MA water level, which is designed to protect organic soils from oxidation and subsidence. The MA stage elevation of 33.5 ft NGVD, when combined with the hydroperiod category of typically saturated, is a low water event of 180 days that can recur with a return interval of approximately 1.5 years (i.e., about 67 such low water events during a century, on average).

The recommended MA level provides saturation or inundation for a frequency and duration that should protect the organic soils defined by the histic epipedon/histosol zone and provides for 0.7 ft of water over the landward elevation of the *Nuphar* (32.8 ft NGVD, Table 3). The MA stage elevation of 33.5 ft NGVD should allow for water depths of up to 5.4 ft in the deep marsh to provide refugia, nesting, and foraging habitats for aquatic and wetland-dependant fauna associated with the lake, while it also allows for drawdown conditions needed by swamp species for seed germination and seedling establishment.

Minimum Frequent Low (FL) Level

The recommended 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 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.*). Relative to the organic soils within the hardwood swamp community of the lake, the hydroperiod category semipermanently flooded means that inundation in these areas persists in most years. When surface water is absent during moderate droughts, the water table is near the surface. A return interval of 5 to 10 years for several or more months is expected (Rule 40C-8.021(16), *F.A.C.*).

The recommended FL level for Lake Dias is 32.2 ft NGVD, with an associated hydroperiod category of semipermanently flooded. The FL level was calculated by subtracting 1.67 ft (i.e., 20-in. drawdown) from the mean surface elevation of the histic epipedon/histosol on Transect 1 (33.82 ft NGVD, Table 3). The MFLs program routinely uses the 1.67-ft factor to calculate minimum frequent lows where organic hydric soils ≥ 8 in. thick are present (Hall et. al. 2006). The factor 1.67 ft (20 in.) was calculated as the mean of the range of dry-season water table depths reported by the Natural Resources Conservation Service for many organic soils within the SJRWMD (e.g., USDA-SCS 1974 and 1980). These soils are reported to have typical dry-season low water table depths of between –10 in. and –30 in. below the soil surface (–0.83 ft and –2.50 ft.). Additionally, Environmental Science and Engineering Inc. (ESE) (1991) calculated an average minimum dry-season water table depth of –53 cm ± 13.5 cm (–1.74 ft ± 0.4 ft) below soil surface based upon field data reported from the scientific literature for 29 seasonally flooded freshwater marshes.

The recommended FL level allows for periodic dewatering within the hardwood swamp communities for approximately 90–120 days. During moderate droughts, the stage elevation of 32.2 ft NGVD dewaters the waterward-most cypress (i.e., 32.55 ft NGVD) by 0.35 ft (approximately 4 in.) along Transect 1, but results in approximately 0.9 ft of water over the average elevation of nine waterward cypress trees measured along the north and south shores of the lake. This FL level provides foraging habitats for a variety of wading birds that may utilize the shallow portions of Lake Dias during drought periods (Bancroft et al., 1990). In addition, for reference, the median return interval for dewatering the maximum elevation of deep marsh for 30–90 days is approximately 10 years, on average. Finally, the minimum elevation of waterward cypress (e.g., 30.8 ft NGVD), an indicator of lower but less frequent water events, is 1.4 ft lower than the elevation component of the recommended FL. The seeds of most woody swamp plant species, including cypress, cannot germinate on inundated soils (Mitch and Gosselink, 2000).

CONCLUSIONS AND RECOMMENDATIONS

The adopted and newly recommended minimum surface water levels for Lake Dias, Volusia County, Florida, are presented in Table 3, and the differences briefly discussed below.

The SJRWMD multiple minimum flows and levels (MFLs) method (SJRWMD 2006, Neubauer et. al. 2007) was used to determine the recommended minimum lake levels. Determination of MFLs is based on evaluations of topographic, soils, and vegetation data collected within plant communities associated with the water body. Best available information also included the use of surface water inundation/dewatering signatures (SWIDS), recently developed by MFLs staff (Neubauer et. al 2004), that quantitatively defined flooding and dewatering signatures for the minimum, mean, and maximum elevations of selected plant communities. The recommended minimum average and minimum frequent low levels were 0.6 ft lower than the adopted levels because organic soils, determined by a soil scientist, occurred at slightly lower elevations than organic soils identified during the original MFLs determination. The recommended minimum frequent high is 0.1 ft higher than the adopted level, because elevations of the entire extent of hardwood swamp were measured for the reevaluation.

The hydrologic model for Lake Dias was calibrated for 2001 conditions (CDM 2003). These conditions included the most recent land use information and groundwater levels consistent with 2001 regional water use. Based on hydrologic model results, SJRWMD concludes that the recommended MFLs for Lake Dias are protected under 2001 conditions. To determine if changes in groundwater use allocations subsequent to 2001 would cause lake levels to fall below the recommended MFLs for Lake Dias, the existing Lake Dias hydrologic model should be run using Floridan aquifer potentiometric level declines that reflect these changes in water use allocation.

Information included in Appendix B concerning use of the hydrologic model and applicable SJRWMD regional groundwater flow model should be utilized to assess whether water levels are likely to fall below MFLs under specific water use and land use conditions.

Results presented in this report are considered recommendations until the MFLs are adopted as rule and listed in Chapter 40C-8.031, *F.A.C.*

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APPENDIX A—RECOMMENDED MINIMUM SURFACE WATER LEVELS DETERMINED FOR LAKE DIAS, JULY 11, 1997

MEMORANDUM **F.O.R. 94 -1514**

DATE: July 11, 1997

TO: Jeff Elledge, Director
Resource Management Department

THROUGH: Charles A. Padera, Director 7-14-97
Water Resources Department

Edgar F. Lowe, Ph.D., Director EFL
Environmental Sciences Division

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

FROM: Clifford P. Neubauer, Ph.D., Supervising Environmental Specialist CPN
Environmental Sciences Division

RE: Recommended minimum Surface Water Levels determined for Lake Dias, Volusia County, Project #01-43-00-5161-XXXX-10900

The purpose of this memorandum is to forward recommended minimum lake levels with associated hydroperiod categories (Table 1) determined for Lake Dias to the Department of Resource Management. Lake Dias was identified as a high priority lake. Field data for this memorandum were collected on May 21, 1997. A hydrologic water budget model is not available for Lake Dias.

Table 1. Recommended minimum surface water levels for Lake Dias. Terminology is defined in 40C-8021, F.A.C.; the category names and definitions are adapted from the water regime modifiers of Cowardin et. al., (1979).

MINIMUM LEVEL	ELEVATION (ft NGVD)	HYDROPERIOD CATEGORY
Minimum Frequent High Level	34.5	Seasonally Flooded
Minimum Average Level	34.1	Typically Saturated
Minimum Frequent Low Level	32.8	Semipermanently Flooded

INTRODUCTION

Lake Dias is a 711 acre lake (@ stage=35 ft NGVD) which is located approximately 3 miles northwest of Ponce DeLeon Springs and approximately 1.5 miles north of DeLeon Springs Heights (Figs.1-2). Lake Dias is a black-water lake located in the Crescent City-Deland Ridge Physiographic Division (4d) of the Central Lakes District and is immediately adjacent to the Volusia Ridge Sets subdivision (1c) of the Eastern Flatwoods District. The Crescent City-Deland Ridge Division consists of sandhills with summits generally between 80-100 feet in

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elevation. Plio-Pleistocene sand and shell rest directly on the Floridan Aquifer. The soils are very thick. The Central Lake District is described as a region of active sink-hole development with internal drainage and is the principle recharge area of the Floridan aquifer (Brooks, 1982). The lake is located in a low recharge zone (0-4 inches/year) and adjacent to higher recharge zones (up to 12 or more inches/year) according to Boniol et al., (1993). Although, the regional nature of this map product precludes accurate site specific references concerning actual recharge, Lake Dias may not contribute significant recharge to the Floridan Aquifer because the lake remained stable during the drought of the early 1990's when extremely low water levels were recorded from nearby lakes (i.e. Lakes Daugharty, Hires, and Winona).

A hydrologic record (Fig. 3) exists for Lake Dias from April 1985 to the present. The maximum and minimum water levels for the period of record are: 35.18 (11/23,24/94) and 33.42 feet NGVD (7/16/95), respectively. The mean and median water levels for the period of record was 34.22 ft NGVD. A percent exceedence curve, which illustrates the percentage of time the lake stage was at/or above an elevation, is presented in Fig. 4.

The USGS (1:24,000 scale) quadrangle (Fig. 2) shows one surface water outflow near the east shore of Lake Dias to Little Haw Creek. A 24 foot wide and 3.5 ft high box culvert exists at the outflow. Approximately 0.8 ft of water was measured at the lake-side end of the culvert (which corresponds to 33.2 ft NGVD) with approximately 1.1-1.2 ft of water present on the Haw Creek side (which corresponds to 32.9-32.8 ft NGVD) of the structure. Water did not appear to be flowing from the lake indicating that the hydraulic control for this system is likely downstream from the culvert (toward Haw Creek). The elevation of the hydraulic control is not known. Water enters the lake via direct precipitation, seepage from the surrounding watershed, and may also inflow through wetlands located adjacent to Lake Dias from Lake Caraway when the latter lake is at high stages. Additionally, water may flow into the lake if the water level of Haw Creek becomes greater than that of the hydraulic control or Lake Dias during high flow events in the Haw Creek system.

There are 20 active permitted water withdrawals (CUP's) within 1 mile of Lake Dias (Fig. 5, Mary McKinney, Res. Mgt. Dept.). The total maximum allocation for these permits is 684.43 MGY with an additional total frost and freeze allocation of 263.3 MGY.

Soils

Three types of hydric soils (total area = 1305 acres) were delineated by the SCS (1980) adjacent to Lake Dias (Fig 6). These soils were Hontoon mucky peat (MUID #27), Pompano-Placid complex (MUID #53), and Samsula muck (MUID #56). These hydric soils account for approximately 75% of the total area of soils (as determined from GIS soil polygons) adjacent to Lake Dias.

Hontoon mucky peat is described as very poorly drained, nearly level organic soil which occurs in freshwater swamps and marshes within the flatwoods. The surface is dark reddish-brown mucky peat about 5 inches thick. The underlying layer is well decomposed organic material to a depth of more than 52 inches. During most years, the water table is at or above the soil surface for 6-9 months and within 10 inches of the surface for 6 months or more. Natural fertility is moderate. Natural vegetation of dense swamp hardwoods characterize this soil. This soil requires water near the surface to prevent excessive oxidation of the organic layers.

Pompano-Placid complex is described as nearly level, poorly drained Pompano soils and very poorly drained Placid soils in depressions in the flatwoods. The Pompano soil is slightly higher and surrounds the Placid soil. The Pompano soil has a water table less than 6 inches above the soil surface and is saturated within 10 inches of the surface in summer and fall. Frequently, this soil is covered with standing water during the wet season. It is low in natural fertility and organic matter content. Placid fine sand typically has a surface layer which is 11 inches of black fine sand and 4 inches of very dark gray fine sand. The Placid soil has a water table less than 6 inches above the soil surface and is saturated within 10 inches of the surface in summer, fall, and winter. Frequently, it is covered with standing water during the wet season. It is moderate in natural fertility and organic matter content. The natural vegetation is of swamp hardwoods interspersed with slash pine and cabbage palm.

Samsula muck is described as very poorly drained, nearly level organic soil which occurs in broad flats, small depressions, freshwater marshes and swamps. The surface layer is about 9 inches of black muck underlain by 27 inches of dark reddish-brown muck with sand below. The water table is at or above the soil surface except during extended dry periods. Organic matter is high and fertility is moderate. The natural vegetation ranges from wetland grasses to dense swamps of cypress, various wetland hardwoods, or mixtures of these trees and longleaf pine. This soil is susceptible to oxidation and subsidence when dewatered.

<u>Wetland Vegetation</u>-
The US Fish and Wildlife Service National Wetlands Inventory maps (Lake Dias, FL., quadrangles, 1987) identified 11 classes of wetlands adjacent to Lake Dias (Fig. 7). These classes are presented in Table 2.

Table 2. Classified wetlands mapped at Lake Dias by the US Fish and Wildlife Service.

MAPPED WETLANDS- USFWS WETLAND INVENTORY MAP	
Wetland Id	Wetland Class/Hydroperiod Category
PEM1A	Palustrine Emergent Persistent Temporarily Flooded
PEM1C	Palustrine Emmergent Persistent Seasonally Flooded
PEM1F	Palustrine Emergent Persistent Semipermanently Flooded
PFO1/3C	Palustrine Forested Broad-Leaved Deciduous/Broad Leaved Evergreen Seasonally Flooded
PFO1/3F	Palustrine Forested Broad-Leaved Deciduous/Broad Leaved Evergreen Semi-permanently Flooded
PFO3/4C	Palustrine Forested Broad-Leaved Evergreen/Needle-Leaved Evergreen Seasonally Flooded
PFO3C	Palustrine Forested Broad-Leaved Evergreen Seasonally Flooded
PFO6/3C	Palustrine Forested Deciduous /Broad-Leaved Evergreen Seasonally Flooded
PFO6/3F	Palustrine Forested Deciduous/Broad-Leaved Evergreen Semipermanently Flooded
PFO6C	Palustrine Forested Deciduous Seasonally Flooded
PSS1/7C	Palustrine Scrub-Shrub Broad-Leaved Deciduous/Evergreen Seasonally Flooded

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Transect #1 (Fig. 8)
Transect #1 was located on the southeast shore of Lake Dias (Fig 2) and traversed a portion of a mixed hardwood swamp. This community was characterized by red maple, water ash, and laurel oak canopy with louisiana wood-fern, saw fern blechnum, and arrow-arum understory. The elevation of 0-150 ft distance indicated that this zone was slightly higher than that of distance 150-200 ft; the latter delimited a slight depression. Wetlands were identified as Palustrine Forested Broad Leaved Deciduous/Broad Leaved Evergreen Semipermanently flooded (PFO1/3F) by the USFWS Service. The mapped hydric soil was Hontoon mucky peat (MUID #27); muck depths >2.8 ft were measured at stations 5, 50, 100, 150, and 200 feet along the transect.

Transect #2 (Fig. 9)
Transect #2 began near the waterward edge of the swamp described as transect #1 (Fig 2), crossed an aquatic bed and terminated at open water. Water depths were measured at approximately 10 ft intervals across the aquatic bed which was characterized by spatter-dock with scattered water ash near the shore of the swamp. This aquatic bed was mapped by the USFWS as Lacustrine Limnetic Open Water Permanently Flooded (L1OWH) and the substrate of the aquatic bed were mapped as open water by the SCS.

Transect #3 (Fig. 10)
Transect #3 traversed a section of low flatwoods (Fig. 2) which was characterized by slash pine, loblolly bay, saw palmetto, and cinnamon fern. The vegetation present suggested that the area had not burned recently resulting in the invasion of the flatwoods by loblolly bay. Wetlands were identified as Palustrine Forested Broad Leaved Evergreen Seasonally Flooded (PFO3C) by the USFWS. A non-hydric soil, Immokalee sand (MUID #29) was mapped at transect #3. This soil is described as poorly drained with a water table within 10 inches of the surface for 1-2 months during most years and between 10-40 inches of the surface more than half of the time. Muck soil was present near the waterward end of the transect (@ 15 ft, 34.9 ft NGVD), a red fibrous peat was present at station 50 ft (35.5 ft NGVD) with mineral sand at station 100 ft (35.6 ft NGVD).

The minimum levels for Lake Dias are based upon three elevation transects and spot elevations measured by a District surveyor (Mike DeLoach), vegetation and soils analysis by ES staff, information contained in the Volusia County Soil Survey (SCS, 1980), and the US Fish and Wildlife National Wetland Inventory map. Table 3 contains elevations of reference features measured at Lake Dias.

Table 3. Spot, maximum, mean, and minimum elevations measured at Lake Dias. Elevations are in feet NGVD.

Location	Feature	Spot	Max	Mean	Min	N
Lake Shore	Top of dock (deck top)		37.2	36.5	35.5	6
Transect #3	Low flatwoods		35.9	35.3	34.7	21
Transect #1	Mixed swamp (0-200 ft)		35.2	34.5	34.0	21
Transect #1	Mixed swamp (150-200 ft)		34.8	34.3	34.0	6
Transect #2	Waterward scattered water ash	32.0				

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Transect #2	Waterward outlier water ash	31.6				
Lake Shore	Waterward bull-rush		30.9	30.7	30.6	8
Transect #2	Aquatic bed		32.8	30.7	29.1	14
Lake Shore	Waterward maidencane		30.4	29.5	27.9	3
Transect #2	Aquatic bed/Open water ecotone	29.1				
Lake Shore	Waterward spatter-dock		30.0	29.0	27.4	18
Lake Shore	Lake bottom at waterward docks		31.2	28.9	25.2	6

Common and scientific names of plants species found along the transects at Lake Dias are presented in Table 4. Three levels with corresponding hydroperiod categories are recommended. Short descriptions of the functions of each minimum level and the related data used in their determination are presented below.

MINIMUM FREQUENT HIGH LEVEL

The Minimum Frequent High level (34.5 ft NGVD), and the assigned hydroperiod category of Seasonally Flooded was calculated by subtracting 10 inches (0.83 ft) from the mean elevation of the low flatwoods measured at transect #3 (35.33 ft NGVD-0.83 ft =34.5 ft NGVD). The water table of this soil type is expected to be within 10 inches of the surface during 1-2 months during "normal" rainfall years (SCS, 1980).

This minimum level results in frequently saturated conditions near the waterward end of the low flatwoods (transect #3) protecting the structure of this community and maintaining existing pockets of hydric soils. This minimum level also results in frequent inundation of the portions of the mixed swamp and muck soils identified at transect #1, (mean elevation of transect #1=34.5 ft NGVD) allows for as much as 0.5 foot of water over the lower elevations of the swamp (as measured at stations 150-200 ft, transect #1), approximately 3.8 feet of water over the average elevation of the adjacent aquatic bed with 5.4 ft of water over the waterward end of the of the spatter-dock aquatic bed at transect #2. The recommended minimum level allows water levels of sufficient frequency and duration to: 1) inhibit the invasion of the swamp and aquatic beds by upland plant species, and 2) allow fish and other species access to these wetlands associated with the lake. This recommended minimum water level is 0.7 feet below the maximum recorded level (35.2 ft NGVD) for the period of record. This minimum level also corresponds to the 25th percentile of exceedence on a duration curve (Fig 5). Although the period of record is considered to be relatively short, the duration curve may be representative because this system is very stable and extreme wet and dry events have occurred during the period stage data were collected.

Additionally, this recommended minimum level allows for approximately 5.6 feet of water at the waterward end of the average of 6 measured docks and is approximately 2.0 feet below the average top of deck elevation of measured docks.

MINIMUM AVERAGE LEVEL

The Minimum Average level (34.1 ft NGVD), with the assigned hydroperiod category of Typically Saturated was calculated by subtracting a quarter foot from the mean elevation (Hall, 1987) of the lowest portion (150-200 ft) of the mixed swamp (transect #1, 34.3 ft NGVD - 0.25=34.05 ft NGVD). The entire length of the swamp zone was not used because the 0.25 ft depth criteria was developed and used in marsh systems which are generally considered to be inundated/saturated for longer periods and more frequently than swamps.

This minimum average level results in the inundation or saturation of the swamp and muck soils present at transect #1 and the inundation of the existing aquatic beds adjacent to the lake. This protects muck soils from oxidation while allowing for wetland plant seed germination on the exposed muck soils present at higher elevations along the transect. This water level also corresponds to approximately the 60th percentile of exceedence on the stage-duration curve (Fig. 4).

Additionally, this recommended minimum level allows for approximately 5.2 feet of water at the waterward end of the average of 6 measured docks and is approximately 2.4 feet below the average top of deck elevation of measured docks.

MINIMUM FREQUENT LOW LEVEL

The Minimum Frequent Low level (32.8 ft NGVD), with the assigned hydroperiod category of Semipermanently Flooded corresponds to the average elevation of the swamp at transect #1 minus 1.67 ft which reflects a 20 inch drawdown, which is reasonable for a moderate drought. This water level also corresponds to the ecotone between the mixed swamp and the aquatic bed measured at transect #2.

This minimum level allows for drawdown conditions of muck soils present in the swamp (transect #1) while inundating the aquatic beds adjacent to the lake. This drawdown will promote aerobic soil conditions which stimulate decomposition and promote seed germination (required by many wetland plant species), while protecting fish habitat during low water conditions. This water level is 0.6 ft lower than the lowest water level recorded from this system (Fig. 4); increasing the range of fluctuation may be beneficial to fish populations of a system with a narrow hydrologic range.

Additionally, this recommended minimum level allows for approximately 3.9 feet of water at the waterward end of the average of 6 measured docks and is approximately 3.7 feet below the average top of deck elevation of measured docks.

Please call me (ext. 4343), Jane Mace (ext. 4389) or Ric Hupalo (ext. 4338) if you wish you to discuss these minimum levels.

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CPN:bs

attachments

c:				
	Kathryn Mennella	Hal Wilkening	Tommy Walters	Larry Battoe
	David Clapp	Ric Hupalo	Jane Mace	Larry Fayard
	Sandy McGee	Price Robison	Bob Freeman	MFL-REG Tech

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Table 4. Plant species, common names, with DEP and USACOE wetland classes.

SPECIES	COMMON NAME	DEP	USACOE
Acer rubrum	red maple	FACW	FAC
Blechnum surrulatum	sawfern blechnum	FACW	FACW+
Cephalanthus occidentalis	buttonbush	OBL	OBL
Crinum americanum	swamp-lily	OBL	OBL
Dryopteris ludoviciana	louisiana woodfern	FACW	FACW
Fraxinus caroliniana	water ash	OBL	OBL
Gordonia lasianthus	loblolly bay	FACW	FACW
Itea virginica	virginia sweetspire	OBL	FACW+
Magnolia virginiana	sweetbay	OBL	FACW+
Myrica cerifera	wax myrtle	FAC	FAC+
Nuphar luteum	spatter-dock	OBL	OBL
Osmunda cinnamomea	cinnamon fern	FACW	FACW+
Osmunda regalis	royal fern	OBL	OBL
Peltandra virginica	arrow-arum	OBL	OBL
Persea palustris	swamp bay	OBL	FACW
Pinus elliottii	slash pine	UPL	FACW
Quercus laurifolia	laurel oak	FACW	FACW
Saururus cernus	lizard tail	OBL	OBL
Serenoa repens	saw palmetto	UPL	UPL
Toxicodendron radicans	poison ivy	UPL	FAC
Ulmus americana	american elm	FACW	FACW
Vaccinium corymbosum	highbush blueberry	FACW	FACW
Vitis rotundifolia	muscadine grape	UPL	FAC
Woodwardia areolata	netted chain fern	OBL	OBL
Woodwardia virginica	virginia chain fern	FACW	OBL

Fig 1. Lake Dias location map. Copy from Florida Atlas and Gazetteer, DeLorme Mapping Co., Freeport, Maine, USA.

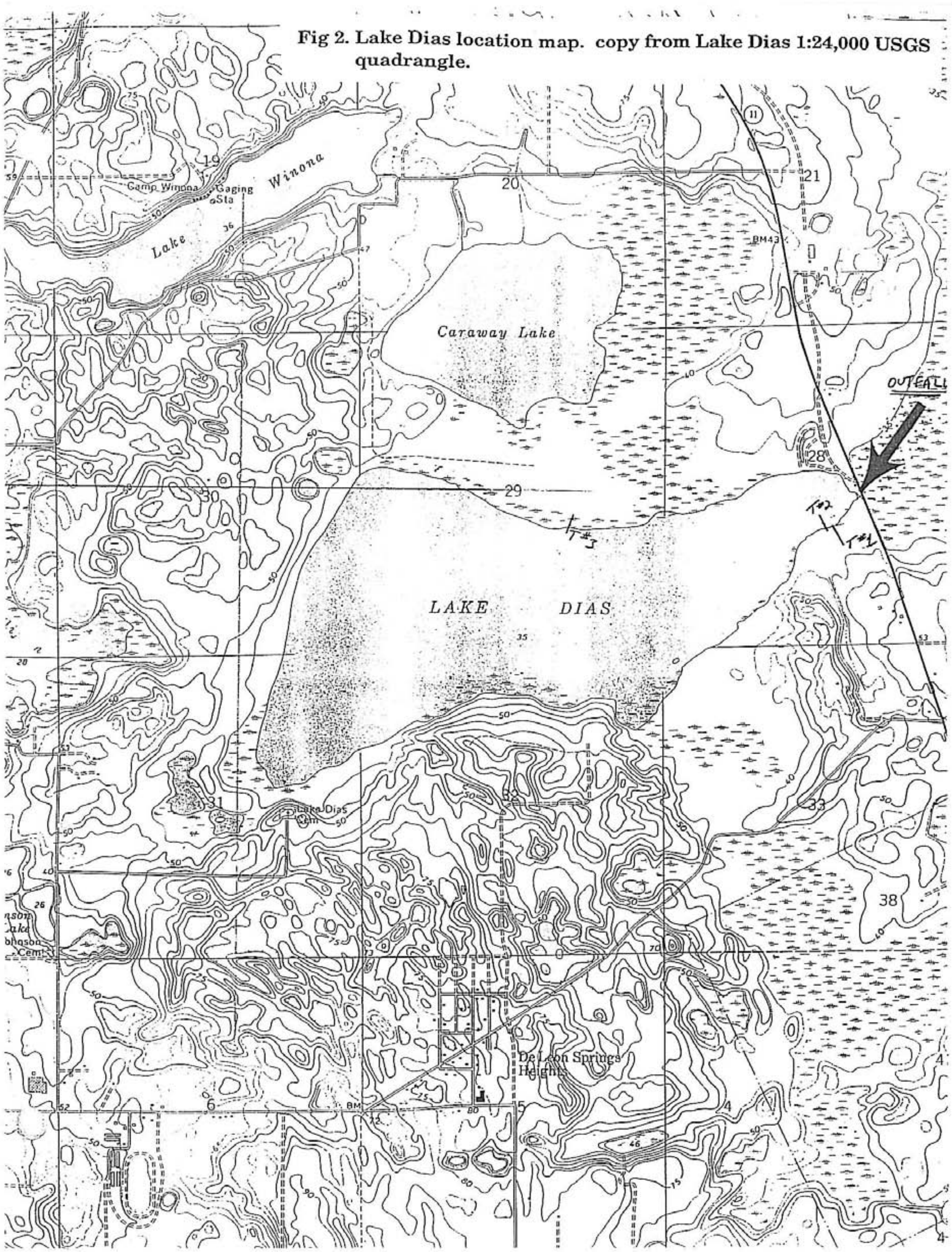


Fig 2. Lake Dias location map. copy from Lake Dias 1:24,000 USGS quadrangle.

Fig 3. Hydrologic record from Lake Dias. (1985 to the present)

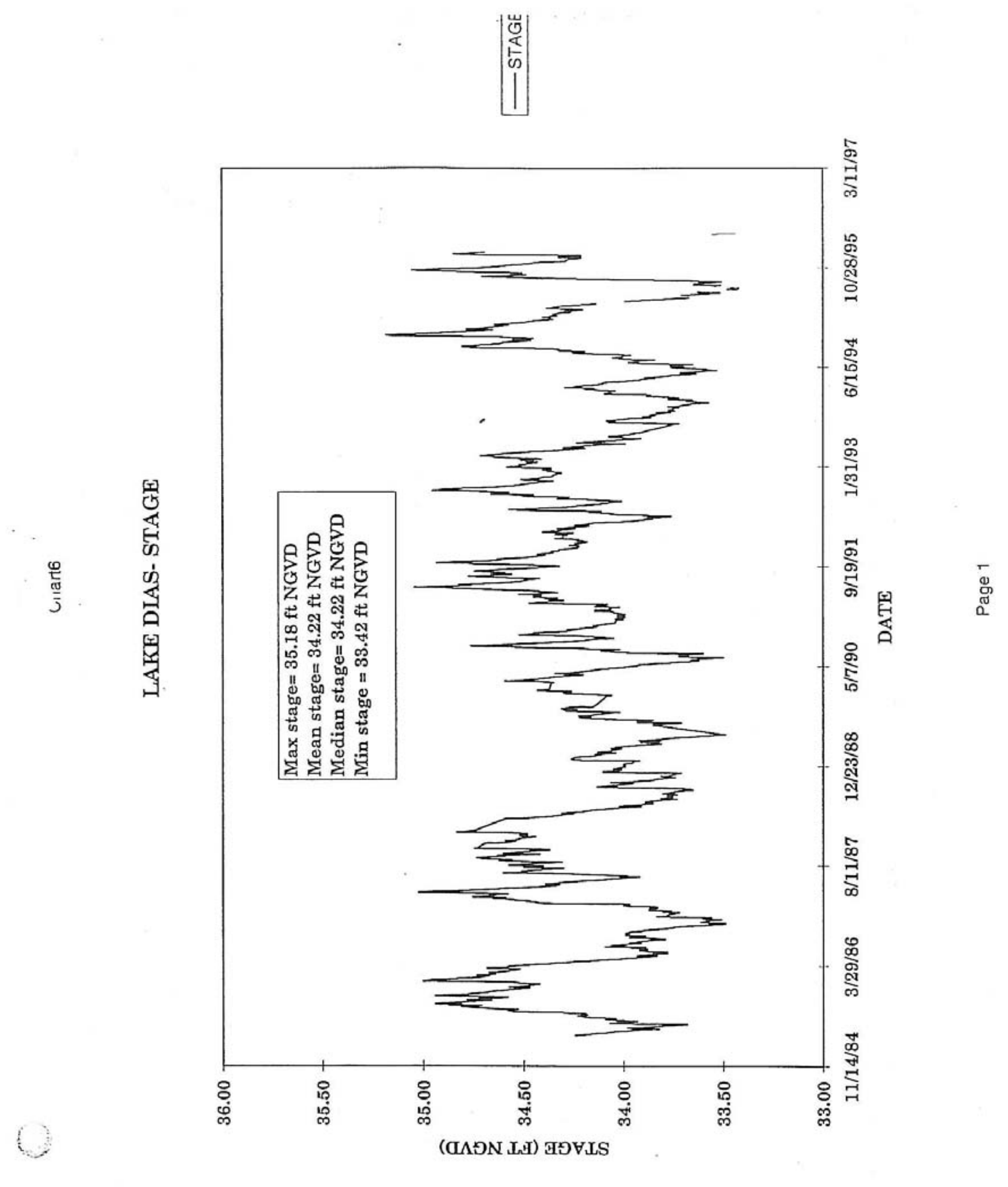


Fig 4. Percent Exceedence Curve developed from daily data from Lake Dias.

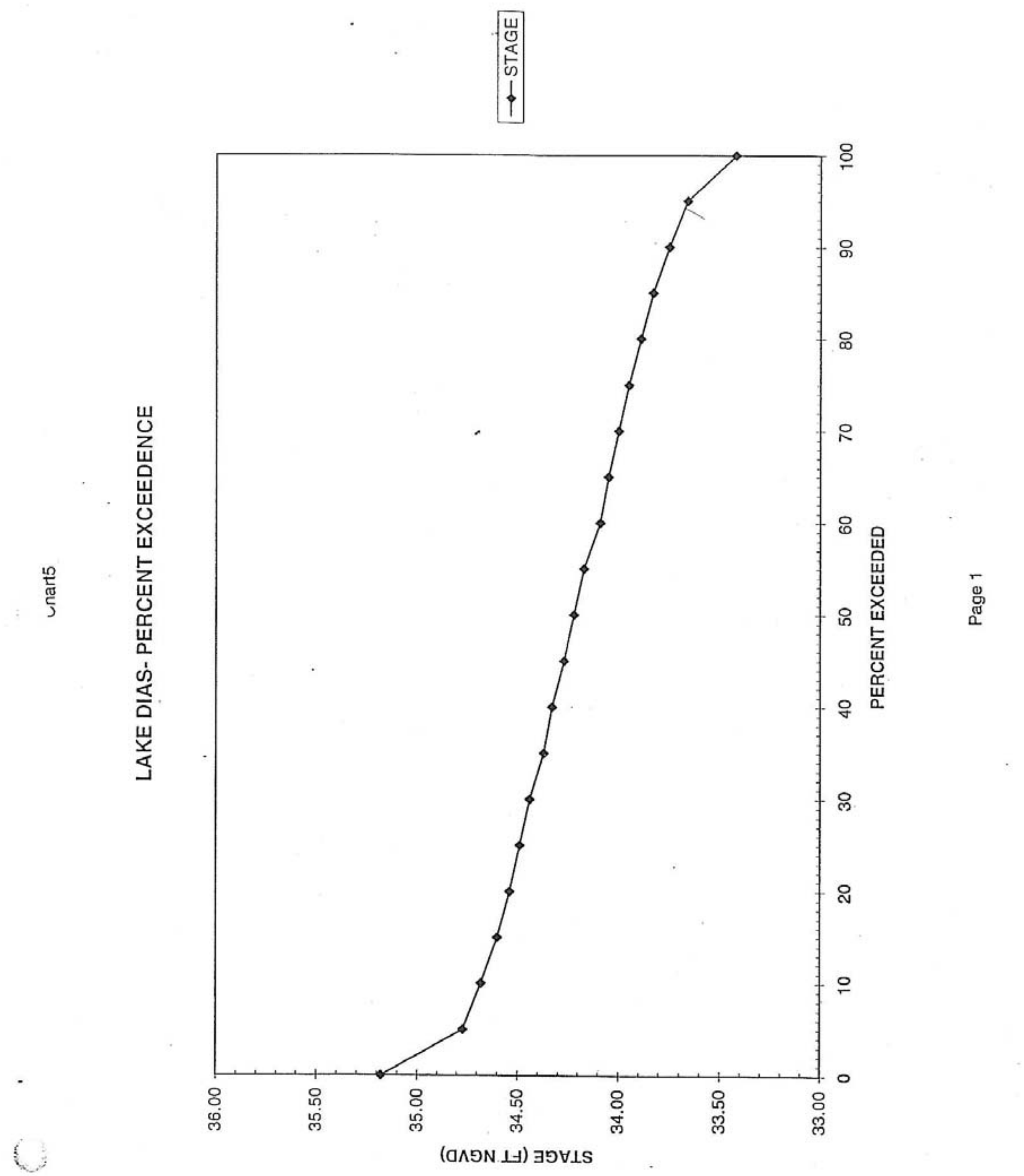
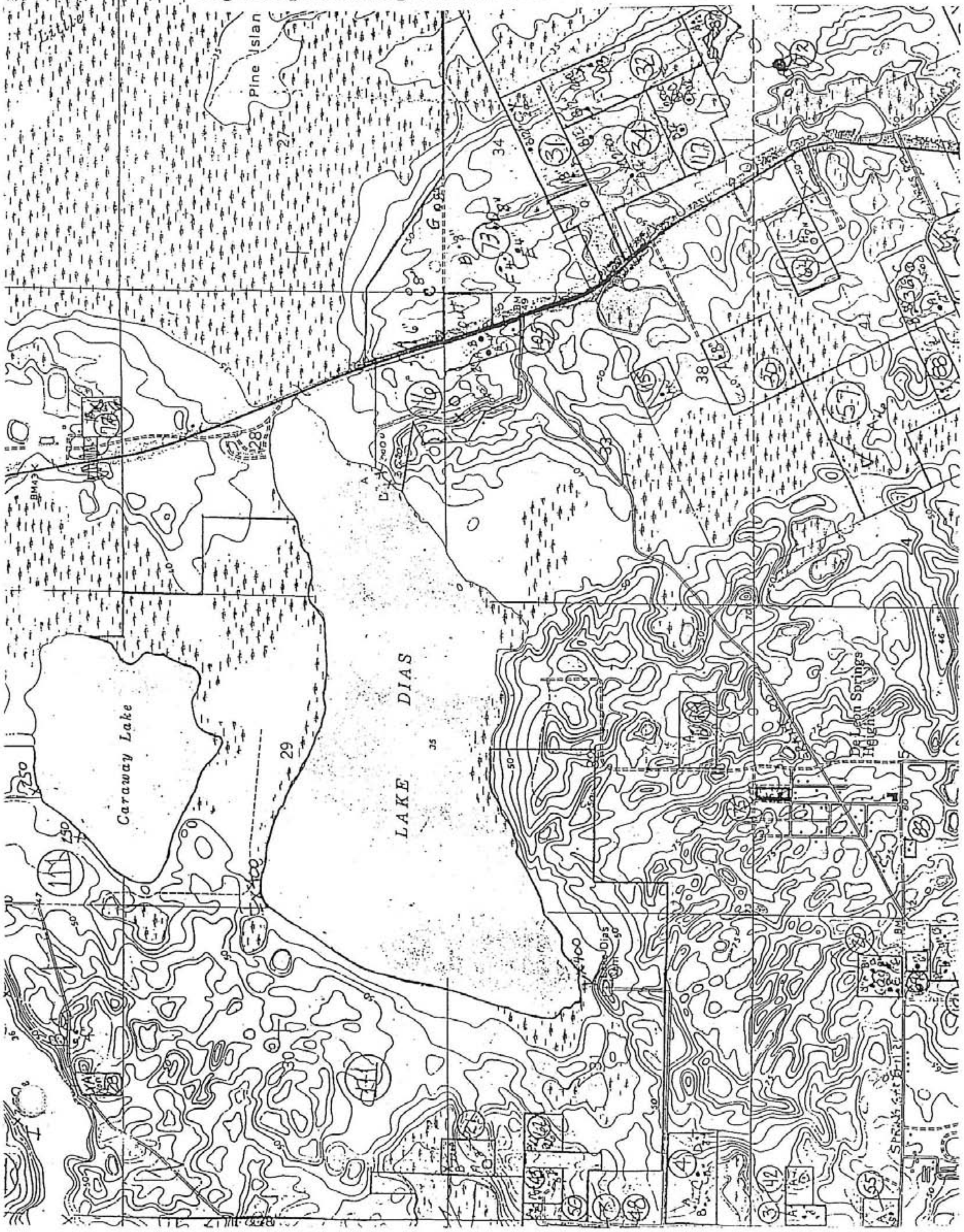


Fig 5. Map indicating location of consumptive uses permitted near Lake Dias.



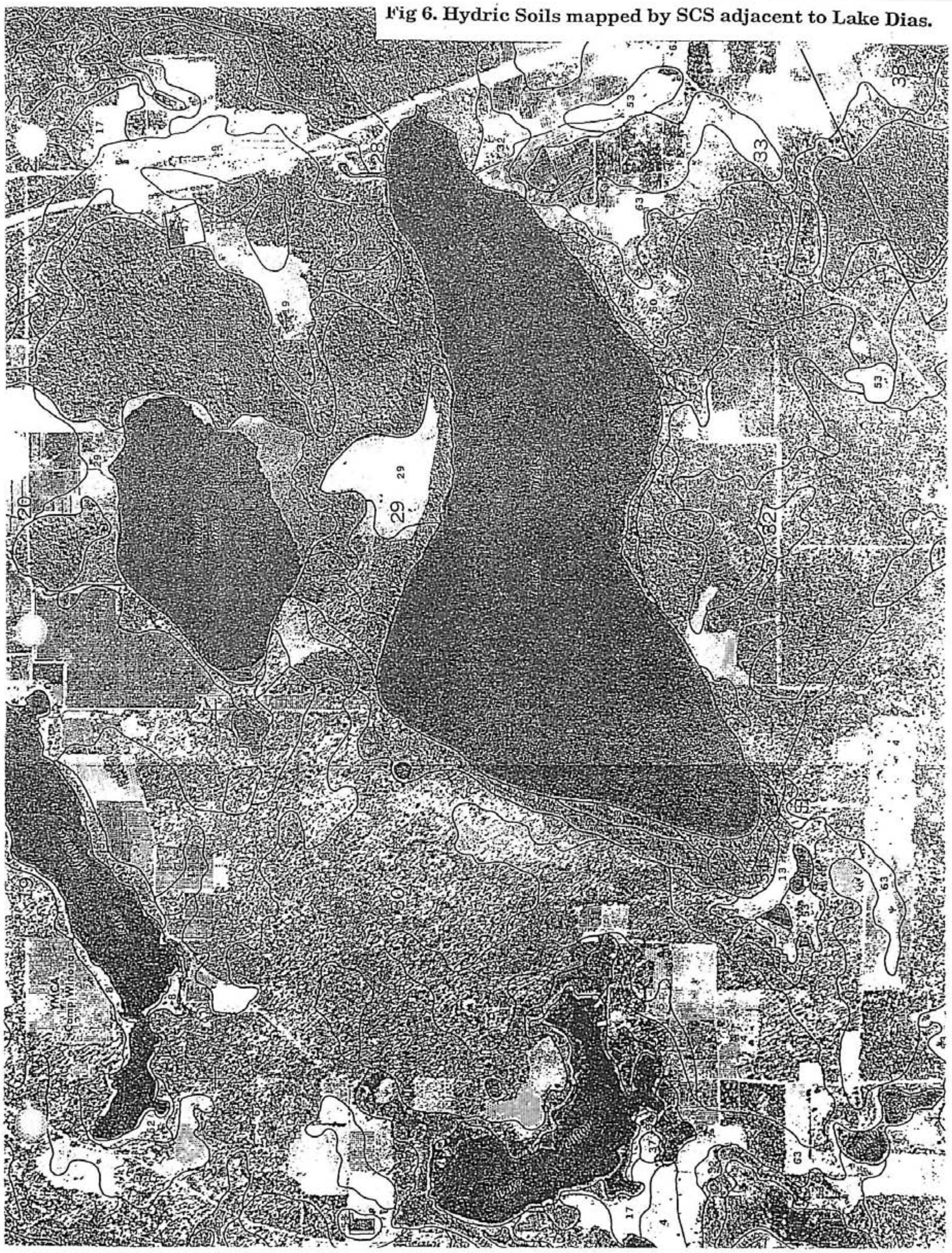


Fig 6. Hydric Soils mapped by SCS adjacent to Lake Dias.

Fig 7. US Fish and Wildlife Wetland Inventory mapped wetlands adjacent to Lake Dias.

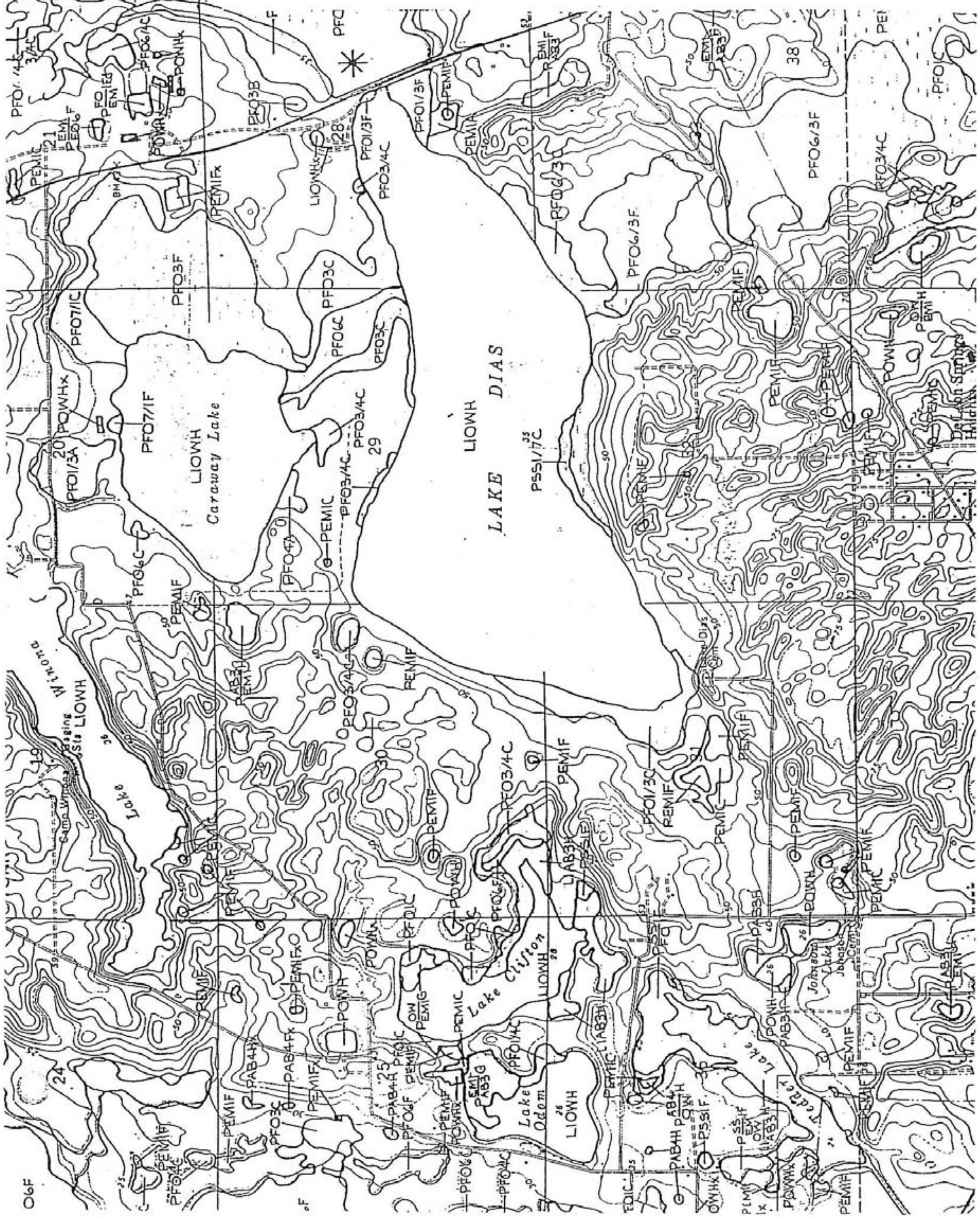
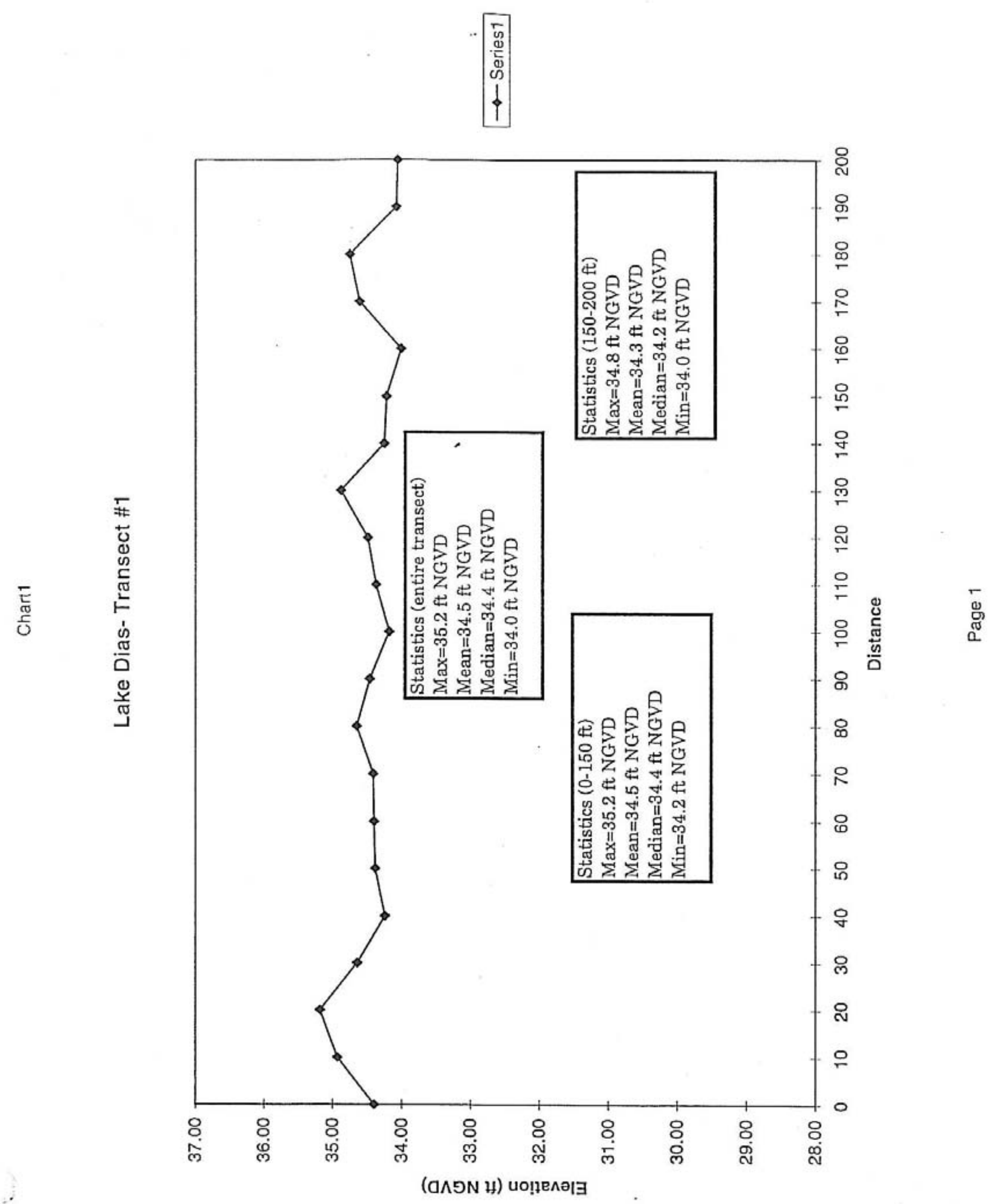


Fig 8. Transect #1 from Lake Dias.



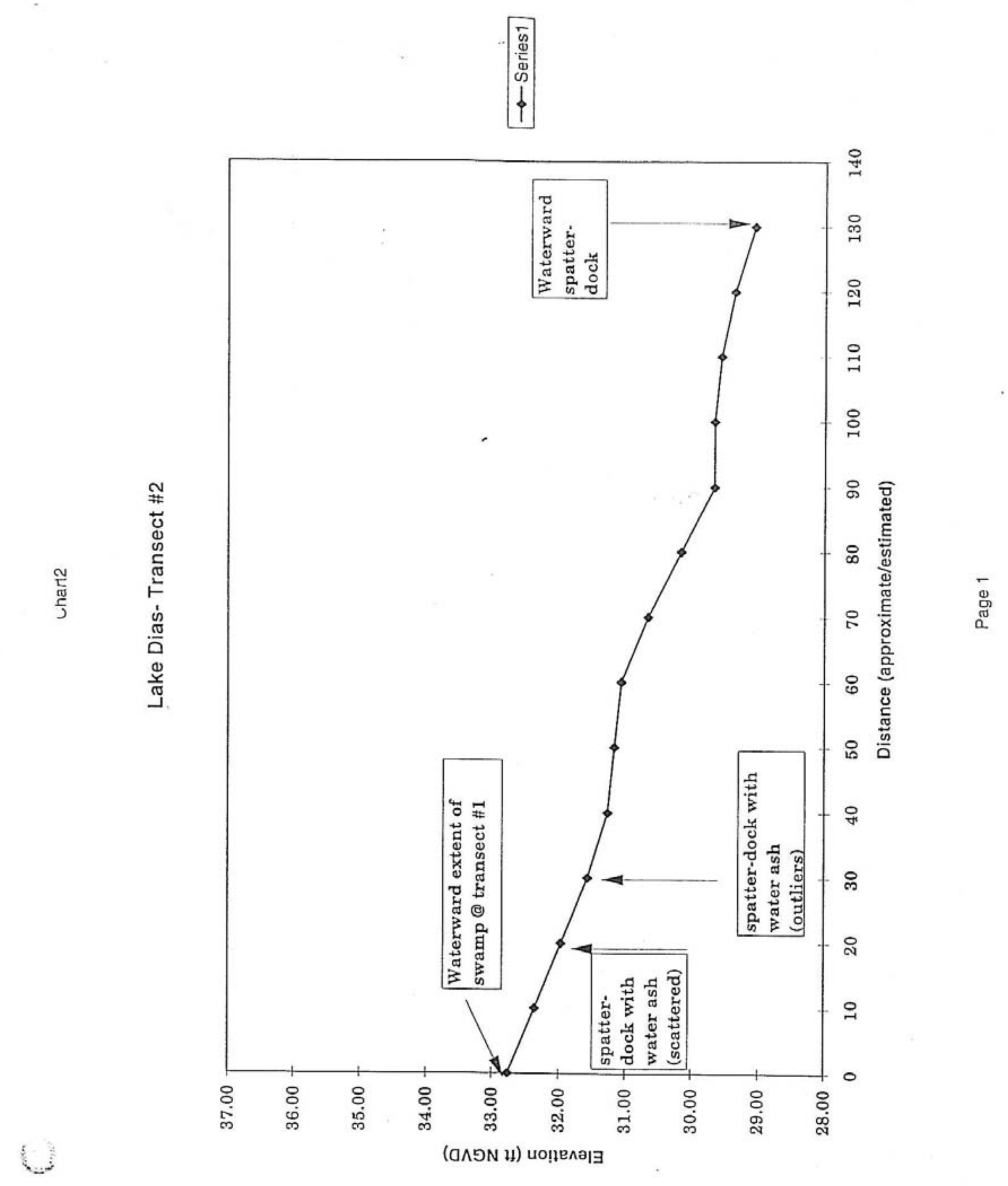
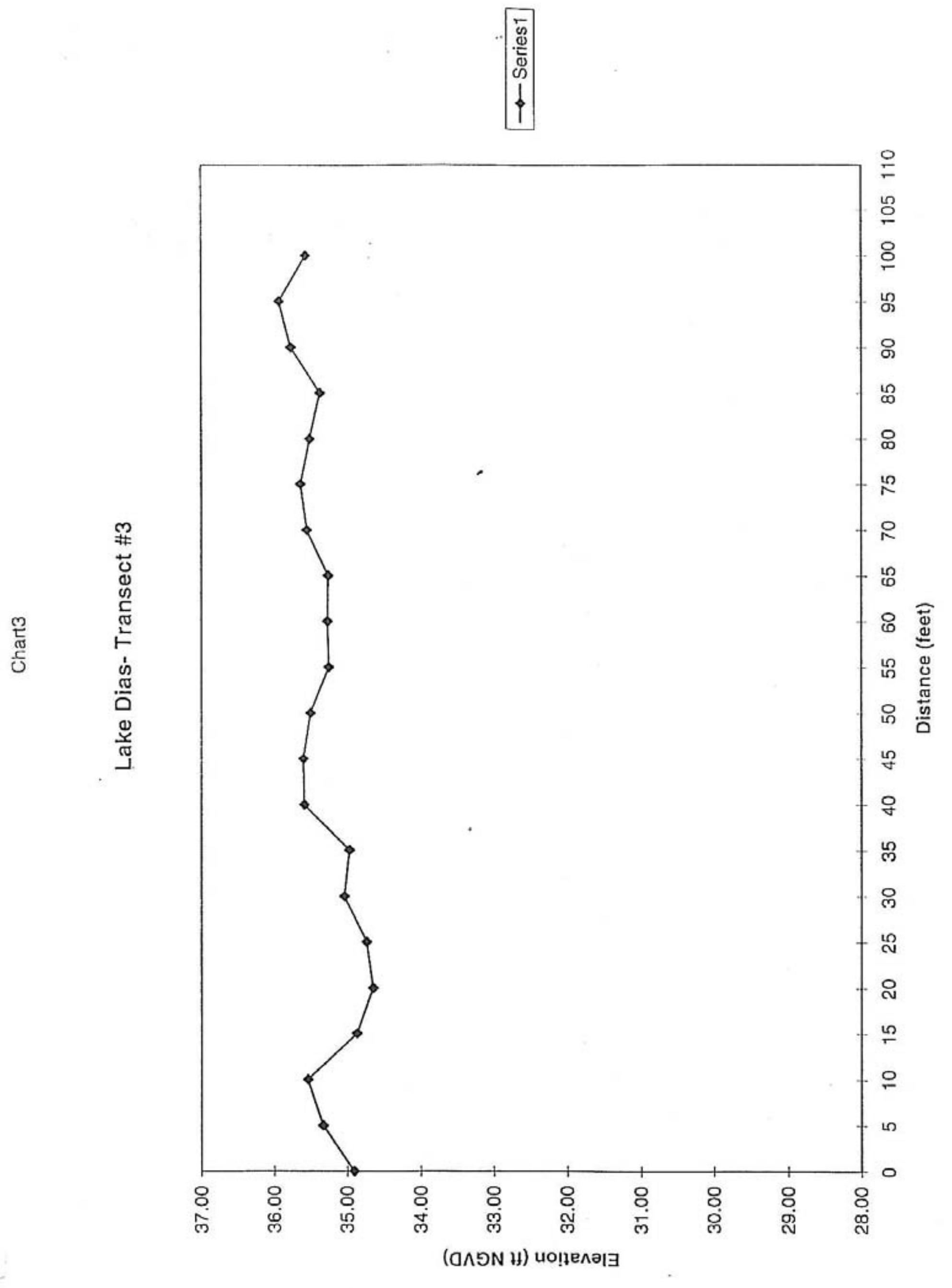


Fig 9. Transect #2 from Lake Dias.

Fig 10. Transect #3 from Lake Dias.



APPENDIX B—IMPLEMENTATION OF MFLS FOR LAKE DIAS

Prepared by
C. Price Robison, P.E., St. Johns River Water Management District (2007)

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 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:

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

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

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

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

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

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

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

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

$$T = \frac{1}{P} \qquad \text{(B8)}$$

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

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

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 Dias MFLs

This section describes the process used to relate long-term hydrologic statistics to the establishment of MFLs. SJRWMD has determined three recommended MFLs for Lake Dias: (1) a minimum frequent high (FH) level; (2) a minimum average (MA) level; and (3) 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 three 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 Dias (CDM 2003). 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 surface water withdrawals occurred at the same level at which they occurred in 2001. The Lake Dias model included water surface withdrawals for irrigation of 35 acres of fern and freeze protection of 14 acres of fern. 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 3 years on the right; and (3) a vertical line corresponding to a frequency of occurrence of once every 2 years on the left is superimposed on the plot (Figure B7). Similar analyses were performed for the MA level (Figure B8) and for the FL level (Figure B9). All three levels are being met under these conditions.

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

Based on model calibration, there is no significant connection between Lake Dias and the Floridan aquifer. Therefore, regional groundwater withdrawals will not significantly affect Lake Dias stages.

Table B1. Summary of recommended MFLs for Lake Dias

MFLs	Level (ft NGVD)	Duration	Series	Water Year	Statistical Type	Minimum Return period	Maximum Return period
Minimum frequent high (FH)	34.6	30 days	Annual	June 1–May 31	Maximum, continuously exceeded	NA	3 yrs
Minimum average (MA)	33.5	180 days	Annual	Oct. 1–Sept. 30	Minimum mean, not exceeded	1.5 yrs	NA
Minimum frequent low (FL)	32.2	120 days	Annual	Oct. 1–Sept. 30	Minimum, continuously not exceeded	5 yrs	NA

ft NGVD = feet National Geodetic Vertical Datum

References

[CDM] Camp, Dresser and McKee. 2003. *Model Development for MFL Evaluation of Lake Dias, Volusia County*. Jacksonville, Florida.

Linsley, R.K., M.A. Kohler, and J.L.H. Paulhus. 1982. *Hydrology for Engineers*. 3rd ed. New York: McGraw-Hill.

Ponce, V.M. 1989. *Engineering Hydrology: Principles and Practices*. Englewood Cliffs, N.J.: Prentice Hall.

[USGS] U.S. Geological Survey. 1982. *Guidelines for Determining Flood Flow Frequency*. Bulletin 17B. Reston, Va.: Interagency Advisory Committee on Water Data.

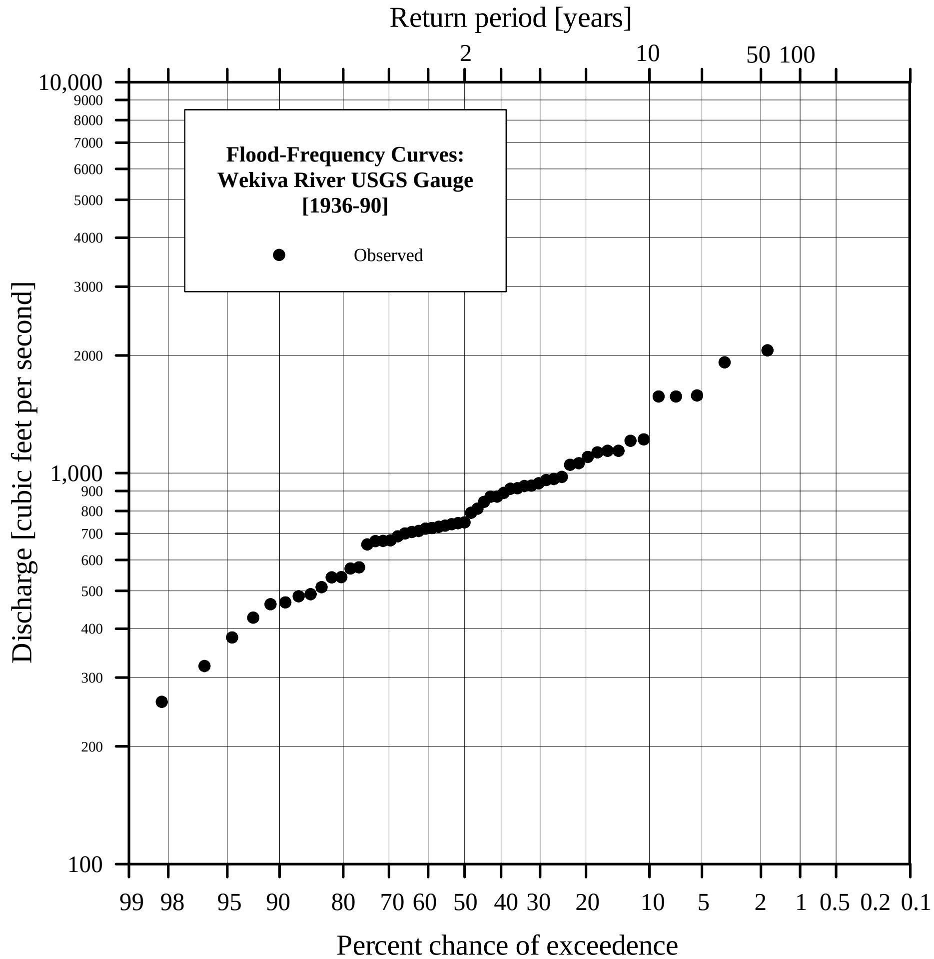


Figure B1. Flood frequencies for the Wekiva River at the USGS gauge near Sanford, Fla.; the 1–day peak flows have been sorted, ranked, and plotted according to the Weibull plotting position formula

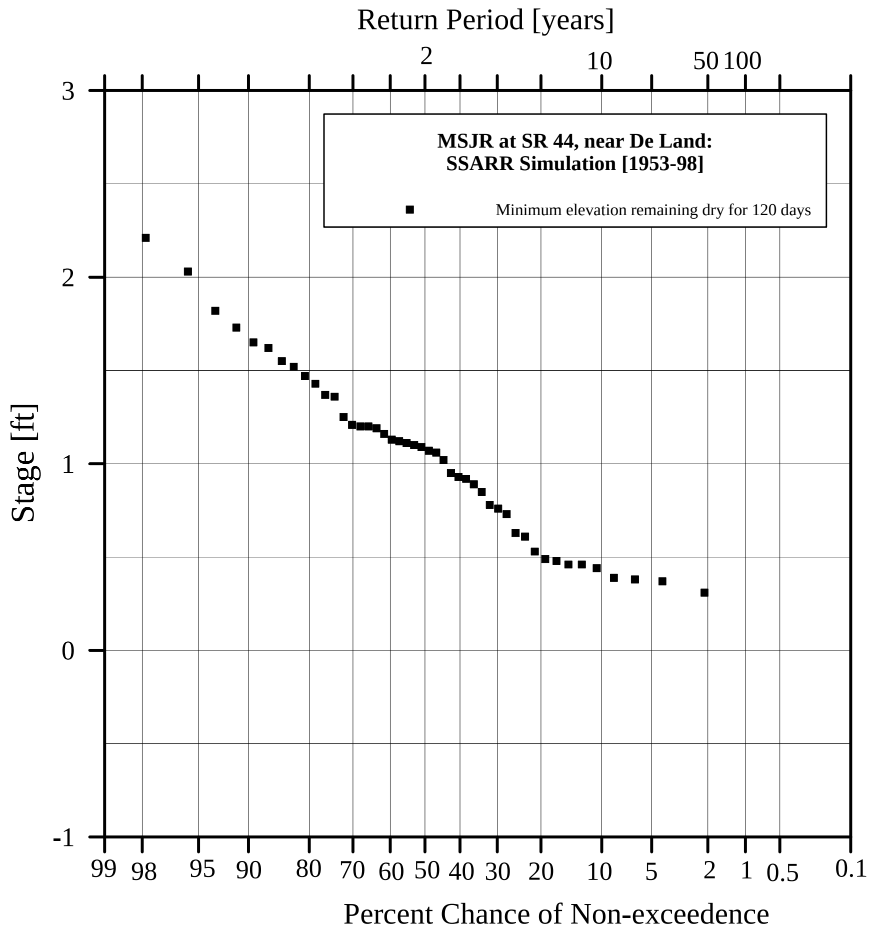


Figure B2. Drought frequencies computed using daily stages simulated by the MSJR SSARR model at SR 44, near DeLand; the minimum stages continuously not exceeded for 120 days have been sorted, ranked, and plotted according to the Weibull plotting position formula

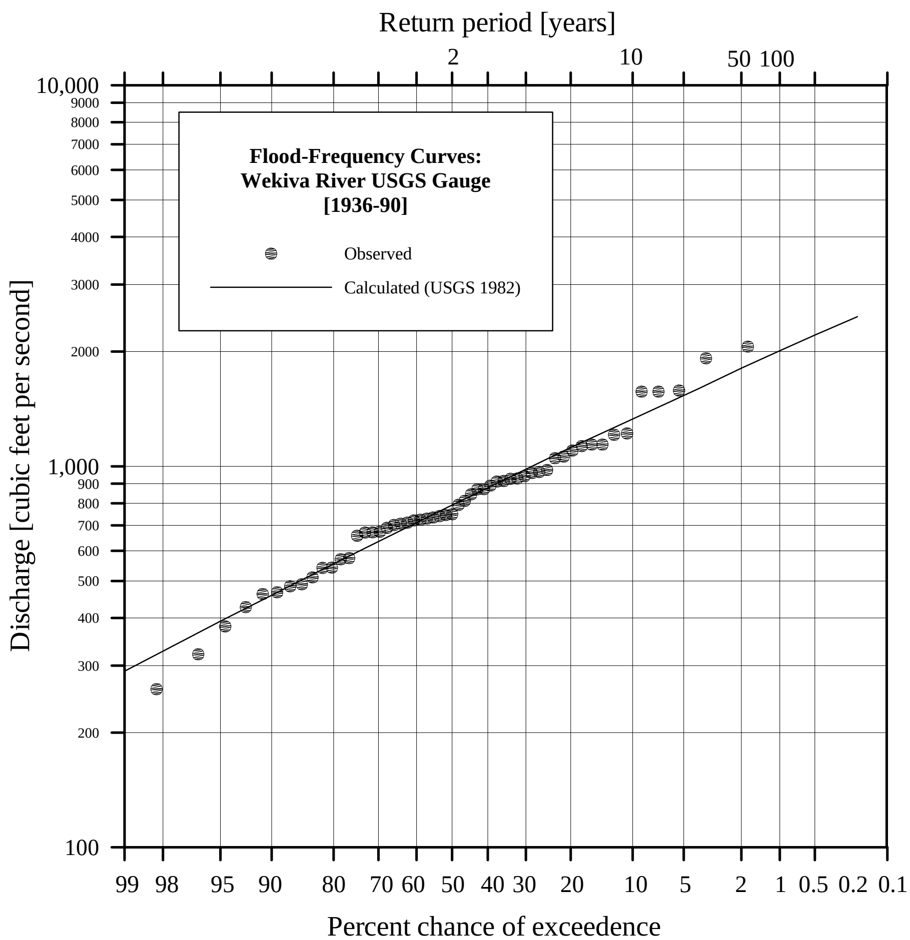


Figure B3. Flood frequencies for the Wekiva River at the USGS gauge near Sanford, Fla.; fitted by standard mathematical procedure

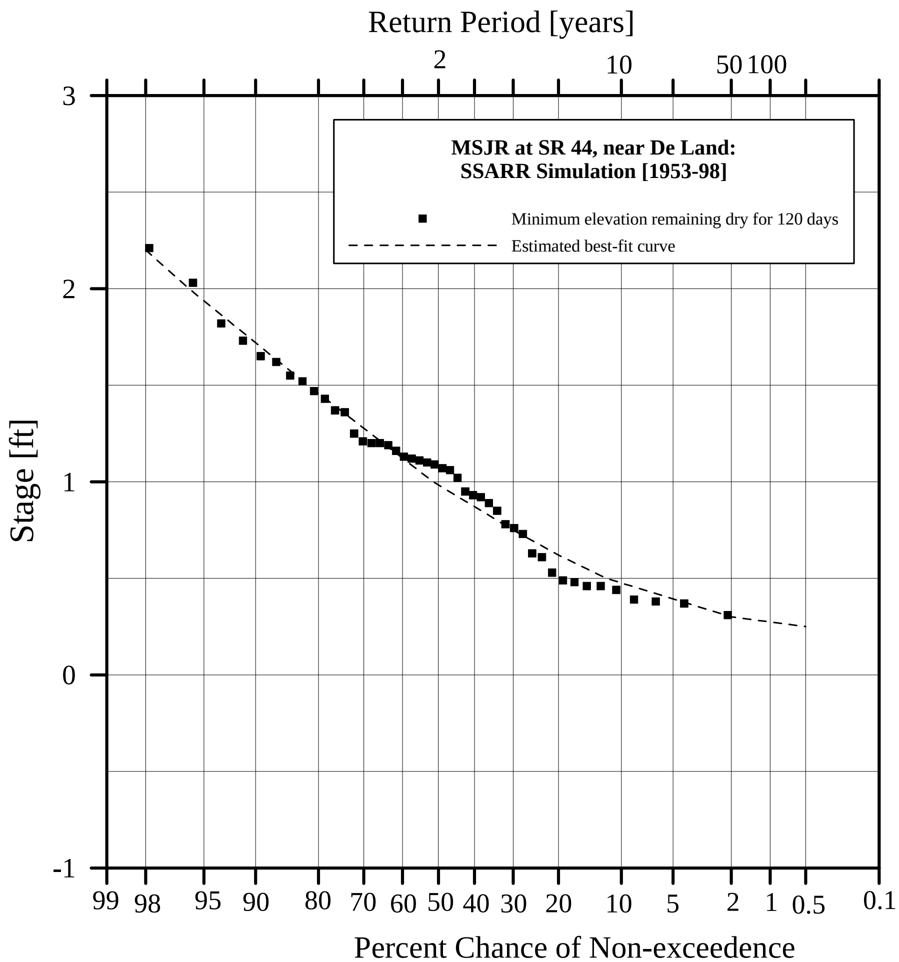


Figure B4. Drought frequencies computed using daily stages simulated by the MSJR SSARR model at SR 44, near DeLand, fitted by the graphical method

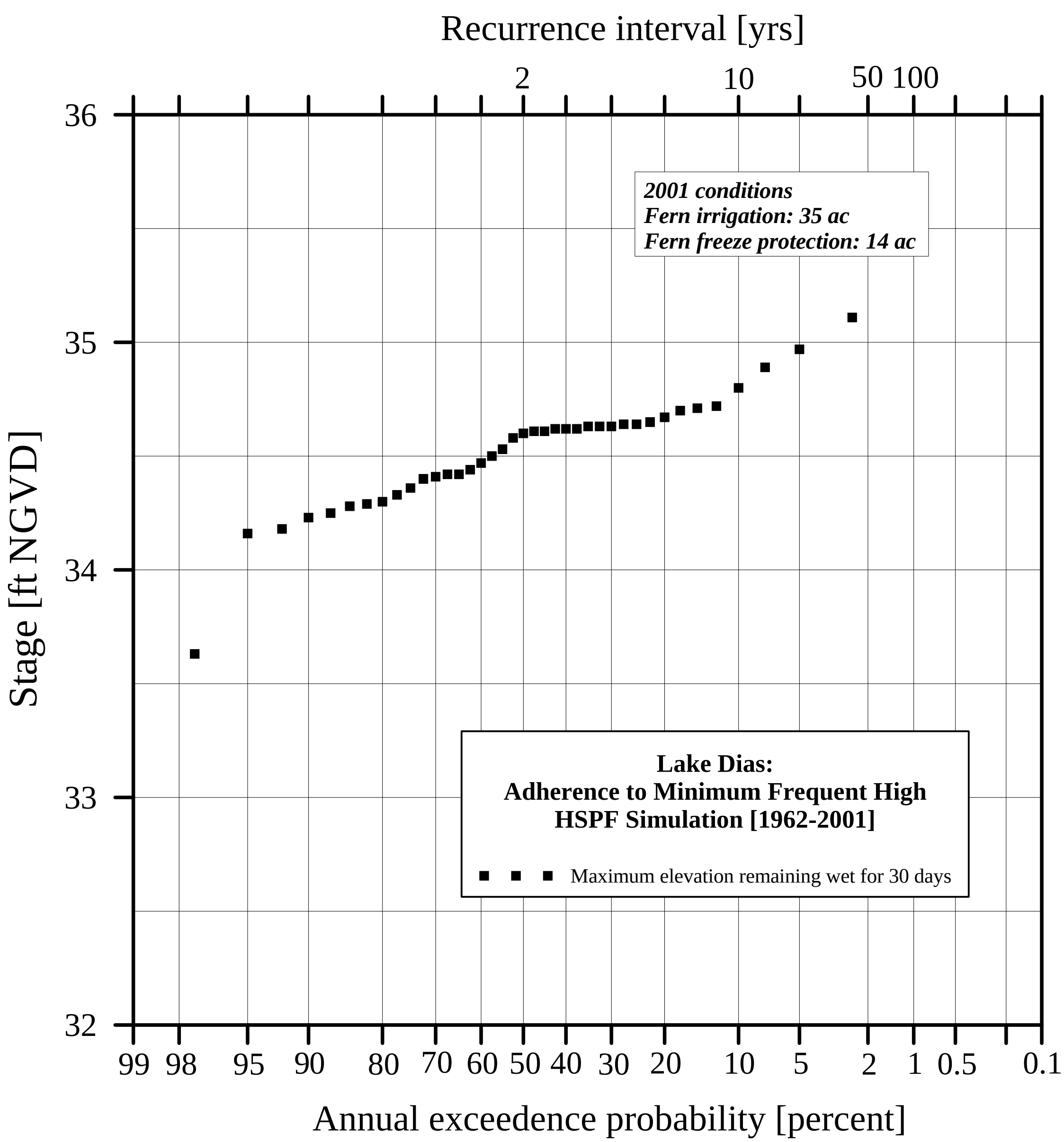


Figure B5. Flood frequencies computed using daily stages from model simulations of Lake Dias, for elevations continuously wet for 30 days and 2001 conditions; the model included surface water withdrawals for irrigation of 35 acres of fern and freeze protection of 14 acres of fern

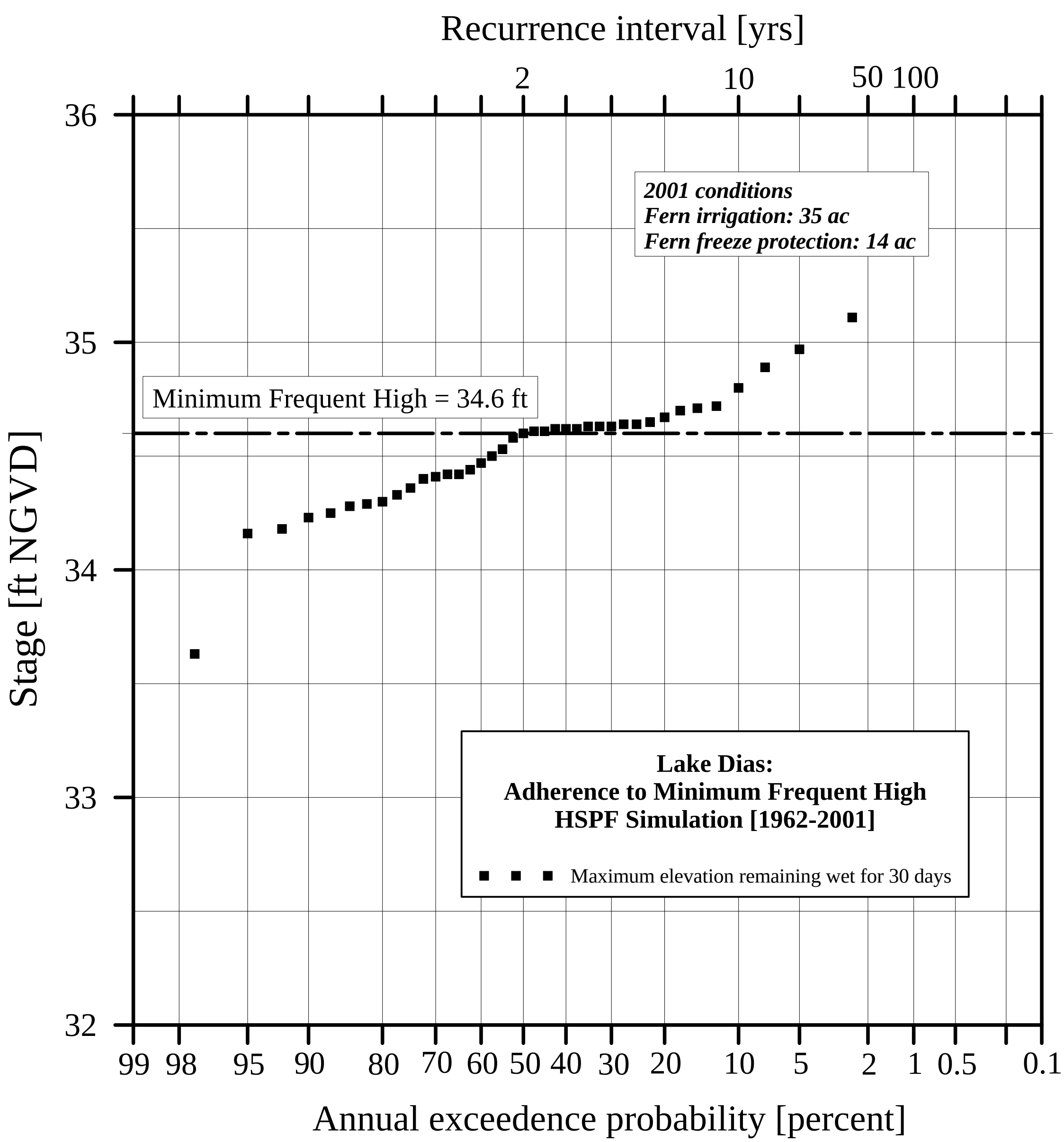


Figure B6. Flood frequencies computed using daily stages from model simulations of Lake Dias, for elevations continuously wet for 30 days and 2001 conditions with the FH of 41.2 ft NGVD superimposed; the model included surface water withdrawals for irrigation of 35 acres of fern and freeze protection of 14 acres of fern

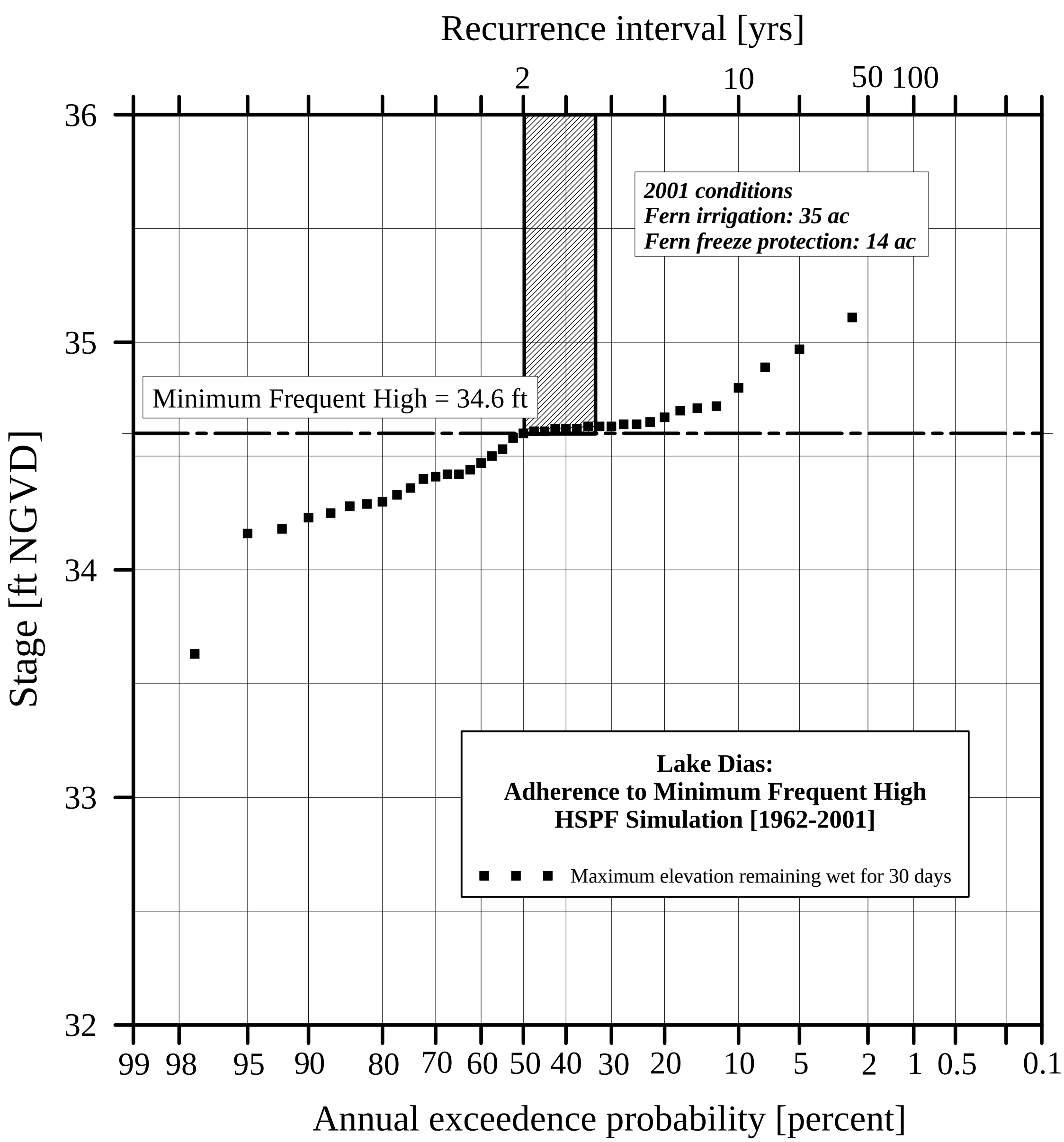


Figure B7. Flood frequencies computed using daily stages from model simulations of Lake Dias, for elevations continuously wet for 30 days and 2001 conditions with a superimposed box bounded by: (1) the FH; (2) a vertical line corresponding to a return period of 2 years; and (3) a vertical line corresponding to a return period of 3 years; the model included surface water withdrawals for irrigation of 35 acres of fern and freeze protection of 14 acres of fern

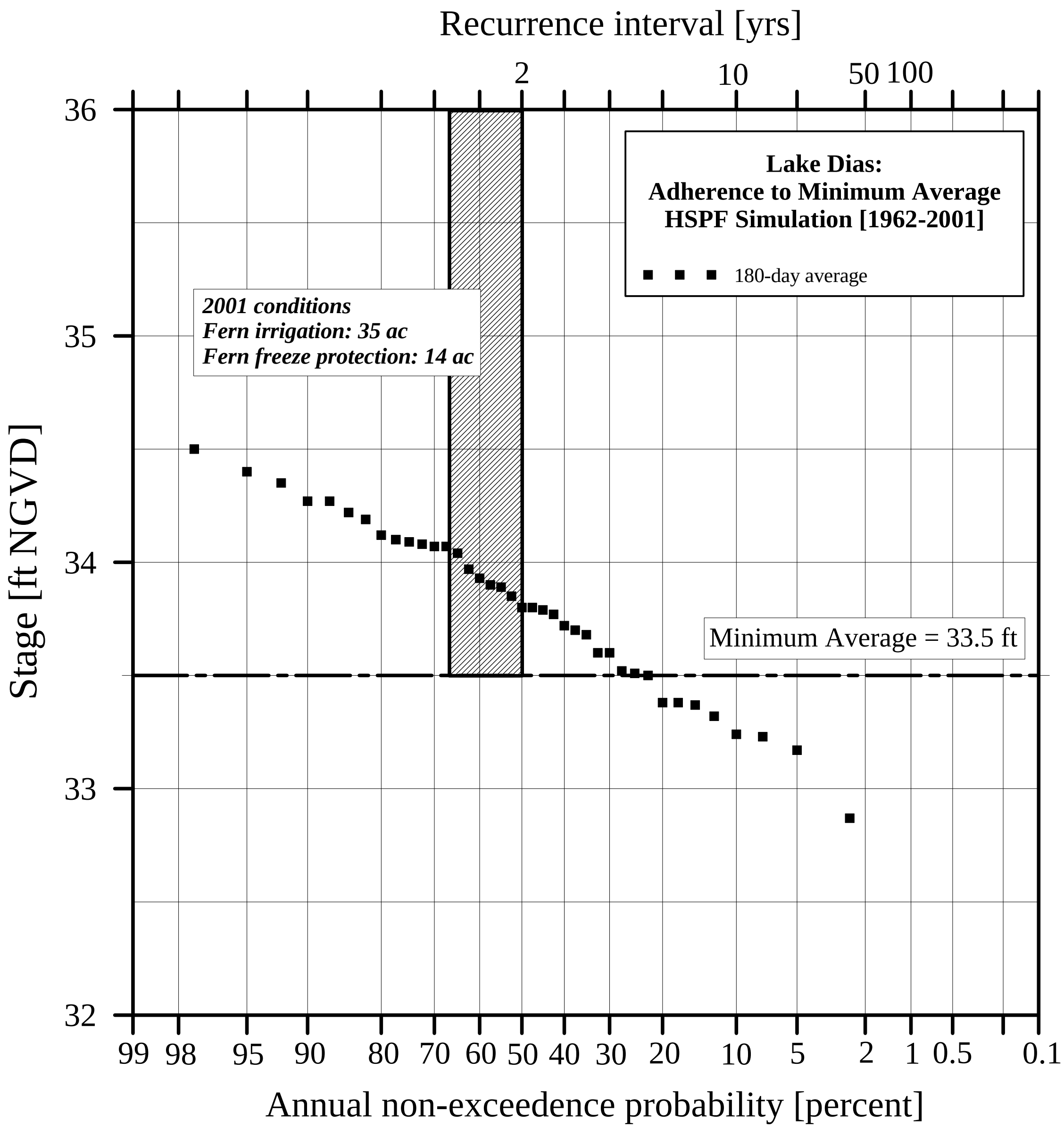


Figure B8. Drought frequencies computed using daily stages from model simulations of Lake Dias, for the MA level and 2001 conditions; the model included surface water withdrawals for irrigation of 35 acres of fern and freeze protection of 14 acres of fern

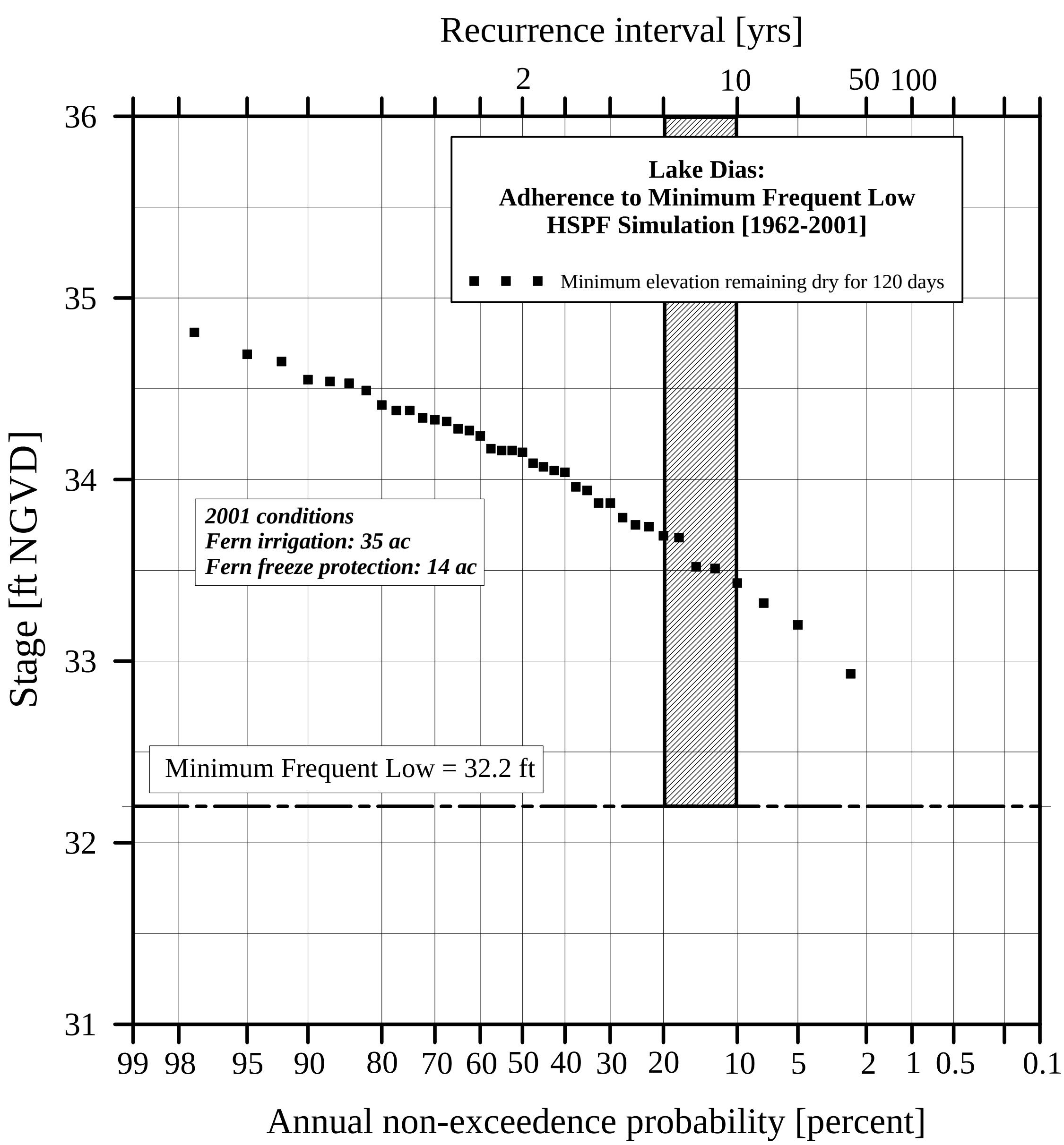


Figure B9. Drought frequencies computed using daily stages from model simulations of Lake Dias, for the FL level and 2001 conditions; the model included surface water withdrawals for irrigation of 35 acres of fern and freeze protection of 14 acres of fern