Report of the
SCIENTIFIC PEER REVIEW PANEL

ON THE

DATA, THEORIES, AND METHODOLOGIES
SUPPORTING THE
MINIMUM FLOWS AND LEVELS RULE
FOR THE
NORTHERN TAMPA BAY AREA, FLORIDA

Prepared for

SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT
ENVIRONMENTAL CONFEDERATION OF SOUTHWEST FLORIDA
HILLSBOROUGH COUNTY
TAMPA BAY WATER

Prepared by

PEER REVIEW PANEL: Phil Bedient
Mark Brinson
Forrest Dierberg
Steven Gorelick
Kenneth Jenkins
Don Ross
Kenneth Wagner
Dave Stephenson, Chair

August 3, 1999

Report of the
SCIENTIFIC PEER REVIEW PANEL
ON THE
DATA, THEORIES, AND METHODOLOGIES
SUPPORTING THE
MINIMUM FLOWS AND LEVELS RULE
FOR THE
NORTHERN TAMPA BAY AREA, FLORIDA

Prepared for

SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT
ENVIRONMENTAL CONFEDERATION OF SOUTHWEST FLORIDA
HILLSBOROUGH COUNTY
TAMPA BAY WATER

Prepared by

PEER REVIEW PANEL: **Phil Bedient**
Mark Brinson
Forrest Dierberg
Steven Gorelick
Kenneth Jenkins
Don Ross
Kenneth Wagner
Dave Stephenson, Chair

August 3, 1999
Report of the PEER REVIEW PANEL

Report of the PEER REVIEW PANEL

TABLE OF CONTENTS

List of APPENDICES

List of FIGURES

List of TABLES

ACRONYMS & DEFINITIONS

AGWQMP	Southwest Florida Water Management *District's Ambient Ground-water Quality Monitoring Program*
BOD	biological oxygen demand
Category 1 Lakes	Cypress wetland fringed lake where structural alterations do not prevent Historic P50 from rising above an elevation equal to normal pool minus 1.8 feet. Note that the 1.8 foot was derived from reference palustrine cypress wetlands and represents a threshold which, when subtracted from the normal pool, will cause significant harm if the difference (i.e., normal pool minus1.8 feet) is lower than the P50 for a palustrine cypress wetland.
Category 2 Lakes	Cypress wetland fringed lake where structural alterations prevent Historic P50 from rising above an elevation equal to normal pool minus 1.8 feet, but the cypress wetland continues to provide functions deemed beneficial to the lake.
cfs	cubic feet per second
CGWQMP	Southwest Florida Water Management District's *Coastal Ground-Water Quality Monitoring Program*
Control Structure	A structural alteration to a lake outlet that affects the lake water level.
Control Point **(CP)**	The elevation of the point along the control structure profile or outlet channel that controls water level.
Current	From a time period in which impacts from wells are considered *significant.*
District	Southwest Florida Water Management District
DO	Dissolved oxygen
EMAL	Environmental Minimum Aquifer Level
FS	Florida Statutes
High Guidance Level **(HGL)**	An estimate of the high water level for purposes of siting buildings, docks and related structures. Depending upon the presence of historic data and structures, HGL is set as follows [*see Figure 13 of the Lakes White Papers*]: ▪ Where historic data exist, HGL = historic P10. ▪ Where only current data exist and structural alteration has not lowered the control point below the normal pool, HGL = current P10 or normal pool, whichever is higher.

- Where only current data exist and structural alteration has lowered the control point below the normal pool, HGL = current P10 or control point, whichever is higher.
- Where no water- level data exist, HGL = control point or normal pool elevation, whichever is lower.

Hydrologic Indicator **(HI)** A measurable permanent feature which allows determination of historical water levels and equivalent to the normal pool; cypress buttress base elevations as measured by the location of the inflection point were used for the test lakes addressed in this document.

Historic From a time period in which impacts from wells are considered *insignificant*.

Historic P50 The P50 value estimated for the time period when well impacts were insignificant, calculated as follows [*see Figure 14 of the Lakes White Papers*]:

- Where historic data exist, Historic P50 = P50 from historical data.
- Where only current data exist and Current P10-Current P50 < RLWR50, Historic P50 = HGL - (Current P10 - Current P50). Note that HGL may equal Historic P10, Current P10, normal pool or the control point.
- Where only current data exist and Current P10-Current P50 > RLWR50, Historic P50 = HGL-RLWR50.
- Where no data exist, Historic P50 = HGL-RLWR50.

High Minimum Level **(HML)** A regulatory P10 value for avoiding unacceptable impacts and is set as follows [*see Figure 15 of the Lakes Section (Part 2) in the White Papers*]:

- If Historic P50 > normal pool minus 1.8 feet (Category 1 Lakes), then the HML = normal pool minus 0.4 foot. Note that 0.4 foot comes from evaluation of impacts of water level on reference palustrine cypress wetlands.
- If Historic P50 < normal pool minus1.8 feet (Category 2 Lakes), then the HML = HGL. Note that HGL may equal Historic P10, Current P10, normal pool or the control point

IR Infrared (aerial photography)

Low Guidance Level **(LGL)** A regulatory P90 value and an estimate of the low water level for purposes of siting buildings, docks and related structures, and management of outflow control structures. Depending upon the presence of historic data and structures, LGL is set as follows [*see Figure 16 of the Lakes White Papers*]:

- Where historic data exist, LGL = Historic P90.
- Where only current data exist and Current P10 - Current P90 < RLWR90, LGL = HGL minus (Current P10 - Current P90).
- Where only current data exist and Current P10 - Current P90 > RLWR90, LGL = HGL minus RLWR90.
- Where no water-level data exist, LGL = HGL minus RLWR90.

MFL	Minimum flows and levels
mgd	Million gallons per day
mg/L	Milligrams per liter
***Minimum Level* (ML)**	A regulatory P50 value for avoiding unacceptable impacts and is set as follows [*see Figure 15 of the Lakes White Papers*]:

- If Historic P50 > normal pool minus 1.8 feet (Category 1 Lakes), then the ML = normal pool minus 1.8 feet.
- If Historic P50 < normal pool minus 1.8 feet (Category 2 Lakes), then the ML = Historic P50. Note that Historic P50 may equal P50 from historical data, HGL minus (Current P10 - Current P50), or HGL minus RLWR50.

NGVD	National Geodetic Vertical Datum
***Normal Pool* (NP)**	The historic "high" water level as estimated from hydrologic indicators. Generally assumed to be close to the P10 level, but not necessarily identical to it.
NTBWRAP	Northern Tampa Bay Water Resource Assessment Project
Outliers	Points in a data set that represent a suspiciously large deviation from the fitted curve.
P10	Lake surface elevation that is exceeded 10% of the time; generally a measure of the highest water level likely without extreme conditions.
P50	Lake surface elevation that is exceeded 50% of the time; median lake level.
P90	Lake surface elevation that is exceeded 90% of the time; generally a measure of the lowest water level likely without extreme conditions.
Panel	Scientific Peer Review Panel
Parties	District and Requesters
POR	Period of record
ppt	parts per thousand

Reference Lakes	A set of 22 (out of 88) reviewed lakes from the Lakes Terrace region determined to have either no significant water-level changes from well withdrawals (16 lakes) or at least 10 years of historic (pre-withdrawal) water-level data (6 lakes).
Requesters	Hillsborough County, Tampa Bay Water, and the Environmental Confederation of Southwest Florida
Reference Lake Water Regime (RLWR)	The set of median differences between P10, P50 and P90 as statistically defined from a set of reference lakes. For the set of 22 reference lakes from the Northwest Hillsborough Region, the median of (P10-P50) = RLWR50 = 1.0 foot, and the median of (P10 - P90) = RLWR90 = 2.1 feet.
ROMP	Southwest Florida Water Management District's *Regional Observation Monitoring Program*
S-160	Structure 160 on the Tampa Bay Canal;
sd	Standard deviation
SWFWMD	Southwest Florida Water Management District
TBC	Tampa Bypass Canal
TDS	Total dissolved solids
Ten-Year Flood Guidance Elevation (TYF)	An undescribed measure of flood potential. This appears in the test lake scenarios and is given for many lakes in the WRAP study (Ref-42), but has no defined role in the setting of minimum water levels through this process.
TOC	Total organic carbon
TSS	Total suspended solids
USGS	U.S. Geological Survey
Water Resources Assessment Project (WRAP)	This Northern Tampa Bay 1996 study was of an area including parts of Hernando, Pasco, Hillsborough, and Pinellas Counties, and containing the Lakes Terrace, Brooksville Ridge, and other defined regions. The water-level review for this report involved only the Lakes Terrace region (also known as the Northwest Hillsborough Region).
WUP	Water Use Permit

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

This is a summary of the Scientific Peer Review Panel's evaluation of scientific and technical data, assumptions, and methodologies used by the Southwest Florida Water Management District in the development of its proposed Minimum Flows and Levels. To aid in conveying the Panel's responses to the "Specific Tasks" given within *the Charge to the Scientific Peer Review Panel*, a summary is presented in **Table 1**. The table provides answers to the questions posed in the Charge to the Panel. The Panel reformatted these original questions into declarative statements to give four possible responses: *substantially supported, partially supported, not substantially supported*, or *not applicable*. Readers are strongly encouraged to examine the entire report to gain a better understanding of the analyses supporting the tabular summary.

Although there are many areas in which the Panel believes the District could have enhanced its database and associated analyses, the Panel finds that the District approached a complex set of issues in a scientific and comprehensive manner. To the best of the Panel's knowledge, many of the issues had not been successfully addressed anywhere previously, and the District's effort is on the cutting edge of water-management science. However, as it is the nature of a peer review process to be critical, the Panel has pointed out areas where assumptions or analyses are inadequately supported by the data and has raised questions about the corresponding results. The Panel has, to the best of its ability, attempted to provide guidance for future efforts to refine the process of setting Minimum Flows and Levels. The Panel commends the District for its efforts to seek sound scientific answers to difficult technical questions.

The methodologies proposed by the District for the establishment of Minimum Levels are generally sound and reasonable. The methodologies, assumptions, and conclusions for the establishment of Minimum Flows (Tampa Bypass Canal) are significantly deficient.

The Panel finds that the approaches taken to determine Minimum Levels represent good starting points for further methodological improvements. Upon review of the information provided, the Panel observed no significant deficiencies in the manner in which data were collected or occasionally discarded, and the information utilized appeared in most instances to be the best available. Review of the technical assumptions led the Panel to conclude that, for determination of Minimum Levels, there were no significant deficiencies in the reasonableness of assumptions employed, and that, in general, other analyses would require more assumptions or would not have yielded better results. Assumptions were not eliminated to the extent possible, but this was not considered to be a major impediment except in the case of the analysis of wetlands.

Upon review of procedures, the Panel raised many questions about the appropriateness, completeness, proper handling of limitations, and proper application of analyses. This review led the Panel to find that the conclusions are largely, but not entirely,

Table 1
Responses to Questions Posed to Panel in the Charge

	Statements Based on Questions Posed to Panel	WETLANDS	LAKES	SWI	EMAL	TBC
	Review the Information					
1a	Reasonable quality assurance assessments were performed on the information.	●	■	●	NA	●
1b	The discarding of relevant information was properly justified.	○	○	○	NA	●
1c	Data used in the establishment of Minimum Flows and Levels were collected properly.	●	●	○	NA	○
1d	"Best information available" (as of July 1997) was utilized in developing Minimum Levels for isolated cypress wetlands and flows for the TBC..	○	NA	NA	NA	○
1e	"Best information available" (as of July 1998) was utilized in developing Minimum Levels for salt-water intrusion in the Upper Floridan aquifer and lakes with fringing isolated cypress wetlands.	NA	○	●	NA	NA
	Review the Technical Assumptions					
2a	Assumptions are reasonable and consistent given the "best information available".	○	●	○	●	■
2b	Assumptions were eliminated to the extent possible with available information.	■	○	○	NA	○
2c	Assumptions are clearly stated.	○	●	○	○	○
2d	Other analyses that would require fewer assumptions but provide comparable or better results were not available using existing data.	○	○	●	●	■
	Review the Procedures					
3a	Analyses were appropriate and reasonable given the "best information available".	●	○	●	NA	■
3b	Analyses include all necessary factors.	○	●	○	●	■
3c	Analyses were correctly applied.	○	●	○	NA	○
3d	Limitations and imprecisions in the information were handled reasonably.	○	○	●	NA	○
3e	Analyses are repeatable.	●	●	●	●	●
3f	Conclusions are supported by the data.	○	○	○	NA	■

NOTE:

●	The statement is substantially supported; sufficient information has been provided and/or evaluation by Panel finds no significant deficiencies.
○	The statement is partially supported; questions about information or analyses exist, but deficiencies are not currently viewed as extremely detrimental.
■	The statement is not substantially supported; insufficient information has been provided and/or evaluation by Panel has found significant deficiencies.
NA	Not Applicable

supported by the data. Although the methodologies may be acceptable, deficiencies in their application led to the establishment of Minimum Levels that require future adjustment.

Specific conclusions regarding Minimum Levels and Minimum Flow for each of the targeted resources are summarized below.

Palustrine Cypress Wetlands

The Panel found that the procedures and analyses used to evaluate palustrine cypress wetlands were generally laudable, that care was taken to use data properly and to avoid corrupted data, and that most technical assumptions were reasonable and did not adversely affect the outcome.

There are two substantive deficiencies in the establishment of the Minimum Levels for wetlands, both of which are believed curable. First, because the hydrological data set was relatively short and coincided with a series of drought years, the Panel found the water-level data were not representative of long-term conditions. Several methods have been advanced in this report to adjust the data for the drought. Second, statistical properties were discovered in the reference wetland data that appear to bias the results. Remedies are proposed for this problem.

Several alternative preferred methodologies are suggested for establishment of Minimum Levels. The perspective on hydrology should be broadened so that depth of flooding and water-table fluctuations are recognized and evaluated as fundamental predictors of change. Assessment of wetland area changes and the monitoring of wetland clusters are suggested as potential approaches to a more sophisticated use of Minimum Levels so that they do not rely on a single metric. As additional data are collected, the opportunity to classify cypress domes by hydrogeologic characteristics and other relevant features will help reduce variability and increase sensitivity for detecting change. Until enough data are available to support classification, a potential method is proffered for using normal pool and estimated P50s to establish wetland-specific Minimum Levels in cases where the blanket Minimum Level may not provide the desired level of protection.

Category 1 and Category 2 Lakes

The Panel concludes that the methodology used to establish the Minimum Levels for Category 1 and Category 2 lakes was done in a scientifically reasonable and defensible manner. The Panel further finds that the methodological approach for establishing the Reference Lake Water Regime and its application to the adopted lakes data set were appropriate. Even though more effort should have been devoted to quality control procedures and the reference lake selection process, the Panel agrees that the data were properly collected and provided a reasonably representative database.

The data analyses support the assumption that altered Upper Floridan and surficial aquifer hydraulic heads do impact lake-water levels in a quantifiable manner. However, the Panel is concerned about the reliability of using a single value of 1.8 feet in calculating a median water level for protecting cypress wetlands surrounding lakes. Not only did the Panel feel that 1.8 feet was too high of a standard (resulting in Minimum Levels being set too low), but the suitability of any single numeric standard for setting Minimum Levels for all lakes in the Lakes Terrace region is questioned.

The need for additional lake indicators of lake condition was apparent for Category 2 lakes, since they are unlikely to support healthy fringing cypress wetlands over the long-term as a consequence of structural alterations. Further improvements to reduce hydrologic variability and add value to the process of establishing Minimum Levels in cypress fringing lakes include: expanded assessment of the ecological health of reference lake wetlands, enhanced measurement methods for determining the elevation of the cypress buttress swell, and the establishment of at least two reference lake classes based on hydrologic variability.

Seawater Intrusion

The Panel concurs that the methodology to establish seawater intrusion Minimum Levels using a network of transects of monitor wells is an appropriate and scientifically reasonable approach. The Panel further finds that the District is justified in its initial emphasis on the areas near the Eldridge-Wilde and Northwest Hillsborough wellfields. The District should augment the existing monitor-well transects A-A′ and B-B′ to provide greater spatial coverage and should not rely only on the current sparse monitoring network of seven monitor wells. However, the seawater intrusion Minimum Levels established for the seven monitor wells are too low because the period-of-record used to determine their values was not representative of the sought-after range of recent historical potentiometric levels. The short records were overweighted by low values that included a substantial period of drought.

A preferred methodology to establish seawater intrusion Minimum Levels would embody the following attributes. First, the monitoring network should be based on transects of multi-level samplers at which hydraulic heads and solute concentrations would be measured synoptically. Based on the one-to-one correspondence between the heads and the concentrations, more precise seawater intrusion Minimum Levels could be established. Second, additional transects should be added that extend inland from the coast to protect the Upper Floridan aquifer water resources in Hernando County, west-central Pinellas County, and the northern portion of Pasco County. Third, site-specific but region-wide Minimum Levels should be established to prevent upconing of saline waters at pumping centers.

Given the importance of *hydrologic process simulation* in the analysis of the impacts of pumping on seawater intrusion, the District should devote significant resources to the development of a modern three-dimensional groundwater flow and solute transport simulation model.

Environmental Minimum Aquifer Levels (*EMALs*)

Although no EMALs have been established to-date, the Panel finds that the methodology employed by the District to establish EMALs is logical, flexible, and capable of producing defensible values. The methodology relies significantly on the ability to simulate changes in the potentiometric levels of the Upper Floridan aquifer, the consequent drawdown in the water table of the surficial aquifer, and ultimately the response of water levels of targeted wetlands and lakes.

It is recommended that a concerted effort be directed toward enhancing and improving the Northern Tampa Bay groundwater model in order to establish realistic initial values for the EMALS. Resources should be expended to develop a high resolution, three-dimensional simulation model for which modern statistically-sound calibration methods are employed. Such a model would enable better simulation of hydraulic response and estimation of predictive uncertainty. In addition, the District should develop a modern simulation-management model to identify optimal pumping programs that minimize groundwater-supply costs subject to hydraulic, economic, logistical, and environmental constraints.

Tampa Bypass Canal (*TBC*)

The Panel finds that the available data and the empirical approach taken do not provide an adequate basis for setting a Minimum Flow of zero for the Tampa Bypass Canal at this time. Moreover, the District has failed to address the effects of the frequency and duration of the Minimum Flow on the Palm River/McKay Bay system. The Panel finds that the zero Minimum Flow for the TBC is not supported by the data, and the analyses fail to address the frequency and duration of zero discharge.

The Panel recommends that the District undertake the development of a mechanistic model that can be used to evaluate and predict the effects of various Minimum Flow strategies on the Palm River/McKay Bay system. Additional data may be required for this modeling effort to improve spatial and temporal resolution in the critical zero flow range. The Panel recommends that additional modeling and data collection be undertaken before adopting the proposed Minimum Flow value of zero.

Panel Observations

The Panel has a key observation concerning the scientific conceptual basis for establishing Minimum Levels. The approach employed by the District relies on a single maximum permissible water-level decline that applies to all wetlands and Category 1 Lakes, regardless of their hydrologic variability. The Panel has concluded that this approach is a good starting point but recognized that it may not adequately protect lakes and wetlands characterized by low hydrologic variability. This is because individual wetlands and lakes exhibit site-specific ranges of water-level fluctuations, and local biota have adapted to those particular ranges.

Basing Minimum Levels on a single-value water-level decline could expose healthy wetlands that had adapted to a shallow flooding environment to conditions in which flooding was rare or absent. To alleviate this deficiency, the Panel recommends that the District develop an approach founded on Minimum Levels that are determined in proportion to site-specific historic hydrologic variability. Although the concept of a proportionality approach is discussed, the Panel does not recommend a specific method but emphasizes that the aim of such an approach is to better protect resources that are vulnerable because they have historically low hydrologic variability, or are sensitive to altered hydrodynamics in other ways.

The Panel also observed that the Minimum Levels determined by the District may be acceptable temporary starting values at this time; however, based on the Panel's re-analysis of available data, the proposed Minimum Levels are too low and should be adjusted upward as they are revisited in the future. The Minimum Flow established for the Tampa Bypass Canal cannot be justified based on the District's analysis, and the zero discharge value also should be revisited.

1.0 INTRODUCTION

The Florida Legislature, pursuant to Section 373.042 of the Florida Statues (1996), directed the Southwest Florida Water Management District *(District)* to establish minimum flows for surface-water courses and minimum levels for aquifers and surface waters. The purpose for establishing minimum flows and levels is:

> *". . . to identify a limit at which further groundwater withdrawals would be 'significantly harmful' to the water resources or ecology of the area. The SWFWMD Governing Board interprets the phrase 'further withdrawals' to mean continued withdrawals that would cause water levels or flows to drop below the established minimum flows or levels."* (District, June 7, 1999 Memo)

In October 1998, the District proposed minimum flows and levels for certain lakes, wetlands, the Upper Floridan aquifer, and the Tampa Bypass Canal in the North Tampa Bay area. However, prior to formal establishment of a minimum flow or level, a substantially affected person or entity could petition for an independent scientific peer review of the data and methodologies used by the District in developing the minimum flows and levels [Section 373.042(4)(a), Florida Statutes (1996)]. Such a peer review was originally requested by Hillsborough County, the Environmental Protection Commission of Hillsborough County, Pinellas County, Tampa Bay Water, and the Environmental Confederation of Southwest Florida (hereinafter referred to as "*Requesters*"). An independent scientific Peer Review Panel (*Panel*) was assembled by the District and Requesters (together referred to as the *Parties*). The Panel was composed of recognized experts in the fields of estuarine biology/ecology, groundwater hydrology, hydrology, hydrogeology, limnology, and wetland biology/ecology. Prior to initiation of the Panel's activities, Pinellas County withdrew from the process. Shortly after initiation of Panel activities, the Environmental Protection Commission of Hillsborough County also withdrew.

This report presents the findings and conclusions made by the Panel regarding its critique of the scientific and technical data, assumptions, and methodologies used by the District in the development of its proposed Minimum Flows and Levels. The Panel, in the development of this report, considered that the primary audience of this report would be the Governing Board of the District. Therefore, with full appreciation of the importance of this review, the Panel undertook its assignment beginning on April 6, 1999 and ending 120 days later on August 3, 1999, mindful of the *information supplied* (References and Supplemental Information), but hopeful of obtaining additional *original data* and other information.

1-A. Charge to the Panel

The Panel was instructed to:

1) Evaluate five scientific White Papers (listed in **Appendix A**) that described the methods used by the District in developing its proposed minimum flows and levels;
2) Review, as appropriate, supporting references to these five papers (listed in **Appendix B**);
3) Review, as appropriate, supplemental documents identified by Requesters (listed in **Appendix C**); and
4) Consider and deliberate "Issues of Concern" developed by the Requesters (presented in **Appendix D**).

Specific Tasks Assigned to the Panel

The Panel was directed to evaluate the data and methods used by the District for proposing each minimum flow or water level and to:

1) Determine whether each methodology is scientifically reasonable by evaluating the scientific and technical analyses utilized by the District to develop the particular minimum flow or level methodology.

   (a) Review the information and data that supports each methodology to determine the nature and character of the information utilized?

   - Were reasonable quality assurance assessments performed on the information?
   - Was relevant information available but discarded without proper justification?
   - Were the data used in the establishment of minimum flows and levels collected properly?
   - Was "best information available" as of July 1997 utilized in developing Minimum Levels for isolated cypress wetlands and flows for the Tampa Bypass Canal?
   - Was the "best information available" as of July 1998 utilized in developing Minimum Levels for salt-water intrusion in the Upper Floridan aquifer and lakes with fringing isolated cypress wetlands?

   (b) Review the technical assumptions inherent in each methodology:

   - Are the assumptions reasonable and consistent given the "best information available"?

- Were there types of information available that could have been used to eliminate any of the assumptions?
- Are the assumptions stated clearly? What, if any, assumptions are implied or inherent in the methodologies?
- Were other analyses available that would require fewer assumptions but could provide comparable or better results?

(c) Review the procedures and analyses used in developing quantitative measures:

- Were the analyses appropriate and reasonable given the "best information available"?
- Do the analyses include all necessary factors?
- Were the analyses correctly applied?
- Were any limitations and imprecisions in the information reasonably handled?
- Are the analyses repeatable?
- Are the conclusions supported by the data?

2) If a given methodology is not scientifically reasonable based on the evaluation conducted pursuant to questions 1a through 1c (above) or as judged by other means determined by the Panel, the Panel shall:

(a) Enumerate and describe scientific deficiencies and evaluate the error associated with the enumerated deficiencies.

(b) Determine if the identified deficiencies within the methodology can be remedied.

(c) If the identified deficiencies can be remedied, then enumerate and describe the necessary remedies, including the precision, accuracy, and an estimate of time and effort required to develop and implement each remedy.

(d) If the identified deficiencies cannot be remedied, then identify one or more alternative methodologies that are scientifically reasonable. If an alternative methodology is identified by the Panel, the Panel shall also describe the precision, accuracy, and estimate the time and effort required to develop and implement the other scientifically reasonable methodologies.

3) If a given methodology is scientifically reasonable, based on the evaluation conducted pursuant to questions 1a through 1c, or as judged by other means determined by the Panel, but perhaps does not embody the preferred methodology as determined by the Panel, then the Panel may enumerate another scientifically reasonable methodology and develop a qualitative assessment of the relative strengths and weakness of the other scientifically reasonable methodology (e.g,

precision, accuracy, and the time and effort required to develop and implement the other scientifically reasonable methodology).

1-B. Constraints to the Panel

The Panel was informed that certain assumptions, conditions, and established legal and policy interpretations ("givens") were not in the scope of the Charge to the Panel, and therefore, were not open for review or comment. These givens include the District Governing Board's policy decisions in developing the Minimum Flows and Levels, including:

1) The selection of the water resources (wetlands, lakes, rivers, and aquifers) for which Minimum Flows and Levels have initially been set;
2) The selection of the baseline from which "significant harm" is to be determined by the Panel;
3) The definition of what constitutes "significant harm" to the water resources or ecology of the area; and
4) The consideration given to changes and structural alterations to watersheds, surface waters, and aquifers, and the effects and constraints that such changes or alterations have had or placed on the hydrology of a given watershed, surface water, or aquifer.

The Panel was further informed of the constraints and conditions described in Section 373.042 of the Florida Statutes (1996) affecting the District's development of minimum flows and levels:

1) Minimum Flows and Water Levels shall be calculated using the "best information available";
2) When appropriate, Minimum Flows and Levels may be calculated using seasonal variations; and
3) How the District's Governing Board factored into establishment of minimum flows and levels the effects of changes or structural alterations to watersheds.

An additional constraint on the Panel was that the review of methodologies to identify the limit at which significant harm occurs to the water resources or ecology of the area was not to be influenced even if groundwater withdrawals have already caused water levels or flows to drop below the established Minimum Flows or Fevels.

1-C. Panel Organization

The Panel consisted of:

Chairman & Hydrogeology:	**David Stephenson, PhD** S.S. Papadopulos & Associates, Inc. Jackson, Wyoming
Surface-Water Hydrologist:	**Phil Bedient, PhD, PE** Rice University, Department of Environmental Science and Engineering Houston, Texas
Wetland Biologist/Ecologist:	**Mark Brinson, PhD** East Carolina University Greenville, North Carolina
Limnologist:	**Forrest Edward Dierberg, PhD** Aqua Chem Analyses, Inc. Rockledge, Florida
Groundwater Hydrologist:	**Steven Gorelick, PhD** Stanford University, Department of Geological & Environmental Sciences Stanford, California
Estuarine Biologist/Ecologist:	**Kenneth D. Jenkins, PhD** JSA Environmental, Inc. Long Beach, California
Wetland Biologist/Ecologist:	**Don Ross** Florida Environmental, Inc. Port Charlotte, Florida
Limnologist:	**Kenneth Wagner, PhD** ENSR, Inc. Northboro, Massachusetts

To address the assigned tasks, the Panel organized itself as follows:

TOPICS OF CONCENTRATION FOR PANELISTS	
TOPIC	**PRIMARY CONCENTRATION**
Wetlands	Mark Brinson Don Ross
Lakes	Forrest Dierberg Kenneth Wagner
Seawater Intrusion	Steve Gorelick Dave Stephenson
Aquifers/Groundwater	Steve Gorelick Dave Stephenson
Tampa Bypass Canal	Phil Bedient Kenneth Jenkins

A brief overview of the resources and resource use are in the study area is provided in Section 2.0. The results of the Panel's review of the District's establishment of minimum flows and levels for each of the water resource areas (above) is presented in Section 3.0 of this report. Section 4.0 is a presentation of the Panel's observations that transcend the specific issues discussed in detail elsewhere in this report. References are cited in this report as follows:

- Citations of and referrals to the "Northern Tampa Bay Minimum Flows & Levels *White Papers*" are indicated as, for example, "***Lakes White Paper, page 6***." The five sets of White Papers provided to the Panel by the District are listed in **Appendix A** of this report.
- Citations of materials provided by the District are indicated as, for example, "***Ref-1, Ref-32, Ref-45***, etc" -- which are located in **Appendix B**. of this report.
- Citations of supplemental materials provided by the District are indicated as, for example, "***Sup-1, Sup-29***, etc." -- which are located in **Appendix C** of this report.
- All other citations are listed in **Section 5.0** of this report.

2.0 OVERVIEW *

2-A. Northern Tampa Bay Water Resource Assessment Project Area

The Northern Tampa Bay Water Resource Assessment Project (*NTBWRAP*) area is comprised of the counties of Pinellas, Pasco and the northern portion of Hillsborough (***Figure 1***). These counties are located in southwest Florida and surround the northern half of Tampa Bay. Pinellas County is almost entirely urbanized, as is much of northwest Hillsborough County and southwestern Pasco County. Inland areas of Pasco County also are rapidly becoming urbanized.

Potable water supplies for these counties and the municipalities within these counties are principally from 11 regional wellfields that are located in Hillsborough and Pasco counties (***Figure 2***). The 11 wellfields draw from the Upper Floridan aquifer, which is the principal source of potable water in west-central Florida. The first of the regional wellfields began operating in the early 1930's; the eleventh wellfield began operating in 1996. In addition to other sources, wellfields continue to be brought on-line in the area to meet the potable water supply needs of the Northern Tampa Bay area.

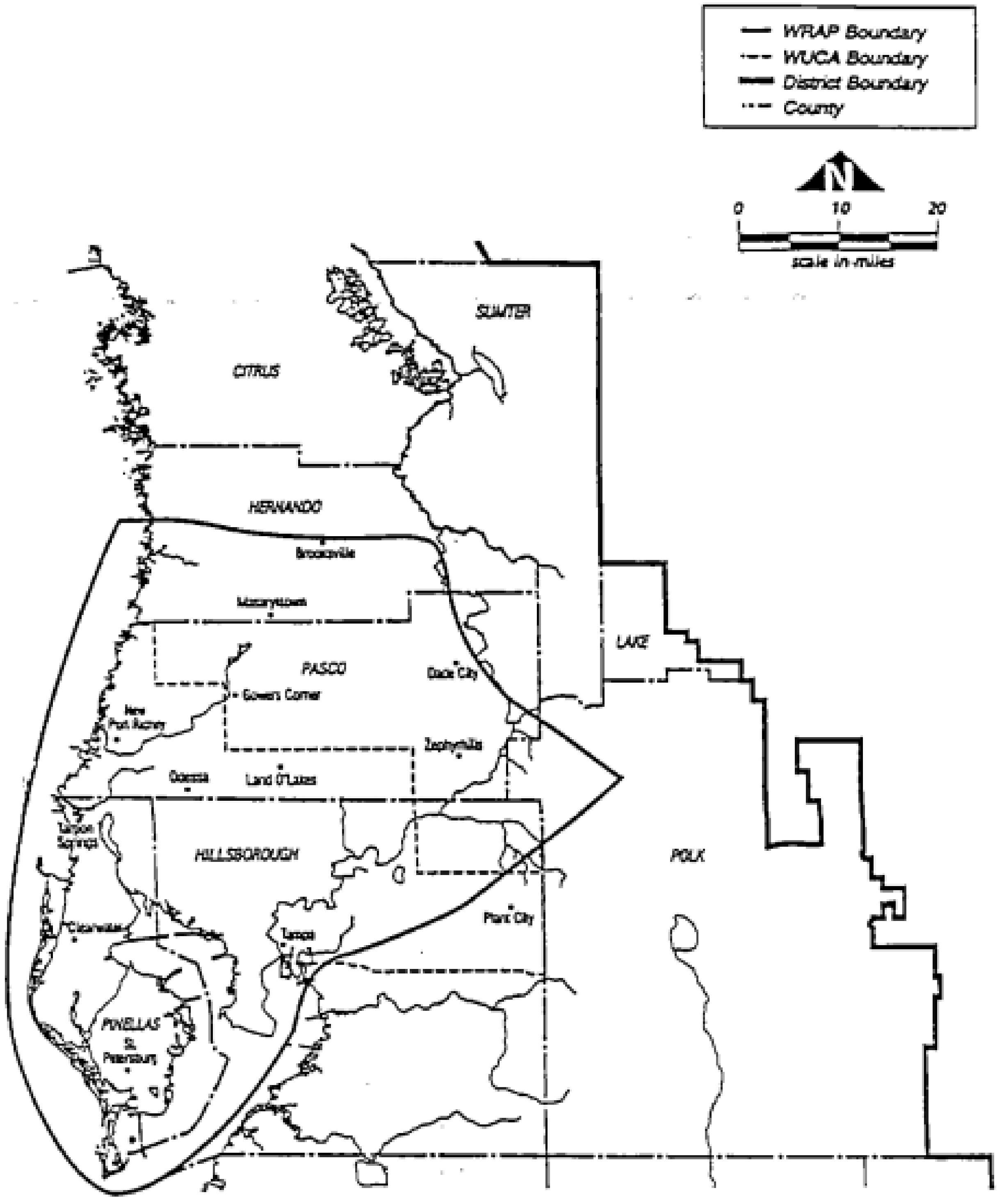
The climate of the Northern Tampa Bay area is humid sub-tropical. The total annual precipitation is about 52 inches, but distribution is variable depending on local conditions. The average rainy season (i.e., about 60 percent of total annual precipitation) occurs from June through September, with generally low rainfall from October through May (Ref-42).

Average evapotranspiration (*ET*) is about 39 inches per year, with the highest ET occurring in May and June.

2-B. Land and Water Use in NTBWRAP Study Area

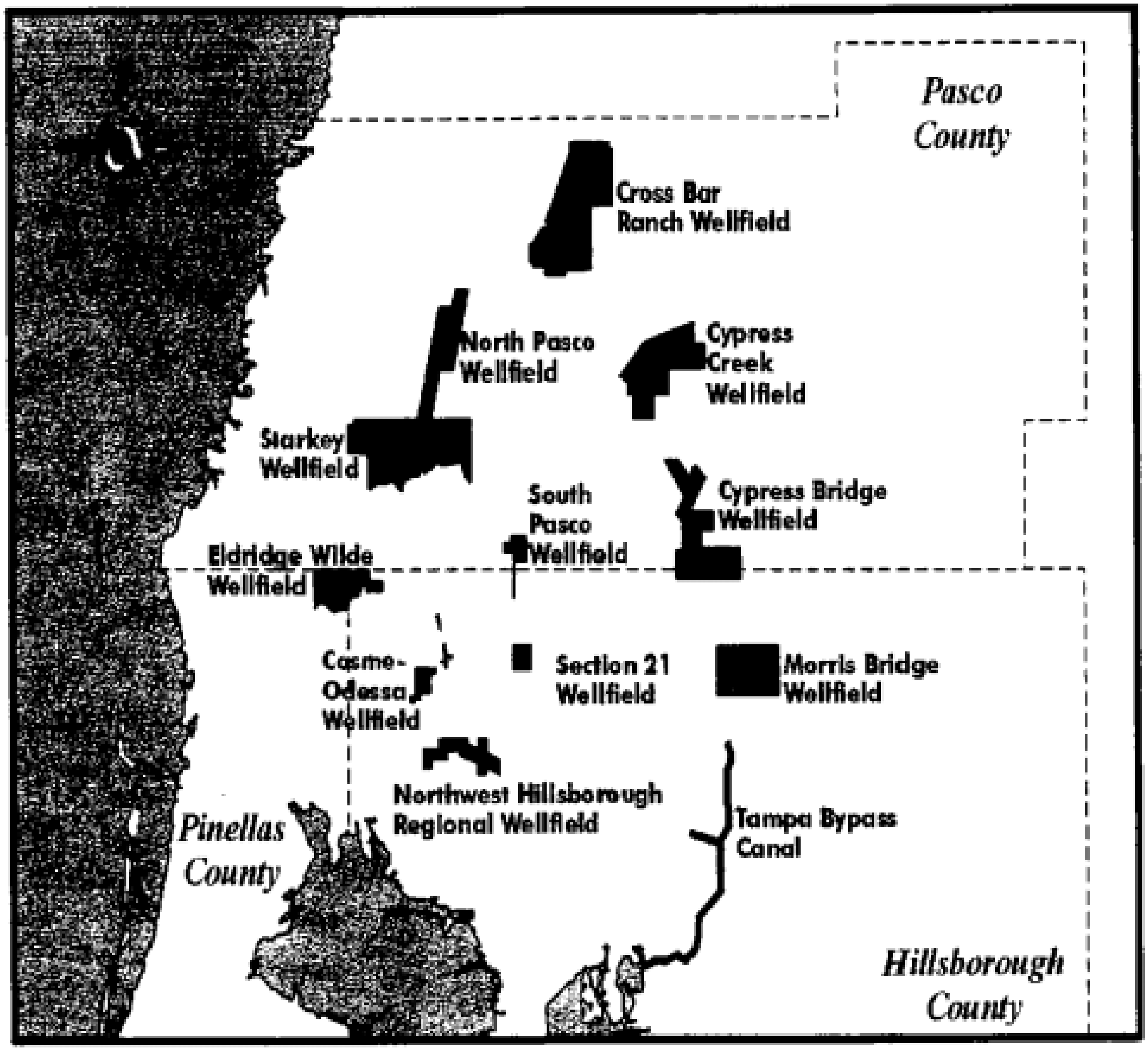
Waters and wetlands account for approximately 23 percent of the land area within the Northern Tampa Bay area. In the mid 1980's, the District declared the northwest Hillsborough County area and limited portions of Pinellas and Pasco Counties, within which several of the wellfields are located, to be an "area of special concern regarding the condition of local water resources." As Stewart (1998) described, "Adverse environmental effects caused by groundwater withdrawals . . . have created years of conflict between water users, property owners, and regulatory agencies."

* ***[Adapted from a Southwest Florida Water Management District Overview and Ref- 42.]***



Source: adapted from Figure 2-1, Ref-42 (WRAP)

Report of the Scientific Peer Review Panel August 3, 1999	NTBWRAP SITE LOCATION MAP	Figure 1



Not to Scale

Source: Figure supplied by Tampa Bay Water

Report of the Scientific Peer Review Panel August 3, 1999	WELLFIELD LOCATION MAP	Figure 2

In 1987, the District undertook a water-resource assessment project *(WRAP)* to examine the water resources within the area of special concern. In 1989, based on preliminary information from the WRAP, the District declared the area as the *"Northern Tampa Bay Water Use Caution Area"* in recognition of environmental stress identified by the District.

In 1992, the WRAP study area was expanded and became identified as the "Northern Tampa Bay Water Resource Assessment Project" (*NTBWRAP*). The NTBWRAP is the District's most recent attempt at determining the condition of the water resources in the area of the regional wellfields.

2-C. Summary of Geology, Hydrogeology, Lakes, and Ecosystems of the NTBWRAP Area

The surficial geologic unit in the NTBWRAP area is comprised of fine-grained sand, silt, and clay. This unconsolidated unit varies in thickness from less than 10 feet to over 100 feet, but is generally 20 to 50 feet thick (Ref-42). The Surficial aquifer is within this unconsolidated unit. Because of the sand content, infiltration rates tend to be high. In areas where silt and clay are more prominent, water tables are high and contribute to the extensive wetlands in west-central Florida (Stewart, 1998).

Beneath the surficial sediments are extensive carbonate rocks (limestones and dolomites). A portion of these carbonate rock units comprise the Upper Floridan aquifer. Rock units in this aquifer are (in descending order): the Tampa member of the Arcadia Formation, the Suwanee Limestone, Ocala Limestone, and the Avon Park Formation (Ref-42). This series of carbonate rocks are the principal source of groundwater withdrawn for municipal and other uses in the NTBWRAP area. The Upper Floridan aquifer is the focus for the creation of minimum aquifer levels.

The surface-water environment within the Northern Tampa Bay area is highly interconnected with the groundwater system. Because of the occurrence of karst geology (closed surface depressions and sinkholes) that characterizes the area, a discontinuous and leaky confining layer provides a high degree of hydraulic connection between the Surficial aquifer and the underlying Upper Floridan aquifer. Although localized areas of relatively high confinement exist, overall the Upper Floridan aquifer is described as poorly to moderately confined within the Northern Tampa Bay area. As a result, water levels in the aquifers are linked and fluctuate similarly. Other than groundwater withdrawals, recharge from rainfall to the Surficial aquifer, discharge by evapotranspiration, and flow from the Surficial aquifer are the only significant driving forces of these fluctuations.

Groundwater withdrawals from the Upper Floridan aquifer lower the potentiometric surface of that aquifer causing induced leakage from the Surficial aquifer downward to the

Upper Floridan aquifer. The result is a lowering of the surficial water table. Assessments have shown that in leaky areas of the Northern Tampa Bay area, a high percentage of groundwater pumped from the Upper Floridan is derived by vertical leakage downward from the Surficial aquifer (Ref-28). Thus, water-level fluctuations in the Upper Floridan aquifer caused by groundwater withdrawals affect Surficial aquifer water-level fluctuations, as well as the water levels of lakes and wetlands that are connected to the Surficial aquifer.

The Lakes Terrace region of west-central Florida includes northwest Hillsborough, northeast Pinellas, and south-central Pasco counties. These lakes are primarily shallow depressions in sandy soils, some with considerable accumulations of organic sediments. Lakes provide habitat for a wide range of aquatic plants and animals, and provide many benefits to the human population as well. Watershed-to-lake area ratios tend to be small, indicating that precipitation and groundwater may be more important in the water budgets of most of these lakes than surface-water flow. Many of these lakes and their watersheds have been subjected to extensive modification by human activities, including development, drainage modification, withdrawal, augmentation, dredging, and structural alteration of outlets. Category 1 and Category 2 lakes, both fringed to some extent by cypress wetlands, are discussed in this report. The difference between Category 1 and 2 lakes is a function of lake level control through structural alterations (see *Acronymns and Definitions*).

The most sensitive ecosystems within the NTBWRAP area are wetlands. Within this report, wetlands of concern are palustrine cypress domes and the McKay Bay portion of Tampa Bay, which receives freshwater inflow from the Tampa Bay Canal. Wetlands of the cypress dome type are unevenly distributed within the three-county area, but are dominant features of the landscape. Cypress dome wetlands are dependent on a viable hydraulic relationship to the surficial aquifer for ecologic health.

2-D. Discussion of Review Process

The Panel attempted to approach this peer review process with the concept that it would be similar to other review efforts in which the members have individually participated. However, from the onset, the Panel felt that its Charge was more difficult to complete than it should have been. Part of this difficulty was related to the Florida Sunshine law; however, this restriction on inter-communication was a lesser impediment compared to the delays caused by the initial non-responsiveness of the Parties and their refusal to fill requests for data. This situation was reversed during the June 25/26 meeting where (1) a productive dialog between the Panel and the Parties was commenced; (2) the Parties made a commitment to give reasonable priority to data requests; and (3) a 30-day extension for report submission was openly discussed. The Parties, who were all represented at the June 25/26 meeting, caucused and reported to the Panel that the 30-day extension was granted, contingent on submittal of an official letter of request from the Panel Chair on behalf of the entire Panel, which was done.

The Panel believed that the June meetings were a watershed event and that the result would facilitate the peer review process. The Panel thus operated for three weeks under the reasonable belief that the time extension was in place. During those three weeks, there was a free flow of information, unlike the previous two months, and the Panel was progressing well in development of detailed improvements to some of the methodologies identified for each of the White Papers. The process stopped abruptly when the Panel was informed that the August 3rd deadline was being enforced. The Panel had no choice but to terminate productive investigations and begin report preparation.

This turn of events created considerable consternation among Panel members and resulted in a regrouping, redirecting of efforts, and focusing on writing the report instead of continuing analysis of and deliberation on the databases so recently received. Although the substance of the report is acceptable to the Panel, the form and level of cohesion are not as planned. The Panel believes that this report will be a valuable document for the Governing Board's use. It is of high scientific quality and represents a consensus of the Panel. The Panel regrets the missed opportunity of developing more options for the Governing Board and suggesting more definitive improvements to the methodologies used to establish Minimum Flows and Levels.

3.0 RESULTS OF PEER REVIEW

The Panel's review of methodologies supporting the Minimum Flows and Levels Rule (Chapter 40D-8, Florida Administrative Code) was governed by the "Charge to the Scientific Peer Review Panel." In implementing that Charge, the Panel regrouped into five teams, identified in Chapter 1, based on the individual Panel member's discipline. Each Panel team reviewed specific portions of the District's Minimum Flows and Levels White Papers (Appendix A), District-provided references (Appendix B), supplemental references (Appendix C), and Panel-requested references (some of which are identified in Section 5.0 - *References Cited in this Report*).

Each of the five sections within this chapter was developed by the specific team, but received input and critique by the whole Panel. The teams worked from a Panel-developed generic outline that incorporated issues and requests presented in the Charge and Issues of Concern (Appendix D). However, given the different lengths of the White Papers, and the attendant information and data available, the following sections are themselves of different lengths.

Table 1 is presented as a summary of the Panel's response to the "Specific Tasks" posed by the Parties within the Charge. For this table, the questions posed in the Charge were reformatted into declarative statements for standardization of response by the different teams. The Panel responses to the statements are *substantially supported, partially supported, not substantially supported,* or *not applicable*. Each of the three categories of statements (review of information, review of technical assumptions, and review of procedures) are also discussed within the text of each of the following sections.

It is a natural tendency of scientists, especially those also professionally engaged in resource-management and resource-policy project work, to look at broad issues, including cause-and-effect relationships, policy implications of an action, and alternative options. Despite having these natural tendencies, the Panel believes that this report adheres to the conditions given in the Charge.

Table 1
Responses to Questions Posed to Panel in the Charge

	Statements Based on Questions Posed to Panel	WETLANDS	LAKES	SWI	EMAL	TBC
	Review the Information					
1a	Reasonable quality assurance assessments were performed on the information.	●	■	●	NA	●
1b	The discarding of relevant information was properly justified.	○	○	○	NA	●
1c	Data used in the establishment of Minimum Flows and Levels were collected properly.	●	●	○	NA	○
1d	"Best information available" (as of July 1997) was utilized in developing Minimum Levels for isolated cypress wetlands and flows for the TBC..	○	NA	NA	NA	○
1e	"Best information available" (as of July 1998) was utilized in developing Minimum Levels for salt-water intrusion in the Upper Floridan aquifer and lakes with fringing isolated cypress wetlands.	NA	○	●	NA	NA
	Review the Technical Assumptions					
2a	Assumptions are reasonable and consistent given the "best information available".	○	●	○	●	■
2b	Assumptions were eliminated to the extent possible with available information.	■	○	○	NA	○
2c	Assumptions are clearly stated.	○	●	○	○	○
2d	Other analyses that would require fewer assumptions but provide comparable or better results were not available using existing data.	○	○	●	●	■
	Review the Procedures					
3a	Analyses were appropriate and reasonable given the "best information available".	●	○	●	NA	■
3b	Analyses include all necessary factors.	○	●	○	●	■
3c	Analyses were correctly applied.	○	●	○	NA	○
3d	Limitations and imprecisions in the information were handled reasonably.	○	○	●	NA	○
3e	Analyses are repeatable.	●	●	●	●	●
3f	Conclusions are supported by the data.	○	○	○	NA	■

NOTE:	
●	The statement is substantially supported; sufficient information has been provided and/or evaluation by Panel finds no significant deficiencies.
○	The statement is partially supported; questions about information or analyses exist, but deficiencies are not currently viewed as extremely detrimental.
■	The statement is not substantially supported; insufficient information has been provided and/or evaluation by Panel has found significant deficiencies.
NA	Not Applicable

SECTION 3.1
PALUSTRINE CYPRESS WETLANDS

3.1 PALUSTRINE CYPRESS WETLANDS

3.1 -A. Target Resources

Palustrine cypress wetlands, commonly called cypress domes, are the wetland resources evaluated for the establishment of Minimum Flows and Levels. Not included in this review are other types of freshwater wetlands such as cypress sloughs, lacustrine fringe cypress, riverine hardwood swamps, isolated marsh depressions dominated, and sea level controlled wetlands.

Cypress domes receive water from precipitation, surrounding surficial groundwater flow, and overland flows (Crownover et al., 1995). Cypress domes lose water by evapotranspiration and infiltration as well as down-gradient movement of surficial groundwater and overland flows. Downward infiltration below some domes is very slow due to low hydraulic conductivity of underlying strata (Spangler, 1984). These confining to semi-confining units consist of clay and overlying muck that are capable of maintaining surface water in the depression for periods ranging from a few months per year to almost continuously. Surface water in domes is also maintained by hydraulic heads in surficial and Upper Floridan aquifers. In these cases, reversals in head due to groundwater pumping can cause wetland water tables to drop rather quickly. This indicates that underlying confining layers are lacking or are discontinuous.

The water regime or hydroperiod in a typical dome has a tendency to flood when precipitation exceeds evapotranspiration and to become dry when this relationship reverses. Consequently, atmospheric exchange of water by precipitation and evapotranspiration is responsible for much of the month-to-month change in water storage.

Dominant tree species are pond cypress as well as other associates including red maple and black gum. Most cypress domes contain several shrub species and an herbaceous component. Plant species are adapted for life in conditions of soil saturation and flooding due to their capacity to withstand low oxygen or to transport oxygen to roots. By default, cypress domes exclude other plant species not so adapted, and thus maintain a flora characteristic of wetland conditions. The animal community consists of aquatic vertebrates (birds, mammals, fish, amphibians, reptiles) and invertebrates (insects, crustaceans, mollusks, etc.). Some are adapted, through a variety of mechanisms, to persisting during periods when little or no surface water is present. Other animals migrate away from the wetland until surface water returns.

Within the Northern Tampa Bay area, cypress domes are unevenly distributed but are dominant landscape features of Pasco and Hillsborough Counties. They are less abundant in Pinellas and Hernando Counties. The Green Swamp, northeast of the Northern Tampa Bay area, has abundant cypress domes. Because of the lack of pumping influence in the Green

Swamp, data from these cypress domes are viewed as representing relatively unaltered conditions.

3.1-B. Summary of Methodologies Used to Establish Minimum Levels

The objectives of the study to establish Minimum Levels for palustrine cypress wetlands were: (1) investigate the relationship between certain ecological parameters and hydrologic parameters in wetlands, and (2) identify a hydrologic threshold, expressed as a water level, beyond which it would be reasonable to expect that "significant harm" will occur in a wetland. (Wetlands White Paper).

Data were available for 655 wetland sites, mostly in Hillsborough and Pasco Counties. These sites were subjected to the following criteria to be chosen as "reference wetlands":

1. The wetland is classified as a palustrine (isolated) cypress swamp.
2. Adequate water-level data, collected at least monthly, allow comparison with other wetlands over the water years 1989 through 1995.
3. Ditches or other features that divert or obstruct surface-water flows have not substantially altered the drainage characteristics of the basin contributing runoff directly to the wetland.
4. Sites are accessible to collect/verify ecological assessment information and survey normal pool indicators.
5. The wetland size is greater than one-half acre.

From the original population, 36 reference wetlands were identified as to meeting the above criteria. District staff chose four of several possible field-tested indicators of ecosystem change to estimate the severity of impact due to water-level and water-table drawdown:

- the invasion of weedy species,
- changes in vegetation zonation (colonization by species indicating drier conditions),
- soil surface subsidence, and
- changes in shrub strata composition.

Other indicators – ground cover composition, overstory composition, canopy condition, incidence of leaning or fallen trees -- were rejected for a variety of reasons, including low correlations and long response times. Water levels themselves were not used as indicators of change because they were considered a cause of ecosystem change and not of ecological condition.

Simultaneously, District staff identified biotic "markers" or hydrologic indicators that corresponded to an upper flooding level that would be achieved approximately 10 percent of the time. Indicators include:

- the root crowns of *Lyonia lucida*,
- the lower limit of epiphytic bryophytes on cypress trunks,
- the upper limit of adventitious roots on *Hypericum fasiculatum*,
- the inflection point between the bole and buttress of cypress trees, and
- the ground elevation of cypress trees at the outside edge of the dome.

The elevation derived by using the above hydrologic indicators is called "normal pool" (*NP*). Based on the condition of these wetlands and the amount to which water levels have departed from normal pool, criteria were established for Minimum Levels.

Through a series of analyses of cumulative departure of water levels from normal pool for a group of 36 cypress domes, "a palustrine cypress swamp is predicted to show signs of significant alteration if the median state (based on a seven-year stage record) is lowered to a level between 1.8 and 1.9 feet below the unaltered normal pool elevation." (Wetlands White Paper, page 7). This value is a departure of 0.8 to 0.9 foot from the P50 of the subset of wetlands distinguished as "not significantly changed" at the time of assessment.

Several other measurements were considered in meetings of the Wetland Subcommittee in the process of developing estimates of ecosystem condition and change. One of the most discussed was to identify the presence and abundance of plant species classified as "increasers" or "decreasers," with the anticipation that these would act as indicators of hydrologic change. An index based on increasers and decreasers would allow vegetation change to be monitored as a surrogate for water levels. This approach had the potential advantage of early detection of change primarily through the use of species that tend to be good colonizers of altered hydrologic conditions. The success of using the normal-pool approach and associated indicators described in the previous paragraph appears to have pre-empted the need for using plant species change.

The relationship between departure from normal pool and ecological condition is an instantaneous assessment or 'snapshot' based on cumulative frequency curves of past records. Ecological condition does not reveal how rapidly ecological or hydrological changes are occurring and whether change would continue to occur if water tables were stabilized or raised. Several of the indicators require months to several years to be expressed. In fact, many water tables of the wetlands that were evaluated in detail appear to be decreasing in elevation. This is not a criticism of the assessment but rather a clarification of its limits.

3.1-C. Evaluation of Scientific Reasonableness

3.1-C(1). Review of Nature and Character of Information Utilized

3.1-C(1a). Quality Assurance

There were three functions in the development of Minimum Levels for palustrine cypress wetlands that lend themselves to quality assurance procedures. Each is described and below.

(1) Ecological assessments

The wetland ecological assessment method requires the reviewer to place the wetland into one of three categories based on qualitative assessments (e.g. whether weedy species were "dominant," "common," or "rare") or estimates of quantities (e.g., >50 percent, <10 percent, or in between for a measurable characteristic). While relatively easy and expedient to apply, these kinds of assessments are subject to substantial variation in judgment, especially toward the extremes of the continuum being estimated.

It is quite common, however, for ecological assessment methods to rely on categorical assignments for a number of parameters. Variability can be controlled by using a team of reviewers, by extensive cross training, or by using the same reviewer or team throughout the project. Short of controlling variation, systematic error can be partitioned in the statistical analyses if records are kept of which reviewers assessed the various wetlands. The Panel received testimony from Dr. Shirley Denton, a consultant for Pinellas County, who stated that, except for the Green Swamp wetlands, she performed all of the original wetland evaluations used by the District. She used a method adapted from previous work done by the West Coast Regional Water Supply Authority, now Tampa Bay Water.

The Panel's review of the level of quality assurance found that while there was not an explicit plan, there are indications that quality assurance was recognized as important, especially in the establishment of normal pool indicators discussed next.

(2) Normal pool indicators

The District has used normal pool indicators in the regulatory arena for over a decade (Ref-22). Establishing a normal pool elevation is one of the best known, most commonly practiced applications of a field assessment technique in Florida. In one sense, the procedure incurs a quality assurance check every time the District staff reviews normal pool with consultants for permit applications.

In addition to the above framework for quality assurance, the Berryman & Henigar report (Ref-2) documents almost complete conformance between the normal pool elevations set by the District and Berryman & Henigar. Berryman & Henigar had been retained by the West Coast Regional Water Supply Authority, the predecessor agency to Tampa Bay Water, "to determine the extent to which there may be variation between NP [normal pool] elevations set by environmental professionals." They concluded,

> "In nearly all cases, these concerns can be eliminated or ameliorated by competent, professional wetland scientists recording multiple elevation data points for a variety of existing biological and physical indicators, and establishing the N.P. elevation as the mean of the surveyed indicators representing the historic N.P."

District staff indicated that the establishment of normal pool elevations using hydrological indicators was a tightly controlled process either conducted by or under the supervision of a single individual.

The Panel's review of the level of quality assurance found that quality assurance in the work performed was commensurate with the possibility for human error. The Panel found no reason to doubt the veracity or applicability of normal pool elevations.

(3) Historic water levels

The Panel has seen no evidence that any specific kind of quality assurance program was conducted on the collection of the wetland water-level data. While data were collected based on a datum established by professional surveyors, the actual water-level readings were not subjected to quality assurance checks. These data have been collected by a variety of entities over the course of years, and are now being used to set Minimum Levels. The sources of variability for this kind of quantitative data, however, are limited, and the measurement techniques have been applied for decades.

The Panel believes that the District used reasonable care to review and delete suspicious water-level data and found no reason to doubt the veracity or applicability of the results.

3.1-C(1b). Justification for Data Discarded

Two types of data were reported to have been discarded: historic wetland water-level data and ecological assessment data. Each is described and below.

(1) Historic wetlands water-level data

There are reported to be 655 wetlands that have historic monitoring data in the municipal wellfield region, mostly in Hillsborough and Pasco Counties. The meeting summary of the December 19, 1996 Minimum Flows and Levels (*MFL*) Wetland Subcommittee meeting indicates that only 48 sites had both canopy and long-term hydroperiod data. No other information was found in the meeting summaries that explained the elimination of 12 sites (bringing the total number of reference sites down to 36). However, upon the Panel's request, the District staff provided reasons for the elimination of the12 wetlands from the original 48. Five were eliminated because of insufficient "non-dry" data with which to calculate a P50. Three were eliminated because of atypical hydrographs: one for paucity of data; one for the inability to obtain access permission from the landowner within time constraints; one because of the inability to reconcile differences in water levels from two different consultants; and one for a wetland that was determined not to be isolated.

The Panel has accepted the quality assurance reasons for elimination of these wetlands.

(2) Ecological assessment data

Five of the nine ecological parameters evaluated for reference wetlands were later eliminated from further consideration. Four were eliminated because of low statistical correlation with the P50 departure from the normal pool. Hydrology was dropped because it was said to be more a measure of the cause of ecological conditions than a response.

The decision to eliminate hydrology is debatable. On one hand it is the principal controller of the other indicators. On the other hand, hydrology is a fundamental component of ecological condition.

Of the four parameters eliminated from the rating system because of low statistical correlation with P50 departure from normal pool, two were not statistically significant in their correlation. Not surprisingly, these were the measures of leaning trees (cypress falling over) and overstory dominance. One might expect these to be time-lagged effects and, perhaps, not particularly useful for early detection of hydroperiod changes.

The remaining two have a correlation of high statistical significance. Ground cover has a correlation of 0.505 ($P = 0.002$), while canopy foliage (thinning) has a correlation of 0.475 ($P = 0.003$). Given the rather crude rating system and the inherent variability of ecological data, the Panel believes that a statistically significant correlation around 0.5 is useful information, and that the parameters should not have been eliminated.

In the January 7, 1997 meeting summary of the Wetlands Subcommittee, a preference to "focus on the herbaceous and canopy data, where it exists" was recorded. Elimination of these parameters seems contrary to that preference.

While the Panel believes it may have been unwise to remove statistically significant parameters, leaving only four, there is no evidence that the decision to eliminate hydrology, ground cover, and canopy foliage would have changed results. Review of the Summary of Field Scores (Wetlands White Paper, Appendix B) indicates that the median values would not have changed with the addition of the three deleted indicators.

3.1-C(1c). Collection of Data

Three classes of data were collected for the purpose of developing Minimum Levels for palustrine cypress wetlands: wetland water levels, qualitative assessment of wetlands, and elevation of hydrologic indicators of normal pool. Of the three, the least is known about the collection of wetland water-level data. The Panel was told that most of these data were collected by various consultants operating under contracts to water suppliers to comply with monitoring conditions of water-use permits. The fact that so few of the 655 wetlands that have historic monitoring data could be used as reference sites gives some insight into the quality of these data for the present purpose. Part of the difficulty of identifying reference wetlands was finding continuous data sets without unexplainable anomalies. Several wetlands were rejected because of the inability to resolve abnormalities in the data, and there is no indication that the collection of the data for the remaining reference wetlands was in any way compromised.

Data for the qualitative assessment of wetlands was said to have been originally collected by a single individual for a majority of the wetlands and later verified by others. The qualitative variables are sufficiently redundant that the Panel believes the data are robust and not easily subject to meaningful error. However, sampling replication within wetlands was apparently not practiced in a way that would allow expression of 'within wetland' variation. A single individual collected all or most of the normal pool data. Quality assurance procedures described in Subsection 3.1-C(1a), above, indicate the data are of high quality.

3.1-C(1d). <u>Best Information Available?</u>

The District stated in the Wetlands White Paper that certain selection criteria were used to reduce 655 monitored wetlands to the 36 wetlands considered for development of the Minimum Level. The Panel is charged with evaluating whether the District used the "best information available" as of July 1997 to set Minimum Levels for isolated cypress wetlands. The Panel understands the reduction of 48 wetlands considered by the Wetlands Subcommittee to 36, of which only 21 were determined not to be significantly altered and, therefore, suitable for establishing the relationship between hydroperiod and normal pool. The question remains about the elimination of 607 wetlands for which some data were available.

There are three kinds of data used to develop the Minimum Level for palustrine cypress wetlands:

- Hydrographic (i.e. water-level records);
- Qualitative assessments to screen wetlands that have been significantly altered; and
- Normal pool elevations.

Of the three types of data, it appears from the Wetlands White Paper that only hydrographic data would have had to exist as of July 1997. Criterion No. 4 for selecting reference wetlands reads, "Sites are accessible to collect/verify ecological assessment information and survey normal pool indicators." The criterion for accessibility implies that the District had the ability to obtain qualitative assessments and normal pool information on a reasonable number of wetlands.

The Panel has been given a number of wetland monitoring reports prepared by various consultants. These reports typically describe the quality of wetlands and provide some hydroperiod data for the period covered. It is difficult to determine from the reports alone whether wetlands exist that would have been suitable to include in the data set or to know what proportion of the monitored wetlands these reports represent.

On June 13, 1999, the Panel requested a description of wetland hydroperiod data available to the District for periods before 1989. The request was for the wetlands to be identified on a map with summary information about the wetland type, its quality, and the hydroperiod data available. In response to that request, the Panel received a cryptic table with summary information about hundreds of wetlands. Much of the information was in code and no key was provided. Even with a key to the code, the Panel had no contextual information with which to evaluate the information.

The Panel received sworn public testimony (Denton and Durbin, 1999) on June 25, 1999 to the effect that more wetlands may exist that may be suitable as reference wetlands. Specifically mentioned were the following categories of potentially suitable reference wetlands:

- "Control" wetlands around wellfields,
- Northwest Hillsborough Regional Wellfield data,
- Hillsborough River State Park wetlands, and
- Various assessments by District staff for the Starkey, Morris bridge, Eldridge-Wilde wellfields and assessments by District scientist Ted Rochow for a large number of wetlands in the Northern Tampa Bay area.

As a result of this testimony, the Panel requested from the Parties, on July 5, 1999, a list of additional (beyond the original 36) wetlands that have reliable hydroperiod data comprising 48 or more discrete measurements before July 1997. For any such wetlands, the Panel requested the period of record for the hydrographic data, its frequency of collection, and any limitations that the provider knows about the data. In addition, the Panel requested excerpted quotes from any reports that discuss the ecological health of each wetland listed.

During the July 20, 1999 meeting, District staff informed the Panel that there had not been sufficient time to respond to the request. At the same meeting, the Panel was informed that its 30-day extension had been denied and that the Panel's report would be due on August 3, 1999. It was impossible to obtain an answer to the July 5, 1999 request because of the Parties' delay in responding to requests for additional information and data until the June 25, 1999 public meeting and the denial of any time extension

At the July 20, 1999 public hearing, Mr. Michael Skelton, representing Pinellas County, referenced a website where consultants to Pinellas County had posted wetland data sets for the Panel to review. Review of these data sets did not provide adequate information to determine if the District had or had not used "best information available." Time constraints imposed by the report deadline did not allow any detailed investigation of these data.

The Panel reluctantly concludes that it has insufficient basis to determine whether "best information available" was used. There is every appearance of highly professional conduct in the establishment of Minimum Levels for cypress domes, and there is no evidence of available information not used. There is, however, sworn testimony suggesting that additional information may have been available, and early restrictions on access to data and the latter time constraints did not permit investigation of those data or an affirmative denial by the District that additional usable data did not exist.

3.1-C(2). Review of Technical Assumptions

3.1-C(2a) Reasonableness and Consistency with Available Data

Seven technical assumptions, listed below, appear to be adopted for the procedure explained in the Wetlands White Paper and the choice of a threshold value for "no significant change" for cypress wetlands. These assumptions were not explicitly stated in the Wetlands White Paper.

Assumption 1: Cypress domes greater than 0.5 acre are sufficiently homogeneous to constitute a representative population to which a single set of protective standards can apply.

Assumption 2: The relationship between hydrologic factors and wetland condition is sufficiently robust that lag times need not be incorporated in explaining the relationship between hydrologic alteration and a significantly altered ecological condition.

Assumption 3: The 7-year period of hydrologic record for the 21 "no significant change" cypress domes was appropriate for setting departures from normal pool as the limit for median stage (P50).

Assumption 4: Vegetation and soils in a broad sense (i.e., weedy species, succession, soil subsidence, and shrub composition) are adequate indicators of significant ecological alteration from the reference condition.

Assumption 5: Stage frequency analysis is an appropriate way to characterize water-level/water-table regimes.

Assumption 6: Normal pool (approximately P10) and median level (P50) are sufficient metrics to characterize the hydrodynamics of cypress domes for the purpose of separating significantly altered from control wetlands.

Assumption 7: It was unnecessary to include loss of wetland area due to drying as a measure of ecological change.

3.1-C(2b). Opportunities to Eliminate Assumptions

Each of the assumptions 1-7 (listed above) will be evaluated for opportunities to be eliminated:

Assumption 1: *Cypress domes greater than 0.5 acre are sufficiently homogeneous to constitute a representative population to which a single set of protective standards can apply.*

Response: No attempt was made to sub-classify reference (i.e., not significantly altered ecologically) cypress domes into more homogeneous subsets. While there was a several-fold difference in P50s (from 0.42 foot to greater than 2.0 feet below normal pool), there were insufficient number of sites for which further analysis might justify separation into subclasses. It is likely that this assumption could be eliminated only by evaluating a larger population of reference wetlands. The result would be better correspondence between P50s and ecological conditions.

Assumption 2: *The relationship between hydrologic factors and wetland condition is sufficiently robust that lag times need not be incorporated in explaining the relationship between hydrologic alteration and significantly altered ecological condition.*

Response: Lag times were recognized in the Wetlands White Paper but were partially eliminated by omitting from consideration those indicators of wetland condition that did not have the highest correlations with P50s. Eliminated parameters included ground cover, canopy condition, leaning/fallen trees, and overstory composition. The last three of these indicators, and especially the last two, have slow response times to hydrological alteration. As such, they could have been used to trigger a "worst" ecological condition because they are associated with severe degradation of cypress domes that has either been present over a long time or has been so acute as to be expressed rapidly. This assumption could be partially eliminated by broadening the use of indicators associated with protracted periods of alteration. From a practical perspective, better resolution at separating classes of wetlands that are severely degraded wetlands is probably not warranted for protection purposes (restoration strategies may benefit, however, from such information). Rather, partitioning the natural variation among two or more subclasses of reference wetlands would allow better resolution between wetlands that have not been significantly altered and those that are at the least altered end of the significantly altered continuum.

Assumption 3: *The 7-year period of hydrologic record for the reference and significantly altered cypress domes was appropriate for setting departures from normal pool as the limit for median stage (P50).*

Response: The effects of the 1989-1993 drought period on the establishment of Minimum Levels are discussed in Section 3.1-D, along with suggestions for eliminating or at least further qualifying this assumption.

Assumption 4: *Vegetation and soils in a broad sense (i.e., weedy species, succession, soil subsidence, and shrub composition) are adequate indicators of significant ecological alteration from the reference condition.*

Response: It has been described elsewhere in this report that the lack of indicators for the condition of the aquatic phase of cypress domes is a serious omission. The singular focus given to departure from normal pool may have diverted attention from the importance of depth of flooding and other dimensions of hydroperiod (i.e., the duration of flooding, duration of 'dry' conditions, and seasonal modifiers of flooding). Vegetation and soils are inadequate by themselves to characterize ecological conditions of cypress domes due to the omission, for example, of aquatic habitat for vertebrate and invertebrate animals. Lack of available data appears to preclude elimination of this assumption.

Assumption 5: *Stage frequency analysis is an appropriate way to characterize water-level/water-table regimes.*

Response: This assumption is one of the strengths of the methodology. The District is to be commended for utilizing this means of characterizing the hydrodynamics of wetlands. There is no need or opportunity to eliminate this assumption.

Assumption 6: Normal pool (approximately P10) and median level (P50) are sufficient metrics to characterize the hydrodynamics of cypress domes for the purpose of separating significantly altered from control wetlands.

Response: P10 and P50 appear to be effective in separating altered from reference wetlands for the set of 36 wetlands in the population. There is no reason to eliminate this assumption.

Assumption 7: It was unnecessary to include loss of wetland area due to drying as a measure of ecological change.

Response: As mentioned in the response to Assumption 4 above, the singular focus given to departure from normal pool (a vertical dimension) may have diverted attention from other measures of altered ecological condition, such as changes in surface area (a horizontal dimension).

3.1-C(2c). Implied or Inherent Assumptions

Because assumptions were not explicitly stated in the Wetlands White Paper, most are implied or inherent whether recognized by the authors or not. Many could not be eliminated because data were not available.

3.1-C(2d). Review of Alternative Analyses to Reduce Assumptions

Subsection 3.1-C(2b) above contains suggestions for alternative analyses, including: (a) development of a larger data set of more wetlands and of wetlands that have a longer period of record, (b) sub-classifying the reference wetlands into data sets that more effectively partition natural variation (in order to more easily identify variations due to hydrologic alterations), (c) routine measurements of water tables below the surface, (d) estimations of water depth and flooding duration with appropriate measures including depth/volume relationships (basin hypsometry), (e) compensation for the drought period of 1989-1994, and (f) utilization of a broader set of indicators to characterize ecological condition.

3.1-C(2e). Other Considerations

It was assumed that hydrology itself could not be used as an indicator because of auto-correlation with the "independent variable." While this is true superficially, at the same time it unfairly and categorically eliminates hydrology as a variable that characterizes habitat for aquatic organisms. This can be resolved by distinguishing frequency distributions of water-levels/water-tables from more qualitative variables that correspond to specific habitat conditions. This includes but is not limited to the presence or absence of surface water and the duration of flooding during specified seasons (such as during amphibian breeding seasons).

3.1-C(3). Review of Procedures and Analyses

3.1-C(3a). Appropriateness and Reasonableness of Procedures and Analyses

The District convened a group of experts from the regulated public to serve on the "Wetlands Subcommittee of the Minimum Flows and Levels Technical Committee." This committee was charged to develop Minimum Levels for wetlands -- a task not heretofore undertaken in Florida or elsewhere. The subcommittee worked for several months, and from the brainstorming and discussions between the District staff and the subcommittee emerged the seed ideas that were later developed into the Minimum Level method for palustrine cypress wetlands. The Wetland Subcommittee and District staff worked to:

- Assemble available, reliable data;
- Find appropriate metrics for wetland quality and wetland hydrology;

- Understand the relationship between wetland health and hydrological characteristics; and
- Synthesize their understanding of this relationship into a simple, easy-to-use regulatory tool.

That they succeeded within the short timeframes prescribed speaks highly of their collective expertise in hydrology and wetland ecology, their honest personal efforts, and their professional diligence. The District and Wetlands Subcommittee were faced with a number of challenges:

- They needed wetlands that have concurrent periods of reliable, continuous hydrological data extracted from over 655 known wetland monitoring sites;
- In order to establish a set of "not significantly changed" reference wetlands, they had to select a qualitative method for quickly assessing wetland health;
- They needed a method to relate hydrological data to a common wetland indicator;
- A dependable, robust metric was required to relate wetland health to hydrology; and
- They had to build a logical path from where they started with raw data to a rule that would withstand challenge.

These challenges are readily apparent from the Panel's retrospective view. In Wetlands Subcommittee meeting summaries of late 1996 and early 1997, none of this was so clear, and each challenge seemed to carry at least one unproductive avenue for a solution.

Success under such circumstances is a matter of degree. In general, the Panel believes that the procedures and analyses followed through the course of establishing Minimum Levels for cypress dome wetlands are laudable. In particular, the establishment of a standard relative elevation (i.e., normal pool) as a reference point for Minimum Levels, thus allowing application of the Minimum Level to this class of wetland almost regardless of current condition, is a breakthrough. The Panel believes this work is the foundation for future efforts to establish more sophisticated and useful Minimum Levels for these wetlands and to expand the application to other aquatic resources.

3.1-C(3b). Necessary Factors Considered?

District staff conducted the actual analysis of hydrological data and developed the Minimum Level. Three essential factors are necessary to develop the Minimum Level:

- Hydrological data;
- Qualitative assessment of wetlands; and
- The standard relative elevation (normal pool).

The methods used to develop the Minimum Level from these elements are described in the Wetlands White Paper and are recapitulated in appropriate sections of this report. Under many circumstances, the above three factors would have been sufficient. In this case, however, circumstances seemed to conspire to require a fourth factor: rainfall data. Because of an apparent tradeoff between the number of reference wetlands and the length of data sets, the hydrological data set was relatively short (seven years). A relatively rare series of lower-than-normal rainfall years happened to coincide with the data set, and as a result, the Panel determined that hydrological data were not representative of normal hydrology.

The Panel recommends several approaches to address this issue in Section 3.1-D and believes this deficiency is curable. The hydrological data may be "normalized" for the drought period by any of several techniques that use either extended data available for a subset of the reference wetlands or rainfall as a covariable. The effect of these adjustments would appear to raise the Minimum Level substantially.

3.1-C(3c). Application of Analyses

The District developed a thoughtful and unique approach to statistical analysis of the data. While the analyses were not originally familiar to the Panel, the District provided an explanation that satisfied the Panel that the analyses had been correctly applied. Also, by developing additional information about the data distributions for the Panel, District staff uncovered some areas of concern that the Panel believes should be addressed to make the analyses stronger. One point of confusion for the Panel was the statement that the threshold for Minimum Levels had been set so that alpha and beta errors were equal. Upon questioning, it turned out that the equality of alpha and beta errors had not been prescribed but was merely fortuitous. The Panel believes that Minimum Levels should be set by generally accepted levels of alpha and beta errors, but that they should not necessarily be equal.

The Panel was also concerned about the way the analyses dealt with a limitation in the data set for "not significantly impacted" reference wetlands. This issue is discussed in more detail in the following section.

3.1-C(3d). Limitations and Imprecision in Information

The Panel is generally satisfied with the quality of the information available to the District to establish Minimum Levels. It is not unusual, however, to identify anomalies in otherwise "well-behaved" data, and this occurred with the 21 "not significantly altered" wetlands, from which the median departure from normal pool was measured. The median differences between normal pool and P50 (the median water level) for each of the 21 wetlands was plotted as cumulative frequency distributions and tested for the assumption that the data were normally distributed. The Kolmogorov-Smirnov test indicated that the data were normally distributed for the 21 reference wetlands, and a normal curve was plotted using the mean and the standard deviation from the sample. The normal probability curve then became the basis for establishing the Minimum Levels for isolated cypress wetlands. Comparison of the normal curve to the actual data points, however, raised questions about the quality of the fit and the effect of two data outliers (points in a data set that represent a suspiciously large deviation from an assumed distribution).

As more fully described in Section 3.1-D below, the Panel believes the analyses can be improved by removing one or more data outliers from the data set. Removal of the outliers will have the combined effect of lessening the average difference between normal pool and P50 and decreasing the variance around the mean, thus slightly raising the Minimum Level.

3.1-C(3e). <u>Repeatability of the Analyses</u>

All of the analyses are easily repeatable by appropriately trained individuals. The wetland qualitative assessments and determination of normal pool are repeatable on each wetland. Obviously, it is not possible to repeat the collection of historical data, but all aspects of data collection are transparent and utilized familiar techniques. The Panel using different approaches tested the statistical analyses. Once assumptions were standardized, the Panel's results corresponded to the District's.

3.1-C(3f). <u>Relation of Conclusions to the Data</u>

Because of two areas of concern raised above in Subsection 3.1-C(3b) and (3d) and addressed in greater detail in the following section, there is no reason to expect the data to support the specific conclusions (i.e. the Minimum Level) until specific remedies are applied. As discussed in Section 3.1-D, there are specific remedies available to resolve these deficiencies. When implemented, these remedies will result in greater correspondence between the data and the results, in a more defensible conclusion, and in greater certainty for resource protection.

3.1-D. <u>Evaluation of Deficiencies</u>

3.1-D(1). <u>*Period of Record*</u>

(1) <u>Description of Deficiency and Associated Error</u>

The period of record from 1989 through 1995 was chosen for establishing Minimum Levels because it was the only period for which sufficient data were available. Most of the wetlands used in the evaluation had a complete monthly water-level data set. The District stated (Wetlands White Paper):

"The period of record used in our study, water years 1989 through 1995, was chosen because it is believed long enough to be considered representative of long term conditions and lessens the effect of a single year with uncommonly wet or dry conditions. Although a longer period of record may have provided better hydrologic information, requirements for a longer period of record would further reduce the number of available wetland sites."

The question is whether the seven-year data set is sufficiently representative of long-term conditions to establish Minimum Levels that would protect wetland resources. The NTBWRAP report (Ref-42, Volume 1) documents the long-term climatic record of the area. Rainfall records from 1915 to 1995 were used to determine if the average of 38 stations located within and immediately outside the NTBWRAP area demonstrated a long-term trend. While no long-term trend is evident for the entire period of record, there are periods of short-term deviations.

Analysis of the five-year moving average of annual rainfall for the 38 stations reveals several periods in which rainfall was abnormally low. The five-year periods ending in 1970, 1976, 1978 are cited as having five-year averages of 47.6 inches, which is 4.7 inches below the annual average of 52.3 inches. The five-year average ending in 1993, however, represented the single driest five-year interval in the period of record: 6.6 inches below the average. Therefore, the 1989 through 1995 period of record for developing Minimum Levels for palustrine cypress wetlands substantially overlaps a record-breaking period of low rainfall. The potential effect of using data from a period of below-normal rainfall is to bias the choice of Minimum Levels to ones lower than justified. This could lead to wetland degradation over the long term. While no period is likely to be "normal," the extreme abnormality of the period of record cannot be ignored.

(2) <u>Discussion of Possible Remedies</u>

One way to test, and perhaps adjust, the Minimum Level derived from a questionable period is to extend the period of record for the analysis for those wetlands for which the data are available. The Panel asked the District to analyze existing data from the six reference wetlands in the Green Swamp – a data set of about 21 years. The purpose of this request was to determine if there was an apparent "drought effect" in the seven-year period of record for the Green Swamp wetlands, when compared to the full period of record. The District's analysis of the full period of record revealed that the average difference between normal pool and P50 was 0.22 foot less than that indicated by the 7-year period of record. Another parameter that affects the establishment of regulatory levels, the standard deviation, was also lower. These results indicate that there may be a "drought effect" that is potentially causing the average departure from normal pool to be overestimated.

The District's data were subjected to a t-test to establish the level of statistical significance of the 0.22-foot difference. When the comparison is between the 7-year data set used by the District to set Minimum Levels and the full 21-year data set (including the 7-year data set), the 0.22-foot difference reported by the District is *significant at the* $P < 0.07$ *probability level*.

A better test, however, is to compare the 7-year data set with the 14-year data set that remains of the full period of record when the seven years is separated. The difference between normal pool and P50 for these two sets of data is 0.35 foot, significant at the $P < 0.05$ probability level. (This probability level is generally accepted for physical/chemical comparisons and means that there is less than a 5-percent chance that the measured difference is sampling artifact.)

(3) Identification of Specific Remedies and Their Attributes

The 21-year Green Swamp wetland hydrograph data may be used to adjust for the apparent effect of drought during the period of record. The Panel has discussed possible techniques with District staff and recognizes that an iterative approach may be appropriate to "bootstrapping" the 21-year Green Swamp wetland hydrograph data into the overall analysis to remove bias associated with the abnormal precipitation during the 7-year period. This approach cannot be prescribed without further knowledge of the limitations of the data set, but should be performed by staff who have expertise in statistical analysis and wetland ecology. Similarly, methods for estimating missing data (e.g., cokriging, see below) could potentially allow the inclusion of a great number of wetlands in the reference set.

Since the District was mandated to use "best information available" to develop Minimum Levels, an aggressive approach to removing bias in the reference wetland data is justified. Normally accepted statistical tolerances may not be achievable until more data are available. Failure to attain desired levels of statistical confidence should not be the sole obstacle to making adjustments for "drought effect," as long as good scientific judgment and sound numerical methods are employed.

(4) Alternative Methodologies

An alternative methodology to remove drought effect bias from the seven-year period of record may be to use statistical techniques to partition the effect of year-to-year variation from the other sources of variation in the wetland hydrograph data. This would allow an adjustment based on the estimated difference between the seven-year period of record and the total period of record.

Another alternative may be to use precipitation data as a co-variable to partition the effect of precipitation on water-level data. This may allow for an estimation of precipitation effects and comparison of data "normalized" for precipitation.

There is not sufficient time or information available for the Panel to evaluate further the options of partitioning year-to-year variation or creating a precipitation co-variable. These, however, are standard analysis of variance techniques used by researchers in many fields of study (Snedaker and Cochran, 1967).

The above techniques require statistical expertise that may exceed the capacity of technical staff. Use of sophisticated statistical techniques carries the burden of greater and often more subtle assumptions about the nature of the data set and the range of inference from the analyses. While software programs make even the most sophisticated analyses universally available, knowing when and how to use the analyses is still the critical element.

The District should consider the use of a statistician to extract more value from its data by overcoming inherent limitations. Data are valuable and expensive to collect. However, the use of sophisticated statistical techniques to maximize its usefulness is usually cost-effective.

A third alternative, which is almost self-evident, is for the District to continue collecting and analyzing data from the wetlands currently monitored to build a larger, more robust data set. As demonstrated by the utility of the Green Swamp wetland data and the vulnerability of the seven-year period of record, the value of environmental information increases greatly with the length of continuously collected data. Finally, it may be possible to use estimation techniques for missing data. Using these techniques would not only expand the period of record but would potentially allow expansion of the number of reference wetlands available for assessment. If wetland water levels are correlated over space and/or time with water levels of other records, cokriging (Solow and Gorelick, 1986) is one technique that should be tested for estimating water-level data of wetlands that have incomplete records.

An alternative that the Panel does *not* recommend is the expansion of the 1989-1995 data set through 1998 as the sole means to correct for drought bias. While water levels associated with the El Niño in 1998 would tend to compensate for the drought bias, this approach of using opposing extreme events is not as sound as the statistical techniques described above. While it may be useful to expand the period of record in the future, the bias of extreme events should be examined for possible removal. Inclusion of extreme events in opposite directions may cancel effects on measures of central tendency, but will increase variability of resultant standards or thresholds.

3.1-D(2). *Treatment of Outliers*

(1) Description of Deficiency(s) and Associated Error

Twenty-one wetlands were identified as "*not significantly changed*" and appropriate for use as reference wetlands to establish a standard. The determination of "not significantly changed" was made on the basis of a qualitative assessment of wetland condition, without respect to hydroperiod data.

The median differences between normal pool and P50 (the median water level) for each wetland were plotted as cumulative frequency distributions and tested for the assumption that the data were normally distributed. The Kolmogorov-Smirnov test determined that the data were normally distributed for the 21 reference wetlands. Once the data were determined to be normally distributed, a normal curve was plotted using the mean and standard deviation of the sample. The normal probability curve then became the basis for establishing the Minimum Levels for isolated cypress wetlands. Comparison of the normal curve to the actual data points, however, raised questions about the quality of the fit and the effect that two data outliers may have on the establishment of regulatory levels. ("Outliers" are points in a data set that represent a suspiciously large deviation from an assumed distribution.)

While removal of the outliers sometimes allows a better understanding of the phenomenon that the data describe in terms that have been preconceived, the danger lies in rejecting valid information from extreme events or circumstances. Sometimes extreme or rare events hold the key to understanding. (One wouldn't eliminate high rainfall events from a data set in Florida, for instance.) Therefore, there is a continuing philosophical discussion in statistical analysis circles about the appropriateness of eliminating outliers from a data set.

Obviously, when a reason can be found to explain the deviation, the decision to remove the point from the data set is easier. In the case of the wetland data, however, the wetlands in question were not found to be qualitatively different from others in the reference data set. Neither was there evidence that the water-level data nor the normal pool determinations were faulty.

Extensive qualitative research on the reference wetlands, however, was never conducted because of the time constraints imposed on the rule-making process. To the Panel's knowledge, the two wetlands in question have never been inspected with the purpose to understand their large deviations from the reference data set. One of the "givens" in this process is the use of "best available information" as of July 1997.

(2) **Discussion of Possible Remedies**

The Panel asked the District to provide greater detail in the analysis of data distributions. The District provided histograms and normal probability plots of the data for each qualitative set of wetlands, along with additional descriptive statistics and tests for normality. Of particular interest to the Panel is the additional analysis provided for the 21 reference wetlands used to establish Minimum Levels. The acceptance of outliers in this data set affects the Minimum Levels set. Because the outliers were on the high end of the distribution, the effect would be to set lower Minimum Levels than would be set without them.

The probability plots graphically demonstrated the position of the outliers relative to 95 percent confidence limits for the distribution. Two points were relatively far outside the confidence limits and one was close to the limit, but outside of it. The expected number of data points outside the 95 percent confidence interval is one in 20. For a data set of 21, the probability plot showed three points outside the confidence interval, thus greatly exceeding expectations.

In addition to the Kolmogorov-Smirnov test originally used by the District, the Shapiro-Wilkes test was used. It failed to corroborate the Kolmogorov-Smirnov test results and rejected the assumption of normality for the reference wetland data set. Removing the highest value of the outliers (Wetland EW11) from the data set and testing again, the assumption of normality was accepted.

Possible remedies include the removal of one or two outliers from the reference wetland data. Removal of the most extreme of the outliers is justified by the Shapiro-Wilkes test. Removal of the second would have to be justified on other grounds.

(3) Identification of Specific Remedies and Their Attributes

There are two specific remedies available. One is to revisit the qualitative assessments of the two wetlands identified as outliers and determine if there is reasonable justification for their being removed from the data set. The qualitative analysis performed to-date on these wetland data was essentially the minimum necessary to develop the Minimum Levels with "best information available." Additional evaluation may reveal a cause for these wetlands having hydroperiods different from the remaining reference wetlands.

A second approach would be to remove one or two of the outliers based on the statistical analysis and the desire to take a more conservative approach to resource management. Removal of EW11 is justified by the Shapiro-Wilkes test results. Without additional qualitative data on the second of the outliers, its removal would have to be justified by its desired effect on the establishment of Minimum Levels.

Removal of outliers will have the combined effect of lowering the average difference between normal pool and P50 *and* decreasing the variance around the mean. Removing the most extreme of the outliers changes the mean difference between normal pool and P50 from 1.09 feet to 1.03 feet. Removing the second most extreme point changes the mean difference to 0.97 foot. While it is unlikely that these differences (0.06 foot for each of the rejected outliers) are by themselves biologically significant, the effect of their removal on the shape of the normal distribution curve must also be considered. The Minimum Level was established on the tail of the normal distribution curve at the point where the probability of error was five percent. Changes in the shape of the curve, therefore, may have as much or more effect on Minimum Levels than displacement of the mean. The combined effect of mean displacement and reducing the width of the normal distribution curve is likely of a magnitude that is biologically significant.

(4) Alternative Methodologies

No other alternatives are recommended.

3.1-E. Evaluation of Preferred Methodologies

3.1-E(1). *Broadened Perspective on Hydrology*

(1) Description of Alternative Preferred Methodology(s)

Changes in hydrology are a fundamental element of establishing Minimum Levels, and the assumptions regarding hydrology define how wetlands are assessed. Hydrology (the study of the distribution and flow of water) is often used synonymously with hydroperiod (the depth, duration, frequency, and seasonality of flooding). Description of these components of hydroperiod follow:

- *Depth* –The depth of water in wetlands controls the species composition of vegetation, influences the types of aquatic life that can be supported, and is proportional to surface-water storage that contributes to overall water balance. While depth seldom remains constant over time, there is a tendency for water levels to return to a regular flooding depth often controlled by the elevation of an overflow. One of the chapters in the leading wetland ecology textbook (Mitsch and Gosselink, 1993), entitled "Southern Deepwater Swamps," conveys an image of a continuously flooded forest in the bayous of Louisiana. Each wetland, regardless of the spatial and temporal variation, has a characteristic depth of flooding that partially describes its hydroperiod.
- *Duration* – The duration of flooding or saturation to the surface is a defining component of the regulatory definition of wetlands. The growing season, when most plants are active, is the period in which saturation and flooding are most influential in selecting which plant species are able to survive and compete (i.e., hydrophytes). As with depth, duration varies greatly among wetlands, but each wetland, on the average, has a characteristic duration of flooding.
- *Frequency* – The use of flooding frequency tends to be restricted to tidally influenced wetlands where once or twice daily flooding are predictable events that maintain constant soil saturation, and where semi-monthly flooding influences the higher elevation zones of tidal wetlands. The Panel is not aware of specific studies of freshwater wetlands, and particularly isolated cypress wetlands, that rely on how many times a wetland floods during a year or a

growing season. In fact many wetlands, such as the deepwater swamps that remain permanently flooded during most years (i.e., they are intermittently exposed), have a frequency approximating 1.0. The frequency modifier appears to carry little significance in either characterizing a wetland type or defining the characteristics of a wetland, except in tidal situations.

- *Seasonality* – Most wetlands have a strong seasonal component of flooding. For wetlands maintained largely by atmospheric water balance, the interplay between precipitation and evapotranspiration defines the seasonality. For Florida wetlands, the warm season supplies the most precipitation, thus extending the duration of flooding over a longer period than would otherwise occur if precipitation were evenly distributed throughout the year.
- *Flooding* – This tends to be a "given" in the definition of hydroperiod, but it is commonly understood to represent the point at which the water table rises above and crosses the soil surface, regardless of the source of water. This does not mean that the free water surface must always be above the soil surface for water to have an ecological influence. In fact, much of the environmentally selective influence of water in wetlands occurs below the surface because soil saturation restricts the diffusion of oxygen through the soil. Biogeochemical cycles that are sensitive to redox potentials are profoundly affected by saturation-desaturation cycles. Relevant elements include phosphorus, iron, manganese, nitrogen, and sulfur. However, free water above the surface (e.g., flooding) contributes to the duration of saturation, and thus cannot be separated from subsurface effects.

The main conclusion that can be drawn from this overview is that wetland hydroperiod defines the type and condition of a wetland. Consequently, hydroperiod in the broadest sense should be regarded as not only defining the relatively unaltered condition of a wetland, but also as a predictor of change in condition. The threshold at which a particular wetland site undergoes a change to a different type because of altered hydroperiod is not well established. Too much water can kill trees and displace species of invertebrates. Too little water can cause water stress (drought symptoms in plants), subsidence of organic-rich soils, and ultimately conversion of wetland to upland. In any case, the biota of a given wetland is, by definition, adapted to the hydrology that has been historically experienced. This is not to suggest that wetlands are hydrologically static, but rather, that the water regime fluctuates within a range of conditions that is neither too much nor too little to support the biota that exist in a particular wetland.

Monitoring of the position and fluctuations of water tables below the surface also provides valuable information on wetland condition, particularly biogeochemical processes discussed above. The P90s would be of potential value in characterizing these fluctuations. This metric could not be calculated for many wetlands because only water-surface measurements were made.

The reason for addressing these "first principles" of wetlands is to emphasize how hydroperiod and associated hydrology are fundamental in assessing wetland condition. This is apart from the methodology of measuring water levels, the instruments used for measurement, the resolution of the data (precision and accuracy), and data analysis. If it is not known how deep the water is and how long soil saturation persists over portions of a wetland, then the ability will be greatly limited in detecting whether hydrology, biogeochemistry, plants, and animals are altered.

(2) Qualitative Assessment of Alternative Preferred Methodologies

In order to identify aspects of wetland hydroperiod, additional surveying of basin cross-sections (depth and shape) would be required. These data would characterize depth-area relationships (hypsometry) that could then be related to the stage-frequency distribution for the period of record for both reference wetlands and any others with adequate hydrologic data.

Records of water-table depths (fluctuations below the surface) are a serious omission from many of the wetland monitoring sites. Water table fluctuations would provide potentially important information for wetland condition and processes, would allow the calculation of P90, a potentially useful co-variable of some indicators of ecological change. The development of P90 metrics may serve as another threshold useful for characterizing wetland condition.

3.1-E(2). *Assessment of Wetland Area*

(1) Description of Alternative Preferred Methodology(s)

Hydrology, vegetation, and soils are the three criteria used to define jurisdictional wetlands in Florida (Gilbert et al., 1995) and elsewhere in the United States (U.S. Army Corps of Engineers, 1987). For isolated cypress wetlands, hydrophytic vegetation and hydric soils can be used to identify the extent of a wetland (wetland-upland boundary). When water-level drawdowns occur due to human activity, vegetation and soils are not reliable indicators of the principal driving force -- hydrology. The reduced hydroperiod would not be able to sustain hydrophytic vegetation. Eventually, reduced hydroperiod would cause the loss of indicators normally associated with hydric soils (such as a surface muck layer). With the lack of sufficient hydroperiod to sustain vegetation and soils, these two criteria would be considered "relict" and thus would be disregarded as positive indicators of wetland condition.

For isolated cypress domes, the center tends to be the deepest zone with the basin elevation gradually rising toward the edge of the wetland. As the boundary with the upland is approached, duration and depth of flooding diminishes, hydric soil indicators become reduced in number and strength of expression, and vegetation trends toward fewer obligate and facultative wet species. (Obligate and facultative are terms indicating the proportion of time a species occurs in a wetland environment.)

It is this drier portion of the wetland that will be affected first during a reduction in hydroperiod and hydropattern. Because a wetland becomes reduced in size as it dries out from the periphery, the proportional decrease in wetland size varies with hypsometry of the basin and initial size of the wetland. With regard to hypsometry, a funnel-shaped wetland will experience greater initial wetland surface loss per unit of water level reduction than a bowl-shaped wetland. With regard to size (and keeping hypsometry constant), a small wetland will lose a proportionately larger area than a large one. For absolute change in wetland size, the opposite tends to be true within certain size thresholds.

(2) Qualitative Assessment of Alternative Preferred Methodologies

At what point during the process of wetland drying-out can wetland loss be determined? Presumably the judgment could be made instantaneously when a reduction in water levels, below that of relatively unaltered reference wetlands, would lead to drier conditions than the threshold needed for sustaining wetland characteristics. Thus, as soon as water levels could be judged to maintain new "set points" (P10s, P50s, etc., but in relation to the soil surface) around which hydroperiod and hydropattern fluctuate, the newly established upland-wetland boundary could be determined. By definition, any hydric soil indicator or facultative or obligate hydrophytes within the newly dried-out zone would be considered technically "relict," presumably because they could not compete with species adapted to drier conditions. While this approach sounds plausible and technically feasible, it may be difficulty to put into practice. One of the major impediments would be having enough data over the short term to know the new "set points."

3.1-E(3). *Condition of Wetland Clusters*

(1) Description of Alternative Preferred Methodology(s)

Any environmental assessment methodology should be accurate, precise, and practical for its intended purpose. While accuracy and precision have relatively standard statistical definitions, the meaning of practicality can be ambiguous. Practicality should include both efficiency (ratio of assessment effort to the amount of information produced to support a decision) and effectiveness (whether the information is in a form that can be used to supporting decisions on resource management). It is the responsibility of scientists developing methodologies to address both of these aspects of practicality. This has led the Panel to question whether the 'Minimum Level' approach provided thus far can produce information to adequately address the condition of the wetland resource.

The approach taken so far with establishing departure from normal pool has attempted to answer the question: Does a cypress dome have a distribution of water levels over a multi-year period sufficient to maintain an ecological condition that is relatively unaltered? One of the omissions of the existing methodology is whether nearby wetlands have shown evidence of altered water levels and ecological conditions as potential predictors of the condition of a given wetland. In other words, does the geographic position of a wetland place it in a category that is more or less likely to be affected based on the condition of neighboring wetlands? Stated another way, would signs of ecological alteration in one or more domes in a cluster of wetlands (that otherwise appear unaffected at the time) serve as early warning for other wetlands in the cluster? While it is apparent that some unaltered wetlands are located in the vicinity of water table drawdowns, and that other altered wetlands appear to occur outside the cone of influence, there are fairly obvious patterns that geographic 'hot spots' of alteration exist. The risk is higher in some areas than others that altered conditions will develop or have already occurred. Explicit recognition of such patterns could help managers establish priorities on which wetlands to monitor most intensively and which clusters are in need of remedial action.

(2) <u>Qualitative Assessment of Alternative Preferred Methodologies</u>

The description of patterns would require that a much larger population of wetlands be considered than the original reference set. In fact, nearly every wetland could be assessed to some degree from aerial photographs where the severely degraded wetlands show deterioration in terms of tree fall and other evidence from color and false-infrared color photography. For example, Sup-15 reported that tree fall areas expanded in size considerably over a period of several months. This was an interpretation based on color infrared photos at 1-inch = 1000 feet. It is likely that other attributes of wetlands using remote sensing could be used to develop wetland classes based on aerial data. Remote indicators could be analyzed in similar fashion to the land-based indicators (shrub encroachment, weedy component, etc.). While the detail would necessarily be at a lower resolution than ground-based assessments, the purpose would be to rapidly and independently identify geographic areas of high risk.

3.1-E(4) *Partitioning Variation in Cypress Domes*

(1) <u>Description of Alternative Preferred Methodology(s)</u>

Expansion of sample size by increasing the number of wetlands monitored cannot be considered a "preferred methodology" because it is merely an extension of current methodology. Nevertheless, the Panel would be remiss if it did not offer suggestions on sample size and the related topic of classification. The Panel suggests that the most improvement on the existing approach may not necessarily be made by simply increasing the number of wetlands in the reference and altered group. The set of 21 "not significantly changed" reference wetlands, for example, already has a great deal of natural variation embedded in it. The choice of additional reference wetlands alone may not substantially reduce the natural variation, especially given the professional judgment of the scientists involved in choosing a representative set of reference wetlands.

Land depressions in the Northern Tampa Bay region range from (1) deep to shallow, (2) forested to aquatic, (3) hydrologically connected (at the surface) to isolated, and (4) hydrologically influenced by deep aquifers to uninfluenced. Within this array of conditions, the isolated cypress domes addressed by the District represent a subset of conditions that are relatively shallow, forested, isolated, and have varying amounts of influence from underlying aquifers.

The paper by Watson et al. (1990: Sup-10) is one of the few that attempts to explain some of the variation. The authors separate cypress domes into three categories: (1) shallow depressions with underlying confining layers that restrict vertical leakage, (2) transitional domes intermediate between shallow depressions, and (3) the relict sinkhole types which have underlying solution features. The transitional type that they examined also had a confining layer of clay just below the surface layers of peat. Both the shallow depressions and transitional domes were unaffected by pumping. They report that the relic sinkhole had been affected by pumping, probably because underlying confining zones were discontinuous.

There are a number of reasons that classification would be useful in cypress domes. The major reason would be to provide an understanding of disparate responses to aquifer drawdown among closely spaced cypress wetlands. If wetlands exist that have hydrologic properties that are virtually independent of regional groundwater dynamics, one would need to know whether that is simply a property of the wetland (i.e., it has its own effective confining layer) or whether it is a function of underlying stratigraphy which may change with pumping from the Upper Floridan aquifer (i.e., induced recharge).

Among wetlands responsive to subsurface hydrologic alterations, wetlands with deep peat may respond differently to the same amount of water table drawdown than ones with shallow peat or those lacking peat. For example, a wetland that is underlain primarily with mineral soil will not undergo land subsidence to the degree that one with thick peat/muck layer will. Similarly, a shallow basin wetland may convert entirely to upland with reductions in water tables while a wetland within a deep depression, and an equal reduction in water level, will maintain a wet central portion. Hypsometric curves (water depth or volume plotted against elevation, with the deepest part representing zero depth and volume) for wetlands would contribute to this knowledge base.

(2) **Qualitative Assessment of Alternative Preferred Methodologies**

Reduction of natural variation can be handled by further partitioning variation through another iteration of classification. Just as criteria were established for the original reference set (i.e., isolated cypress swamps, size greater than 0.5 acre), consideration should be given to classification factors such as deep versus shallow depressions, number of distinctive vegetation and hydroperiod zones, and thickness of the organic-rich layer.

Subsets of the original classification would be contingent upon obtaining a substantially larger reference set. The three types of depressions suggested by Watson et al. (1990) provide a stratigraphic and hydrologic perspective. This is not to suggest that geotechnical information be collected for all or most reference cypress domes. Rather, some of the more obvious differences are size and shape of the basin. The purpose of the classification should be reconsidered if further classification is to be contemplated. The classification should reflect the purpose to which it is intended, and not be an exercise in taxonomy. In other words, if sub-classification does not enhance the resolution of the method, it is not worthwhile.

3.1-E(5). ***Using Estimated P50's in Wetlands***

(1) **Description of Alternative Preferred Methodology(s)**

Establishment of a Minimum Level for cypress domes in the Northern Tampa Bay area is a necessary first step to protect the wetland resource. Nevertheless, there is a legitimate concern that the natural variability in wetland hydrology does not lend itself to a single Minimum Level for all cypress domes in the area. Citing only the limited data available for the 21 reference wetlands deemed "not significantly changed," one can see at least a four-fold difference in the average separation between normal pool and P50. With this magnitude of variation for high quality, unaltered wetlands, reliance on a single median value for protection may be meaningless.

Over the range of natural variation, many wetlands will not be sufficiently protected. NW115, for instance, has a median difference between P50 and normal pool of 0.42 foot. If the wetland were altered to the extent that the median P50 was allowed to drop to 1.8 feet below normal pool, it is easy to picture the degradation that would occur. This problem led the Panel to wonder how difficult would it be to establish individual Minimum Levels for each wetland.

The Minimum Level is currently established as the median difference between the normal pool and P50. The normal pool is usually measurable in the field instantaneously, whereas P50 currently requires the accumulation of many years of water-level readings. In wetlands, however, there may be markers or indicators that correspond to P50, just as the normal pool has its indicators. If these indicators were identified in the 21 reference wetlands by correspondence with the established P50, then these indicators could possibly be used to "transfer" P50 to ungaged wetlands, allowing the real difference between P50 and NP to be estimated for any wetland that possessed the same indicators. Once the ability is gained to set Minimum Levels for each wetland, then wetlands like NW115 would be protected.

(2) Qualitative Assessment of Alternative Preferred Methodologies

Since the 21 "not significantly altered" reference wetlands already have documented P50s and vertical datums, it would be a relatively simple surveying procedure to determine what kind of indicators cluster around the median water level. Since biological indicators are likely responding to depth and duration of flooding, it seems highly likely that a set of recognizable indicators will sort out around a standard level. Even if none is located exactly at the P50, it may be possible to estimate P50 by knowing its departure from the indicator, positive or negative. The variance associated with P50 indicators may be higher than that for normal pool indicators, but the gain in accuracy for setting Minimum Levels based on the actual difference between the normal pool and P50 would greatly offset that shortcoming for wetlands with small normal pool minus P50 values.

The application of wetland-specific Minimum Levels based on the difference between estimated P50 and the normal pool could be fairly simple. Using the proportion established between the median difference between normal pool and P50 and the Minimum Level (i.e., the ratio, 1.8:1), the difference between estimated normal pool and P50 is scaled proportionally to establish a site-specific Minimum Level. For instance, if a site demonstrated a difference between the estimated P50 and a normal pool of 0.8 foot, its scaling would be calculated as (0.8)(1.8) = 1.4 feet. This value would then serve as the basis for establishing the wetland-specific Minimum Level as the normal pool minus 1.4 feet.

Generalizing this methodology, the maximum allowable decline divided by the median normal pool minus P50 departure for wetlands yields a proportionality constant that shall be called (for purposes of demonstration here) the "Maximum Decline Constant" (MDC). For the Northern Tampa Bay area, the number appears to be approximately 1.8 (i.e., 1.8/1.0), but it could be determined for any region. The "Individual Allowable Decline" (IAD) for a particular site simply equals the wetland-specific normal pool minus P50 value times the MDC, or in the example, 0.8 times 1.8 = 1.4.

While this method has the advantage of considering wetland-specific variability, it has the potential drawback of requiring an estimate of P50. But even a poor estimate of P50, erring on the low side, would be better justified than applying a blanket 1.8-foot Minimum Level to all cypress domes, regardless of their natural range of variability.

There may be other specific techniques to achieve the same goals. Here we lay them out in conceptual fashion only. In short, using a derivative of the natural variation for individual wetlands has the advantage of reducing the consequences of inappropriate management.

3.1-F. Discussion and Conclusions

The District developed a Minimum Level for palustrine cypress wetlands, commonly called cypress domes, in the Northern Tampa Bay area by establishing an average water level, below which "significant change" might be expected to occur. The Panel reviewed the quality of information used, the methodology and assumptions used to develop the Minimum Level. Limitations in the review process prevented the Panel from determining that the District had used "best information available." The Panel found, however, that the procedures and analyses were generally laudable, that care was taken to use data properly and to avoid corrupted data, and that most technical assumptions were reasonable and did not adversely affect the outcome.

The Panel identified two substantive deficiencies in the establishment of the Minimum Levels, both of which are believed curable. Because the hydrological data set was relatively short and coincided with a series of drought years, the Panel found that the water-level data were not representative of long-term conditions. Several methods have been advanced to adjust the data for the drought or to estimate missing data. Second, statistical properties were discovered in the reference wetland data that appear to bias the results. Remedies are proposed for this problem, as well.

In addition to the above evaluation, the Panel has proposed alternative conceptual approaches for establishing Minimum Levels. In general, methodologies based on a broadened perspective on hydrology – where hydrology is used not only to define the unaltered condition of the wetlands, but as a predictor of change -- would provide a more robust tool. Assessment of wetland area changes and the monitoring of wetland clusters are suggested as potential approaches to a more sophisticated use of Minimum Levels that do not rely on a single metric. As additional data are collected, the opportunity to classify cypress domes by relevant features or hydrogeologic characteristics will help reduce variability and increase sensitivity for detecting change. Until enough data are available to support classification, a potential method is proffered for using estimated P50's to establish wetland-specific Minimum Levels in cases where the blanket Minimum Level may not provide the desired level of protection.

SECTION 3.2
CATEGORY 1 AND CATEGORY 2 LAKES

3.2 CATEGORY 1 AND CATEGORY 2 LAKES

3.2-A. Target Resources

The target resources include lakes in the Lakes Terrace region (also known as the Northwest Hillsborough region) which encompasses Northwest Hillsborough, Northeast Pinellas, and South-Central Pasco Counties. These lakes are fringed to some extent by cypress wetlands. The categories (Category 1 and 2) refer to the presence or absence of structural alterations that affect water level. Lake area, depth, water quality, and uses are not intended to be factors in the selection or classification of lakes for the purpose of establishing minimum water levels, and watershed area is also not a consideration for selection. Lakes without any fringing cypress wetlands are considered to be Category 3 lakes and are not considered in this review. Location in the Lakes Terrace region is intended to minimize major geologic dissimilarities that affect lake hydrology.

Target lakes for which Minimum Levels are established are referred to as *adopted lakes* and include the entire lake volume and the peripheral cypress swamp as integral parts of the system. Resources of concern include all biological components of the system and water chemistry, as well as physical lake features.

3.2-B. Summary of Methodologies Used to Establish Minimum Flows and Levels

The methodology for defining Minimum Levels for target lakes involves 20 specific determinations and derivations that are defined below:

1. **WRAP** – Northern Tampa Bay Water Resources Assessment Project; 1996 study of area including parts of Hernando, Pasco, Hillsborough, and Pinellas Counties, and containing the Lakes Terrace, Brooksville Ridge, and other defined regions. This water-level evaluation involved only the Lakes Terrace region, also known as the Northwest Hillsborough region.
2. **Historic** – from a time period in which impacts from wells are considered insignificant.
3. **Current** – from a time period in which impacts from wells are considered significant.
4. **Control Structure** – a structural alteration to a lake outlet that affects the lake water level.
5. **Control Point Elevation (CP)** – the elevation of the point along the control structure profile or outlet channel that controls water level.
6. **P10** – lake surface elevation which is exceeded 10% of the time; generally a measure of the highest water level likely without extreme conditions.
7. **P50** -- lake surface elevation which is exceeded 50% of the time; median lake level.

8. **P90** -- lake surface elevation which is exceeded 90% of the time; generally a measure of the lowest water level likely without extreme conditions.

9. **Reference Lake Water Regime (RLWR)** –the set of median differences between P10, P50 and P90 as statistically defined from a set of reference lakes. For the set of 22 reference lakes from the Northwest Hillsborough region, the median of (P10-P50) = RLWR50 = 1.0 foot, and the median of (P10-P90) = RLWR90 = 2.1 feet.

10. **Reference Lakes** – a set of lakes from the Lakes Terrace region determined to have either no significant water-level changes from well withdrawals (16 lakes) or at least 10 years of historic (pre-withdrawal) water-level data (6 lakes).

11. **Normal Pool (NP)** – the historic "high" water level as estimated from hydrologic indicators. Generally assumed to be close to the P10 level, but not necessarily identical to it.

12. **Hydrologic Indicator (HI)** – a measurable permanent feature which allows determination of historical water levels and the associated normal pool; cypress buttress inflection elevations were used for the adopted lakes addressed in this report.

13. **High Guidance Level (HGL)** – an estimate of the high water level for purposes of siting buildings, docks and related structures. Depending upon the presence of historic data and structures, HGL is set as follows (see Figure 13 of the Lakes Section in the White Papers):
    - Where historic data exist, HGL = Historic P10.
    - Where only current data exist and structural alteration has not lowered the Control Point below the normal pool, HGL = Current P10 or normal pool, whichever is higher.
    - Where only current data exist and structural alteration has lowered the control point below the normal pool, HGL = Current P10 or control Ppoint, whichever is higher.
    - Where no water level data exist, HGL = control point or normal pool elevation, whichever is lower.

14. **Historic P50** – P50 value estimated for the time period when well impacts were insignificant, calculated as follows (see Figure 14 of the Lakes Section in the White Papers):
    - Where historic data exist, Historic P50 = P50 from historical data.
    - Where only current data exist and Current P10-Current P50 < RLWR50, Historic P50 = HGL minus (Current P10-Current P50). Note that HGL may equal Historic P10, Current P10, normal pool, or the control point in accordance with Number 13 above.
    - Where only current data exist and Current P10-Current P50 > RLWR50, Historic P50 = HGL minus RLWR50.
    - Where no data exist, Historic P50 = HGL minusRLWR50.

15. **Category 1 Lakes** – Cypress wetland fringed lake where structural alterations do not prevent Historic P50 from rising above an elevation equal to normal pool minus 1.8 feet. Note that the 1.8-foot elevation is given as the level below which significant harm is done to reference palustrine cypress wetlands.

16. **Category 2 Lakes** - Cypress wetland fringed lake where structural alterations prevent Historic P50 from rising above an elevation equal to normal pool minus1.8 feet, but the cypress wetland continues to provide functions deemed beneficial to the lake.

17. **High Minimum Level (HML)** – a regulatory P10 value for avoiding unacceptable impacts, set as follows (see Figure 15 of the Lakes Section in the White Papers):

    - If Historic P50 > (normal pool minus 1.8 feet), then the HML = normal pool minus 0.4 foot). Note that 0.4 foot comes from evaluation of impacts of water level on reference palustrine cypress wetlands.
    - If Historic P50 < (normal pool minus 1.8 feet.), then the HML = HGL. Note that HGL may equal Historic P10, Current P10, normal pool or the control point in accordance with Number 13 above.

18. **Minimum Level (ML)** – a regulatory P50 value for avoiding unacceptable impacts, set as follows (see Figure 15 of the Lakes Section in the White Papers):

    - If Historic P50 > (normal pool minus 1.8 feet), then the ML = (normal pool minus 1.8 feet).
    - *If Historic P50 < (normal pool minus 1.8 feet), then the ML = Historic P50.* Note that Historic P50 may equal P50 from historical data, HGL minus (Current P10-Current P50), or HGL minus RLWR50 in accordance with Number 14 above).

19. **Low Guidance Level (LGL)** -- a P90 value used as an estimate of the low water level for purposes of siting buildings, docks and related structures, and management of outflow control structures. Depending upon the presence of historic data and structures, LGL is set as follows (see Figure 16 of the Lakes Section in the White Papers):

    - Where historic data exist, LGL = Historic P90.
    - Where only current data exist and Current P10-Current P90 < RLWR90, LGL = HGL minus (Current P10-Current P90).
    - Where only current data exist and Current P10-Current P90 > RLWR90, LGL = HGL minusRLWR90.
    - *Where no water level data exist,* LGL = HGL *minus* RLWR90.

20. **Ten-Year Flood Guidance Elevation (TYF)** – an elevation associated with flood potential with a recurrence frequency of 10 years. This appears in the adopted lake scenarios and is given for many lakes in the WRAP study (Ref-42), but has no defined role in the setting of Minimum Levels through this process.

The lakes portion of the overall effort to develop minimum standards for flows and water levels in the Northern Tampa Bay area revolves around setting target water levels in accordance with the above measures that are then expected to protect associated resources. To accomplish this, effort was made to characterize and understand:

a. Historic water level regimes.
b. Structural alterations that control water level.

c. Well withdrawal impacts on water level.
d. Potentially impacted resources and their relation to water level.

Each of these is addressed below.

(a) Historic Water-Level Regimes

Historic water-level regimes were determined from a set of reference lakes for which water levels are believed to be unaffected by well water withdrawals. Lines of evidence supporting the 22 choices include:

- Some lake-level data are from a period when there were no major wells operating in the area.
- Numerical modeling of regional groundwater levels indicates that some more recent lake-level data are relatively unaffected by groundwater withdrawals.
- Comparison of distance-drawdown relationships for lakes in zones of potential well influence suggest that some lakes are in an area that is distant enough from the nearest wellfield to be unaffected by groundwater pumping. Further support for this observation was provided by the synchrony of the surface-water level fluctuations among the reference lakes over an extended period of record (*POR*; see Lakes White Paper, Appendix E).
- Lack of a significant statistical trend before and after wellfield withdrawals in the Upper Floridan aquifer water level of a well in close proximity to one of the reference lakes (Lake Thomas).

Water-level data for the chosen reference lakes were used to construct P10, P50 and P90 values (Lakes White Papers, Table 2). The average and median difference between P10 and P50 was 1.0 foot, with a range of 0.4 to 2.4 feet and a standard deviation of 0.44 foot. The average difference between P10 and P90 was 2.3 feet, and the median difference was 2.1 feet, with a range of 1.2 to 4.4 feet and a standard deviation of 0.73 foot. Committee meeting minutes indicate that use of more statistical treatments involving standard deviation or other refinements were dropped in favor of a simple RLWR50 of 1.0 foot and a RLWR90 of 2.1 feet. In other words, the median values for differences between P10 and P50 or P90 for the reference lakes were adopted as standard. Where historic data or structural modifications do not dictate otherwise, these values are used to establish the Historic P50 and Minimum Level.

(b) Structural Alterations

Structural alterations that control water level were found to be common. All but one reference lake has been structurally altered (Lakes White Papers, Table 1). A policy decision was made that target water levels could not be set without consideration of those structural alterations. New control points (*CPs*) could either raise or lower the water level, affecting the normal pool (*NP*) and the water-level regime. Where a lake has been structurally altered, the CP is used to establish the HGL if it is lower than the NP or higher than the Current P10.

(c) Groundwater Withdrawal Impacts

Well water withdrawal impacts on lake water level are a function of the rate of withdrawal, the distance of the lake from the well, and the interconnectedness of the surficial and deep (Upper Floridan) aquifers. The first two factors are fairly easy to determine, while the last one is the subject of considerable hydrogeologic investigation. Reference materials (Sup-3, Sup-2, Ref-28) suggest that where the surface and deep aquifers are separated by a leaky confining layer, the time necessary for changes in potentiometric level in the Upper Floridan aquifer is on the order of tens of days. The time for response in the water table, and by extension in lakes, can be on the order of weeks to months.

Major wellfields in the study area (primarily from Ref-49) are listed in Table 2.

Table 2

Wellfields of the Lakes Terrace Region

Wellfield	Intiation Date	Est. Pumpage (mgd)
Cosme-Odessa	1930	5.7 to 8.7
NW Hillsborough	1932	8.8 to 9.4
Eldridge-Wilde	1956	23.5 to 27.6
Section 21	1963	8.5 to 9.4
South Pasco	1973	11.7 to 12.3
Starkey	1974	12.0
Cypress Creek	1976	25.1 to 28.6
Morris Bridge	1979	5.0
Crossbar	1980	29.9 to 31.8
North Pasco	1992	2.7 to 2.8
Cypress Bridge	1996	1.1

It is readily apparent that the withdrawal of water from these wells, in addition to private wells that may exist, could have an effect on water levels of unperched lakes (i.e., seepage lakes) within the zone of influence of those wells. While there may be some perched lakes in the study area, nearly all lakes are expected to interact freely with the water table. However, the degree of impact will be dependent on a variety of hydrologic features, including precipitation, evaporation, surface inflow and outflow, and direct augmentation and withdrawals, as well as the groundwater level. Additionally, the physical nature of sediments in the lake (location and thickness of any muck layer) will affect losses via groundwater in response to any lowering of the water table.

The Lakes Terrace region is described in the Lakes White Paper as an area with a semi-confined aquifer. Therefore, interaction between lakes and the surficial aquifer is likely but variable among lakes, complicating prediction of impacts and necessitating some flexibility in management approach.

(d) Resource Impacts

Resources that could be impacted by changing water-level regime include the range of plants and animals that live in or around lakes, lake water quality, and lake morphometry. Committee meeting minutes and reviews provided by third parties indicate consideration of lake morphometry, water quality, plant communities, plankton, fish, and overall biological diversity as impact indicators. The Committee appears to have concluded that the impact of changing water-level regime on fringing cypress trees was the most practical means of setting target water levels. The inflection point elevation of the cypress buttresses was considered an appropriate hydrologic indicator of NP elevation, and impacts were linked to a P10 decline of 0.4 foot and a P50 decline of 1.8 feet. (see Lakes White Papers). This determination, however, was based on impacts in palustrine wetlands and not on examination of lake-fringing cypress wetlands.

All lakes used as test cases had fringing cypress wetlands. These adopted lakes were divided into two categories: those where any structural alterations have not caused the Historic P50 to decline below the level of NP minus1.8 feet (Category 1), and those where structural alteration has caused such a decline in the Historic P50 (Category 2). The Historic P50 can be estimated several ways, but the central feature is that it is the median water level in the absence of well withdrawal impacts. Of the adopted lakes, four were classified as belonging in Category 1 while 11 were placed in Category 2.

Returning to the actual derivation of Minimum Levels, the values derived for each key hydrologic feature of the lake (see definitions above for the HGL, Historic P50, HML, ML, and LGL) are used to set water-level targets for each of the 15 adopted lakes. Cypress buttress inflection point elevations were used in each case to set NP. There were no historical data for any adopted lake.

For the Category 1 lakes, HML, ML and LGL are dependent on NP:

- HML = (NP minus 0.4 foot) and ML = (NP minus 1.8 feet). Of the four lakes in Category 1, three were not structurally altered and the other had an outlet structure that appears to be operated to allow outflow only at an elevation equal to NP.
- LGL = HML minus RLWR90 or (Current P10-Current P90), whichever produces the higher water level. Current P90 was calculated for only one of the four Category 1 lakes, and all applied LGL = HML minus RLWR90.

Considering future water-level management needs for Category 1 lakes, the Current P10 exhibited no consistent relationship with the HML (= target P10), ranging from 1.2 feet lower to 0.3 foot higher (based on only 3 data points). The Current P50 exhibited a similarly inconsistent relation to the ML (= target P50), ranging from 2.9 feet lower to 0.1 foot higher (again, based on only 3 data points).

For the Category 2 lakes, HML and ML are not a function of NP, but rather of the higher of CP and Current P10:

- HGL = CP or Current P10, whichever is higher. Only 1 of 11 Category 2 lakes applied CP to derive HGL; the Current P10 was the higher water level in 10 of 11 cases.
- Historic P50 = HGL minus RLWR50 or (Current P10-Current P50), whichever provides the higher water level. All 11 Category 2 lakes used RLWR50 to derive the Historic P50; Current P10-Current P50 was always > 1.0 (usually around 2.0 feet).
- HML = HGL.
- ML = Historic P50.
- LGL = HML minus RLWR90 or (Current P10-Current P90), whichever produces the higher water level. All 11 Category 2 lakes used RLWR90 to derive LGL; no estimates of Current P90 were provided.

Considering future water-level management needs for Category 2 lakes, the HML was derived from the Current P10 in all but one case. Therefore, the HML and Current P10 are identical except for the one case in which CP was used to generate HML (in which Current P10 is 0.9 foot lower than HML). The Current P50 is consistently lower than ML for Category 2 lakes, with an average difference of 1.3 feet and a range of 0.2 foot to 3.8 feet.

3.2-C. Evaluation of Scientific Reasonableness

3.2-C(1). Review of Nature and Character of Information Utilized

3.2-C(1a). Quality Assurance

Issues pertaining to quality assurance include maintenance of staff gages, missing hydrographic data, incorrect National Geodetic Vertical Datum (*NGVD*), and failure to independently corroborate the hydrologic indicator (*HI*), described as follows:

- **Staff gages** -- Some of the staff gages in the reference and adopted lakes are in need of maintenance and/or relocation. For example, the staff gages in Bird Lake and Lake Padgett are above the surface water during periods of low water levels. In some cases (e.g., Lake Padgett), lowering the scale on the staff may suffice, but in other cases (e.g., Bird Lake), the gage needs to be moved to a deeper location since the surface-water level was several tenths of a foot behind the gage toward the center of the lake. In addition to its shallow location, the Bird Lake staff gage has rusted so as to render it unreadable. Some lakes occasionally have missing monthly data on the spreadsheets, suggesting water levels may have been below the staff gage.

- **Missing hydrographic data** -- For several of the reference lakes (i.e., Bell, Big Vienna, Geneva, Gooseneck, Minniola, Seminole, and Tampa), the historic period of record (POR) was punctuated with missing data. Frequently the missing data gap occurred at the beginning of the POR after only a few initial data points (Bell, Geneva, Gooseneck, Minniola, Tampa), but in one lake (Seminole) the data gap occurred at the end of the POR. For those lakes that have long periods of no data collection, the historic POR should have been shortened to correspond to the years when the hydrographic record was unbroken. For instance, Gooseneck's POR is shown between 1978 and 1997; however, there is only one datum (March 1978) prior to November 1987. Lake Tampa has two data points (March and May 1978) prior to December 1986, yet its POR is 1978 to 1997 in the Lakes White Paper. Thus, more appropriate POR for Gooseneck Lake is1987 to 1997 and for Tampa Lake is 1986 to 1997.

- **Incorrect National Geodetic Vertical Datum (NGVD)** -- The P10 and P90 elevations for one of the reference lakes, Bird Lake, are reported to be 66.8 and 64.4, respectively, in Table 2 and on the hydrograph in the Lakes White Paper. However, the reference lake database spreadsheet provides P10 and P90 elevations of 49.6 and 46.2, respectively, for Bird Lake. There apparently is a constant error in the base elevation (NGVD), which may be related to two different Bird Lakes being confused. The results of a survey of Bird Lake (Pasco County) by one of the Panel members supports the 66.8- and 64.4-foot elevations.

- **Independent Corroboration of the Hydrologic Indicator** -- Given that the determination of the inflection point in the butt swell of cypress stems, to within a few inches, is more of an "art" than a "science", an independent measure of the inflection point should have been part of the quality assurance program. This could have been accomplished in two ways: (1) a different wetland team could have measured the same cypress trees to confirm that the technique employed by the designated wetland team was unbiased and repeatable; or (2) the designated wetland team could have measured another population of cypress trees located at a different area of the lake for consistency in the inflection point elevations among two separately located cypress tree populations. There were instances where the replicate inflection point elevations among the trees within a lake yielded poor precision (Lakes Juanita, Stemper, and Sunset), which may have been due to the measurement error of a different wetland team than the one typically charged with the field measurements (as indicated by District scientists at the first Public Meeting). This indicates a need for cross-training among the wetland teams.

3.2-C(1b). Justification for Data Discarded

Since the reference lake set was used to determine the RLWR, the selection of reference lakes is a critical aspect of setting Minimum Levels for lakes. Establishment of the largest possible data set and careful evaluation of sources of variability are important considerations. Several hundred lakes were available for consideration, but apparently only 88 were evaluated in any detail. Out of the 88 lakes considered, only 22 were chosen. Key criteria for selection included the existence of at least 10 years of usable data, no evidence of impact from well withdrawals, and location in the targeted hydrogeologic setting (Lakes Terrace region). Justification for discarding some lakes and the associated data has been provided both verbally at public meetings and in the Lakes White Paper, but the selection/discard process has not been thoroughly documented.

Further examination of lake hydrographs in the WRAP report (Ref-42) by the Panel revealed that, in addition to the 22 selected reference lakes, another 32 lakes appeared to have the potential for inclusion in the reference lake data set. This initial analysis was based on the appearance of the hydrograph, specifically lack of upward or downward trends in the median water level and absence of extreme variation in the maximum and minimum water levels. Further assessment of these 32 candidates for such features as major withdrawals or augmentation, location within the targeted area, and proximity to wellfields allowed elimination of 20 of those lakes, although the variability represented by those lakes provided valuable insights.

Seven lakes (Browns, Buck, Crescent, Keene, Keystone, Mound, and Pretty) of the 12 remaining lakes may be candidates for elimination, but only after a more detailed explanation is provided. The similarity of the water-level regimes of these lakes to many chosen as reference systems is striking. Even accepting these deletions, the Panel can find no reason to discard the data from the remaining five supplementary reference lake candidates, all of which are in close proximity to other lakes that were chosen as reference lakes. These lakes (Carroll, Chapman, Hiawatha, Lipsey, and White Trout) have water-level regimes similar to lakes chosen as reference systems and have no available record of any augmentation, direct withdrawal, or change in outlet structure during the applied POR.

The Panel's analysis of the 54-lake data set (22 reference lakes plus 32 potential candidates) showed a slight positive correlation between hydrologic measures (e.g., P10-P90) and the number of observations for a lake. The removal of lakes with less than 75 data points resulted in the elimination of any significant relationship, suggesting that a reference lake should have at least 75 observations before it is included in the data set. While 10 years of data may be a desirable goal for reference data sets, it would have been possible to have valid data sets with fewer years of data (7 years of monthly data) and invalid data sets for longer periods [15 years of seasonal (quarterly) data]. Consequently, the criterion of 10 years of data for reference lakes may not be entirely justified, and data may have been unfairly discarded.

The above limitations in the reference lake selection process resulted in a less robust data set for reference conditions, but affected the established RLWR to only a minor extent. Although the inclusion of the P10-P50 data for the 5 additional lakes to the 22-lake reference data set would not have changed the mean P10-P50 value, it would have lowered the median P10-P50 to 0.9 foot (from 1.0 foot). Addition of those 5 lakes plus the 7 lakes that appeared reasonable for inclusion would have lowered the RLWR mean and median P10-P50 to 0.9 foot (from 1.0 foot). In the Panel's opinion, these are not especially large changes, however, and do not represent a major flaw in the analysis.

3.2-C(1c). Collection of Data

There are two issues pertaining to data collection:

- **Sample Size** -- Most wetland scientists work with large numbers of trees when they examine hydrologic indicators. The measurement of only a few trees per lake (from 2 to 11 trees) restricts the level of significance in statistical analyses that use standard errors of the estimate, correlation coefficients, and confidence intervals.
- **Inclusion of Wetlands Lacking Sampling Data** -- Two of the 15 adopted lakes do not have independent data. Although Lake Sunshine is connected to Lake Dosson by a ditch, there are no hydrologic indicator or hydrographic data presented for Lake Sunshine. In another set of connected lakes, Little Moon and Rainbow, one of the lakes does not have an independent observation of the hydrologic indicator but does have surface-water hydrographic data. Unless it can be demonstrated that each of these two lake pairs are hydrologically connected to such an extent that they are not isolated, then their inclusion in the data set is questionable.

3.2-C(1d). Best Information Available

Although the Panel believes that the analysis conducted for selecting the reference lakes (as presented in the Lakes White Paper) is still valid, it does not appear to incorporate the best available data.

- **Additional Reference Lakes** -- As described in Section 3.2C(1b) above, there appear to be more data suitable for inclusion in the reference lake data set, but such inclusion would result in only a slight reduction in the RLWR measures. The addition of reference lakes to the data set would enhance the subsequent analyses of RLWR and might have allowed the establishment of two or more classes of reference lakes based on geographic locale and associated features.

- **Suspect Reference Lakes** -- There are four lakes included in the reference set that are suspect: Gooseneck, Tampa, Bird, and Moon. Gooseneck, Tampa and Bird Lakes are located in south-central Pasco County and have seemingly high variability in their hydrographs. They meet the minimum criteria for selection as described previously, but may bear increased scrutiny as a consequence of the higher variability in water levels. If this variability is natural, it should indeed be incorporated into the reference database. However, such a situation would suggest a likely need for at least two classes of reference lakes, a possible improvement in the approach (discussed in Section 3.2-D and -E below).
- **Inconsistent Selection** -- Moon Lake appears to have hydrologic features similar to those of Crews Lake, which was not chosen as a reference lake. Both are near wellfields on the edge of the border between two hydrogeographic areas (Areas 2 and 3 on Figure 6, Lakes White Paper), and both exhibit greater water-level variability than most other reference lakes. If it is appropriate to include Moon Lake, it would seem appropriate to include Crews Lake. It may be more appropriate to establish another class of reference lakes that would include at least these two lakes, but that issue is addressed below.
- **Alternative Hydrologic Indicators** -- The use of only one HI is also a concern. Most of the adopted lakes lacked alternative hydrologic indicators, such as the crowns of Lyonia roots, lichen lines, and moss collars. This mandated the use of just one HI (cypress butt swell inflection) as the sole HI for normal pool for all the wetlands. However, some of the wetlands did have extensive and consistent alternative indicators of the normal pool. The most common was the presence of a lichen line. For those adopted lake wetlands possessing an alternative HI (e.g., Little Moon), measurement of the bottom elevation of the lichen line would have provided valuable data for justifying reliance on only the cypress butt swell inflection point in establishing normal pool.
- **Aerial Photography** -- Aerial photography may not have been applied to its most beneficial use for evaluating lake conditions. A common approach used by wetland scientists in assessing ecological impacts is to compare a time series of aerial photographs. At a minimum, aerial photography can identify areas where wetlands have been altered to such an extent that they no longer exist. Depending on the scale and season (spectral reflectance of cypress trees during the fall and winter is different than for upland tree species and wetland shrubs), false color infrared (IR) aerial photographs may also provide valuable information on cypress standing crop (stems per ha), prevalence of an understory, and extent of subsidence.

Aerial photography for the WRAP area dates as far back as 1938 for a few of the wetlands. More commonly, aerial black and white photographs of lake cypress communities began in 1948 to 1969. False color IR replaced black and white photography in the early 1980s. False color IR images captured during 1994-1995 were provided for the adopted lakes in the White Paper.). The Lakes Subcommittee notes list aerial photography with contouring available (e.g., 1:2000 IR; 1:200 black-and-white) as one of 10 criteria used to select the adopted lakes, but there was no reference to reviewing these aerial photographs found in the Lakes White Paper or the Lakes Subcommittee notes.

One Panel member examined a time series of aerial photographs for seven of the reference and adopted lakes. The Tampa Bay Water Authority has a catalogue of aerial photographs dating back to 1948. Unfortunately, the scale (1:24,000) did not provide sufficient resolution to discern anything but gross wetland area lost or gained. However, it appeared that there had not been significant incremental loss of wetlands surrounding any of the seven lakes (Alice, Little Moon, Merrywater, Sunset, Bird, Padgett, and Thomas) since the beginning of aerial photographing to the present. It seems that conversion of wetlands to other land uses had occurred prior to either 1948 (in the case of Lakes Alice, Little Moon, Merrywater, and Sunset) or 1967 (Lakes Bird, Padgett, and Thomas). Since most of the housing developments during the last three to five decades have been on mostly former agricultural lands, minimal losses in areal coverage of fringing wetlands is likely. The amount of wetlands that have been drained, ditched, and logged for agricultural pursuits (most notably citrus crops) prior to 1948 and 1967 is unknown.

Although nothing can be gained concerning the community structure or functions of cypress wetlands from aerial photography at this scale, the fact that only minor wetland losses have occurred during the past three to five decades is significant, at least for the subset of the seven fringing wetlands examined. Whether it takes this period of time (or longer) before cypress mortality to occur, given the stresses placed on them by altered hydroperiods, is uncertain.

While the Panel can not conclude that the best available information was applied, the limitations described above are not viewed as critical. Failure to include all available information may slightly detract from the overall utility of the analyses and may result in a RLWR that is too large by a few tenths of a foot. However, failure to include all available information does not invalidate the approach for estimating RLWR.

3.2-C(1e). Other Considerations

Three general questions are raised in reviewing data selected from a larger data set for any purpose:

- Are criteria for selection and rejection clearly stated and applied?
- Are selections and rejections adequately documented?
- Can corrections be made later in an adaptive mode in light of new information?

Data used to establish the RLWR and to set Minimum Levels for adopted lakes were generally not collected with that purpose in mind. The data sets that made this analysis possible extend back two to seven decades, and their collection involved multiple individuals, agencies and methods. Changes in water routing and storage due to human influence complicate the analysis, and long-term variation in precipitation may also be a significant factor. The existence of the long-term database is essential to the process of setting Minimum Levels, but that database must be manipulated to facilitate the process.

The process by which data were reviewed and utilized has been explained in public meetings and to some extent in the Lakes White Paper. The District staff responsible for such analysis approached the problem in a scientific manner. The criteria for inclusion as a reference lake are clearly stated, but the documentation of the selection process provided to the Panel is lacking in detail and leaves some selections and rejections open to interpretation. The Panel's interpretation is that the selected reference lakes provide a reasonable data set for the intended purpose, but that it may not be the best available data set. Furthermore, variability among lakes warrants further evaluation within the context of establishing reference conditions. Further examination of reference lakes and possible establishment of reference lake classes is not precluded by the actions taken to date, however, and allows adaptive management in the future.

3.2-C(2). Review of Technical Assumptions

3.2-C(2a). Reasonableness and Consistency with Available Data

The establishment of minimum water levels for adopted lakes depends upon the following technical assumptions:

(a) Groundwater withdrawals affect lake water levels.

(b) Data are available for lakes that are not significantly affected by groundwater withdrawals, either from a period prior to withdrawal or from locations minimally impacted by such withdrawal or from lakes with levels not tightly linked to groundwater levels.

(c) The set of reference lakes adequately represents water-level fluctuation in other lakes in the absence of groundwater withdrawals.

(d) The HI is a reasonable indicator of NP for lakes.

(e) HML = NP minus 0.4 foot and ML = NP minus 1.8 feet will be sufficient to minimize impact of water level fluctuation on fringing cypress wetlands.

(f) Maintenance of a water level that limits impact on fringing cypress wetlands will be sufficiently protective of other lake resources.

(g) Where achievement of a water level that limits impact on fringing cypress wetlands is not possible due to structural alteration of the lake outlet, maintenance of the RLWR in relation to the established HML (CP or Current P10, whichever is higher) will be sufficient to protect remaining lake resources.

(h) The establishment of HML (target P10) and ML (target P50) values is sufficient to define a water-level distribution that is suitably protective of lake resources.

All of these assumptions are plausible, which some may interpret as reasonable. It would seem more appropriate from a scientific perspective to concentrate on whether these assumptions are consistent with the available data. Each of these assumptions is addressed below:

Assumption (a): *Groundwater withdrawals affect lake water levels:*

For groundwater withdrawals to have an effect on the surface-water levels of lakes in the region, there has to be a hydraulic connection between the lake and the underlying groundwaters. Hydrogeologic studies of isolated palustrine wetlands in the Eldridge-Wilde and Starkey wellfields have demonstrated that those wetlands can be highly variable in their hydraulic connection to the Upper Floridan aquifer, depending on the presence or absence of solution features or relict sinkholes (Ref-10). However, it is the Panel's opinion that the assumption made in the Lakes White Paper that the lakes in the Lakes Terrace region function primarily as seepage lakes is valid for most of the lakes included in the reference and adopted lake data sets. As such, these lakes are (and will continue to be) affected by groundwater withdrawals. We offer the following evidence in support of that assumption:

- *Reconstructed Water Budgets* -- Reconstructed water budgets were calculated for an 11-lake subset of the 22 reference lakes in the following manner. The method employed assumed that:

  i. a low watershed to lake area ratio results in minimal surface inflows into the lake during a period of low rainfall (1989-1994);

  ii. control points near or above the P10 of a lake result in minimal to no surface water outflow from the lake during the period of low rainfall (1989-1994); and

iii. if there is no net change in the lake level from the beginning to the end of the reconstructed water budget period, then the difference between the precipitation and evapotranspiration (*ET*) is the amount of water delivered to groundwater aquifers by seepage.

The areal watershed to lake ratio is less than 9 for each of the 11-member lake subset (see Table 3 below). With the exception of Lake Tampa, the CP for each lake was near or above the P10 of each lake. There were very few excursions except for Lakes Cow and Tampa during the reconstructed period when the surface-water level within each lake was above the CP elevations (Table 3). The Lake Hobbs data for 1989-1995 was the only data set that required the calculation of the change in storage (Table 4); all the other data sets indicated that surface-water elevation was nearly identical immediately before and after the reconstructed POR, indicating that changes in storage within the lakes were negligible in contributing to the water budget.

During the selected dry periods, all 11 lakes discharged to the surrounding groundwaters on a net basis (Table 3), making them seepage lakes under these conditions. Lake-level lowerings due to seepage bracketed a narrow range of 0.8 foot/year to 1.1 feet/year. When a high rainfall year (1988: 60 inches) is included in the data set, as was done with Lake Minniola, the seepage rate drops by 0.3 foot/year, indicating that either seepage rates were less and/or surface-water overflow occurred. These data indicate that, on average, the reference lakes function as seepage lakes at least during lower rainfall periods. Thus, increasing head potentials between the surficial and aquifer groundwaters will most likely result in increased seepage and thus lower lake water levels.

- *Pre- and Post-Groundwater Drawdown Hydrographs for Individual Lakes* -- Hydrographs for several reference lakes in the data set contain a POR that is sufficiently long to pre-date the initiation of groundwater pumping. For some of those lakes (e.g., Stemper and Hobbs), the hydrographic record is unbroken from 1946 to the present. The hydrographs for those two lakes in particular show a decreasing trend in the surface-water elevations after commencement of pumping from nearby wellfields (Section 21 in 1963 and South Pasco in 1973). In fact, Lake Stemper was designated as both a reference and adopted lake in the Lakes White Paper because of this apparent cause-and-effect relationship. Thus, for some of the lakes, long-term hydrographic data can demonstrate a probable cause-and-effect relationship between groundwater withdrawals and declining, more erratic water levels.

Table 3

Major Structural and Hydrologic Characteristics for a Subset of Reference Lakes that Received Reconstructed Water Budget Analyses

Lake	Control Point (CP) (in feet)	CP Above (+) or Below (-) the P10 (in feet)	Watershed: Lake Areal Ratio	Dredged	POR for Reconstructed Water Budget		Lake Surface-water Elevation Beginning and End of POR	Excursions Above CP Elevation During Period of Reconstructed Water Budget	
					Dates	Yrs	(in feet)	No. of Times	Duration (months)
Curve	None	No CP	3.4	No	1/90-1/97	7	77.5 - 74.4	0	0
Thomas	73.8	-0.8	3.9	Yes	1/90-12/93	4	72.8 - 72.8	1	5
Cow (East)	77.5	-0.5	3.9	Yes	12/89-12/93	4	77.5 - 77.5	4	35
Big Vienna	68.4	-0.4	8.4	No	1/91-12/94	4	66.9 - 67.1	1	2
Gooseneck	72.6	-0.2	6.4	Yes	12/91-1/95	3	70.3 - 70.3	0	0
Tampa	61.1	-3.2	2.5	Yes	1/91-1/95	4	61.6 - 61.7	3	31
Hobbs	65.5	+0.1	8.8	Yes	1/91-1/93	2	61.0 - 60.9	0	0
Hobbs	65.5	+0.1	8.8	Yes	1/89-1/95	6	64.7 - 60.0	0	0
Stemper	61.2	+0.1	3.8	Yes	1/90-12/96	7	59.2 - 59.1	0	0
Seminole	?	?	4.6	Yes	1/90-1/95	5	46.6 - 46.6	?	?
Minniola	?	?	6.6	Yes	1/88-12/93	6	49.1 - 49.0	?	?
Minniola	?	?	6.6	Yes	1/90-12/93	4	49.1 - 49.0	?	?
Moon	65.5	+0.9	2.4	Yes	1/91-1/95	4	36.5 - 36.5	0	0

Table 4

Reconstructed Water Budgets for a Subset of Reference lakes

Lake	Surface Area	Cumulative Rainfall for POR		Cumulative ET* for POR		Δ Lake Stage	Recharge (+) vs. Seepage (-)			
	(ha)	(m)	($m^3 \times 10^6$)	(m)	($m^3 \times 10^6$)	($m^3 \times 10^6$)	($m^3 \times 10^6$)	(m)	(feet)	(ft/yr)
Curve	10.5	8.57	0.90	6.31	0.66	0	-0.24	2.26	-7.4	-1.1
Thomas	66.4	4.63	3.08	3.61	2.40	0	-0.68	1.02	-3.3	-0.8
Cow (East)	39.7	4.63	1.84	3.61	1.43	0	-0.41	1.02	-3.3	-0.8
Big Vienna	14.6	4.95	0.72	3.61	0.53	0	-0.19	1.34	-4.4	-1.1
Gooseneck	10.9	3.67	0.40	2.71	0.30	0	-0.10	0.96	-3.1	-1.0
Tampa	23.6	4.95	1.30	3.61	0.95	0	-0.35	1.34	-4.4	-1.1
Hobbs	27.1	2.50	0.68	1.80	0.49	0	-0.19	0.70	-2.3	-1.1
Hobbs	27.1	7.06	1.91	5.41	1.47	-0.13	-0.57	2.10	-6.9	-1.1
Stemper	51.0	8.57	4.37	6.31	3.22	0	-1.15	2.26	-7.4	-1.1
Seminole	5.7	5.94	0.34	4.51	0.26	0	-0.08	1.43	-4.7	-0.9
Minniola	12.1	7.28	0.88	6.31	0.76	0	-0.12	0.97	-3.2	-0.5
Minniola	12.1	4.63	0.56	3.61	0.44	0	-0.12	1.02	-3.35	-0.8
Moon	40.1	4.95	1.98	6.31	2.53	0	-0.55	1.36	-4.46	-1.1

Notes: * Based on average of 35.5 inches/year (Ref-42).

- *Distance-Drawdown Relationships* -- The WRAP report (Ref-42) provides an assessment of the proximity of many lakes experiencing declining and more erratic surface-water levels (over a 20-year POR) to Cosme-Odessa, South Pasco, and Section 21 wellfields. All but 2 of the 14 lakes that were considered to be highly stressed because of lowered surface-water elevations are located near the 3 wellfields.

  More localized studies have scrutinized the impacts that wellfields can have on lake levels, especially for lakes that lie within a 2- to 3-mile radius of a wellfield (CDM, 1985; Schultz, 1995). Groundwater withdrawals accounted for 54 to 63 percent of the variation or decline in Starvation Lake, which lies within the Section 21 wellfield, according to multiple (Shultz, 1995) or linear (CDM, 1985) regression analyses. Groundwater models indicated that withdrawals at the rate of 7.5 mgd induces measurable increases in lake seepage rates within a 2- to 3-mile radius of the Section 21 wellfield (CDM, 1985).

Although distance from a wellfield is a critical factor in determining the degree of impact on a lake's surface-water level due to groundwater pumping (Lopez and Fretwell, 1992), it is not the only factor. Certainly the amount of groundwater withdrawal and the antecedent rainfall are important, but so are the morphometry, hydrogeology, and surface hydrology of the lake. For example, two similarly sized lakes (Mound and Calm) within one-quarter mile of each other and lying on opposite sides of the Cosme-Odessa wellfield display wide differences in the fluctuations of their surface-water levels (Ref-42). Since neither lake has a control structure or a significant inlet or outlet, the likely explanation for the differences in the variability of their hydrographs is either due to differences in bathymetry or the leakage of the semi-confining layer. Sinclair (1977) observed an asymmetric water-table response to changes in the potentiometric surface around the Section 21 wellfield because of thin or absent clay conditions to the east.

Assumption (b): *Data are available for lakes that are not significantly affected by ground water withdrawals.*

The reference lake data set includes six lakes from a period prior to significant groundwater withdrawal. Data from 16 other lakes was added to the reference data set based on a lowered probability of withdrawal influence. This probability was based on distance of lakes from active wellfields and numerical modeling of groundwater withdrawal influence. Although there could be some debate over the level of groundwater influence in some cases, the choices are generally sound.

Review of hydrographic data by the Panel concluded that as many as 12 additional lakes were worthy of inclusion in the reference set, and that other lakes might deserve additional consideration. Furthermore, actual lake water level was not used to establish the RLWR, but rather relative water level (P10-P50, P10-P90). There appear to be sufficient lakes for which groundwater influence is low enough to allow establishment of a valid RLWR, at least within a few tenths of feet for each measure.

A quick check to test the validity of the assumption that the reference lake data as a whole were unaffected by groundwater withdrawals for the PORs covered can be made by comparing the mean and median P10-P50 and P10-P90 values for the 22 reference lakes listed in Table 2 of the Lakes White Paper to the values for just the 6 lakes that have historic data that pre-date groundwater pumping. The mean and median values for Lakes Cooper, Ellen, Hanna, Hobbs, Platt, and Stemper are 0.7 feet for the P10-P50, and 2.0 feet (mean) and 1.9 feet (median) for P10-P90.

These are only approximately 0.3 foot lower than the means and medians for the entire 22-lake data set. This comparison is consistent with the assumption that the reference lakes were not significantly affected by groundwater withdrawals.

Assumption(c): *Reference lakes adequately represent other lakes in the absence of ground water withdrawals.*

As the reference lakes are scattered among the adopted lakes, and appear to represent the geographic range of lakes targeted for Minimum Levels, it appears reasonable to assume that the reference lakes adequately represent the conditions that would be expected in the absence of groundwater withdrawals. There do appear to be at least two and possibly as many as four classes of reference lakes, so some reference lakes may not be representative of some adopted lakes. It may have been possible to establish an adequate database for each reference lake class from available data, but it was reasonable to establish a single RLWR using the data from the selected reference lakes. Although the RLWR may incorporate less variability than exists naturally for some lakes, and may reflect slightly more variability than is found in some other lakes, it is still generally representative of the RLWR expected for lakes without significant influence from groundwater withdrawal.

However, more careful consideration should have been given to the possibility that some of the reference lakes may lie within a different hydrogeological zone than the typical one characterized by a thin, leaky confining layer with high head differences between the surficial and Upper Floridan aquifers. Table 5 represents an analysis of reference lakes that are ranked in descending order according to their geographical position in an attempt to discern how local hydrogeology may affect the surface-water P10-P90 values.

Table 5

Summary of Hydrographic Information for the Reference Lakes

Lake	POR[a]	LWL[b] Historic P10-P90 (in feet)	Drought Years (1989-1994)			SWL[c] vs. FWL[d] in Nested Wells	
			ΔLWL (in feet)	ΔSWL (in feet)	ΔFWL (in feet)	Equality	R^2
Curve	1976-97	2.6	3.8				
Thomas	1968-97	2.2	3.1				
King	1970-97	2.2	3.7				
Bell	1977-97	2.1	5.0				
Cow (East)	1976-97	1.2	1.4				
Padgett	1965-97	1.9	3.8	5.5	8.4	SWL>FWL	0.9
Saxon	1983-97	2.0	3.1				
Big Vienna	1986-97	2.1	3.5	5.5	8.4	SWL>FWL	0.9
Bird	1986-97	2.4	5.0	5.5	8.4	SWL>FLW	0.9
Gooseneck	1987-97	4.4	6.1				
Tampa	1987-97	3.4	5.2				
Hobbs*	1947-62	3.2	6.5	6.0	6.5	SWL>FWL	0.7
Cooper*	1946-56	1.4	3.7	6.0	6.5	SWL>FWL	0.7
Hanna*	1946-55	1.8	5.5	8.8	8.1	SWL>FWL	0.9
Stemper*	1946-62	2.1	6.2	8.8	8.1	SWL>FWL	0.9
Platt*	1946-56	2.0	4.0	6.6	6.4	SWL>FWL	0.7
Ellen*	1946-56	1.7	2.9?				
Parker	1969-97	2.4	3.6	5.9	5.9	SWL=FWL	1.0
Parker	1969-97	2.4	3.6	4.6	7.9	SWL>FWL	0.8
Seminole	1969-97	2.3	2.8	4.6	7.9	SWL>FWL	0.8
Geneva	1986-97	1.6	2.7	4.6	7.9	SWL>FWL	0.8
Minniola	1986-97	1.6	2.6	4.6	7.9	SWL>FWL	0.8
Moon	1965-97	3.4	4.3	5.0	4.5	SWL≈FWL	0.9

Notes: * Historic data are prior to 1963 Section 21 withdrawals.
[a] POR = Period of Record
[b] LWL = Lake Surface-water Level
[c] SWL = Surficial Aquifer Water Level
[d] FWL = Upper Floridan Aquifer Water Level

To simplify the analysis, the 1989-1994 low rainfall period was selected for evaluating the change in the lake surface, surficial, and Upper Floridan water levels. The changes in LWL, SWL, and FWL are from data presented in the hydrographs from the Lakes White Paper and from Appendix E of the WRAP report (Ref-42). There is a rationale to their order: the descending order corresponds to the lakes' position going from north to south until Lake Parker (*Note:* the double entry for that lake is for the two very closely placed wells), which marks a shift of the reference lake population towards the west and from a "recharge" to a "neutral to discharge" zone (Ref-42). For a well to qualify as being associated with any particular lake, it had to lie within 1 mile of that lake. Also, the drought period data represent the maximum and Minimum Levels for the entire period, regardless of when they occurred.

The LWL P10-P90 values for the first 9 lakes in Table 5 are close to each other (exception Lake Cow). There is also a fair degree of agreement for the change in LWL during the drought period with the exception of Cow, Bell, and Bird. The change in the Upper Floridan aquifer water levels during the low rainfall years exceed that associated with the surficial water table (Table 5), indicating the presence of a semi-confining unit. Unfortunately, only one nested groundwater well was located near these lakes, but it showed connectivity between surficial and Upper Floridan aquifer groundwaters ($R^2 = 0.9$).

Hydrographic data for Lakes Gooseneck and Tampa (Nos. 10 and 11 in Table 5) indicated both higher historical P10-P90s and higher amplitude of water-level changes during the drought than for the preceding 9 lakes. These are the farthest easterly located lakes and may be influenced by a different hydrogeological regime.

The next category of lakes begins with Lake Hobbs and ends with Lake Ellen (Table 5). These lakes lie farthest south in the eastern chain of reference lakes. They all have early historical data (Table 5), whose P10-P90 average is lower by 14 percent than the P10-P90 average for the remaining 16 lakes that have more recent PORs. These lakes clearly show a larger maximum-minimum difference during the drought period than did the first 9 lakes in Table 5. The Panel interprets this to mean that Lakes Hobbs, Cooper, Hanna, Stemper, Platt, and Ellen are currently suffering from groundwater withdrawals as well as by the regional lowering of aquifers from the drought. Considering that these six reference lakes are nestled among the adopted Minimum Level lakes, impacts from groundwater withdrawal may be expected *a priori*. There were three different nested well sites located within 1 mile of these 6 lakes, and they all indicated recharge potential with a high degree of connectivity between the aquifers (i.e., head differences between the surficial and Upper Floridan are the same).

The fourth group of lakes (Parker through Minniola) is located to the west of the other 17 lakes. They occur in a complex "mixed" hydrogeology zone, where hydrographs from adjacently located wells indicate recharge to discharge conditions (and at times with steep vertical gradients) (Appendix E of Ref-42). Lake Parker is shown in Table 5 vis-a-vis two different closely placed monitoring wells -- one indicating no head difference between the surficial and Upper Floridan aquifers, and the other with a large (average 7.0-foot) difference. Contrary to the previous six lakes, the bottom of these lakes may be less permeable, as the changes in the Upper Floridan aquifer water levels are greater than those of the surficial aquifer (Table 5). Finally, the LWLs during the drought are slightly higher than the low LWL P10-P90 values; similar values were seen for the first 9 lakes in Table 5. Again, this may indicate little impact from groundwater extraction.

Of all the reference lakes in the data set, Lake Moon is probably the closest to being a hydrogeological "neutral" lake (i.e., no net infiltration or seepage). It lies (all by itself) in a region characterized by negligible to slightly positive head differences between the Upper Floridan and surficial aquifers.

This analysis indicates that there is no hydrogeological evidence for the lakes in the Lakes Terrace region to be perched; instead they are all likely to be connected to the water table, which is influenced by the Upper Floridan aquifer. These lakes are therefore likely to be affected by groundwater withdrawals if wellfields are located near them, or by a cumulative, regional lowering of the Upper Floridan aquifer level.

The analysis also indicates that the reference lakes can be grouped into four categories based on differences in the hydrogeological conditons: (1) the northernmost set of lakes, which are the least affected by groundwater withdrawals; (2) the southern "part" of the first set which is affected by groundwater withdrawals, but fortunately possess pre-withdrawal historic data; (3) lakes that lie to the west in an area that is mixed by recharge/discharge hydrology but probably are more of a recharge than a discharge group of lakes; (4) the fourth category of lakes is the one occupied by Lake Moon and is the closest to being a non-net exporter to, or importer from, the Upper Floridan aquifer.

Even though there are hydrogeological differences within the reference lake data set, it is important to emphasize that the reference lakes do appear to adequately represent the population of lakes in the study area.

Assumption (d): *HI is a reasonable indicator of NP for lakes*

One implied assumption in the methodology for determining the HI was that the inflection point on the swollen buttresses of cypress trees was an adequate indicator of NP elevation for lakes. Absent the presence or use of any other HIs, the validity of this assumption is paramount for the successful establishment of NP. Although very old and very young trees were excluded from the population of trees selected for measurements in the adopted lakes (Clark Hull, personal communication, June 1999), the relative age of the trees was not considered in the selection process. Given the small sample size and the occasionally high variation among trees within a lake (Table 6), there is cause for some concern that the assumption may not be valid, especially since the cohort of trees selected in each lake were from only one small area (Lakes White Paper).

Table 6

Average, Range, Standard Deviation, and Sample Size Reported for the Hydrologic Indicator as Measured by the Inflection Point of the Butt Swell on Cypress Trees in the Adopted Minimum Level for Lakes

Lake	Average (feet above WL[a])	Range (feet)	sd[b]	n[c]
Alice	1.8	0.3	0.1	6
Bird	1.6	0.1	0.1	3
Brant	0.6	0.3	0.1	5
Camp	1.4	0.3	0.1	5
Crystal	1.5	0.0	0.0	2
Deer	1.2	0.2	0.1	5
Dosson/Sunshine	1.4	0.2	0.1	11
Juanita	1.3	0.6	0.2	6
L. Moon/Rainbow	1.5	0.3	0.1	5
Merrywater	1.8	0.4	0.2	3
Sapphire	0.6	0.1	0.1	2
Stemper	0.5	0.8	0.3	9
Sunset	1.2	1.7	0.7	7

Notes: [a] WL = Water Level
[b] sd = standard deviation
[c] n = sample size

With the exception of Lakes Stemper and Sunset, the cypress tree measurement taken in the adopted lakes in Table 6 indicate a high precision (i.e., low standard deviations). Also, the Panel's independent field analysis of the inflection point determination of the cypress along Lake Alice [(see Section 3.2-C(3c) below] yielded a high degree of agreement between the Panel and the District in the accuracy of measuring the inflection point. Taken together, the weight of evidence supports the inherent assumption that the inflection point on the cypress butt swell can be a reliable hydrologic indicator.

Assumption (e): HML = NP minus 0.4 foot and ML = NP minus 1.8 feet will protect fringing cypress wetlands.

This assumption is important to both wetland and lake resources, and is dealt with more fully in the Wetlands (Section 3.1) of this report. Whether or not this assumption is supported by the available data is an open question subject to considerable controversy. The Panel finds that while the derivation of these water-level standards was performed in a scientific manner, it may not have been the most appropriate approach. Alternative approaches aimed at generating a single standard for each of HML and ML tend to result in higher targeted water levels by several tenths of feet. This warrants future scrutiny and possible adjustment, if standard values are to be used.

Of greater concern, however, is the appropriateness of generating a single standard like NP minus 0.4 foot or NP minus 1.8 feet in light of the high variability among wetland systems, fringing or otherwise. The fairly wide distribution of P10 and P50 values for reference lakes and wetlands suggests that these single values for HML or ML will be too strict in a few cases and too lenient in most others. Any adjustment will suit some systems but not others, unless classes of wetlands and lakes are created, each with a narrow distribution of P10 and P50 values and its own link to HML and ML. The alternative is to have a sliding scale for HML and ML, linking each to the *P10* or *P50* for the adopted lake or wetland (assuming such data are available).

This issue affects the Category 1 lakes more substantially, as HML and ML for Category 2 lakes are not linked to NP. However, the definition of a Category 2 lake depends on the current P50 being below NP minus 1.8 feet, so this issue does still pertain to Category 2 lakes. Many in-lake resources may be unaffected by the NP minus 0.4 foot and NP minus 1.8 feet values for HML and ML, respectively, but damage to many fringing cypress wetlands is expected.

Assumption (f): *Water levels that limit impacts on fringing cypress wetlands will protect other lake resources.*

Based on limnological principles, it is reasonable to assume that protection of the fringing cypress wetlands by water-level management will benefit the lake as a whole. Water levels expected to support the fringing cypress wetlands would also support existing aquatic life, healthy littoral zone communities, and maintenance of maximum lake volume under prevailing precipitation patterns.

It is not clear, however, that all aspects of lake ecology will be significantly harmed if the fringing cypress wetlands are not protected to the extent possible by water-level management. The associated impact is not predictable without considerable additional data, but is theoretically tied to the role of the fringing cypress wetlands in lake ecology. Many aspects of the aquatic ecosystem do not depend strongly on the presence of those fringing cypress wetlands, although those wetlands represent a distinct factor in overall lake ecology.

For the purpose of establishing Minimum Levels, the assumption that protecting fringing cypress wetlands will also maximize protection of other lake resources is justified by the available data.

Assumption (g): *Maintenance of the RLWR in relation to the established HML will be sufficient to protect remaining lake resources in structurally altered lakes.*

Where the water level has been structurally altered, such that impact to the fringing cypress wetland appears inevitable, defaulting to the CP or Current P10 as the starting point for setting the target water levels in accordance with the RLWR appears reasonable from a strictly practical viewpoint. The Panel has been instructed to accept structural alterations as part of the lake water-level regime, and water-level targets must be set accordingly.

It is assumed that the resulting water-level distribution will protect the lake from further impact beyond that caused by structural alteration of the outlet. This assumption can not be scientifically validated or refuted with existing information. No indicators of lake condition have been set other than the fringing cypress wetlands, which do not appear to be viable long-term reference points for Category 2 lakes (with structural alterations that reduce median water level below NP minus 1.8 feet). It appears reasonable to assume that further damage beyond that caused by structural alteration will be minimized by maintenance of the RLWR. However, evaluation of the impacts of the established RLWR on in-lake resources is recommended for the future.

Assumption (h): The establishment of HML and ML values is sufficient to define a water-level distribution that is suitably protective of lake resources.

The use of HML and ML values represents the establishment of regulatory P10 and P50 water levels, respectively. These are two of the three key points in the water level distribution used to establish the RLWR; the other point is the P90 level. P90 is equivalent to the LGL, but the LGL is only a guidance level, not a regulatory criterion. Therefore, in terms of regulation, only the P10 and P50 levels are applicable.

It does not seem unreasonable to assume that a well-managed lake water regime that meets HML and ML targets will also meet the LGL. However, it is possible that the lake water regime could be managed to meet the HML and ML without meeting the LGL, and that such management could be detrimental to lake resources. Application of the ML, which is the overall median (P50) level over time, means that levels above or below the ML cancel out without any consideration of how far above or below that ML those values are. The addition of the HML, or P10 value, still allows for a few extremely high water levels, but limits such levels to 10 percent of the time. Failure to establish a regulatory P90 means that the water level could be very far below the ML much of the time and still meet the regulatory standards, as long as refill of the lake was possible over a relatively short period of time.

It seems unlikely that simple cessation of well pumping would allow rapid refill of a lake without extreme precipitation events, unless the lake had a large and actively contributing watershed or was located in an area of ground water discharge. Only a small subset of potential adopted lakes meets either of these criteria, but some lakes could be subject to large and fairly rapid changes in water level. The rate of change itself could be detrimental to some biota, and extreme low water levels could cause significant harm to sensitive biota over a brief time period (e.g., hours to days).

The assumption of adequacy of the HML and ML cannot be clearly refuted based on available data, but conditions under which the assumption might not hold true can be envisioned. Future evaluation of the adequacy of setting only two regulatory points on the water-level distribution is warranted.

3.2-C(2b). Opportunities to Eliminate Assumptions

- *Inclusion of the P90 as a Third Regulatory Criterion.* The assumptions listed in 3.2-C(2a) can not be completely eliminated by application of available information within the context of the described approach to establishing minimum water levels for Category 1 and 2 lakes. The assumption of the adequacy of the use of only P10 and P50 values as regulatory points along the water-level distribution could be altered by inclusion of a third regulatory point corresponding to P90. This would lead to a new assumption, namely that those three points provided adequate assurance that the desired distribution would be met. The Panel would be more comfortable with elevating the LGL to a regulatory Low Minimum Level based on P90.

- *Additional Indicators of Lake Condition.* The assumption that meeting the target water levels will protect lake resources could not be eliminated, but could be reduced in importance by establishing additional indicators of lake condition beyond fringing cypress wetlands. This is especially critical for Category 2 lakes, in which the eventual demise of the fringing cypress wetlands appears unavoidable without a revocation of structural alterations that have lowered water levels below NP minus 1.8 feet. As there is some controversy over the validity of the NP minus 1.8-foot value, additional indicators of lake condition would also be helpful for Category 1 lakes.
- *Corroboration of the HI to the P10 in Reference Lakes.* The HI for the fringing cypress wetlands surrounding lakes is the inflection point of the butt swell in cypress stems. Based on data collected from cypress trees in isolated palustrine wetlands, this HI is approximately equal to the P10. However, any relationship between water level and HI was not corroborated in the fringing cypress wetlands of the reference lakes. Since hydrographic data had already been assembled for each lake so that the calculations of the P10, P50, and P90 could be made, it would not have taken that much more effort to measure the inflection points of the cypress trees associated with each reference lake. Failure do so is probably not a serious consequence to the overall assumption that the $HI \approx P10$ in fringing cypress wetlands.

3.2-C(2c). <u>Implied or Inherent Assumptions</u>

Assumptions are discussed in more detail in Subsection 3.2-C(2a) above. The assumptions inherent in the methodology were not clearly listed in the manner exhibited in Subsection 3.2-C(2a), but the methodology was laid out in a clear manner and it was not difficult for the Panel to discern the assumptions. Documentation in support of assumptions was supplied in the White Papers and supporting information to a reasonable degree in most cases.

3.2-C(2d). <u>Review of Alternative Analyses to Reduce Assumptions</u>

Within the context of available data, and beyond those adjustments described in 3.2-C(2b) above, the only alternative analysis that appears capable of reducing assumptions and improving results relates to the representativeness of reference lakes -- which might be accomplished by grouping the reference lakes into separate classes. There are several ways by which this could be done.

For example, Table 7, below, indicates that the reference lakes are affected differentially during a period of low rainfall. The hydrographs of four of the lakes in the 22-lake data set were relatively unaffected by the 6-year drought (P90 < LW L< P10; LWL ≈ P50), while five of the lakes were severely affected (i.e., WL ≤ P90); the remaining 13 lakes were considerably affected (P90 < WL < P50), but not to the same extent as the severely affected lakes (Table 7). The severely impacted category is readily explainable since four of the five lakes are ones that had historic data (prior to groundwater withdrawals). Those four lakes now appear affected by groundwater withdrawals. Those four lakes are grouped very closely together (Figure 7 in the Lakes White Paper) and in an area where the nested surficial-Upper Floridan wells indicated high connectivity with the Upper Floridan (R-square = 0.7 - 0.9; Figure 4-4 in Ref-42). However, an explanation for the remaining two categories of reference lakes (Negligible and Considerable) in Table 7 is not as obvious. The Panel suspects that hydrogeological differences such as the thickness of the semi-confining layer and head differences between the surficial and Upper Floridan aquifers are responsible. For example, Sinclair (1977) observed an asymmetric water-table response to changes in the potentiometric surface around the Section 21 wellfield because thin or absent clay conditions to the east caused water tables to be lowered. This area would encompass the lake basins of Lakes Cooper, Hanna, Hobbs, and Stemper.

Table 7

Variable Impacts of the 1989-1994 Drought on the Reference Lakes

Nature of Impacts		
Undetectable to Negligible [P90 < LWL* <P10; Ave. LWL ≈ P50]	**Considerable [P90<LWL<P50]**	**Severe [LWL ≤ P90]**
Cow (East)	Bell	Cooper
Curve	Big L. Vienna	Hanna
Geneva (Mud)	Bird (Pasco Co.)	Hobbs
Minniola	Ellen	Moon
	Gooseneck	Stemper
	King @ Drexel	
	Padgett	
	Parker	
	Platt	
	Saxon	
	Seminole	
	Tampa	
	Thomas	

Notes: *LWL = Lake water level.

Exclusion of the drought period from the POR might change the lake groupings based on features of their hydrographs, and the length of the total POR for a lake will also affect the susceptibility of summary statistics (such as P10-P90) to events such as droughts. Lake Ellen, for example, has a long POR and shows little difference in P10-P90 for the period prior to well withdrawal or when the recent drought period is excluded. An analysis of the reference lake data set for length of POR and low rainfall periods is provided in Subsection 3.2-C(3a).

If the reference set is augmented by the potential additional reference lakes described in 3.2-C(1b) above and then is broken up into groupings based on geography (and attendant P10-P90 differences), classes of reference lakes could be created. Such classes would reduce the variability within each reference set from that of the overall reference database, and would result in slightly different HMLs and MLs for adopted lakes in each defined area. This possible alteration in approach will be addressed in more detail in Subsection 3.2-E below.

Likewise, if one or more relationships between water level and lake resources -- other than fringing cypress wetlands -- could be established, this could greatly enhance the power of the HML and ML, especially for Category 2 lakes. This exercise will be essential for the Category 3 lakes, which have no fringing wetlands and are the subject of a developmental exercise outside of the Panel's scope of review. It is not clear that any defensible relationship between water level and in-lake resources could be defined based on available data, but it would not be unreasonable to make a policy decision about the degree of acceptable loss of lake area or volume until a more scientific relationship can be established. Such acceptable loss could be incorporated in a manner that follows the current HML and ML methodology (e.g., lake 90 percent full 10 percent of the time, lake at 75 percent of NP area 50 percent of the time). An idea for such an approach is discussed in greater detail in Section 3.2-E below.

3.2-C(2e). Other Considerations

Assumptions are inherent in all scientific endeavors. It is reasonable to rely on assumptions, but it is appropriate to clearly define assumptions and to test them with the available data. While this process might have been better documented, it does appear that District staff recognized and tested assumptions wherever possible. While not all assumptions are strongly supported by the available data, no assumption could be completely refuted either. What is needed now is a plan for gathering the data necessary to further test assumptions to facilitate future adjustments as warranted.

3.2-C(3). Review of Procedures and Analyses

3.2-C(3a). Appropriateness and Reasonableness of Procedures and Analysis

A key assumption was independently tested and verified by the Panel: whether uneven PORs and the impacts of the 1989-1994 drought unduly influenced the calculated percentiles in the reference lakes.

The data sets for the reference lakes varied in their PORs, which may have resulted in skewing the percentiles, depending on climatic factors during the more recent POR (i.e., past 10 years) compared to earlier years of the POR. The hydrographic data for the reference lakes were parsed in two ways in order to check whether either the varying lengths of the POR or the 1989-1994 drought affected the percentiles derived by the District. In addition, the percentiles of the original reference lake data set (without any alterations) were recalculated to determine the accuracy of the original percentiles reported in the Lakes White Paper.

The results indicate that the original percentiles (P10, P50, P90) calculated using the entire data set were not substantially affected by the varying PORs (average < 0.1 foot), but excluding the 1989-1994 drought period resulted in P10, P50, and P90 values that were 0.2 foot, 0.4 foot, and 0.4 foot, respectively, higher than when the 1989-1994 drought is included in the POR (Table 8). Thus, the drought which occurred between 1989 through 1994 was severe enough to cause the P50 and P90 values to be between 0.4 and 0.5 foot lower on average than what would be expected under more normal climatic conditions.

Table 8 also indicates that the original calculations are repeatable. The elevation data for Bird Lake is correct for the District's reported value in the Lakes White Paper since that value was confirmed by a Panel member's supplemental field visit to the site. The lower elevation data for that lake appeared in the spreadsheet containing the raw data that was submitted by the District, and is believed to be due to the incorrect inclusion of data from another lake (with the same name) in the spreadsheet.

Even though the P10, P50, and P90 values are dissimilar between the data set with the 1989-1994 drought excluded and the original data set, the P10-P50 and P10-P90 values remained relatively unchanged (Table 9). There was only one paired comparison that yielded a statistically significant (two-tailed, $\alpha = 0.05$) difference, and that was only slightly numerically different (Table 9).

Table 8

Effects of the Length of the POR and the 1989-1994 Drought on the P10, P50, and P90 Values of the Reference Lake Data Set

Lake	POR	P10 (in feet) District Original Data set	P10 Panel Original Data set	P10 Panel POR: 1983-96	P10 Panel Excluding 1989-94	P50 (in feet) District Original Data set	P50 Panel Original Data set	P50 Panel POR: 1983-96	P50 Panel Excluding 1989-94	P90 (in feet) District Original Data set	P90 Panel Original Data set	P90 Panel POR: 1983-96	P90 Panel Excluding 1989-94
Curve	1976-96	76.6	76.7	76.6	76.8	75.4	75.5	75.4	75.9	74.0	74.1	74.1	74.2
Thomas	1968-96	74.6	74.6	74.6	74.6	73.6	73.6	73.7	73.6	72.4	72.4	72.6	72.4
King	1970-96	72.6	72.6	72.5	72.7	71.7	71.8	71.6	72.0	70.4	70.4	70.3	70.9
Bell	1977-96	71.6	71.6	71.6	71.7	70.5	70.5	70.5	70.7	69.5	69.5	69.6	69.8
Cow (East)	1976-96	78.0	78.0	78.0	78.0	77.6	77.6	77.7	77.5	76.8	76.9	77.1	76.8
Padgett	1965-96	70.5	70.5	70.4	70.6	69.6	69.7	69.5	69.8	68.6	68.6	68.4	68.8
Saxon	1983-96	70.5	70.5	70.5	70.7	69.6	69.6	69.6	69.8	68.5	68.5	68.5	68.8
Big Vienna	1986-96	68.8	68.8	ND	68.9	67.6	67.7	ND	68.4	66.7	66.9	ND	66.9
Bird	1986-96	66.8	49.6	49.5	49.9	65.4	47.8	47.7	48.5	64.4	46.2	46.2	46.9
Gooseneck	1987-96	72.8	72.8	NA	73.2	70.4	70.3	NA	72.3	68.4	68.4	NA	70.4
Tampa	1987-96	64.3	64.4	ND	65.6	62.8	62.6	ND	64.2	60.9	60.9	ND	63.1
Hobbs*	1947-62	67.0	67.0	NA	NA	65.9	65.9	NA	NA	63.8	63.8	NA	NA
Cooper*	1946-56	61.6	61.5	NA	NA	61.0	61.0	NA	NA	60.2	60.2	NA	NA
Hanna*	1946-55	61.7	61.7	NA	NA	61.2	61.2	NA	NA	59.9	59.9	NA	NA
Stemper*	1946-62	61.5	61.5	NA	NA	61.0	61.1	NA	NA	59.4	59.4	NA	NA
Platt*	1946-56	49.8	49.8	NA	NA	48.9	48.9	NA	NA	47.8	47.8	NA	NA
Ellen*	1946-56	40.6	40.6	NA	NA	39.9	39.9	NA	NA	38.9	38.9	NA	NA
Parker	1969-96	48.0	48.0	47.8	48.2	46.8	46.9	46.8	47.1	45.6	45.6	45.6	45.7
Seminole	1969-96	48.2	48.2	47.8	48.2	46.9	46.9	46.8	47.3	45.9	45.9	46.1	45.9
Geneva	1986-96	49.8	49.8	49.7	49.9	49.2	49.3	49.3	49.5	48.2	48.4	48.4	48.3
Minniola	1986-96	49.8	49.8	48.8	49.9	49.3	49.3	49.4	49.4	48.2	48.4	48.4	48.4
Moon	1965-96	39.9	39.9	40.1	40.0	38.6	38.6	38.5	38.9	36.6	36.6	36.4	36.9

Notes: * Historic data prior to 1963 Section 21 groundwater withdrawals.
ND = no data.
NA = not applicable.

Table 9

Effects of the Length of the POR and the 1989-1994 Drought on the P10-P50 and P10-P90 Differences for the Rreference Lake Dataset

Lake	POR	P10-P50 (in feet)				P10-P90 (in feet)			
		District	Panel			District	Panel		
		Original Data set	Original Data set	POR: 1983-96	Excluding 1989-94	Original Data set	Original Data set	POR: 1983-96	Excluding 1989-94
Curve	1976-96	1.2	1.2	1.2	0.9	2.6	2.6	2.5	2.6
Thomas	1968-96	1.0	1.0	0.9	1.0	2.2	2.2	2.0	2.2
King	1970-96	0.9	0.8	0.9	0.7	2.2	2.2	2.2	1.8
Bell	1977-96	1.1	1.1	1.1	1.0	2.1	2.1	2.0	1.9
Cow (East)	1976-96	0.4	0.4	0.3	0.5	1.2	1.1	0.9	1.2
Padgett	1965-96	0.9	0.8	0.9	0.8	1.9	1.9	2.0	1.8
Saxon	1983-96	0.9	0.9	0.9	0.9	2.0	2.0	2.0	1.9
Big Vienna	1986-96	1.2	1.1	ND	0.5	2.1	1.9	ND	1.9
Bird	1986-96	1.4	1.8	1.8	1.4	2.4	3.4	3.3	3.0
Gooseneck	1987-96	2.4	2.5	NA	0.9	4.4	4.4	NA	2.8
Tampa	1987-96	1.5	1.8	ND	1.4	3.4	3.5	ND	2.5
Hobbs*	1947-62	1.1	1.1	NA	NA	3.2	3.2	NA	NA
Cooper*	1946-56	0.6	0.5	NA	NA	1.4	1.3	NA	NA
Hanna*	1946-55	0.5	0.5	NA	NA	1.8	1.8	NA	NA
Stemper*	1946-62	0.5	0.4	NA	NA	2.1	2.1	NA	NA
Platt*	1946-56	0.9	0.9	NA	NA	2.0	2.0	NA	NA
Ellen*	1946-56	0.7	0.7	NA	NA	1.7	1.7	NA	NA
Parker	1969-96	1.2	1.1	1.0	1.1	2.4	2.4	2.2	2.5
Seminole	1969-96	1.3	1.3	1.0	0.9	2.3	2.3	1.7	2.3
Geneva	1986-96	0.6	0.5	0.4	0.4	1. 6	1.4	1.3	1.6
Minniola	1986-96	0.5	0.5	0.4	0.5	1.6	1.4	1.4	1.5
Moon	1965-96	1.3	1.3	1.6	1.1	3.3	3.3	3.7	3.1
Mean		1.00	1.01	0.95	0. 88**	2.27	2.28	2.09	2.16
± sd		0.45	0.52	0.44	0. 30	0.74	0.82	0.76	0.55

Notes: * Historic data prior to 1963 Section 21 groundwater withdrawals. ** Statistically significantly different than the P10-P50 as calculated by the District on the original database.
ND = no data. NA = not applicable

3.2-C(3b). Consideration of Necessary Factors

The establishment of minimum water levels for adopted lakes appears to incorporate all necessary factors. NP is determined from inflection points on cypress trees in fringing wetlands. Lake category is determined from the presence of an outlet structure and evaluation of its effect on water level (CP and Current P10) relative to NP minus 1.8 feet. HGL, HML, ML, and LGL are established in accordance with a series of if-then statements revolving around NP and RLWR for Category 1 lakes and CP or Current P10 and RLWR for Category 2 lakes (see Subsection 3.2-B above). Two regulatory points (HML and ML) and two guidance points (HGL and LGL) are thereby set along the distribution of potential water levels for the adopted lake.

There has been considerable evaluation and debate of the details of each element of this process, but the overall process appears sound and all factors were accounted for in the setting of Minimum Levels for 15 adopted lakes. A major strength of the approach is that it recognizes the importance of water-level distribution over time. Extremes and variability are as important as means and medians to lake ecology. While the regulatory aspect of the approach will depend upon only two points on the water-level distribution when the use of three points may be justified, the emphasis on measuring a distribution of water levels is highly appropriate.

3.2-C(3c). Application of Analyses

Although several quality control issues have been raised in Section 3.2-C(1) regarding the use and measurement of the cypress buttress swell as the sole hydrologic indicator, the process used for pin-pointing and measuring the inflection point of the buttress swell appears to be reproducible. This is based on an independent investigation performed by one of the Panel members on five cypress trees along the shore of Lake Alice on June 24 and 27, 1999.

Lake Alice provided a unique set of features that made it ideal to independently corroborate the assumptions and methodology of identifying and measuring the normal pool by a single HI. Those features included the positioning of four cypress trees in a near straight line and equidistant from the lake's edge (6.2 meters). The trees probably were not of the same age (as indicated by the diameter at breast height) but were similar enough in age for each to have been exposed to similar historical hydroperiods.

In addition to the position of the trees relative to each other and the lake, the staff gage used to measure lake levels for the past 28 years was close by. Thus, it was not only possible to measure the elevation of the inflection point of each tree and compare it with the others for consistency, but it was also possible to compare the measured inflection point elevation with that reported for Lake Alice in the Lakes White Paper. Those elevations were measured on six trees during March 30, 1998, when the water levels were higher and therefore covering the soil surface. These were not the same cypress trees that were surveyed by the Panel member in June 1999.

Since standing water was absent, a level mounted on a pole had to be used to ensure that the elevation selected on one tree or on the staff gage could be transferred to another tree using the same vertical datum. This device, consisting of an eyepiece mounted on a collapsible pole and equipped with a horizontal crosswire and an external bubble assembly, was used along with a stadia rod and flagging to compare the accuracy (within 3 cm) and reproducibility of inflection point designations among trees as measured by either the same individual or between two individuals (Table 10).

Table 10

Results of Inflection Point Comparisons Among Five Cypress Trees Located at the Edge of Lake Alice

[inflection points were measured by District staff on March 30, 1998 and by Panel member on June 24 and 27, 1999]

	Cypress Tree No. (from south to north)				
	1	2	3	4	5
Diameter at breast height :	59 cm	32 cm	29 cm	56 cm	44 cm
Buttress shape:	Large and slightly asymmetric	Large and symmetrical	Nearly absent	Very large and very asymmetrical	Nearly absent and closer to the ground
Deviation of inflection point along a level plane on June 27, 1999:	0	0	0	+42 cm	-17 cm
Agreement between inflection point elevations as measured by Panel member and District on different populations of cypress	6-15 cm	7-16 cm	8-17 cm	9-18 cm	No data

As a second, independent check on the accuracy of the horizontal elevation established using the mounted level, a long board was aligned horizontally between points of equal elevation on two adjacent trees. An indication of the degree of equal elevation on both trees was then determined by measuring the degree of slant with a hand level placed on top of the board. The hand level indicated a horizontal plane had been achieved by the positions fixed on the cypress stems by the pole-mounted level and eyepiece.

The data in Table 10 indicate that desirable precision among cypress trees Nos. 1, 2, and 3 is possible for closely spaced trees as long as the trees are rooted at comparable elevations and are not grotesquely buttressed. However, morphological deviations, different ages, and differences in root crown elevations with respect to ground level can seriously affect the precision and accuracy of inflection point measurements. For example, cypress tree No. 4 possessed a very asymmetric butt swell, which made it very difficult to locate the inflection point. This resulted in the identification of the inflection point that was 42 cm above the inflection point elevations of trees Nos. 1, 2, and 3. Fortunately, this type of mis-shaped cypress tree would not have been included in the population of trees surveyed by District scientists (Clark Hull, personal communication, June 1999). Cypress trees No. 3 and No. 5 did not possess a pronounced butt swell, which added ambiguity to identifying the location of the inflection point. Lastly, tree No. 5 was rooted at a higher elevation than the other four trees; yet the slight butt swell was 17 cm lower than what it should have been had it responded equally as the other four trees to past hydrologic conditions. Deposition of the dredged material from the lake may explain the variance of this tree.

The most significant result of this survey was the close agreement between the inflection point elevations measured by the Panel member in June 1999 and the District scientists nine months prior on cypress trees inhabiting different areas of the lake (Table 10). The differences ranged from 6 to 15 cm for tree No. 1, to 9 to 18 cm for tree No. 4, with the Panel member's inflection point elevation higher than the District's. Considering that a 9-cm range, corresponding to the 0.3-foot range reported for the 6 trees measured in the Lakes White Paper, is the typical field variability for the cypress population surrounding Lake Alice, then the agreement between the Panel member and the District is excellent.

3.2-C(3d). Limitations and Imprecisions in Information

As the independent verifications presented in Subsection 3.2-C(2a, 3a, and 3c) have demonstrated, the limitations and imprecisions in the procedures and analyses used in developing quantitative measures were not of a serious nature. Technical assumptions were generally supported by the Panel's independent analyses of the seepage nature of the lakes [Subsection 3.2-C(2a)] and the effect of the varying PORs on the percentile values for the reference lakes [Subsection 3.2-C(3a)]. These analyses reaffirmed the validity of the RLWR concept and its application to setting minimum water levels in adopted lakes.

Although there were some sample size and methodological problems, it appears that, for the most part, the measurements were correctly taken. The Panel's independent check on both the relative and absolute determinations of the inflection point elevation for the cypress bordering Lake Alice [Subsection 3.2-C(3c)] was in very close agreement to the elevations reported in the Lakes White Paper (within acceptable field error tolerances).

Taken together, the Panel's independent analyses of critical aspects of the assumptions and the procedures employed in developing the Minimum Levels in the Lakes White Paper supports the conclusion that the limitations and imprecisions inherent in the methodology were handled reasonably well. As more data are gathered, assumptions will need to be tested and future adjustment made as necessary.

3.2-C(3e). Repeatablility of Analyses

Every aspect of the analysis is repeatable. Although field verification of past water-level measurements is not possible, most other measurements can be checked (e.g., cypress inflection point elevation) and all measurements can be repeated in a consistent and seemingly reliable manner. Data may be excluded or supplemented and derivation of distributional measures (e.g., P10, P50, P10-P90) can be repeated at any time. Although the process is complicated by many options, the flow charts for determining HGL, HML, ML and LGL and their component factors are clear and easy to follow, allowing trained professionals to repeat the procedure as applied to each adopted lake.

3.2-C(3f). Relation of Conclusions to Data

There are uncertainties associated with variability in the reference data set and the suitability of NP minus 1.8 feet as the P50 that will protect fringing cypress wetlands and associated lake resources. Consequently, the Panel has some reservations about just how well the conclusions are supported by the data. However, the procedures appear logical and appropriate; most questions relate more to the precise values chosen as standards than to the procedures themselves. Reductions that result from alternative choices for standard values (e.g., RLWR50, NP minus 1.8 feet) are on the order of tenths of feet, not multiple feet. As such, concern is expressed over the fine tuning of the approach, not the basis of the approach or its application. The primary exception is the application of NP minus 1.8 feet, which might be replaced at some future date with a measure more closely tied to the distribution of water levels for a given lake, rather than a single numeric standard for all Category 1 lakes.

3.2-C(3g). Other Considerations

None observed.

3.2-D. Evaluation of Deficiencies

3.2-D(1). Description of Deficiencies and Associated Error

Although the methodology as it currently exists relies on assumptions and incorporates variability that we would like to reduce, the Panel finds that the methodology is scientifically reasonable and is not clearly deficient in any essential aspect. Most of what might be described as deficiencies are more appropriately defined as areas where improved analyses appear possible, either with existing data now or with data to be collected in the future. Establishment of classes of reference lakes, with the potential to have different RLWRs for different geographic areas based on noted hydrographic affinities, is one such case. A reduction in dependence on fringing cypress wetlands as the sole indicator of lake condition is another example of enhancements that could be construed as correcting deficiencies. These cases are addressed in Section 3.2-E below.

3.2-D(2). Discussion of Possible Remedies

None offered.

3.2-D(3). Identification of Specific Remedies and Their Attributes

None offered.

3.2-D(4). Alternative Methodologies

None offered.

3.2-E. Evaluation of Preferred Methodologies

3.2-E(1). Description of Alternative Preferred Methodologies

There are five preferred alternatives that could enhance the methodology as the Panel currently understands it:

- *Link lake water levels to ecological health of the fringing wetlands.*

  The ecological health of the reference lake wetlands should be assessed. The composite ratings relating ecological health to hydroperiod that was deployed in the palustrine wetlands was not repeated for the fringing lake wetlands. Without a measure of ecological response parameters under altered and unaltered hydrologic conditions, the relationship between systematic water withdrawals (resulting in reduced water levels and altered hydroperiod) and impacts on the fringing wetlands will remain unknown.

- *Develop composite ratings of independent indicators for measuring the effects of altered hydroperiods on ecological health.*

  A more detailed investigation into the time lags of ecological responses (e.g., peat subsidence, invasion of exotics, cypress heartwood rot) of the lake cypress community to reduced hydroperiods would lead to composite ratings of wetland health based on several independent indicators. This would assist in setting priorities, establishing target water levels (i.e., Minimum Levels), and managing the resource.

- *Deploy a more rigorous technique for determining the HI from cypress butt swell.*

  There is general agreement among wetland scientists that several independent hydrologic indicators should be used in identifying the historic normal pool. These include moss collars, lichen lines, *Lyonia* root crown, and cypress butt swell. Unfortunately, moss collars, lichen lines, and *Lyonia* are usually not present in most of the fringing wetlands surrounding reference and adopted lakes. Therefore, a high reliance was placed on the butt swell of cypress stems since it was the only biological indicator that was consistently present in the lake wetlands.

  There is also agreement among wetland scientists that the position and degree of cypress buttress swelling, a response known as hypertrophy, is indicative of some aspects (normal flooding and inundation period) of the hydroperiod (Brown, 1984; Varnell, 1998). However, cypress hypertrophy is variable in both size and form, depending not only on the surface-water hydrologic regime, but also on the age of the tree (Varnell, 1998; Keeland and Conner, 1999) and the individual tree's peculiar response. Therefore, it is not uncommon to find variable shapes of trunks of cypress trees within the same swamp (Brown, 1984). Due to the asymmetry of the buttress, different inflection points can frequently be measured depending on whether one is standing on one side of the buttress or the other. Moreover, the buttress often tapers in a gradual fashion, which makes identifying the inflection point a very subjective process.

  To complicate matters even more, there is no commonly accepted (or practiced) method for measuring the position and extent of swelling, nor is there an accepted methodology for relating the parameter to the hydroperiod. For conical buttresses, Brown (1984) states that the high-water level is about two-thirds of the height of the buttress. Varnell (1998) developed regression algorithms that quantitatively determine the relationship between baldcypress stem form and the surface-water hydrologic regime. He relied on the population of cypress in the measured subset to be the same age. Still others (Dicke and Toliver, 1988; Parresol and Hotvedt, 1990) use a fixed mean height (e.g., 2.9 meters) of the butt swell for similar age cypress as the indicator of stem hypertrophy.

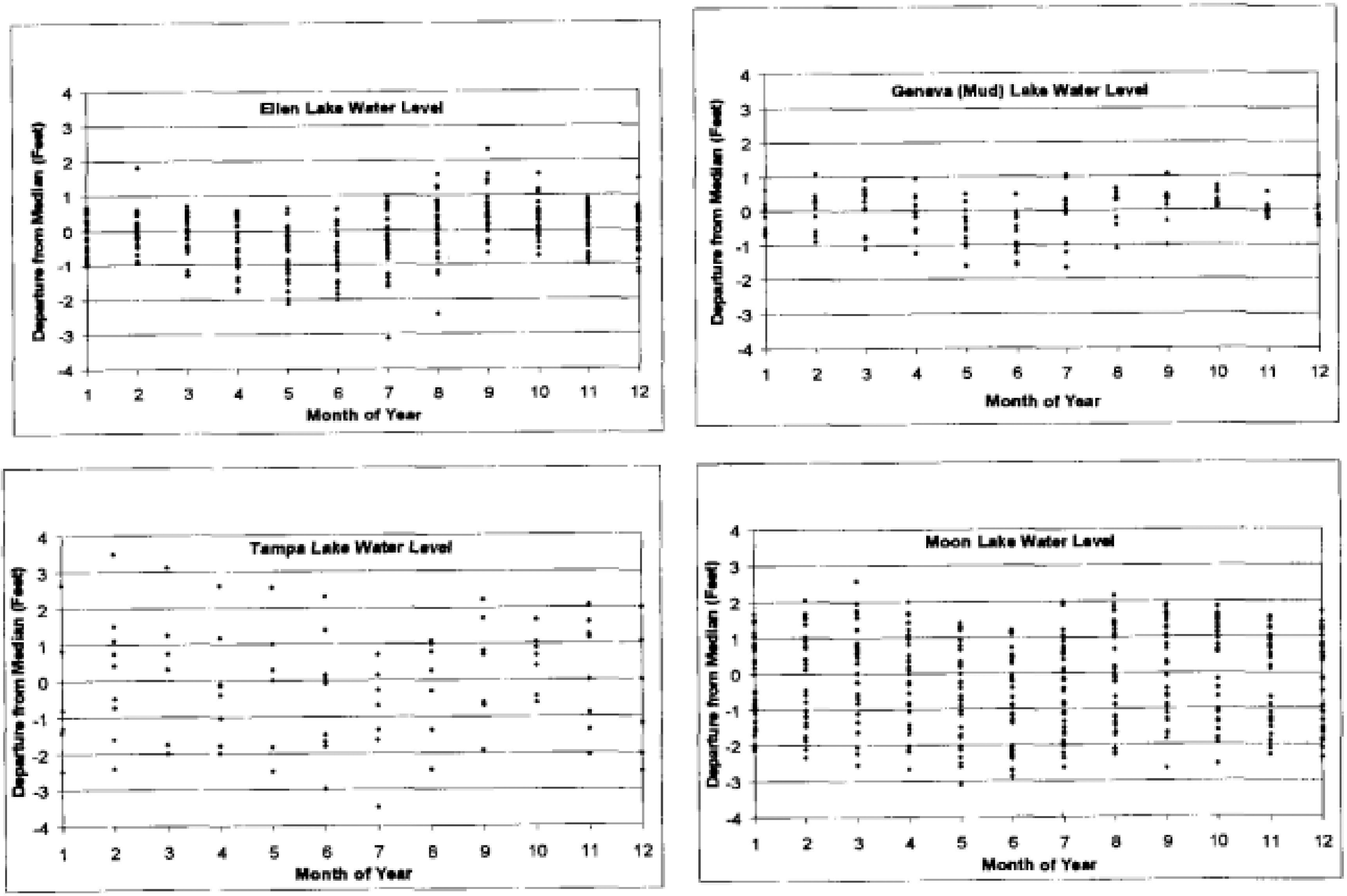
- *Create at least two classes of reference lakes, based on hydrographic features.*

  The variability observed in the reference lake data set appears to stem from the position of lakes within the groundwater flow pattern, with some local effects from karst interactions and/or human involvement. Representative patterns in reference lake hydrographs are shown in ***Figure 3***, which depicts multiple years of data for water-level departure from the median over the 12 months of the year. The general pattern of early spring and late summer peaks, with a late spring-early summer minimum, is evident. The range of values for a given month is striking, however, when the individual graphs in Figure 3 are compared. Reasonable interpretations of this variation would include differential linkage to the water table and location along a gradient of groundwater recharge through discharge. Although there is distinct variability within geographic areas, assessment of groundwater flow patterns (see Section 3.3) suggests that positioning within areas of greater or lesser difference in head between surficial and Upper Floridan aquifers may explain much of the variability across geographic areas. Creation of separate reference lake classes might, therefore, be justifiable and could alter the assigned RLWR in a meaningful way.

- *Utilize in-lake measures as indicators of lake condition to supplement the use of fringing cypress wetland features.*

  Even for Category 1 lakes, where fringing cypress wetlands might be reliable indicators of general lake condition, it would appear desirable to link water levels to other features of lakes. For Category 2 lakes, where structural alteration has lowered water levels substantially, establishing links between water-level and other variables seems highly desirable. While Category 3 lakes are not part of this assessment, the lack of fringing cypress wetlands associated with those lakes will necessitate the establishment of alternative linkages. The review by Biological Research Associates (1999) provides a concise summary of alternative measures, with qualitative indications of likely value and probable cost.

Figure 3. Representative Hydrographs for Reference Lakes



Out of 20 potential indicators evaluated, 6 were considered to have high value at low expense. These included assessment of changes in water volume, surface area, bottom exposure, connectivity to other water bodies, and alteration of littoral plant coverage and species composition. The change in surface area and bottom exposure are tightly linked, and the changes in the littoral plant community could be considered as a single, multi-element indicator. The connectivity among water bodies has limited applicability for the many isolated lakes in the area, and is complicated by human drainage alterations. This leaves changes in lake volume, area and littoral plant community as three clear choices for investigation as possible indicators of overall lake condition.

3.2-E(2). Qualitative Assessment of Alternative Preferred Methodologies

Measures of Ecological Health of Reference Lake Wetlands

The supplemental field trip by one of the Panel members (on June 5, 1999) to three reference wetlands (Lakes Thomas, Padgett, and Bird) revealed that two of these lakes' fringing wetlands (Thomas and Padgett) were stressed (as indicated by soil subsidence and exotic/transitional vegetation invasion). Since the POR supposedly represents a period of stability in water-level fluctuations, then these wetland changes must have started prior to the POR, and probably continued during the POR. The probability is that the structural alterations that occurred prior to the POR resulted in a lowering of water levels. It can therefore be expected that further wetland degradation will occur even with no further groundwater withdrawal impacts. The lack of quantitative (or even qualitative) relationships between surface-water levels in the lake and biological/soil indicators within the reference lakes exacerbates the task of linking past and future hydroperiod alterations in the adopted Minimum Level lakes to measurable ecological responses.

One possible approach is to measure the response of several critical structural components of the wetland to changes in the hydroperiod for a given POR. As a starting point, the following independent indicators should be considered as meaningful ecological response variables (*Note*: not a definitive list of candidates):

i. peat or muck subsidence.

ii. invasion of exotics.

iii. invasion by transitional species (indicators of succession toward more mesic system)

iv. loss of overstory

Since many of the responses have already begun in most of the wetlands, the primary focus should be on the rates of subsidence, invasion, and cypress loss. For instance, the peat substrate elevations could be surveyed in year 2000 and then again in year 2005 or 2010 for individual wetlands. Then the change in surface peat elevation between the two measurement years could then be correlated to the number of times and duration of inundation (i.e., hydroperiod) that occurred over the same period. Thus a relationship between rate of subsidence and hydroperiod may be determined.

A composite rating scale based on these long-term structural components of wetlands would be an advancement by providing a more quantitative and integrated tool for managing the resource. This will require a substantial commitment of resources, similar to that applied to the development of palustine cypress wetlands health indicators.

Hydrologic Indicator of Cypress Butt Swell

It needs to be emphasized that it is the cypress trunk shape, and not the inflection point *per se*, that is the indicator of normal flooding (Brown, 1984). The Panel, therefore, believes that it is worth exploring the utility of using algorithms that quantitatively define the stem buttress and the magnitude of stem hypertrophy for relating tree form to the surface hydroperiod in a manner similar to Varnell (1998). If successful, this procedure may result in less variation and subjectivity in determining the HI than is inherent in the inflection point method.

The stem form algorithm method addresses the mensuration problems associated with asymmetry and fluting in cypress stems. The methodology standardizes mean stem form of a population of cypress trees, and then by treating the stem as a frustum (cone in which the ends are parallel planes), the degree of hypertrophy (i.e., extent of buttressing) can then be related to an inundation index by regression analysis.

This is a fairly straightforward improvement in the method, and will require only limited resources and time to implement.

Reference Lake Classes

Table 11 provides summary data for lakes that have the potential as reference systems. Included are all reference lakes chosen by the District plus others that appeared to meet the criteria in accordance with the discussion in Subsection 3.2-C(1b) above. Lakes have been placed in one of four groupings, corresponding to geography and features of their hydrographs:

Group 1: The Pasco-Hillsborough East set is located along a north-south line extending from south-central Pasco County into north-central Hillsborough County within the Lakes Terrace Region. This string of lakes lies east of the South Pasco, Section 21 and Northwest Hillsborough wellfields and west of the Cypress Creek, Cypress Bridge and Morris Bridge wellfields. Some lakes have historic data that predate the wellfields, but most have fairly stable hydrographs during a substantial portion of wellfield operation.

Table 11

Potential Groupings for Reference Lakes

Group 1: Pasco-Hillsborough East

Lake:	Browns	Stemper	Cooper	Hanna	Platt	Chapman	Ellen	Lipsey	White Trout
County:	Hill.	Hill.	Hill.	Hill.	Hill.	Hill.	Hill.	Hill.	Hill.
POR	71-89	46-62	46-56	46-55	46-56	78-89	48-99	69-99	78-97
N	220	195	124	111	120	144	352	298	224
AVG	61.5	60.7	60.9	61.0	48.9	50.4	39.8	39.5	35.1
MEDIAN	61.6	61.1	61.0	61.2	48.9	50.5	39.9	39.6	35.2
MAX	62.9	61.8	62.3	62.4	50.7	52.1	42.2	41.4	36.1
MIN	59.1	58.0	58.8	57.9	46.9	48.9	36.7	37.0	33.2
P10	62.5	61.5	61.6	61.7	49.8	51.2	40.5	40.4	35.8
P50	61.6	61.1	61.0	61.2	48.9	50.5	39.9	39.6	35.2
P90	60.4	59.4	60.2	59.9	47.8	49.7	38.8	38.5	34.4
P10-P50	0.9	0.4	0.5	0.5	0.9	0.7	0.6	0.8	0.7
P50-P90	1.2	1.7	0.8	1.3	1.1	0.8	1.0	1.1	0.8
P10-P90	2.1	2.1	1.4	1.8	2.0	1.5	1.7	1.9	1.5
Lake Area (ac)	30	126	82	30	63	43	53	22	75
WS Area (ac)	832	448	U	U	5888	1216	2688	128	1344

Group 1: Pasco-Hillsborough East *(continued)*

Lake:	King	Cow (East)	Curve	Bell	Thomas	Padgett	Saxon	Big Vienna
County:	Pasco	Pasco	Pasco	Pasco	Pasco	Pasco	Pasco	Pasco
POR	70-98	76-98	76-98	77-98	68-99	65-97	83-97	86-98
N	249	234	261	205	365	379	171	95
AVG	71.6	77.5	75.4	70.5	73.5	69.6	69.5	67.8
MEDIAN	71.8	77.6	75.5	70.5	73.5	69.6	69.6	67.7
MAX	73.3	78.5	77.2	73.9	75.1	71.1	71.2	69.6
MIN	69.3	75.8	73.0	68.4	71.5	67.1	67.2	65.4
P10	72.6	78.0	76.7	71.6	74.5	70.5	70.5	68.9
P50	71.8	77.6	75.5	70.5	73.5	69.6	69.6	67.7
P90	70.4	76.8	74.0	69.5	72.4	68.6	68.5	66.9
P10-P50	0.8	0.4	1.2	1.1	1.0	0.9	0.9	1.2
P50-P90	1.4	0.7	1.5	1.0	1.1	1.1	1.1	0.9
P10-P90	2.2	1.2	2.7	2.1	2.1	2.0	2.0	2.0
Lake Area (ac)	263	98	26	80	164	200	81	36
WS Area (ac)	U	U	U	U	U	U	U	U

Notes: U = Unknown or unmeasured.

Table 11 *(continued)*

Potential Groupings for Reference Lakes

Group 2: Pasco-Hillsborough West								
Lake:	Keystone	Hiawatha	Mound	Crescent	Geneva (Mud)	Minniola	Parker (Ann)	Seminole
County:	Hill.	Hill.	Hill.	Hill.	asco	Pasco	Pasco	Pasco
POR	46-62	81-99	72-89	78-89	1-98	81-97	69-98	69-98
N	201	210	173	140	130	129	334	273
AVG	40.6	49.3	49.5	41.1	49.2	49.1	46.8	47.0
MEDIAN	40.5	49.3	49.7	41.3	49.3	49.3	46.9	47.0
MAX	42.3	50.7	50.6	42.1	50.4	50.4	48.7	48.9
MIN	38.6	47.5	47.2	38.8	47.6	47.6	44.2	44.8
P10	41.5	50.2	50.2	41.9	49.8	49.8	48.1	48.2
P50	40.5	49.3	49.7	41.3	49.3	49.3	46.9	47.0
P90	39.6	48.5	48.7	39.9	48.2	48.2	45.6	46.0
P10-P50	1.0	0.9	0.5	0.6	0.6	0.5	1.2	1.2
P50-P90	0.9	0.8	1.1	1.4	1.0	1.1	1.3	1.0
P10-P90	1.9	1.7	1.5	2.0	1.6	1.6	2.5	2.2
Lake Area (ac)	417	136	79	46	13	30	93	14
WS Area (ac)	6400	U	192	768	U	U	U	U

Group 3: Pasco-Hillsborough East "Outliers"					
Lake:	Gooseneck	Bird	Tampa	Hobbs	Carroll
County:	Pasco	Pasco	Pasco	Hill.	Hill.
POR	78-98	78-98	78-98	47-62	46-62
N	105	204	88	197	192
AVG	70.8	47.8	62.9	65.6	36.0
MEDIAN	70.8	47.6	63.0	65.9	36.1
MAX	74.2	51.4	66.5	67.8	39.4
MIN	66.7	45.5	59.5	62.4	32.4
P10	73.0	49.6	64.8	67.0	37.4
P50	70.8	47.6	63.0	65.9	36.1
P90	68.4	46.2	61.0	63.8	34.5
P10-P50	2.2	2.0	1.8	1.1	1.3
P50-P90	2.4	1.4	2.0	2.1	1.6
P10-P90	4.6	3.4	3.8	3.2	2.9
Lake Area (ac)	27	150	65	67	191
WS Area (ac)	U	U	U	576	1088

Group 4: Pasco West "Edge" Lakes		
Lake:	Moon	Crews
County:	Pasco	Pasco
POR	65-98	64-89
N	388	191
AVG	38.3	52.3
MEDIAN	38.5	52.4
MAX	41.1	56.5
MIN	35.4	47.4
P10	39.7	54.5
P50	38.7	52.4
P90	36.9	50.2
P10-P50	1.1	2.2
P50-P90	1.8	2.2
P10-P90	2.8	4.4
Lake Area (ac)	99	693
WS Area (ac)	U	U

Note: U = Unknown or unmeasured.

Group 2: The Pasco-Hillsborough West set is clustered in the northwestern portion of Hillsborough County and a small part of Pasco County directly to the north. The area is just east of the Eldridge-Wilde wellfield. Groundwater assessment (see Section 3.3) suggests that this is an area of lesser head difference between the Upper Floridan and surficial aquifers. This area was at one time a groundwater discharge zone, although there may now be some induced recharge as a consequence of well withdrawal. Although there are few data predating the operation of the Eldridge-Wilde wellfield, hydrographs for lakes in this area are rather stable over a major portion of the period of record. The hydrographs for these lakes are similar to those of Group 1 despite apparent differences in ground water flow pattern.

Group 3: The Pasco-Hillsborough East "Outliers" is a set of five lakes, three of which are in close proximity in south-central Pasco County. The other two are in north-central Hillsborough County. All are in close proximity to Group 1 lakes. The hydrographs for these lakes are similar to each other but dissimilar to the Groups 1 and 2 lakes in that they have much greater variability for any month of the year. The reason for this variability remains unclear, but definitely skews the results of analyses that include these lakes with Groups 1 and 2 lakes.

Group 4: The Pasco West "Edge" Lakes include just two lakes, each just west of a wellfield and each on the border of Areas 2 and 3 (Figure 6 of the Lakes Section of the White Papers). These lakes have hydrographs similar to the Group 3 lakes, despite very different groundwater flow pattern and location. Moon Lake was included in the District's reference lake set, but Crews Lake was not.

The P10-P50 and P10-P90 values, essential to establishing the RLWR, are summarized for each group in Table 12. The similarity between the values for Groups 1 and 2 and also between values for Groups 3 and 4 is striking, and suggests that only two classes of reference lake are needed from a functional perspective. There may be other differences between these lake groups that bear further inspection, and the Panel has chosen to leave the four groups separate for illustrative purposes. One lake from each group is represented in Figure 3.

The median P10-P50 value for Groups 1 and 2 is 0.8 foot, while the median P10-P90 values are 2.0 and 1.8 feet, respectively. For Groups 3 and 4, the median P10-P50 values are 1.8 and 1.6 feet, respectively, and the median P10-P90 values are 3.4 and 3.6 feet. Value ranges (maximum-minimum) are always less than 1.7 feet, and are as small as 0.7 foot. The use of at least two classes of reference lakes minimizes variability within classes and results in a much tighter range of values than for the total District's reference lake set. The main difficulty presented by this multi-class approach is knowing which lakes belong in the "outlier" class; this issue is best surmounted by an evaluation of lake hydrographs, if available.

Table 12

Comparison of Potential Reference Group RLWR Values

	MAXIMUM	MEDIAN	MINIMUM
Group 1: Pasco-Hillsborough East			
P10-P50	1.2	0.8	0.4
P10-P90	2.7	2.0	1.2
(n = 17)			
Group 2: Pasco-Hillsborough West			
P10-P50	1.2	0.8	0.5
P10-P90	2.5	1.8	1.5
(n = 8)			
Group 3: Pasco-Hillsborough East "Outliers"			
P10-P50	2.2	1.8	1.1
P10-P90	4.6	3.4	2.9
(n = 5)			
Group 4: Pasco West "Edge" Lakes			
P10-P50	2.2	1.6	1.1
P10-P90	4.4	3.6	2.8
(n = 2)			

Using two classes of reference lakes would lead to RLWR50 values of NP minus 0.8 foot and NP minus 1.7 feet, and RLWR90 values of NP minus 1.9 feet and NP minus 3.5 feet. The differences between RLWR values for the two classes appear too large to be ignored. The District's RLWR from a single data set includes RLWR50 = NP minus 1.0 foot and RLWR90 = NP minus 2.1 feet. The Panel believes that the creation of reference lake classes represents an improvement that should result in greater fairness in the setting of Minimum Levels. Use of the classes established here would involve limited effort.

In-Lake Indicators

While the Panel concurs that water levels that protect fringing cypress wetlands should be sufficiently protective of other lake resources, the uncertainty associated with the status of other lake resources when water levels do not sufficiently protect fringing cypress wetlands calls for the development of additional indicators of lake condition. The three most logical choices that occurred to the Panel and were reiterated by the recent Biological Research Associates (1999) submission involve lake volume, lake area, and littoral plant assemblages.

Lake volume and area will decline as a function of decreasing depth and the morphometry of the lake. Some assumption of general lake shape (truncated inverted cone) would allow a calculation of approximate loss of volume or area with decreasing depth, but more detailed morphometric information would not be difficult to collect for adopted lakes. The more difficult aspect of this approach is deciding at what level of lost volume or area there is significant harm to the lake. Any detailed, quantitative estimate will require further study, so the District is not to be faulted for failing to apply this approach on purely scientific grounds.

However, it would reasonable to make an initial policy decision about approximate levels of loss that would be tolerated until a more scientific study could be completed. Losses such as 10 percent of the volume or area for up to 90 percent of the time would be consistent with the RLWR approach. Setting a maximum loss for the other end of the distribution is more difficult. Surely the lakes cannot sustain a 90 percent loss for up to 10 percent of the time; values more on the order of 75 percent for up to 10 percent of the time seem more appropriate. However, this is largely a policy decision based on reasonable scientific constraints, and should be adjusted over time as information becomes available through concerted studies or routine monitoring of adopted lakes.

The use of the littoral plant community is a possible surrogate for fringing cypress wetlands, as some form of littoral vegetation would be expected in almost all lakes whether or not there are cypress trees present. The impact of water level decline on littoral vegetation has been studied extensively (Cooke et al., 1993), and vegetation community analysis is not an especially difficult or expensive task. Aerial photographs or digital image analysis techniques would be advantageous in this regard, if the scale is appropriate. Field investigations could focus on test plots that could be monitored on a standard time scale, much like water-level gauges.

Setting the level of acceptable impact will require a combination of local study and policy decision, but it seems appropriate to suggest that any water level decline that eliminates aquatic species from the littoral community would be unacceptable. Replacement of aquatic species with terrestrial forms would be a clear indication of unacceptable alteration of the water level regime. Lesser degrees of loss could be assessed on the basis of areal coverage, community richness, or community diversity. As many factors other than water level affect the littoral zone plant assemblage (e.g., herbicide application, disease, herbivory), the relationship of water level to the aquatic plant community is unlikely to be as reliable as for cypress trees, but this approach has potential.

Implementation of this improvement could come in phases. Initial adoption of target lake volume and area values would require considerable discussion but limited field effort.

Establishing quantitative relationships between in-lake features and water levels will be a major and protracted effort, much like the development of wetland health indicators.

3.2-F. Discussion and Conclusions

The Panel was charged with evaluating the approach to setting minimum water levels for lakes with regard to the adequacy of the data, assumptions, and procedures, and with quantifying any major deficiencies or improvements in the process which could enhance the scientific credibility of the resultant regulatory water levels. With this Charge in mind, the Panel finds that:

- While quality control procedures appear to require improvement, data seem to have been properly collected and provide a reasonable database from which analyses can be conducted.
- The exclusion of data from some lakes and the inclusion of data from others are not sufficiently documented. The Panel concludes that while the database is reasonable, the best available data were not used.
- The resultant reference lake database appears to represent all lake types within the target zone, but excludes data from lakes that appear suitable for inclusion. The reference lake data set includes lakes that have enough hydrographic variability in water levels to warrant consideration of more than one class of reference lake. While the resultant analysis appears valid, it could be improved.
- Assumptions can be easily gleaned from the documentation, but justification for some assumptions is not so easy to obtain. Most assumptions can be justified by analysis of existing data. However, there is concern over the reliability of the NP minus1.8 foot level as the proper P50 for protecting fringing cypress wetlands, and over the suitability of any single numeric standard for all wetlands. The need for additional indicators of lake condition is also apparent; Category 2 lakes are unlikely to support healthy fringing cypress wetlands over the long-term as a consequence of structural alteration.
- There do not appear to be alternative analyses that can eliminate or even substantially reduce assumptions with equal or better results based on available data. However, improvements in the chosen approach might reduce reliance on certain key assumptions and enhance overall reliability of the process.
- The approach of establishing a Reference Lake Water Regime is very appropriate, and a scientifically reasonable methodology has been developed. Application of the methodology includes all necessary factors, is repeatable, and yields results that are generally consistent with the available data. Improvements might reduce some of the variability inherent in the current process and provide minimum water levels better suited to specific adopted

lakes. The methodology itself is defensible, scientifically reasonable, and appropriate.

- Four areas of possible improvement have been described: (1) expanded assessment of the ecological health of reference lake wetlands; (2) enhanced measurement methods for determining the elevation of the cypress butt swell; (3) establishment of at least two reference lake classes, each with substantially different RLWR values; and (4) the addition of indicators of lake condition aside from fringing cypress wetlands.

SECTION 3.3
SEAWATER INTRUSION

3.3 SEAWATER INTRUSION

3.3-A. Target Resources

The resource of concern regarding seawater intrusion in the Northern Tampa Bay area is the Upper Floridan aquifer (White Paper Part 3, page 6):

> "... the District has established that the goal of Minimum Levels to prevent seawater intrusion in the Northern Tampa Bay area is to allow no further significant advancement of seawater intrusion to protect the regional freshwater aquifer of the area."

The above statement appears to be a comprehensive goal aimed at protecting Upper Floridan aquifer groundwater resources throughout the area; however at this stage, the intention of the established Minimum Levels is to protect a modest geographical portion of the resource. The following District statement is illustrative of the situation (Seawater Intrusion White Paper, page 7):

> "Finally, Section 373.042(3)(1996 supp.) of Florida Statutes requires that the District focus its initial implementation of Minimum Levels in priority areas. Although the District is concerned about protecting all areas from seawater intrusion, the current data and conceptualization of the Northern Tampa Bay area do not support a great concern for seawater intrusion in coastward sections of Hillsborough County where withdrawals are minimal, or in all of Pasco County."

Although the Charge to the Panel directs its review effort away from policy matters, the Panel simply acknowledges that the decision of the District to narrow the geographical limits of the target resource by selecting priority areas for immediate protection was apparently not based solely on scientific and technical data and methodologies.

There are seawater intrusion Minimum Levels for seven monitor wells (White Paper Part 3,). These wells are located along two transects: transect A which is south of the Northwest Hillsborough well field and consists of three monitor wells, and transect B which is west of the Eldridge-Wilde well field and consists of four monitor wells (Seawater Intrusion White Paper, Figures 6, 7, 8; and Table 1). The District established these levels based on its judgment of average potentiometric heads that are believed to represent "current long-term water levels associated with existing drawdown conditions" in the Upper Floridan aquifer. Long-term is defined as a period spanning the range of hydrologic conditions that is expected to occur based on these "historical" records. The duration of the records used to set the Minimum Levels was between 6 and 10 years.

Historic Seawater Intrusion and the Coastal Margin

An important subregion of the water resources of the Upper Floridan aquifer in the Northern Tampa Bay area is the coastal margin where seawater intrusion due to pumping has already occurred. The Panel considers these historic occurrences to represent significant changes in those areas. That this has already occurred has not influenced our review of the methodology to determine the limit at which significant harm occurs (Charge to the Panel, Section 1-A of this report). There is clear historic evidence of degradation of the coastal aquifer water resources. Wells installed at the turn of the century supplied potable groundwater, but well fields were forced inland due to seawater intrusion. In 1906, Tampa had 11 public supply wells whose depths ranged from 193 to 328 feet and whose production reached 2.75 million gallons per day (*mgd*) by 1913. Tampa shifted to surface-water supplies in 1925 because of salinization of the wells tapping the Upper Floridan aquifer. St. Petersberg's water supply was obtained in part from groundwater, employing a 432-foot deep well that was abandoned because of increasing chloride concentrations. Consequently, St. Petersberg began operating a well field in northwest Hillsborough County in 1932 that pumped about 12 mgd by 1951.

Other coastal wells had salinity problems, including industrial wells in Tampa that had to be abandoned due to salinization in the late1940's and 50's. Pinellas County peninsula wells were reported to exhibit saline conditions in the 1950's (Heath and Smith, 1954) and a similar situation occurred in local coastal wells in the New Port Richey area of Pasco County. The East Lake Road well field is currently inoperative due to water quality problems including high chloride concentrations. While in operation, the East Lake Road well field never pumped to capacity because of salinity problems. During 1992 for that well field, a 400-foot-deep well showed an increase in total dissolved solids (*TDS*) from near 0 to over 5000 milligrams per liter (*mg/L*) and a 700- to 788-foot-deep well had an increase in TDS from about 19,000 to 27,000 mg/L (Ref-49). The chloride concentration also increased. These historic problems of seawater intrusion and upconing span much of the century in the coastal margin. Prevention of further salinization is therefore the target of current regulatory efforts.

3.3-B. Summary of Methodologies Used to Establish Minimum Levels

As background to the establishment of seawater intrusion Minimum Levels, the District considered two categories of methods to help determine if seawater intrusion was a regional problem. These include inferences based on values and trends in concentrations of chloride and TDS at numerous monitor-well locations throughout the area (Ref-42, Ref-49, Ref-19, Ref-20), and modeling assessment of the regional freshwater-seawater interface (Ref-24). No specific methodological basis or prototype was cited by the District for the establishment of heads to serve as seawater intrusion Minimum Levels. Rather, the physical justification was based on reasoning that recent historic hydraulic heads and gradients in the Upper Floridan aquifer are responsible for the current position of the freshwater-seawater interface. Therefore, if these long-term average heads are maintained, additional significant seawater intrusion is not likely.

3.3-C. Evaluation of Scientific Reasonableness

3.3-C(1). Review of Nature and Character of Information Utilized

The information utilized to determine the extent and nature of seawater intrusion consisted of databases containing measured values of concentrations of chloride and TDS found in groundwater at many locations in the Northern Tampa Bay area. The District (Ref-42) discusses three sources of data: SWFWMD Water Use Permit (*WUP*) data, the U.S. Geological Survey (*USGS*) Automated Data Processing System data, and the District's Ambient Ground-water Quality Monitoring Program (*AGWQMP*) data. The information presented from databases and/or reports (e.g., AGWQMP, 1990a, b, c; AGWQMP, 1991; AGWQMP, 1992; ROMP, 1994, Ref-49) appears to be consistent in showing the general landward extent of the seawater-freshwater interface. The WUP and USGS data contain values for the period beginning January 1973. The WUP data show that 481 wells were sampled for water quality as of October 1994. Because the WUP samples are collected and analyzed by individual permit holders, the data are likely to lack the consistency of those collected by the USGS. The USGS database consisted of 68 wells (Ref-42) in the Northern Tampa Bay area. The District's AGWQMP database contained 65 wells in the Northern Tampa Bay area that were monitored from January 1991 to October 1994 (Ref-42). The AGWQMP samples were analyzed solely by the District and therefore consistency is expected. Samping at the AGWQMP wells is done in accordance with the District's quality assurance plan.

Trend Analyses

Trend analyses were performed by the District on the WUP and USGS data after a few outliers were removed (Ref-42). Additional data were included from the AGWQMP. Although the nature of the outliers was not reported, the results of the District's analysis are generally consistent with that conducted by the USGS. Data were categorized into two sampling depth intervals -- the Tampa/Suwannee Limestones and the Avon Park formation. Data were further separated into three 6-year time periods covering 1973 to 1993. The non-parametric Kendall-Tau test was employed to indicate the presence of an increasing or decreasing trend for 377 WUP wells (268 Suwannee and 109 Avon Park), 44 USGS wells (31 Suwannee and 13 Avon Park), and 65 AGWQMP wells (58 Suwannee and 7 Avon Park). The Kendall-Tau test provides no information on the rate of change of the time series.

Trend analyses were conducted by the USGS (Ref-49) for the Northern Tampa Bay area. This work provides, to some degree, a check on the trend analysis presented by the District. The Yobbi et al. (Ref49) report was based on water-quality data from the USGS Automated Data Processing System, District WUP regulatory data, and District Coastal

Ground-Water Quality Monitoring Program (*CGWQMP*) data. The USGS data covered the period from 1960 to 1991. The WUP data covered the period from 1971, and the CGWQMP data covers the period from 1991. Trend analyses were performed and are reported for the period beginning as early as 1960 for some wells and ending in late 1995 or early 1996. Most time series begin in the 1970s and 1980s. Yobbi et al. (Ref-49) deleted certain data where it was believed that transcription errors or faulty chemical analyses occurred. Trend analyses were conducted for two periods, 1985-1995 and a longer period depending upon the length of records. Data consisted of measurements from 287 public supply wells and 99 monitor wells. All of the supply wells and slightly more than half of the monitor wells were part of the WUP database. Yobbi et al. (Ref-49) also employed the Kendall-Tau test but additionally used the Seasonal Kendall Slope Estimator to describe the magnitude of identified trends.

Simulation Analyses

The second approach used to assess seawater intrusion was simulation. A sharp-interface model was developed by HydroGeoLogic, Inc. (Ref-24). The model treats seawater and freshwater as two non-mixing fluids and tracks the position of the seawater-freshwater interface wherein the dense seawater underlies, and is seaward of, fresh groundwater. The model relied upon simulation results from the District's (Northern Tampa Bay area groundwater) modeling effort (Ref-41) to establish boundary conditions, primarily the fixed position of the water table. Simulation results suggested that the position of the freshwater-seawater interface is quite stable under a variety of pumping scenarios.

3.3-C(2). Review of Technical Assumptions

There are three types of technical assumptions that were made by the District in their identification of seawater Intrusion Minimum Levels: (1) those assumptions associated with the detection of seawater intrusion and associated water-quality trends with time; (2) assumptions employed in the model of the position of the seawater-freshwater interface; and (3) assumptions made to establish the existing Seawater Intrusion Minimum Levels. These technical assumptions are discussed in turn below.

The detection of seawater intrusion and analysis of water-quality trends rely on a network of monitor and pumping wells. The analysis conducted by the District (Ref-42) was substantially duplicated by the USGS (Ref-49). The District's work is based on sound logic regarding the use of chloride and TDS concentrations in groundwater as the fingerprint of intruding seawater. The Kendall-Tau test is non-parametric and compares all combinations of pairs of data, recording a plus for an increase and a minus for a decrease, and scoring the sum. The method is a valuable screening tool for identifying trends, but it may not detect increases or decreases that occur early or late in the time series. There are no obvious assumptions that prevent its use for the water quality data available for the Northern Tampa Bay area. As with all statistical methods, the Kendall Tau test should be used in concert with visual inspection of time series data and logic regarding interpretation of apparent trends and misinterpretation of corrupted data.

Although the results of the trend analyses showed geographically limited increases in chloride and TDS concentrations, the network of sampling points had notable gaps in coverage, particularly in northwestern Pasco County. Apparently, it was assumed that seawater intrusion had not occurred in these unmonitored areas to an extent that called for additional monitor well installation or protection through seawater intrusion Minimum Levels. Yobbi et al. (Ref-49) note that the majority of public supply and monitor wells for which a long-term (1970-1995) increase in chloride concentration was detected are within well fields in Pinellas County. Finally, it was assumed that measured concentrations of chloride and TDS would detect incipient seawater intrusion. The vast majority of water quality samples are usually taken from boreholes, each one open over an extensive vertical interval. Such samples represent a composite of solute fluxes entering the well from many horizons. The detection at any particular horizon of early fingered breakthrough of seawater can be masked by the dilution of freshwater entering the well at other horizons. The water quality of individual horizons can be measured by collecting water through multi-level samplers.

Both the assumed position and stability of the seawater-freshwater interface are based, in part, on simulation analysis. The Panel recognizes that all models are simplifications and that the simulation model using the sharp-interface approach was merely a screening tool to examine the sensitivity of interface behavior to pumping scenarios. However, such an approach is highly simplified in its conceptualization of coastal aquifer dynamics and provides the non-conservative approximation that saline water is farther seaward than it actually may be. Information based on water-quality measurements presented by Trommer (1993) clearly shows that the seawater-freshwater interface is hundreds of feet thick. This dispersed transition zone is present in the Upper Floridan aquifer and yet is assumed to be absent using the sharp-interface model. The reported modeling results did not, for example, indicate detection of upconing that is apparent in data for a deep multizoned monitor well in the Cypress Creek well field and a deep well in the South Pasco well field.

Sharp-interface simulations were based on the assumption that the water table could be fixed for a particular pumping scenario and treated as a specified-head boundary condition (Ref-24). The sharp-interface model simulated only the Upper Floridan system, and the fixed heads in the surficial aquifer were generated by independent simulation using the Northern Tampa Bay groundwater model (Ref-41). This assumption is problematic in two respects. First, it implies that the water table serves as an infinite source of freshwater that repels the advancement of saline water. Second, all of the errors and uncertainties due to limitations and assumptions inherent in the Northern Tampa Bay groundwater model are transferred to the sharp-interface model. The most notable limitations of the Northern Tampa Bay groundwater model are its inability to represent vertical flow within each of the two very large model layers representing the Upper Floridan aquifer, and more importantly, the limited manual calibration that was undertaken. The Panel believes that groundwater modeling is and will undoubtedly continue to be an indispensable component of the District's water management. Many of the technical assumptions associated with the existing models can be eliminated by adopting more sophisticated models and calibration procedures. Although the Panel is critical of some aspects of the groundwater models, we are in agreement with the general conclusion that the inland extent of seawater is apparently not terribly sensitive to the expected range of inland wellfield pumping conditions.

The basis for establishing the seawater intrusion Minimum Levels presented in the White Paper (Part 3) relies on the following assumptions or, in some cases, conclusions from analyses that were conducted:

(a) Seawater intrusion is not a regional problem.

(b) Karst conditions have not led extensively to direct conduits for seawater by connecting the Gulf of Mexico to inland aquifer locations.

(c) Vertical head differences within the Upper Floridan aquifer are unimportant in establishing and continually monitoring Minimum Levels.

(d) Seawater intrusion monitoring using Minimum Levels will only protect two priority areas by focusing at this time on Upper Floridan aquifer water resources seaward of two major well fields (Eldridge-Wilde and Northwest Hillsborough).

(e) Maintaining potentiometric water levels as Minimum Levels along the two specified transects that consist of a total of seven monitor wells is adequate three-dimensional coverage at this time.

(f) Areas of seawater intrusion between the coast and the major well fields, and in unmonitored areas, are not priorities at this time. In other areas, seawater intrusion represents a set of local problems, and Minimum Levels are not now needed.

(g) No baseline set of Minimum Levels should be established to prevent future intrusion in areas currently under conditions of moderate groundwater use, in areas yet to be developed for water supply, or in areas of potential upconing of saline water.

(h) The position of the seawater-freshwater interface is very stable under pumping conditions ranging from predevelopment to developed.

(i) The specific values selected for seawater intrusion Minimum Levels use a historic period that is representative of recent long-term averages. The time series presented in the hydrographs used to derive the seawater intrusion Minimum Levels span a period not unduly influenced by drought. In the seawater intrusion White Papers, the District states,

> "...Minimum Levels were determined by averaging the water levels measured in each well over many years, representative of the current withdrawal rates. Likewise, compliance with the Minimum

Levels should also be based on long-term averages. 'Long term' is *defined as a period which spans the range of hydrologic conditions* which can be expected to occur based on historical records."

3.3-C(3). Review of Procedures and Analyses

Most of the procedures used to analyze the occurrence of seawater intrusion and trends in the migration of the seawater-freshwater interface were reasonable, but the translation of the results of the analyses into seawater intrusion Minimum Levels lacks requisite conservatism. For example, the period used to set the Minimum Levels included all or part of the drought that occurred between 1989 and 1994. Depressed water levels appear during this period for monitor wells RMP-13D, RMP-8D1, and Tarpon Road Deep and may be present in the data for some or all of the other monitor wells. The most obvious case in point is the Tarpon Road Deep well Minimum Level which relies on a period of data that does not appear to be representative of the range of hydrologic conditions apparent in the recent "long-term" record. Consequently, the established seawater intrusion Minimum Levels are too low.

Best available information appears to have been utilized to determine the extent of seawater intrusion but not to determine the values of the Minimum Levels. Of tangential interest to the establishment of Minimum Levels, concerns about the adequacy of the monitoring network for the Northwest Hillborough County saltwater monitoring program were raised (Ref-20) wherein five additional monitor wells and two optional wells were suggested and extending the area of data collection toward the Cosme-Odessa well field.

In terms of water-quality trend analysis, imprecisions in the water quality data appear to have been properly handled and the analyses appear to be repeatable. The simulation analysis was oversimplified and based on simulation models that are preliminary by modern standards. Specifically, the Northern Tampa Bay groundwater model (Ref-41) appears to be a useful screening tool but lacks the detail and sophistication needed to provide the predictions used to establish Minimum Levels. As an element of the sharp-interface model, the Northern Tampa Bay groundwater model is, at best, pushing the limits of its demonstrated predictive capability.

3.3-D. Evaluation of Deficiencies

The general methodology used to analyze seawater intrusion was justifiable and led to reasonable conclusions about the nature and extent of the problem. Although the Panel is critical of some elements of the District's analysis, we support the concept of using a network of monitor wells at which seawater intrusion Minimum Levels are in force. The Panel does not believe that there is a general approach to establishing seawater intrusion Minimum Levels that would require fewer assumptions but provide better results using existing data. Initial implementation of the District's methodology could be improved and extended to other subregions in the Northern Tampa Bay area. Translation of the District's understanding of the seawater intrusion problem into the two transects of only seven wells for which seawater intrusions Minimum Levels have been established leaves much of the Upper Floridan aquifer water resources unprotected.

Given the extent of seawater intrusion in the Upper Floridan aquifer in other near-coast areas, there is a notable deficiency in the number of established seawater intrusion Minimum Levels monitoring sites. Specifically, deficiencies could be overcome by (1) providing a more extensive network of locations for Minimum Levels to protect the areas near Eldridge-Wilde and Northwest Hillsborough well fields, and (2) adding transects along the coast of Pasco and Hernando Counties that extend 5 to 10 miles inland. At the very least, monitoring transects are recommended to the west of transect A-A′ and to the north of transect B-B′ (seawater intrusion White Paper , Figure 6).

The near-coast environment is viewed as a subregion that is most susceptible to further seawater intrusion, and Minimum Levels should be put in place to prevent further water quality degradation. Although inland well fields have not experienced substantial upconing of saline waters, baseline Minimum Levels could be established based on observed water quality trends for deep wells at or near the center of cones of depression.

3.3-E. Evaluation of Preferred Methodologies

The concept adopted by the District of establishing transects of seawater intrusion Minimum Levels monitor wells in endangered areas is rational and supported by the Panel. A preferred methodology would be to establish transects of multi-level monitor wells at which water quality and hydraulic heads at each interval were measured simultaneously. This one-to-one correspondence of heads to concentrations could then be used to update and specify more precisely the values of seawater intrusion Minimum Levels.

For both the seawater intrusion Minimum Levels and the Environmental Minimum Aquifer Levels (*EMALS*), simulation is expected to be a vital tool for evaluation of water development impacts and management of aquifers. The foundation for modeling seawater intrusion is a proper tool for predicting aquifer hydraulic behavior. The Panel recommends that a major investment be made in the development, calibration, and testing of a high-resolution three-dimensional groundwater flow model. The Northern Tampa Bay groundwater model (Ref-41) is a valuable screening tool to make qualitative assessments. Development of the District's groundwater model was a key initial step in building a valid three-dimensional predictive tool, but that effort did not go far enough. The existing model does not produce simulated hydraulic responses with the necessary resolution and neglects error-bound determination. The current model has limited ability to predict potentiometric levels and is incapable of quantifying uncertainty in predictions because parameter values were manually calibrated without the benefit of simulation-regression methods or other inverse modeling approaches (Carrera and Neuman, 1986; Cooley and Naff, 1990; Gailey et al., 1991; Harvey and Gorelick, 1995; Hill, 1998; Wagner, 1992; Yeh, 1986). It does not take advantage of modern modeling methods of model calibration, parameterization, parameter uncertainty analysis, predictive uncertainty analysis, and stochastic simulation-management modeling (Gorelick, 1997; James and Gorelick, 1994; Tiedeman and Gorelick, 1993; Wagner, 1995).

An ongoing effort should be initiated to construct a regional flow model that provides the District with the tool required for prediction and planning. A regional solute transport model should be developed to predict the fate of invading seawater, the potential for upconing, and water quality degradation of the Upper Floridan aquifer from overlying contaminant sources.

3.3-F. Discussion and Conclusions

Regarding the state of seawater intrusion in the Northern Tampa Bay area, the Panel concludes:

- The District's analysis is correct that advancement of the seawater interface does not currently represent a tremendous threat to the entire Northern Tampa Bay regional Upper Floridan aquifer system.
- The District's analysis is correct that the subregion most threatened by seawater intrusion lies along the coast in the area of the Eldridge-Wilde and Northwest Hillsborough well fields. The inland tri-country area -- Subarea C (Ref-42) is one where the hydrogeology is "characterized by highly fractured limestone with numerous sinkholes, caverns and solution channels" which serve as "potential conduits between the Upper Floridan aquifer and the brackish waters underlying the aquifer and west in the Gulf of Mexico." This area, especially that near Lake Tarpon, exhibits intrusion through preferred pathways (Sup-31). Thus, he District is justified in targeting the areas near the Eldridge-Wilde and Northwest Hillsborough wellfields for immediate protection.
- The coastal margin has experienced localized problems of seawater intrusion and should be considered a sensitive subregion where there is a continuing threat of water-quality degradation.

Regarding the establishment of seawater intrusion Minimum Levels, the Panel concludes that:

- Establishing a network of Minimum Level monitor wells consisting of transects of monitor wells is an appropriate approach. However, a preferred methodology would be to install transects of multi-level samplers at which hydraulic heads and solute concentrations would be measured synoptically. Based on the one-to-one correspondence between the heads and the concentrations, more precise seawater intrusion Minimum Levels could be established. Sampling horizons should focus on the top of the dispersed seawater-freshwater transition zone and extend into the freshwater zone. Water quality and head data were often collected from wells open over large vertical intervals. Ideally, both head and concentration data should be collected from piezometers and multi-level samplers for short and specific open intervals.

- Minimum Levels should not be based on brief time series that substantially rely on data from the period 1989 to 1994, a drought period. Such Minimum Levels are biased and are likely to be too low.
- The District should augment the existing transects A-A′ and B-B′ to provide greater spatial coverage and should not rely (solely) on the current sparse monitoring network (seven wells). At all monitor wells, head measurements should be made and water-quality samples should be collected and analyzed.
- The District should add additional transects extending inland from the coast to protect the Upper Floridan aquifer water resources in Hernando County, west-central Pinellas County, and the northern portion of Pasco County.
- The District should develop site-specific but region-wide Minimum Levels to prevent upconing of saline waters at pumping centers.
- Groundwater modeling is recommended as an essential tool for the establishment of Minimum Levels. The existing models employed by the District must be enhanced to better represent the three-dimensional physical behavior of the aquifer system and to provide estimates of heads, drawdowns, solute concentrations, and predicted uncertainty of each. An initial effort would require a focus on model development and modern calibration for a 1.5- to 2-year period. Subsequent updating and improvement of the groundwater model should then become a standard part of District operations.
- The District must not only have a state-of-the-practice simulation tool to predict the consequences of various water-development actions, but must have a tool to specify how those actions should be brought online without undue consequences. To accomplish the latter, the District should develop a modern groundwater simulation-management model. This model would facilitate optimal wellfield management and safe water-supply expansion decisions made under a broad variety of physical, economic, environmental, and logistical constraints. The construction of a simulation-management model should proceed in concert with continued development of, and improvements in, the groundwater model. The simulation-management model should also become a constantly maintained tool used by the District to evaluate and determine optimal design alternatives.

The average historic potentiometric levels would be identified in one of four ways for each site, depending upon the availability and adequacy of head data:

1. If there is a nearby monitor well with sufficient pre-withdrawal (historic) head data, then the average of those data would be used.
2. If there is a monitoring well but insufficient pre-withdrawal data, then the historic average would be estimated using "best available data and methods." The estimation methods may include transferring data from a hydrogeologically similar region and using statistical analyses to estimate the historic potentiometric level.
3. If no pre-withdrawal data exist at the monitoring well, then the estimated average cumulative drawdown would be calculated and added to the current average potentiometric level.
4. If there is no nearby monitoring well, then the average historic potentiometric level would be identified using regional potentiometric data and maps.

3.4-C. Evaluation of Scientific Reasonableness

3.4-C(1). Review of Nature and Characterization of Information Utilized

Although no EMALs have been established, the Panel has reviewed a significant quantity of information and data relevant to evaluating the proposed methodology. There are hydraulic head data for the Upper Floridan aquifer that enable the relationship between pumping and drawdown to be measured (note, for example, Ref-3, -6, -11, -12, -23, -38, -41, -42; and Sup-1, -2, -4, -8, -12, -13, -14, -15, -16, -17, -18, and -19). There are also abundant hydrogeologic characterization data (e.g., Ref-11, -12, -21, -23, -28, -38, -41, -42; and Sup-3, -6, -7), much of which have been incorporated into the existing Northern Tampa Bay groundwater model (Ref-41) and other local wellfield models. Much of the head data are stored in databases that the Panel had limited opportunity to review, but appear to be of good quality. The EMAL methodology relies more upon Upper Floridan aquifer potentiometric level data than on water table values of the surficial aquifer. This is appropriate given the relative abundance of Upper Floridan aquifer data (versus shallow water-table data) and the great range of Upper Floridan aquifer potentiometric level changes in response to pumping (versus consequent small changes in the water table).

As can be seen in Table l, the questions posed to the Panel relative to review of information were largely considered to be "not applicable." Because EMALs have not been developed and applied, the Panel cannot evaluate at this time whether best available information was utilized or if adequate quality assurance procedures will be followed whenever the methodologies are utilized.

3.4-C(2). Review of Technical Assumptions

Key technical assumptions, stated or implied, in the EMAL methodology are:

- Potentiometric level changes in the Upper Floridan aquifer cause drawdowns in the surficial aquifer, which in turn can differentially influence lake levels and water levels in wetlands or lakes.
- The quantitative effects of pumping on the Upper Floridan aquifer potentiometric level and the consequent changes to the water table can be simulated using industry-standard groundwater flow models and analytic techniques.
- Groundwater flow models are better able to predict drawdowns than hydraulic heads in the Upper Floridan aquifer and surficial aquifers. Head values can vary, can be locally sensitive to a multitude of factors, and can be difficult to simulate on a site-specific basis. Changes in heads (e.g., drawdowns) are a direct measure of particular hydraulic stresses, such as withdrawals, and are more robustly simulated.
- Groundwater models can be used to identify the allowable drawdowns in the Upper Floridan aquifer. Allowable drawdowns are those that enable the Minimum Levels to be achieved in the targeted lakes and wetlands "based solely on withdrawal management."
- Regional potentiometric maps accurately portray historic conditions at site-specific locations of a given wetland or lake.

The Panel believes that all of the above are reasonable assumptions, although they are not well stated in the EMAL description within the EMAL White Paper. These assumptions are judged reasonable given that values obtained through data analysis or simulation aim to estimate average values, including average long-term water use and hydrologic conditions; historic average potentiometric levels; and current average potentiometric levels. No other reasonable analysis would provide comparable or better results given existing data.

3.4-C(3). Review of Procedures and Analyses

The Panel is not aware which groundwater model would serve as the basis for identifying the requisite drawdowns used in the EMAL methodology. If the existing Northern Tampa Bay groundwater model will be used, then review comments are appropriate.

The Northern Tampa Bay groundwater model (Ref-41) is a tool that can be used to initially establish EMALs. As mentioned in the Seawater Intrusion Minimum Level review (Section 3.3 of this report), the model has not been developed to the state where both predicted values and predictive uncertainty can be simulated. The model does possess most of the key conceptual elements of the hydrogeologic system of the region, but improvements in its ability to simulate flow in three dimensions and in its resolution could be made.

One important modification of the EMAL methodology is to back away from the definition of "long-term simulation" as synonymous with steady-state simulated average hydraulic heads. Steady-state conditions mean that no water comes from aquifer storage; all water supplying pumping wells ultimately originates from boundaries (such as lakes and rivers), and/or from recharge from net precipitation, or from changes in evapotranspiration. Steady-state conditions are dependent upon, and likely sensitive to, the choice and location of constant head and flux boundaries and values. Steady-state simulation depends on assumptions about the nature of changes to recharge and discharge versus pre-withdrawal conditions. At steady-state, one must evaluate the realism of the simulated sources of water supply; as stated above, one must identify if it is realistic that the source of pumped water is:

- flow induced from assumed constant head boundaries;
- capture of natural discharge such as elimination of flow from springs;
- induced recharge; or
- reduction or elimination of evapotranspiration.

Such sources of steady-state supply may be unimportant when considering transient (non-steady-state) conditions. For example, discharge from a spring might be a realistic boundary condition for a transient simulation, but under heavy pumping at steady-state, this discharge may be reduced or eliminated due to spring capture. In essence, it is not necessary to have an EMAL methodology in which the definition of long-term is tied to steady-state conditions; long-term transient conditions can be simulated. If steady-state conditions are reached, the source of water to supply wells must be evaluated.

In Table 1, it should be noted that "Not Applicable" (NA) is used in answer to the questions posed to the Panel in the Charge since the EMAL methodology has not been applied. The Panel believes that the eventual application of the method would be repeatable and necessary factors would be included.

3.4-D. Evaluation of Deficiencies

The generic EMAL methodology presented by the District (White Papers, Part 4) has few deficiencies. One unnecessary feature is the distinction among four methods to obtain historic average potentiometric levels. Methods (2) and (3) for determining historic potentiometric levels (presented above in Section 3.3-B) correspond to Sections 1.ii and 1.iii in the White Paper (Part 4). These two methods could be combined and the best one used to identify historic average potentiometric levels depending on site-specific conditions.

3.4-E. Evaluation of Preferred Methodologies

The Panel accepts the EMAL methodology as one that is logical, flexible, and capable of producing defensible values. The method does rely upon the existence of a calibrated model of the groundwater system. If the Northern Tampa Bay groundwater model is to be used to establish EMALs, it is suggested that that model be considered the starting-point platform for the development of a state-of-the-science simulation model.

For the purpose of determining EMALs, the focus of calibration should be on changes in hydraulic heads, and not on the magnitude of those heads. There are two reasons for this. First, within the EMAL methodology, the groundwater model will be used primarily to estimate allowable drawdowns (a change in head), so this should be the primary dependent variable. Second, it is far easier to develop and calibrate a groundwater model that can predict changes in head due to pumping than it is to predict the potentiometric surface, which is a strong function of initial conditions, boundary conditions, and both local and regional hydrogeologic features.

The EMAL methodology relies on simulation to establish allowable drawdowns in the Upper Floridan aquifer. This drawdown (EMALs White Paper) "allows the Minimum Levels to be achieved in MFL wetlands and MFL lakes based solely on withdrawal management." Optimal withdrawal management will be central to maximizing water supplies while maintaining high environmental quality for lakes and wetlands. Problems involving groundwater simulation in the context of optimal wellfield design and management are not amenable to simulation methods alone. Rather they are a class of problems for which simulation-management modeling methods have been developed. These methods combine predictive simulation with optimization techniques that identify the best allocation of scarce resources.

The scarce resource in the Northern Tampa Bay area is groundwater -- indispensable both as a source of water supply and to the environment. Simulation-management models identify the best location and pumping schedules for wellfields. They are formulated with an objective such as minimizing the cost of installation and operation of a wellfield, and contain constraints on heads, drawdowns, groundwater head gradients, groundwater velocities, and individual pumping rates, for example. The result is the identification of the best pumping program that minimizes groundwater-supply costs and addresses all hydraulic, economic, logistical, and environmental concerns.

Simulation-management models have been used to develop optimal wellfield designs that balance the competing interests of the public and private sectors, evaluate groundwater policy instruments such as taxes and quotas, manage regional aquifers subject to seawater intrusion, and protect water quality by preventing the migration of contaminants (see reviews by Gorelick, 1983, 1990, 1997; Wagner, 1995). The South Florida Water Management District in West Palm Beach, Florida, used a simulation management model (MODMAN) to evaluate optimal pumping for the proposed permitting of wellfields (R. Greenwald, HIS-

Geotrans, Inc., personal communication, July 29,1999). The District is encouraged to develop a groundwater management model that incorporates an improved three-dimensional flow model. MODFLOW has been used by the District for the Northern Tampa Bay groundwater model and its continued use is valid. The program MODMAN, distributed by the International Groundwater Modeling Center in Colorado, employs MODFLOW as the simulation component in the simulation-management model.

3.4-F. Discussion and Conclusions

No EMALs have been established, but the methodology to derive their values is sound and defensible. The approach relies on reasonable assumptions and an appropriate combination of data and simulation. The methodology adequately considers contingencies for different conditions of data availability. However, establishment of a Minimum Level for a wetland or lake must predate development of an EMAL for that same wetland or lake. The Minimum Level would control the allowable drawdown required in the EMAL methodology. In setting an EMAL, it may be difficult to apply an historic regionally-based potentiometric level to a site-specific case.

Although the District could use the Northern Tampa Bay groundwater model to establish initial values for the EMALs, the Panel recommends improvements to that model. The current model appears to predict reasonable patterns of drawdown due to pumping, but also appears to be only moderately well-suited to predict site-specific potentiometric head values. Resources should be expended to develop a high resolution, three-dimensional simulation model for which modern calibration methods are employed. Such a model would enable both better simulation and estimation of predictive uncertainty. Statistically based simulation-regression models should be used (see, for example, Carrera and Neuman, 1986; Cooley and Naff, 1990; Gailey et al., 1991; Harvey and Gorelick, 1995; Hill, 1998; Wagner, 1992; and Yeh, 1986). These calibration methods have been applied in numerous field environments and are an invaluable tool for model development and uncertainty analysis.

SECTION 3.5
TAMPA BAY CANAL (AT STRUCTURE 160)

3.5 TAMPA BAY CANAL (AT STRUCTURE 160)

3.5-A. Target Resources

Target resources for the Tampa Bypass Canal (*TBC*) are those biological resources that utilize or have the potential for utilizing the Palm River/McKay Bay estuarine system. McKay Bay is a shallow estuary, about 980 acres in size, and is one of the most important areas for birds in Florida. The Palm River was significantly altered by the U.S. Army Corps of Engineers for flood control and now contains some of the poorest quality water in Tampa Bay (Florida Department of Community Affairs, 1995). The biological resources in the Palm River/McKay Bay system include estuarine and saltwater fish species, benthic invertebrate species, phytoplankton, zooplankton, ichthyoplankton, and estuarine plant species. Many of these species are particularly sensitive to estuarine salinity gradients, a factor that must be taken into account when evaluating Minimum Flows of freshwater at Structure 160 (*S-160*).

3.5-B. Summary of Methodologies Used to Establish Minimum Flows and Levels

Eight references cited in the TBC White Papers summarized the various methodologies used in studying the issues involved with the TBC. Those references specifically referred to in the TBC White Papers were reviewed, along with several others. The following is a brief summary of the methodologies used by the District to establish Minimum Flow (across S-160) that is required to maintain the ecological integrity and productivity of the Palm River/McKay Bay estuarine system. [Specific references and methodologies used are addressed in Subsection 3.5-C(1)]:

Hydrologic analyses included:

- Development of groundwater models for baseflow and seepage calculations and interaction with surface systems such as the TBC and Hillsborough Reservoir; and
- Use of large-scale water balances and models to maximize the safe-yield potential of the TBC and other water resources.

Environmental/Ecological assessments include:

- On-going monitoring programs of key parameters such as salinity and dissolved oxygen (*DO*) to determine the impact of minimizing flows on water quality and ecosystems in the study area.
- Combined hydrobiological studies to establish and evaluate correlations between bypass flow reductions and the biological/ecological health of downstream systems.

3.5-C. Evaluation of Scientific Reasonableness

3.5-C(1). Review of Nature and Character of Information Utilized

References cited in the TBC White Paper were reviewed for general accuracy and validity. A significant amount of information and resources are available on the TBC and other related water resources in the area. The majority of sources, especially those cited directly in the TBC White Papers, were found to be highly reliable. The information utilized by the District for calculations, comparisons and report findings were generally based on sound methodologies. Sufficient quality assurance assessments were performed on source data, and more importantly, specific data results were often repeated by independent sources with consistent results. Based on the Panel's review of the available information, it appears that the District has considered most of the pertinent and essential information sources in its analysis.

Issues regarding the TBC and its impacts include hydrologic, biological/ecological, recreational, and water-quality concerns. The majority of the cited references in the TBC White Paper are limited by data collection and/or focus on one of these varied issues and do not directly address the overall impacts of Minimum Flow Levels on the Palm River/McKay Bay system. Although information presented in the TBC White Papers was of sufficient quality and can be considered the "best information available" as of July 1997, most reports make reference to the need for a more in-depth analysis to provide a greater number of sampling points to support their conclusions. This is especially true with respect to hydrologic issues such as the large-scale water balances involved with determining safe yields for the middle pool of the TBC, since information is limited to available stream-flow and rain gauge data. Similarly, assessing the extent of groundwater interaction with the TBC and the Hillsborough reservoir is limited by the number and location of monitoring wells in critical areas of the study site. Most importantly, these studies have minimal data on either water quality or ecological function for flows at or near the District's proposed zero Minimum Flow.

Eight of the most pertinent references are summarized below to provide an overview of the nature of information utilized.

(a) Model Study of the Palm River (Ross, 1980) -- This study presents results of a mathematical model to determine the causes of occasional water-quality problems in the Palm River and to determine a possible release schedule from the TBC to alleviate water-quality problems. The model is capable of simulating unsteady hydraulic and water-quality conditions. The model was used to test releases in the range of 200 to 1000 cubic feet per second (*cfs*), clearly outside the range of flows that can be easily managed for the system. It was concluded that the major cause of reduced DO in the Palm River is organic material introduced with stormwater runoff. Although this study was included in the TBC White Paper references, there is no evidence that the District relied on this source in their analysis. This is not unreasonable as the study is rather old, and results should not be used without some consideration of the current use of the system for water supply.

(b) Impacts of the TBC on the Areal Hydrology, Hillsborough County, Florida (Knutilla and Corral, 1984) -- This report summarized that the baseflow discharge is about twice that of the pre-construction period since the TBC breached the Upper Floridan aquifer. The TBC had little effect on aquifer levels downstream of S-160, but lowered levels from 2 to 4 feet upstream of S-162 in the middle pool. In general, the report shows that areal impacts on the surficial aquifer are greater in the upstream portions compared to the tidal reach areas. The support for their conclusions is based on observed changes in baseflows, monitoring well levels, and water-quality parameters. The report recognizes that the number of samples analyzed and the period of record were too short to adequately evaluate trends and impacts on the area.

(c) Evaluation of Hydrologic Monitoring Program (Schreuder and Davis , 1993) -- This study was undertaken with the objective of implementing a hydrobiological monitoring program. A comprehensive management plan is recommended that allows maximum water-supply production while minimizing biological and water-quality impacts downstream of S-160 on the TBC. The report generally concludes that up to 12 additional monitoring stations are needed to adequately quantify inputs/outputs to perform water balances for the Hillsborough reservoir and the TBC pools. The current water balance calculations have a large number of unknown factors that could be easily rectified with additional monitoring stations.

(d) Environmental Assessment of the Palm River, Tampa/Hillsborough County, Florida (HDR Engineering, 1994) -- This report describes the past and current conditions of the river with respect to water quality and wildlife habitat issues. The findings include:

- Altered bathymetry due to the TBC has adversely impacted the DO in the river.
- Untreated stormwater adversely affects the water quality of the Palm River.
- Surficial sediments are highly contaminated with toxic chemicals.
- An abandoned landfill on the north bank adversely

affects habitat of the river.

Recommended restoration measures include a re-evaluation of the TBC design, modification of the channel bottom bathymetry, additional sediment analyses, abatement of point and non-point pollution sources, and restoration of important wetland and upland habitat.

(e) Second Interpretive Report - TBC and Hillsborough River Hydrobiological Monitoring Program [Water and Air Research, Inc. and SDI Environmental Services, Inc. (WAR/SDI), 1995] -- This extensive report documents a study on the southern reaches of the TBC and Hillsborough River, including an assessment of all biological and water-quality data collected during the monitoring program and an evaluation of various withdrawal and augmentation schemes. In this study, vertical profiles of salinity and DO were collected at four stations in the Palm River and five stations in McKay Bay. Samples were collected from the surface to the bottom at 1-meter intervals. Data were collected on a monthly basis over a three-year period (1992-1994). Additional sampling was conducted within 48 hours of major rainfall or discharge events. A goal was to determine if additional withdrawals of 20 mgd, up to 82 mgd on an average day, would have an unacceptable adverse impact on water quality for selected biota in the study area.

Parameters evaluated during the study included salinity, DO, light penetration, biological oxygen demand (*BOD*), color, nitrogen compounds, phosphorus compounds, total organic carbon (*TOC*), total suspended solids (*TSS*), turbidity, and chlorophyll-a. Phytoplankton, benthic fauna, and fish were also evaluated for adverse impact from the proposed plan. Regression models were used to evaluate correlations between flow at S-160 and each of the measured water-quality and biological parameters. The average flow for the 14 days prior was used in comparing daily flow data with water-quality and biological parameters that were sampled on a monthly basis.

Water year 1990 was considered representative of a low rainfall/runoff year and was accepted for the base case analysis. The hydrologic model was used to simulate various withdrawal/augmentation plans from the TBC. The results indicated a total decrease of 0.8 billion gallons (about 3.6 cfs) in discharge from the Hillsborough River dam during water year 1990, and a decrease from 50 cfs to 5 cfs in discharges over the S-160 structure. Discharges of 500 to 1000 cfs from S-160 reduced surface salinities at station 12 by 5 to 10 parts per thousand (*ppt*), with most values remaining above 15 ppt. Based on the regression analyses, the authors conclude that a proposed 45 cfs reduction would result in very small salinity changes on the Palm River. This report concluded that the 45 cfs reduction would have minimal impact on water quality and biological communities in the Palm River or McKay Bay segments.

This study provides important empirical information regarding the correlations between flow and water quality and organism densities in the Palm River/McKay Bay. However, it was not designed to evaluate the effects of a minimum flow of zero on this system and includes only two observations of zero-flow. Moreover, the temporal resolution of the data is limited by the one-month sampling frequency.

(f) Surface-water Quality Data, 1992-1994 (Hillsborough County Environmental Protection Commission, 1995) -- These data include over nine years of monthly salinity and DO measurements at two stations in the Palm River and one in McKay Bay. Surface, mid-depth and bottom samples were collected for much of this period. Although this study provides a longer record than the WAR/SDI study, the temporal resolution of the data is again limited by the one-month sampling frequency. The spatial resolution of these data was also quite limited with only two stations in the Palm River and one in McKay Bay.

(g) Evaluation of Aquifer Test Data near the TBC (SDI Environmental Services, 1997) -- The study, which was a review and re-analysis of the 1984 aquifer test data, found that the upper permeable zone is nearly five times greater than the lower zone. A semi-confined zone exists between the two permeable units. SDI estimated that between 4 and 14 percent of the water pumped from well TPW-1 during the 1984 test could have been contributed by the TBC. This is in contrast to the 80 percent indicated in a study by CH2M-Hill (CH2M Hill Inc., 1985). SDI recommends drilling several additional wells at several suitable sites to assess the extent of the upper permeable zone.

(h) An Analysis of the Effects of Freshwater Inflows on Salinity Distributions, Dissolved Oxygen Concentrations, and Habitat Characteristics of the Hillsborough River and Palm River/Tampa Bypass Canal (Coastal Environmental, 1997) -- A major source relied upon by the District is this report of a study sponsored by the Tampa Bay National Estuary Program. This study, unlike previous studies, was specifically designed to support the development of Minimum Flows for the TBC and the Hillsborough River. However, no new data were collected for this study. Instead this study relied entirely on the data sets developed in the WAR/SDI and

Hillsborough County Environmental Protection Commission studies. This analysis, therefore, suffers from the same limitations in the data sets, including limited temporal and spatial resolution and minimal data in the critical zero flow range.

Like the WAR/SDI study, this study employed a regression-based analysis to empirically evaluate relationships between flow, salinity, and DO. Discrepancies among the flow, salinity, and DO data were dealt with differently than the WAR/SDI study. Salinities and DO were compared against same day flow data, and data for one day previous and two days following the salinity and DO measurements. This analysis employed a stepwise linear regression and log normal transformed flow and salinity and DO data. Separate analyses were preformed for the four WAR/SDI stations in the Palm River.

3.5-C(2). <u>Review of Technical Assumptions</u>

There are several basic flaws in the technical assumptions presented in the District's TBC White Paper. The most significant discrepancy is that the District assumes that it can set a Minimum Flow of zero without giving full consideration to the frequency or duration of zero flow periods. Frequency and duration are critical factors in determining the impact of a Minimum Flow on the biological resources in the Palm River/McKay Bay system. However, the proposed Minimum Flow provides no constraints on the duration or frequency of zero flow periods. Instead, the District simply makes the assumption that the zero flow condition across S-160 will not occur for prolonged periods of time. Given the past periods of increased reservoir withdrawals, the limited water resource alternatives (Sulphur Springs and Morris Bridge wellfield), and the documented increasing number of zero flow days, it is essential that the District address this issue directly rather than relying on these unfounded assumptions.

Another related assumption deals with the re-evaluation of the Minimum Flow if conditions change. In establishing the Minimum Flow for the TBC, the District's technical analysis focused on the effects of flow at S-160 on the water quality and biological communities in the Palm River and McKay Bay downstream of S-160 with the following baseline assumption. In their analysis, the District points out that the Palm River has undergone extensive structural alterations (TBC White Paper, Section 4.3). The river channel has been widened, deepened and straightened. The banks have been steepened and the natural shoreline replaced by a grassy berm. These modifications have significantly affected the hydrology, water quality and ecology of the Palm River. The large flow volume of the Palm River relative to the discharge at S-160 has resulted in "a truncated estuary" having salinities in excess of 20 ppt generally extending up to S-160. As discussed in the TBC White Paper (Section 7.1), it is this significantly altered system that serves as the baseline for the analysis. Although the report specifically mentions that a re-evaluation of the zero flow minimum would be required in the event of any substantial physical modifications to the TBC, the benefits of any alteration to the system (physical or otherwise) are only briefly addressed

A final assumption that should be re-evaluated relates to the sustainable yield for the middle pool. The report has shown that the TBC has impacted the Upper Floridan aquifer in terms of altering water levels and base flow in the system. The sustainable dry season yield from the TBC middle pool has been quantified to some extent. However, a detailed statistical discussion should be included showing that the period of record is of sufficient length to support an accurate determination of the maximum sustainable yield for the middle pool. Schreuder and Davis, Inc. (1993) pointed out the need for a number of additional monitoring points in the TBC system.

3.5-C(3). Review of Procedures and Analyses

In its technical analysis, the District evaluated the relationship between rates of freshwater discharge at S-160 and a number of physical, chemical and biological parameters measured in the Palm River/McKay Bay estuary system. The primary parameters evaluated in this analysis were salinity and DO (TBC White Paper, Section 5.2). According to the District, these two parameters were chosen because they are "critical water quality variables affecting the abundance and distribution of organisms in the Lower Hillsborough River and the tidal reaches of the Tampa Bypass Canal." (TBC White Paper, page 5.2). These two parameters were also deemed to be the most important water-quality parameters by the Minimum Flow Advisory Group of the Tampa Bay National Estuary Program. The Panel agrees that these parameters are likely to be the primary factors affecting habitat quality in the Palm River/McKay Bay system.

The relationships between flow and number of secondary parameters were also evaluated by regression analysis. These parameters included water quality measures (e.g., TSS, pH, temperature) and measures of biological populations/communities (e.g., phytoplankton, benthic invertebrates, ichthyoplankton and juvenile fish).

As a result of this technical analysis, the District concluded that a Minimum Flow of zero was appropriate for the TBC at S-160. The District provided several lines of evidence in support of this Minimum Flow. First, with regard to salinity, alterations of the Palm River have resulted in a system "which even during high flow events, does not encompass a complete salinity gradient" (TBC White Paper, page 7.2). Based on regression analysis, the District found that "salinity values would remain over 20 ppt over the length of the Palm River, even if the flows at S-160 are maintained at their post-construction median value (73 cfs)" (TBC White Paper, page 7.2). These analyses also indicated that changes in flows at the low end of the recorded range of discharges flows at S-160 (e.g., 0 to 20 ppt) would result in no more than a 2 ppt change in surface salinity. Based on these types of analyses, the District concluded that salinity in the Palm River is relatively insensitive to variations in discharge (in the 0 to 200 cfs range) from S-160.

The second factor considered in the District's analysis was DO. Low DO has routinely been observed in deeper waters of the Palm River. However, based on regression analyses, the District concluded "there are very few relationships between dissolved oxygen concentrations and freshwater inflow in the Palm River/McKay River System." The District further concluded "bottom waters throughout the length of the Palm River exhibited problems with hypoxia regardless of the freshwater inflow" (TBC White Paper, Section 7.2).

The District also considered the relationship between flow and the structure and function of biological communities utilizing the Palm River. The District concluded that the primary factor affecting benthic invertebrate abundance and diversity was low DO, which is insensitive to freshwater flow. They further concluded that phytoplankton species in the Palm River were indicative of high saline environments and "it is unlikely that a zero minimum flow will have any limiting effect on phytoplankton production and related zooplankton abundance in the Palm River and McKay Bay" (TBC White Paper, page 7.3).

Finally, the District concluded that for fish, the existing modest freshwater input from S-160 may serve as an attractive nuisance by drawing estuarine species to the upper end of the Palm River where the salinity gradient is truncated and the habitat is poor. The District refers to this phenomenon as a habitat bottleneck. Based on these observations, the District concluded that although habitat in the Palm River is altered and often not optimum, "the proposed zero cubic feet per second minimum flow will not allow significant harm to the ecology or water resources of the Palm River/McKay Bay system."

There are several critical flaws in this analysis. First, the data sets are substantially limited and do not provide an adequate basis for the conclusions presented in this analysis. Second, the statistics relied upon in the District's analysis do not provide a basis for accurately predicting the effects of zero flow conditions on the water quality or biota of the Palm River/McKay Bay system. Finally, the District has failed to consider the effects of the frequency and duration of zero flow periods on the water quality or biota of the Palm River/McKay Bay system. These issues are discussed in more detail in the following sections of this report.

Analysis of Relationships between Flow and Salinity

The three-year hydrobiological study (WAR/SDI, 1995) used regression models to evaluate correlations between discharge at S-160 and salinity. Daily discharge data were available for S-160 during this time period. However, as indicated previously, the monthly sampling for salinity limited the temporal resolution of the regression analysis.

The results of these regressions are presented in Appendix L of the WAR/SDI (1995) report. These results are presented graphically by station location in Appendix J, and scatter plots depicting the relationship between salinity measurements and 14-day average flows are presented in Appendix S. These regression analyses demonstrate significant negative correlations between flow at S-160 and salinity at each of the downstream stations over the three-year study period.

These analyses indicate that salinities throughout the Palm River/McKay Bay system respond to changes in flow at S-160. However, as the District points out, the effects of increased freshwater flow on salinity were relatively modest. As an example, during September 1992, salinities remained in the 18 to 22 ppt range in spite of high discharge rates (300 to 400 cfs) at S-160 and heavy rainfall. Even at flows as high as 1,000 cfs, surface salinities were above 15 ppt at all but station 12, immediately downstream of S-160. These results would seem to confirm that the truncated salinity gradient in the Palm River is relatively insensitive to variations in flow at S-160.

However, it is important to note that these analyses do not directly address the potential effects of a zero Minimum Flow on salinities in the estuary. Indeed, during the entire three-year period, there were only two sampling events where there was zero discharge from S-160. Moreover, the monthly sampling limits the temporal resolution of this analysis. These factors limit the usefulness of these data in evaluating the effects of zero flow.

From data provided by the Hillsborough County Environmental Protection Commission, the District developed scatter plots to evaluate relationships between salinity and the 8-day average discharge from S-160. Separate scatter plots showing the full range of flows and the 0- to 200-cfs range flows are presented in Appendix M-1 of the TBC White Paper. For the 0- to 200-cfs flows, surface salinities generally range from 15 to 25 ppt and show modest declines with increased flow. Data for bottom samples range from 20 to 30 ppt and appears less sensitive to flow than the surface salinities. By comparison, the mid-depth appear somewhat anomalous with a number of very low salinity measurements (< 2 ppt). The expanded scatter plots show substantial declines in salinity with levels often below 10 ppt at flows greater than 600 cfs. These plots indicate that the Hillsborough County Environmental Protection Commission data are generally consistent with those from the WAR/SID (1995) study and indicate that over the 0- to 200-cfs range, the salinities in the Palm River are relatively insensitive to flow.

Coastal Environmental (1997) used regression analysis on the two previous data sets as a basis for developing a model to be used for predicting salinity in the Palm River for a range of flows at S-160. As indicated previously, this study was specifically designed to support the setting of Minimum Flows for the TBC and Hillsborough River. The model estimates the salinity for each 0.1 mile of river based on the regression results for the station nearest each 0.1-mile segment. This model was then used to predict the effects of flows at S-160 (from 0 to 200 cfs) on salinity based habitat metrics in the Palm River. The habitat metrics are expressed as shoreline length or surface area in a given salinity range. The results of this analysis are presented in Table 7-2 of the Coastal Environmental, Inc. report (1997). The model predicts that changes in flow from a baseline of 0 cfs to a maximum of 100 cfs would have no impact on the habitat metrics. Increasing the flow to 200 cfs would result in a predicted increase of 37,531 feet in shoreline habitat and a 195-acre increase in surface area in the 11- to 18-ppt salinity range but no change in the habitat metrics in the lower salinity ranges.

The results of this modeling suggest that variations in flow in the 0- to 100-cfs range should have no discernable effects on the habitat metrics. Although this analysis is designed to address the zero minimum flow proposed by the District, there are several factors that limit its usefulness. The first deals with the representativeness of the data. This analysis, which is based on empirical relationships from regression equations that are derived from the same data sets discussed previously, suffer from the same limitations of these other analyses (e.g., limited temporal resolution). Moreover, given that these analyses are based on separate regressions for the four sampling locations, it is likely that the spatial resolution is significantly more limited than 0.1-mile intervals of the model would suggest. Finally the data set only includes a few points at the critical zero flow range.

As with the WAR/SDI (1997) study, the regression analyses employed are constrained by the quality of the data sets. Given the significant limits in the existing salinity data sets, particularly in the near 0 cfs range, the results of these empirical analyses must be considered to have limited utility in evaluating effects of zero flows on the Palm River/McKay system.

Analysis of Relationships between Flow and Dissolved Oxygen (DO)

In evaluating the relationships between flow at S-160 and DO levels, the District relied upon the same sources used to evaluate salinity: the WAR/SDI (1995) report, the Hillsborough County Environmental Protection Commission data, and the Coastal Environmental (1997) report. The WAR/SDI (1995) study collected vertical profiles of DO at four stations in the Palm River and five stations in McKay Bay on monthly basis over a three-year period (1992-1994) and within 48 hours of major rainfall or discharge events. Time-series plots showed significant seasonal variability in DO levels that varied inversely with temperature. DO levels generally increased progressively downstream of S-160 and decreased with depth. Station 12, immediately downstream of S-160, consistently had the lowest DO levels. The authors attributed these lowest levels at Station 12 to reduced tidal flushing and lower phytoplankton densities. Levels of DO at the bottom were often below the 4 mg/L Minimum Level proposed by the Tampa Bay National Estuary Program Minimum Flow Advisory Group.

In the WAR/SDI (1997) study regression models were again used to evaluate correlations between discharge at S-160 and DO. The results of these regressions are presented in Appendix L of the WAR/SDI (1997) report. These results are presented graphically by station location in Appendix J and scatter plots depicting the relationship between DO measurements and 14-day average flows are presented in Appendix S. These regression analyses confirmed a strong negative correlation between DO levels and temperature. However, no significant correlations were seen between the 14-day average flow at S-160 and DO at each of the downstream stations over the 3-year period of the study. These analyses suggest that DO levels throughout the Palm River/McKay Bay system are generally insensitive to changes in flow at S-160. However, these analyses do not directly address the potential effects of a zero minimum flow on DO levels in the estuary.

The District also evaluated the DO data from the Hillsborough County Environmental Protection Commission monitoring program. These data include over nine years of monthly

DO measurements at two stations in the Palm River and one in McKay Bay. Surface, mid-depth, and bottom samples were collected for much of this period. These data were generally consistent with those from the WAS/SDI (1997) study. The DO levels decreased with depth and increased downstream of S-160. Data from the mid- and bottom depths at Station 12, which is immediately downstream of S-160, were consistently below the proposed 4-mg/L standard. Scatter plots were used to evaluate relationships between DO and the 8-day average discharge from S-160. Separate scatter plots showing the full range of flows and flows in the 0- to 200-cfs range are presented in Appendix M-1 of the TBC White Paper. Although these data show significant scatter, the highest DO levels are consistently found in the 20- to 60-cfs flow range for the two stations in the Palm River and 40- to 100-cfs range at the single station in McKay Bay. This pattern is most apparent at the surface and mid depths. DO levels below 20 cfs are generally consistent with those above 100 cfs. These plots suggest that in the 0- to 200-cfs flow range, DO levels may be more sensitive to flow than indicated by the simple regression statistics employed in the WAR/SDI (1997) study.

The final source relied upon by the District was the report of a study sponsored by the Tampa Bay National Estuary Program (Coastal Environmental, Inc., 1997). Like the WAR/SDI (1997) study, the Coastal Environmental (1997) study employed a regression-based analysis to empirically evaluate relationships between flow same day and DO levels. Flow data were presented as same-day data, and data for one day previous and two days following the DO measurement. Both the minimum daily DO levels and the mean daily DO levels were evaluated. The analyses employed a stepwise linear regression and log normal transformed flow and DO data. Separate analyses were preformed for the four WAR/SDI (1997) stations in the Palm River. The results of these regressions were to be used as a basis for developing a model for predicting DO in the in the Palm River for a range of flows at S-160 similar to that described for salinity. The results of this study were consistent with those of the WAR/SDI (1997) study. A highly significant negative correlation was found between DO levels and temperature but not for flow. The authors conclude that "the sum of the other sources of variability DO (e.g., BOD, chemical oxygen demand, water column circulation, and measurement error of DO, flow and temperature) had a greater effect than flow on the days sampled."

The results of the two sets of regression analyses suggest that variations in flow in the 0- to 200-cfs range are small compared to those caused by temperature changes and other uncontrolled variables. However, the District's plots of the Hillsborough County Environmental Protection Commission data suggest some potential for flow-related changes in the surface and mid-depths of the Palm River with an optimum flow in the 20- to 100-cfs range. This pattern is less apparent in the bottom samples and, thus, may not be relevant to the low DO levels found in bottom waters in the Palm River. The District acknowledges this pattern in their discussion of the data but rely on regression statistics in their analyses.

As indicated previously, the regression analyses are based on empirical relationships and, thus, are limited by the available data. Although these analyses support the District's conclusion that DO in the Palm River is relatively insensitive to variations discharge from

S-160 in the 0- to 200-cfs range, the limits of the data set and the regression analyses do not provide a sufficient basis for evaluating the effects of zero flow in the Palm River/McKay Bay system.

3.5-D. Evaluation of Deficiencies

There are several basic deficiencies in the technical approach employed by the District. The most important of these is the District's implicit assumption that it can set a Minimum Flow of zero without giving specific consideration to the frequency or duration of zero flow periods. These critical factors have not been addressed in any substantive way in the District's analysis. Instead, the District indicated that a zero flow condition across S-160 will not occur for prolonged periods of time. However, the proposed Minimum Flow provides no constraints on the duration or frequency of zero flow periods. Instead, the District assumes that permitted withdrawal allocations are not expected to increase. Given the past periods of increased reservoir withdrawals, the limited water resource alternatives, and the documented increasing number of zero flow days, it is essential that the District address this issue directly.

A second deficiency deals with the adequacy of the data employed in the District's analysis. As indicated in previous sections, the lack of significant data in the critical zero flow range, and the limitations in temporal resolution of this analysis, significantly limit the usefulness of these data in evaluating the effects of zero flow. Thus, although the data considered by the District may be the best available as of July 1997, as employed by the District, these data do not currently provide an adequate basis for setting a Minimum Flow of zero.

Finally the District's evaluation of relationships between flow and the critical salinity and DO parameters is empirical and based entirely on regression statistics. These regression analyses allow correlations to be evaluated between key parameters in the existing data sets. Thus, these analyses are constrained by the quality of the data sets. Given the significant limits in the existing salinity and DO data sets, particularly in the near zero flow range, the results of these empirical analyses must be considered to have limited predictive capabilities. This deficiency will only become more prevalent as water demands increase in the Tampa Bay area and a re-evaluation of the safe-yield of the TBC becomes necessary.

3.5-E. Evaluation of Preferred Methodologies

The preferred methodology would be the development of a mechanistic model for the evaluation of relationships between salinity and DO over a range of low flows that are critical to setting a minimum flow at S-160. An early version of such a model was developed and presented by Ross (1980). Results of several more recent modeling exercises would also likely contribute to the development of such a model (e.g., Schreuder and Davis, Inc., 1993; WAR/SDI, 1995). It is unclear why the District did not take full advantage of these existing tools in developing its analysis strategy, given the lack of data for the system. This type of model would provide a much more effective predictive tool than the empirical approach adopted by the District. The development of such a model will likely require additional data to improve spatial and temporal resolution in the critical zero flow range.

3.5-F. Discussion and Conclusions

The Palm River/MacKay Bay, in their current configuration, represent the "baseline" from which "significant harm" is to be determined. Based on its analysis, the District has concluded that the existing alterations of the Palm River have resulted in a truncated estuary that is relatively insensitive to freshwater flow at S-160. Moreover, the District has concluded that even though this system has substantial habitat limitations, a minimum flow of 0 cfs would not significantly alter the existing habitat quality or biological communities using that habitat. According to the District, a minimum flow of 0 cfs would not result in a significant change from the existing baseline conditions in the Palm River/McKay Bay system.

On the surface, the analyses conducted by the District appear to support this position. However, the available data and the empirical approach taken do not provide an adequate basis for setting a Minimum Flow of zero at this time. Moreover, the District has failed to address the effects of the frequency and duration of the Minimum Flow on the Palm River/McKay Bay system. The Panel finds that the zero Minimum Flow for the TBC is not supported by the data because the analyses fail to address the frequency and duration of zero discharge.

The Panel recommends that the District undertake the development of a mechanistic model that can be used to evaluate and predict the effects of various Minimum Flow strategies on the Palm River/McKay Bay system. Additional data may be required for this modeling effort to improve spatial and temporal resolution in the critical zero flow range. The Panel recommends that these additional modeling and data collections be undertaken before any significant increased withdrawals are allowed from the TBC.

4.0 PANEL OBSERVATIONS

In conducting its review and analyzing the data, the Panel made two observations that appear to transcend the specific issues discussed in detail in this report. These observations concern (1) *the scientific conceptual basis for establishing Minimum Levels*, and (2) *Minimum Levels: values too low*. Each of these observations is discussed in turn below.

The Scientific Conceptual Basis for Establishing Minimum Levels

In the final stages of the peer review process, the Panel deliberated matters ranging from fine detail of methodologies used to select particular numerical values, to broad philosophical issues inherent in the establishment of Minimum Levels. In this discussion, the focus is on the latter.

From a broad perspective, the Panel identified two different scientific philosophies that can underlie the establishment of Minimum Levels and their accompanying corresponding methodologies. One approach is that proposed by the District in which Minimum Levels for wetlands and Category 1 lakes rely on a single maximum permissible water-level decline (e.g., Normal Pool minus 1.8 feet). In the case of the Northern Tampa Bay area, the particular value for the permissible water-level decline of 1.8 feet was determined by the District. The District employed what the Panel refers to as a "one size fits all" approach that constrains all wetlands and lakes, regardless of their hydrologic variability, using a single-value water-level decline.

The second approach is one that explicitly recognizes important individual differences and natural hydrologic variability inherent in substantially natural systems. In that case, the basis for establishing Minimum Levels accepts the fact that individual lakes and wetlands exhibit site-specific ranges of water-level fluctuations and that local biota have adapted to those particular ranges. As such, the Minimum Level that can be tolerated by one wetland or lake may not be appropriate for another that has a different water-level regime. Given this perspective, and to protect against significant change, Minimum Levels should be established based on the historical range of variability to which an individual natural system has adapted.

Through its deliberations, the Panel concluded that the "one size fits all" approach that the District has employed is a reasonable starting point for the establishment of Minimum Levels for wetlands and Category 1 lakes. However, given the information it reviewed for wetlands, the Panel believes that value selected for the allowable decline from normal pool is a maximum. The value of 1.8 feet yields Minimum Levels that are appropriate for some lakes and wetlands but too low for many others characterized by low hydrologic variability.

The Panel also concluded that the value of 1.8 feet should be reduced for many Category 1 Lakes and Wetlands exhibiting smaller ranges of hydrologic variability (e.g., historic P10-P50). For example, consider a healthy wetland that is adapted to a hydrologic environment showing a departure of the median water level from normal pool, or NP-P50, of 0.4 foot. Using the District's approach, the Minimum Level would be set 1.8 feet below the normal pool. This means that half the time the water level could be 1.4 feet below the median historic water level at that site. In that case, a healthy wetland that had adapted to a shallow flooding environment could be forced to survive under conditions in which flooding was rare or absent.

The Panel developed the concept of proportionally-based Minimum Levels only for individual wetlands and lakes and does not recommend a specific algorithm for accommodating site-specific hydrologic variability. The strategy is discussed here and in Section 3.1 of this report. The principle underlying the suggested approach is that Minimum Levels should reflect the natural hydrologic variability of the local environment and not merely average the natural variations of a range of wetlands and lakes.

A specific example of the approach would be as follows: suppose the established upper bound on the allowable water-level decline from the normal pool is 1.8 feet. For an individual wetland or Category 1 lake, the normal pool would be estimated in the manner already employed by the District. The historic median water level would be estimated based on hydrologic data, or if that did not exist it would be based on biologic, morphologic, lithologic, or hydrogeologic indicators. For the fringing wetlands surrounding lakes, the identification of a suitable indicator for the median water level absent hydrologic data would have to be developed from direct observations within each wetland or wetland type.

Once the historic median water level is determined, the estimated departure of normal pool from the historic median water level would be a measure of individual natural variability for that site (for example, 0.7 foot). Given an acceptable maximum decline from normal pool of 1.8 feet, and the mean P10-P50 value from data for all Reference Lakes and Wetlands of about 1.0 foot, then the allowable decline can be computed on a proportional basis to the maximum -- that is, 0.7 foot times (1.8/1.0) or 1.26 feet. This is the value that would then serve as the basis for establishing the individual Minimum Level, NP minus 1.26 feet. In essence this approach is founded on Minimum Levels that are proportional to the maximum allowable water level decline based on the population of Reference Lakes and Wetlands, given their characteristic average flood levels in the Northern Tampa Bay area.

The maximum allowable decline divided by the mean P10-P50 departure for Reference Lakes and Wetlands yields a proportionality constant that the Panel has termed the "Maximum Decline Constant (MDC)." For the Northern Tampa Bay area, that number appears to be approximately 1.8 (i.e., 1.8 / 1.0) but could be determined to be a different value for any region. The "Individual Allowable Decline (IAD)" for a particular site simply equals the individual normal pool minus historic P50 value times the MDC, or in the example, 0.7 times 1.8 = 1.26. This approach is slightly more complicated than the "one size fits all" approach, but it accounts for the natural fluctuations of individual wetlands and lakes. The approach has the drawback that it requires an estimate of the historic median water level for an individual lake or wetland. This is less of a problem for wetlands than for lakes due to the latter having weak or unresolved indicators of historic P50. However, even a rough estimate would seem to be better justified than applying a blanket 1.8-foot allowable decline to all wetlands and Category 1 lakes throughout the region.

The Panel suggests that a proportionality approach, with attributes of the one outlined above, be developed by the District to establish Minimum Levels. Meanwhile, for both wetlands and lakes, the maximum allowable water-level decline of 1.8 feet could serve as an upper bound, and the proportionality approach would only reduce that value for certain wetlands and lakes -- those characterized by NP minus Historic P50 values of less than 1.0 foot. The Panel does not suggest the approach for the Category 2 lakes. For some wetlands and Category 1 lakes, an Individual Allowable Decline of less than 1.8 feet would be more protective of those resources. The Panel emphasizes that the proportionality approach is aimed at protecting those lakes and wetlands that are particularly vulnerable. These vulnerable resources have historically low hydrologic variability as measured by the departure of the historic median water level from the normal pool, or they are sensitive to altered hydrodynamics in other ways.

Minimum Levels: Values Too Low

The Minimum Levels determined by the District may be acceptable temporary starting values at this time; however, based on the Panel's re-analysis of available data, they are too low and should be adjusted upward as they are revisited in the future. The Minimum Flow established for the Tampa Bypass Canal cannot be justified based on the District's analysis, and the zero discharge value should be revisited. The basis for this judgment follows:

a) For Reference Lakes, the median value of normal pool departure from median water level was approximately 1.0 foot. Analyses by the Panel indicate that this value is too large by perhaps 0.2 foot. The Panel did not consider the exact determination of the value to be within its purview. The Panel believes that this over-estimation occurred because the District used a historical record that includes a drought period and mixed data from lakes having distinct hydrogeologic regimes.

b) The District's proposed maximum allowable decline in water level before significant harm is done to cypress Wetlands also appears to be too large by a few tenths of a foot. The Panel believes that the 1.8-foot value calculated by the District was based on a historic record that was overweighted by a drought period, and on an analysis that included too many outlying values of large hydrologic variability representing a couple of reference wetlands.

c) In the case of seawater intrusion Minimum Levels, the values are too low because the period-of-record used to determine their values was not representative of the sought-after range of recent historical potentiometric levels. The short records were overweighted by low values that included a substantial period of drought.

d) In the case of the Tampa Bypass Canal, the zero value established as the Minimum Flow is too low because the available data and the empirical approach taken do not provide an adequate basis for setting a Minimum Flow at this time. The analyses fail to address the frequency and duration of zero discharge.

5.0 REFERENCES CITED IN THIS REPORT

Ambient Ground-Water Quality Monitoring Program (AGWQMP), 1990a, *Ground-water Quality Sampling Results from Wells in the Southwest Florida Water Management District: Northern Region (Section 1).* Southwest Florida Water Management District, March 1990.

Ambient Ground-Water Quality Monitoring Program (AGWQMP), 1990b, *Ground-water Quality Sampling Results from Wells in the Southwest Florida Water Management District: Central Region (Section 1).* Southwest Florida Water Management District, March 1990.

Ambient Ground-Water Quality Monitoring Program (AGWQMP), 1990c, *Ground-water Quality Sampling Results from Wells in the Southwest Florida Water Management District: Southern Region (Section 1).* Southwest Florida Water Management District, March 1990.

Ambient Ground-Water Quality Monitoring Program (AGWQMP), 1991, *Ground-water Quality Sampling Results from Wells in the Southwest Florida Water Management District: Central Region (Section 2).* Southwest Florida Water Management District, April 1991.

Ambient Ground-Water Quality Monitoring Program (AGWQMP), 1992, *Coastal Ground-water Quality Monitoring Program Report: Volume II.* Southwest Florida Water Management District, December 1992.

Biological Research Associates, 1999, *Detecting and Quantifying Ecological Impacts Resulting from Lake Level Reduction.* Unpublished submission to the Minimum Flows and Level Panel, Tampa Bay, Florida.

Brown, C.A., 1984, Morphology and Biology of Cypress Trees. in Cypress Swamps, K.C. Ewel and H.T. Odum (eds.), University Presses of Florida, Gainesville, Florida, Chapter 2, pp. 16-24.

Camp, Dresser, & McKee (CDM), 1985, *Section 21 Wellfield Lakes Impact Study – Northwest Hillsborough County, Florida.* Prepared for West Coast Regional Water Supply Authority, Clearwater, Florida, 96 p.

Carrera, J. and S.P. Neuman, 1986, *Estimation of Aquifer Parameters Under Transient and Steady State Conditions:* 1 -- Maximum Likelihood Method Incorporating Prior Information. Water Resources Research, v. 22, no. 2, pp. 199-210.

CH2M Hill, Inc., 1985, *Test Production Well Investigations to Determine Recharge Potential of the Tampa Bypass Canal*. Prepared for the West Coast Regional Water Supply Authority, Clearwater, Florida.

Coastal Environmental, 1997, *An Analysis of the Effects of Freshwater Inflows on Salinity Distributions, Dissolved Oxygen Concentrations, and Habitat Characteristics of the Hillsborough River and Palm River/Tampa Bypass Canal*. Report prepared for the Tampa Bay National Estuary Program, St. Petersburg, Florida.

Cooke, G.D., E.B. Welch, S.A, Peterson, and P.R. Newroth, 1993, *Restoration and Management of Lakes and Reservoirs*. Lewis Publishers, Boca Raton, Florida.

Cooley, R.L., and R. L. Naff, 1990, *Regression Modeling of Groundwater Flow*. US Geological Survey, Technical Water Resource Investigation 03-B4, 232 p.

Crownover, S.H. N.B. Comerford, D.G. Neary, and J. Montgomery, 1995, *Horizontal Groundwater Flow Patterns Through a Cypress Swamp-Pine Flatwoods Landscape*. Soil Scientist Society of America Journal, no. 59, pp.1199-1206.

Denton, S.R. and D.J. Durbin, 1999, Information Supplement provided to the Minimum Flows and Levels Peer Review Panel on behalf of Pinellas County. Public meeting testimony, June 25, 1999, Tampa Florida.

Dicke, S.G. and J.R. Toliver, 1988, *Effects of Crown Thinning on Baldcypress Height, Diameter, and Volume Growth*. Southern Journal of Applied Forestry, no. 12, pp. 31-34.

Florida Department of Community Affairs, 1995, *Strategic Management Initiative for McKay Bay: A Comprehensive Management Plan*. Tampa, Florida.

Gailey, R.L., A.S. Crowe, and S.M. Gorelick, 1991, *Coupled Process Parameter Estimation and Prediction Uncertainty Using Hydraulic Head and Concentration Data*. Advances in Water Resources, v. 14, no. 5, pp. 301-314.

Gilbert, K.M., J.D. Tobe, R.W. Cantrell, M.E. Sweeley, and J.R. Cooper, 1995, *The Florida Wetlands Delineation Manual*. The Florida Department of Environmental Protection and several water management districts, Tallahassee, Florida.

Gorelick, S.M, 1983, *A Review of distributed-Parameter groundwater management modeling methods*. Water Resources Research, v. 19, no. 2, pp. 305-319.

Gorelick, S.M., 1990, *Large-Scale Nonlinear Deterministic and Stochastic Optimization: Formulations Involving Simulation of Subsurface Contamination*. Mathematical Programming, 48, pp. 19-39.

Gorelick, S.M., 1997, *Incorporating Uncertainty into Aquifer Management Models, in Subsurface Flow and Transport.* Edited by G. Dagan and S.P. Neuman, Cambridge University Press, pp. 101-112.

Harvey, C.F. and S.M. Gorelick, 1995, *Mapping Hydraulic Conductivity: Sequential Conditioning with Measurements of Solute Arrive Time, Hydraulic Head, and Local Conductivity.* Water Resources Research, v. 31, no. 7, pp. 1615-1626.

HDR Engineering, Inc., 1994, *Environmental Assessment of the Palm River, Tampa/Hillsborough County, Florida.* Report prepared for the Palm River Management Committee.

Heath, R.C., and P.C. Smith, 1954, *Ground-Water Resources of Pinella County, Florida.* Florida Geological Survey Report of Investigations No. 12, 139 p.

Hill, M.C., 1998, *Method and Guidelines for Effective Model Calibration.* US Geological Survey, Water- Resources Investigation Report 98-4005, 90 p.

Hillsborough County Environmental Protection Commission, 1995, *Surface Water Quality, 1992-1994.* Tampa, Florida.

James, B.R. and S.M. Gorelick, 1994, *When Enough is Enough: The Worth of Monitoring Data in Aquifer Remediation Design.* Water Resources Research, v. 30, no. 12, pp. 3499-3513.

Keeland, B.D. and W.H. Conner, 1999, *Natural Regeneration and Growth of Taxodium distichum (L.) Rich. in Lake Chicot, Louisiana after 44 years of Flooding.* Wetlands, v. 19, pp. 149-155.

Knutilla, and Corral, 1984, *Impacts of the Tampa Bypass Canal System on the Areal Hydrology, Hillsborough County, Florida.* U.S. Geological Survey Water Resources Investigations Report 84-4222, 65 p.

Lopez, M.A.,and J.D. Fretwell, 1992, *Relation of Change in Water Levels in Surficial and Upper Floridan Aquifers and Lake Stage to Climatic Conditions and Well-field Pumpage in Northwest Hillsborough, Northeast Pinellas, and South Pasco Counties, Florida.* U.S. Geological Survey Water-Resources Investigations Report 91-4148, 94 p.

Mitsch, W.J. and J.G. Gosselink, 1993, *Wetlands.* Van Nostrand Reinhold, New York.

Northern Tampa Bay Water Resource Assessment Project (NTBWRAP), 1996, *Volume 1--Surface-Water/Ground-Water Interrelationships.* Southwest Florida Water Management District, Brooksville, Florida.

Parresol, B.R., and J.E. Hotvedt, 1990, *Diameter Measurements in Baldcypress.* Forest Ecology and Management, v. 33/34, pp. 509-515.

Ross, B.E., 1980, *A Model Study of the Palm River.* University of South Florida Center for Mathematical Models, Report submitted to the Southwest Florida Water Management District.

Schreuder and Davis, Inc. (SDI), 1993, *Evaluation of the Hydrologic Monitoring Program for Hillsborough River Reservoir and Tampa Bypass Canal.* Prepared for West Coast Regional Water Supply Authority, SDI Project No. WCF-601, 43 p.

Schultz, R.W, 1995, *Trend Analysis of Starvation Lake Level, Hillsborough County, Florida.* Southwest Florida Water Management District, Brooksville, Florida.

SDI Environmental Services, Inc., 1997, *Evaluation of Aquifer Test Data near the Tampa Bypass Canal.* Prepared for Parsons Enginering Science, Inc. and West Coast Regional Water Supply Authority, SDI Project WCF-760, 42 p.

Sinclair, W.C., 1977, *Experimental Study of Artificial Recharge Alternatives in Northwest Hillsborough County, Florida.* U.S. Geological Survey Water-Resources Investigations Report 77-13. 52 p.

Snedaker, G.W. and W.G. Cochran, 1967, *Statistical Methods.* Iowa State University Press, Ames, Iowa.

Solow, A.R. and S.M. Gorelick, 1986, *Estimating Monthly Streamflow Values Using Cokriging.* Mathematical Geology, v. 18, no. 8, pp. 785-809.

Spangler, D.P., 1984, *Geologic Variability among Six Cypress Domes in North-Central Florida.* in Cypress Swamps, K.C. Ewel and H.T. Odum (eds), University Presses of Florida, Gainesville, Florida, pp. 60-66.

Stewart, M.T., 1998, *The Florida Water Wars: A Geologic Perspective.* Geotimes, v. 43, no. 3, pp. 24-27.

Tiedeman, C. and S.M. Gorelick, 1993, *Analysis of Uncertainty in Optimal Groundwater Contaminant Capture Design.* Water Resources Research, v. 29, no. 7, pp. 2129-2153.

Trommer, J.T., 1993, *Description and Monitoring of the Saltwater-Freshwater Transition Zone in Aquifers Along the West-Central Coast of Florida.* US Geological Survey, Water-Resources Investigation Report 93-4120, 56 p.

U.S. Army Corps of Engineers, 1987, *U.S. Army Corps of Engineers Wetlands Delineation Manual.* Environmental Laboratory, U.S. Army Engineer Waterways Experiment Station Technical Report Y-87-1, Vickburg, Mississippi.

Varnell, L.M., 1998, *The Relationship Between Inundation History and Baldcypress Stem Form in a Virginia Floodplain Swamp.* Wetlands, v. 18, pp. 176-183.

Wagner, B.J., 1992, *Simultaneous Parameter Estimation and Contaminant Source Characterization for Coupled Groundwater Flow and Contaminant Transport Modeling.* Journal of Hydrology, v. 135, pp. 275-303.

Wagner, B.J., 1995, *Recent advances in Simulation-Optimization Groundwater Management Modeling.* Review in Geophysics, 33 (supplement Part 2), pp. 1021-1028.

Water and Air Research, Inc. and SDI Environmental Services, Inc., 1995, *Second Interpretive Report: Tampa Bypass Canal and Hillsborough River Hydro-Biological Monitoring Program.* Prepared for West Coast Regional Water Supply and the City of Tampa, Florida.

Watson, J.D., M. Stedje, M. Barcelo, and M. Stuart, 1990, *Hydrogeologic Investigations of Cypress Dome Wetlands in Wellfield Areas North of Tampa, Florida.* Proceedings of Focus Eastern Conference, October 17-19, 1990; National Water Well Association, Dublin, Ohio.

Yeh, W.W., 1986, *Review of Parameter Identification Procedures in Groundwater Hydrology: The Inverse Problem.* Water Resources Research, v. 22, no. 2, pp. 95-108.

APPENDIX A

NORTHERN TAMPA BAY MINIMUM FLOWS & LEVELS
WHITE PAPERS:

LIST OF FIVE SCIENTIFIC PAPERS

Northern Tampa Bay
Minimum Flows & Levels
White Papers

Peer Review Final Draft
March 19, 1999

Part 1: ***Establishment of Minimum Levels in Palustrine Cypress Wetlands.***

Southwest Florida Water Management District, Final Draft - March 18, 1999.

Part 2: ***Establishment of Minimum Levels for Category 1 and Category 2 Lakes.***

Prepared by the Resource Conservation and Development Department, Southwest Florida Water Management District, March 1999.

Part 3: ***Seawater Instrusion Minimum Levels for Northern Tampa Bay.***

Prepared by the Hydrologic Evaluation Section, Resource Conservation and Development Department, Southwest Florida Water Management District, Draft - March 1999.

Part 4: ***Environmental Minimum Aquifer Levels (as used in Rule 40D-8, F.A.C.)***

Final Draft - March 19, 1999.

Part 5: ***An Analysis of Hydrologic and Ecological Factors Related to the Establishment of Minimum Flows for the Tampa Bypass Canal at Structure 160.***

Southwest Florida Water Management District, Final Draft - March 17, 1999.

APPENDIX B

LIST OF REFERENCES FROM THE FIVE SCIENTIFIC PAPERS

(Charge Exhibit B)

EXHIBIT B

SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT REFERENCES FROM THE FIVE SCIENTIFIC PAPERS

1. Barcelo, M.D., 1985. Tampa Bypass Canal, effects of construction of ground water resources in the vicinity of S-159 and canal section 4B; SWFWMD, pp.25.

2. Berryman & Henigar. 1997. Establishment of normal pool elevations in forested wetlands for the purpose of establishing minimum wetland levels. Report submitted to the West Coast Regional Water Supply Authority, October, 1997.

3. Berryman & Henigar. 1997. J.B. Starkey Wellfield Ecological/Hydrological Monitoring Program, Water Year 1996, Annual Monitoring Report, in association with ViroGroup, Inc., March 28, 1997.

4. Biological Research Associates. 1996. Use of indicators of historic inundation patterns in isolated wetlands as reference elevations to determine areal extent and intensity of reduced water levels near areas of groundwater withdrawals. Report submitted to the West Coast Regional Water Supply Authority, November, 1996.

5. Bulger, A.J., B.P. Hayden, M.E. Monaco, D.M. Nelson, M.G. McCormack-Ray. 1993. Biologically-based estuarine salinity zones derived from a multivariate analysis. Estuaries. 16:2 p. 311-322.

6. CH2M Hill, Inc. 1985. Test production well investigations to determine recharge potential of the Tampa Bypass Canal; Prepared for the West Coast Regional Water Supply Authority, Clearwater, Florida.

7. Coastal Environmental. 1997. An analysis of the effects of freshwater inflows on salinity distributions, dissolved oxygen concentrations, and habitat characteristics of the Hillsborough River and Palm River/Tampa Bypass Canal. Report prepared for the Tampa Bay National Estuary Program. St. Petersburg, FL.

8. OMITTED

9. Environmental Science and Engineering. 1987. Water Supply Analysis and Simulation for Tampa Reservoir (Final Report); Prepared for City of Tampa Water Department, Tampa, Florida.

10. Florida Dept. of Community Affairs. 1995. Strategic Management Initiative for McKay Bay. A Comprehensive Management Plan. Tampa, FL.

11. Fretwell, J. D. 1988. Water Resources and Effects of Ground-Water Development in Pasco County, Florida, U.S. Geological Survey Water-Resources Investigations Report 87-4188, Tallahassee.

12. Geraghty and Miller, Inc. 1976. Management of the Water Resources of the Pinellas-Anclote and Northwest Hillsborough Basins, West-Central Florida (Volume I- Report & Volume II Basic Data), March.

13. Geraghty and Miller, Inc. 1982. Evaluation of Water-Supply Potential of the Tampa Bypass Canal. Prepared for West Coast Regional Water Supply Authority, Clearwater, Florida, 53 pp w/appendices.

14. Geraghty and Miller, Inc. 1986. Analysis of the 20 Year Safe Yield from the Tampa Bypass Canal. Prepared for West Coast Regional Water Supply Authority, Clearwater, Florida, 31 pp w/appendices.

15. Goetz, C.L., Reichengaugh, R.C., and Ogle, J.K. 1978. Water Supply Potential of the Lower Hillsborough River, Florida. U.S. Geological Survey Water Resources Investigations Report 78-29, Tallahassee, Florida.

16. HDR Engineering, Inc. 1994. Environmental assessment of the Palm River, Tampa/Hillsborough County, Florida. Report for the Palm River Management Committee.

17. Hillsborough County Environmental Protection Commission. 1995. Surface Water Quality 1992-1994, Tampa, FL

18. HSW Engineering. 1992. Tampa Bypass Canal and Hillsborough River Biologic Monitoring and Assessment; Task I. Prepared for the West Coast Regional Water Supply Authority.

19. HSW Environmental Consultants, Inc. 1996. Investigation of Increasing Chloride and Sulfate Concentrations for Wells RMP-9D, RMP-13PZ, RMP-14D, and RMP-16D, Northwest Hillsborough Regional Wellfield, prepared for the West Coast Regional Water Supply Authority, May.

20. HSW Environmental Consultants, Inc. 1997. Monitoring Well Site Selection, Northwest Hillsborough County Saltwater Monitoring Program Expansion, Letter report to Jim Liu of the West Coast Regional Water Supply Authority, July 30, 1997.

21. Hickey, J.J. 1990. An assessment of the flow of variable-salinity ground water in the middle confining unit of the Floridan aquifer system, west-central Florida: U.S. Geological Survey Water-Resources Investigations Report 89-4142. 13p.

22. Hull, H.C. Jr., J.M. Post Jr., M. Lopez, and R.G. Perry. 1989. Analysis of water level indicators in wetlands: Implications for the design of surface water management systems. In: Wetlands: Concerns and Successes. Proceedings of the American Water Resources Association, Tampa, D. Fisk (Ed.), pages 195-204.

23. Hutchinson, C.B., 1985. Hydrogeology of the Cross Bar Ranch Well-Field area and projected impact of pumping, Pasco County, Florida, U.S. Geological Survey Water-Resources Investigations Report 85-4001.

24. HydroGeoLogic, Inc. 1994. Modeling Assessment of the Regional Freshwater-Saltwater Interface in the Northern Tampa Bay Ground-Water Basin, prepared for the Southwest Florida Water Management District, July.

25. Jassby, A.D., W.J. Kimmerer, S.T. Monismith, C. Armor, J.E. Cloern, T.M. Powell, J.R. Schubel, T.J., Vendlinski. 1995. Isohaline position as a habitat indicator for estuarine populations. Ecological Applications, 5(1) 272-289.

26. King Engineering Associates. 1992. Review and Synthesis of Historical Water Tampa Bay Water Quality Data. Report prepared for the Tampa Bay National Estuary Program. St. Petersburg, FL.

27. Knutilla, and Corral. 1984. Impacts of the Tampa Bypass Canal System on the Areal Hydrology, Hillsborough County, Florida. U.S. Geological Survey Water Resources Investigations Report 84-4222, 65 pp.

28. Lui, Jim Jinyou and Polmann, Donald J. 1996 (draft). Nonsteady-state Drawdown simulation in the Vicinity of section 21 Wellfield using both Analytical (NSCOU) and Numerical (MODFLOW) Solutions for Two Coupled Aquifers. West Coast Regional Water Supply Authority, Clearwater, June 13.

29. Motz, L.H. 1975. Hydrologic Effects of the Tampa Bypass Canal System. Florida Bureau of Geology Report of Investigations 82. Tallahassee, Florida.

30. Nguyen, H.T. 1986. Lower Hillsborough Flood Detention Area and the Tampa Bypass Canal flood routing model; SWFWMD Resource Management Department, pp.94.

31. Nguyen, H.T. 1987. Investigation and analysis of the Tampa Bypass Canal secondary drainage system; SWFWMD Resource Management Department, pp 44 plus appendices.

32. Odum, W.E., E.P. Odum and H.T. Odum. 1995. Nature's pulsing paradigm. Estuaries 18:4 p 547-555.

33. Peebles, E.B. and M.S. Flannery. 1992. Fish nursery use of the Little Manatee River estuary (Florida); relationships with freshwater discharge. Report of the University of South Florida Dept. of Marine Science to the Southwest Florida Water Management District.

34. Richter, B., J.V. Baumgartner, R. Wigington, and D.P. Braun. 1997. How much water does a river need. Freshwater Biology 37, 231-249.

35. Rochow, T. R. 1994. The Effects of Water Table Changes on Fresh-water Marsh and Cypress Wetlands in the Northern Tampa Bay Region - a Review. Technical Report 1994-1, Southwest Florida Water Management District. February 1994.

36. Ross, B.E. 1980b. A model study of the Palm River. University of South Florida Center for Mathematical Models. Report for the Southwest Florida Water Management District.

37. Schrueder & Davis, Inc. (SDI). 1993. Evaluation of the hydrologic monitoring program for Hillsborough River Reservoir and Tampa Bypass Canal; prepared for WCRWSA, SDI Project No. WCF-601; 43 pp.

38. Schreuder & Davis, Inc. (SDI), 1997: Evaluation of Aquifer Test Data Near the Tampa Bypass Canal; prepared for west Coast Regional Water Supply Authority, SDI Project No. WCF-760.

39. Dklar, F.H. and J.A. Browder. 1998. Coastal environmental impacts brought about by alterations to freshwater flow in the Gulf of Mexico. Environmental Management 22:4, 547-562.

40. Southwest Florida Water Management District. 1988. Basis of Review for Surface Water Permit Applications in the Southwest Florida Water Management District.

41. Southwest Florida Water Management District. 1993. Computer Model of Ground-Water Flow in the Northern Tampa Bay Area: Southwest Florida Water Management District, Draft - August 1993.

42. Southwest Florida Water Management District. 1996. Northern Tampa Water Resources Assessment Project, Volumes I & II, March.

43. Southwest Florida Water Management District. 1997. Letter from John Heuer to City of Tampa and West Coast Regional Water Supply Authority, dated 10/22/97.

44. OMITTED

45. Stoker, Y.E., V.A. Levesque and W.M. Woodam. 1996a. The effect of discharge and water quality of the Alafia River, Hillsborough River, and the Tampa Bypass

Canal on nutrient loading to Hillsborough Bay, Florida, U.S. Geological Survey Water-Resources Investigation Report 95-4107, 69 pp.

46. Stoker, Y.E., V.A. Levesque and W.M. Woodam. 1996b. Discharge, water quality characteristics, and nutrient loads from McKay Bay, Delaney Creek, and East Bay, Tampa, Florida, 1991-1993. U.S. Geological Survey Water-Resources Investigation Report 95-4167.

47. OMITTED

48. U.S. Army Corps of Engineers. 1961. Comprehensive report on Four Rivers Basins, Florida; Jacksonville, Florida.

49. United States Geological Survey. 1996. Trends in Chloride, Sulfate, and Dissolved Solids Concentrations in Water From Selected Public Supply and Monitor Wells in the Tampa Bay Area, Florida, Open-File Report 96-480, Tampa, FL.

50. Water and Air Research, Inc. and SDI Environmental Services, Inc. 1995. Second interpretive report Tampa Bypass Canal and Hillsborough River hydro-biological monitoring program, Volumes I and III (with appendices); prepared for West Coast Regional Water Supply and the City of Tampa, Florida.

APPENDIX C

List of Supplemental Technical Documents Identified by Requesters

(Charge Exhibit C)

EXHIBIT C

SUPPLEMENTAL TECHNICAL DOCUMENTS

1. Black, Crow, and Eidsness, Inc. 1974. Hydrologic and Ecologic Effects of Groundwater Production at Eldridge-Wilde Wellfield, Pinellas County, Florida. Engineering Report for the Pinellas County Water System. September 1974.

2. Bredehoeft, J.D., I.S. Papadopulos, and J.W. Stewart. 1965. Hydrologic effects of ground-water pumping in northwest Hillsborough County, Florida, U.S. Geological Survey Open-File Report.

3. Cherry, R.N., J.W. Stewart and J.A. Mann. 1970. General hydrology of the Middle Gulf Area. Florida Department of Natural Resources, Bureau of Geology, Report of Investigation No. 56, Tallahassee, FL.

4. Guyton, William F. and Associates. 1974. Estimated Effects of Ground-Water Pumping in Pasco County, Florida, January.

5. Hull, H.C. 1998. Video tour of wetlands in Northern Tampa Bay (Minimum Flows and Levels).

6. Sinclair, W.C. 1974. Hydrogeologic Characteristics of the Surficial Aquifer in Northwest Hillsborough County, Florida, Florida Bureau of Geology, Information Circular #86.

7. Southwest Florida Water Management District. 1994. Aquifer Characteristics within the Southwest Florida Water Management District, prepared by the Technical Services Department, Resource Regulation, June, 1994.

8. Stewart, J.W. 1968. Hydrologic Effects of Pumping from the Floridan Aquifer in Northwest Hillsborough, Northwest Pinellas, and Southwest Pasco Counties, Florida, U.S., Geological Survey Open-File Report 68-005.

9. Subsurface Detection Investigations Incorporated (SDII). 1995. Ground Penetrating Radar Survey, Selected Lakes in Hillsborough and Pasco Counties, FL. Prepared for the Southwest Florida Water Management District, October 1995.

10. Watson, J., D. Stedje, M. Barcelo and M. Stewart. 1990. Hydrogeologic investigation of cypress dome wetlands in well field areas north of Tampa, Florida. Proceedings of Focus Eastern Conference, October 17-19, 1990. National Water Well Association, Dublin, Ohio

11. Southwest Florida Water Management District's Review of Green Swamp Report by Sydney T. Bacchus, April 28, 1998.

12. Comprehensive Annual Environmental Assessment Report for the Cross Bar Ranch Wellfield - Water Year 1997, Final Report, prepared by CCI Environmental Services, Inc. and Terra Environmental Services, Inc., for West Coast Regional Water Supply Authority, May 26, 1998.

13. Cypress Bridge Wellfield Hydrobiological Monitoring Program, Water Year 1997, Tenth Annual Report, prepared by The Institute for Environmental Studies, (University of South Florida, Tampa) and Terra Environmental Services, Inc., for West Coast Regional Water Supply Authority, June 1998.

14. 1998 Annual Wellfield Operation and Hydrologic Assessment Report, Eldridge-Wilde Wellfield, prepared by Leggette, Brashears & Graham, Inc., for Tampa Bay Water, March 1999.

15. Final Annual Comprehensive Report: Ecological and Hydrological Monitoring of the Cypress Creek Wellfield and Vicinity - Pasco County, Florida, Water Year 1997, prepared by Reynolds, Smith & Hills, Inc. and SDI Environmental Services, Inc., for West Coast Regional Water Supply Authority, May 7, 1998.

16. J.B. Starkey Wellfield Ecological/Hydrological Monitoring Program, Annual Monitoring Report, Water Year 1997, prepared by Berryman & Henigar, Division of Environmental Sciences in association with ViroGroup, Inc., Florida Division, for West Coast Regional Water Supply Authority, March 31, 1998.

17. Ecological Monitoring of the Morris Bridge Wellfield, Annual Report, Water Years 1994, 1995 and 1996, prepared by Biological Research Associates, Inc., for the City of Tampa Water Department, January 1997.

18. North Pasco Regional Wellfield Ecological/Hydrological Monitoring Program, Annual Monitoring Report - Water Year 1997, prepared by Berryman & Henigar, Division of Environmental Sciences in association with ViroGroup, Inc., Florida Division, for West Coast Regional Water Supply Authority, March 31, 1998.

19. Northwest Hillsborough Region Comprehensive Annual Ecological Monitoring and Environmental Assessment Report - Water Year 1997, prepared by Water & Air Research, Inc. and HSW Environmental Consultants, Inc., for West Coast Regional Water Supply Authority, April 1998.

20. Tampa Water Department Water Use Permit No. 202062.03 (Morris Bridge Wellfield, Hillsborough River Reservoir, and Sulphur Springs) and Joint Water Use Permit No. 206675.02 (Tampa Bypass Canal) with the West Coast Regional Water Supply Authority, Annual Hydrologic Report, FY 1998, prepared by the City of Tampa.

21. Lewis, R.R., III., and Estevez, E., 1988: The Ecology of Tampa Bay, Florida, an estuarine profile. Prepared for U.S. Department of Interior Fish and Wildlife Service, National Wetlands Research Center, Washington D.C. 20240.

22. Seaman W., and McLean R.,(editors), 1977: Seminar Proceedings: Freshwater and the Florida Coast: Southwest Florida, SWFWMD Report Number 1977-1, Sea Grant Report Number 22.

23. Treat, S.F., and Clark, P.A., eds. Proceedings, Tampa Bay Area Scientific Information Symposium 2. 1991 Feb. 27 - March 1; Tampa, Florida 528 p.

24. Water and Air Research Inc., 1993, First Progress Report- Tampa Bypass Canal and Hillsborough River Biological Monitoring Program, Volume 1.

25. Bacchus, S. T., 1998. Determining sustainable yield in the southeastern coastal plain *in*: J.W. Borchers (ed.) Case Studies and Current Research: Proceedings of the Joseph F. Poland Symposium on Land Subsidence, October 2-8, 1995, Sacramento, California. Association of Engineering Geologists Special Publication No. 8. (in press).

26. Littlefield, J. R., M. A. Culbreth, S. B. Upchurch, and M. T. Stewart, 1984. Relationship of modern sinkhole development to large scale-photolinear features. Pp. 189-195. In: B. F. Beck (ed.) Proceedings of the First Multidisciplinary Conference on Sinkholes, Orlando, Florida, 15-17 October 1984. A. A. Balkema Publishers, Accord, Massachusetts.

27. Patton, T. H. and J-G. Klein, 1989. Pp. 25-31 in., B. F. Beck (ed.) Proceedings of the Third Multidisciplinary Conference on Sinkholes, St. Petersburg Beach, Florida, 2-4 October 1989. A.A. Balkema Publishers, Brookfield, Vermont.

28. Warner, D., 1997. Hydraulic properties of the karstic upper Floridan aquifer near Albany, Georgia. pp. 401-406. *in*: K.J.Hatcher (ed.) Proceedings of the 1997 Georgia Water Resources Conference, held March 20-22, 1997, at the University of Georgia, Athens, Georgia.

29. J. G. Newton, Review of induced sinkhole development. In B.F. Beck (e.d.) Proceedings of the First Multidisciplinary Conference on Sinkholes, Orlando, Florida, 15-17, 1984.

30. Preliminary Evaluation of the Hydrobiological Monitoring Station Control Wetlands in the Green Swamp Wilderness Reserve, Florida, Reconnaissance Report. Prepared by Sydney T. Bacchus, Institute of Ecology, University of Georgia, Athens, Georgia.

31. Saltwater intrusion in the Floridan aquifer system, northeastern Florida. pp. 398-400 *in*: K.J. Hatcher (ed.) Proceedings of the 1997 Georgia Water Resources Conference, held March 20-22, 1997, at the University of Georgia, Athens, Georgia

APPENDIX D

ISSUES OF CONCERN

(*Charge Exhibit A*)

EXHIBIT A

Issues of Concern

WETLANDS – Rating Method

1. Are the parameters used to assess the ecological condition of a wetland appropriate? Is the process used for the selection of the parameters appropriate? (Bacchus 511, 514)
2. Is the classification scheme used to rank wetlands based on ecological conditions valid?
3. A variety of factors (such as preceding climatic conditions, water withdrawals, fire, etc.) can affect the current condition of a wetland. Does this affect the validity of the analysis or alter the conclusions for the purpose of establishing minimum levels?
4. For purposes of establishing a minimum level, is it scientifically valid for the District to combine those wetlands categorized as significantly altered and those categorized as severely altered into one wetland alteration category? [Establishment of Minimum Levels in Palustrine Cypress Wetlands, p.7]

WETLANDS – Normal Pool

5. Is it appropriate to use a historic normal pool based on biologic indicators as a local elevation datum in wetlands?
6. Were a sufficient number of replicate normal pool measurements taken at each sampling site?
7. Was the method for determining normal pool elevations for wetlands adequate and appropriate?

WETLANDS – Sampling Design

8. Were the number and location of sampling sites adequate to characterize palustrine cypress swamps in the study area depicted in Figure 1?
9. The wetlands analyzed were not randomly selected. Does the selection process affect the validity of the conclusions drawn from the numerical analysis?
10. The District relied on ecological and hydrologic data collected primarily from systems at or near public supply facilities. Does this affect the validity of the District's analyses or the conclusions drawn from those analyses?

WETLANDS – Spatio-temporal Issues

11. Is it appropriate to assume that ecological conditions of a wetland in any point in time is adequately a function of the hydrologic conditions over the previous six years?
12. Does there exist an underlying assumption that ecological conditions at all wetlands analyzed respond similarly (in both character and time scale) to like hydrologic change, and, if so, do different "qualities" among the wetlands that may exist in this regard affect the validity of the conclusions drawn from the analysis?

13. Can a hydrologic relation to significant ecological change in a wetland be determined by comparing ecological conditions across a group of wetlands at one time to their "hydrologic history" based on stage-duration, or, alternatively, does the individual "ecological history" of a wetland need to be known coincident with its "hydrologic history" in order to ascertain significant change in that wetland? Is a statistical assessment of varying conditions observed among a group of wetlands at one time equivalent to assessing varying conditions observed at a single wetland at many times with a corresponding statistical assessment of many such wetlands? More succinctly, does the analysis depend on the concept of ergodicity and, if so, have applicable principles and assumptions been met?

14. The wetlands analyzed were not of uniform ecological condition at the beginning of the period represented by the stage-duration curves. Does this circumstance affect the validity of the conclusions drawn from the analysis?

15. Is it scientifically valid to discard those wetland rating factors which had less correlation to the P50 value in establishing a minimum level for wetlands? Is it scientifically valid to choose only the four most sensitive ecological parameters (succession, weedy species, soil subsidence, and shrubs) to rank reference wetlands? In establishing a minimum level for wetlands, is it scientifically valid to focus on "early change indicators rather than those associated with a delayed response?" [Establishment of Minimum Levels in Palustrine Cypress Wetlands , p.4]

16. Does the wetland minimum level methodology adequately address seasonality? (Bacchus 507-508, 514)

17. What resource functions of wetlands, if any, are affected by establishing minimum levels on a "long-term" average basis? (Bacchus 507-508)

<u>WETLANDS – Analyses and Results</u>

18. The District does not claim to use data from unaffected wetlands (i.e. controls). Does that lack of such control data invalidate their wetland method? (e.g. Page 3, Establishment of Minimum Levels in Palustrine Cypress Wetlands: "a rating of 3 represents departure") (Bacchus 515, 516-517; Bacchus report at 10-35)

19. Was the method used in developing stage-duration curves adequate and appropriate?

20. Are the methods of data collection and analysis performed by the District repeatable and verifiable?

21. Are the analyses performed appropriate for the data utilized in the study?

<u>LAKES - RLWR</u>

22. Is the reference lake water regime (RLWR) a reasonable means of characterizing the hydrologic regime of lakes in the area?

23. Is the approach used to develop the RLWR reasonable?

24. Does the lake level methodology adequately consider the ecological and hydrologic variability among lakes within the area to which it was applied [Establishment of Minimum Levels for Category 1 and Category 2 Lakes, Figure 1]?

25. Is it scientifically valid to use the District's Northern Tampa Bay Groundwater Flow Model as part of the RLWR methodology [Establishment of Minimum Levels for Category 1 and Category 2 Lakes, p.18]?
26. Does the selection process in developing the RLWR affect the validity of the conclusions drawn from the numerical analysis?
27. Was the selected group of lakes analyzed of sufficient number and adequately representative to have not affected the validity of the conclusions drawn from the analysis?
28. Does the District's lake methodology adequately determine whether "historic" data exist for lakes? According to the methodology, "historic lake level data refer(s) to lake level data that cover(s) a period when there were no measurable impacts due to withdrawals" [Establishment of Minimum Levels for Category 1 and Category 2 Lakes, p.4]. If the methodology does not adequately determine whether historic data exist for lakes, how does that affect the reasonableness or validity of the methodology?
29. The lakes analyzed were not randomly selected. Does the selection process effect the validity of the conclusions drawn from the numerical analysis?
30. The District relied on ecological and hydrologic data collected primarily from systems at or near public supply facilities. Does this affect the validity of the District's analyses or the conclusions drawn from those analyses?
31. The District claims to use "reference" data from lakes that have "little to no impact by ground-water withdrawals" [Establishment of Minimum Levels for Category 1 and Category 2 Lakes, p.12, 18]. Is that claim reasonable? If the reference lakes are affected by water withdrawals, how does that affect the validity or reasonableness of the District's lake methodology? (Bacchus 515, 516-17; Bacchus report 10-35)
32. The District assumed that lakes must be in region 2 to be included as reference lakes [Establishment of Minimum Levels for Category 1 and Category 2 Lakes, Fig. 6] because lakes in that region are of similar hydrogeology [Establishment of Minimum Levels for Category 1 and Category 2 Lakes, p.12] Is that a reasonable assumption? If lakes from outside region 2 were used as reference lakes, how would that affect the lake methodology? (Bacchus Report 10-35; Bacchus 515-17)

LAKES - Normal Pool

33. Were the measurements of normal pool in lake fringing cypress swamps made in an appropriate manner?
34. Lake Alice, for example, has lake-fringing cypress wetlands in more than one area around the lake perimeter. Is it valid in such cases to determine the normal pool elevation in only one wetland area of the lake?

LAKES - P10

35. Is the methodology for establishing the current P10 of a lake appropriate?

LAKES - Structural Alterations

36. Is the definition and application of control points reasonable and appropriate?

37. Were historic alterations (other than groundwater withdrawal) in the watersheds of the RLWR lakes, and lakes for which levels were set, adequately accounted for?
38. Should inflows to lakes differences in lake catchment sizes and bathymetry be assessed and accounted for in the District's analyses?

LAKES - Ecologic Interactions

39. To what extent should lake fringing wetlands be considered in establishing minimum levels to prevent significant harm to a lake?
40. The District methodology assumes that the hydrologic regimes of palustrine cypress swamps are similar to hydrologic regimes of lake fringing cypress swamps. Is that assumption appropriate?
41. The District's lake level methodology relies upon criteria regarding lake-fringing wetlands rather than parameters such as volume, surface area, shoreline development ratio, fisheries, and littoral zone area. Is this reasonable and appropriate?
42. Is protecting a wetland fringing around a lake adequate or necessary to protect the ecology of the lake?

LAKES - Analyses and Results

43. Is the District's use of "Historic" and "Current" as applied to data and periods of record scientifically valid?
44. Does the proposed lake minimum level methodology adequately address seasonality? (Bacchus 507-08, 514)
45. What, if any, resource functions of lakes are affected by establishing minimum levels on a "long-term" average basis? (Bacchus 507-08)
46. For Category 1 lakes, the High Minimum Level is 0.4 feet below normal pool and the minimum level is 1.8 below normal pool in the lake fringing cypress wetlands regardless of the natural or historic fluctuation regime of the lake or the characteristics of the watershed in which that lake is located. Is this methodology appropriate given the natural diversity of the lakes and the variability of natural hydrologic regimes?

SEAWATER - General

47. Is the literature coverage and interpretation reasonable? (Generally Spechler)
48. Is the conceptualization of the problem rational? (Generally Spechler)
49. Is the conclusion that sea water intrusion is not currently a regional problem in the Northern Tampa Bay area valid? (Generally Spechler)
50. Are the conclusions reached from regional modeling analysis reasonable? (Generally Spechler)
51. Are the conclusions reached from data trend analysis reasonable? (Generally Spechler)
52. Is the reasoning for using long-term data for establishing seawater minimum levels valid? Is a six to ten year average appropriate to establish long-term water levels? (Generally Spechler)

TAMPA BYPASS CANAL - General

53. Are the analytical tools that were used appropriate and sufficient for establishing a minimum flow for the TBC?
54. Do the methodologies for minimum flows appropriately consider effects on downstream systems?
55. Did the District evaluate and apply meaningful physico-chemical and biological variables in determining the minimum flow?
56. Will any organisms or biological communities in the ecosystem downstream of ~~Structure 160 be diminished in diversity, abundance, or other~~ character if the minimum flow is adopted?
57. Are the conclusions reached by the District in establishing a minimum flow for the TBC supported by the data analysis?

EMALS - General

58. If geophysical data regarding regional fracture flow are unavailable, does the District's EMAL methodology accurately correlate water levels in lakes and wetlands with water levels in the Upper Floridan aquifer? (Spechler; Bacchus 508, 510, 512; Warner; Bacchus report 2-3)
59. Does the methodology adequately address ground surface subsidence? Is the methodology valid without addressing ground surface subsidence? (Spechler; Bacchus 510; Newton; Patton; Littlefield)
60. The EMALS rely upon an assumption that definable relationships exist between surface-water bodies and either or both the surficial aquifer and/or the Floridan aquifer system. How would any uncertainty in the numerical analysis of the relationships affect the utility of using groundwater levels to manage water levels in wetlands and lakes? (Spechler)