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EXECUTIVE SUMMARY

This purpose of this report is to document the data, methods and assumptions used by staff of the South Florida Water Management District (SFWMD) to develop minimum flow technical criteria for the Northwest Fork of the Loxahatchee River. The Loxahatchee River and Estuary watershed is located on the southeastern coast of Florida in Martin and Palm Beach counties. It includes the Northwest, Southwest and North Forks of the Loxahatchee River, a major drainage canal (C-18), the surrounding watershed, and the estuary. This system is of particular importance because the Northwest Fork was designated as Florida's first Wild and Scenic River, in 1985. It is located at the southern end of the Indian River Lagoon (part of the National Estuary Program), and includes a State Park and an Aquatic Preserve.

Florida law requires the water management districts to develop a priority list and schedule for the establishment of minimum flows and levels (MFL) for surface waters and aquifers within their jurisdiction (Section 373.0421 F.S.). This list, included in the *District Water Management Plan* for the South Florida Water Management District (SFWMD 2000a), identified the need to develop an MFL for the Loxahatchee River by 2002.

Section 373.042(1) F.S. defines the *minimum flow* as the ". . . imit at which further withdrawals would be significantly harmful to the water resources or ecology of the area. . . ." For purposes of establishing the minimum flow, SFWMD Rule 40E-8.021 defines *significant harm* as the "…temporary loss of water resource functions which result from a change in surface or ground water hydrology, that takes more than two years to recover, but which is considered less severe than serious harm…". Water resource functions protected under Chapter 373 are broad and include flood control, water quality protection, water supply and storage, fish and wildlife protection, navigation, and recreation. Water management districts must also consider any changes and structural alterations that have occurred, and develop a recovery and prevention strategy for water bodies that do not, or are not expected to, meet the proposed criteria during the planning horizon.

The focus of this report is on the development of MFL criteria for the Northwest Fork of the Loxahatchee River to protect the remaining floodplain swamp community and downstream estuarine resources against significant harm. Due to the lack of recent flow or biological data from the North Fork, the inability to regulate flow from the North Fork and the highly altered nature of the Southwest Fork, these two arms of the Loxahatchee Estuary were not considered for MFL establishment at this time.

Prior to development, nearly level, poorly drained lands, which were subject to frequent flooding, characterized most of the region. The current managed system includes a primary and several secondary drainage systems and associated water control facilities that have been constructed to make this region suitable for agricultural and residential development. Structural changes that were considered during criteria development included: excavation and stabilization of the Jupiter Inlet; dredging, filling, and bulk heading within the estuary and Northwest Fork; construction of major canals (C-18) and water control structures (S-46); secondary drainage systems; and the effects of consumptive uses within the basin.

Effects of such changes on regional hydrology, river flow, estuary hydrodynamics and river vegetation communities are documented. Over a century of water control and structural modifications to this system have led to changes to the quality, quantity, timing, and distribution of flows delivered to the river and estuary, resulting in hydrologic and ecological changes to the system. Salinity impacts observed within the river occurred in association with construction and dredging of Jupiter inlet in 1947 and subsequent upstream navigational improvements over time. Drainage and land development activities have changed the timing and distribution of flows from the watershed to the river, producing large discharges during wet periods and extended periods of little or no discharge during extreme dry periods. The estimated magnitudes and impacts of these changes are described in the report.

Pursuant to the requirements contained in Chapter 373 of the Florida Water Resources Act, water resource functions are identified and technical relationships of these functions to water flows and levels are described based on best available information. This information includes: results of a literature review and incorporation of results obtained from previous investigations; analysis of current and historical flow and salinity data; interpretation of aerial photography/GIS studies of the river over time; results from river vegetation surveys; results of a preliminary river soil salinity survey; development and application of a hydrodynamic/salinity model to estimate long-term salinity trends at selected sites; development of empirical flow/salinity relationships; a floodplain hydrology analysis; and modeling to determine the overall effect of consumptive uses on the ability to provide flows to the Northwest Fork.

Proposed minimum flow criteria for the Northwest Fork are linked to the concept of protecting valued ecosystem components (VEC) from significant harm. The VEC identified for the Northwest Fork is the river's freshwater floodplain swamp. An assemblage of six freshwater tree species and associated vegetation community parameters were identified that characterize the VEC. The designation of the Wild and Scenic River identified the floodplain swamp and its associated cypress forest as a resource of outstanding value that needs to be protected. Since cypress trees themselves appear to tolerate a wide range of salinity conditions and are slow to show a response to salinity stress, researchers at the SFWMD identified the above six freshwater swamp species that, as a group, appear to be a more sensitive indicator of adverse salinity conditions. Protection of these species will assure that the floodplain swamp and their associated communities of freshwater species are also protected from significant harm.

Proposed MFL criteria for the Northwest Fork of the Loxahatchee River were based on determination of the following:

- Biological surveys were conducted along the Northwest Fork to characterize vegetation changes that occur in relationship to the existing salinity gradient.
- Results showed highly correlated relationships between salinity conditions at a site and measured vegetation community parameters (canopy structure, number of species, abundance, tree height and trunk diameter, presence of saplings or seedlings). Based on these results, proposed definitions of stress, harm, and significant harm were developed for the Northwest Fork.

- Results of this study indicate that sufficient quantities of fresh water from the Lainhart Dam are required to protect the floodplain swamp and associated bald cypress habitat against significant harm. This freshwater forest community was identified as a valued ecosystem component (VEC) for the Wild and Scenic portion of the Northwest Fork of the Loxahatchee River.
- Research conducted by the SFWMD identified locations on the river where both "healthy" and "stressed" floodplain communities exist (at river miles 10.2 and 9.7, respectively), and identified downstream locations where significant harm to this community is presently occurring (river mile 9.2).
- In order to protect the remaining healthy and stressed floodplain swamp community and the area that currently is experiencing significant harm, sufficient flow should be provided from the Lainhart Dam whenever possible to maintain essentially freshwater conditions in the river upstream of river mile 9.2.
- Modeling results indicate that flows below 35 cubic feet per second from Lainhart Dam cause salinities in excess of 2 ppt to occur at sites where remaining stressed and harmed plant communities exist along the Northwest Fork of the Loxahatchee River. Frequent exposure to salinity levels in excess of 2 ppt were associated with damage to freshwater vegetation.
- During periods of regional drought, due to the limited storage capacity of the basin, it may not be possible to maintain fresh water conditions at river mile 9.2 or to meet the 35-cfs flow criterion at all times. In order to prevent damage or stress from occurring to the floodplain swamp community at river mile 10.2 and significant harm from occurring at river mile 9.2, freshwater flows should not decline below a discharge rate of 35 cfs at the Lainhart Dam for a period of more than 20 consecutive days, more often than once every six years.

Based on the above information, SFWMD staff propose the following MFL criteria for the Northwest Fork of the Loxahatchee River:

> *An MFL violation occurs within the Northwest Fork of the Loxahatchee River when an exceedance of the minimum flow criteria occurs more than once every six years. An "exceedance" is defined as when Lainhart Dam flows to the Northwest Fork of the river decline below 35 cfs*[*] *for more than 20 consecutive days within any given calendar year.*

Currently, during dry periods, flows to the Northwest Fork of the Loxahatchee River do not meet the proposed MFL criteria. Therefore, when the MFL Rule is adopted, a Recovery Plan will be implemented to achieve the MFL as required under Section 373.042(1) F.S. The proposed Recovery Plan includes structural, operational and regulatory components that when implemented will provide sufficient additional water to the Northwest Fork to meet the proposed MFL by 2006.

[*] A flow of 35 cfs is equivalent to a recorded stage of 10.68 ft. NGVD as measured upstream of the Lainhart Dam at the SFWMD maintained gauge named "LNHART_W".

The Recovery Plan includes the following key projects to be completed by 2006:

- Construction of the Loxahatchee Slough structure (G-160) to capture and store water in the Slough to maintain a more natural hydroperiod for the Slough and provide water deliveries to the Northwest Fork during the dry season
- Construction of a flow-way under Northlake Boulevard (G-161) to provide additional water from the regional system through the Grassy Waters Preserve to the C-18 Canal and provide supplemental flows to the river during the dry season.
- Widening the M-canal and increasing the capacity of the Control 2 pump station to provide increased water conveyance capacity for the system.
- Under the Recovery Plan the SFWMD will continue to provide 50 cfs of flow to the Northwest Fork whenever water is available.

The Recovery Plan also includes a regulatory component. The goal is to regulate the amount of water withdrawn from the river, its tributaries (C-18, Cypress Creek, Hobe Grove Ditch and Kitching Creek), and the surficial aquifer adjacent to the river consistent with District rules governing consumptive uses that may influence a MFL water body in recovery (Rule 40E-8 F.A.C.). The regulatory component will apply to consumptive use applications for renewals, new uses, and modifications to existing permits that influence the MFL water body. Future Environmental Resource Permit rulemaking will be initiated to establish supplemental criteria to be applied to permit applications for projects located within the Loxahatchee River Watershed. The rulemaking initiative will consider the inflow needs of the river from both a water quality and water quantity perspective. Additional hydrologic watershed analyses will be needed to establish the appropriate technical criteria.

While implementation of the Recovery Plan to meet the MFL is ongoing, the SFWMD is also committed to restore the Loxahatchee River and Estuary in addition to protecting the Northwest Fork from significant harm through the proposed MFL. The SFWMD and the Florida Department of Environmental Protection are partners with other agencies and local governments to establish a practical restoration goal, and associated restoration plan, for the Loxahatchee River watershed. The SFWMD is also committed to implement, along with its other river restoration partners, projects for restoration contained in the LEC Plan, the NPBCCWMP, and CERP. Several projects are being considered in the CERP, North Palm Beach County Project, Part 1, which will create increased storage and water conveyance within the basin to provide more water for the Loxahatchee River and Estuary.

The SFWMD will adopt water reservations for the Loxahatchee River to protect water made available for the recovery and restoration of the river. It is the intent of the SFWMD to adopt an initial water reservation for the Northwest Fork of the river by 2004 to protect existing flows delivered to the river for protection of the floodplain swamp and its associated fish and wildlife. Over the next twenty years, subsequent reservations will be adopted for the river as new projects are designed consistent with the Recovery Plan. Additionally, reservations will be adopted for the Loxahatchee River consistent with other water bodies and will address the needs of the natural system across a broad range of hydrological conditions. Water reservations will prevent water reserved for the environment from being allocated to consumptive uses. The reservations will be implemented over time through permit criteria, operational protocols and water shortage rules.

The Recovery Plan also includes an adaptive assessment approach to research and monitoring of the watershed, which is designed to (a) fill gaps in our knowledge of the hydrodynamics and ecology of the Loxahatchee River and Estuary, and (b) improve the District's understanding of what are the additional water needs of the river and estuary. The proposed MFL criteria will be refined as new information is assimilated into the MFL development process and new restoration goals are defined for the river and estuary.

And finally, the SFWMD plans to add the following tributaries: Cypress Creek, Hobe Grove Ditch, and Kitching Creek, which provide significant flows to the Northwest Fork of the Loxahatchee River, to the District's 2003 MFL priority water body list. MFL criteria and implementation rules for each of these three tributaries will be developed in conjunction with preparation of restoration goals, objectives and performance measures associated with the northern Palm Beach County CERP project.

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ACRONYMS AND ABBREVIATIONS

^{o}C or C	degrees Centigrade
^{o}F or F	degrees Fahrenheit
ac-ft	acre-feet
aerial photo quad	topographical quadrant map overlain on an aerial photograph
AGR	agriculture (water use category)
AFSIRS	Agricultural Field-Scale Irrigation Requirements Simulation
ASR	aquifer Storage and Recovery
ATV	all-terrain vehicle
AWT	advanced water treatment
BMP	best management practice
C&SF Project	Central and Southern Florida Project
CERP	Comprehensive Everglades Restoration Plan
Ch.	chapter (general used to reference a legal document)
CITES	Convention on International Trade in Endangered Species
CUP	Consumptive Use Permit
cfs	cubic feet per second
cm	centimeters
CDD	Community Development District
CWMP	Comprehensive Water Management Plan
Db	duration of time between salinity exposure events
DBH	Diameter at Breast Height (tree measurement)
DBHydro	hydrologic database maintained by SFWMD
DDM	Design Documentation Memorandum
DERM	Department of Environmental Resource Management
District	South Florida Water Management District
DO	dissolved oxygen
DOC	dissolved organic carbon
DOQ	digital ortho quadrangle (electronic aerial photograph)

DRP	Diviison of Recreation and Parks
Ds	duration of exposure to a salinity concentration
EAA	Everglades Agricultural Area
E	Endangered
EIS	Environmental Impact Statement
ENCON	Loxahatchee River Environmental Control District
ERP	Environmental Resource Permit
F.A.C.	Florida Administrative Code
FAS	Floridan Aquifer System
FIND	Florida Inland Navigational District
FDA	Food and Drug Administration
FDACS	Florida Department of Agriculture and Consumer Services
FDEP	Florida Department of Environmental Protection
FDNR	Florida Department of Natural Resources
FDOT	Florida Department of Natural Transportation
FORTRAN	Formula Translation Model
F.S.	Florida Statutes
FWC	Florida Fish and Wildlife Conservation Commission
FY	Fiscal Year
GDM	General Design Memorandum
GIS	geographic information system
GOL	golf course irrigation (water use category)
gpd or GPD	gallons per day
gpcd	gallons per capita per day
GRR	General Re-evaluation Report
HSPF	Hydrologic Simulation Program – FORTRAN
ICW	Intracoastal Waterway
IFAS	Institute of Food and Agricultural Science
IND	industrial (water use category)
IRL	Indian River Lagoon
ITID	Indian Trail Improvement District

ITR	independent technical review
JDSP	Jonathan Dickinson State Park
JID	Jupiter Inlet District
km	kilometers
LAN	landscape irrigation (category of water use)
LEC	Lower East Coast
LECRWSP	Lower East Coast Regional Water Supply Plan
LRD	Loxahatchee River Environmental Control District
LRI	Loxahatchee River Initiative
LWDD	Lake Worth Drainage District
MFL	Minimum Flows and Levels
m	meters
mgd or MGD	million gallons per day
mg/l	milligrams per liter
mgy or MGY	million gallons per year
µmho	micromhos (unit of conductivity measurement)
MOA	Memorandum of Agreement
MODFLOW	MODular 3-dimensional finite-difference groundwater FLOW model
MOU	Memorandum of Understanding
MSL	Mean Sea Level
NA	not applicable or not available
NEPA	National Environmental Policy Act
NGVD	National Geodetic Vertical Datum
NMFS	National Marine Fisheries Service
NOAA	National Ocean and Atmospheric Administration
NPBCCWMP	Northern Palm Beach County Comprehensive Water Management Plan
NPDES	National Pollution Discharge Elimination System
NRCS	Natural Resources Conservation Service
NSM	Natural Systems Model
NW Fork	Northwest Fork of the Loxahatchee River
OFW	Outstanding Florida Waters

OPE	Other Project Elements
PAC	Policy Advisory Committee
PBA	Palm Beach Aggregate, Inc.
PIR	Project Implementation Report
PMP	Project Management Plan
POR	Period of Record
ppm	parts per million
ppt	parts per thousand
PWS	Public Water Supply
RECOVER	REstoration, COordination, and VERification
Restudy	Central and Southern Florida Project Comprehensive Review Study
RMA-2/RMA-4	models developed by Resource Management Associates, Inc.
RO	reverse osmosis
SAS	surficial aquifer system
SAVELOX	SAlinity and VEgetation model for the LOXahatchee
SFWMD	South Florida Water Management District
SFWMM	South Florida Water Management Model
SIRWCD	South Indian River Water Control District
SPF	standard project flood
SSC	species of special concern
STA	stormwater treatment area
SW Fork	Southwest Fork of the Loxahatchee River
SWIM	Surface Water Improvement and Management
SWMM	South Florida Water Management Model
T	threatened
TAC	technical advisory committee
TBD	to be determined
TDS	total dissolved solids
TMDL	total maximum daily load
topo quad map	topographical quadrant map
UEC	Upper East Coast

LECRWSP	Upper East Coast Regional Water Supply Plan
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VEC	valued ecosystem component
WCA	Water Catchment Area
WMA	Wildlife Management Area
WCI	Watermark Communities, Inc.
WPB	West Palm Beach
WQ	water quality (especialyy referring to a monitoring station)
WRDA	Water Resources Development Act
WTL	Wetlands Package (MODFLOW component)
WTP	Wastewater Treatment Plan
WSE	Water Supply and Environmental

CHAPTER 1 -- INTRODUCTION

BACKGROUND

This report documents the methods and technical criteria used by staff of the South Florida Water Management District (SFWMD or District) to develop minimum flows and levels (MFLs) for the Northwest Fork of the Loxahatchee River.

The District Water Management Plan (DWMP) for South Florida (SFWMD, 2000a) includes a schedule for establishing MFLs for priority water bodies within the District. Section 373.042(2), Florida Statutes (F.S.), requires the water management districts to annually review this list and schedule and make any necessary revisions. This list identified the need to establish MFLs for the Loxahatchee River and Estuary. The Minimum Flows and Levels Priority List and Schedule was modified in November 2001 and the deadline for establishing these criteria and associated rule development was extended to December 2002 (letter from Henry Dean, SFWMD to David Struhs, FDEP dated October 16, 2001 -- see **Appendix Q**).

These MFLs are being developed pursuant to the requirements contained within the "Florida Water Resources Act," specifically Sections 373.042 and 373.0421, F.S., as part of a comprehensive water resources management approach geared towards assuring the sustainability of the water resources. The proposed MFLs are not a “stand alone” resource protection tool, but should be considered in conjunction with all other resource protection responsibilities granted to the water management districts by law. This includes consumptive use and environmental resource permitting, water shortage management and water reservations. A model framework identifying the relationship between these tools is discussed in this document and was used in developing the MFLs. In addition, the SFWMD has completed Regional Water Supply Plans pursuant to Chapter 373.0361 F.S., which also include recommendations for establishment of minimum flows and recovery and prevention strategies (SFWMD 2000b, 2000c and 2000d).

Establishing *minimum* flows and levels alone will not be sufficient to maintain a sustainable resource or protect it from significant harm during the broad range of water conditions occurring in the managed system. Setting a minimum flow is viewed as a starting point to define water needs for sustainability. The necessary hydrologic regime for restoration of the Loxahatchee River and Estuary ecosystem must also be defined and implemented through regional water supply plans, the use of water reservations and other water resource protection tools.

For the Loxahatchee River and Estuary, periodic large volume freshwater flows also impact the resource. *Maximum* flows for the Loxahatchee River and Estuary occur when excess storm water is discharged to tide by the operation of Canal C-18 through structures G-92 (Northwest Fork) and S-46 (Southwest Fork) and the South Indian River Water Control District’s Canal 14 (C-14).

The Florida Department of Environmental Protection (FDEP) and the SFWMD have initiated a separate process to develop a restoration plan for the Loxahatchee River and Estuary. This effort will not only identify the amount of flow required to protect this system from harm but will identify seasonal flow requirements for the river and estuary, and maximum amounts of flow that can be sustained by this system without causing damage to the resource. This restoration effort will be used as input to the ongoing Comprehensive Everglades Restoration Plan (CERP) effort in northern Palm Beach and southern Martin Counties (USACE and SFWMD 1999). Achieving the required flows and water levels throughout the Loxahatchee River and Estuary is a long term component of CERP.

As a first formal step to establish MFLs for the Loxahatchee River and Estuary, this report includes the following:

- Description of the framework for determining MFLs based on best available information (this approach may be applied to other surface and ground waters within the District).
- Development of a methodology and technical criteria as a basis for establishing MFLs for the Northwest Fork.
- Supporting data and analyses.

This document received independent scientific peer review pursuant to Section 373.042, F.S. and rule development workshops were held to discuss concepts proposed for the Northwest Fork of the Loxahatchee River. Persons who wish to receive notice of future workshops, other public meetings and results of the scientific peer review process, should notify the District.

PROCESS AND BASES FOR ESTABLISHMENT OF MINIMUM FLOWS AND LEVELS

Process Steps and Activities

The process for establishing minimum flows for the Northwest Fork of the Loxahatchee River can be summarized as follows:

1. Through the development of the Lower East Coast Regional Water Supply Plan, the Northern Palm Beach County Comprehensive Water Management Plan and concurrent staff research and analysis, a methodology and technical basis for establishment of the MFLs was developed.
2. An initial draft of the MFL technical criteria document was completed in February 2001.
3. A technical workshop was conducted to review the initial draft, and the draft was revised to incorporate comments received from the public and various agencies. A revised draft was released in May 2001.
4. Scientific peer reviews of the technical documents were conducted in July of 2001 to verify the criteria pursuant to Section 373.0421, F.S.

5. Revisions to the MFL report, as recommended by the peer review panel, were incorporated into the criteria. A revised draft of the technical report was completed in July 2002 and sent to the peer review panel, the public and other agencies for additional comments, which have been incorporated into this document.
6. Further public consideration of the technical basis and methodology for establishing the MFLs and review of the first draft of the rule will be conducted during rule development workshops, beginning in November 2002.
7. A final rule will be presented to the Governing Board for adoption in December 2002.

Legal and Policy Bases for Establishment of Minimum Flows and Levels

Florida law requires the water management districts to establish MFLs for surface waters and aquifers within their jurisdiction (Section 373.042(1), F.S.) The minimum flow is defined as the ". . . limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area." The minimum level is defined as the ". . . limit at which further withdrawals would be significantly harmful to the water resources of the area . . . ." (Section 373.042(1), F.S.) The statute further directs water management districts to use the best available information in establishing the MFL. Each water management district must also consider, and at its discretion may provide for, the protection of non-consumptive uses in the establishment of MFLs (Section 373.042, F.S.) In addition, a baseline condition for the protected resource functions must be identified through consideration of changes and structural alterations in the hydrologic system (Section 373.042(1), F.S.).

The following sections outline the legal and policy factors relevant to establishing MFLs under the MFL law. In summary, the following questions are addressed:

A. What are the priority functions of each water resource and what is the baseline condition for the functions being protected?

B. What level of protection for these functions is provided by the MFL standard of protection, significant harm?

Identify Relevant Water Resource Functions

Each surface water body or aquifer serves an array of water resource functions. These functions must be considered when establishing a MFL as a basis for defining significant harm.

The term "water resource" is used throughout Chapter 373. Water resource functions protected under Chapter 373 are broad, as illustrated in Section 373.016, F.S., which includes flood control, water quality protection, water supply and storage, fish and wildlife protection, navigation and recreation.

The State Water Resource Implementation Rule, Section 62-40.405, F.A.C, outlines specific factors to consider, including protection of natural seasonal changes in water flows or levels, environmental values associated with aquatic and wetland ecology and water levels in aquifer systems. Other specific considerations include:

- Fish and wildlife habitat and the passage of fish
- Maintenance of freshwater storage and supply
- Water quality
- Estuarine resources
- Transfer of detrital material
- Filtration and absorption of nutrients and pollutants
- Sediment loads
- Recreation in and on the water
- Navigation
- Aesthetic and scenic attributes

This policy determination as to which resource functions to consider in establishing MFLs is within the Governing Board's purview. This analysis requires a comprehensive look at sustainability of the resource itself as well as its role in sustaining overall regional water resources. **Chapter 3** of the MFL document provides a detailed description of the relevant water resource functions of the Loxahatchee River and Estuary.

Identify Considerations and Exclusions: Baseline Conditions to Protect Water Resource Functions

Once the water resource functions to be protected by a specific minimum flow or level have been defined, the baseline resource conditions for assessing significant harm must be identified. Considerations for making this determination are set forth in Section 373.0421(1)(a), F.S., which requires the water management districts when setting a MFL, to consider changes and structural alterations that have occurred to a water resource. Likewise, Section 373.0421(1)(b), F.S., recognizes that certain water bodies no longer serve their historical function and that recovery of these water bodies to historical conditions may not be feasible. These provisions are discussed in **Chapter 3**, to examine their applicability to the minimum flows that are proposed for the Northwest Fork of the Loxahatchee River.

Level of Protection for Water Resource Functions Provided by the MFL Standard of *Significant Harm*

The overall purpose of Chapter 373 is to ensure the sustainability of water resources of the state (section 373.016, F.S.). To carry out this responsibility, Chapter 373 provides the District with several tools with varying levels of resource protection standards. MFLs play one part in this framework. Determination of the role of MFLs and the protection that they offer, versus other water resource tools available to the District, is discussed below.

The scope and context of MFLs protection rests with the definition of significant harm. The following discussion provides some context to the MFLs statute, including the significant harm standard, in relation to other water resource protection statutes.

Sustainability is the umbrella of water resource protection standards (Section 373.016, F.S.). Each water resource protection standard must fit into a statutory niche to achieve this overall goal. Pursuant to Parts II and IV of Chapter 373, surface water management and consumptive use permitting regulatory programs must prevent **harm** to the water resource. Water shortage statutes dictate that permitted water supplies must be restricted from use to prevent **serious harm** to the water resources. Other resource protection tools include reservation of water for fish and wildlife, or health and safety (Section 373.223(3), F.S.) and aquifer zoning to prevent undesirable uses of the ground water (Section 373.036(4)–(5), F.S.). By contrast, MFLs are set at the point at which **significant harm** to the water resources, or ecology, would occur. The levels of harm cited above -- harm, significant harm and serious harm -- are relative resource protection terms, each playing a role in the ultimate goal of achieving a sustainable water resource. The SFWMD has proposed that the conceptual relationship among the terms harm, significant harm, and serious harm can be represented as shown in **Figure 1.**

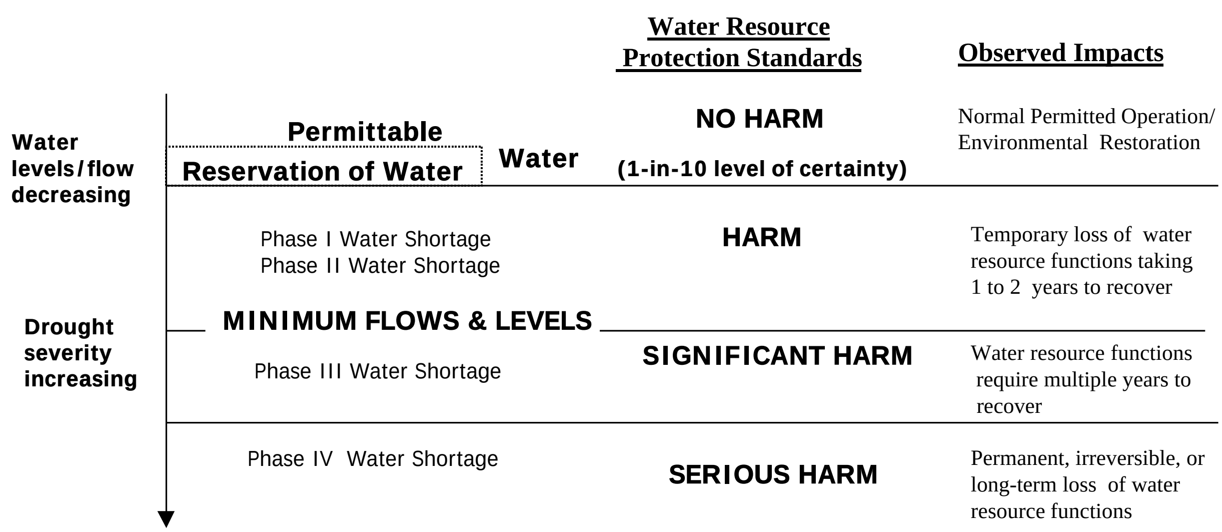


Figure 1. Conceptual Relationships Among the Terms Harm, Significant Harm and Serious Harm

The general narrative definition of significant harm proposed by the SFWMD (Chapter 40E-8.021(24), Florida Administrative Code (F.A.C.)) for the water resources of an area is as follows:

> "Significant Harm – means the temporary loss of water resource functions, which result from a change in surface or ground water hydrology, that takes more than two years to recover, but which is considered less severe than serious harm. The specific water resource functions addressed by a MFL and the duration of the recovery period associated with significant harm are defined for each priority water body based on the MFL technical support document" (Chapter 40E-8.021(24), F.A.C.)

Other Levels of Harm Considered in Florida Statutes

A discussion of the other levels of harm identified in the conceptual model for consumptive use permitting and water shortage is provided below to give context to the proposed significant harm standard.

Consumptive Use Permitting Role - Harm Standard

The resource protection criteria used for Consumptive Use Permitting (CUP) are based on the level of impact that is considered harmful to the water resource. These criteria are applied, to various resource functions, to establish the range of hydrologic change that can occur without harm. The hydrological criteria include level, duration and frequency components and are used to define the amount of water that can be allocated from the resource. Saltwater intrusion, wetland draw-down, aquifer mining and pollution prevention criteria in Chapter 40E-2, F.A.C., together define the harm standard for purposes of consumptive use allocation. These harm criteria are applied using climate conditions that represent an assumed level of certainty. The level of certainty used in the Lower West Coast, Lower East Coast and Upper East Coast Regional Water Supply Plans (SFWMD 2000b, 2000c and 2000d) is a 1-in-10 year drought frequency, as defined in the District's permitting rules. The 1-in-10 year drought level of certainty is also the water supply planning goal that was established in Section 373.0361, F.S. The standard for harm used in the CUP process is considered as the point at which adverse impacts to water resources can be restored within a period of one to two years of average rainfall conditions. These short-term adverse impacts are addressed for the CUP program, which calculates allocations to meet demands for use during relatively mild, dry season events, defined as the 1-in-10 year drought.

Water Shortage Role - Serious Harm Standard

Pursuant to Section 373.246, F.S., water shortage declarations are designed to prevent serious harm from occurring to water resources. Serious harm, the ultimate harm to the water resources contemplated under Chapter 373, F.S., can be interpreted as long-term, irreversible or permanent impacts. Declaration of water shortages is the tool used by the Governing Board to prevent serious harm. These impacts associated with serious harm occur at drought events that are more severe than the 1-in-10 level of drought used in the CUP criteria.

When drought conditions exist, water users increase withdrawals to supplement water not provided by rainfall, typically for irrigation or outside use. In general, the more severe the drought, the more supplemental water is needed. These increased withdrawals increase the potential for serious harm to the water resource.

The SFWMD has implemented its water shortage authority by restricting consumptive uses based on the concept of equitable distribution between users and the water resources (Chapter 40E-21, F.A.C.). Under this program, different levels or phases of water shortage restrictions are imposed relative to the severity of drought conditions. The four phases of the current water shortage restrictions are based on relative levels of risk posed to resource conditions leading up to serious harm impacts. Under the SFWMD's program, Phase I and Phase

II water shortages are primarily designed to prevent harm, such as localized, but recoverable, damage to wetlands or short-term inability to maintain water levels needed for restoration. Actions that may be taken include reducing water use through conservation techniques and minor use restrictions, such as car washing and lawn watering. Phases III and IV, however, require use cutbacks that are associated with some level of economic impact to users, such as agricultural irrigation restrictions.

MFL RECOVERY AND PREVENTION STRATEGY

MFLs are implemented through a multifaceted recovery and prevention strategy, developed pursuant to Section 373.0421(2), F.S. A MFL recovery and prevention strategy is presented in **Chapter 6** of this document.

Section 373.0421(2), F.S., provides that if it is determined that water flows or levels will fall below an established MFL within the next 20 years or that water flows or levels are presently below the MFL, the water management district must develop and implement a recovery or prevention strategy. The twenty-year period should coincide with the regional water supply plan horizon for the area and the strategy is to be developed in concert with that planning process.

The general goal of the recovery and prevention strategy is to take actions to achieve the MFL criteria while continuing to provide sufficient water supplies for all reasonable-beneficial demands. If the existing condition of the resource is below the MFL, recovery to the MFL must be achieved "as soon as practicable." Many different factors influence the water management district's ability to punctually implement proposed actions, including funding availability, detailed design development, permittability of regulated actions, land acquisition and implementation of updated permitting rules.

From a regulatory standpoint, depending on the existing and projected flows or levels, either water shortage triggers, interim consumptive use permit criteria, or both, may be recommended in the recovery and prevention strategy. The approach varies depending on whether the MFL is currently exceeded or not, and depending on the cause of the MFL exceedance, e.g., consumptive use withdrawals, poor surface water conveyance facilities or operations, over drainage, or a combination of the above.

Incremental measures to achieve the MFL must be included in the recovery and prevention strategy, as well as a timetable for the provision of water supplies necessary to meet reasonable beneficial uses. Such measures include development of additional water supplies and conservation and other efficiency measures. These measures must make water available "concurrent with, to the extent practical, and to offset, reductions in permitted withdrawals, consistent with …[Chapter 373]." The determination of what is "practical" in identifying measures to concurrently replace water supplies will likely be made through consideration of economic and technical feasibility of potential options. Additional information about the recovery and prevention strategy recommended for the Northwest Fork of the Loxahatchee River is provided in **Chapter 6**.

DOCUMENT STRUCTURE

The next section of this report, **Chapter 2**, describes the geographic setting, the resources at risk and major issues concerning the use and conservation of resources within the Loxahatchee River and Estuary.

Chapter 3 describes resource functions, considerations and exclusions for the Loxahatchee River and Estuary.

Chapter 4 documents the methods that were used to establish significant harm criteria for the different areas, resources and functions.

Results of analyses and the specific hydrologic criteria developed to indicate the point at which significant harm occurs are described in **Chapter 5**, including an analysis of the specific relevant factors and implications of the proposed definition of significant harm. **Chapter 5** also presents conclusion and recommendations.

Chapter 6 includes the recovery and prevention strategies for the Northwest Fork of the Loxahatchee River, description of research needs and the literature cited.

Appendices A through **J, N, P** and **R** are provided, in separate volumes, and include technical information, such as descriptions and analysis of methods and tools, supplemental data and analyses, literature and results of the peer review. **Appendices K** through **M, O, Q** and **S** present supplemental information that was used to support this plan, including results of the peer review, related correspondence, laws, rules and other activities in the watershed.

CHAPTER 2 -- DESCRIPTION OF THE WATER BODY

INTRODUCTION

The Loxahatchee River and Estuary and its upstream watershed are located along the southeastern coast of Florida within the Lower East Coast Planning area (SFWMD, 2000a). This watershed drains an area of approximately 210 square miles, is located within northern Palm Beach and southern Martin Counties, and connects to the Atlantic Ocean via the Jupiter Inlet, near Jupiter, Florida. The Loxahatchee Estuary central embayment is located at the confluence of three major tributaries -- the Northwest Fork, the North Fork and the Southwest Fork. The Northwest Fork originates at the G-92 Structure in northern Palm Beach County, flows north, enters Martin County, continues north and bends east through Jonathan Dickinson State Park (JDSP), and then flows southeast through the central embayment **(Figure 2**). The Atlantic Coastal Ridge in Eastern Martin County defines the headwaters of the North Fork, which flows south-southeast into the central embayment. All but one mile of the Southwest Fork has been channelized to form the C-18 Canal (C-18), which flows northeast through Palm Beach County to discharge into the central embayment. The central embayment connects to the Atlantic Ocean through Jupiter Inlet.

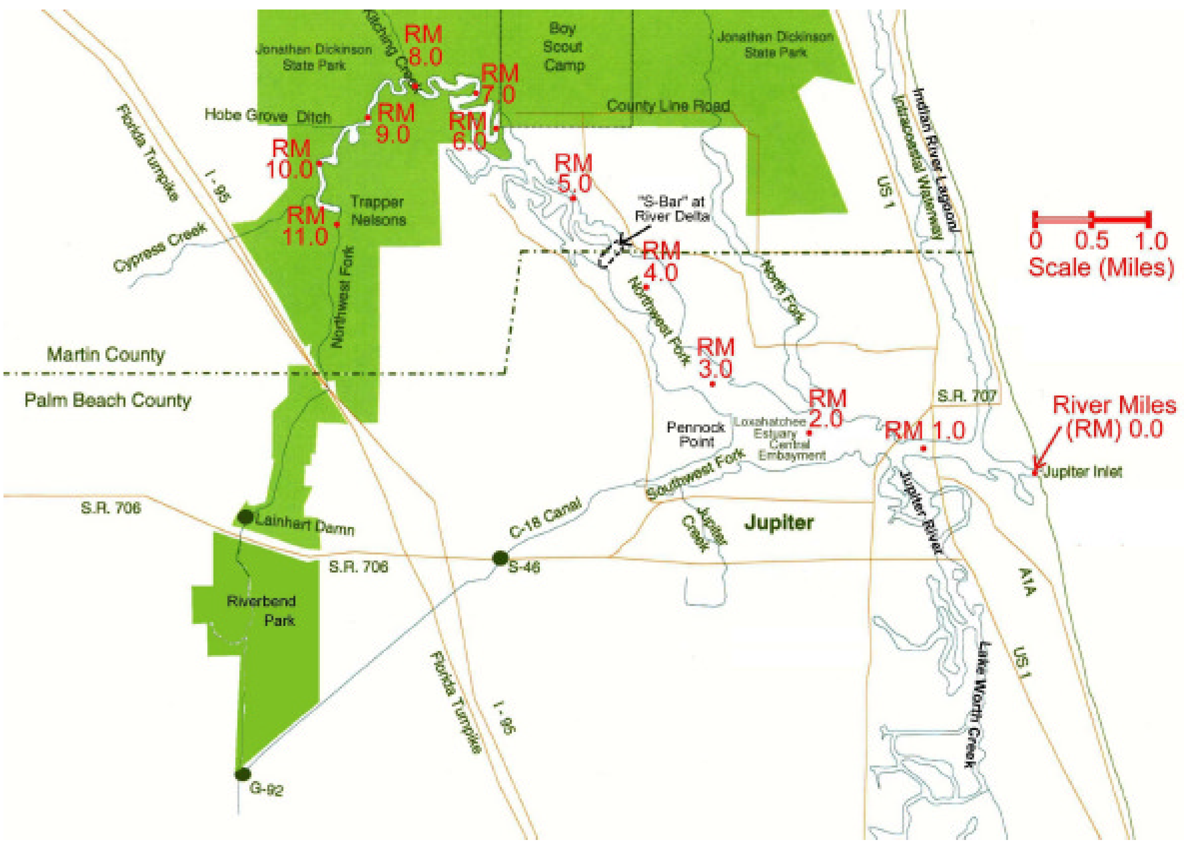


Figure 2. Locations of Major Features in the Loxahatchee River and Estuary. (RM = river miles upstream from Jupiter Inlet)

The Loxahatchee River and upstream floodplain are unique regional resources in several ways. The river has often been referred to as the "last free flowing river in southeast Florida". In May 1985, a 7.5 mile reach of the Northwest Fork of the Loxahatchee River was federally designated as Florida's first Wild and Scenic River. In addition, different portions of the river and estuary are designated as an aquatic preserve, Outstanding Florida Waters and a state park. The Northwest Fork represents one of the last vestiges of native cypress river-swamp within southeast Florida. Large sections of the river's watershed and river corridor are included within JDSP, which contains outstanding examples of the region's natural habitats.

The watershed is unique in that it contains a number of natural areas that are essentially intact and in public ownership. These areas include the J.W. Corbett Wildlife Management Area, JDSP, Hungryland Slough Natural Area, Loxahatchee Slough Natural Area, Hobe Sound National Wildlife Refuge, Juno Hills Natural Area, Jupiter Ridge Natural Area, Pal-Mar, Cypress Creek and the Atlantic Coastal Ridge. These natural areas contain pinelands, sand pine scrub, xeric oak scrub, hardwood hammock, freshwater marsh, wet prairie, cypress swamp, mangrove swamps, ponds, sloughs, river and streams, seagrass and oyster beds and coastal dunes. These areas support diverse biological communities, including many protected species (FDEP, 1998).

Preservation and enhancement of the outstanding natural and cultural values are the primary goals of the SFWMD's management program for this unique, "wild and scenic river" this area. The SFWMD vision for protecting the water resources of the river include: 1) maintaining surface water and ground water flows to the Northwest Fork; 2) providing minimum flows to control upstream movement of the saltwater wedge during dry conditions; 3) maintaining existing water quality in the river by eliminating identified water quality problems; 4) providing freshwater flows needed to sustain natural systems within the downstream river and estuary. In addition, The SFWMD and FDEP jointly developed a *Proposed Restoration Vision for the Northwest Fork of the Loxahatchee River* in September 2001 and are presently working with other agencies, local interests and concerned citizens to develop a practical restoration plan for this river.

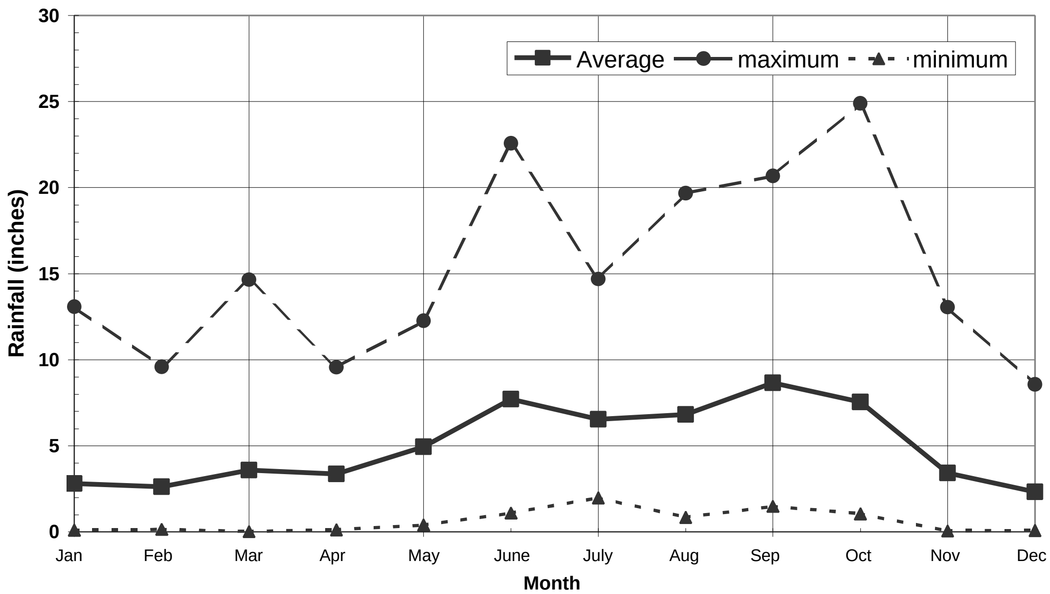
DESCRIPTION OF THE WATERSHED

Climate, Rainfall and Seasonal Weather Patterns

The climate is subtropical with daily temperatures ranging from an average of 82^{o} F in summer to an average of 66^{o} F in winter. Winters are mild with warm days and moderately cool nights. August is the warmest month, usually having more than 29 days with temperatures above 90 ^{o} F. Even in the coldest winters, temperatures at or below freezing are rare. The average annual temperature is 75^{o} F (Breedlove, 1982).

Prevailing winds are east/southeast, providing a marine influence, with an average velocity of approximately 10 miles per hour. Air in the study area is moist and unstable. These characteristics lead to frequent rain showers, usually of short duration. During the summer months, thundershowers occur on average, every other day.

Rainfall within the Loxahatchee River watershed averages about 61 inches annually (Breedlove, 1982; Dent 1997a) with a median value of about 57 inches. Heaviest precipitation occurs during the wet season. Dent (1997a) reports that since the early 1960s, about two-thirds of this precipitation (40.63 inches) occurs during the wet season (May through October), while the remaining one-third (20.42 inches) falls during the dry season (November–April). These data agree with rainfall data generated from the South Florida Water Management Model (SFWMM) (SFWMD 1998) for a longer period of record (1914–2000) for northern Palm Beach and southern Martin Counties **(Figure 3).**

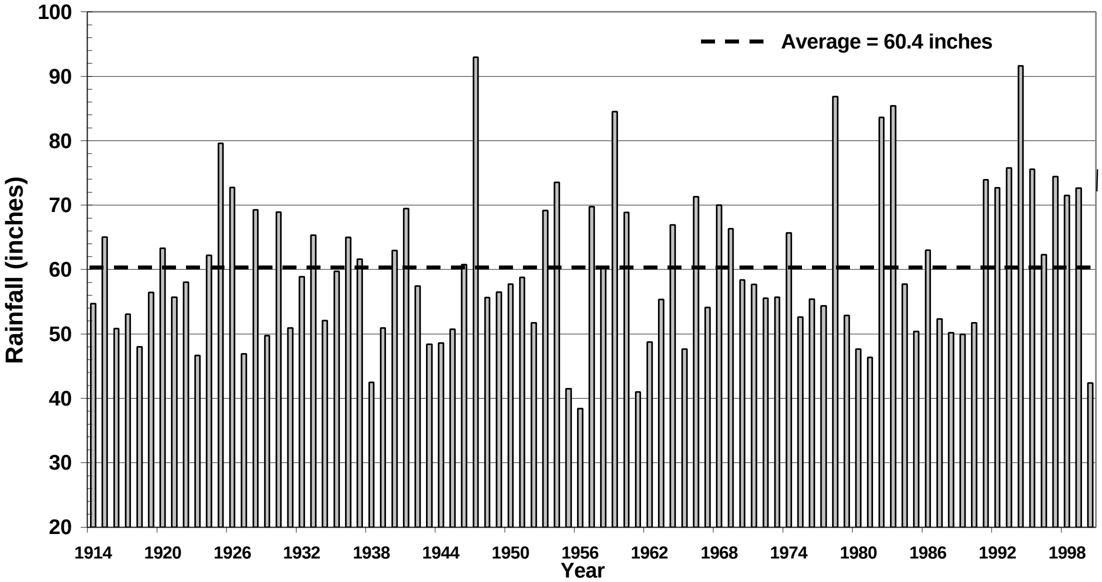


Source: Model results from the South Florida Water Mangement Model (SFWMM)

Figure 3. Average, Minimum and Maximum Rainfall Values, by Month, for Northern Palm Beach and Southern Martin Counties (1914–2000)

On average, the highest rainfall of 8.7 inches per month occurs during the month of September, while minimum average values range from 2.3–2.8 inches/month for the months of December, January and February **(Figure 3)**. May and November are transitional months and sometimes represent key months for either prolonging or relieving a drought or flood condition (Dent, 1997a). During the winter and early spring, some years have long periods of little or no rainfall, resulting in a regional drought condition. In contrast, tropical storms or hurricanes over the area can produce as much as 6 to 10 inches of rainfall in one day. Total annual rainfall can be as much as 93 inches or as low as 38 inches (**Figure 4).**

Figure 4 provides a summary of annual rainfall amounts received within northern Palm Beach and southern Martin Counties from 1914–2000 (data from South Florida Water Management Model, version 9.7). Mean annual rainfall for the full 86 year period of record was 60.4 inches with a median of 57.7 inches. The maximum amounts of rainfall recorded were 92.9 (1947) and 91.6 inches (1994). Minimum rainfall values occurred in 1956 (38.4 inches) and 1961 (41 inches). Review of the distribution of annual rainfall data over time showed that a variance of about 10 percent of the mean (plus or minus 6 inches) occurs about once every three years on average. Extreme dry and wet periods can be defined as a variance of more than 20 percent of the mean (± 12 inches). Based on this definition, the long-term record shows that an extreme dry period occurs within the basin about once every 8.6 years, while extreme wet periods occur about once every 5.7 years.



Source: South Florida Water Mangement Model
Data obtained from the following grid cells representing northern Palm Beach and southern Martin counities: Row 65 columns 32-38, Row 64 columns 30-38, Row 63 columns 30-38, Row 62 columns 30-38, Row 61 columns 30-37, Row 60 columns 31-37, Row 59 columns 32-37, Row 58 columns 33-

Figure 4. Long-term Annual Rainfall for Northern Palm Beach and Southern Martin Counties (1914–2000)

Comparison of the rainfall data contained in **Figure 4** to the period of time (1971–2001) that we have known flow records for the Northwest Fork of the Loxahatchee River shows that the 1970s and 1980s were a relatively dry period compared to the 1990s. For example, annual rainfall amounts exceeded more than 12 inches of the mean seven out of 10 years from 1990–2000 (**Figure 4**). These large rainfall differences between the 1970s and 1980s and the 1990s are thought to be an important factor that needs to be considered in reviewing past impacts to the river and its flora and fauna. These relationships are explained in detail later in this report.

Dent (1997a) provides information about the spatial distribution of rainfall across the Loxahatchee River watershed. Unpublished data and the results of modeling work on the Loxahatchee slough both indicate that wet season rainfall is higher inland as compared to rainfall stations located nearer the coast. Wet season rainfall recorded at the Jonathan's Landing development located near the coast was 12 percent less than observed at the more centrally located Loxahatchee River District site, and 34 percent lower than the western Pratt & Whitney site. Summer wet season rainfall data collected at the Loxahatchee River District monitoring site (located near the I-95 corridor) was 25 percent lower than experienced at the western edge of the watershed (Dent, 1997a). These results are similar to MacVicar (1981) who reported that the predominance of convective type rainfall in South Florida during the wet season results in much higher rainfall totals on the mainland than along the shore or coastal islands.

Evapotranspiration (ET) is the sum of evaporation and transpiration. Like rainfall, ET is generally expressed in terms of inches of water per year. For the South Florida area, ET returns approximately 45 inches of water per year to the atmosphere. The excess of average precipitation over average ET (15 inches) is equal to the combined amounts of average surface water runoff and average ground water recharge.

Pre-Development Hydrology

The Loxahatchee River historically received flow into the Northwest Fork from the Loxahatchee Marsh (Slough) and the Hungryland Slough (see **Figure 5**). Both of these wetland areas drained to the north from the low divides near State Road (SR) 710 (Parker et al., 1955). Historically, this area was characterized by swampy flatlands interspersed with small, often interconnected ponds and streams that produced sheet flow that might be directed north or south, depending on local conditions. Drainage patterns were determined by the poorly defined natural landforms of the area.

The major features that presently influence drainage in the river basin are the C-18 canal, the Florida Turnpike, Interstate 95 (I-95), Beeline Highway (SR 710) and Bridge Road (SR 708), which act as important subbasin divides, and the extensive system of secondary canals developed by special drainage districts and landowners within the basin. Since the turn of the century, human activities have altered almost all of the natural drainage patterns within the basin. Many areas that once were wetlands, ponds and sloughs, are now a network of drainage canals, ditches, roads, super-highways, well-drained farms, citrus groves, golf courses and residential developments. The drainage network has lowered ground water levels and significantly altered surface water flows to the estuary (McPherson and Sabanskas 1980). In 1957–1958, the C-18 Canal was constructed through the central portion of the Loxahatchee Slough (the headwaters of the Loxahatchee River) for flood protection purposes. This project redirected flows from the Northwest Fork to the Southwest Fork from the early 1960s up to 1974, when the G-92 structure was constructed to reconnect the C-18 and Loxahatchee Slough with the Northwest Fork.

Coastal development has also greatly affected the hydrology of the Loxahatchee River Estuary. The natural mouth of the estuary, the Jupiter Inlet, opened and closed many times as the result of natural conditions. Originally the inlet remained open due to flows from the Loxahatchee River, Jupiter Sound, Jupiter River and Lake Worth Creek. Near the turn of the century, some of this flow was diverted by the construction of the Intracoastal Waterway (ICW) and the Lake Worth Inlet, and modification of the St. Lucie Inlet. Subsequently the Jupiter Inlet remained closed much of the time (except when it was periodically dredged) until 1947 when it became permanently opened by the United States Army Corps of Engineers (USACE) (McPherson and Sabanskas, 1980).

Major Drainage Sub-Basins

The major feature of the watershed is the Loxahatchee River, which historically drained 270 square miles of inland sloughs and wetlands. Some of the major tributary streams, such as the North Fork, the Northwest Fork and Kitching Creek exist today largely within their historic banks. Other creeks, such as the Southwest Fork, Limestone Creek and parts of Cypress Creek, have been greatly altered. Today the watershed encompasses about 80 percent of its historic size (about 210 sq. miles). More than half of the land still remains undeveloped and the remainder has been altered by agricultural or urban development. Undeveloped lands consist of wetlands and uplands. The watershed also contains about 4000 acres of open water including lakes and the estuary (FDEP, 1998).

Although the total area of the watershed has not changed dramatically, drainage patterns have been significantly altered due to road construction (e.g., S.R. 710, I-95, and Florida Turnpike), construction of the C-18 and associated water control structures, and development of an extensive secondary canal network. The canals were designed primarily to provide drainage and flood protection for agricultural and urban development and associated water conveyance for potable use and irrigation. Drainage and development have lowered ground water levels and altered natural flow regimes and drainage patterns.

The watershed contains seven drainage subbasins, varying in size from 17 to 100 square miles, which provide runoff to the three forks of the Loxahatchee River (**Figure 5**). The subbasin boundaries were based primarily on hydrology and secondarily on land use. Each of these subbasins plays an important role in the watershed.

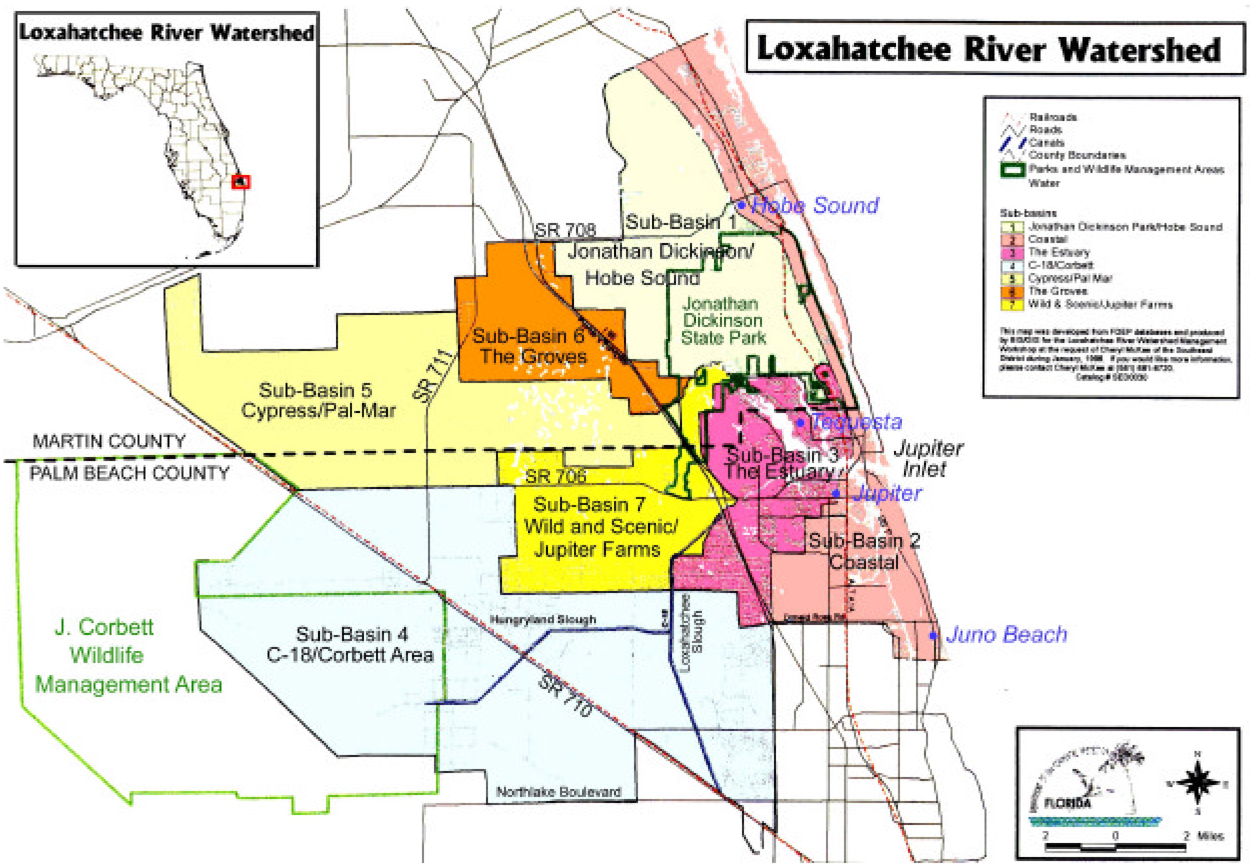


Figure 5. Major Drainage Basins in the Loxahatchee River Watershed (source: FDEP, 1998)

Subbasin 1: Jonathan Dickinson. The northeastern portion of the Loxahatchee River watershed actually consists of two parallel basins, the North Fork of the Loxahatchee and Kitching Creek. Over 40 percent of the 36 square miles of this subbasin are within the boundaries of JDSP, and contribute runoff from natural lands. A portion of surface and ground waters from this basin flows into the North Fork River. The remainder flows into Kitching Creek and discharges into the Northwest Fork near river mile 8.2.

Subbasin 2: Coastal. This subbasin consists of approximately 34 square miles of land that drains to the ICW and out the Jupiter Inlet. The coastal subbasin has been developed for maximum urban residential, commercial and recreational use. Very few small and isolated natural areas remain. Most of the surface water and ground water from this sub-basin discharges to marine waters rather than towards to the freshwater portion of the Northwest Fork.

Subbasin 3: Estuary. This central drainage subbasin is highly developed with urban land uses and contributes significant runoff to the major embayment of the Loxahatchee River. Consisting of over 21 square miles of the watershed, this subbasin provides aquatic recreational opportunities that sometimes exceed the river's carrying capacity on weekends and holidays. Runoff and groundwater from most of this sub-basin discharge to brackish waters of the estuary.

Subbasin 4: C-18/Corbett Wildlife Management Area (WMA). Over 100 square miles make this the largest subbasin in the watershed. Much of the land in this subbasin, comprising the southwestern portion of the watershed, is publicly owned and protected. This subbasin includes the remnants of the Hungryland and Loxahatchee Sloughs, which historically fed the Northwest Fork of the Loxahatchee River. At one time, the Loxahatchee Slough extended south into what is now known as the Grassy Waters Preserve (West Palm Beach Water Catchment Area), which is the source of drinking water for the City of West Palm Beach. Water from this sub-basin discharges to C-18 Canal, and is discharged to either the Southwest Fork or through the G-92 structure to the upper end of Northwest Fork of the Loxahatchee River

Subbasin 5: Cypress Creek/Pal-Mar. Cypress Creek, a large 46 square mile subbasin, drains a sizable wetland located in the western extremities of the watershed and is one of the major tributaries to the Loxahatchee River. Most of these wetlands remain intact, however the eastern flow ways leading to the creek have been disturbed by rural development. Water from this sub-basin flows into Cypress Creek and discharges at the upper end of the Northwest Fork near river mile 10

Subbasin 6: Groves. While agricultural operations are found in four of the seven subbasins, the predominant land use in this 17 square mile subbasin is primarily citrus. Although the hydrology in this subbasin has been altered to support agriculture, wildlife utilization is good and the land provides a valuable greenway link between large natural areas within the watershed. Water from this sub-basin flows into Hobe Groves Ditch and discharges into the Northwest Fork near river mile 9

Subbasin 7: Wild and Scenic River/Jupiter Farms. This subbasin is over 23 square miles and is divided into a larger upstream section, which has been channelized and now supports substantial rural development (Jupiter Farms), and the downstream portion that comprises the "wild and scenic" Northwest Fork of the Loxahatchee River. Water quality in the Northwest Fork is a concern in this subbasin (FDEP, 1998). Water from the upstream section of this sub-basin discharges into the upper end of the Loxahatchee River between the G-2 structure and Lainhart Dam. The downstream section of this sub-basin discharges directly into the Northwest Fork.

WATERSHED COMPONENTS

The Loxahatchee River and Estuary system can be divided into three components that affect, or are affected by the need to establish minimum flows and levels (MFLs). These include:

- The Northwest Fork of the Loxahatchee River (especially the "wild and scenic river" corridor) and its upstream watershed which includes the Loxahatchee Slough, JDSP, Cypress Creek, Hobe Grove Ditch and Kitching Creek.
- Downstream areas include the Northwest Fork Estuary, Southwest Fork, North Fork, and the central embayment.
- Adjacent coastal waters of the ICW, Jupiter River and Jupiter Inlet.

Northwest Fork of the Loxahatchee River and Upstream Watershed

Physical Features

The Northwest Fork of the Loxahatchee River originates in the Loxahatchee Slough. The slough receives discharges from C-18 Canal and runoff and groundwater inflow from adjacent uplands. Downstream from the slough, the Northwest Fork receives additional input from three major tributaries -- **Cypress Creek,** which drains Ranch Colony, Pal Mar and a portion of the Groves subbasin; **Hobe Grove Ditch**, which drains a portion the Groves subbasin, and **Kitching Creek,** which drains wetlands north of the river **(Figure 2).** The Northwest Fork passes through cypress swamp, mangrove forest, historical and archeological sites, and JDSP to the saline waters of the estuary. The Northwest Fork is a natural river channel. Average depths generally range from 3 to 6 feet deep (Chiu, 1975). Maximum depths range from 10 to 16 feet upstream near Cypress Creek. Farther upstream, maximum depths are generally less than 10 feet. Much of the watershed remains in a natural (undeveloped) state or in low-intensity agricultural use so that the quality of runoff water from most areas is good. Large tracts are protected in parks or preserves, and additional land is being purchased by various private interests and government entities for preservation.

Floodplain Plant Communities

The floodplain of the Northwest Fork of the river is a prime example of a pristine subtropical riverine cypress swamp and represents a last vestige of this community within southeast Florida (USDOI and NPS, 1982). The cypress swamp community extends 4 miles down the Northwest Fork from Indiantown Road. Originally the cypress forest extended further downstream to near river mile 5.5 (McPherson unpublished data). Today, freshwater cypress and hardwood communities share the floodplain with saltwater tolerant mangroves from river mile 8.6 to river mile 10 (see **Appendix B** and **Appendix C**) as a result of saltwater intrusion. The remaining cypress swamp community along this stretch of the river exhibits high species diversity due to the overlap of tropical and temperate zone communities. Tropical vegetation, such as wild coffee, myrsine, leather fern, and cocoplum may be found along with pop ash, water hickory, red bay, royal fern and buttonbush, which are considered to be more northern flora (USDOI and NPS, 1982). The slightly elevated areas that border the Northwest Fork of the river are dominated by slash pine and saw palmetto. Also common are areas of dwarfed and gnarled scrub oak and many herbs and grasses. Threats to floodplain vegetation include periods of saltwater intrusion within upstream areas of the river, which result in death or stress to the remaining freshwater species, replacement by salt tolerant species, such as red mangroves and replacement by exotic species such as Brazilian pepper and climbing ferns.

Existing historical aerial photographs were used to compare spatial and temporal changes in the distribution and abundance of vegetation communities along the floodplain of the Northwest Fork of the Loxahatchee River, document changes in vegetation cover, and correlate those changes to major events in the watershed. A detailed description of the methods and results of this study are available in **Appendix B**.

1940 Vegetation Communities

Figure B-2, **Appendix B** shows the distribution of major vegetation communities found along the Northwest Fork and adjacent areas (including the floodplain, wetlands in JDSP and some uplands) in 1940, based on a review of historical black and white aerial photographs. **Table 1** summarizes the coverage (in acres) and changes in coverage of each community type for 1940, 1985 and 1995.

Table 1. Interpreted Vegetation Coverages (acres) for 1940, 1985 and 1995 for the Northwest Fork and Adjacent Areas, from River Miles 4.5 to 11.2, Based on Aerial Photography.

VEGETATION	1940 Coverage	1985 Coverage	1995 Coverage	Acres Difference 1940-1985	Acres Difference 1940-1995	Acres Difference 1985-1995
Freshwater Plant Communities						
Swamp Hardwood Cypress Stream Swamp**	467	338	326	-129	-141	-12
Inland Ponds and Sloughs	59	39	39	-20	-20	0
Freshwater Marsh	NA	5	2	NA	NA	-3
Cabbage Palm	3	7	4	+4	+1	-3
Category Total	***529***	***389***	***371***	***-145***	***-160***	***-18***
Saltwater Tolerant Plant Communities						
Mangrove	163	161	152	-2	-11	-9
Other						
Disturbed or Cleared Lands	27	84	84	+57	+57	-0
TOTAL	**719**	**635**	**607**	**-90**	**-114**	**-27**

*Coverage in acres
** Since swamp hardwood, stream swamp and cypress communities could not be accurately distinguished in the 1940s photographs, these subcategories were combined to provide a basis for comparison.

Results show that the watershed was relatively undeveloped in 1940. The most obvious features are the extensive freshwater swamp and mangrove swamp forests, the abundance of wetlands associated with sloughs and wet prairies, and the lack of urban development throughout most of the watershed.

According to the 1940 U.S. Census, the Town of Jupiter contained 215 residents (**Table B-3, Appendix B**). Interstate 95 and the Florida Turnpike had not yet been constructed. The major roads at that time were Center Street, SR 706 (Indiantown Road), SR 710 (Beeline Highway), U.S. Highway 1, SR 708 (Bridge Road) and Northlake Boulevard. Although the C-18 had not yet been constructed, there was evidence of ditching from the Loxahatchee and Hungryland Sloughs to the River. The Jupiter Inlet was open in the 1940 photograph, but the presence of sandbars probably reduced the amount of saltwater coming in during high tides. The inlet was not permanently stabilized for navigation until 1947. On the Northwest Fork, tides, winds and periodic storm events may have had sufficient effects upstream past the mouth of Kitching Creek to promote growth of what appear on the photographs to be mangroves along the northern river bank, extending upstream to river mile 7.8. In **Figure B-2 of Appendix B,** the 1940s distribution of the swamp hardwood (dominated by cypress) community is color-coded green, while mangroves are color-coded orange. This coverage represents our earliest photographic record of mangrove and freshwater community distribution. Extensive freshwater communities occur upstream of river mile 6.5 and intermittently downstream to river mile 5.8.

Flow from the three main tributaries of the river and runoff from the surrounding lands feed into the northern loop of the river, while the uplands and sloughs provide a network of interconnecting lakes, ponds and wetlands (**Figure B-1, Appendix B**) that feed into the tributaries. There are extensive wetlands (prairies and four major sloughs) between Kitching Creek, the North Fork and Bridge Road at the north end of JDSP in Martin County. Two of the sloughs appear to connect the North and Northwest Forks. These four areas historically may have provided surface water flows to the river, but only Wilson Creek is still connected to the river.

Table 1 (see also **Figure B-2** in **Appendix B)** shows that in 1940, there were about 163 acres of mangroves and 467 acres of cypress and stream swamp within the floodplain. Of the total 719 acres of floodplain vegetation identified in the 1940 aerial photography, 65 percent was represented by stream swamp and cypress and mangroves represented about 23 percent. Disturbed or cleared land represented 27 acres or about 4 percent of this coverage and the remaining 8% consisted of inland ponds and slooughs and cabbage palms. Mangroves dominated the floodplain between river miles 4.5 and 6.0 and were present up to river mile 7.8. Stream swamp and cypress were present upstream from about river mile 6.5 and were dominant above river mile 8.0.

1985 and 1995 Vegetation Communities

Beyond the publicly owned lands and agricultural fields, the eastern portions of the Loxahatchee River Watershed were highly urbanized by 1985 and 1995 (see **Figure 8** on page 48). A 1999 census estimate showed the Town of Jupiter with a reported population of 33,925 residents within the city limits. Jupiter residents plus neighboring municipalities accounted for a population of 77,484 residents (**Table B-3, Appendix B**). This number, however; does not include the residents of unincorporated Palm Beach County in the western portion of the watershed (e.g. Jupiter Farms). According to the Palm Beach County Planning and Zoning

Department records, the 1999 census estimated an additional 10,506 residents in Jupiter Farms and 3,536 in Palm Beach Country Estates. Interstate 95 and the Florida Turnpike stand out as major features that bisect the landscape along with extensive areas of agriculture (primarily citrus and cattle grazing), and the 11,471 acres of JDSP.

The most striking features noted in the comparison between the 1940 photos and those taken in 1985 and 1995 were (a) the dredging and filling of former mangrove islands between river miles 4.5 and 5.5; (b) the loss of floodplain and wetlands due to apparent flow diversions, invasion of upland species and development; and (c) the effects of the placement of bulkheads along both shorelines of the estuary and lower Northwest Fork. Also, the islands and oxbows appear to have been heavily scoured over the years. These changes are reflected in total acreage differences between the 1940, 1985 and 1995 coverages. There is an overall loss of approximately 114 acres (17%) of wetland/floodplain area during this 55-year period (**Table 1**).

Figures B-3 and B-4 of Appendix B illustrate the 1985 and 1995 distributions of vegetation within the floodplain. Color infrared photography allowed for the identification of a greater number of plant categories and better observation of vegetative changes. The 1985 photo represents the distribution of vegetation at the time that the Loxahatchee was designated as Florida's first Wild and Scenic River. Whereas in 1940, mangroves were dominant between river miles 4.5 and 6.5 and were present up to RM 7.8, mangroves became dominant between river miles 5.5 and 8.7 and extended upstream to RM 10.4 by 1985. The floodplain in 1985 included 163 acres of mangroves, which represented 25 percent of the vegetation coverage in the Northwest Fork, and 389 acres of freshwater vegetation, representing approximately 61 percent of the coverage (**Table 1**). Therefore, between 1940 and 1985, there was about a 10 percent loss of freshwater vegetation and a 4 percent increase in mangroves within the floodplain area. One would suspect that mangrove encroachment should be higher; however, between 1940 and 1985, there was a loss of mangroves reflected in the category Disturbed and Cleared Land, which increased from 4 percent in 1940 to 13 percent in 1985. Also, the floodplain decreased in acreage from 719 acres to 635 acres.

There were no major changes in coverage between 1985 and 1995 (**Tables 1** and **Figures B-5** and **B-6** in **Appendix B**). This relative stability of plant communities may be attributed to two factors. First, in 1987 additional culverts and operational criteria were added to G-92 to reconnect the Loxahatchee Slough with the Northwest Fork, resulting in more water being added to the Northwest Fork (see section on *Hydrologic and Salinity Conditions* at the beginning of **Chapter 5**). Second, there was above normal rainfall (**Figure 4**) and flow to the river during the 1990s (see **Figure 19, Chapter 5**). These increased flows may have helped to stabilize the distribution of fresh and saltwater communities.

Both the 1985 and 1995 photographs show apparent changes in the distribution of mangroves and freshwater plant community coverages in the Hobe Grove Ditch and Cypress Creek areas. In 1985 and 1995, mangroves were present within the lower portion of Kitching Creek. Near the mouth of the creek, mangroves appear as forests whereas further upstream they appear as understory vegetation with a cypress/cabbage palm canopy. Areas dominated by cypress appear to be more closely associated with wider floodplains.

Summary

Results of the comparisons of aerial photographs from 1940, 1985, 1995 and other years showed the following:

- 1940 aerial photography of the watershed revealed an abundance of swamps, wet prairies, inland ponds and sloughs. Mangroves were present from river mile 4.5 to river mile 6.0 and extended upstream to river mile 7.8. Freshwater stream swamp and cypress communities were present upstream from river mile 6.5 and were dominant within the floodplain portion of the study area above river mile 8.0, comprising about 73 percent of the vegetative coverage of the Northwest Fork, while mangroves represented 23 percent.
- An apparent reduction in total acreage of the river floodplain between 1940 and 1995 can be attributed to several causes, including scouring of the riverbed, bulkheading, development, and loss of wetland vegetation to transitional and upland species due to flow diversion and lowering of water levels in the watershed. Most of the vegetation changes occurred in the lower and middle segments of the Northwest Fork and were documented by more detailed examination of the area between river miles 6.6 and 8.9 (**Appendix B**)
- By 1985, much of the watershed had been developed with the exception of JDSP. Freshwater communities represented 61 percent of the total coverage. Mangroves represented 25 percent of the coverage and may have extended upstream above river mile 10. Mangroves experienced only a 4 percent increase in overall coverage due to floodplain urbanization. Freshwater communities decreased by 10 percent.
- Freshwater flows to the Northwest Fork increased during the period between 1985 and 1995, due to construction and improved operation of the G-92 Structure and increased rainfall. These changes may account for the fact that only minor differences in vegetation coverage occurred during this ten-year period.
- Improved aerial photography that was used during 1985 and 1995 made it possible to distinguish differences in structure and composition of the freshwater communities. This improved resolution may account for the apparent increase in number of species and apparent loss of cypress dominance along the immediate river corridor upstream of river mile 9. Such changes could also be explained by the impact of saltwater intrusion and decreased surface and ground water inflow.

Wild and Scenic River Designation

In May 1985, a 7.5-mile, pristine portion of the upper Northwest Fork was designated by the U.S. Department of the Interior (USDOI) for inclusion in the Federal Wild and Scenic Rivers System, following designation by the state of Florida as a Wild and Scenic River in 1983 (C. 83-358, Laws of Florida, Approved June 24, 1983). Special consideration should be given to ensure that the watershed surrounding this portion of the river is protected to maintain natural flow conditions, good water quality and high quality natural areas. A number of management goals were developed for this system as identified in the *Loxahatchee River National Wild and Scenic River Management Plan* (FDEP and SFWMD 2000). A goal of particular relevance to the development of river flow criteria is to preserve historic communities and functions, especially the bald cypress community, which includes a number of trees 300–400 years old. The estuary, downstream from the "wild and scenic river," is part of the Loxahatchee River-Lake Worth Creek Aquatic Preserve.

Tributary Inflows

A detailed analysis of freshwater flow delivered to the Loxahatchee River and Estuary is provided in **Chapter 5.** Four major sources (G-92 and the Lainhart Dam, Cypress Creek, Hobe Grove Ditch and Kitching Creek) provide freshwater flow to the Northwest Fork. Of these four sources, the Lainhart Dam, which provides flow to the main stem of the river, is the largest contributor providing between 51 and 56 percent of the flow to the Northwest Fork during the wet and dry seasons. The main stem of the Loxahatchee River originates in the Loxahatchee Slough, a pristine cypress swamp and wet prairie wetland located southwest of the river **(Figure 5**). Outflow from the Loxahatchee Slough travels downstream through the C-14 Canal (C-14) and G-92 structure and over the Lainhart Dam to the Northwest Fork of the river.

The second largest contributor is Cypress Creek (26–32%), followed by Kitching Creek (11–13%) and Hobe Grove Ditch (5%). In terms of average dry season flows, the Lainhart Dam provides about 70 cfs; Cypress Creek, 32 cfs; Kitching Creek, 16 cfs; and Hobe Grove Ditch, 7 cfs, for an average total of 125 cfs of freshwater delivered from the Northwest Fork of the river to the Loxahatchee Estuary (see **Table 23** in **Chapter 5**).

In terms of water management, the G-92 structure (upstream of the Lainhart Dam) represents not only the largest source of water delivered to the Northwest Fork, but also the only structure that can be operated by the District to increase or decrease flows delivered to the river. Flows received from Kitching Creek are currently unregulated and are largely rainfall driven. Cypress Creek and Hobe Grove Ditch have water control structures that are operated by the Hobe-St. Lucie Conservancy District.

Hobe Grove Ditch was constructed over a historical flowway known as Moonshine Creek, and then dredged through uplands to the river in the 1960s. Water is held upstream in this system to provide recharge for irrigation wells; hence very little water is released through the structure except when flooding occurs in the groves. Cypress Creek is a primary drainage outlet for the southern portion of Pal-Mar. The water control structure helps to slow the flow from this system and hold more water upstream.

Downstream Areas

Historically, the inlet periodically opened and closed to the sea as a result of natural events. The inlet was kept open by flows from the Loxahatchee River, Lake Worth Creek and the southern part of the Indian River Lagoon. Near the turn of the century, some of this flow was diverted by creation of the ICW and the Lake Worth Inlet, and by modification of the St. Lucie Inlet (Vines 1970). Subsequently, Jupiter Inlet remained closed much of the time until 1947, except when periodically dredged. After 1947 it was permanently opened, and is presently maintained by periodic dredging (USACE 1966).

In the early 1900s, the inlet was artificially opened on several occasions. In 1921, the Jupiter Inlet District (JID) was established and provided oversight for dredging of the inlet in 1922, 1931, 1936 and every few years after 1947. Dredge and fill operations have also been carried out in the estuary embayment and forks. In the early 1900s, placement of fill at the present site of the railroad bridge narrowed the estuary at that location from about 1,200 feet to 700 feet. In the mid-1930s to about 1942, sediments were removed from areas around this bridge and used for roads and construction. In 1976–1977, an additional estimated 30,000 cubic yards were removed from the estuary at the bridge and from an area to the west extending about 600 feet. Some dredging was done in the Southwest Fork near C-18 in the late 1960s and early 1970s. In 1980, three channels were dredged in the central embayment area and an estimated 30,000 cubic yards of sediment were removed (McPherson et al. 1982).

Processes of sedimentation and erosion undoubtedly still have a profound influence in the estuary. A large horseshoe-shaped sand bar, which developed in the central embayment area over the 20 years period from 1960 to 1980, is an example of how sediment transport and deposition continue to alter bathymetry of the estuary (McPherson et al. 1982).

The United States Geological Survey (USGS) measured the volume of incoming and outgoing tides within the Loxahatchee Estuary for several days in 1980. Thirty-nine percent of the incoming tide went into the north arm of the Intracoastal Waterway on August 27. On average, 57 percent of the incoming tidal water at the inlet flowed into the Loxahatchee Estuary west of the Alternate A1A Bridge. The volume of water that enters the estuary during an incoming tide is called the tidal prism and can be estimated based on the following equation:

$$P = A \times T + F \times I$$

where: P is the tidal prism volume, A is the surface area of the estuary west of the Alternate A1A Bridge (1,280 acres), T is the tidal range, F is the area of the floodplain inundated at high tide (256 acres), and I is the average depth in the floodplain at high tide (about one-half foot) based upon observations. Using this equation, McPherson et al. (1982) calculated the tidal prism for the Loxahatchee Estuary for three days in 1980 when the direct total discharge was measured at the Alternate A1A Bridge. The mean tide range for the 1979 and 1980 water years was 2.42 feet and the mean tidal prism was estimated to be 3,226 acre-feet. This volume represents about 63 percent of the total volume of the estuary west of Alternate A1A. In a related study, Chiu (1975) reported that 45 percent of the tidal flow entered the Loxahatchee River Estuary, while 55 percent enters the northern and southern branches of the Intracoastal Waterway.

These data indicate that freshwater inflow to the Loxahatchee River Estuary is very small in comparison with tidal flow. Dry season freshwater inflows from the major tributaries represented only about one percent of the tidal inflow at the A1A Bridge on April 16 and August 26 and 28, 1980 (McPherson et al. 1982). Total freshwater inflow from the same tributaries during the wet season (May to September 1980) represented about five percent of the total tidal discharges at the Alternate A1A Bridge based upon the mean tidal prism. Of this total freshwater inflow (52,870 acre-feet), 77 percent was discharged into the Northwest Fork, 21 percent into the Southwest Fork from the C-18 and two percent into the North Fork (McPherson et al. 1982).

Central Embayment

The central embayment is shallow with an average depth of 3.5 feet, maximum depth of 15 feet and an area of 380 acres (Russell and McPherson 1984; FDEP 1998; Antonini et. al. 1998). The central embayment is dominated by tidal changes. Physical changes in the estuary, such as permanent opening of the Jupiter Inlet, dredging of main channels, expansion and contraction of the opening at the Florida East Coast Railroad trestle and water control structure management have influenced salinity regimes in the estuary (Law Environmental, Inc. 1991b).

In terms of freshwater flow, the central embayment receives on average about 283 cfs (560 acre-feet/day) of freshwater from all surface sources during the wet season conditions (**Table 23, Chapter 5**). This amount is reduced by about 34 percent during the dry season to 187 cfs (370 acre-feet/day. Inflows to the central embayment are highly influenced by releases from S-46, which can release water up to 3240 cfs during extreme flood events.

Oyster reefs in the central embayment contain small and mostly relict shells, and are associated with shoals near points, sandbars and mangrove islands. Thinning, narrow bands of seagrass were observed along the shoreline of the upper central embayment and three tributaries (Law Environmental, Inc. 1991a). Historical evidence indicates that this section of the estuary had highly variable salinity regimes, because of the periodic opening and closing of the Jupiter Inlet due to natural events.

The central embayment contains viable seagrass and oyster communities, which indicates that this area receives sufficient freshwater flow to encourage growth of oysters, while at the same time, there is a need to avoid excessive freshwater discharges that will destroy these biological communities. Maintenance of a salinity regime in the range between 15 and 30 parts per thousand (ppt) should meet these general requirements. Monitoring is needed to ensure that any proposed dredging in the inlet and the embayment area does not result in further saltwater intrusion. West of the bridge crossings, from river miles 2.0 to 2.5, the central embayment of the Loxahatchee Estuary divides into three branches -- the North, Northwest and Southwest Forks **(Figure 2).**

North Fork

The North Fork is a very shallow tributary and presently contributes only a small percentage of the total freshwater flow to the estuary (Russell and McPherson 1984; Sonntag and McPherson 1984). Estuarine conditions extend approximately 5 miles up this branch from the mouth of the Inlet (McPherson and Sabanskas 1980). The North Fork of the estuary has an average depth of 3.4 feet, maximum depth of 6.6 feet, an average width of about 0.15 miles and covers a total area of about 200 acres. Freshwater flow to the North Fork is uncontrolled. Russell and McPherson (1984) indicated that freshwater flow from the North Fork represented only about 2 percent of total freshwater flow to the estuary. Much of the upper end of the watershed of the river lies within JDSP. The shoreline along the lower estuary is surrounded by residential development and most of the shore is bulkheaded. The sediments generally consist of fine sand and mud. Some areas have very deep pockets of soft mud that has a high content of organic material. Water quality is often poor due to high levels of turbidity and color that limit light penetration, low levels of dissolved oxygen (DO) and occasional high concentrations of fecal coliform bacteria (Dent et al. 1998). Due to the low input of freshwater, bottom salinities in the lower section of the North Fork are generally above 25 ppt, while salinities further upriver average about 14 ppt.

Management considerations in the North Fork include the need to improve water quality conditions. Reduction of turbidity levels and suspended solids would help increase light penetration to encourage growth and development of seagrasses. Retrofitting of existing storm water systems or other actions that can help reduce turbidity would also be beneficial to oysters, other benthic invertebrates and fish populations. Any steps that can be taken to remove or stabilize the soft organic sediments will help to reduce turbidity and improve biological conditions. Although there is no direct control over freshwater inflows to this reach of the estuary, any actions that can be taken to improve flushing and exchange of water with the North Fork estuary should be encouraged as a means to improve water quality.

Northwest Fork Estuary

The Northwest Fork of the Loxahatchee Estuary has been less impacted than the Southwest Fork, but has been considerably altered from its original condition due to development of the shoreline and dredging. The estuarine portion of the Northwest Fork extends from the central embayment north and west for approximately 2 miles to a point (near river mile 4.5) where the estuary constricts to form the river channel (**Figure 2**). This area has an average width of about one-half mile, depth of 4.2 ft, maximum depth of 12.5 ft, and contains an area of about 320 acres. Brackish water conditions can extend for many miles upstream, depending on flow. For this analysis the dividing line between the river and the estuary is approximately river mile 5, which is located downstream from JDSP. This section of the estuary receives the direct outflow from the Loxahatchee River and thus may experience large and rapid fluctuations in salinity. The Northwest Fork originally drained most of the Loxahatchee basin and still provides, on average, about 65–67 percent of the total freshwater flow to the estuary. During dry periods, as much as 89–94 percent of the total flow to the estuary is derived from the Northwest Fork (**Table 24, Chapter 5**). Generally the waters remain saline during most of the year due to saltwater inflow from the inlet.

Flows from the Northwest Fork of the Loxahatchee River historically were sufficient to maintain the estuary as a brackish water system that supported diverse estuarine fish, benthic fauna and oyster communities in its upper reaches and more marine seagrass communities downstream near the juncture with the central embayment. Bottom salinities in the Northwest Fork Estuary generally remain above 25 ppt. Bottom salinities are fairly stable in the range from 20 ppt up to 35 ppt during typical wet season conditions. The water column can be highly stratified, however so that freshwater may be present at the surface. Salinities throughout the Northwest Fork may decline below 10 ppt during extreme discharge events (Russell and McPherson 1984).

Southwest Fork

The Southwest Fork (**Figure 2)** has been heavily altered, dredged and channelized (McPherson et al. 1982). The Southwest Fork is important for navigational and recreational use because it provides access to local marinas and private homes. It also provides a mixing zone for freshwater discharges from C-18 before they reach more sensitive grass beds and oysters located further downstream.

Freshwater discharges to this waterway, with the exception of a couple of small creeks, are controlled by S-46, an automated structure providing overflow from Canal C-18. Salinity is influenced in the Southwest Fork primarily by the S-46 structure in C-18 (FDEP, 1998). The lower segment of the Southwest Fork extends for about 0.7 miles from its junction with the central embayment to the eastern end of the C-18, has an average width of 0.16 miles, depth of 5.5 ft and covers an area of about 70 acres. The C-18 is reported to drain approximately one-half of the entire Loxahatchee watershed (Hill, 1977) and the S-46 water control structure prevents saline waters from moving upstream beyond river mile 4.8. Estuarine conditions occur in the C-18 for a distance of about 1.5 miles below the base of S-46. This portion of the canal has an average width of about 220 feet, depth of 10 ft and an area of about 40 acres. The Southwest Fork represents about 7 percent of the total estuarine area of the Loxahatchee River system west of the Alternate A1A Bridge. Discharges from C-18 through the Southwest Fork provide about 33 percent of the total freshwater inflow to the estuary **(Table 2**). Periodically, very large discharges of floodwaters ranging upwards from 1,000–3,000 cfs occur from the C-18 Basin that turn much of the estuary into freshwater. In contrast, during dry periods there are long periods of time when the estuary receives no flow from C-18.

The Town of Jupiter Water System operates a reverse osmosis (RO) water treatment plant that produces a concentrate solution as a waste product that is discharged to the C-18 at the Central Blvd. Bridge, downstream of the S-46 structure. The RO concentrate salinity is typically about 16 ppt, and is less saline on average than the receiving water. The current plant is permitted to discharge up to 4 million gallons per day (mgd) of RO concentrate from water obtained from the Floridan Aquifer, and currently discharges an average of 2.0 MGD. The current permit allows a mixing zone of 400 meters on each side of the outfall. This water flows to the estuary in an area of Class II surface waters (shellfish harvesting), although no harvesting is conducted now. Total ammonia concentrations average approximately 2.5 milligrams per liter (mg/l), and have been reported as high as 7 mg/l. The Town of Jupiter and the DEP have agreed to work together in assessing any impacts from the RO concentrate during the upcoming Total Maximum Daily Load (TMDL) review [Letter from Tom Swihart (FDEP) to SFWMD, June 18, 2001]. Additional RO concentrate is released by the Village of Tequesta Water Treatment Plant near the northeast side of the US Highway 1 Bridge, just downstream of the embayment area. This release is relatively new and does not appear to be causing any problems, due to the presence of strong currents in this area near the inlet.

The Southwest Fork historically was an estuarine system that probably maintained slightly higher salinities than the Northwest Fork Estuary, supporting both oyster and seagrass bottom communities. Bottom salinities in this portion of the estuary generally remain above 25 ppt except during periods when large amounts of water are discharged from C-18.

THE LOXAHATCHEE ESTUARY

Physical Features

Inlet Configuration/Coastal Influences

Key events in the history of hydrological alterations of the estuary include the creation of the ICW in the late 1800s and early 1900s by dredging the connection between Lake Worth and the Jupiter Inlet, continuing into Biscayne Bay to the south (Russell and McPherson 1984). The Lake Worth Inlet was also constructed and modifications to the St. Lucie Inlet during this period further diverted flows away from the Jupiter Inlet. Fill added to the present site of the Florida East Coast Railroad trestle reduced the cross-sectional area of the river mouth in the early 1900s (Wanless et al. 1984). Past measurements and calculations indicate that 56 percent of the tidal flow enters the northern and southern branches of the ICW (Chiu 1975). Other activities being equal, those projects that tend to increase tidal exchange and prism, and decrease shoaling of the Jupiter Inlet, should produce a saltier system in the Loxahatchee Estuary by increasing tidal exchange and decreasing the residence times of freshwater within the system.

Drainage Alterations

In total, drainage alterations have rerouted flows to reduce the effective size of the Loxahatchee Basin and therefore total runoff (McPherson and Sabanskas 1980). These drainage alterations primarily serve to deliver freshwater runoff to the estuary more rapidly and abruptly, flushing the estuarine portions with higher maximum flows. During periods of dry weather, however, drained marshes and lowered water tables are not able to provide the same historic base flows of freshwater to prevent upstream encroachment of saline estuarine waters (Rodis 1973; Alexander and Crook 1975). Overall lowering of the water table throughout the watershed due to canal construction and the need to maintain lower water levels to protect subsequent land development have resulted in a net loss of an estimated 8,000 acre-feet of storage in the C-18 Basin (SFWMD 2002).

Various proposals have been developed and actions implemented to increase the amount of freshwater flow from the Northwest Fork or reduce the upstream movement of saline water. These proposals include a modification of the release schedule from S-46 to permit discharge only during large storms, installation of an additional culvert at G-92 and construction of physical barrier or weir across the Northwest Fork (FDNR 1985; Birnhak 1974). The capacity of G-92 was increased in 1987. Due to this increased capacity, revised operating criteria and abnormally high rainfall conditions during eight of the past ten years (**Figure 4**), the average amount of water released to the Northwest Fork over the last decade has increased. This increased flow, however, has not been sufficient to protect the river from the periodic upstream movement of saltwater during dry periods, or to substantially alter salinity conditions in the estuary.

Shorelines

Shorelines near the Florida East Coast Railroad trestle and in the central embayment are mostly altered upland and wetland areas, although there are some remaining areas where natural upland fronts the water. Above the river delta, shorelines are heterogeneous, with mixed uplands, wetlands and filled areas. Much of the JDSP shoreline is undeveloped wetland and upland shoreline that fronts directly on the river.

In a 1990 survey, hardened shorelines, including bulkhead, rip-rap and debris-filled banks, occupied most (about 65%) of the downstream reach (river miles 0.9 to 2.0) and more than 60 percent of the shore was hardened to river mile 4. The relative amount of hardened shore declined by approximately half in each successive mile of the Northwest Fork. Overall, about 37 percent of the shoreline of the Northwest Fork was hardened, compared to 51 percent in the North Fork and 12 percent in the Southwest Fork. Shoreline hardening increases with river mile in the North Fork, but declines once the stream enters the Park (Law Environmental Inc. 1991a).

Sediments

The uppermost sediment veneer in an estuary controls and/or affects sediment resuspension, exchanges of oxygen and nutrients between the water column and bottom, and the number and kinds of animals living in and on the bottom. The types of bottom sediment in the Loxahatchee River Estuary vary with water depth, flow characteristics, location in the estuary and biological community.

Sonntag and McPherson (1984) observed that fine sand is predominant throughout much of the estuary. Shell debris, larger than sand size, comprises less than one percent of the sediment except on oyster bars where it is abundant. Silt, clay and organic matter are least abundant in the channels and on sand bars, somewhat more abundant in adjacent seagrass beds, and in greatest abundance in the black to gray sediments that occur in the estuary. Soft, black sediments, which are common in the deeper waters of the estuary, contain the largest percentage of clay, silt and organic matter. Black and gray sediments range in thickness from a few inches to several feet.

Law Environmental Inc. (1991a) noted that the central embayment contains sediments that are white in color on the surface, but sediments 2.0 centimeters (cm) or more below the sediment surface are blackened over large areas. In general, top sediments of the central embayment contain less than 10 percent silt and clay whereas in the three tributaries sediments usually range from 10 to 50 percent silt and clay. The upper reach of C-18 contains a higher proportion of silt and clay (65–74%). The Northwest Fork has low amounts of fine surface sediment in the mangrove-forested area and at the river delta. Deposition of fine organic matter has been observed in deep holes in the side channels of the main stem of the river. The two river deltas contain coarse sediment throughout due to peak-flow deposits and bed transport. The tidal delta sediments are much finer at depth because of oceanic material that is deposited in the inlet. Sediments in the shallow areas off Pennock Point (**Figure 2**) had unusual color and texture, indicating that these mudflats are sites of lateral ground water movement into the estuary (Law Environmental Inc. 1991a).

Salinity

Those regions with the highest variability of surface and bottom salinities are presumably most responsive to hydrologic variables, such as tide stage and discharge. In general, surface salinity is most variable between river mile 2.6 and river mile 6.9, while bottom salinity is most dynamic between river miles 5.0 and 8.0 (**Figure 2**). The station at river mile 5.0 experiences both extremely saline and extremely fresh conditions. Stratification is prominent between river miles 2.6 and 8.0 and is usually at a maximum at river mile 3.7. Little vertical stratification generally occurs below the confluence of the three forks (Law Environmental Inc. 1991a)

Biological Resources

Biological resources of the Loxahatchee River Estuary are greatly affected by freshwater and tidal flow and by human activities. In undisturbed estuaries in south Florida, mangrove forest, oyster bars and seagrass beds constitute major biological communities in brackish and saline environments. Mangroves are abundant in the upper reaches of the Northwest Fork of the Loxahatchee Estuary. Marshes are few and small in size, and are usually limited to a narrow fringe of emergent grass species seaward or landward of mangroves, or growing along upland shorelines. Seagrass communities are present in the central embayment and oyster bars grow in the estuary where there is suitable, undisturbed substrata and adequate tidal flow and salinity.

Mangroves

Mangrove-swamp, consisting primarily of red mangroves (*Rhizophora mangle*) with occasional white mangroves (*Laguncularia racemosa*) is the dominant natural feature along the shorelines of brackish-water areas of the Northwest Fork. “Forests” of mangrove only occur in Jonathan Dickinson Park. Elsewhere, mangroves grow as thin borders along natural shorelines, filled banks or in front of hardened shorelines. In the Loxahatchee River Estuary, mangrove forest is most extensive in the Northwest Fork. Small stands of mangrove occur in the upper reach of the North Fork, in the central embayment, in Jupiter River and other small tributaries and on several islands. Mangroves along the Northwest Fork range from brackish water estuary conditions near the eastern edge of Jonathon Dickinson Park at river mile 6 into predominantly freshwater environments and are eventually replaced by a floodplain swamp community (dominated by cypress) by river mile 10.

Mangroves are very salt tolerant and tend to colonize shorelines where the substrate has been stabilized or protected from the effects of wave action or erosion. The continued spread of mangroves upstream in the river floodplain, displacing less salt tolerant species, such as cypress and hardwoods, has been viewed as an impact to the ecosystem. These slow changes in river vegetation communities are linked to the combined effects of saltwater intrusion caused by the permanent stabilization of Jupiter inlet, dredging of the estuary and construction of C-18.

Even though the spread of mangroves into formerly freshwater environments is viewed as an adverse condition for the river, mangroves serve an important role in the estuary ecosystem, since these plants provide a stable substrate for many other species to colonize (Savage, 1972). Mangroves are also a significant source of primary productivity and the physical and bacterial decomposition of mangrove leaf litter provides a major food source for detritivores in the estuary food chain (Heald and Odum, 1970). Mangroves are susceptible to frost damage and may be completely destroyed during a hard freeze.

Submerged Aquatic Vegetation

Four species of seagrasses are commonly observed in the Loxahatchee Estuary. Shoal grass (*Halodule wrightii*) tends to be the most abundant species. Stargrass (*Halophila* sp.) sometimes occurs with shoal grass, but its biomass tends to be insignificant except in localized areas. The presence of Johnson's seagrass (*Halophila johnsonii*) in the Loxahatchee Estuary was noted by Kenworthy (1992). Manatee grass (*Syringodium filiforme*) and turtlegrass (*Thalassia testudinum*) occur rarely in the estuary. The distribution and composition of seagrass communities changes considerably from year to year. Shoal grass has the broadest salinity tolerance, followed by turtle grass and manatee grass. *Halophila* spp. are the most stenohaline species of those in the study area (Zieman, 1982). Turtlegrass has an optimum range of 24–35 ppt. Salinity, temperature and water clarity are quite variable in the estuary compared with the north arm of the ICW, where inflow of ocean water maintains relatively high salinity, moderate temperature and relative high water clarity. Manatee grass and turtlegrass are dominant under these conditions and form dense stands just north of the estuary in the north arm of the ICW.

At the time of the survey by McPherson et al. (1982), shoal grass was the dominant species, extending from slightly above to several feet below the low tide line. The largest area of shoal grass, about 70 acres, occurred in the eastern part of the central embayment. The biomass diminished in the western part of the central embayment and in the forks of the estuary. Only sparse growth was observed in 1980 near Pennock Point, which is located at the juncture between the central embayment and the Northwest Fork.

During a 1990 survey conducted by Law Environmental, Inc. (1991a), the highest density of seagrass distribution occurred near the inlet, with heavy growth on shoals and bars. Thin, narrow bands of grass were observed along the shorelines of the upper central embayment and the three tributaries. The best, developed fringing beds were along Pennock Point. No beds were found upstream of the mouth of the Southwest Fork. Grasses were found in isolated patches along the western shore of the Northwest Fork, immediately upstream of Pennock Point. Grasses grew in a narrow, thin strip along both banks of the North Fork to the Tequesta Drive Bridge.

Shoal grass is the dominant seagrass species upstream of the Florida East Coast Railroad trestle. It extends from the trestle area to the limits of seagrass distribution in each tributary. Other species occurred in large to small uniform beds, or patches within shoal grass beds, between the Florida East Coast Railroad trestle and Anchorage Point. Moving upriver from the trestle, star grass ended first, and then turtle grass and manatee grass, at about the same river location. Small areas of turtle grass occurred upstream along the southern shore of the central embayment, almost to the mouth of the Southwest Fork. Small areas of manatee grass were found along the west bank of the Northwest Fork. None of the grasses grew in depths of water greater than about six feet at low tide. The species most often found in the deeper areas was shoal grass. The seagrass species that are less tolerant to freshwater (i.e., turtle, manatee and stargrass) grew on level, shallow and often white-colored sands (Law Environmental, Inc. 1991a).

Law Environmental, Inc. (1991a) compared their data to previous studies and noted that significant changes had occurred in the distribution and abundance of seagrasses in the estuary during the past 10 years. Some of these changes could be attributed to seasonal variation, differences in techniques or mapping errors. In spite of these differences, a large area of seagrasses between the channel and south shore apparently disappeared over a five-year period from 1980 to 1985 and grasses (mostly shoal grass) colonized sand bars that were not vegetated in 1980–1981. Species composition also changed from 1985 to 1990. Deeper water fringing beds of star grass were not conspicuous in 1990. Manatee grass extended its range, with expansion into former shoal grass beds in the lower part of the central embayment, or upriver to about river mile 2.5. These changes may have been the result of succession, encouraged by stable, relatively high salinities in the eastern end of the central embayment. This corresponds to a river reach where mean bottom salinity was greater than 30.0 ppt and variance was low. The western portion of the embayment was an area of high turbidity and few seagrasses, but with some oysters, suggesting transitional conditions.

A waterway evaluation study conducted by Antonini et al. (1998) included data collected in 1994, 1996 and 1998. These data indicated that seagrass communities in the middle of the central embayment shifted significantly between sampling periods, presumably in response to changes in sediment composition and distribution, river flow and perhaps boating activity. Their data also indicated that seagrass communities (species not listed) occupied the lower reaches of the North, Northwest and Southwest Forks in areas that did not contain seagrasses in 1982.

A recent survey by Ridler et al. (1999), which included one site in the central embayment, showed moderate changes in distribution of seagrasses at this location relative to the data collected by Antonini et al. (1998). More importantly, Ridler et al. (1999) found that Johnson's seagrass (*Halophila johnsonii*) was more abundant than shoal grass at the site they sampled. A subsequent study conducted in the summer of 2000 at their study site in the central embayment showed that overall seagrass distribution increased from 32 percent bottom coverage to 70 percent bottom coverage, relative to the 1998 study. However, the coverage of Johnson's seagrass declined from 43 percent to 10 percent during that same period (Ridler et al. 2000).

Because of its limited geographical distribution (i.e. Sebastian Inlet to northern Biscayne Bay), National Marine Fisheries Services published a rule on September 14, 1998, which listed Johnson's seagrass as a threatened species. A threatened species recovery team was convened in February 1999 to prepare a recovery plan and develop recommendations for critical habitat for this species. One of the 10 sites identified as essential habitat is located just within Jupiter Inlet and the Loxahatchee River. The recovery team established five criteria for establishing this designation, which included: (1) populations which have persisted over 10 years; (2) populations with persistent flowering; (3) locations at the northern and southern range limits; (4) populations with unique genetic diversity; and (5) core locations with a documented high abundance of grass compared to other areas in the species' range. The 4.3-acre site located just west of Dubois Park near the entrance to Zeke's Marina will continue to be monitored as a part of the recovery plan (National Marine Fisheries Service 2000). Any proposals to alter flow conditions in the Northwest Fork to the extent that they may impact the local population of Johnson's seagrass, will have to be reviewed and approved by the National Marine Fisheries Service.

Oysters

Periodic tidal exposure, sediments and water quality influence oysters and their associated fauna. Oyster spawning depends on salinities greater than 7.5 ppt and spat grow best above 12.5 ppt; the optimum range of salinity for adult oysters is 10–28 ppt and lower salinities repel marine predators (Sellers and Stanley 1984). In the Loxahatchee Estuary, oyster reefs grow mostly in intertidal and shallow subtidal areas. Oysters also grow on rip-rap, seawalls and bridge piers. Islands upstream of the Northwest Fork River delta (river mile 4) are fringed with oysters growing on red mangrove roots. Reefs grow as point bars, usually on the downstream ends of the mangrove islands. In 1990, reefs were present in the Southwest and Northwest Forks but were rare in the North Fork. Reefs in the central embayment are small; contain mostly relict shells; and are associated with shoals, point-bars and mangrove islands (Law Environmental, Inc. 1991a).

Field observations in the Loxahatchee Estuary (Law Environmental, Inc. 1991a) showed that oysters were smallest at upstream and downstream locations and largest in the central part of their range. In the Northwest Fork, the largest living oysters (standard length 80–90 millimeters) occurred between river miles 4.0 and 6.0 (**Figure 2**), where average high tide surface salinities were between 7 and 22 ppt, and ranged from about 2 to 28 ppt. The river delta ("S-Bar"), located at approximately river mile 4.5 (**Figure 2**), played a controlling role in upriver salinities and was the most active oyster ground (Law Environmental, Inc. 1991a).

Benthic Macrofauna

Various surveys of macrofauna have been conducted in the estuary (McPherson et al., 1984, Strom and Rudolph 1990, Law Environmental, Inc. 1991a, Dent et al., 1998). McPherson et al. (1984) studied fouling organisms in the estuary and noted that two of eight barnacle species occurred only in marine salinities, while other species occurred in lower salinities. Only one species occurred as far upstream as the JDSP. Overall, diversity, density and growth of fouling communities are greater in high salinity areas, greater before the summer wet season, and higher after tropical storms. Strom and Rudolph (1990) observed that representatives of brackish fauna occurred as far upstream as the Trapper Nelson site (river mile 10.7), although most of the species at this location were typical of freshwater environments.

Samples collected by Law Environmental, Inc. (1991a) from oyster reef communities in the estuary contained a total of 41 invertebrate taxa within seven phyla. Analyses of these data indicated that four taxa had a broad distribution along the river and occurred upriver to the limit of their survey within JDSP. Almost a third of the taxa were marine species, requiring high salinities that occurred no farther upstream than the oyster reef at the mouth of the Southwest Fork. Based on distribution and abundance of oysters and associated macroinvertebrates, the authors concluded that salinities in the central embayment were high (>30 ppt), with a narrow range, and salinities near the river delta are lower (3–20 ppt) with a wide range. Salinities near JDSP were generally below 20 ppt and eventually fall to near zero at river mile 7 (**Figure 2**), suggesting that brackish conditions occur between the river delta and the Park. A recent status report on ongoing studies (Dent et al., 1998) listed 410 taxa that occur in the estuary and adjacent waters. The locations of estuarine stations sampled and the major species collected in these samples are shown in **Table 2** and **Figure 6.**

Table 2: Synopsis of General Taxonomic Composition 1992–1997 (from Dent et al., 1998)

Station	Abundance (total mean)	annelid	crust	mollusc	Other	Total # of Species	Dominant Taxa'	Genus species	Mean total taxa	Mean diversity (Shannon -Wiener)	Mean % dominant
41	*2812*	*54*	*36*	*64*	*4*	*73*	*Pelecypoda*	*Macominae unid,*	*23*	*2.92*	*60.96*
							Polychaeta	*Pnonospio sp.*			
							Oligochaeta	*Tubificidae unid.*			
							Polychaeta	*Polydora socialis*			
							Polychaeta	*Scolelepis texana*			
60	*1599*	*39*	*41*	*15*	5	*85*	*Tanadacea*	*Hargeria repax*	*18*	*3.34*	*52.94*
							Polychaeta	*Capitella capitata*			
							Nemertinea	*Nernenea unid.*			
							Polychaeta	*Scolelepis texana*			
							Gastropoda	*Caecum pulchellum.*			
70	*2795*	*61*	*22*	*11*	6	*113*	*Polychaeta*	*Streblospio benedicti*	*28*	*3.17*	*77.75*
							Polychaeta	*Capitella capitata*			
							Polychaet	*Branchiomma sp.*			
							Amphipoda	*Grandidierella bonnieroides*			
							Polychaeta	*Lumbrineris verrilli*			
62	1913	17	48	13	22	*76*	*Isopoda*	*Cyathura polita*	*19*	*2.96*	*52.81*
							Diptera	*Polypedilum scalaenum group*			
							Amphipoda	*Grandidierella bonnieroides*			
							Tanadacea	*Halmyrapseudes bahamensis*			
							Tanadacea	*Hargeria repax*			
54	*1605*	*44*	*42*	*4*	*10*	*66*	*Polychaeta*	*Streblospio benedicti*	*13*	*2.32*	*48.62*
							Amphipoda	*Grandidierella bonnieroides*			
							Tanadacea	*Halmyrapseudes bahamensis*			
							Amphipoda	*Ampelisca vadorum*			
							Nemertinea	*Nernenea unid.*			

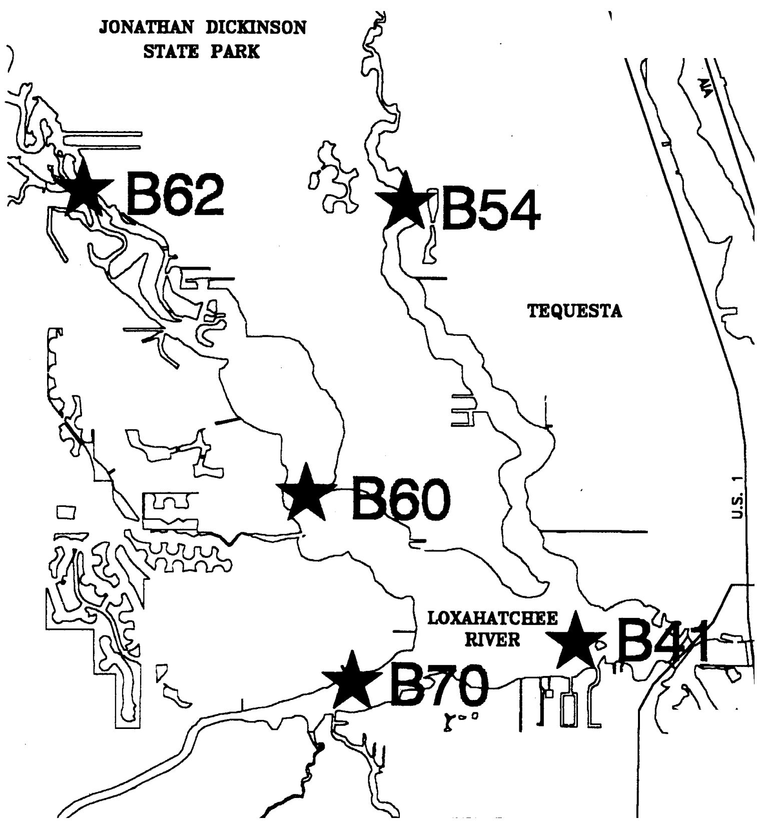


Figure 6. Location of Loxahatchee Estuary macroinvertebrate sample sites used by Dent et al. 1998.

Results of the recent studies (Dent et al., 1998) indicated that the estuarine stations, overall, generally contained fewer taxa than stations located in more marine waters. Estuarine stations contained a larger proportion of crustaceans (44%) than annelids (33%) or molluscs (11%), whereas stations in more marine waters contained a predominance of annelids (58%), about 30 percent crustaceans and 7 percent molluscs. Preliminary analyses of these data, and comparison with data from other studies, suggest that this invertebrate community shows seasonal changes in species composition, short-term changes due to specific rainfall or discharge events and long-term trends.

Several studies have examined fish communities within the Loxahatchee River, including Christensen (1965), Synder (1984) and Hedgepeth (unpublished). Salinity studies have been conducted by Birnhak (1974), Rodis (1973), Chiu (1975) and Russell and McPherson (1984). The Loxahatchee River Environmental Control District has ongoing studies of fishes and salinity as well as invertebrates and seagrasses. Studies of fishes indicate that a significant relationship exists between community composition and salinity on the Loxahatchee River. The upstream area of the river (above river mile 9) is characterized by freshwater species and the lower portion (from the inlet to river mile 5) is characterized by marine and estuarine species.

Fishes

Data from a study of fishes in the Loxahatchee Estuary by Hedgepeth (unpublished) and Hedgepeth et al. (2001) indicate that season of the year, salinity and availability of habitat affect fish abundance, distribution and diversity in the estuary. The dominant fishes in the Loxahatchee Estuary are listed in **Table 3.**

Table 3. Relative Abundance and Ranking of the Most Abundant Fishes in the Loxahatchee Estuary, Based on Samples Collected During 1982–1983 (Hedgepeth et al., 2001).

Species	Specimens Rank	Biomass Rank	Appearance Rank	Sum of Ranks	Overall Rank
Dasyatis americana	16	15	16	47	19.3
Harengula humeralis	8	14	16	38	12.5
Harengula jaguana	2	3	16	21	7
Jenkinsia lamprotaenia	15	16	16	47	19.3
Sardinella aurita	9	12	16	37	11
Anchoa hepsetus	**1**	**2**	**13**	**16**	**3**
Anchoa lyolepis	6	16	16	38	12.5
Anchoa michilli	**3**	**8**	**7**	**18**	**5**
Synodus foetens	16	16	15	47	19.3
Strongylura notata	16	9	6	31	10.5
Strongylura timucu	16	16	11	43	15
Trachinotus falcatus	16	16	12	44	16
Diapterus auratus	16	13	9.5	38.5	13
Eucinostomus argenteus	**4**	**4**	**1**	**9**	**1**
Eucinostomus gula	**10**	**5**	**2**	**17**	**4**
Eucinostomus jonesi	13	16	16	45	17
Gerres cinereus	14	16	16	46	18.5
Archosargus probatocephalus	16	16	14	46	18.5
Lagodon rhomboides	12	10	5	27	9
Leiostomus xanthurus	**5**	**1**	**9.5**	**15.5**	**2**
Mugil cephalus	7	7	8	22	8
Mugil curema	11	6	3	20	6
Sphyraena barracuda	16	11	4	31	10.5
Spheroides testudineus	16	16	10	42	14

Bold text indicates the most abundantspecies abundant species

Peaks of anchovies and herring were noted during the month of February, while sciaenids, anchovies, herring and mojarras peaked in July. These peaks reflected spawning periods for these groups. The seagrass beds of the central embayment, the lower North Fork and lower Southwest Fork tend to support the highest number of species and individuals (**Table 4**). Abundance and diversity were also higher at sites where average salinities were above 25 ppt. At sites where salinities averaged 5 ppt. or lower, the number of species declined significantly. The most abundant species were striped anchovy (*Anchoa hepsetus*); scaled sardines (*Harengula jaguana*); spotfin mojarra, (*Eucinostomus argenteus*); and spot (*Leiostomus xanthurus*).

Table 4. Numbers of Fish Collected in Loxahatchee Estuary as a Function of Salinity (1982–1983)

Station Location	# of Individuals	# of Species	Salinity Mean	Salinity Minimum	Salinity Maximum
Loxahatchee River	258,482	144	15.6	0.0	35.0
Embayment Area	185,936	102	24.6	3.0	35.0
Lower North Fork	20,405	62	21.3	6.0	35.0
Upper North Fork	945	30	3.7	0.0	22.0
Mid-Northwest Fork	911	30	4.6	0.0	19.0
Upper Northwest Fork	869	40	0.4	0.0	4.0
Lower Southwest Fork	49,416	68	9.8	0.0	27.0

Source: Hedgepeth et al. 2001

Manatees

The Florida manatee (*Trichechus manatus*) is an important marine mammal that lives in or seasonally visits the Loxahatchee River system (Packard, 1981). Manatees are protected at the federal level by the Marine Mammal Protection Act of 1972 and the Endangered Species Act of 1973. At the state level they are protected by the Florida Manatee Sanctuary Act of 1978, which establishes the entire state as a refuge and sanctuary for manatees. Manatees are also protected by the Loxahatchee River-Lake Worth Creek and Indian River Lagoon Aquatic Preserve Management Plans (Law Environmental, Inc. 1991b). Recently, the United States Fish and Wildlife Service (USFWS) developed a Manatee Recovery Plan (USFWS 1996). The State of Florida requires 13 counties within the state (including Martin and Palm Beach Counties) to develop individual Manatee Protection Plans for waters within their jurisdictions. The USFWS further identified actions that need to be taken to protect manatees as part of the Multispecies Recovery Plan (USFWS 1999).

The Loxahatchee River (Northwest and Southwest Forks) is considered a high priority water body because this area has a well documented history of manatee use. Manatees are found primarily in the Southwest Fork near S-46, the lower North Fork, Jupiter Inlet (river mouth) and residential canals. Nearby Jupiter Sound has also been identifed as a seasonally important manatee feeding ground. The largest concentrations of manatees occur in October, January and December (Law Environmental, Inc., 1991b). Manatees and their calves have been observed apparently drinking freshwater at the S-46 structure. This area may also be an important nursery area and mating behavior has been observed in this vicinity (Law Environmental, Inc. 1991b). Although manatees can often be seen skimming freshwater off the surface and congregating at spillways and other freshwater sites, ingestion of freshwater in this manner is not a requirement

(USFWS 1996). In general, manatees avoid areas with high boat traffic and tend to migrate upstream into JDSP during rough weather. Concerns have been raised that hydrologic alteration of freshwater flows delivered to the estuary could potentially contribute to changes in the distribution or abundance of submerged aquatic plant communities, a reduction in water quality and/or a reduction in adequate levels of warm water that manatees require (FDEP 1998).

Estuary Water Quality

Water quality in the estuary is a dynamic process. Estuaries are receiving bodies for discharge from tributary rivers and streams and ground water inflow. This water mixes with seawater that is exchanged through the mouth of the estuary and the inlet during daily tidal cycles and is subject to monthly and seasonal changes in flows and tides as well as the effects of severe storm events. Water quality in the estuary is thus highly variable and is subject to potential contamination or degradation of water quality from both directions. Many freshwater and marine organisms periodically use the resources of an estuary during parts of their life cycles and some organisms are highly dependent on the dynamic range of conditions in an estuary to survive. The productivity of an estuary depends upon maintaining a sufficient range of variation, while providing adequate stability of the distribution of this range to prevent undue stress on the organisms that live in these systems.

The nutrients that enter the system from upland runoff, combined with the transition from freshwater to saltwater environment, can result in large concentrations of brackish water organisms that exploit these conditions. Planktonic (floating) organisms generally live near the surface where oxygen concentrations and light levels are highest and tend to move back and forth due to the action of tide and wind. Benthic (bottom dwelling) organisms are generally restricted to particular locations and can be severely damaged by rapidly fluctuating conditions. Nektonic (swimming) organisms can move throughout the estuary and seek out favorable conditions.

Salinity

Freshwater from rivers such as the Loxahatchee contains little or no salt and is less dense than seawater. Freshwater tends to “float” above saltwater, resulting in stratification of salinity and often other water quality conditions unless the water is very shallow or is well mixed by wind or turbulence. Estuaries typically contain a range that varies from very low salinity (less than 5 ppt) near the upstream end to full strength seawater (35 ppt) at the ocean interface. This range of salinities is important because many types of organisms are adapted to utilize particular salinity ranges. The management goal for an estuary should therefore be to provide an appropriate flow regime from the river that, when balanced with the influx of seawater, will create a distribution of freshwater, brackish and marine salinity conditions in the estuary that is seasonally stable and sufficiently extensive so as to maintain the desired species composition.

Nutrients

Estuaries typically receive large amounts of nutrients. Ground water is often high in nutrients, such as nitrogen and phosphorus. Nutrients are also derived from natural breakdown processes in soils and water, by runoff of fertilizers from yards and gardens and from airborne chemicals that enter the water by precipitation and rainfall. The rapid transition from freshwater to saltwater conditions also results in the death of organisms that cannot tolerate the changes, and the rapid destruction of cells and tissues due to osmotic stress. This mortality also contributes to the rapid cycling of nutrients and high productivity that occurs in estuarine environments.

Turbidity and Color

Color is a natural feature of freshwater environments, especially in areas such as marshes and swamps that often have highly organic soils. In such areas, the water is often brown or yellow in color due to the presence of "tannins," which are water-soluble byproducts of decomposition of plant materials. Tannins and other complex organic materials tend to precipitate and settle out when they mix with seawater, often creating a color gradient across the estuary that ranges from brown at one end to blue at the other end. Turbidity is the presence of fine suspended particles in the water that may include organic materials, silt or clay sized inorganic materials or microscopic organisms, such as bacteria, algae and protozoans. Oysters play an important role in these ecosystems because they are filter feeders and tend to remove suspended materials from the water column. Seagrasses and other benthic communities help to reduce turbidity because many of their associated organisms are filter feeders. Additionally, seagrasses tend to reduce the amount of wave scouring that occurs at the substrate-water interface and help to bind together sediment particles to prevent resuspension in the water column.

Oxygen and Temperature

Freshwater entering the system is often of substantially different temperature than the seawater. Any time that such differences exist, there is a potential to increase the effects of stratification. Warmer water also has less ability to hold oxygen. In summer, warmer water from the land, combined with lower salinity, may "float" across the surface of the estuary, resulting in stratification. If this water is also turbid or contains large amounts of plankton, it may block light penetration into the deeper layers. The result is that water near the bottom may contain little or no oxygen. Cooling of water at night may result in better mixing, although the lack of light may cause oxygen concentrations to continue to decline.

Light

Color, suspended materials and the presence of planktonic plants and animals are all factors that reduce the transparency of the water and reduce light penetration. Light is important in the estuary because it controls the ability of plants to photosynthesize -- to produce organic matter and oxygen, while consuming carbon dioxide. If light is absent, oxygen levels will decline. If light cannot penetrate to the bottom due to high turbidity, then seagrasses and algae will die and oxygen levels will decline, causing death of aerobic benthic organisms

Pollutants

Storm water runoff may contain petrochemical residues, spilled industrial chemicals, paints and solvents, pesticides used on lawns and gardens, etc. Other forms of pollution may occur due to seepage from septic tanks and discharge of sewage from boats. Dangerous substances may also be released as by products from industrial processes, such as desalination. All of these materials may be toxic to plants and animals in the estuary and results in a loss of overall productivity or selective loss or decline of particular species.

Sources of Water Quality Degradation

The Watershed Action Plan (FDEP, 1998) identified a number of potential water quality issues within the Loxahatchee Basin. Possible sources of water quality degradation included: highly colored water from natural areas; contamination from septic tanks; agricultural and urban storm water runoff containing petrochemical residues, suspended solids, pesticides, nutrients and fecal coliform bacteria; chemical contamination from a regional landfill; discharge of effluent from a reverse osmosis water treatment plant; and low levels of DO due to ground water influx and loading of organic materials.

State Listing of Impaired Waters

A more detailed examination of water quality issues in the basin was conducted by the Florida Department of Environmental Protection (FDEP) in conjunction with their ongoing efforts to identify waters that are degraded and develop Total Maximum Daily Load (TMDL) criteria for waters throughout the state. The St. Lucie and Loxahatchee Basin Status Report, (FDEP, 2001), initiated Phase 1 of the five-phase TMDL process in the Loxahatchee Basin. Most of the information presented in the Basin Status Report was generated from the biennial Water Quality Assessment Report that is developed by FDEP for submittal to the United States Environmental Protection Agency (USEPA) under section 305(b) of the Clean Water Act (FDEP, 1996). **Table 5** below provides a summary of the recent re-assessment of water quality in the estuarine segments of the Loxahatchee watershed (**Figures 2 and 6**).

Table 5. Quality Assessment of Water Body Segments of the Loxahatchee Estuary (FDEP 2001)

Water Segment Name	Water Body Type	Class	1998 303(D) List Parameters	Parameters Potentially Impaired Per IWR	Integrated Assessment Category	Comments
Jonathan Dickinson	Estuary	3M		DO	3c planning list	Need to determine causative pollutant for DO violation
Loxahatchee River (estuary)	Estuary	3M			2 meets some uses	
NW Fork Loxahatchee (estuary)	Estuary	3M	DO, nutrients		2 meets some uses	
SW Fork Loxahatchee (estuary)	Estuary	3M	DO, nutrients, coliform		2 meets some uses	
Jupiter Inlet	Estuary	3M			2 meets some uses	

Classes - Class III – Recreation, propagation and maintenance for a healthy, well-balanced population of fish and wildlife. M=marine,
Integrated Assessment Category
Category 2 – Data are available to assess if some beneficial uses are being met, while insufficient data are available to assess whether all beneficial uses are being met.
Category 3c – Enough data are available to meet the requirements for the Planning List in Rule 62-303 and the water body is potentially impaired for one or more designated uses.

The assessment was based on the Impaired Water Rule criteria (IWR, Chapter 62-303, Florida Administrative Code) using established criteria and methodology to determine the extent that water bodies are impaired in their ability to meet their intended use. Estuary segments of the

Loxahatchee River are Class III water bodies that are used for recreation and for propagation and maintenance of healthy, well-balanced fish and wildlife populations. The original (1998) 303(d) list was based primarily on the state's 1996 305(b) Water Quality Assessment Report (FDEP, 1996). The report identified specific parameters in each water segment that did not meet the state water quality standards as identified in rules 62-302.500 and 62-302.530 F.A.C. In the estuarine areas of the system, the Northwest Fork did not meet DO and nutrient standards and the Southwest Fork did not meet DO, nutrient and coliform standards.

The projected year for developing the TMDL for these water segments within the Loxahatchee Basin, as identified in the 1998 303(d) list, is 2010. However, interested stakeholders can take earlier steps to establish technology-based effluent limitations or other pollution control programs for the constituents of concern. Pursuant to section 403.067 Florida Statutes (F.S.), if steps are taken to attain water quality standards for impaired water bodies by the next time the 303(d) list is due to be submitted to the USEPA, then those water bodies do not need to be placed on the verified list.

The data for the verified list of impaired waters is tentatively due by March/April 2003 and includes any data collected from 1991–2001. The draft verified list is currently expected to be published at the end of June 2003, public workshops will be held throughout the state in July, and the verified list would be adopted by the FDEP Secretary at the end of August 2003. October 1, 2003, is the deadline for the publication of the Group 2 verified list of impaired waters in the Florida Administrative Weekly and submittal to the USEPA.

Water Quality Initiatives

A number of projects are underway in the Loxahatchee River watershed that are jointly funded by local interests, the state and SFWMD and are designed to improve water quality conditions in the watershed and the estuary. In addition, the Loxahatchee Restoration Initiative, between the FDEP and SFWMD, will not only consider the additional quantities of water needed for the Loxahatchee River and Estuary, but also the quality, especially for major constituents of concern, including DO, nutrients and coliform bacteria. The SFWMD is also carefully reviewing Environmental Resource Permit (ERP) applications for projects in this watershed for opportunities to improve the quality of runoff generated from these projects. A new 3-dimensional hydrodynamics/salinity model is also being developed that will incorporate water quality data. Additional flow stations are also being installed in the river. The Loxahatchee River Environmental Control District will collect additional water quality samples bimonthly to provide improved estimates of the loads and DO levels associated with specific flows and salinity values in the Loxahatchee River and Estuary.

ADJACENT COASTAL WATERS

The Coastal Subbasin encompasses approximately 34 square miles and stretches from Hobe Sound south to Juno Beach, a distance of 20 miles (**Figure 5).** This area includes the Jupiter Inlet and adjacent offshore waters and the ICW, which is also known as the Indian River

Lagoon north of the Jupiter Inlet and Lake Worth Creek south of the Jupiter Inlet. The movement of water in this sub-basin is predominantly influenced by tides, with lesser impacts from wind and drainage of upland areas. On incoming tides, most of the seawater enters the inlet and moves westward into the estuary and northward into the Indian River section of the ICW. A substantially smaller interface is created between the incoming tides and the portion of Lake Worth Creek between the inlet and Juno Beach. Under normal conditions, water is discharged out the inlet from the estuary on an ebb tide.

Lands adjacent to these areas include both developed land and natural landscapes. A major defining characteristic of the Coastal Sub-basin is the Atlantic Coastal Ridge. Water drains quickly in the area due to the fine sands. Storm water can have an impact on the area by leaching fertilizer and pesticide to the ground water. Ground water beneath much of the Coastal Sub-basin consists of deep saline areas overlain by thin freshwater lenses. The volume of freshwater available for withdrawal is very limited.

The urbanized corridor of U.S. Highway 1 is a major feature of the watershed in Palm Beach and Martin Counties. Storm water contributions come from a number of developments. Some have canal systems that open into the ICW, others pipe runoff into the surface waters. Publicly-held conservation lands are located at both ends of the sub-basin, in Juno Beach and along the Jupiter oceanfront. The basin includes a small portion JDSP and Hobe Sound National Wildlife Refuge.

WATERSHED FEATURES AND ALTERATIONS

During the past 100 years, the natural hydrologic regime of this watershed has been altered by drainage activities associated with urban and agricultural development. Historically the watershed was defined by the natural landforms of the region. The Northwest Fork of the Loxahatchee River drained the majority of the Loxahatchee Basin. The headwaters of the river originated in the marshes of the Loxahatchee and Hungryland sloughs. As water levels rose during the rainy season, due to the area's flat topography, freshwater drained off gradually as shallow sheet flow during the dry season (Breedlove, 1982). Today much of the area has been transected by canals, levees and drainage ditches. The area's water table has been lowered and lands drain more rapidly because of these activities. Construction of the C-18 for drainage and flood protection has diverted much of this surface flow to the Southwest Fork of the river (Breedlove, 1982). McPherson and Sabanskas (1980) reported that the Loxahatchee River basin historically covered about 270 square miles defined solely by its topography. Today the basin covers about 210 square miles and is defined by its topography and manmade features.

In addition to opening of the Jupiter inlet, several other major changes also occurred within the watershed. The first report of a basin drainage project was in 1928 when a small agricultural ditch was constructed to divert water from the Loxahatchee Marsh to the Southwest Fork of the Loxahatchee River. This project was further expanded in 1957–1958 when the USACE constructed the C-18 Canal to provide increased flood protection for the area (**Figure 7).** Construction of C-18 essentially drained a large portion of the Loxahatchee Slough, a natural wetland area at the headwaters of the Northwest Fork, and redirected water that historically flowed to the Northwest Fork to the Southwest Fork where it could be discharged to tide through Structure 46 (S-46). The C-18 currently drains over one-half of the Loxahatchee Basin.

A number of other hydrologic alterations occurred directly on the Northwest Fork and its tributaries. During the 1930s, two local families constructed the Masten and Lainhart Dams **(Figure 7**) on the upper Northwest Fork to slow down the flow of freshwater between Indiantown Road (SR 706) and Trapper Nelson's settlement. Sometime between 1940 and 1953, Hobe Grove Ditch and the Federation Canal were dredged to drain low-lying areas for citrus groves in the late 1960s. Sod farming has been a more recent agricultural change. The Chinese vegetable farm was operating years before sod farming was undertaken. Flows to the Northwest Fork via Kitching Creek were further reduced during the 1940s by the construction of Bridge Road (County Road 708) and Jenkin's Ditch and by the introduction of citrus groves and sod farming. By the 1970s, much of the Loxahatchee Basin had been drained for residential or agricultural uses.

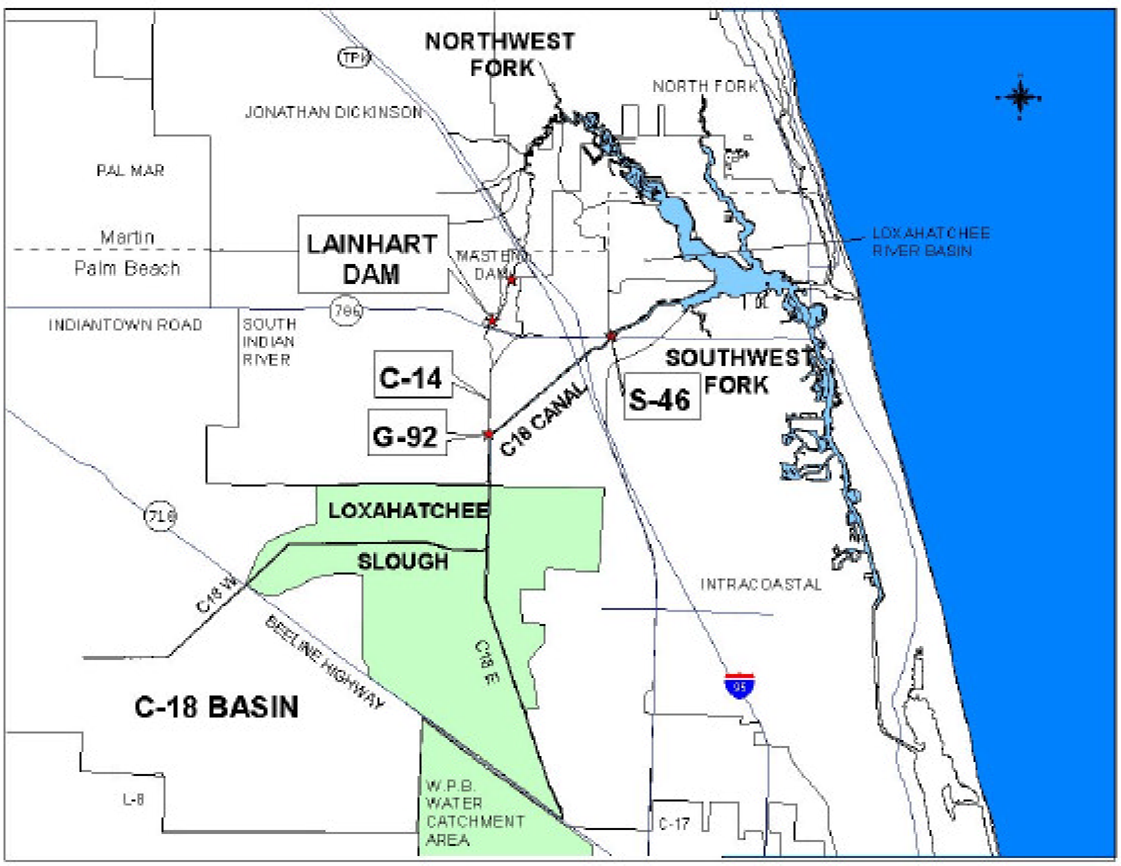


Figure 7. Major Features that Influence Drainage in the Loxahatchee River Basin

In response to public concerns that the C-18 diversion was detrimental to the river, a SFWMD structure known as G-92 was constructed to reestablish the connection between the Loxahatchee Slough and the Northwest Fork (**Figure 7).** Originally a small culvert, this structure was enlarged to convey up to 130 cfs in 1975. In 1987, G-92 was replaced by a gated control structure capable of passing up to 400 cfs in either direction. This structure is operated via remote telemetry under a joint agreement with the South Indian River Water Control District (SIRWCD) to permit conveyance of environmental flows to the Northwest Fork. G-92 also functions to convey excess water from the SIRWCD into the C-18 during extreme storm events (FDEP and SFWMD 2000). The District has an agreement to operate G-92 to provide 50 cfs of flow to the river whenever water is available (see **Appendix L**).

During the severe drought of 1980–1981, the operation of the S-46 structure was modified to provide storage of water in the canal to reduce the amount of freshwater lost to tide. The S-46 structure allows discharge to the Southwest Fork only when water levels are greater than 15 feet above mean sea level.

An extensive network of regional drainage canals and dikes has been constructed and connected to the C-18 system as it flows north out of the Loxahatchee Slough. The C-14, which parallels the C-18, was constructed by the SIRWCD to re-divert water from the C-18 back to the Northwest Fork via G-92 (**Figure 7**).

The C-14 terminates where the river's natural meandering pattern begins about one-half mile south of Indiantown Road (SR 706) as shown in **Figure 7**. The C-14 receives inflow from a series of smaller canals and drainage ditches. Construction of C-14 further enhanced the amount of water that can be delivered to the Northwest Fork from G-92 (Russell and McPherson, 1984).

Several projects are in planning stages or underway to restore sheet flow and enhance wetlands in Kitching Creek and Cypress Creek Sub-basins and Loxahatchee Slough. Other current projects involve storing runoff in treatment areas for later release to the Northwest Fork during low flow periods. These projects are discussed further in **Chapter 6**.

Surface Water Hydrology

Water is the most essential component of the Loxahatchee River ecosystem. Clean fresh water of sufficient quantity and appropriate periodicity is essential to maintain the area's scenic qualities and diverse native plant communities and wildlife populations. Human alterations to the river's natural drainage patterns have reduced the quantity and quality of water in the river, and these changes have contributed to corresponding declines in the river's natural and scenic qualities (FDEP and SFWMD 2000).

A report prepared by the USGS (Rodis, 1973) concluded that the primary cause of environmental problems facing the river was the upstream movement of saltwater, which, in turn, resulted in changes to the flora and fauna in JDSP, and other portions of the river. In this study, based on salinity, freshwater flow data, and the drainage and development conditions that existed at that time, it was concluded that a minimum continuous flow of 23,000 gallons per minute (50 cfs) was required across the Lainhart Dam. This minimum continuous flow would retard further upstream movement of saltwater into the Northwest Fork.

Much of the reduction in flow observed by the USGS has been attributed to the diversion of historic Northwest Fork flows due to construction of the C-18. The C-18 drainage system is the most prominent feature in the Loxahatchee River basin (**Figure 7).** The C-18 was constructed in 1958 as part of the Central and South Florida Flood Control Project to improve drainage and flood protection for adjacent agricultural, residential, and industrial land as well as the J.W. Corbett Wildlife Management Area. This system drains a 106 square-mile area (more than 50 percent of the river basin), and empties into the Southwest Fork through control structure S-46. The C-18 is of particular significance because it: (a) drained the Loxahatchee Slough; (b) redirected water that historically flowed from the slough to the Northwest Fork to the Southwest Fork; and (c) allowed agricultural and residential development to occur in the basin, requiring maintenance of lower water levels and a consequent loss of water storage capacity. The other major drainage system in the Loxahatchee River basin is the C-14 (**Figure 7)** maintained by the South Indian River Water Control District (SIRWCD). It lies west of C-18 in an area known as Jupiter Farms. This area has been subdivided and sold as residential tracts ranging in size from one to five acres. Drainage occurs through a series of seven east-west collector canals into the C-14, and a North-South canal administered by SIRWCD. The C-14 discharges directly into the Northwest Fork, just south of the bridge at Indiantown Road.

Water from the Loxahatchee Slough flows north toward the Loxahatchee River via the C-14, the G-92 structure and the Lainhart Dam as shown in **Figure 7** providing the primary source of flow to the Northwest Fork. On average, the Lainhart Dam accounts for 51–56 percent of the total discharge to the Northwest Fork during the wet and dry seasons (see **Table 23, Chapter 5**). On a monthly basis, however, discharge from this source can range from as low as 28 percent to as high as 72 percent of the total discharge (Russell and McPherson, 1984).

The operation schedule for G-92 structure is important to the river management program because it determines water flow to the Northwest Fork. Water is discharged from C-18 through the diversion structure depending on the relationship between water levels in C-18 and the Northwest Fork at Indiantown Road. Water is diverted to C-14 when (a) flows in C-14 fall below 50 cfs; and (b) when levels in C-18 exceed 12.5 feet above sea level (normal canal stage is 14.5 feet). Under this operational schedule discharges to the Northwest Fork have increased significantly since the operation of G-92 began. This is partially because of: (a) higher rainfall amounts; (b) C-18 has been maintained at higher levels; and (c) water levels at Indiantown Road have been improved due to the reconstruction of Lainhart and Masten Dams, (two small weirs located about 0.1 mile and 1.2 miles respectively, downstream of Indiantown Road). Erosion of these weirs, along with canal construction in the basin, probably increased historic drainage of the area, thus contributing to increased discharges into the river and subsequent over-drainage and potential loss of base flow. In addition to flows coming in from upstream via the C-14, the segment of the Northwest Fork between Indiantown Road and the Florida Turnpike/I-95 receives an average of nearly 12 percent of its total flow from groundwater inflow and several small, unnamed tributaries within this reach.

Since the C-18 has very little capacity to store water for a prolonged controlled discharge, supplemental discharges may be terminated during extended dry periods. Since the installation of G-92, flows to the Northwest Fork have increased considerably, partially due to improved conveyance capacity and improved operations, and partly due to increased rainfall in the watershed during the 1990s. These improved flows, however, have not been sufficient to completely achieve a sustained flow of 50 cfs (a stage of 10.9 feet at the Lainhart dam), which is desired to preserve the freshwater character of the river. Restoration of more historic water levels in the Loxahatchee Slough, which could then sustain longer base flow discharges to the Northwest Fork during drought, is the next step toward achieving this objective. In addition, Palm Beach County has acquired 10,389 acres within the Loxahatchee Slough as a component of the Palm Beach County's Environmentally Sensitive Lands Acquisition Program. A plan for hydrologic restoration of the Slough and flow enhancement to the Northwest Fork is currently being developed (SFWMD 2002). Palm Beach County also has a wetlands restoration project underway in Riverbend Park, located downstream from the slough, which may provide additional flow attenuation and water quality benefits to the Northwest Fork.

Cypress Creek **(Figure 2**) is another significant source of surface water to the Northwest Fork, particularly during periods of low flows. This tributary enters the river from the west, just downstream from the Trapper Nelson Interpretive Site in JDSP. Discharges from Cypress Creek are normally less than those provided by the Lainhart Dam. Cypress Creek provides on average from 26–32 percent of the total flow discharged to the Northwest Fork (**Table 23, Chapter 5**)

Cypress Creek is an outlet for an extensive network of agricultural canals, draining an area of about 29,000 acres, maintained by the Hobe-St. Lucie Conservancy District. Flows from Cypress Creek to the Northwest Fork are controlled by a structure that is operated by a local drainage district. The first portion of the Cypress Creek subbasin is composed of undeveloped wet prairie. These undeveloped areas are experiencing reductions in water levels due to canal construction, but still act as an important freshwater reservoir for Cypress Creek and the Northwest Fork. In 1995, Palm Beach County acquired 367 acres near Cypress Creek as part of their Environmentally Sensitive Lands program. This acquisition, and more importantly the Pal-Mar wetlands acquisition, with modification of agricultural practices, will result in some improvements to the subbasin hydrology.

Hobe Groves Ditch (canal) drains a large agricultural area (10,700 acres) east of the Florida Turnpike and enters the river at approximately River Mile 9.0. The “ditch” has a water control structure that is operated by local groves. Discharges from this canal averages less than five percent of the freshwater flow into the Northwest Fork **(Table 23, Chapter 5).**

Kitching Creek originates in an area of scattered ponds and marshes both north of and within, JDSP. Kitching Creek average between 11 and 13 percent of the total flows delivered to the Northwest Fork **(Table 23, Chapter 5).** Its drainage basin is the least developed of all the major tributaries of the Northwest Fork and allows for a high degree of water retention.

Surface Water and Ground Water Relationships

Major Aquifer Systems

The geologic formations underlying the area of the Loxahatchee River form two aquifers separated by confining beds. The two major aquifers are the shallow, upper 200 feet of sand, (non-artesian) Surficial aquifer and the Floridan aquifer, which are more than 1,000 feet deep (**Table 6).** The Surficial aquifer is composed of permeable Pamlico sand, Anastasia limestone, shell beds and Caloosahatchee marl. Although the shallow Surficial aquifer represents the primary source of potable water for the watershed, its water-bearing qualities vary widely throughout the area. Most of the recharge for the Surficial aquifer is supplied by local rainfall. The bottom of the shallow aquifer is generally about 180 feet below the land surface (Lukasiewicz and Smith, 1996; SFWMD, 1998).

Table 6. Generalized Hydrogeology of the Loxahatchee Watershed

Hydrogeologic System	Hydrogeologic Unit	Aquifer Thickness (Feet)	Water Resource Potential
Surficial Aquifer System	Units not distinct	100-200	Primary source of potable water
Floridan Aquifer System	Upper Hawthorn Confining Zone	500	May only be used for potable drinking water with desalinization.
	Upper Floridan Aquifer		

Source: (Lukasiewicz and Smith, 1996; SFWMD; 1998)

The Floridan aquifer, is separated from the Surficial by several hundred feet of relatively impermeable clay, and extends to depths of about 1,500 feet. This confined aquifer contains water under sufficient pressure to cause it to flow to the surface. In the Loxahatchee River area, the aquifer is composed of limestone of the Hawthorn, Tampa, Suwannee, Ocala and Avon Park formations, ranging in age from 30 to 60 million years. This aquifer is hydrologically isolated from the Surficial aquifer, and is highly mineralized and contains moderately high salt concentrations. It can be used for potable drinking water supply only with desalinization treatment. The principal recharge area for the Floridan aquifer is located in Polk and Pasco Counties in central Florida. These two aquifers supply all of the drinking water for this watershed (FDEP, 1998).

Relationship between Ground Water and Surface Water Resources

The surficial aquifer system in northern Palm Beach and southern Martin Counties interacts directly with surface water in streams, rivers, canals, ponds, lakes and wetlands. The presence of a manmade (e.g. canals) or natural (stream or river) channel provides a conduit by which water flows downhill, generally towards the ocean. As water levels decline in the channel, water flows into the channel from adjacent surface water storage (ponds, lakes or wetlands) or by ground water seepage. Rainfall provides the major source of “new” freshwater that fills the surface water bodies and channels and recharges the shallow aquifer system.

In the historic Loxahatchee River watershed, an extensive network of wetlands, lakes and seasonal ponds formed a vast reservoir of freshwater that was refilled each year during the rainy season. This water flowed into the network of tributaries that fed the Loxahatchee River and was discharged to tide at the river mouth. As water levels in the wetlands, tributaries and river declined during the dry season, water continued to enter the natural channels by ground water seepage from the surficial aquifer, so that flow in the river was maintained, probably year-round, except during extremely dry conditions.

Today, canals and ditches that have drained many of the wetland areas and seasonal ponds to allow agricultural and residential development have intersected much of the watershed. Rain that falls in these areas during wet periods is rapidly shunted to the major canals and river and does not accumulate in wetlands or the shallow aquifer. Therefore, the river and canals are discharging more water during the wet season. During the dry season, much less surface water and ground water is available to maintain river flow.

The amount of water that enters the Loxahatchee River system is thus divided among direct rainfall, surface water flow and ground water seepage. The SFWMD has reviewed available information and attempted to analyze all three of these components. Some previous studies provided data and estimates of rainfall and surface water flows from major tributaries. By measuring total river flow at the mouth, it is possible to estimate flow from sources other than rainfall and surface flow. These ”other” flows are generally attributed to ground water seepage.

Mathematical models were developed and applied by the District to determine the interaction between ground water and surface water resources in the Palm Beach County portion of the Loxahatchee River watershed. Use of these models provides a convenient way to summarize existing information about this system and to make predictions concerning the amount and timing of river discharges. Details of historical flows and the interactive surface water-ground water modeling effort are provided in **Chapters 4 and 5** and **Appendix I**.

Soils

Soils of the Atlantic Coastal Ridge and the Eastern Flatlands within the Jonathan Dickinson/Hobe Sound sub-basin consist of old dunes and flatlands. The dunes, dune ridges and other minor dune patterns that are present near the west side of U.S. Highway 1 run north to south and consist of fine, white sand of the Paola-St. Lucie association. The flatlands contain flat terraces with poorly drained sandy soils that are interspersed with shallow depressions. Soils in the Coastal sub-basin are generally those associated with Paola-St. Lucie sands and are well-drained and highly permeable. In tidal zones, thin muck overlays permeable sands (FDEP 1998; Zahina et al. 2001a).

The northeastern portion of the Estuary sub-basin generally has well drained sands of the St. Lucie-Urban-Paola association. Well-drained sands of the St. Lucie-Urban-Paola association and Pomello and Basinger sands make up the area between the North Fork and the C-18, Southwest Fork drainage Channel. The area south of the estuary and C-18, Southwest Fork Drainage Channel consists mostly of nearly flat, poorly drained sands of the Wabasso-Riviera soils (FDEP 1998; Zahina et al. 2001a).

Wetland areas of the watershed in the C-18/Corbett sub-basin contain soils that are generally of the Riviera sand series, consisting of poorly drained sandy soils with loamy subsoil. In the eastern or "Loxahatchee Slough" area some of the soils have a thin layer of muck at the surface. Soils in the Cypress/Pal-Mar sub-basin are mostly of the Wabasso, Riviera and Pineda series: poorly drained and sandy to a depth of 20 to 40 inches (FDEP 1998; Zahina et al. 2001a).

The Groves sub-basin contains predominantly Hobe fine sand and Nettles sand in the river corridor and immediately west. The groves themselves consist mostly of Wabasso-Riviera sands with Pineda-Riviera soils along the northwestern boundary. The western and southwestern areas are predominately Pineda-Riviera-Boca soils. These soils are poorly drained and sandy to a depth of 20 to 40 inches. Soils in the Wild and Scenic/Jupiter Farm sub-basin are predominantly poorly drained sands, such as those within the Riviera and Wabasso Series and also include Pineda and Oldsman (FDEP 1998; Zahina et al. 2001a).

Land Use

Much of the Loxahatchee River watershed remains undeveloped. Wetlands comprise a large portion of the river's upper watershed and total almost one-half of the drainage basin's 200 square miles. Urban areas and areas committed to urban uses make up one-quarter of the basin. The large agricultural and forested upland areas in the northern portion of the basin collectively comprise another one-quarter of the basin **(Figure 8). Tables 7** and **8** provide a detailed breakdown of the major land use categories (agricultural, range land, residential, industrial, commercial, undeveloped, transportation, conservation, institutional and other) for each of the seven major drainage basins located within the watershed.

Land in the river's watershed has most typically been converted to urban uses. The extreme southeastern section of the basin along the eastern edge of Loxahatchee Slough is one of the fastest developing areas in the basin. Another major area of land development is located in the central portions of the basin, both east and west of C-18. Jupiter Farms, located west of the Loxahatchee River and south of Indiantown Road, is one example of the type of land development activity that has occurred in this portion of the basin. This 9,000-acre subdivision was platted in the 1920s and consists of parcels generally ranging in size from one to five acres. When completed, the project will contain over 4,600 dwelling units and a population of more than 11,000 residents. Since the area was subdivided before current water quality regulations were in effect, modern provisions for the retention of surface water runoff were not included. A third area undergoing urbanization is located north of Indiantown Road, bordered on the west, northwest and east by the Northwest Fork. Existing land use activity is predominately agricultural, with most of the land in pasture or pine flatwoods. Major residential developments and golf courses have been proposed or approved in this area.

Land use patterns in the immediate vicinity of the Northwest Fork are similar to those throughout the rest of the drainage basin. Wetlands are characterized primarily by extensive areas of wet prairie, freshwater swamp and mangroves. Agriculture accounts for approximately 23 percent of the land use in the vicinity of the Northwest Fork. Croplands, consisting mainly of vegetable farms were, until quite recently, located along either side of the middle segment of the

river. In most cases, these areas are separated from the river corridor by a band of pine and scrubby flatwoods. Orchards and groves predominate in the northwestern sections of the river area. Several small citrus groves are located in the Indiantown Road area within approximately 250 feet of the river. Improved pasture comprises a portion of the agricultural land cover east of the Florida Turnpike/I-95 corridors. Areas that are committed to urban uses are scattered throughout the eastern and southern portions of the mapped area, primarily in the areas south of JDSP and south of Indiantown Road. A small community shopping center is located 0.2 miles west of the river on Indiantown Road (FDEP and SFWMD 2000).

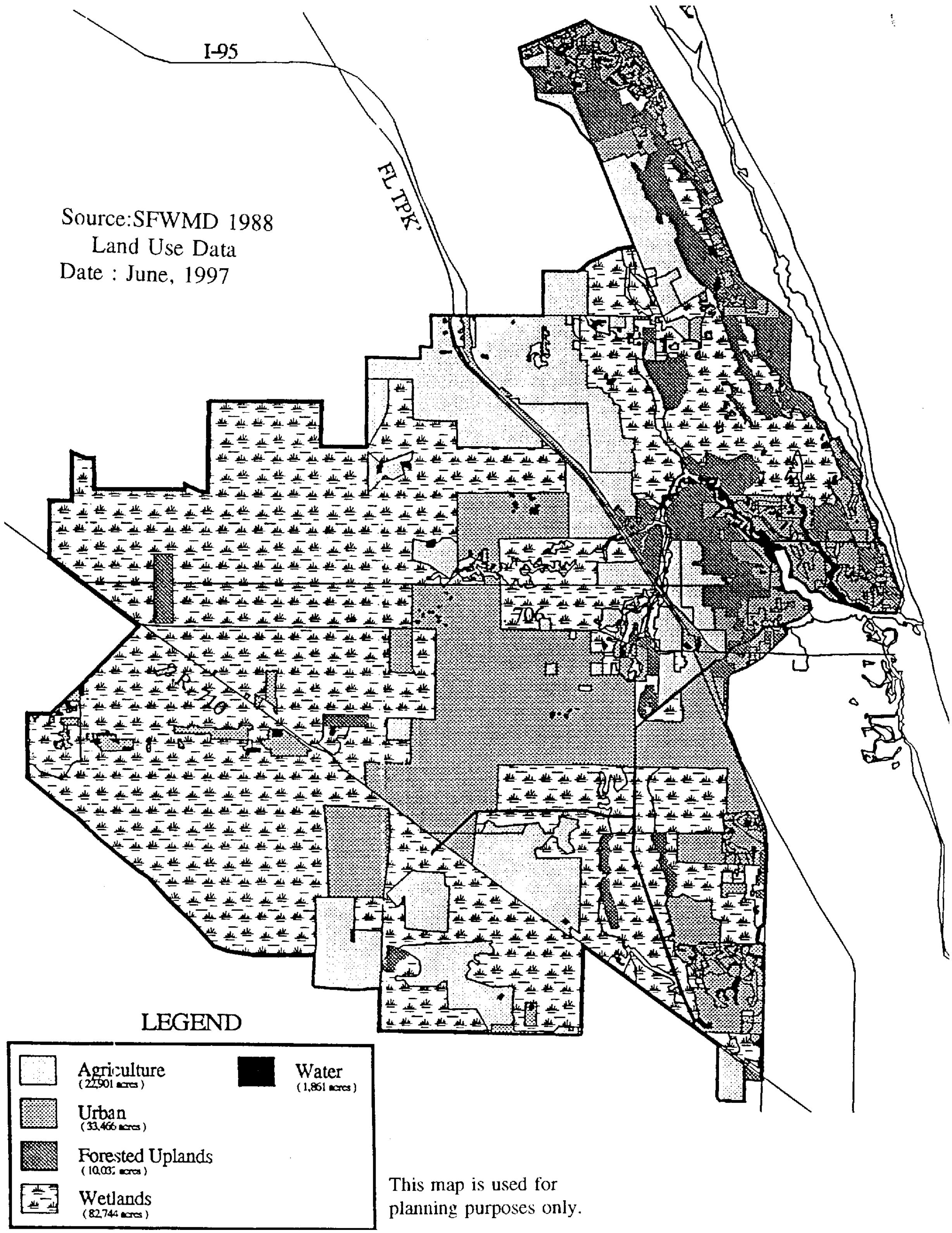


Figure 8. Current Generalized Land Use/Land Cover in the Loxahatchee Watershed (from FDEP and SFWMD 2000).

Table 7. Acreage Percentage by Land Use for Subbasins within the Loxahatchee River Watershed

sb	Subbasin Name	Land Use Categories											
		Water	Agriculture	Range Land	Residential	Recreational	Industrial	Commercial	Undeveloped	Transportation	Conservation	Institutional	Other Urban
1	Jonathan Dickinson/ Hobe Sound		10.9%	4.8%	3.8%	1.6%	0.3%	0.0%	37.6%		41.0%		
2	Coastal		2.6%		30.4%	7.6%	2.3%	4.1%	50.2%	2.8%			
3	The Estuary	11.1%	4.8%		56.0%	5.5%	2.4%	1.2%	16.6%	1.8%		0.6%	
4	C-18/Corbett	2.4%	8.0%		3.5%	2.1%	3.8%	0.1%	78.0%	1.8%			
5	Cypress/Palmar	2.2%	12.1%		3.7%	1.2%			79.5%	0.2%			1.1%
6	The Groves	1.2%	59.5%		0.5%	0.5%			34.8%	3.0%			0.5%
7	Wild & Scenic/Jupiter Farms	2.1%	5.4%		56.8%	1.3%	3.3%	0.1%	29.8%	0.6%			0.6%

sb = Subbasin Number Source: SFWMD 1995 GIS Land Use Database

Table 8. Acreage by land use for subbasins within the Loxahatchee River watershed

sb	Subbasin Name	Land Use Categories												
		Water	Agriculture	Range Land	Residential	Recreational	Industrial	Commercial	Undeveloped	Transportation	Conservation	Institutional	Other Urban	Total Acres
1	Jonathan Dickinson/ Hobe Sound		2,509	1,105	875	368	69		8,656		9,439			23,021
2	Coastal		572		6,692	1,673	506	902	11,050	616				22,012
3	The Estuary	1,524	659		7,690	755	330	165	2,280	247		82		13,732
4	C-18/Corbett	1,540	5,132		2,245	1,347	2,438	64	50,039	1,155				64,153
5	Cypress/Pal-Mar	652	3,587		1,097	356			23,569	59			326	29,647
6	The Groves *	129	6,382		54	54			3,733	322			54	10,726
7	Wild & Scenic/ Jupiter Farms *	316	813		8,549	196	497	15	4,485	90			90	15,051
	Total	4,161	19,661	1,105	27,201	4,749	3,831	1,146	103,812	2,490	9,439	82	470	178,342

sb = Subbasin Number Source: SFWMD 1995 GIS Land Use Database

* Ongoing boundary studies may change the total size of the basins which would result in slight changes to the land use areas.

Water Supply

How Water is Allocated and Used:

The withdrawal of surface or ground water for consumptive use is regulated through permits issued by the SFWMD. All sources of supply are regulated except seawater (with total dissolved solids greater than 18,000 mg/l), reclaimed water and water used for domestic self-supply and fire-fighting. A consumptive use permit is not a permanent right to water but is issued with a finite duration. At the end of the permit tenure the user may apply for a renewal. Renewals are treated as initial applications (except in cases of competing applications) and reviewed under the rules in place at the time of the renewal application.

In order for a proposed use to qualify for a consumptive use permit the applicant must demonstrate that the use is reasonable and beneficial, will not interfere with existing legal users and is in the public interest (Chapter 373 F.S.). The SFWMD has rules which outline how such reasonable assurance shall be provided. These assurances must be met for all consumptive use classes including public water supply, irrigation, dewatering, industrial etc. The reasonable assurance must cover hydrologic conditions up to and including moderate drought conditions known as the level of certainty. In South Florida this level of certainty is being established by rule as a 1-in-10 year drought condition.

The amount of water allocated in a permit is sufficient to meet the reasonable demands of the use over the life of the permit up to the level of certainty (1 in 10 year drought). For most use classes the reasonable volume of water needed is less than the allocation during normal to wet conditions and increases as droughts become more severe. This trend is most noticeable with irrigation uses. In some cases the need for water increases over time as the project grows (public water supply and some agricultural projects).

Irrigation allocations are currently determined using the modified Blaney-Criddle algorithm to calculate supplemental irrigation based on several factors including evapotranspiration (ET), crop type, rainfall, time of year and soil type. This algorithm was developed by the University of Florida Institute of Food and Agricultural Sciences (IFAS) and has been used in consumptive use permitting since the mid 1980s. The algorithm calculates the plant supplemental irrigation demand that occurs during a maximum month (under the 1 in 10 year drought condition) and on an average annual basis. Recent studies of actual water use and plant transpiration indicate that the Blaney-Criddle algorithm overestimates annual average plant demand but is accurate for the maximum month during 1-in-10 drought conditions.

Public water supply allocations are based on population and historic per capita use rate. The use of water generally varies seasonally as a function of population (including tourism) and rainfall patterns. The per capita use rate is calculated by dividing the volume of untreated water used by the permanent population served. The allocation is based on the projected population for the last year of the permit life multiplied by the per capita use rate adjusted for water conservation. The per capita rates can vary widely if the service area uses potable water for irrigation or has a significant commercial/industrial demand. In situations where saline water is used for drinking water supply, the per capita use is about 15–20 percent higher due to the treatment losses associated with the desalinization process. Per capita use rates average 203 gallons per capita per day (gpcd) in the north Palm Beach County area.

Once the reasonable needs for water are defined, the applicant must provide reasonable assurance that the water resources (wetland, saltwater intrusion, MFLs, etc.) and existing legal users are not harmed during a 1-in-10 drought condition. This is generally done by evaluating the area of impact of the proposed use, assuming that the maximum monthly demand is sustained day and night for 90 days without rainfall. This combination significantly overstates the impact of the proposed use under all but excessive drought conditions. As a result, the impacts of the actual use are, in most cases, less than what is evaluated in order to obtain a permit. The thresholds for *no harm* are contained in District permit criteria.

Computer ground water models and field monitoring data are used to provide reasonable assurances that the permit criteria will be met. In cases where the criteria cannot be met, the applicant may propose alternatives that mitigate the impact of the proposed withdrawal. Examples of mitigation include relocating the point of withdrawal, reducing the demand for water from the source by augmenting the need for water from other sources, such as reclaimed or potable water, or by developing different sources of supply, such as the Floridan Aquifer System (FAS). In the event that reasonable assurances cannot be provided, the applicant may withdraw the application or the District will deny the application.

Permits may also be conditioned to include monitoring of use and impacts of the withdrawal. All individual water use permits issued since 1993 are required to report the amount of water used. In addition, projects that have the potential to impact wetlands, alter the position of a saline/freshwater interface, produce a plume of pollutants or affect other existing legal users, are required to monitor water levels and or quality as appropriate.

Overview of Consumptive Uses within the Watershed:

As of May 2002, the combined annual allocation for all individual water use permits within the watershed was 37,672 million gallons per year (an overall average of about 100 million gallons per day). A more detailed analysis of permitted water uses is provided in **Appendix O.** Locations of the 404 permitted wells and 232 surface water pumps are shown on **Figure 9.**

Figure 10-A shows the relative degree of contribution of water supply allocations by source type within the basin. Ground water provides for the majority of the demands followed by surface water, the FAS and reclaimed water. Reclaimed water and the saline water of the FAS are considered alternative sources of supply. Together these alternative sources comprise 22 percent of the water used within the watershed. The volume of reclaimed water represents 100 percent of the dry season treated wastewater flows generated from the public water supply. The reclaimed water is recycled into the basin as irrigation water during the dry season. During the wet season, when demands for irrigation water drop below the rate of reclaimed water production, the unused portion of reclaimed water is stored for later use or disposed of by deep well injection. The volume of reclaimed water in the watershed is expected to increase in proportion to growth in demands for potable water. For those utilities that use the FAS as a source for potable water (Town of Jupiter and Village of Tequesta), the proportion of reclaimed water recovered from the FAS represents an increase in supply to the surficial system.

Figure 10-B shows the relative degree of water allocation by million gallons per year (mgy), by use class in the watershed. Public water supply has the largest allocation (63% or 23,638 mgy) followed by agriculture (18% or 6,943 mgy), golf course irrigation (8% or 2,973 mgy), industrial use (6% or 2348 mgy), and landscape irrigation (5% or 1770 mgy).

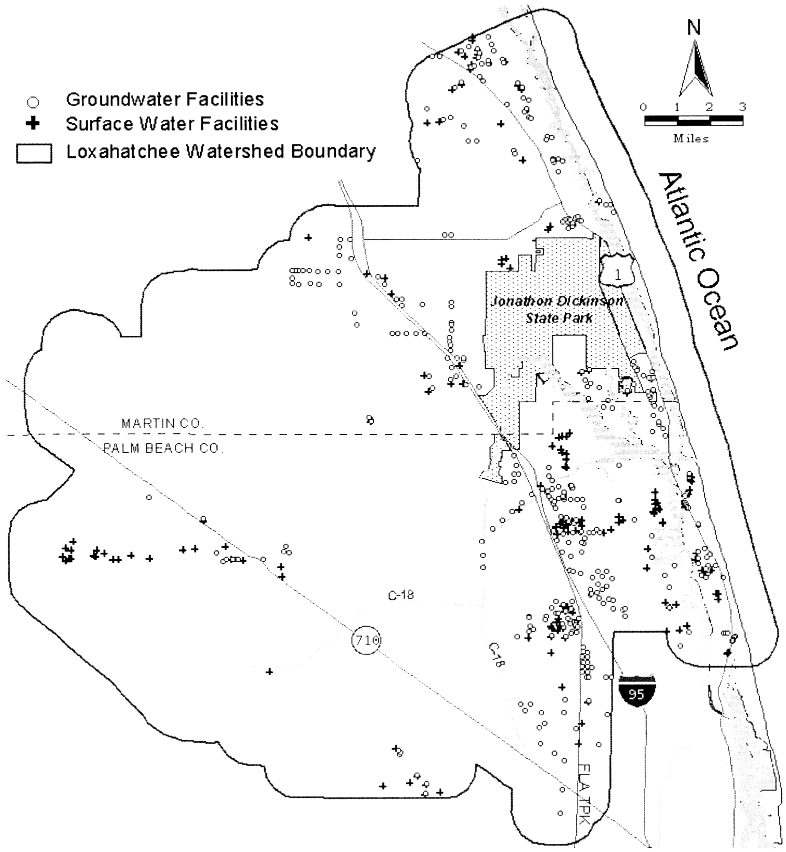


Figure 9. Locations of Permitted (individual permits) Withdrawal Facilities within the Loxahatchee River Watershed Area, May 2002.

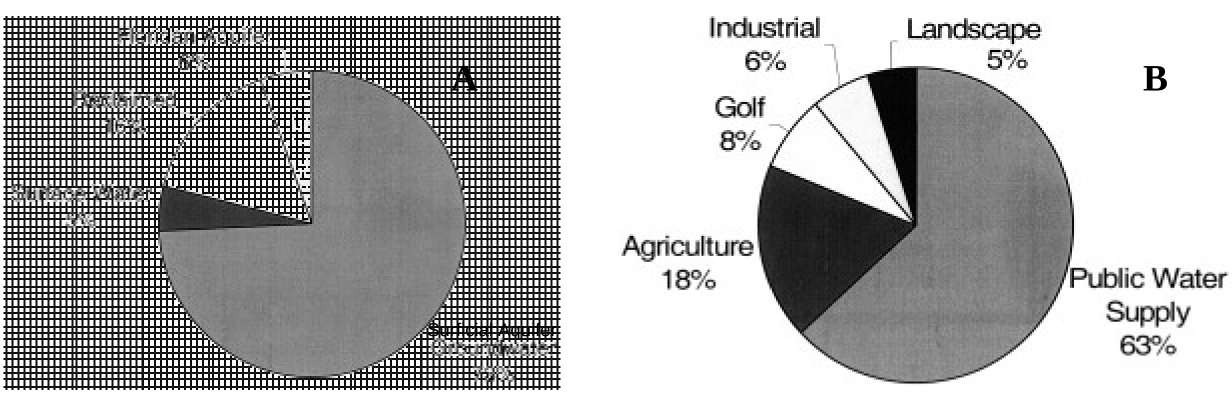


Figure 10. Water Use in the Loxahatchee River Watershed from Different Sources (A) and for Different Uses (B) based on SFWMD Consumptive Permit Allocations as of May 2002.

Additional details are provided in **Appendix O**. It is important to note that the actual uses on any given day are usually considerably less than the permitted allocations, except during periods of severe and sustained drought. For instance, all irrigation allocations are geared to provide sufficient water to survive a moderate drought where actual use is dependent on rainfall. When rainfall drops off, the use increases and approaches the allocation. However during normal or wet conditions, the use is lower than the allocation. Also, demands for water do not coincide for all users. The peak demand for irrigation of citrus occurs in a different month than the peak demand for turf grass. The amount of acreage planted (and the corresponding amount of water used) during any given year for growing vegetables are market driven. If the market is down, crops are not planted and water use is less than the allocation. Only when the market is good and there is a moderate drought would the actual use approach the allocation for vegetables.

In some cases, the allocated demands are not achieved until the end of the permit. Public water supply allocations are based on the estimated demand at the end of the permit duration. For example, comparison of actual public water supply pumpage to permit allocations within the watershed during 2000 (the last full year prior to the water shortage), shows that actual use was 40–90 percent of the permitted allocation. However, it should be noted that due to improvements in the accuracy of the methods for estimating future public water supply demands, combined with shorter duration permits, the gap between actual use and permitted use is smaller.

Water Quality

During the last 25 years, the surface waters of the Jupiter Inlet-Loxahatchee River have been extensively sampled and analyzed for water quality. In the 1970s and 1980s, the United States Geological Survey provided a water quality monitoring presence from the federal perspective. The FDEP and the SFWMD each sponsored monitoring programs from the state and regional perspective. On the county and local level, the Palm Beach County Health Department, Palm Beach County Department of Environmental Resources Management and the Loxahatchee River District also monitored water quality.

Since 1992, the Loxahatchee River Environmental Control District (Loxahatchee River District or LRD) has assumed responsibility for comprehensive monitoring in the watershed, monitoring 29 stations every other month. In recent years, additional monitoring stations have been added. **Figure 11** shows the applicable water quality sampling sites. In the early 1990s, the LRD, in cooperation with a technical advisory committee comprised of representatives of other monitoring efforts, organized the existing water quality data by collecting and screening all prior data. A common database was established, and the data presented in a format which could be indexed, composited and compared to Florida State values and standards. The resultant information was further organized by dividing the Loxahatchee watershed into 29 sample locations in four ecological segments (Marine, Estuarine, Wild and Scenic and Freshwater Tributaries). Five time-groupings covering 22 specific water quality parameters were developed. This summary was presented to the Loxahatchee River Management Coordinating Council in 1995 and is updated every six months.

Seven reaches or groups of stations have been monitored over the years within the “wild and scenic” portion of the Loxahatchee River. Additionally, six sampling sites are located in the freshwater tributaries flowing into the designated corridor. In general terms, the sampling results show that the water quality of the freshwater tributaries discharging to the “wild and scenic” corridor have remained fair for the period of record 1970–1993. The trend is for an overall decline in water quality in inflows over time. The “wild and scenic river” corridor also graded fair for the first portion of the monitoring period, then improved to good in the mid-1980s.

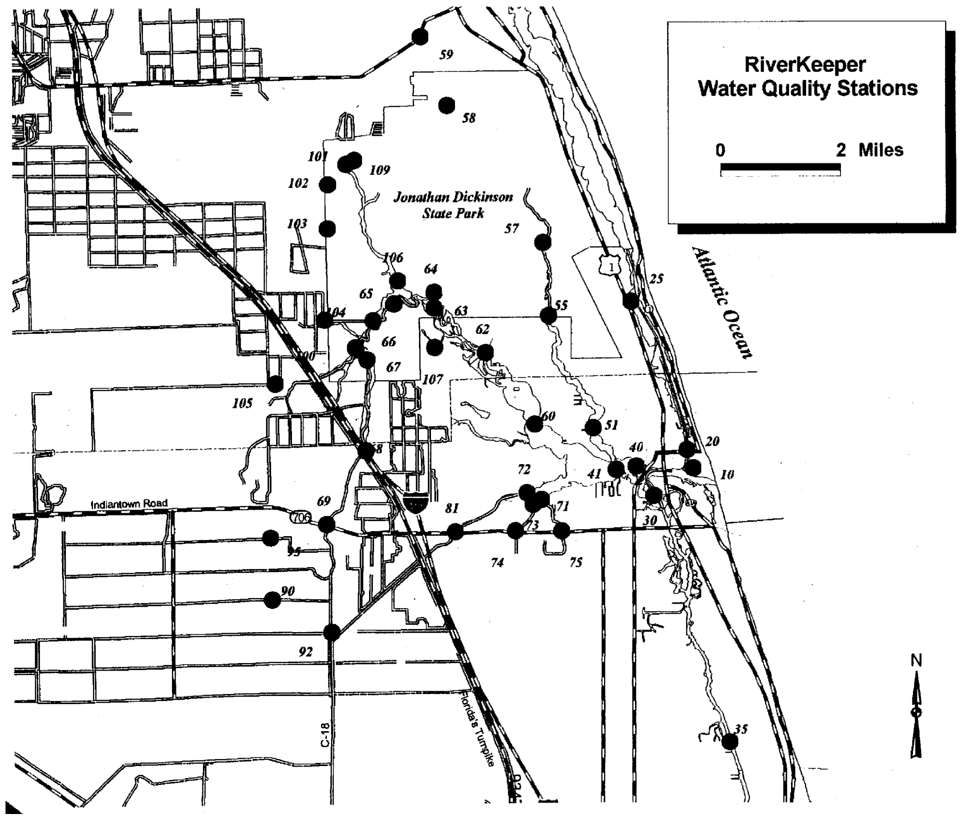


Figure 11. Water Quality Stations Sampled by the Loxahatchee River District

The major reason for the improvement and apparent inconsistency with the declining quality of input waters, is believed to be the increased flows to the Northwest Fork from the SFWMD C-18. The quality of water in the C-18, a Class I waterbody, has rated superior to the other freshwater inputs and has not shown significant degradation over time. Comparison of the long-term composite values for the Loxahatchee River Wild and Scenic River corridor with typical Florida stream water quality values (as documented by FDEP) yields the following conclusions:

- Clarity of the river water is near the statewide mean.
- Dissolved oxygen concentrations are low, ranking below about two-thirds of the other streams in Florida.
- Organic content of the waters is moderately better than statewide averages.
- Trophic status, predominantly nutrient concentration, is slightly better than values for other streams.
- Biological integrity of the "wild and scenic" reach is on the low side of the state mean, with six out of ten state streams displaying better results.
- Bacteria counts are substantially higher than the state standard, ranking ahead of only about 30 percent of other streams.

The Florida Water Quality Index for several thousand stream sampling sites averages 43. The statewide Water Quality (WQ) Index considers ratings of 45 or below as good, while ratings above 45 are considered fair. The 24-year average for the "wild and scenic" corridor is 48, however the index number for the period since 1985 has improved to 43. A station-to-station comparison of the river shows long-term water quality in each reach to display an index number near the mid-1940s with three exceptions. The reach above Indiantown Road, and the reach near the Trapper Nelson Interpretive Site both have index numbers at, or above, 50. These numbers are in the fair range, but more closely approximate poor. Flows entering from the C-18 have a composite index number of 40, which is very good.

Natural Systems

Major Plant Communities

The principal wetland plant communities in the vicinity of the river corridor are freshwater floodplain swamp and saltwater-tolerant mangrove swamps (**Figure 12**).

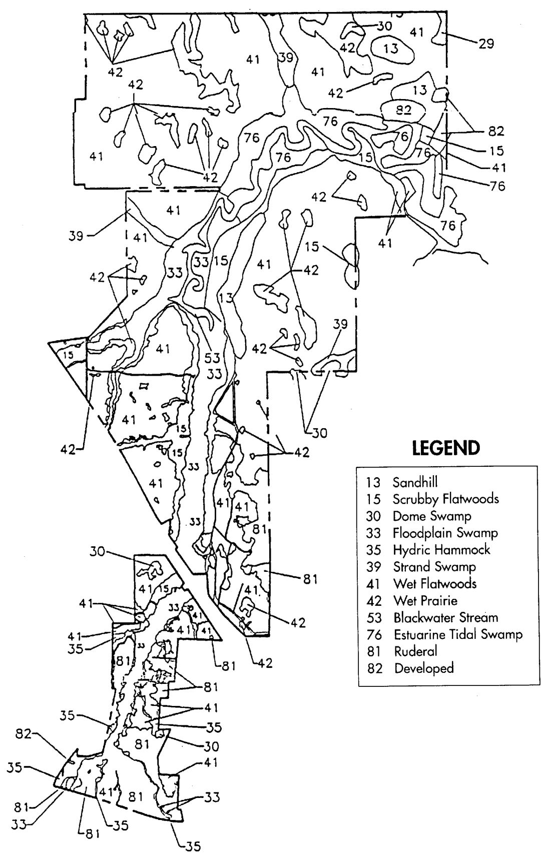


Figure 12. Wild and Scenic Corridor Plant Communities within Jonathan Dickinson State Park. (Source: FDEP and SFWMD 2000)

Low pine flatwoods and scrubby flatwood communities occupy the slightly higher elevations bordering the floodplain. Other vegetation communities found in the area include sandhill, cypress dome swamp, hydric hammock, cypress strand swamp and wet prairie. The hardwood/cypress swamp community flanks the river and its tributaries upstream from the Trapper Nelson Interpretive Site, and is the dominant community for approximately one mile downstream of the site. This community is composed of bald cypress, southern red maple, cabbage palm, pop ash, pond apple, laurel oak and water hickory. Shrubby species mixed among the taller vegetation include cocoplum, wild coffee, myrsine and buttonbush. Vines, ferns, bromeliads and orchids also are characteristic of this community.

The mangrove community lines the Northwest Fork from approximately one mile downstream of the Trapper Nelson Interpretive Site. Red mangroves front the river where they are most fully exposed to tidal flows. Some dead cypress trees tower above the red mangroves for approximately three quarters of a mile downstream from this point, evidence of the extent of freshwater vegetation that existed before changes in the upstream movement of saltwater. White mangroves are further back from the river channel but near enough to be inundated at high tide.

The low pine flatwood community is dominated by widely scattered South Florida slash pine. The slightly elevated, level sandy areas in which this plant community is found lack the soils and drainage conditions necessary to support the type of dense understory found in the floodplain. Vegetation is typically shrubby in nature, and includes the saw palmetto, gallberry and fetterbush. Ground cover includes wiregrass, broom sedge and various herbaceous species. Scrubby flatwoods typically occupy the elevations above the pine flatwoods and alongside the floodplain. The sandy soil is usually several feet deep and drains rapidly even under extremely wet conditions. The dominant species is the South Florida slash pine, as in the pine flatwoods, but the understory is characterized by scrub oak and other scrub vegetation.

The principal problem affecting the river's plant communities is the gradual reduction in the number and geographic extent of healthy floodplain swamp and bald cypress and their replacement by mangroves. Virtually all of the cypress in the lowermost area of the “wild and scenic river” segment are now dead, or are stressed and not reproducing. Approximately one mile upstream of Kitching Creek, the number of live trees increases with increasing distance up the river. An analysis conducted by the U.S. Geological Survey between 1979 and 1982 documented the extent of environmental stress in the cypress trees along the Loxahatchee River corridor (McPherson, unpublished). The study examined core samples to identify changes in tree ring width and quality. The results of the study indicated that although the trees sampled had experienced stress at periodic intervals over their life histories, the proportion of stressed trees in the downstream section (below river mile 9.0) increased from 30 percent in 1940 to 80 percent in 1982. Stressed trees above river mile 9.0 decreased from 11 percent to 3 percent during that period. Further, the incidence of growth stress was highly correlated with high salinities in surface water and soils (Duever and McCollom 1982).

Based studies conducted as part of the Wild and Scenic River Management Plan (SFWMD, 2000) it was concluded that the decline of cypress in the river was due to the upstream movement of saltwater. Exposure to saline waters may have either acute or chronic toxic effects. Occasional inundation by slightly saline surface water probably does not result in serious or long-term impacts. Periodic exposure to high salinity water or frequent exposure to lower salinities, however, may increase the salinity of the floodplain's peat soils. The principal causes of saltwater intrusion were identified and attempts are underway to establish correlations between degree and duration of salinity stress and effects on tree reproduction growth and survival tree growth. Four contributing factors were identified as causes of increased upstream salinity exposure as follows: (1) permanent opening of the Jupiter Inlet in 1947, (2) Construction of C-18 Canal in 1957-58, resulting in insufficient dry season flows to the Northwest Fork; (3) dredging in the river's estuary, the ICW and Jupiter Inlet; and (4) the drawdown of ground water levels by wells in the Jupiter-Tequesta area. Each of these factors must be addressed if deterioration of the river's cypress communities is to be reversed (SFWMD, 2000)

Wetlands

The Loxahatchee River Basin Wetland Planning Project (Treasure Coast Regional Planning Council, 1999) was initiated in 1994 to identify wetlands in the Loxahatchee River Basin and provide information about the functions and values of these wetlands. The major wetland systems in the Loxahatchee River basin are listed in **Table 9.** Interpretation of the infrared aerial photographs resulted in the identification of areas of high, medium and low quality wetlands. Seventy-nine percent of the wetlands in the project area are located in areas of high quality wetlands, 13 percent in areas of medium quality wetlands and 8 percent in areas of low quality wetlands. The largest area of high quality wetlands is the Loxahatchee Slough. The second largest area of high quality wetlands is Pal-Mar. Other locations identified as areas of high quality wetlands include Corbett Wildlife Management Area, the Cypress Creek Area, the Loxahatchee River Save Our Rivers property north of Indiantown Road, large preserve areas on the North Palm Beach County General Aviation Airport and PGA National and a portion of Vavrus Ranch.

The largest areas of medium quality wetlands occur in Unit 11 of the Acreage, the Sandhill Crane Addition to the Loxahatchee Slough Natural Area, portions of the Vavrus Ranch and Loxahatchee River Save Our Rivers property south of Indiantown Road. Other locations identified as areas of medium quality wetlands are the preserve areas on sites that have been developed during the last 20 years. These include Old Marsh Golf Club, Palm Beach Park of Commerce, and the smaller preserve areas on PGA National and the North Palm Beach County General Aviation Airport. Two additional sites, which have since been developed, were areas of medium quality wetlands -- Golf Digest (Mirasol) and Country Lakes of Jupiter.

The main areas of low quality wetlands include Jupiter Farms, Palm Beach Country Estates, Caloosa and the Acreage south of Mecca Farms. A portion near the center of Vavrus Ranch is also identified as an area of low quality wetlands.

Twenty-four percent of the wetlands in the watershed are freshwater marsh and wet prairie, hardwood swamp and cypress swamp. The main concentrations of freshwater marsh and wet prairie are located in and near the Loxahatchee Slough, Corbett Wildlife Management Area and Pal-Mar. The largest concentration of hardwood swamp occurs along the Loxahatchee River. The main concentrations of cypress swamps occur in and just east of the Cypress Creek area north of Indiantown Road, and in and adjacent to the Loxahatchee Slough, especially near the Beeline Highway. A large stand of cypress also occurs in Corbett Wildlife Management Area just south of Pratt & Whitney (Treasure Coast Regional Planning Council, 1999).

Table 9. Major Wetland Systems in the Loxahatchee River Watershed

Wetland System	Area	County	Location	Ecosystems	Hydrology
Atlantic Coastal Ridge	12,700 ac.	Eastern Martin	Between I-95 and U.S. Hwy 1	Extensive upland and wetland systems, including wet flatwoods, marshes, forested sloughs and coastal scrub	Includes the headwaters of the South Fork of the St. Lucie River, North Fork of the Loxahatchee River and Kitching Creek
Cypress Creek	4.5 sq. mi.	Martin & Palm Beach	North of Indiantown Rd., west of the Northwest Fork	Forested and interspersed with marshes, cypress swamps and wet prairies	Forms the headwaters of Cypress Creek
Jonathan Dickinson State Park	11, 500 ac.	S.E. Martin	The Park surrounds Kitching Creek and portions of Cypress Creek, the Northwest Fork and the North Fork of the Loxahatchee River	Extensive wet pine flatwoods, marshes, wet prairies and forested swamps	Surrounds Kitching Creek and portions of Cypress Creek, the Northwest Fork and North Fork of the Loxahatchee River
J.W. Corbett Wildlife Management Area	57, 000 ac.	Northern Palm Beach	Adjacent to DuPuis Reserve	Wet flatwoods, mesic flatwoods, wet prairies, marshes, cypress swamps and remnants of the Everglades	The Hungryland Slough begins in Corbett and flows east until it meets the Loxahatchee Slough
Hungryland Slough	3,000 ac[1]	Palm Beach	Northwestern portion of the Loxahatchee Slough Natural Area	Pine flatwoods, wet flatwoods, cypress swamps, depression marshes and wet prairies	A remnant slough; formerly flowed from the area near Corbett WMA to merge with the northern portion of the Loxahatchee Slough; drained by the west leg of the C-18; drainage is to the east toward the Loxahatchee Slough
Loxahatchee River Preserve Area	1, 926 ac.	Southern Martin & Northern Palm Beach	Adjacent to JDSP and Palm Beach County's Riverbend Park	River floodplain	Surrounds the Loxahatchee River and includes a portion of the historic floodplain of the Northwest Fork
Loxahatchee Slough	>13, 000 ac.	Palm Beach	West of the Turnpike and north of SR 710	Wet flatwoods, marshes, cypress swamps, wet prairies and hydric hammock	The Loxahatchee Slough flows north from the West Palm Beach Water Catchment Area toward the Northwest Fork of the Loxahatchee River; Drained by the east leg of the C-18
Pal-Mar	37, 000 ac.	Southern Martin & Northern Palm Beach	East of Beeline Hwy., north of Indiantown Rd. and west of SR 711	Pine flatwoods, marshes and wet prairies	Hydrology is nearly unaltered, ditches and canals are present but have not caused significant impact to the historic flow of water
South Fork of the St. Lucie River	184 ac.	NW Martin	Adjacent to the Atlantic Coastal Ridge	Riverine system	Surrounds the lower reaches of the river
West Palm Beach Water Catchment Area	19.3 sq. mi.	Palm Beach	Impounded portion of the Loxahatchee Slough located south of SR 710	Pine flatwoods, hydric pine flatwoods, hardwood hammocks, marsh and cypress heads and cypress-shrub	Limited connection to the Loxahatchee Slough via two culverts under the Beeline Highway; Historic headwaters of the Northwest Fork of the Loxahatchee River

Source: Treasure Coast Regional Planning Council 1999, Martin County Planning Dept. 2000; [1] PBC ERM Staff

Uplands

According to the 1984 National Wetlands Inventory, 61.3 percent of the Loxahatchee River watershed is uplands. Upland communities present in the Loxahatchee River watershed are sandhill, pine flatwoods, hydric pine flatwoods, sand pine scrub, xeric oak scrub, beach and dune systems (Treasure Coast Regional Planning Council, 1999). The watershed contains some of the last remaining coastal sand pine scrub communities on Florida's southeast coast (FDEP, 1998).

Estuary

The estuary is centrally located within the Loxahatchee River watershed **(Figure 2)** and receives freshwater from three major tributaries of the Loxahatchee River and seawater from the Jupiter Inlet. The mixing of seawater and freshwater creates the brackish water characteristic of the estuary. The central embayment is shallow with an average depth of four feet and the area is 0.6 square miles (FDEP, 1998; Antonini et al., 1998).

Natural communities in the estuary are seagrass beds, tidal flats and oyster beds. The tidal and freshwater flows determine bottom sediment characteristics and sustain several distinct biological communities. Seagrass beds and oyster bars grow where suitable undisturbed bottom sediment occurs and where tides maintain adequate salinity and flow conditions (FDEP, 1998). Seagrass covers approximately 5 percent of the water areas. It is found fringing the shoreline; as extensive beds southwest of the sandbar and in shoal water at the mouth of the North Fork, and as patches between Dolphin and Marlin canals and between the mangrove islands and the Alternate A1A Bridge. (Antonini et al., 1998)

Plants and Animals

The combination of climate, vegetation and water bodies in the Loxahatchee River area has resulted in a high diversity of animal species. In 1965, two hundred sixty-seven species, consisting of 169 genera and 78 families were observed in and along the river and its estuary. The area surrounding the Northwest Fork is inhabited by numerous vertebrate species identified as endangered, threatened or of special concern by the Florida Fish and Wildlife Conservation Commission (FWC), or listed as threatened or endangered by the United States Fish and Wildlife Service (USFWS). State and federally listed animals in the watershed are shown in **Table 10** and listed plants are shown in **Table 11.**

In addition, the entire Loxahatchee River has been designated by USFWS as a critical habitat for the West Indian manatee. Invertebrate and vertebrate aquatic animals are numerous in the marshes, lakes and streams in the river area. Freshwater fish include largemouth bass, speckled perch, bluegill, shellcracker, redbreast, warmouth, bowfin, gar, channel catfish and many species of minnows. The manatee, an endangered aquatic mammal, frequents the Loxahatchee River estuary. Numerous turtles also live in and around the river. Saltwater fish include snook, tarpon, mullet, bluefish, jack, sheepshead, drum, sand perch, grouper, snapper and flounder. Mammals and birds are frequently encountered along the riverbank. The more commonly seen species include raccoon, opossum, whitetail deer, osprey, barred owl, egrets, herons and ibis.

Additional species, although not identified on the official lists compiled by the State of Florida, may be identified as being either endangered, threatened or of special concern by the Florida Committee on Rare and Endangered Plants and Animals. The threatened osprey often nests in dead cypress trees in the lower Northwest Fork. The great egret, the black-crowned night heron and the yellow-crowned night heron, classified as Species of Special Concern, are also found in the Loxahatchee River area.

The Loxahatchee National Wild and Scenic River and JDSP contain 52 federal and state species that are endangered, threatened, or of special concern (23 animals and 29 plants). Those species having a federal designation found within this area are: the alligator, indigo snake, scrub jay, bald eagle, wood stork, snail kite, manatee, four-petal paw paw, perforate lichen and Small's milkwort (FDEP, 1998).

Table 10. Threatened and Endangered Animals and Species of Special Concern in the Loxahatchee River Watershed

Scientific Name	Common Name	FCREPA[1]	FWC[2]	FDA[3]	USFWS[4]
MAMMALS					
Blarina carolinensis shermani	Sherman’s short-tailed shrew	SSC	SSC		
Eumops glaucinus	Florida mastiff bat		E		E
Felis concolor coryi	Florida panther		E		E
Peromyscus floridanus	Florida mouse	T	SSC		
Sciurus niger shermanii	Sherman’s fox squirrel	T	SSC		
Trichechus manatus latirostris	West Indian manatee	T	E		E
BIRDS					
Ajaia ajaja	Roseate spoonbill	R	SSC		
Aphelocoma coerulescens	Florida scrub jay	T	T		T
Aramus guarauna	Limpkin	SSC	SSC		
Dendroica kirtlandii	Kirtland’s warbler	E	E		E
Egretta caerulea	Little blue heron	SSC	SSC		
Egretta thula	Snowy egret	SSC	SSC		
Egretta tricolor	Tricolored heron	SSC	SSC		
Eudocimus albus	White ibis	SSC	SSC		
Falco pergrinus tundrius	Arctic peregrine falcon	E	E		
Falco sparverius paulus	Southeastern American kestrel	T	T		
Grus canadensis pratensis	Florida sandhill crane	T	T		
Haliaeetus leucocephalus	Bald eagle	T	T		T
Mycteria americana	Wood stork	E	E		E
Pelecanus occidentalis	Brown pelican		SSC		
Picoides borealis	Red-cockaded woodpecker	E	T		E
Polyborus plancus audubonii	Crested caracara		T		T
Rostrhamus sociabilis	Snail kite	E	E		E
Speotyto cunicularia floridana	Florida burrowing owl	SSC	SSC		
Sterna antillarum	Least tern	T	T		
FISH					
Centropornus undecimalis	Common snook		SSC		
AMPHIBIANS					
Rana capito aesopus	Gopher Frog	T	SSC		
REPTILES					
Alligator mississippiensis	American alligator	SSC	SSC		T(S/A)
Drymarchon corais couperi	Eastern indigo snake	SSC	T		T
Gopherus polyphemus	Gopher tortoise	T	SSC		
Pituophis melanoleucus	Florida pine snake		SSC		

Treasure Coast Regional Planning Council, 1999. Jonathan Dickinson State Park Unit Management Plan -State of Florida Department of Environmental Protection, February 2000. [1] Florida Committee on Rare and Endangered Plants and Animals [2] Florida Fish and Wildlife Conservation Commission [3] Florida Department of Agriculture and Consumer Services [4] United States Fish and Wildlife Service. E=Endangered, R=Rare, T=Threatened, T(S/A)=Threatened/Similarity of Appearance, SSC=Species of Special Concern.

Table 11. Threatened and Endangered Wetland Plant Species that Occur in the Project Area

Scientific Name	Common Name	FCREPA[1]	FDA[3]	USFWS[4]
Acrostichum danaeifolium	Giant leather fern		C	
Actinostachys pennula	Fern ray/Tropical curly-grass fern		E	
Asclepias curtissii	Curtiss' milkweed		E	
Asimina tetramera	Four-petal pawpaw		E	E
Azolla caroliniana	Mosquito fern		T	
Bletia purpurea	Pine pink orchid		T	
Calopogon barbatus	Bearded grass pink		T	
Calopogon multiflorus	Many-flowered grass pink		E	
Campyloneurum latum	Strap fern		E	
Campyloneurum phyllitidus	Long strap fern		E	
Chamaesyce cumulicola	Sand dune spurge		E	
Chrysophyllum oliviforme	Satinleaf		E	
Cladonia perforata	Perforate reindeer lichen		E	E
Conradina grandiflora	Large-flowered rosemary		E	
Dennstaedtia bipinnata	Cuplet fern	E	E	
Drosera intermedia	Water sundew		T	
Encyclia cochleata	Clamshell orchid		E	
Encyclia tampensis	Butterfly orchid		C	
Epidendrum rigidum	Rigid epidendrum		E	
Ernodea littoralis	Beach creeper		T	
Eulophia alta	Wild coco		T	
Habenaria nivea	Snowy orchid		T	
Halophila johnsonii	Johnson's seagrss			T
Hexalectris spicata	Crested coralroot		E	
Ionopsis utricularioides	Delicate ionopsis		E	
Lechea cernua	Nodding pinweed		T	
Lechea divaricata	Pine pinweed		E	
Lilium catesbaei	Catesby's lily		T	
Lycopodium cernuum	Nodding club moss		C	
Nemastylis floridana	Celestial lilt	T	E	
Nephrolepis biserrata	Giant sword fern		T	
Ophioglossum palmatum	Hand adder's tongue fern	E	E	
Osmunda cinnamomea	Cinnamon fern		C	
Osmunda regalis	Royal fern		C	
Pecluma ptilodon	Swamp plume polypody		E	
Peperomia humilis	Low peperomia		E	
Phlebodium aureum	Polyplody fern		T	
Pinguicula caerulea	Blue-flowered butterwort		T	
Pogonia ophioglossoides	Rose pogonia		T	
Polygala smallii	Small's milkwort		E	E
Psilotum nudum	Whisk fern		T	
Pteroglossaspis ecristata	Non-crested coco		T	
Salvinia rotundifolia	Water spangles		T	
Spiranthes laciniata	Lace-lip ladies' tresses		T	
Spiranthes longilabris	Long-lip ladies' tresses		T	
Spiranthes vernalis	Ladies' tresses		T	
Stenorrhynchos lanceolata	Leafless red beak orchid		T	
Thelypteris interrupta	Aspidium fern		T	
Thelypteris kunthii	Aspidium fern		T	
Thelypteris palustris	Aspidium fern		T	
Thelypteris serrata	Dentate lattice vein fern		E	
Tillandsia balbisiana	Inflated wild pine		T	
Tillandsia fasciculata	Common wild pine		E	
Tillandsia flexuosa	Twisted air plant	T	E	
Tillandsia utriculata	Giant wild pine		E	
Tillandsia valenzuelana	Soft-leaved wild pine		T	
Tillandsia variabilis	Soft-leaved wild pine		T	
Tolumnia bahamensis	Dancing lady orchid		E	

Treasure Coast Regional Planning Council, 1999. Jonathan Dickinson State Park Unit Management Plan -State of Florida Department of Environmental Protection, February 2000. [1] Florida Committee on Rare and Endangered Plants and Animals [2] Florida Fish and Wildlife Conservation Commission [3] Florida Department of Agriculture and Consumer Services [4] United States Fish and Wildlife Service. E=Endangered, R=Rare, T=Threatened, T(S/A)=Threatened/Similarity of Appearance, SSC=Species of Special Concern.

Navigation and Recreation

Use of the Loxahatchee River and Estuary by motorized craft is essentially limited by channel depth, width and vertical clearance of bridges. Boats much larger than 25 to 30 feet are limited to the lower portions of the river by both lack of depth and vertical clearance (Law, 1991b). The estuary central embayment is a shallow water region. Over 50 percent of this area is less than two feet deep. The main river channel is the only improved access channel in the central embayment (Antonini et al., 1998).

The reaches of the Loxahatchee included in the "wild and scenic" corridor have relatively limited public access points to the river (**Figure 13**). Existing access and major facilities that support public use are clustered at each end of the 7.5 mile "wild and scenic" segment, concentrating public use in these areas. Most existing river related recreational uses and major

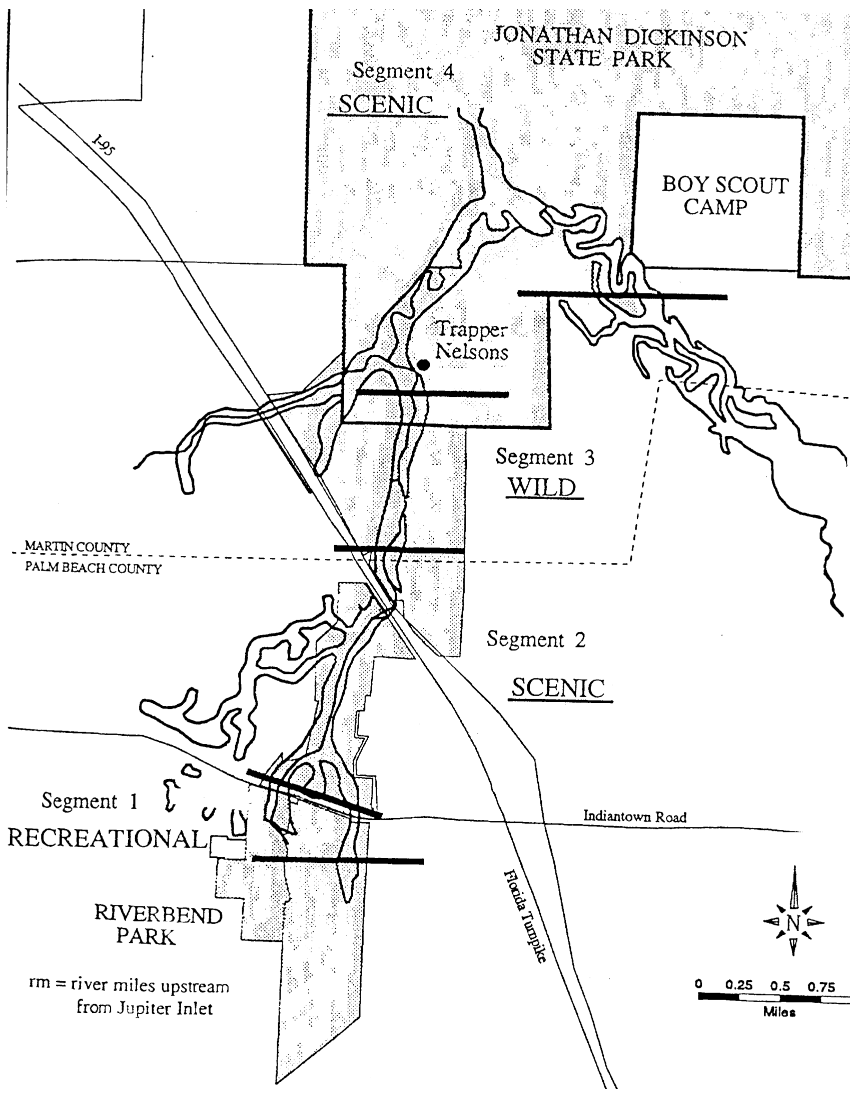


Figure 13. Loxahatchee Wild and Scenic River Corridor Classifications.

facilities occur within JDSP, but in the future other major facilities will be provided and managed by Palm Beach County at Riverbend County Park. Riverbend County Park, which includes the SFWMD's Reese and Gildan tracts, and JDSP are the two primary public access areas on the River. Riverbend County Park, located between Indiantown Road and the C-18, comprises more than 600 acres and encompasses the half mile “recreational” segment of the river corridor.

Public access to the River at the downstream end of the “wild and scenic” corridor is available at two points. Both are JDSP boat docks. The first is the primary launching and take-out point for canoeists who rent boats from the park concessionaire. It is also the staging area for river cruises on the 44-foot "Loxahatchee Queen II", operated by the concessionaire. Restrooms, trails, cabins and picnicking facilities are nearby. The other facility is located 0.5 miles downriver and consists of a concrete boat dock and ramp. It is adjacent to a developed campground within JDSP. This site is used primarily by park visitors who bring their own boats and canoes, but is also used as the take-out point by canoeists completing the trip downstream from Riverbend County Park. Several secondary access, or resting, points exist in the river corridor area, but these are relatively insignificant as contributing sources of use pressure.

The Loxahatchee River's natural features and its proximity to the urban areas of Southeast Florida make it exceptionally well suited to provide outdoor recreation. Historically, canoeing has been the main recreational use of the river and its surrounding area, but other activities include kayaking, fishing, nature study, wildlife observation and motor boating. Motor boating is effectively restricted to the portion of the river downstream from the Trapper Nelson Interpretive Site because of the narrow channel, numerous obstructions and shallow depth of the upper river. Virtually all public recreational use of the upper river involves paddling, either as a recreational activity or as a means of gaining access to the river area to enjoy other activities.

An important function of the river management program is to determine and monitor the quantity and mixture of recreation and other public use, which can utilize the river without adverse impacts on its resource values. The recreation "carrying capacity" of rivers has received the attention of river managers for more than a decade, but there is little consensus as to the most appropriate means for estimating carrying capacity. This is because carrying capacity is a dynamic concept and a number of factors exist, including management objectives, the physical and biological nature of the resource, and the preferences and tolerances of users, which must be considered together in determining a river's carrying capacity (FDEP and SFWMD 2000)

WATER RESOURCE ISSUES -- PROBLEMS IDENTIFIED

The following information was taken from the *Loxahatchee River Watershed Action Plan* (FDEP, 1998).

Surface Water Resources

Altered Hydroperiod. In response to flooding, drainage ditches and canals have been built to drain developed areas. Canals divert water and affect the historical flow patterns to natural wetland systems. Barriers have been built in many areas that interfere with the historical movement of water in this region. These impediments, including canals and roads, intensify flooding in some areas. This network of canals and barriers has reduced water storage in natural areas, caused flooding in other areas and degraded water quality in surface waters.

Water Quality. Most of the upper watershed has not experienced major water quality problems. Some problems have been noted in the lower watershed, including decreasing DO in the "wild and scenic" Northwest Fork of the Loxahatchee River, and nutrient loading in the estuary.

Lack of Surface Water Quality Data. There is a lack of historical surface water quality data in some parts of the watershed, including the North Fork, Cypress Creek and other tributaries of the Loxahatchee River Watershed. Due to chronic water supply issues, the potential for saltwater intrusion and potential impacts to nearby wetlands and the Loxahatchee River, local utilities in this area already make extensive use of the Floridan Aquifer, reuse of reclaimed water and water conservation practices to help meet increasing water demands.

Storm Water Runoff. Storm water runoff introduces contaminants from developed areas into surface water. Contaminants include pesticides, nutrients, oils and grease and suspended solids. These contaminants can reduce DO, which can cause fish kills. The watershed has several older neighborhoods that were developed without adequate storm water systems. This can cause flooding during heavy rainfall.

Saltwater Intrusion. Reduced flow in the Northwest Fork of the Loxahatchee River has allowed saltwater to migrate upriver causing the introduction of mangroves into areas once dominated by freshwater floodplain swamp.

Scouring/Siltation. During heavy rain events, tremendous flows cause scouring in residential and agricultural canals, which increases sediment loading into surface waters. This phenomenon causes sedimentation in the navigable channels and has an adverse effect on the aquatic plants and animals.

Ground Water Resources

Wellfield Pumping. Over pumping ground water has the potential to cause wetland drawdown impacts and saltwater intrusion into the freshwater aquifer. Under SFWMD rules utilities are not allowed to over pump the ground water within the Loxahatchee watershed.

Ground Water Contamination. With the exception of the West Palm Beach Catchment Area, the majority of drinking water within the watershed is derived from ground water. The most common source of ground water contamination is leaking fuel storage tanks. Other contamination sources include dry cleaners, pesticide storage areas and other operations that handle hazardous materials. With the exception of Sub-basin 6, there are known ground water contaminated sites in all of the other subbasins. Further details pertaining to these contaminated sites can be found within the FDEP's 1998 Watershed Action Plan (FDEP, 1998).

Wastewater Treatment. Nutrients leaching from septic tank drainage fields may seep into ground water, which ultimately feeds surface waters. In some areas this can have a negative impact on water quality. Human sewage waste entering surface water poses a health threat to swimmers and other recreational users.

Habitat Management

Sustainable Usage - Recreation and Fisheries. With more and more people moving into the area, there is increased pressure on natural resources and more competition for limited recreational resources. Increased fishing puts more pressure on fish stocks. Boat propellers in shallow areas can damage seagrass beds. Fishing may not be compatible with competing activities, such as water skiing and jet skis. The "wild and scenic" Northwest Fork of the Loxahatchee River is a popular destination for canoe and kayak enthusiasts. Increased boat traffic has caused concern that the river's carrying capacity will be exceeded.

Exotic Pest Plants. Exotic pest plant species have been introduced into Florida for decorative landscaping, agriculture and to dry up wetlands for development. The ability of these exotic species to reproduce rapidly, due to a lack of predatory pressure, allows them to spread quickly into natural ecosystems. The exotic pest plants of most concern in the watershed are Old World climbing fern *(Lygodium microphyllum)*, melaleuca *(Melaleuca quinquenervia)*, Brazilian pepper *(Schinus terebinthefolius)*, Australian pine *(Casuarina* spp.*)* and downy rose-myrtle *(Rhodomyrtus tomentosa)*. Several other exotic aquatic plants occur in natural waterways and canals, impede navigation and cause water quality and habitat problems.

Exotic Animals. Exotic animals also upset the natural balance of ecosystems. Some examples of exotic animals in the Loxahatchee River watershed include feral hogs, armadillos and the black acara.

Fire Management. Fire-dependent plant communities, including pine flatwoods and sand pine scrub, are found throughout the watershed. Due to the proximity of residential neighborhoods to these natural areas, naturally occurring fires from lightning strikes must be controlled to protect property. Land managers implement prescribed burn plans to provide the necessary fire cycle to renew these habitats. Prescribed fire management plans identify optimum wind conditions for conducting controlled bums, so that the smoke will not impact local residents. As more residential homes are constructed adjacent to natural areas, smoke management will become more difficult. The absence of fire management on privately owned land with fire-dependent plant communities presents problems for the implementation of necessary land management practices on publicly-owned land.

Habitat Fragmentation and Habitat Loss. Altered hydroperiod, development, exotic plant invasions and lack of land management have contributed to wildlife habitat loss and fragmentation.

Off-Road Vehicle Damage to Habitat. Users of off-road vehicles are accessing privately owned, undeveloped parcels. The use of these vehicles on undeveloped land damages the native plant understory. Exotic pest plants often invade these disturbed areas.

Solid Waste Dumping. Dumpers use isolated roads in low density residential developments to avoid paying tipping fees at the landfill or costly hazardous waste disposal fees. Hazardous constituents from waste piles can leach into the environment, and also pose physical hazards to wildlife and humans. Waste tire piles, for example, provide breeding habitat for mosquitoes. The cost of cleaning up illegally dumped waste falls on the property owner if the dumper is not identified and forced to pay.

Urban Sprawl: Sprawl is defined as housing areas that are isolated or poorly connected to existing neighborhoods. The impacts of urban sprawl on natural resources can be direct (e.g., loss of habitat) or indirect (e.g., alteration of the water table in nearby wetlands).

Loxahatchee River Watershed Problem Matrix

The following matrix (**Table 12**) indicates which problems occur in the subbasins shown in **Figure 5**. Some problems are found throughout the watershed including altered hydroperiod and exotic pest plants. Other problems are isolated and affect only one or two subbasins, such as beach erosion and off road vehicle damage. Part II of the Watershed Action Plan (FDEP, 1998) proposes projects to address many of the problems identified in the watershed subbasins.

Table 12. Problems Identified Within the Various Subbasins of the Loxahatchee River Watershed

Current Problems	Subbasin 1 Jonathan Dickinson/ Hobe Sound	Subbasin 2 Coastal	Subbasin 3 Estuary	Subbasin 4 C-18/ Corbett	Subbasin 5 Cypress/ Pal-Mar	Subbasin 6 Citrus	Subbasin 7 Wild & Scenic
Altered Hydroperiod	X	X	X	X	X	X	X
Water Quality			X				X
Lack of Water Quality Data	X			X	X	X	X
Storm Water Runoff	X	X	X			X	X
Saltwater Intrusion							X
Scouring/Siltation			X		X		X
Wellfield Pumping	X						
Ground Water Contamination	X	X	X	X	X		X
Wastewater Treatment	X	X	X				X
Sustainable Usage		X	X				X
Exotic Pest Plants	X	X	X	X	X	X	X
Exotic Animals	X			X	X	X	
Fire Management	X	X		X	X	X	
Habitat Fragmentation	X	X	X	X	X	X	X
Off Road Vehicle Impacts				X	X		
Solid Waste Dumping			X	X	X		X
Urban Sprawl	X			X	X		X

CHAPTER 3 -- RESOURCE FUNCTIONS AND CONSIDERATIONS

The following chapter identifies the primary water resources functions to be protected by the proposed minimum flow and level (MFL) as well as the baseline resource conditions for assessing significant harm. Considerations for making this determination are set forth in Section 373.0421(1)(a) Florida Statutes (F.S.), which requires the water management districts to consider changes and structural alterations that have occurred to the water resources when setting a MFL. These considerations and exclusions are discussed below. **Chapter 3** also contains a discussion of resource protection issues, policies and procedures established to protect these resources.

WATER RESOURCE FUNCTIONS

The Loxahatchee River Watershed contains significant water resources that provide a wide range of functions and services to the regional system. These functions need to be clearly identified so that they can be adequately considered in order to protect the resource from significant harm. The primary water resource functions that were considered in the development of MFLs for the Loxahatchee River and estuary include:

- Fish and wildlife habitat, including threatened and endangered plants and animals
- Preservation of the river's "wild and scenic" values
- Providing drainage and flood protection for surrounding areas
- Water supply
- Recreation
- Navigation
- Preservation of historical and archeological values
- Water quality improvement

The Loxahatchee River and Estuary can be divided among a number of different geographic components as described in **Chapter 2**, including the Northwest Fork River and estuary, North Fork River and estuary, C-18 Canal (C-18), Southwest Fork and the central embayment. Based on the resources within these different components and the functions provided, SFWMD staff determined that the most critical need was to develop minimum flow criteria that would protect the Northwest Fork River from significant harm. This decision was reached because of the following: (a) the importance of the Northwest Fork as a Wild and Scenic River; (b) this resource is most threatened by historic, ongoing and potential reductions in flow and consequent changes in salinity; and (c) our initial analyses indicate that providing an acceptable minimum flow to the Northwest Fork River will also protect low-salinity, brackish water and marine resources in the downstream estuary.

Fish and Wildlife Habitat

A large portion of the Loxahatchee River watershed remains undeveloped and retains extensive native plant and animal communities. The river's tributaries and wetlands provide a regional wildlife corridor and habitat for important species, such as manatees, otters, alligators and many varieties of birds. Adequate freshwater flow and water levels are required to maintain these habitats for plants and animals. Maintenance of sufficient water depths and hydroperiods within the upstream watershed, and providing sufficient flows to the river are needed to protect existing plant and animal communities. The upstream freshwater portion of the river provides important habitat for freshwater (riverine) species of fish that are important to both recreational fishing interests and wading birds. Freshwater species include largemouth bass, bluegill, shellcracker, redbreast, warmouth, bowfin, channel catfish and many species of minnows. The freshwater swamp community contains a number of species of trees and shrubs that provide important specialized habitats and food (e.g. fruits) to birds, especially migratory and endangered species and other wildlife. These natural systems also provide treatment capacity to ensure that high quality water flows into the river and estuary.

The downstream estuary provides habitat for juvenile and adult estuarine species, such as snook, mangrove snapper as well as juvenile organisms that populate offshore reef communities. The Loxahatchee Estuary is also habitat for several endangered and threatened species including sea turtles, manatees and Johnson's seagrass (*Halophila johnsonii).* The U.S. Fish and Wildlife Service (USFWS) have designated the entire Loxahatchee River as critical habitat for West Indian manatee (FDEP and SFWMD, 2000). The maintenance of viable estuarine ecosystems requires a proper balance of freshwater inflow -- sufficient freshwater flow to provide brackish conditions at appropriate locations and time periods, and avoidance of high volume freshwater flows that may destroy or damage sensitive plants and animals.

Preservation of the River's Wild and Scenic Values

Based on its natural scenic qualities, diverse native plant and wildlife communities, and in order to preserve the natural landscape, the Northwest Fork of the Loxahatchee River was designated as Florida's first federally designated Wild and Scenic River in 1985. The upstream freshwater portion of the river is characterized by its extensive and diverse floodplain swamp and bald cypress community, which represents an important component of the regional ecosystem. These habitats include cypress and mixed hardwood swamp, freshwater marsh, wet prairie, slough, river, stream, pine flatwoods, sand pine scrub, oak scrub and hardwood hammock. The floodplain swamp community is both a unique and important habitat and represents one of the last remaining areas of this type in South Florida (McPherson and Sabanskas, 1980; United States Department of Interior, National Park Service, 1982).

The floodplain swamp supports a complex and diverse community structure comprised of low understory groundcovers and shrubs, medium height sub-canopy shrubs and hardwoods, and high canopy hardwoods, palms and bald cypress. The high canopy provides important habitat for a number of protected epiphytic plants, such as ferns, bromeliads and orchids (United States Department of Interior, National Park Service, 1982). The area also supports a diverse population of animals, including many that utilize surrounding upland and estuarine habitats. Invertebrates (e.g. leeches, worms, juvenile and adult insects, crustaceans and mollusks), amphibians, fish and reptiles inhabit the inundated and exposed benthic areas of the swamp community. Understory vegetation provides refuge and food for a variety of small to large mammals, reptiles and insects. Tree trunks provide nesting cavities for birds and small to medium-sized mammals. In addition, the swamp forest canopy is an important habitat for birds, offering food (e.g. fruits, berries), refuge, roosting and nesting sites (Ewel, 1990b).

A total of 267 animal species have been observed in and along the river and estuary (FDEP and SFWMD, 2000). The cypress river swamp community supports a number of species that have been identified as endangered, threatened or species of special concern by the Florida Fish and Wildlife Conservation Commission (FWC), or listed as threatened or endangered by the USFWS (**Tables 10 and 11**, Chapter 2).

The long-term decline in the extent and health of the freshwater floodplain swamp community along the upstream portion of the Northwest Fork appears to be linked to hydrologic alterations of the river and its watershed, as well as past dredging activities in the estuary and Jupiter inlet. Combined, these two factors have resulted in reduced freshwater flows to the river, lowering of the ground water table and increased saltwater intrusion of the floodplain swamp community during dry periods. Sufficient freshwater flows are required during the dry season to protect the existing cypress community from further degradation and loss of natural function.

Drainage and Flood Protection

The Loxahatchee watershed and its rivers, canals and wetlands comprise an area of more than 200 square miles. Water levels in the rivers and canal systems are managed to provide for drainage of land and storage of water during the wet season and adequate conveyance capacity to protect lives and property in surrounding upland residential areas from flood damage during severe storm events. The amount of water that can be stored in the basin is limited due to the lack of sufficient storage capacity. For this reason, water must be discharged to tide in order to provide flood protection within the basin. Lack of regional storage can act as a constraint on the District’s ability to fully meet the proposed MFL until increased storage capacity becomes available as a result of water supply development and restoration projects

The primary flood control facility for the Loxahatchee River Watershed is water control structure 46 (S-46). Structure 46 is a reinforced concrete, gated spillway located on the C-18 with discharge controlled by three stem operated, vertical lift gates. Structure 46 also supports water level upstream and downstream remote digital recorders, a gate position recorder and a rain gauge remote digital recorder. Design characteristics of S-46 are shown in **Table 13**.

Table 13. C-18 Flood Discharge Characteristics

Parameter	Design	Standard Project Flood
Discharge rate	3,420 cfs	3,420 cfs
Standard Project Flood	50% SPF	100% SPF
Headwater Elevation	12.8 ft NGVD	16.4 ft. NGVD
Tailwater Elevation	2.2 ft	2.2 ft
Type Discharge	Uncontrolled free	Controlled free

The gates are automatically controlled so that the operating system opens or closes the gates in accordance with the operational criteria discussed below. Structure 46 is located on Canal 18, about 0.5 mile east of the Florida Turnpike/Interstate 95 (I-95) and maintains optimum upstream water control stages in Canal 18. The structure is designed to pass 50 percent of the Standard Project Flood without exceeding the upstream flood design stage (**Table 13**); restrict downstream flood stages and channel velocities to non-damaging levels; and prevents saline intrusion of local ground water. Structure 46 is operated to maintain an optimum headwater elevation of 14.8 feet, when sufficient water is available to maintain this level, through automatic operation of the gates. The automatic controls on the gates function as follows:

- When the headwater elevation rises to 15.0 feet, the gates will open at a speed of 0.4 inches per minute.
- When the headwater elevation rises or falls to 14.8 feet, the gates will become stationary.
- When the headwater elevation falls to 14.5 feet, the gates will close at 0.4 inches per minute.
- During major storm events, the gates are operated manually to lower and maintain a headwater stage of 12.8 feet. A major storm event is defined as any event which causes a tailwater stage at the C-18 Weir to rise above 17.6 feet.

During large eastern basin storm events, the gates are operated manually to lower and maintain an S-46 headwater stage of between 13.0 and 14.0 feet. A large eastern basin storm event is defined as one that prevents adequate gravity drainage of the agricultural area at the junction of C-18 and the Turnpike. This operation will be maintained for 24 hours (or longer if conditions warrant).

Water Supply

The hydrology of the Loxahatchee watershed strongly influences the source and impacts of consumptive use. The orientation of the watershed is shown on **Figure 14**. The watershed is not a true watershed in terms of drainage and ground water flows but is an aggregation of several subbasins as defined by FDEP (1998). Drainage features within the watershed have been highly altered as discussed in earlier portions of this report. As a result, much of the water use in the watershed does not hydrologically influence flows in the Loxahatchee River, as discussed below.

The availability of fresh ground water is limited by the relatively low yielding nature of the shallow aquifer coupled with the presence of saline water to the east and numerous isolated wetlands to the west. The aquifer is inter-layered with low permeable fine sand, silt and hardpan beds that impede the vertical flow of water. The best production zones occur generally between 80 and 150 feet below land surface. Water produced by a well is derived from ground water stored in the interconnected pore spaces of the sediments that comprise the aquifer. Individual wells drilled into the Surficial aquifer in the watershed can produce about 150 to 300 gallons per minute. Larger wells produce more water. In localized areas, especially where the Biscayne Aquifer extends into this area along the Florida Turnpike, production rates may be much higher. The area of influence of a well is dependent primarily on the permeability of the aquifer, the

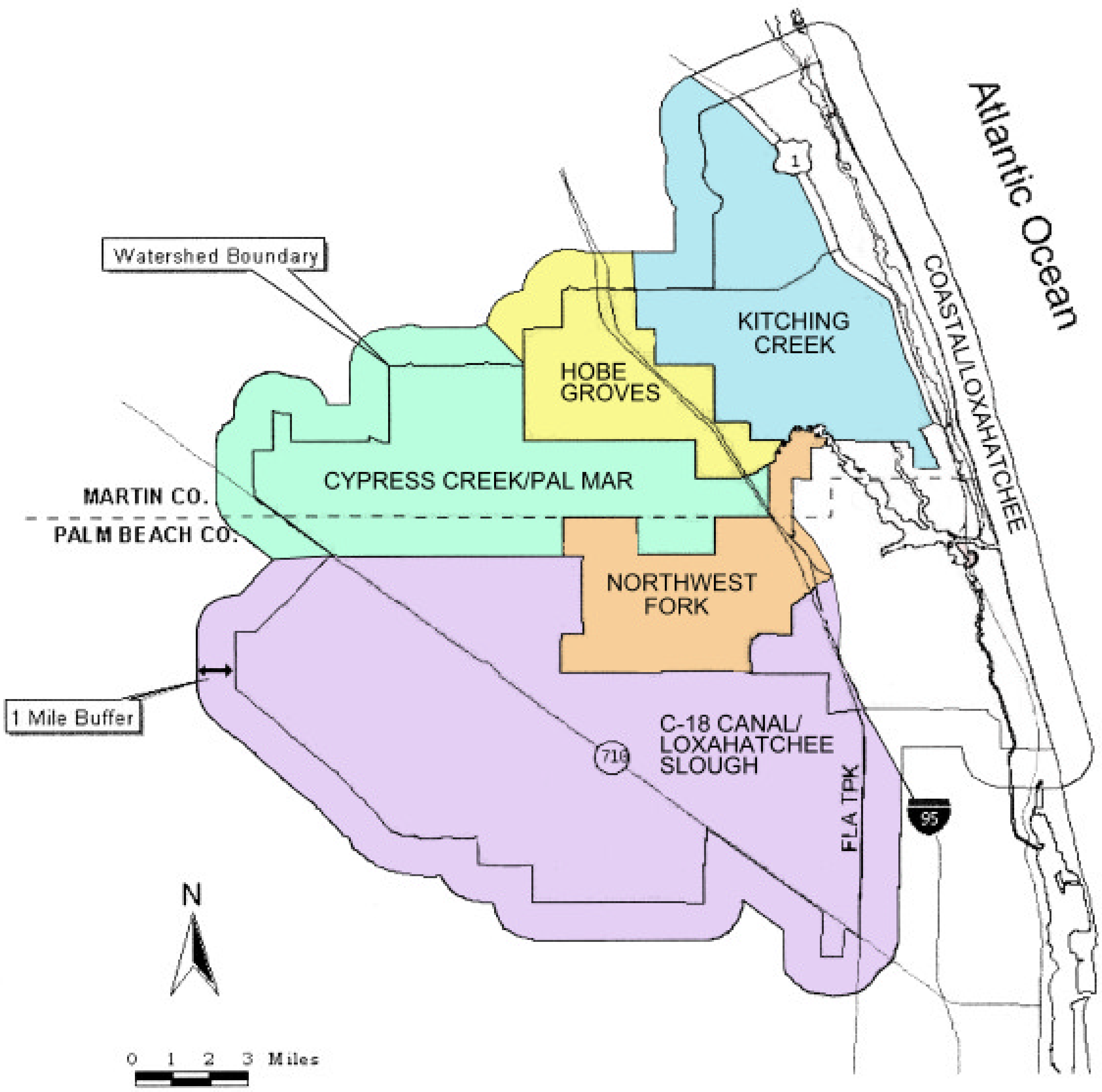


Figure 14. Loxahatchee watershed boundary (based on FDEP 1998) showing locations of sub-basins and 1 mile buffer added to the perimeter.

sustained rate of withdrawal, the storage of the aquifer (the volume of water produced from a unit volume of aquifer when the pressure is reduced by one unit), and the degree to which low permeability sediments (clay and silts) restrict the vertical recharge of ground water or surface water into the well. The area of influence of most domestic production wells within the watershed is generally less than 2,000 feet (an area of about 80 acres), depending on the volume of water pumped. The cone of depression resulting from pumpage may be small in aerial extent but becomes rather steep near the wellhead. Land uses in the basin include about 20,000 acres of agriculture (11% of the basin), 32,000 acres (18%) urban and industrial, 120,000 acres (67%) water and conservation and 8,000 acres recreational and industrial. Total water use in the basin is estimated at about 100 million gallons per day (mgd), of which, agriculture accounts for an estimated 18 percent, public water supply is 68 percent, and golf courses and industrial uses account for about 14 percent. Due to the number of permits already issued and the need to protect the river and wetlands, very little allocable water remains from the surficial aquifer within the watershed.

The general locations of ground water contours during the dry season (April 1984) are shown on **Figure 15**. Ground water flow occurs perpendicular to the contour lines, from areas of high water levels toward areas with lower water levels. This figure was generated using ground water monitor data collected from regional (U. S. Geological Survey) and local monitor wells (water use monitor wells). While the ground water surface changes during the year based on rainfall and pumpage, the general west to east flow direction shown occurs throughout the year.

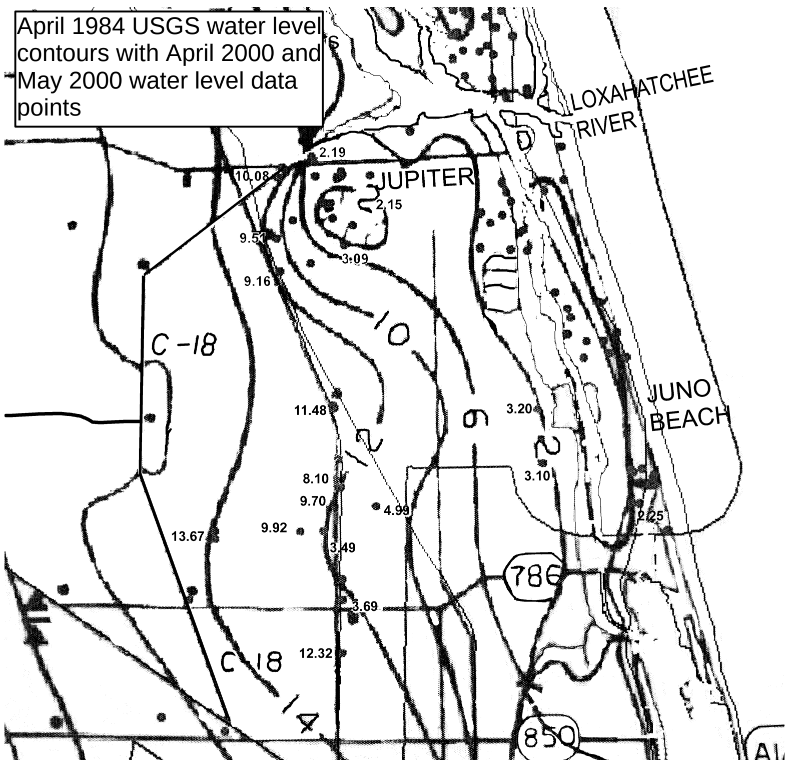


Figure 15. Ground water contours (numbers and lines) in the Loxahatchee watershed (April 1984) with water levels recorded in feet at monitoring wells (dots) during April and May 2000. The direction of ground water flow is perpendicular to the contour lines, from areas of high water levels to areas of low water levels.

As expected near the coast, the predominant direction of ground water flow is toward the Atlantic Ocean. In other areas, the flow is generally toward the east, with localized flow occurring towards the canals and large capacity wellfields. It should be noted that construction of the C-18, which is controlled at an elevation of about 14 feet, significantly changed ground water and surface water stages and flows in the surrounding watershed.

In this watershed, most of the permitted wells occur far enough away from the Loxahatchee River and C-18 that they do not significantly influence the ground water flow patterns to these surface water features. One notable exception is in the vicinity of the Seacoast Hood Road Wellfield where the water table contours suggest a potential influence beneath a portion of the C-18 upstream of G-92 during dry conditions. Ground water uses with areas of influence that do not extend beneath C-18 or the river, and any withdrawals from the Coastal/Loxahatchee Sub-basin (non shaded portion of the watershed in **Figure 14**) were not considered in this analysis.

Due to advances in demineralization technology, and the limited availability of water from the Surficial Aquifer System, the alternative source of the upper portions of the Floridan Aquifer System (FAS) is currently used by both the Town of Jupiter and the Village of Tequesta. These wells have screen intervals located at depths greater than approximately 800 feet and yield brackish water. Elsewhere in northern Palm Beach County, the FAS is also being treated for use as a source for golf course irrigation. The additional capital and operational, maintenance, rehabilitation, repair and replacement required for desalination and the cost associated with disposal of the mineralized concentrate have limited the use of this alternative source.

Surface water from isolated lakes is used to meet small demands or is used in conjunction with ground water for irrigation. Most of the irrigation permits in the watershed that have a permitted surface water source also have a ground water allocation. These permits are established so that ground water, which is naturally high in iron and low in dissolved oxygen, can be aerated in a lake prior to use. Since the use of ground water to maintain lake levels for aesthetic purposes alone is not permitable, permits with both surface and ground water have special conditions that limit the amount of ground water withdrawn to not exceed the volume pumped from lakes for irrigation. Use of water from C-18 and the Loxahatchee River is also limited by environmental constraints and uncertainty in water supply availability during drought.

When a surface water body occurs within the area of influence of a well, the well may induce seepage out of the surface water body. This amount of seepage, if any, is influenced by the following factors:

- The depth of the surface water body compared with the depth of the well.
- The vertical permeability of the earth materials between the bottom of the surface water body and the well.
- The difference in water level elevations between the surface water body and the ground water table.
- The permeability of the sediments at the bottom and sides of the surface water body.

In the Loxahatchee watershed, the canals and river generally drain ground water. This means that the surface water levels are lower than the adjacent ground water table. In order for a well to cause seepage from the surface water body (an indirect withdrawal), the drawdown from the well would have to be large enough to produce a lower ground water level than the water elevation in the surface water body. These conditions rarely occur within the watershed.

Even though lowering of water levels may not be sufficient to result in a net flow of water away from the surface water body, it may cause a reduction in the amount of surface water or ground water that would otherwise have flowed into the water body.

As discussed elsewhere in this report, flows in the Loxahatchee River have been highly altered due to drainage -- specifically, construction of the C-18 and drainage of the Loxahatchee Slough. As a result of drainage, the flows in the river are "flashy," meaning that the flows increase very quickly after a storm event and decrease very rapidly after the drainage is achieved. In predevelopment times, the wetlands became flooded, the water was stored, and would gradually discharge into the river by overland flow and/or ground water seepage as the dry season progressed. Under these conditions, flow rates during storms were not as high and persisted for longer periods of time.

Today, there is not sufficient storage to mimic these conditions. However, beginning in the late 1980s, the district began to operate G-92 structure in a manner that attempted to maximize the time that flows would exceed 50 cubic feets per second (cfs). Under these conditions, a direct connection is maintained between the upper basin and the “wild and scenic river.” During periods when dry conditions persist, however, there is not enough water in the C-18 to deliver to the Loxahatchee River, the C-18 is no longer connected to the river and consumptive use impacts upstream of G-92 may impact flows to the river. Such impacts occur today because the amount of storage available in the eastern portion of the C-18 has been reduced to about 200 acre-feet (water levels between 12.5 and 14.5 feet), which is much smaller than the several thousand acre-feet of storage that existed before construction of the C-18 (SFWMD, 2002)

With the development of additional storage up stream, as detailed in the MFL recovery plan in **Chapter 6**, additional water will be available for delivery to the Loxahatchee River via C-18 during dry conditions. As a result, the impacts of water use in areas adjacent to the C-18 should be offset by sufficient supplemental deliveries from these proposed storage facilities.

Recreation

The many wetlands and surface waters in the watershed provide extensive opportunities for recreational fishing, boating, hunting and waterskiing. The estuary includes DuBois and Jupiter Inlet parks, which are used extensively for recreational boating, fishing and swimming and family picnics. Many of these uses depend on providing adequate water levels, flow and water quality to support healthy plant and animal communities along the Northwest Fork and downstream estuary as well as safe public contact.

Significant recreational opportunities are provided in Jonathan Dickinson State Park (JDSP), including camping, hiking, canoeing, kayaking, boating and wildlife observation. The Trapper Nelson Interpretative Site has educational, historical and archaeological features. The Loxahatchee Queen riverboat offers daily cruises for sightseeing. A Girl Scout Camp and a Boy Scout Camp are located adjacent to the Park. JDSP encompasses 11,480 acres and attracts 169,768 visitors annually (1999-00), largely because of the Loxahatchee River and recreation that depends on it. According to research conducted by FSP, the total direct economic impact of JDSP on the local community is $5,101,443 annually. Deterioration of the ecology and aesthetics of the river are serious concerns that affect tourists and the local community. The FDEP has a statutory responsibility under Ch 258.037 F.S., “to promote the state park system for the use, enjoyment, and benefit of the people of Florida and visitors; to acquire typical portions of the original domain of the state which will be accessible to all of the people, and of such character as to emblemize the state’s natural values; conserve these natural values for all time; administer the development, use and maintenance of these lands and render such public service in so doing, in such a manner as to enable the people of Florida and visitors to enjoy these values without depleting them..."

Maintenance of a minimum flow and level is needed to provide for adequate access and enjoyable use of the resource. MFLs are also necessary to protect the water resources and vegetation communities that provide the landscape and wildlife that support these recreational activities. Impacts on recreational use of the river occur when low flows and low water levels impair the ability of the public to access the “wild and scenic” portion of the river by boat.

Navigation

The estuarine portion of the system supports navigation along the Intracoastal Waterway (ICW), maintained by the U.S. Army Corps of Engineers (USACE) and the Florida Inland Navigational District (FIND). Jupiter Inlet District maintains the Jupiter Inlet with a channel depth of -13 feet National Geodetic Vertical Datum (NGVD). Construction and maintenance of deep channels for navigational use and connection to the ocean at the inlet are in part, responsible for the increased saltwater intrusion that has occurred during the past century.

Discussions with canoe rental concessionaires that use the Northwest Fork on a regular basis indicate that when flows over the Lainhart Dam are less than 35 cfs, navigation and recreational use of the Northwest Fork becomes impaired. Access to the river by recreational boaters, fishermen, canoeists and kayakers becomes limited and at times, is restricted. Persons who have used the river during these low flow periods report that many fallen trees, littoral areas and shoals are exposed or contain only a few inches of water at low tide, thereby creating conditions that limit navigation and recreational use of the resource. Such low water conditions must occur periodically to protect cypress and other communities that require occasional drying of the substrate for seed germination to occur.

Historical and Archeological Values

The upper segment of the Northwest Fork of the Loxahatchee River is noted for its rich historical significance. The area contains numerous sites that were used by pre-historic Indians (e.g. middens). The oldest of these sites date back to the Late Archaic period, from 3000 to 750 BC. Remains of two battles that occurred between Europeans and Indians in pre-settlement times have been located along the river corridor (the “Loxahatchee Battlefield”). A more recent historical site is the Trapper Nelson zoo and homestead, located within JDSP. Segments of the river near these sites have been federally designated as “Wild”, “Scenic” or “Recreational”. The “wild and scenic” segments of the river have been protected in order to preserve the biological (i.e., bald cypress community), cultural and scenic values for future generations. Establishment of MFLs for the Northwest Fork will aide in providing the needed freshwater flows required to maintain these historical and archeological sites in a condition similar to pre-settlement times.

Water Quality Improvement

In addition to its importance as fish and wildlife habitat, the Northwest Fork provides an important source of clean freshwater to the estuary. The District has the responsibility to ensure that the establishment of MFLs does not hinder the ability to meet applicable state and/or federal water quality standards. The Loxahatchee-Lake Worth Creek Aquatic Preserve has Class II and III waters. Outstanding Florida Waters occur within JDSP and along the "wild and scenic" segments of the river. The C-18 is a Class I water body but is not directly utilized as a source of public water supply. These classifications are summarized in **Table 14.**

Table 14. Water Quality Classification of Waters in the Loxahatchee River

CLASS	GENERAL DESCRIPTIVE USE	APPLICATION WITHIN THE LOXAHATCHEE RIVER
I	Potable Water Supply	Freshwater portion of SFWMD Canal C-18; upstream of Control Structure S-46 is indirectly used for public water supply
II	Shellfish Harvesting and Propagation	Estuarine portions of the North, Northwest and South Forks, upstream from FEC Railroad Bridge and in the aquatic preserves are designated for this use.
III	Recreation and Propagation of Fish and Wildlife	Loxahatchee Slough and the SIRWCD Canal C-14; Fresh-water portions of the North and Northwest Forks of the Loxahatchee River; marine and coastal waters downstream from the FEC Railroad Bridge to the Jupiter Inlet,

Source: SFWMD 2000a

Although water quality in this system generally meets applicable standards, problems occasionally occur in the river and estuary with respect to dissolved oxygen levels, coliform bacteria and total nitrogen (FDEP, 1996; 2000).

The primary source of water to the river is the G-92 structure, which drains the Loxahatchee Slough, and has water of good quality. The relatively undeveloped basins along the Northwest Fork and Kitching Creek provide water that has little, if any, human-contributed sources of pollution. Water discharged from some basins along the river contains suspended solids, nutrients, pesticides and other contaminants that impact the river and downstream estuary (FDEP 1998). The floodplain swamp communities that fringe the upstream portion of Northwest Fork potentially provide a significant water quality improvement function (Ewel and Odum 1984; Dierberg and Brezonik 1984; Zahina et al. 2001b). The MFL seeks to minimize significant harm to this community, thus protecting this water quality function.

RESOURCE PROTECTION ISSUES AND CONCERNS

The Northwest Fork contains one of the last examples of a pristine subtropical riverine cypress swamp in south Florida. Protection of this resource requires reducing or reversing the current trend of saltwater intrusion and mangrove invasion within the upstream freshwater portion of the river by maintaining minimum baseline freshwater flows to the Northwest Fork. Maintenance of freshwater habitats in the upper reaches of the river is also desirable to protect existing populations and distribution of wildlife (e.g., fishes, alligators, turtles and otters) that require freshwater habitat. Reduction of sediment loading from tributaries is required to protect benthic communities in the river and estuary.

The Loxahatchee watershed is comprised of both surface and ground water resources that are closely linked together. The Surficial Aquifer System (SAS) receives recharge from the land surface (uplands and wetlands within the watershed). The surficial aquifer also provides an important source of freshwater base flow that maintains upstream wetlands and provides freshwater discharge to the river and estuary. Because of this relationship, withdrawal of water from the SAS during dry periods has the potential to affect water levels in surrounding lakes and wetlands and possibly reduce base flows to rivers and streams. This could affect salinity conditions within the river and estuary, as well as result in further saltwater intrusion of the aquifer. At present, there is very little hydrologic information regarding the roles that ground water discharge and groundwater withdrawals play in providing base flows to the river or estuary.

Much concern has been expressed in public meetings and correspondence that consumptive use withdrawals within the watershed have significant adverse effects on flows in the Northwest Fork and the migration of saltwater upstream. Analysis of existing data, however, suggests that the effects of consumptive uses on the ability to provide flow to the river during dry periods are not very large (i.e., less than 5 cfs) and are much less than the effects of canal construction and the drainage of lands for agricultural and residential development. See **Appendix I** and **Appendix O** for further details. The effects of reduced river flow on migration of saltwater upstream are, in turn, less than the effects of stabilization of the Jupiter Inlet and removal of shoals and sandbars in the Loxahatchee River and Estuary. Monitoring of consumptive use is carried out by the SFWMD during drought periods to ensure that allocations are not exceeded and to determine whether withdrawals of water for human use are decreasing the amount of water available for discharge to the river. The possibility remains that alternative sources may need to be developed if withdrawals in the future are determined to have significant adverse effects on river flow.

Provisions need to be made to ensure that minimum flows to the river occur in order to prevent saltwater intrusion and associated problems. Several options are being investigated as part of the MFL Recovery and Prevention Plan (see **Chapter 6** for details) or implemented as part of the regional water supply planning process to correct some of the problems that have occurred due to structural changes in the watershed, and provide additional water for the river, as follows:

- Improve hydrologic connections between the historic Loxahatchee Slough (i.e., West Palm Beach Catchment Area) and the Northwest Fork.
- Improve management of water levels in Loxahatchee Slough.
- Construct additional pumps, structures and conveyance capacity to allow more water to enter and be stored within the Loxahatchee Slough.
- Construct connections between the C-18 and C-17 basins and between Kitching Creek (Northwest Fork) and South Fork of the St. Lucie River as part of the CERP planning process.
- Conduct a feasibility study to assess the benefits or impacts of the construction of a navigable submerged dam, low or collapsible weir,

- or artificial shoal to obstruct inland movement of the saltwater wedge during dry periods.

CONSIDERATIONS AND EXCLUSIONS

Once the functions of the water resource and the features of the water resource that need to be protected by a specific minimum flow or level have been identified, the baseline resource conditions for assessing significant harm must be determined. The basis for making this determination is set forth in Section 373.0421(1)(a), F.S., which requires the water management districts to consider changes and structural alterations that have occurred to a water resource when setting a MFL. Section 373.0421(1)(b), F.S., provides exclusions from the MFL requirement by recognition that certain water bodies no longer serve their historical function and that recovery of these water bodies to historical conditions may not be feasible.

Considerations

The Loxahatchee River system has a variety of features and functions that affect, or are affected by, the need to establish MFLs as follows:

- Natural Systems
- Hydrology
- Water Supply
- Flood Protection
- Water Quality
- Navigation and Recreation

The section below provides a summary of how each of these elements was considered in the Loxahatchee River system.

Natural Systems

- Natural systems in the Loxahatchee River system have been significantly altered due to human activities during the past century.
- In spite of these changes, many of the original natural features remain in good condition. The Loxahatchee River and Estuary contain significant natural features, including threatened and endangered species and their associated habitats.
- Declaration of the estuarine area by the state as a state aquatic preserve and part of the riverine area by state and federal authorities as a Wild and Scenic River, indicates that necessary efforts should be undertaken to protect or enhance remaining natural features.

Hydrology

Hydrologic changes, which have occurred in the Loxahatchee River and Estuary due to navigation, drainage and flood control activities, have significantly altered the volume, timing and distribution of freshwater flow. Providing sufficient flows to maintain appropriate hydrologic conditions within the basin is the key element needed to maintain the integrity and viability of associated wetland, riverine and estuarine ecosystems. Five primary threats to maintaining the integrity of this system are linked to water flows and levels as follows:

- Seawater (saltwater) access to the river has been increased by the permanent opening of the Jupiter Inlet and by dredging of the ICW and river channels.
- Flow patterns in the river itself have been altered due to construction of the inlet and associated navigational channels and the removal of natural shoals from the estuary.
- Water levels in wetland systems that provide water to Loxahatchee Slough and base flow to the river have been lowered to provide flood protection to adjacent lands, and subjected to unnatural hydroperiods to meet drainage and flood protection needs of surrounding areas.
- Lowering of water levels throughout the watershed, to provide drainage and flood protection, has resulted in overall loss of storage within the basin and thus reduced the total volume of water that is available to the river during the year.
- Withdrawals of surface and ground waters for urban and agricultural use have contributed to alteration of the timing and volume of freshwater storage in wetlands and discharge to the river and estuary.

Water Supply

Two primary sources of water are used for water supply and agricultural irrigation within this watershed -- withdrawals from the surficial aquifer; and withdrawal from the Floridan aquifer.

- Withdrawals from the Suficial aquifer system have the potential to influence water levels in adjacent wetland systems and affect ground water discharge to the river and estuary.
- Withdrawals from the Floridan aquifer system do not influence water flows to the river or estuary directly but create the need for disposal of the reverse osmosis concentrate and therefore require a permit from the FDEP.

Section 373.042 (a) F.S. prohibits allowing significant harm to be caused by existing or future water supply withdrawals. Once the MFL is established, the need to meet existing and future reasonable-beneficial water supply requirements must be factored into the recovery and prevention strategy, as explained in Section Ch. 373.0421(b) F.S.

Flood Protection

- The C-18 is a component of the regional primary drainage system and provides flood protection for an area of 200 square miles. Numerous secondary and tertiary drainage features contribute flow to C-18.
- Construction of the C-18 within the historic Loxahatchee Slough to meet drainage and flood control needs has resulted in a significant lowering of water levels in adjacent

wetlands, loss of regional storage and overall reduction in base flow to the Loxahatchee River and Estuary during dry periods.

- The C-18 has altered regional hydrology significantly by diverting drainage and runoff into the South Fork of the Loxahatchee Estuary. Much of this area, under natural conditions, would have provided sustained, dry-season base flow of freshwater to the "wild and scenic" portion of the Northwest Fork of the Loxahatchee River.
- During wet periods the network of drainage canals and structures results in discharge of excessive volumes of poor quality water, primarily to the estuary, that impact saline and brackish water communities in the Aquatic Preserves.
- The Jupiter Farms area (SIRWCD) covers approximately 10,315 acres and drains primarily to the Northwest Fork of the Loxahatchee River.

Water Quality

- Water quality data have been compiled and analyzed by the Florida DEP to determine current status and trends in this system. Results of this analysis indicate that water quality in this system is generally adequate to meet the designated uses, which include the following:
  - Public water supply (Class I) use for the C-18 upstream of S-46.
  - Fish and wildlife habitat/natural systems (Class III) use in Loxahatchee Slough and C-14 Canal (C-14), the Northwest Fork and the North Fork; marine and coastal waters.
  - Shellfish harvesting (Class II) use in estuarine waters and Aquatic Preserves.
- A few exceptions have been noted where these standards are not met periodically at some locations as follows:
  - Low levels of dissolved oxygen occur periodically in some parts of the system.
  - Total coliform concentrations exceed safe standards in the Northwest Fork near JDSP, in the North Fork near the Girl Scout Camp and at Dubois Park near the Jupiter Inlet.
  - Rapid changes in salinity and increased turbidity are associated with high volume releases of freshwater from C-18 during and after severe storm events.
  - Runoff from residential and agricultural lands, especially during storm events, periodically contain high concentrations of suspended solids that cause siltation and shoaling in the river channel.
  - Waters discharged from agricultural lands occasionally contain measurable quantities of pesticides and low concentrations of dissolved oxygen that may cause fish mortality.
- Water quality issues in the river will primarily be addressed through the identification impaired water bodies and development of Total Maximum Daily Load (TMDL) criteria for segments of the watershed that have significant problems.

Navigation and Recreation

- The Loxahatchee River and Estuary serve important functions as a regional recreational resource and tourist destination. These waters are used extensively and intensively for boating, canoeing, fishing, swimming, waterskiing and observing nature. Related commercial uses are centered around boat services, sightseeing cruises and fishing.
- Construction of the Intracoastal waterway resulted in the deepening and widening of channels, and increased water exchange between freshwater environments of Loxahatchee River and the brackish water systems in the southern end of the Indian River Lagoon and Lake Worth Creek.
- Permanent stabilization of the Jupiter Inlet altered the balance of freshwater-saltwater exchange within this system, resulting in increased flow of saltwater upstream in the Northwest Fork and associated decline of freshwater vegetation along the riverbanks.
- Landward movement of saltwater has been further enhanced not only by drainage activities in the basin (see above) but also by removal of natural shoals, sandbars and oyster bars to reduce the risk to navigation and provide access upstream by larger boats.

Exclusions

As described in **Chapter 1**, Section 373.0421(1)(b), F.S., recognizes that in certain cases, it may not be practical or feasible to restore particular water bodies to historical conditions. District staff suggest that exclusions do not apply to the establishment of minimum levels for Loxahatchee River system. The remaining exclusions in subsections 373.0421(1)(b)2 through 3, F.S. pertain to water bodies less than 25 acres in size or constructed water bodies and as such, do not apply to the Loxahatchee River and Estuary.

The Loxahatchee River and Estuary have been greatly altered by development and associated needs for water supply and flood protection, to the extent that full recovery of water levels and flows in the river headwaters, the river itself and the estuary may be technically and economically infeasible. However, the need to protect and enhance the remaining natural features in this system has been clearly identified. The Loxahatchee River and Estuary and their associated watershed include a federal and state-designated Wild and Scenic River, State Aquatic Preserves, state and local parks and have been designated as Outstanding Florida Waters. The considerations in Section 373.0421(1)(a) F.S. seem to adequately address the changes and alterations in water resource functions applicable to these areas. As a result, there is no apparent basis to invoke the exclusion in subsection (1)(b)1.

A baseline condition for the protected resource functions of the Loxahatchee River and Estuary has been identified, based on consideration of changes and structural alterations in the hydrologic system. This condition is the extent and health of the freshwater floodplain swamp community defined in this report. Evidence presented in this report indicates that the present (2001) location and condition of this community are not significantly different from their extent and condition in 1985, when the Wild and Scenic River designation occurred. The need to document the economic and technical feasibility of restoration of this system to some level of ecological condition that existed prior to 1985 will be addressed through a cooperative study that is presently being developed by FDEP, SFWMD and other interests.

In summary, the SFWMD will establish a MFL for the river that is based on consideration of the effects of structural alterations to the water resource, as allowed pursuant to Section 373.042(1)(a). Section 373.042(a) F.S. prohibits allowing significant harm to be caused by existing or future water supply withdrawals. Once the MFL is established, the need to meet existing and future reasonable-beneficial water supply requirements must be factored into the recovery and prevention strategy.

CHAPTER 4 -- METHODS FOR DEVELOPING MINIMUM FLOW CRITERIA

METHODS CONSIDERED TO DEVELOP MFL CRITERIA

River management is a complex process that requires consideration of a number of variables. Minimum flows are an important component of riverine flow characteristics. However, providing a minimum flow represents only one aspect of management and/or restoration of river hydrology. Focusing on a single aspect of river hydrology (minimum flows) is an overly simplistic treatment of complex ecosystem interactions. Long-term hydrological data, especially measures of variability, have been under utilized in most management decisions aimed at river ecosystem protection or restoration (National Research Council 1992).

Because of the intrinsic ecological complexity of estuaries, scientists and managers have also objected to the idea that minimum flows can be set for estuaries. Complexity in itself, however, is not a sufficient reason to question the concept of minimum flows for estuaries. In fact, it simply supports the fact that complex biological systems, such as those in estuaries, require more study. Due to the lack of understanding and a shortage of previous attempts to establish minimum flows, estuarine scientists and managers do not have even simplistic minimum flow examples to study or criticize. Rather than waiting until all information is available before making a management decision, the best approach is adaptive: 1) set inflows based on best available information, expert opinion and assumptions, and analyses derived from conceptual and mathematical modeling; 2) monitor the results for success or failure; 3) continue research, and reevaluate flow targets; and 4) adjust the inflows as needed based on monitoring and research results.

Appendix R includes a brief review of a number of possible approaches that were considered in the development of Minimum Flow and Level Criteria for the Loxahatchee River. Based on this assessment, it was determined that a combination of approaches would provide the best results to most effectively apply the available information.

1. Estimation of Historical Flow Conditions. Because of a general lack of historical flow and salinity data for the Loxahatchee River and Estuary, a hydrological modeling approach was developed to represent historical water levels and flow patterns. This effort is partly complete, but needs to be extended, at a higher spatial and temporal resolution, to provide more detailed analyses.

2. Estimation of Current Hydrologic Conditions, Groundwater-Surface Water Interactions and Water Budget. A modeling approach was also developed to develop an interactive groundwater-surface water model for the portion of the watershed that lies within northern Palm Beach County. Preliminary results of this analysis are provided in **Appendix I.**

3. Instream Flows. The effects of existing inflows to the river from different surface water sources and groundwater on salinity in the river were initially estimated based on statistical relationships between measured flows and measured salinity data. Results of these analyses are provided in **Appendix D**.

4. Hydrologic Variability. The flow and salinity data were later incorporated into a hydrodynamic model of the river and estuary, which was used to generate salinity profiles for the system under different flow conditions. The hydrodynamic model was also used, in combination with historical USGS flow records, to simulate a 30-year salinity record for the period from 1971-2000, at selected sites along the Northwest Fork (**Appendix E**).

5. Habitat Approaches. The historic condition of the freshwater floodplain swamp community (swamp hardwoods and cypress) was documented based on aerial photography (see **Appendix B**). An assessment of the current condition of this community was made by conducting field surveys (**Appendix C**) and the responses of this community to river flow, salinity and soil conditions were determined. (see **Chapter 5**). A river vegetation/salinity model was also developed that could be used as a tool to predict future changes in the floodplain community that may occur in response to changes in river flow and salinity.

6. Indicator Species. Six species of hardwood trees were identified as indicator species of a freshwater swamp community and predominantly freshwater conditions in the floodplain. Distribution of these species along the river was documented and related to river flow, surface water salinity and soil salinity conditions (see **Chapter 5** and **Appendix C**).

7. Valued Ecosystem Component (VEC). The indicator species approach was expanded to include the VEC concept. Management goals were established based on protection of the VEC species, which in this case represents those freshwater plants that are most sensitive to the environmental factor of interest (salinity), as described in **Chapter 5**.

METHODS USED

Establishing Geographic Locations along the River

During the examination of previous studies of the Loxahatchee River, it was noted that the various researchers used slightly different methods to measure locations along the river. The most common approach was to measure river miles upstream from the Jupiter Inlet along the main channel of the river. Problems occurred when the channel was altered due to changes in oxbow structure. To resolve this issue, and establish a common measurement scale for SFWMD investigations and future studies of the River, locations along the river were re-measured based on current conditions and Global Positioning System (GPS) readings were taken at each mile marker. These readings were later converted to latitude-longitude coordinates. **Table 15** shows how the mileage locations determined by District staff compare to mileage points used in other investigations and provides the corresponding latitude-longitude coordinates for these stations.

Table 15. Comparison of SFWMD river mile locations to river mile and station locations identified in research literature (see Figure 16 for SFWMD station locations).

SFWMD 2001 River Mile**	SFWMD Veg Sites	Lox. River Dist. WQ Sites	Dent 1997b; Dent & Ridler 1997	Law Environmental 1991; Mote Marine Lab 1990a *	Russell & McPherson 1984 Sites	McPherson & Sabanskas 1980	Long.	Lat.
Loxahatchee River Sites								
0				0			-80.070991516	26.944124222
0.7					17C			
1				1		0.9	-80.086639404	26.947099686
1.1					14			
1.3					1			
1.9					2A			
2				2		1.9	-80.102195740	26.950460434
2.2					3			
2.4					3C			
3				2.8		3	-80.116523743	26.956796646
3.2					5			
3.7					5C			
4				3.9	5E	4	-80.124176025	26.967786789
5	5B			4.9		4.8	-80.139039353	26.982712901
5.3					7B			
6				6		5.8	-80.142562866	26.985563278
6.3	6A						-80.143669519	26.984342169
6.6		WQ #63	6.5					
6.9	6B						-80.147410631	26.988542914
7				7	8E	6.7	-80.145202637	26.988861084
7.3	7A						-80.147187791	26.990281967
7.5	7B						-80.149975096	26.991066622
7.8		WQ #64	7.3					
7.9	7C						-80.150862762	26.988849080
8				8.4		8.4	-80.153236389	26.989992142
8.1	8A						-80.153982377	26.990833609
8.4	8B						-80.155118577	26.989388511
8.6		WQ #65	8.1					
8.7	8C						-80.157838347	26.989749400
8.9	8st						-80.159289147	26.986940222
9				9.6		9.3	-80.158821106	26.986169815
9.1	9A				11A		-80.159358557	26.985374195
9.2	9B						-80.160870447	26.983861002
9.4		WQ #66						
9.5	9hl						-80.161667250	26.985204790
9.7	9C						-80.163800034	26.982719318
9.8					12B			
10				10.6		10.8	-80.165061951	26.981418610
10.2	10A						-80.165062424	26.980186754
10.3	10B						-80.164987106	26.978938944
10.6	10C						-80.165192015	26.976525692
10.7		WQ #67			12E			
Kitching Creek Sites								
	A						-80.154898869	26.991771447
	B						-80.155330876	26.992670262
	C						-80.156664449	26.992851025
	D						-80.156095466	26.993647772
	E						-80.155459331	26.994103015
	F						-80.156193578	26.995723248

* Approx. river mile locations based on figures contained in the research literature (specific river mile locations not identified)
**Landmark locations: First Shoal -- 6.8 miles; Second Shoal -- 7.8 miles; Mouth of Kitching Creek -- 8.2 miles

Hydrologic and Hydrodynamic Methods

Review of Historical and Current Conditions

Review of available USGS and SFWMD flow data and stage records was conducted using the District's DBHydro database for the Lainhart Dam, Cypress Creek, Hobe Grove Ditch, and Kitching Creek. Data are provided in **Appendix D. Table 16** shows a summary of the flow records obtained from the DBHydro database used in this study. Stage records from four locations in the upper NW Fork were analyzed, along with ground and water surface elevations, to model floodplain hydrological characteristics of the upper NW Fork (**Appendix N**). Historical salinity data were obtained from the Loxahatchee Environmental Control District for four sites along the river. These data were reviewed and analyzed to produce descriptive statistics, and trend analyses. Selected data were plotted to generate flow vs. probability distributions and time series of flows through structures and tributaries. The long-term flow records and collected salinity database were used as input to a hydrodynamic salinity model developed for the river and estuary (**Appendix E**).

Development of a Hydrodynamic/Salinity Model

A hydrodynamic/salinity model was developed to study the influence of freshwater input on the salinity conditions in the Loxahatchee River and downstream estuary. The purpose of this modeling effort was to predict salinity conditions at various points in the river and downstream estuary with respect of freshwater inflow rates and tidal fluctuations.

Table 16. DBHydro Flow Data Available for the Loxahatchee River and Estuary.

Location	Station Name	Alternate station Id	Data Type	Agency	Period of record	Db Keys
Lainhart Dam	LNHRT_W	20641421 60641421	Mean Flow Mean Flow	WMD WMD	1989-1994 1995-2001	JI987 JI988
G-92 structure	G-92_C	20741421 50741421	Mean Flow Mean Flow	WMD WMD	1977-1988 1988-2001	05624 05623
Lainhart Dam (USGS station upstream of Lainhart Dam)	LOX	02277600	Mean Flow Mean Stage	USGS USGS	1971-2001 1971-2001	00295 00293
Cypress Creek	LOX.CYPR_O	265816080110000 52040421	Mean Flow Mean Flow	USGS WMD	1980-1982 1984-1991	02968 05442
Hobe Grove Ditch	LOX.HOBE_O	265907080103000 51940421	Mean Flow Mean Flow	USGS WMD	1979-1982 1984-1991	02988 05448
Kitching Creek	KITCHING	270022080094600	Mean Flow	USGS	1979-2000	03006
S-46 structure	S46_S	20341421 50341421	Mean Flow	WMD WMD	1992-2001 1961-1993	15734 04370

Model Description

The software used in the development of Loxahatchee River Hydrodynamics/ Salinity Model were computer programs RMA-2 and RMA-4 that were developed by Army Corps of Engineers (USACE 1996). RMA-2 is a two dimensional depth averaged finite element hydrodynamic numerical model. It computes water surface elevations and horizontal velocity components for subcritical, free-surface flow in two dimensional flow fields. RMA-2 computes a finite element solution of the Reynolds form of the Navier-Stokes equations for turbulent flows. Friction is calculated with the Manning's or Chezy equation, and eddy viscosity coefficients are used to define turbulence characteristics. Both steady and unsteady state (dynamic) problems can be analyzed. The program has been applied to calculate: (a) water levels and flow distribution around islands; (b) flow at bridges having one or more relief openings; (c) flow in contracting and expanding reaches; (d) flow into and out of off-channel hydropower plants; (e) flow at river junctions; (f) flow into and out of pumping plant channels; (g) circulation and transport in water bodies with wetlands; and (h) general water levels and flow patterns in rivers, reservoirs and estuaries. The water quality model, RMA-4, is designed to simulate the depth-average advection-diffusion process in an aquatic environment. The model is used for investigating the physical processes of migration and mixing of a soluble substance in reservoirs, rivers, bays, estuaries and coastal zones. The model is useful to evaluate the basic processes and to define the effectiveness of remedial measures. For complex geometries, the model utilizes the depth-averaged hydrodynamics from RMA-2.

The formulation of RMA-4 is limited to one-dimensional (cross-sectionally averaged) and two-dimensional (depth-averaged) situations in which the concentration is fairly well mixed in the vertical direction. It will not provide accurate concentrations for stratified situations in which the constituent concentration influences the density of the fluid. The preliminary results indicated that the model was able to predict the salinity fluctuation driven by the tide cycle and the influence of freshwater input on the salinity regime in the river.

Modeling Assumptions

Due to a lack of data, various assumptions concerning freshwater inflow were made. Measured flow data was not available after 1991 for Cypress Creek or Hobe Grove Ditch. Therefore, discharges from these tributaries were calculated as a constant fraction of discharge at Lainhart Dam. The percent of total river flow contributed by the Lainhart Dam was estimated in the model as 44%. This compares with USGS field measurements, which showed that Lainhart Dam provided about 45% of the flow during the 1980-81 drought dry season, 46% during the 1980-81 drought wet season, 40% during the 1989-90 drought dry season, and 56% during the 1989-90 drought wet season. Based on these data, the flow ratio of 44% used in the model was determined to be a reasonable estimate of the flow contributed by Lainhart Dam, relative to the other tributaries, during dry periods when the minimum flow criteria are most important.

Another important model assumption was a constant input from groundwater of 40 cfs. This estimate was derived from a review of field data obtained from a USGS report (Russell and McPherson 1984) and measured flow/salinity data collected from a dry period in May 1999. From these data it was estimated that each of the four tributaries provide about 10 cfs of groundwater flow to the river during dry periods. The District recognizes that more groundwater flow data would be desirable to confirm the estimate used in the model, but the 40 cfs value currently represents "best available data". These assumptions have two important consequences: a) the total inflow to the Northwest Fork associated with a flow of 35 cfs from Lainhart Dam is therefore somewhat larger and includes discharges from groundwater and other tributaries, and b) the flows for the other tributaries were assumed to be proportional to the flows from Lainhart Dam, and hence may not accurately represent actual flows.

Calibration and Verification

The model was calibrated and verified against field data that were collected from January to June of 1999. Then the model was applied to scenarios that were proposed by the study team. Three series of model simulations were requested. The first simulation included flows from the Northwest Fork of the River and its three tributaries based on flow ratios established by a previous study. The second simulation contained a minimum amount of freshwater input from the three tributaries. The first simulation method was used to predict salinity conditions with various freshwater inflow rates that follow historic freshwater input patterns. Details regarding the basic model setup, data sources and assumptions and calibration/verification process and preliminary model results for these simulations are presented in detail in **Appendix E** of this report. A third simulation was performed, in order to develop a 30-year salinity data set, as described in the following section:

Simulation of a 30-Year Salinity Record for the NW Fork

The next step in the development of minimum flow criteria for the Northwest Fork of the Loxahatchee River was to develop a relationship between the river vegetation database and historical changes in salinity over time. Long-term, continuous salinity records (e.g., 30-years of data) were not available for the river at each vegetation sampling site location. The record of salinity measurements is sporadic. Samples have been collected occasionally, and sometimes intensively, over the last 25 years in conjunction with special studies (e.g. Birnhak 1974; Russell and McPherson 1984, Law Environmental, Inc. 1991a), Since 1992, the Loxahatchee River District has monitored salinity (and other parameters) at 29 stations in the watershed twice each month (LRD) in conjunction with routine water quality monitoring efforts. In addition, the LRD has established continuous salinity recording stations at various locations and times in the river. These data were used to assist model calibration efforts, as discussed in Appendix D and Appendix E.

None of these salinity data sets, however, provided sufficient site-specific, continuous information that could be used to assess long-term impacts of salinity on vegetation communities in the river floodplain. A method was therefore developed to generate a time series of historical salinity data (1971-2001) at each of the seven river vegetation sampling site locations (**Table 17**). This was accomplished through the use of an RMA-2/RMA-4 hydrodynamic/salinity model (USACE 1996) and a computer program developed in house. The computer program, described in **Appendix E** as a long-term salinity model, uses the RMA-2/RMA-4 model output and the freshwater flow at Lainhart Dam to provide an estimate of daily average salinity at eight sites in the upper Northwest Fork.

Table 17. Sites along the NW Fork of the Loxahatchee River where long-term salinity records were simulated using the hydrodynamic/salinity model.

Site Name	Sample Type		Site Location*
	Vegetation	Water Quality	
Site 7-C and WQ #64	X	X	River Mile 7.8
Site 8-B	X		River Mile 8.4
Site V-6 and WQ #65	X	X	River Mile 8.6
Site 8-D (8-st)	X		River Mile 8.9
Site 9-B	X		River Mile 9.2
Site WQ #66		X	River Mile 9.4
Site 9-C	X		River Mile 9.7
Site 10-B	X		River Mile 10.2

* River miles upstream from the Jupiter inlet; see also **Figure 16** and **Table 15** for the location of these sites along the NW Fork of the river.

The input for the long-term salinity model application was the 30 years of flow data (1971-2001) obtained from USGS and SFWMD flow records for the Lainhart Dam. Additional flow data from other tributaries were located and processed (see **Table 16**), but were not used in this analysis. Analysis of the additional historical data indicated that these data were in close agreement with the initial estimates of flow from the three tributaries. Model output consisted of a 30-year simulated time series of mean daily salinity values (1971-2001) plotted for each vegetation sampling site, which are provided in **Appendix H**. **Table 17** provides the location of each river vegetation survey site where long-term salinity records were developed using the hydrodynamic/salinity model. From these data SFWMD staff plotted individual time series, and calculated descriptive statistics (mean, standard deviation, median, mode and maximum daily salinity concentrations) for each site for the 30-year period of record.

A “salinity event analysis” was also conducted to group the simulated salinity data from each site into salinity events that equaled or exceeded a particular salinity threshold. For each threshold of salinity concentration at 1 ppt intervals (e.g. 1 ppt, 2 ppt, 3ppt, etc.) The amount of time in days that this concentration was continuously exceeded (*Ds*) was determined, as well as the number of days that elapsed from one event to the next (*Db*). Salinity conditions at a site were expressed in terms of *Ds* and *Db* for a minimum threshold value as a means to express the degree of exposure to salinity that might be experienced by the vegetation community at that location. As expected, the duration of a salinity event decreases, and time between salinity events increases, as one moves from downstream to upstream sites.

In terms of potential effects of salinity exposure (or any toxic substance) on freshwater vegetation, the magnitude (concentration) and duration of exposure to elevated salinity levels is related to the extent of damage to the freshwater community caused by that exposure (see Pezeshki et al. 1986, 1987, 1990, 1995; Conner and Askew 1992; Allen 1994; Allen et al. 1994, 1997). The time between salinity events is also important to allow sufficient recovery from the last damaging salinity event. Other analyses included calculation of the percent of time that salinity was equal to or above a particular salinity threshold value (e.g., 1 ppt, 2 ppt, 3 ppt, etc.). Results of these analyses are discussed in **Chapter 5** of this report.

Documentation of Historic Water Use within the Loxahatchee Basin

SFWMD Consumptive Use permitting records were examined to identify those permits that were located within the Loxahatchee River watershed and determine their current water usage. In this study, public water supply, landscape irrigation and agricultural water demands within the basin were estimated based on: (a) the annual allocation of each permit holder obtained from District records and (b) the average daily demand values used in the Northern Palm Beach County Comprehensive Water Management Plan hydrologic model (MODFLOW). Permitted withdrawals by use category for 1999 were summarized. Permitted allocation values were also compared to actual pumpage values submitted to the District by the permit holder to get a comparison of the amount of water actually used during normal operations and what is used during peak demand periods.

Although many of the data records were missing or incomplete, this comparison provided a basis to establish general trends, which indicated that a) water use varies seasonally depending on population (seasonal influx of tourists) and local rainfall patterns; and b) actual water use is significantly less than the amount of water allocated, except during extreme events. A listing of existing permits and results of the water use analysis are presented in **Appendix O.** The available data from these permits were used as input to the interactive surface-water groundwater model (see below).

Based on these analyses it was determined that use of the amount of water allocated within the permits as the basis for determining effects of consumptive use on the river was a very conservative approach. If errors occurred, they were likely to overestimate, rather than underestimate, the effects of consumptive uses.

Simulation of Consumptive Uses within the Loxahatchee Basin

The overall effect of consumptive uses (public water supply, agriculture and self-supplied residential wells) on the ability to provide flow to the Northwest Fork was considered as part of the MFL process. Use of the surficial aquifer and river for public water supply is a resource function. Several approaches were used to estimate the proportion of the watershed's hydrologic budget that is comprised of consumptive uses within the basin.

To address this issue, District staff analyzed available hydrogeologic data and conducted a number of groundwater model simulations. Data were obtained from SFWMD and USGS databases. Model scenarios were run using a modified USGS three-dimensional finite difference flow code (MODFLOW-96) model that was developed by the SFWMD for northern Palm Beach County (SFWMD 2002). This model provided a means to determine relative effects of consumptive uses within the basin on water levels in Loxahatchee Slough and deliveries to the Northwest Fork of Loxahatchee River during selected wet, normal and dry periods. Results of this analysis are presented in **Appendix I**.

Biological Methods

Literature Review

Pursuant to Section 373.042(1), F.S., the District is required to utilize best available information to establish the MFL. In this regard the District performed an intensive review of the existing literature to (1) identify the water resource functions of the river and estuary that need protection, and (2) to determine the technical relationships among flow, salinity, and river hydrodynamics that impact key indicator communities, or species present within the NW Fork of the river. Specifically, the review involved: (a) identifying individual species or biological communities that could serve as useful indicators, targets, or criteria for determining a minimum flow for the NW Fork and the estuary; (b) determining how these indicator species or indicator communities have been impacted by structural and/or hydrologic alterations of the river and upstream watershed; (c) reviewing the previous experiences of the SFWMD and other water management districts with respect to the establishment of MFLs for surface water bodies; and (d) evaluating the Valued Ecosystem Component (VEC) approach to establish a MFL for a tidal river. The following is a summary of the information that was reviewed and evaluated for development of the MFL for the Loxahatchee River/Estuary system.

The library card catalogs of the SFWMD, University of Miami (UM) and Florida Atlantic University were reviewed for relevant citations. In addition, Internet searches were performed using open-access general searches and search engines. Individual key words and combinations of key words were searched to cover: Loxahatchee River, cypress, mangroves, seagrasses, vegetation, macro-invertebrates, benthic fauna, submerged aquatic vegetation, forested freshwater wetlands, tidal river, estuary, hydrology, freshwater flow, minimum flows, salinity tolerance, salt intrusion, ground water, soil salinity, and sea level rise.

A literature review was conducted utilizing the *Bibliography on Water Resources in the Loxahatchee River Watershed* (Dent 1997c). Information was also obtained through dialogue with the Loxahatchee River Environmental Control District, Jonathan Dickinson State Park, and the UM Department of Biology.

An additional literature review was conducted to identify the: 1) key species or groups of organisms that may benefit from utilizing cypress swamp and/or cypress riverine wetland communities of the Northwest Fork; 2) life history of bald cypress; 3) salinity tolerance of bald cypress, cabbage palm, laurel oak, Virginia willow, dahoon holly, pop ash, pond apple, red bay, red maple and red mangrove and 4) acute and chronic responses of bald cypress seedlings and adults to salinity 5) historic wetland vegetation changes on the NW Fork and 6) estimates of sea level rise in South Florida. **Appendix A** provides a bibliography of all the documents reviewed by staff as part of the literature review.

River Vegetation Surveys

Semi-Quantitative Vegetation Survey (November 2000/December 2001)

A semi-quantitative vegetation survey method, suitable for statistical analyses, was conducted by SFWMD biologists to examine community-wide changes along the NW Fork of the Loxahatchee River and Kitching Creek. Sixteen sites (labeled 5B through 10C) were selected and surveyed in November 2000 and seven additional verification sites (labeled V1 through V7) were surveyed in December 2001 **(Figure 16)**.

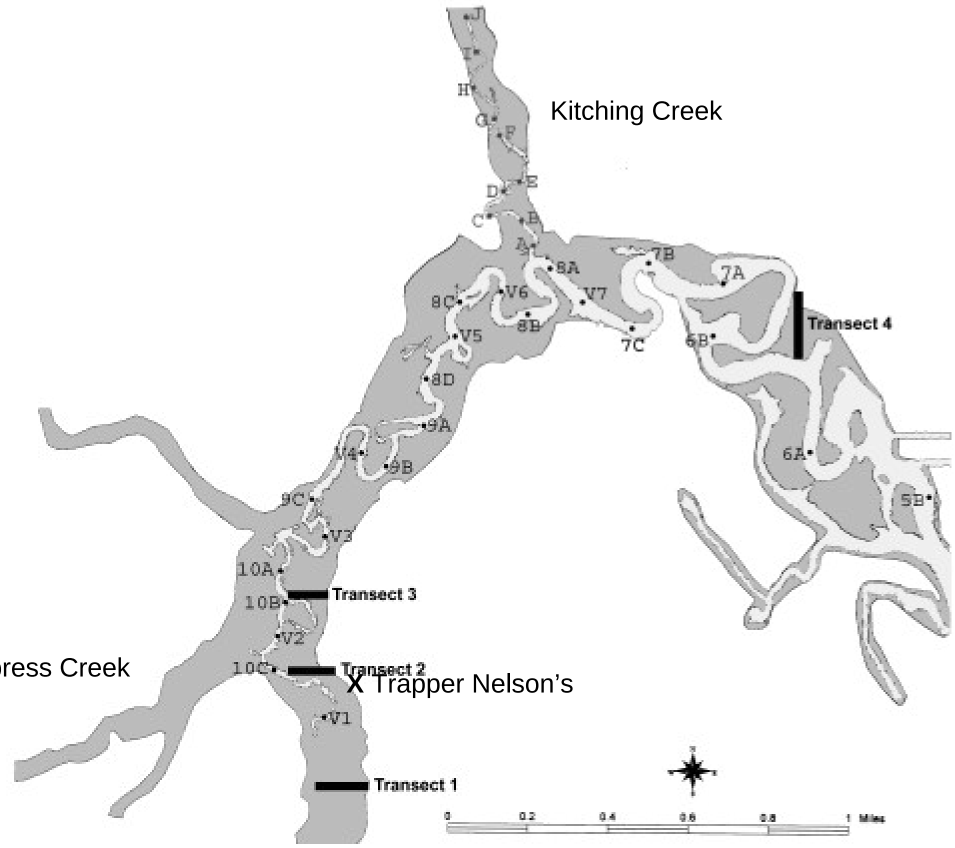


Figure 16. Locations of Vegetation Survey Sites along the Northwest Fork of the Loxahatchee River and Kitching Creek. Semi-quantitative sites (23) were sampled in November 2000 and December 2001. Quantitative Sites (V1, V3, V7, 8B, 8D, 9A, 9B, 9C) were sampled again in January 2002. Transects 1-4 indicate sites where preliminary soil-salinity samples were collected.

Locations of these sites were not random, but rather based upon the following criteria:

- Survey sites were located more than 100 feet from a river bend or oxbow to reduce the potential effects of shifting currents, riverbank dynamics, and river flow energy on vegetation community composition.
- Survey sites were located at or near the center of the River's floodplain and at least 100 feet away from the floodplain-upland transitional zone to reduce the possible influence of freshwater seeps on vegetation community composition.
- The survey examined vegetation within an area approximately 400 feet. (122 m) long by 50 feet. (7.5 m) wide along each river bank, at a site.

- All vascular plant (macrophyte) species present and an estimated abundance index for each species were recorded.

The abundance index was determined from a dichotomous key that categorized a species' abundance or cover into four classes. This method follows a modified version of the Braun-Blanquet cover-abundance scale (Braun-Blanquet 1932, 1965; also see Mueller-Dombois & Ellenberg 1974, Bonham 1989) and was conducted as shown in **Table 18.**

The semi-quantitative survey investigated general vegetation trends along the River that may be associated with different salinity conditions, and identified "key" species of interest, which were sampled in greater detail in the quantitative vegetation survey. **Appendix C** of this report provides more detailed information on the methods and results of the semi-quantitative vegetation survey.

Table 18. Dichotomous Key that was Used as the Basis for Detemining the Abundance Index

Description of Species Population Density	Abundance Index
1a. Species not present……………………………………………………	0
1b. Species present.	
2a. Two or less individuals; rare...……………………………………………	1
2b. More than two individuals.	
3a. Highly abundant or dense population (>75% cover), a dominant component of the plant community………………………………………	4
3b. Species not a dominant component of the plant community	
4a. Sparse; widespread and of low density or restricted to localized populations……………………………………………	2
4b. Common; widespread and of moderate density but not a dominant component of the plant community (<50% cover)…………………	3

Quantitative Vegetation Survey (January 2002)

SFWMD biologists conducted a quantitative vegetation survey along the NW Fork of the Loxahatchee River in January 2002. Nine of the sites previously surveyed by the semi-quantitative method (see previous section) were re-surveyed. Six of these sites (8B, 8D, 9A, 9B, 9C, and 10B) were used to compare against previously collected semi-quantitative data while the remaining three sites (V1, V3, and V7) (see **Figure 16**) were used as verification for the SAVELOX model, which will be discussed in a later section.

At each sampling site, two strip quadrats (belt transects) were established, one along each opposite shoreline. Each strip quadrat was 200 ft (60m) by 25 ft (7.5m), covering an area of 5000 ft^2 (465 m^2). The selected area of each strip quadrat was larger than that typically used to estimate density in tree communities (see Bonham 1989). The strip quadrat approach was used in this study to allow sampling of comparable areas within the floodplain that supported swamp communities and had approximately equal exposure to flooding and drying caused by river water levels. At each of the nine sites, the parameters listed in **Table 19** were measured and recorded for different age classes of the "key" species identified in the semi-quantitative vegetation survey and literature review as having varying degrees of salinity tolerance. Age classes were defined as adults (mature), saplings (juvenile taller than breast height), seedlings (shorter than breast height), and stump sprouts (damaged adults that were resprouting from a trunk).

Table 19. Measured Parameters* for Key Species.

Recorded Parameter	Adults	Saplings	Seedlings	Stump Sprouts
Number of Individuals	X	X	X	X
Mean Canopy Diameter (used to calculate tree cover)	X	X		X
Tree Height	X	X		X
Trunk Circumference (used to calculate DBH**)	X	X		X (cumulative)

*a discussion of the methods and importance of these parameters in forest studies can be found in Mueller-Dombois & Ellenberg 1974, Bonham 1989

**DBH= trunk diameter at breast height

Tree height was estimated using the hypsometer method (Boy Scouts of America 1967; Bonham 1989) while mean tree canopy diameter (length measurements of the shortest and longest branches) and trunk circumference at breast height were measured with a tape measure. Tree cover area was calculated using the following equation: Cover = [(canopy diameter/2)^2]p. The cumulative tree canopy cover for tree height classes was used to examine vertical distribution of the canopy cover and its changes associated with salinity conditions. Tree diameter at breast height (DBH) was calculated using the following equation: DBH = (tree circumference at breast height)/p.

Salinity and Water Level Methods

Soil Salinity Survey

District staff conducted soil sampling along the Northwest Fork in January 2002 to investigate a potential soil salinity concentration gradient along the river and to serve as a reconnaissance effort to gain information upon which to base future sampling projects. Four transects were established across the river floodplain, at sites representing different degrees of salinity exposure from tidal flux, and extended from the riverbank to the edge of the upland-floodplain ecotone (**Figure 16**). Two sites (Transects 2 and 3) were located directly adjacent to vegetation sampling sites 10B and 10C near river mile 10. Site 1 was located upstream at river mile 11.5, in an area where the vegetation has not been noticeably impacted. Transect 4 was located well downstream at river mile 6.5, between vegetation sampling stations 6A and 6B, in an area of the river that receives continual exposure to saline water.

Within each transect, four 10 m^2 plots were established at varying distances from the river channel to examine soil salinity concentration changes relative to the river. Grab samples were collected from the upper one-foot of soil in the plots established in Transects 1, 2, and 3 while a soil corer was used to collect soils from depths of 0-0.33 m, 0.33-0.67 m,, and 0.67-1.0 m increments in the plots established in Transect 4. Transect 4 was sampled more intensively, since this was the site that appeared to be most impacted. Sufficient amounts of soil were collected from all of the plots to provide enough water for conductivity and chloride analysis. The water samples were extracted at the Loxahatchee River Environmental Control District's laboratory and analyzed for conductivity according to the Standard Methods section 2510B and chlorides by an argentometric titration method, as described in Standard Methods (Franson 1998). Conversion tables were used to convert the conductivity and chloride results to salinity values, which were then entered into a spreadsheet and analyzed for trends associated with vegetation and estimated long-term (30-year) salinity conditions at each site. **Appendix G** provides additional information on the soil survey.

Statistical Analyses of Relationships between River Flow and Salinity

A number of approaches were used to develop relationships between flow from Lainhart Dam and salinity conditions at various locations in the River. Results of these analyses are described in **Appendix D.** Comparison of the results of statistical analyses, using SAS software and an Excel spreadsheet, to the output from the hydrodynamic salinity model (discussed above) indicated that all three approaches produced comparable results. However, use of the model was deemed preferable due to the interactive qualities of the model and the fact that it could be used to predict conditions over a larger portion of the river and estuary.

Analysis of Floodplain Water Levels in the Upper NW Fork

Although the primary focus of the proposed MFL has been to address the problem of saltwater intrusion, another major ecological question that was considered is the water level requirements of the floodplain swamp. Of particular concern is that portion of the river designated as “Wild and Scenic” and how the implementation of the proposed MFL will impact or benefit the hydroperiod within that section of the river.

To answer these questions (1) a review of the literature was conducted to identify appropriate water depths and hydroperiods that will sustain a healthy floodplain swamp community, and (2) hydrologic analyses were conducted to determine the relationship between river water levels (as measured at the Lainhart Dam) and river flow (calculated from a weir equation developed for the Lainhart Dam) and how these two parameters affect hydroperiod and water levels within the adjacent floodplain swamp (see **Appendix N**). Once these relationships were developed, District staff used these data to assess potential impacts that might occur as a result of implementation of the proposed minimum flow criteria.

Development of a River Vegetation/Salinity (SAVELOX) Model

Using the vegetation survey results and the salinity time series generated from the hydrodynamic salinity model, correlation analyses were used to examine vegetation trends relative to salinity event duration from specific sites along the river corridor. From these data a river vegetation/salinity model (SAVELOX) was developed using an empirical approach to extrapolate vegetation parameter response given a set of long-term salinity conditions. Where highly correlated relationships ($r^2 > 0.90$) were found between measured vegetation parameters and estimated long-term salinity conditions, formulas were developed to describe these relationships, and a deterministic regression model was constructed to predict (extrapolate) vegetation community response to salinity. The model formulas were based upon the correlation between measured vegetation parameters (i.e. abundance, height of adults, canopy cover, etc.) and a calculated salinity ratio *Ds/Db* (defined below) at those sites where both computed salinity and vegetation survey data existed.

The mean duration of each salinity event (*Ds*) and the mean number of days between events (*Db*) at each site, as derived from the 30-year salinity simulation (see section earlier in this chapter entitled, *Simulation of a 30-Year Salinity Record for the NW Fork*), were combined to create a ratio (*Ds/Db*) that provided a quantitative expression of the degree of exposure to salt water that occurred at each location along the river. Event duration and time between events can be expressed in any time scale (days, weeks, months), however in our application we used *days* as the standard unit of measure for calculation of this ratio. A *Ds/Db* ratio of 1 indicates that half of the time average daily salinity at a site are at, or above, a selected salinity threshold. *Ds/Db* ratio values greater than 1 indicate a predominance of saltwater conditions. In contrast, the ratio decreases rapidly as one travels up river from the central embayment area and approaches zero as constant freshwater conditions are observed **(Figure 17).** For this reason, the *Ds/Db* ratio was used as a general index of salinity at a given location along the River and was a key relationship used to develop the river vegetation salinity model.

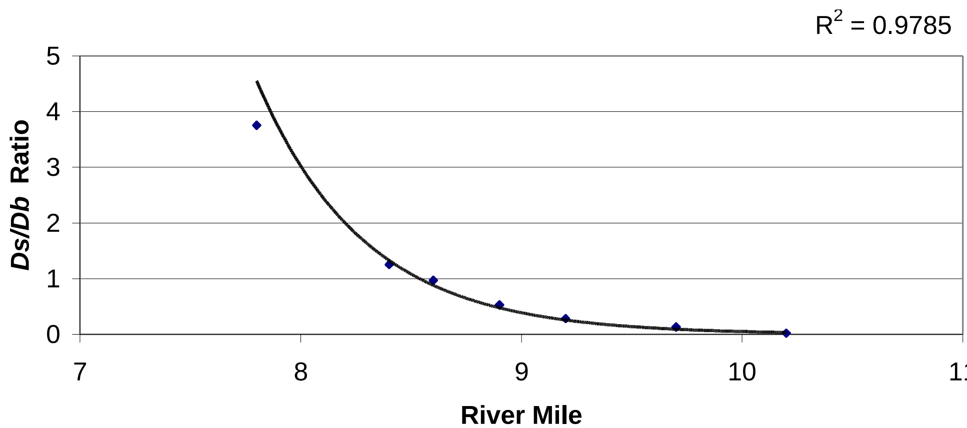


Figure 17. Relationship between the ratio of the amount of time that a station at a particular river mile along the Loxahatchee River was exposed to salinities above 2ppt (*Ds*) and the amount of time that elapsed between exposure events (*Db*) as a function of distance upstream from Jupiter Inlet.

Usually, the model formulas were linear regression models with one independent variable and of the form:

$$f(x) = bx + e, \quad \lim_{x \to c} = g \quad \text{and} \quad \lim_{x \to d} = h$$

where e is the expected error, *x* is the independent or regressor variable, and *b* is the expected change in *f(x)* per unit change of *x* (see Montgomery 1997). The function has an upper limit of *g* as *x* approaches the real number *c*, and a lower limit of *h* as *x* approaches the real number *d*.

The model was developed in a MS Excel workbook and linked to a user input spreadsheet. User input of a salinity event duration (Ds) and duration of time between events (Db) at a specified salinity threshold (e.g. 2 ppt) is used to calculate a predicted vegetation parameter value, which is displayed in numeric and graphical formats. Verification of these relationships and their ability to accurately predict intermediate values were conducted by comparing predicted values with those from verification sites that were not used in formula development. Vegetation parameters calculated by the model are shown in **Table 20.** **Table 21** shows the sites used to derive model formulas and the sites used for model verification.

Table 20. Vegetation Parameters Included in the Salinity-Vegetation Model

Vegetation Parameter	Model Output
Abundance of a species	Species name and estimated abundance index[1]
Number of Adults per site	Estimated number of adults of each "key" species
Canopy cover (percent area of site)	Estimated canopy cover of adults as percent of total surveyed area

[1]see Methods section entitled "Semi-quantitative Vegetation Survey" **Appendix C**

Table 21. Loxahatchee River Sites Used to Derive Model Formulas

Site Name (River Mile)	Data Types			Application		
	Semi-Quantitative Vegetation Data	Quantitative Vegetation Data	Estimated Salinity*	Vegetation Trends	Salinity-Vegetation Relationships	Model Verification
Site 5-B (RM 5.6)	X			X		
Site 6-A (RM 6.2)	X			X		
Site 6-B (RM 6.8)	X			X		
Site 7-A (RM 7.3)	X			X		
Site 7-B (RM 7.5)	X			X		
Site 7-C (RM 7.75) WQ Station 64	X	X	X	X	X	
Site V-7 (RM 8.0)	X	X				X
Site 8-A (RM 8.1)	X			X		
Site 8-B (RM 8.4)	X			X	X	
Site V-6 (RM 8.6) WQ Station #65	X		X			X
Site 8-C (RM 8.7)	X			X		
Site V-5 (RM 8.8)	X					X
Site 8-D (RM 8.9)	X	X		X	X	
Site 9-A (RM 9.1)	X	X		X		
Site 9-B (RM 9.2)	X	X	X	X	X	
Site V-4 (RM 9.35) WQ Station 66	X		X			X
Site 9-C (RM 9.7)	X	X	X	X	X	
Site V-3 (RM 9.9)	X	X				X
Site 10-A (RM 10.1)	X			X		
Site 10-B (RM 10.2)	X	X	X	X	X	
Site V-2 (RM 10.3)	X					X
Site 10-C (RM 10.4)	X			X		
Site V-1 (RM 10.5)	X	X	X			X

*see Appendix E,

CHAPTER 5 -- PROPOSED MINIMUM FLOW CRITERIA (RESULTS)

INTRODUCTION

The following chapter describes the basis for establishing the MFL criteria as required in Chapter 373, Florida Statutes for the Loxahatchee River and Estuary. This chapter provides a summary of the scientific approach and technical relationships that were evaluated in defining significant harm for the water body and a detailed presentation of the proposed MFL criteria with supporting documentation.

Once the water resource functions of the river and estuary that need to be protected by the establishment of the MFL were identified (**Chapter 2**) specific technical relationships were developed and evaluated to define significant harm for the water body. The following sources of information were reviewed and considered in the development of these criteria:

1. **Literature Review**: Results of a literature search produced a bibliography containing nearly 100 citations (**Appendix A)** concerning technical relationships among flow, salinity, hydrodynamics and key biological indicator communities and species for the Northwest Fork, the downstream estuary and similar systems. This review involved (a) review of previous studies that identified relationships among river flow, salinity and resource protection; (b) identification of species or biological communities that could potentially be used as indicators, targets, or criteria for determining a minimum flow for the river and the estuary; and (c) determination of how these indicator species or indicator communities have been impacted by historic hydrologic alterations within the watershed.

2. **VEC Approach:** A "Valued Ecosystem Component" (VEC) approach similar to that developed by the EPA (1987) was developed to establish a minimum flow regime that will protect important components of the river ecosystem from significant harm.

3. **Historical Flow and Salinity Data**: Review of available USGS and SFWMD flow data and stage records was conducted using the DBHydro database for the Lainhart Dam, Cypress Creek, Hobe Grove Ditch, and Kitching Creek. These data were analyzed in terms of descriptive statistics, and reviewed for trends (**Appendix D**). Historical salinity data provided by the Loxahatchee Environmental Control District for four sites along the river were also reviewed. The long-term flow records and collected salinity database were used as input to a hydrodynamic salinity model developed for the river and estuary (**Appendix E**).

4. **Aerial Photography/GIS studies**: Review and interpretation of historical black and white aerial photographs from 1940, 1953, 1964 and color infrared photos from 1979, 1985 and 1995 were used to quantify and document changes over time in the distribution

of the dominant plant communities that comprised the floodplain swamp, wetlands and uplands located along the river corridor **(Appendix B)**.

5. **River Vegetation Survey**: Two vegetation surveys were conducted along the NW Fork of the river to characterize the species and community changes that occur along the salinity gradient upstream from the Jupiter Inlet. These surveys provided both community-based (i.e., canopy structure analysis, total number of observed species, community composition) and species-based (i.e., abundance, number of individuals, height, trunk diameter, age class) information which was used to examine relationships between salinity conditions and vegetation, as well as to construct a model that relates long-term salinity conditions with current vegetation community parameters **(Appendix C)**.

6. **Soil Salinity Samples.** District staff collected soil samples along the Northwest Fork in January 2002 to investigate soil salinity concentrations and provide a basis for future sampling projects. Four transects were established across the river floodplain, at sites representing different degrees of salinity exposure from tidal flux, and extended from the riverbank to the edge of the upland-floodplain ecotone **(Appendix G)**.

7. **Hydrodynamic/Salinity Model**: A two-dimensional depth-averaged finite element hydrodynamic/salinity model (RMA-2 and RMA-4 codes) was used to generate a long-term simulated mean daily salinity times series for each river vegetation sampling site. Descriptive statistics (mean, standard deviation, median, mode, maximum) were calculated to describe the salinity regime for each site and analyzed in terms relevant to the river's vegetation community (i.e., calculation of salinity magnitude, duration of each event, and the period of time between events). A database was developed for each of the seven sites relating measured vegetation community parameters with data derived from the simulated 30-year salinity record **(Appendix E)**.

8. **Vegetation/Salinity Model:** Where highly correlated relationships were found between measured vegetation parameters and modeled long-term salinity conditions, formulas were developed to describe these relationships and a deterministic regression model was constructed to predict (extrapolate) long-term vegetation community response to salinity. A vegetation/salinity model was developed and used to determine salinity conditions and flows associated with plant community parameters.

9. **Consumptive Use Permit Analyses:** The overall effect of consumptive uses (public water supply, agriculture, and self-supplied residential wells) on providing flows to the Northwest Fork of the Loxahatchee River was also investigated. SFWMD staff reviewed and analyzed data from permit applications and conducted groundwater model simulations to estimate the relative effect of consumptive uses on water levels in the Loxahatchee Slough and deliveries to the Northwest Fork of the Loxahatchee River during wet, normal and dry periods **(Appendices I & O)**.

RESULTS OF LITERATURE REVIEW

One requirement for developing minimum flow and level criteria is to use "best available information". The Loxahatchee River has been the focus of numerous studies over the past three decades. A literature review was conducted to review the results of these studies as they may relate to defining a flow/salinity relationship or recommended minimum flow for the Loxahatchee River. Results of the literature review as well as an accompanying bibliography of these studies are provided in **Appendix A** of this report**.** The literature review is organized chronologically beginning in the early 1970s when the problem of saltwater intrusion in the Northwest Fork was first identified in the scientific literature as a major public concern. Major findings derived from this review are summarized below.

1. The Loxahatchee River and estuary is a small (544 km^2) shallow-water body in southeastern Florida that empties into the Atlantic ocean at the Jupiter Inlet. Historical evidence indicates that the inlet periodically opened and closed to the sea as a result of natural events. Originally, freshwater and tidal flows kept the inlet open for some of the time. Near the turn of the century, some flow was diverted by construction of the Intracoastal Waterway and the Lake Worth Inlet and by modification of the St. Lucie Inlet. Subsequently the Jupiter Inlet remained closed for much of the time until 1947. Since 1947, the inlet has been permanently open (Wanless et al. 1984).

2. Fresh water enters the NW Fork of the Loxahatchee River primarily through four major tributaries. Flows received from the Loxahatchee Slough and G-92, on average, represent approximately 57% of the total flow (as measured at SR 706) delivered to the NW Fork, while Cypress Creek contributes another 32%, Hobe Grove Ditch 7% and Kitching Creek, 4% (Russell and McPherson, 1984). These proportions vary considerably in response to seasonal and local rainfall conditions. See also **Table 23** of this Report.

3. In the early 1970's it was recognized that hydrologic alterations of the watershed have reduced freshwater flow delivered to the river causing the upstream movement of saltwater during dry periods as well as saltwater intrusion of the local ground water aquifer (Land et al. 1972, Rodis 1973, Birnhak 1974). The primary cause of observed changes in flora and fauna along the NW Fork of the River was identified as the upstream movement of saltwater during drought periods (Rodis 1973, Birnhak 1974, Alexander and Crook 1975, FDNR 1985, Duever and McCollum, 1982). These studies recommended that to maintain and protect the natural communities of the Northwest Fork, sufficient freshwater should be redirected from inland canals and water storage areas to the Loxahatchee River.

4. Rodis (1973) recommended that a constant freshwater flow of 50 cfs delivered over the Lainhart Dam would be required to restrict the upstream movement of saltwater and preserve remaining natural communities in the middle and upper reaches of the NW Fork. This recommendation included an assumption that other contributing tributaries (Cypress Creek, Hobe Grove Ditch and Kitching Creek) would provide an additional 80 cfs.

5. Birnhak (1974) suggested that flows of about 60 cfs from Lainhart Dam to the Northwest Fork would keep saltwater intrusion below Station 5 near Kitching Creek (river mile 8).

6. Alexander and Crook (1975) produced a comprehensive study of the major changes in vegetation that have occurred in South Florida over the last 30 or more years. One of their study plots included an area of the Northwest Fork near the mouth of Kitching Creek. Based on photo-interpretation of aerial black and white photos taken from 1940 and 1970 they concluded that since 1940, wet prairie and cypress swamp hardwoods had lost ground to pineland and mangrove communities due to a lowering of the groundwater table and invasion of saltwater between river miles 6 and 8.

7. Each of these studies identified the presence of a freshwater layer of water overlying denser seawater within the estuary and portions of the Northwest Fork. This vertical stratification of the water column, or saltwater wedge, is a common feature of estuaries. The upstream tip of the saltwater wedge is characterized as a bottom salinity that exceeds 2 parts per thousand (Russell and McPherson 1984, Mote Marine Lab, 1990b) as shown in the conceptual diagram below (**Figure 18**). Salinity studies conducted within the river (Russell and McPherson, 1984) indicate the average distance of the salinity wedge between top and bottom is approximately 0.5 miles (**Figure 18**). During periods of reduced freshwater input, the saltwater wedge may extend as far as 5 to 10 miles upstream of the Northwest Fork. The saltwater wedge was reported to move daily from 0.5 to 1.5 miles up and down the river in response to freshwater inflow and daily tidal fluctuations (Russell and McPherson, 1984).

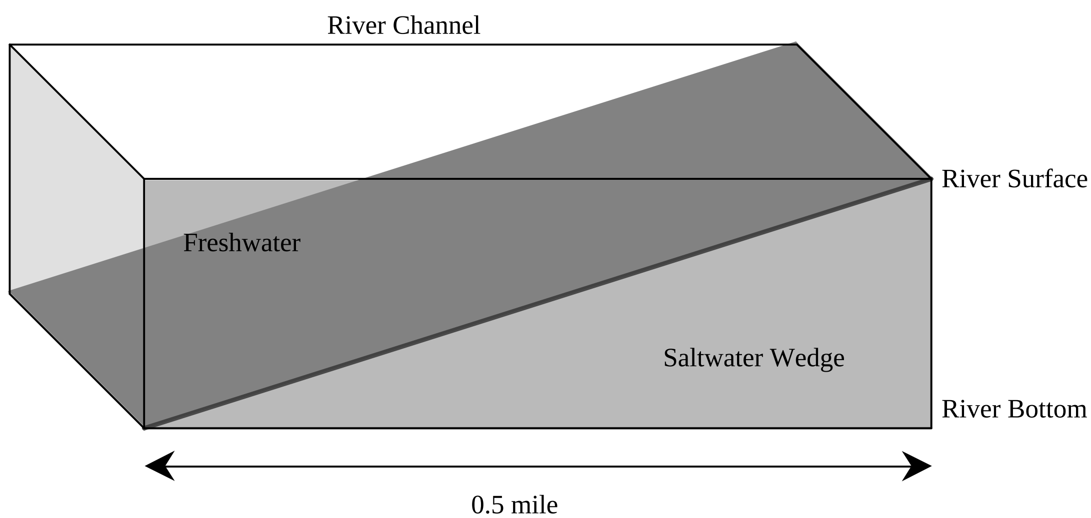


Figure 18. Conceptual diagram of the saltwater wedge.

8. Russell and McPherson (1984) conducted an intensive study of the relationship of salinity distribution and freshwater inflow in the Loxahatchee River estuary from 1980-1982. Freshwater inflows to the major tributaries were measured at six continuous gauging stations including the Northwest Fork, Cypress Creek, Hobe Grove Ditch, and Kitching Creek. Key results of this study showed that the total amount of freshwater [from all sources] needed to restrict brackish water (>2 ppt) from the upstream reaches of the Northwest Fork at mean high tide were estimated to be as shown in **Table 22.**

Table 22. Total mean daily discharges to the Northwest Fork and corresponding upstream extent of the saltwater wedge in river miles (from: Russell and McPherson 1984)

Total* Mean Daily Freshwater Discharge (cfs)	Upstream extent of saltwater wedge in river miles
220	7.0
130	8.0
120	8.2
75	9.0
43	10.0
26	11.0

* Includes NW Fork + all upstream tributaries

Figure F-4, Appendix F provides a summary of salinity profiles (at high tide) developed by Russell and McPherson (1984) for the Northwest Fork under various flow discharge rates. Russell and McPherson (1984) also noted that maintaining the above flow regime would not protect the river under all conditions. During extreme high tides and storm events, saltwater could still move upstream for brief periods. Based on the flow/salinity relationships provided above, the total amount of freshwater (from all sources) needed to restrict the saltwater wedge from the upstream reaches of the river was determined to be 120 cfs at river mile 8.2, for example, which is located upstream of the confluence of Kitching Creek and the Northwest. Of this total flow, 57% (or about 68 cfs) is derived from the Northwest Fork, 32% (38 cfs) from Cypress Creek, 7% (8 cfs) from Hobe Grove Ditch, and 4% (5 cfs) from Kitching Creek.

9. Law Environmental (1991a) summarized unpublished SFWMD flow, salinity and rainfall data collected from 18 sites within the Northwest Fork and downstream estuary from 1985-1988. Average and median flows discharged to the Northwest Fork of the river through G-92 were recorded as 50 and 56 cfs, respectively over the 3-year study. Average bottom salinity recorded at river miles 9.2, 8.0, 6.9, and 5.7 were 0.4, 2, 8, and 17 ppt, respectively. Vertical stratification of the water column was most prominent at river miles 2.6 and 8.0. Under extreme low flow conditions the salinity wedge was transported upstream by slightly more than one river mile. Under these low flow conditions, average bottom salinity recorded at river miles 9.2, 8.0, 6.9, and 5.7 were 3, 13, 17, and 25 ppt. Surface and bottom salinity at river mile 8, located within the area of cypress die-off, was less than 0.2 ppt and 0.4 ppt for 50% of the 1985-1988 data set. Discharges from S-46 were reported to have substantial effects upon salinity regimes many miles upstream of the Northwest Fork. The report concluded that salinity control by a regulated freshwater discharge at average flow conditions of 40 to 50 cfs could benefit the ecosystem by establishing a stable salinity wedge location for the estuary system.

10. McPherson and Halley (1996) in their publication, *The South Florida Environment: A Region Under Stress*, documented the encroachment of mangroves, along with the overall reductions in freshwater flows, maintenance of lower groundwater levels, short duration high volume freshwater flows for flood protection, and changes in the quality of runoff.

11. More recent studies conducted by Dent and Ridler (1997) indicate that flows delivered to the Northwest Fork (as measured at SR 706) that are equal or below 50 cfs, may not be sufficient to maintain freshwater conditions (less than 2 ppt) as far downstream as river mile 8. Their data indicated that over a one-year monitoring period, the 50 cfs target was met only 33% of

the time. When flow was equal to or less than 50 cfs, bottom salinity exceeded 2 ppt upstream of water quality monitoring station 65 (river mile 8.6) 95% of the time while station 64 (river mile 7.7) exceeded 2 ppt 100% of the time. This report recommended a minimum flow rate of 75 cfs (as measured at SR 706 bridge) for the end of the dry season (May) and 130 cfs for the wet season (July-November). They also suggested a maximum flow range, i.e., discharges should not exceed 150 cfs during the months of February-May, and no greater than 300 cfs during the wet season (June-November).

12. Dent and Ridler (1997) also provide information as to the sensitivity in which salinity concentrations within the river react to changes in flow. For example at water quality station 65 (river mile 8.6), a drop in the upstream flow rate from 150 cfs to below 60 cfs over a five day period resulted in the almost immediate movement of salt water into the area.
13. Salinity studies were also conducted by the Loxahatchee River Environmental Control District to determine the effects that physical modifications to the river and estuary, such as filling man-made gaps between the winding oxbows in the Northwest Fork had on salinity conditions in the river. Analyses of salinity data collected before and after the barriers were installed indicate that by redirecting the flow of the river through the original meandering oxbows of the river, approximately 0.7 river mile were restored to the distance needed for saline tidal waters to move upstream. These modifications resulted in a decline in salinity levels upstream of the gaps (Dent 1997b).
14. As late as 2000, the original USGS flow target of 50 cfs established by Rodis (1973) was still identified as the recommended minimum flow target for the Northwest Fork (FDEP & SFMWD, 2000). However, a 1994 study that was presented to the Loxahatchee River Management Coordinating Council determined that flows of 50 cfs were insufficient to meet the stated goals for the River (Dent, unpublished). The origin of this target was based on water flowing over the Lainhart dam; a broad crested weir located 0.1 mile north of SR 706. Previous flow rating curves developed for the dam in 1984 tended to under estimate flow over the dam. The dam was reconstructed in 1998 and flow-rating curves developed for the dam tended to significantly over estimate discharge. For this reason District staff conducted a re-calibration of the rating curve for the Lainhart dam in 1998. Re-calibration of the dam and subsequent statistical review of this new flow/salinity information resulted in the recommendation that a minimum flow target of 64 cfs was needed to maintain the saltwater wedge (as 2 ppt bottom salinity) just downstream of the confluence of Kitching Creek and the Northwest Fork of the river (SFWMD 1999). Details of the re-calibration procedure and a summary of the statistical results are provided in **Appendix D** of this report.
15. Several studies also recommended consideration of the construction of a saltwater barrier to reduce the upstream movement of saltwater during dry periods.

Based on results of the literature review, a number of flow levels have been proposed for the Northwest Fork of the Loxahatchee River during the past 30 years, ranging from a constant flow of 50 cfs to recommended dry and wet season flows of 75-130 cfs. Although these studies have produced valuable information concerning river flow and salinity relationships, none were developed based on the specific statutory minimum flows and levels requirements of Chapter 373.042(1) F.S. i.e. flow conditions that would need to be maintained to prevent significant harm to the resource.

HYDROLOGIC AND SALINITY CONDITIONS

Sources of Freshwater Inflow

Northwest Fork

Table 23 provides a summary of average freshwater flows delivered to the three forks of the Loxahatchee estuary during the wet and dry season as well as during selected drought events. Four major sources of water (G-92 and the Lainhart Dam, Cypress Creek, Hobe Grove Ditch and Kitching Creek) provide the majority of freshwater flow to the Northwest Fork of the Loxahatchee River. Other historical inputs such as Moonshine Creek and Wilson Creek have been highly altered by drainage and development and today provide only a very small portion of flow to the Northwest Fork and are not included in **Table 23.** Of these four sources, the Lainhart Dam (the main stem of the river) is the largest contributor, providing between 51 and 56 percent of the flow to the Northwest Fork during the wet and dry seasons.

Table 23. Summary of Average Wet and Dry Season Flows to the Loxahatchee Estuary.

Tributary	**Average Daily Flow (cfs)**		**1980-81 drought Avg. flow (cfs)**		**1989-90 drought Avg. Flow (cfs)**		Period of Record
	Wet Season	**Dry Season[1]**	**Wet Season**	**Dry Season**	**Wet Season**	**Dry Season**	
Northwest Fork							
Lainhart Dam	95	70	65	35	68	26	1971-2001
Cypress Creek	60	32	57	30	41	30	1980-1991
Hobe Grove Ditch	9	7	11	7	9	7	1979-1991
Kitching Creek	21	16	8	5	3	1	1979-2001
Subtotal	*185*	*125*	*141*	*77*	*121*	*64*	
North Fork[2]							
USGS sites 28B & 28c	4	1	4	1	ND	ND	1980-1982
Southwest Fork							
C-18 Canal@S-46	94	61	61	20	8	8	1961-2001
Total	283	187	206	98	129	72	

[1] Wet season defined as May 15- Oct. 15; Dry season = Oct. 16- May 14
[2]From Russell and McPherson 1984 (POR 1980-1982)

* The average wet and dry season flows calculated for each tributary were based on the available data in each tributary's individual period of record, and were not restricted to the dates in which flow values were concurrently available for all four tributaries.

The second largest contributor is Cypress Creek representing 26 – 32 percent of the total flow delivered to the Northwest Fork, followed by Kitching Creek (11-13%) and Hobe Grove Ditch (5%). In terms of average dry season flows, the Lainhart Dam provides about 70 cfs, Cypress Creek, 32 cfs; Kitching Creek, 16 cfs; and Hobe Grove Ditch, 7 cfs for an average total of 125 cfs of freshwater delivered from the Northwest Fork to the Loxahatchee estuary (**Table 23**). These dry season flows were reduced by more than one-half during 1980-1981 and 1989-90 drought periods with average values ranging between 26-35 cfs for the Lainhart Dam, Cypress Creek (30 cfs), Hobe Grove Ditch (7 cfs) and Kitching Creek (1- 5 cfs) for an average total of only 64 -77 cfs of flow discharged to the estuary during low rainfall periods (**Table 23**).

Review of historical flow records for the Lainhart Dam data over the past 30 years shows that flows delivered to the Northwest Fork have significantly increased since 1990 **(Figure 19**).

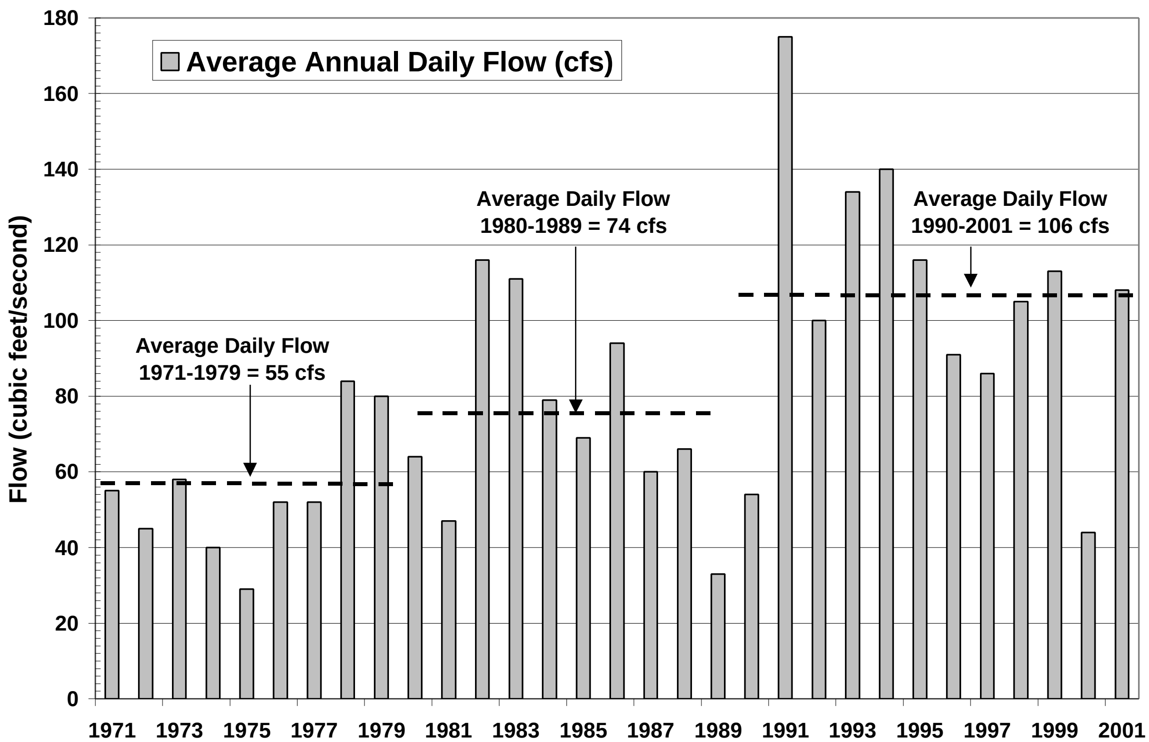


Figure 19. Average Annual Daily Flows (cfs) recorded for the Lainhart Dam (1971-2001).

The purpose of this analysis was to represent decadal differences in freshwater flow patterns, i.e. to compare flow conditions in the 1970's with the 1980's and 1990's. Data from the 1970's and 1980's were considered to be "historical" and data from the 1990's represent more "current" conditions. Average annual daily flows delivered to the Northwest Fork during the 1970's and 1980's ranged between 55 and 74 cfs. These flows increased dramatically during the 1990's reaching an average of 106 cfs due to several factors. First, the 1990's represent a period of increased rainfall within the region (**see Figure 4,** Chapter 2). Increased rainfall experienced within the basin coupled with operational improvements (enlarged culverts and an automated gate) made to the upstream G-92 structure in 1987 most likely played a key role in the District's ability to provide increased flow to the Northwest Fork of the river over the past 12 years.

Table 24 indicates how the distribution of flows has changed at different flow rate thresholds. In general the percentage of time that flows to the river were less than 65, 50, 35 and 25 cfs have decreased. Over the past decade, the 65-cfs flow target for the Lainhart Dam, as proposed in the Northern Palm Beach County Comprehensive Water Management Plan (SFWMD, 2002), is met about 57% of the time. Even though a number of hydrological improvements have been made within the basin over the last decade, there are still periods of time when the river receives very little flow. The occurrence of flow rates less than 10 cfs increased slightly from 6% to 7% during the last 12 years (**Table 24**). During that period, flows less than 35 cfs occurred 73 times with an average duration of 15 days and a return frequency of

2 months. It can be inferred, therefore, that exceedances of the proposed MFL occurred, on average, several times per year and significant harm is continuing to occur to the resource.

Table 24. Comparison of historical and more current flow conditions at the Lainhart Dam (Northwest Fork of the Loxahatchee River) based on USGS data from 1971 to 2000.

Flow Target	Historical (1971-1989)*				Current (1990-2001)**			
	% of time below desired flow rate	No. of Events	Avg. Duration (days)	Return Frequency (months)	% of time below desired flow rate	No. of Events	Avg. Duration (days)	Return Frequency (months)
65 cfs	58 %	124	32	1.8 months	43 %	113	17	1.3 months
50 cfs	47 %	113	29	2 months	36 %	101	15	1.4 months
35 cfs	34 %	94	24	2.4 months	25 %	73	15	2 months
20 cfs	16 %	59	19	3. 8 months	15 %	35	18	4 months
10 cfs	6 %	26	16	8.6 months	7 %	16	19	8.8 months

* =18.75 year period of record, ** =11.8 year period of record

Presently, G-92 is the only structure that can be controlled by the District through remote telemetry to release water from the Loxahatchee Slough and C-18 canal to the Lainhart Dam and the Northwest Fork of the river. The other three tributaries do not have controllable structures. For the most part, flows from these structures are primarily rain-driven. Surface water flows from G-92 combine with surface water runoff from the Jupiter Farms area and SIRWCD C-14 canal to convey water to the Lainhart Dam, the primary source of freshwater for the Northwest Fork. A time series of historical flow data (1971-2001) for the Lainhart Dam is provided in **Appendix D**. These data are summarized in the flow duration curve presented in **Figure 20** for the 30 year

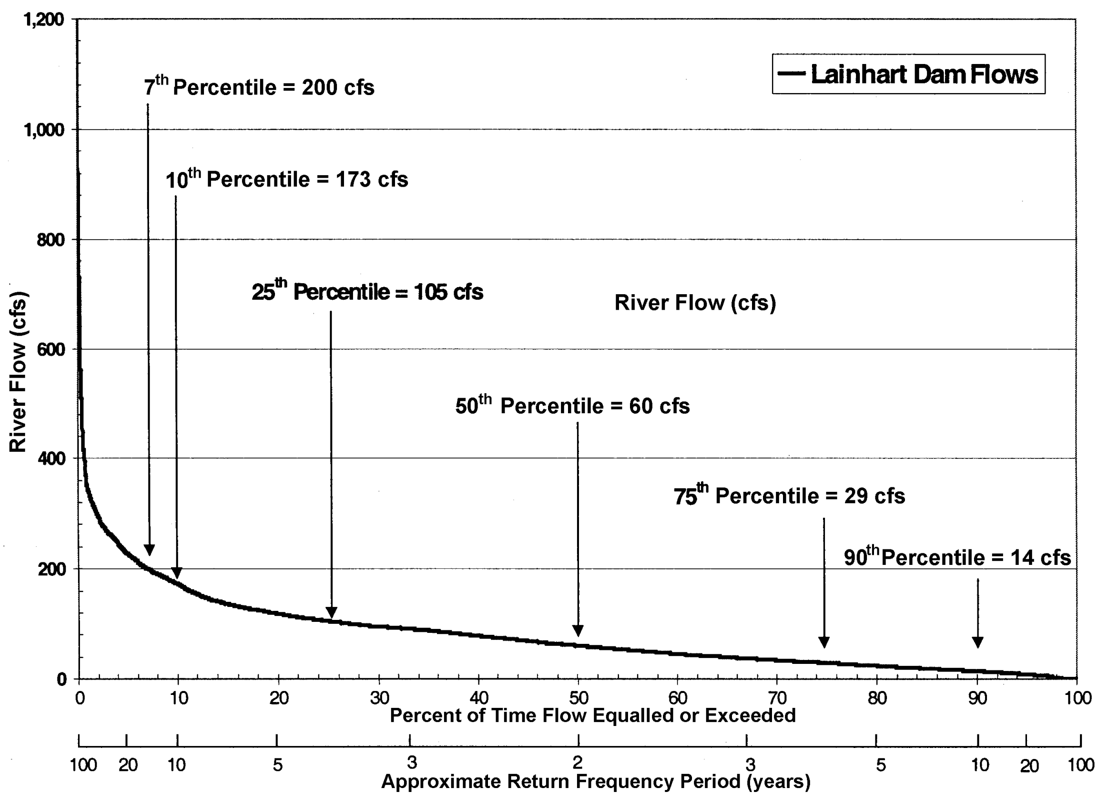


Figure 20. Flow Duration Curve for the Lainhart Dam (1971-2001)

period of record. The median (50th percentile) flow value for the Lainhart Dam is 60 cfs, while the 90th, 75th, 25th and 10th percentiles are 14, 29, 105 and 173 cfs, respectively.

Figure 20 shows that Lainhart Dam flows fall to less than 15 cfs approximately once every 10 years (90^{th} percentile). Under very low flow conditions (<10 cfs) saltwater has been recorded to extend upstream to Trapper Nelson's (river mile 10.7) and river bottom salinities were as high as 7 ppt (Russell and McPherson 1984). These low flow periods have the potential to stress or temporarily eliminate populations of freshwater fish or aquatic invertebrates downstream of Trapper Nelson's when exposed to saline conditions. Low flow events such as these also restrict recreational use of the Wild and Scenic portion of river by canoe and kayak.

North Fork

The North Fork is a shallow tributary that currently contributes only a small percentage of the total freshwater flow to the estuary (Russell and McPherson 1984; Sonntag and McPherson 1984). Brackish conditions extend approximately 5.0 miles up this branch from the mouth of the inlet (McPherson and Sabanskas 1980). The North Fork of the estuary has an average depth of 3.4 feet, maximum depth of 6.6 feet, average width of about 0.15 miles and covers a total area of about 200 acres. Freshwater flow to the North Fork is uncontrolled. A study by Russell and McPherson (1984) indicated that freshwater flow from the North Fork represented only about 2% of total freshwater flow to the estuary **(Table 23)**. Much of the upper end of the watershed of the river lies within Jonathan Dickinson State Park. The shoreline along the lower estuary is surrounded by residential development and is mostly bulkheaded. The sediments generally consist of fine sand and mud. Some areas have deep pockets of soft mud that has a high content of organic material. Water quality is often poor due to high levels of turbidity and color that limit light penetration, low levels of dissolved oxygen and occasional high concentrations of fecal coliform bacteria (Dent et al. 1998). Due to the low input of fresh water, bottom salinities in the lower section of the North Fork are usually above 25 ppt, while salinities further upriver average about 14 ppt.

Southwest Fork

Under normal operating conditions discharges are made to the Southwest Fork of the estuary through the S-46 structure when stages in the C-18 canal exceed 15.0 ft. NGVD. However during a major storm event these gates are operated manually to quickly lower water levels in the canal for flood control and can maintain a headwater between 13 and 14 ft. NGVD for a short period of time. As a result, flows delivered from S-46 to the estuary are highly variable in response to upstream water management (**Figure 21**). Review of flow data collected from S-46 for the period of record 1990-2000 shows that although average flows delivered to the estuary ranged between 61 and 94 cfs for the wet and dry seasons (**Table 23**) the median value was zero. No discharges were made to the estuary for 67% of the time over the period of record. In contrast, during 1995 and 1999 were there were periods when mean daily flows exceeded 2,500 cfs in response to major storm events experienced within the watershed (**Figure 21).** Events such as these are thought to have a major impact on the both water quality and the salinity in estuary.

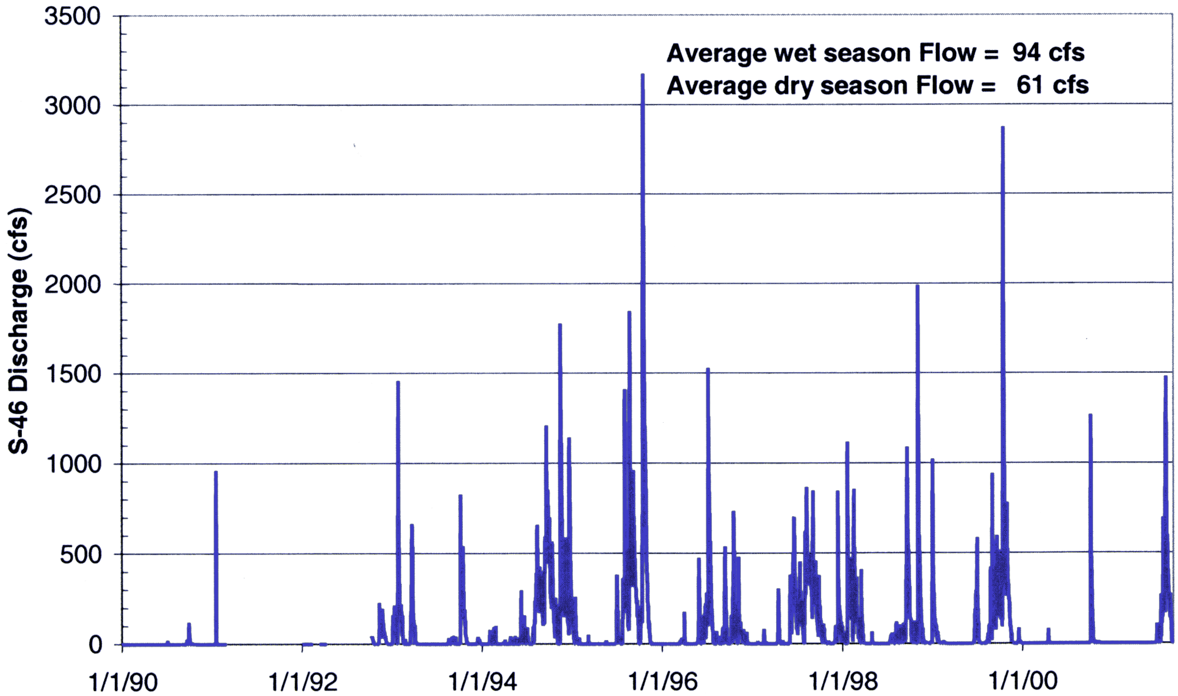


Figure 21. Water Management Releases from the C-18 canal via S-46 (1990-2001)

Salinity Conditions within the Northwest Fork

Historical Data

The following information was summarized from water quality monitoring studies conducted by the Loxahatchee River Environmental Control District (Dent 2002, personal communication). The database includes information periodically collected from 1970 up to 2001. For the following analysis, water quality monitoring sites were grouped into segments defining different salinity zones, or habitats, found within the estuary and River. These include the marine and coastal zone, estuary, wild & scenic segment, and freshwater tributaries. Measured salinity data for these river segments are presented in **Table 25**.

The marine/coastal segment of the river includes the habitat that is near the mouth of the Jupiter Inlet. Average salinity values range from 27.7 to 30.7 ppt for the period of record (1970-2001). Average salinity values for this segment are not significantly different for the two 12-year periods between 1970 and 1993, for the more recent above average rainfall years (1994-1997) or drought years (1998-2001) (**Table 25**). These data indicate that tidal flux, rather than freshwater inflow from upstream, is the primary factor influencing salinity concentrations at this location.

The Loxahatchee River estuary lies in the mixing zones between upstream freshwater inflows delivered by the Northwest Fork and Southwest Fork (C-18 canal) and tidal salinity provided by the Jupiter inlet. Average salinity measured in the estuary from 1970 through 1993 was between 21 and 22 ppt. As expected, the average measured salinity was lower (19.6) during above-average rainfall years (1994-1997) and slightly higher (23.0) in drought years (1998-

Table 25. Measured salinity from the NW Fork of the Loxahatchee River.*

River Segment	Period	Comments	Mean Salinity (ppt)
Marine/Coastal	1970-1981	12-year period	27.7
	1982-1993	12-year period	29.0
	1994-1997	Above-average rainfall years	30.7
	1998-2001	Drought years	30.6
Estuarine	1970-1981	12-year period	22.0
	1982-1993	12-year period	21.2
	1994-1997	Above-average rainfall years	19.6
	1998-2001	Drought years	23.0
Wild & Scenic	1970-1981	12-year period	0.3
	1982-1993	12-year period	0.4
	1994-1997	Above-average rainfall years	0.9
	1998-2001	Drought years	2.5
Freshwater Tributaries	1970-1981	12-year period	0.3
	1982-1993	12-year period	0.4
	1994-1997	Above-average rainfall years	0.4
	1998-2001	Drought years	0.7

*Source: Riverkeeper data from the Loxahatchee River Environmental Control District (Dent 2002, pers. comm.)

2001), reflecting increased and reduced freshwater inputs to the estuary, respectively. These data indicate that for this area, long-term salinity values are only somewhat affected (+/-2 ppt) by annual rainfall variation in upstream basins. The primary factor influencing salinity at this location is tidal flux.

Average salinity values for the Wild & Scenic segments of the river (above river mile 6.5) range from 0.3 to 0.4 ppt during the two 12-year periods between 1970 and 1993. After 1993, salinity in this upstream segment increased in both above-average rainfall years (1994-1997, average salinity 0.9 ppt) and during drought years (1998-2001, average salinity 2.5 ppt). These data suggest that upstream portions the river may have experienced high salinities during the past decade. However, the trend is uncertain because the official Wild and Scenic portion of the river includes at least one station (no. 63) that is estuarine rather than fresh water in character.

Freshwater tributaries are those creeks, streams, and canals that are direct sources of freshwater input to the Northwest Fork. These include Kitching Creek, Hobe Groves Ditch, and Cypress Creek. Average salinity values from these tributaries are comparable to those of the Wild & Scenic (freshwater) segment of the River, with values near 0.3-0.4 ppt for both 12-year periods (1970 through 1993) and the more recent above-rainfall years (1994-1997). As expected, salinity was slightly higher during drought years (1998-2001, average salinity 0.7 ppt) as compared to other time periods but was still below 1 ppt.

Soil Salinity Survey Results

Soil sampling was conducted along the Northwest Fork to investigate soil salinity concentration changes along the river and to serve as a reconnaissance effort to gain information upon which to base future sampling efforts. This analysis was also suggested by the scientific peer review panel that reviewed the 2001 Draft Technical Document. Four transects were established along the Northwest Fork in January of 2002. These four transects represented different river vegetation communities and degree of exposure to salinity from tidal influences.

Location of these four transects are shown in **Figure 16.** **Appendix G** provides a description of the methods used to collect samples and analyze data.

Results of these analyses are shown in **Table 26**. Salinity values determined by measuring conductivity were similar to, but slightly above, the results and trends obtained from chloride analyses. Chloride proved to be a more sensitive measure of differences between sites. It should be noted that many natural waters in Florida have background conductivities ranging from 700 to 1000 µmhos/cm. The lowest surface soil (0-0.33 m. depth) chloride concentrations were found at transect 1 (20–29 mg/L), located near river mile 11.5, the site least impacted by tidal salinity intrusion. Progressively higher chloride concentrations were detected in surface soils from transect 2 (49–95 mg/L near river mile 10.5), transect 3 (67–130 mg/L near river mile 9.9), and transect 4 (2000–3000 mg/L near river mile 6.5). At transect 4, chloride levels also varied within the vertical soil profile near the floodplain/upland ecotone and the river bank.

Table 26. Soil Salinity from Transects, Calculated from Conductivity (Cond., ppt*) and Chloride (Cl, ppt) Analyses.

Collection Date	Tran-sect	Appox. River mile	Plot	Conductivity (µho/cm)	Temp. (°C)	Salinity (Cond., ppt)	Chloride (mg/L)	Salinity (Cl, ppt)
1/22/02	1	11.5	River bed (grab)				29	0.05
1/23/02	1		River bottom	760	23		20	0.03
1/23/02	2	10.5	0-3 m	730	24	0.2	95	0.2
1/23/02	2		3-13 m	630	23	0.2	49	0.1
1/23/02	2		33-43 m	680	23	0.2	69	0.1
1/24/02	3	9.9	0-10 m	710	24	0.2	110	0.2
1/24/02	3		30-40 m	870	23	0.5	130	0.2
1/24/02	3		64-74 m				67	0.1
1/24/02	3		Floodplain/upland ecotone	680	23	0.2	81	0.1
1/24/02	4	6.5	0-10 m (0'-1')	9900	24	5.5	3000	4.9
1/24/02	4		0-10 m (1'-2')	7900	25	4	2500	4.2
1/24/02	4		0-10 m (2'-3')	6000	23	4.5	2000	3.3
1/24/02	4		45-55 m (0'-1')	6600	23	4.5	2000	3.4
1/24/02	4		45-55 m (1'-2')	6600	23	4.5	2100	3.5
1/24/02	4		45-55 m (2'-3')	5500	23	3.0	1900	3.2
1/24/02	4		95-105 m (0'-1')	8100	23	6.5	3000	4.9
1/24/02	4		95-105 m (1'-2')	7700	23	4.2	2400	4.0
1/24/02	4		95-105 m (2'-3')	9300	23	5.2	2700	4.5
1/24/02	4		155-165 m (0'-1')	10400	23	5.9	2800	4.7
1/24/02	4		155-165 m (1'-2')	8200	23	6.5	3000	4.9
1/24/02	4		155-165 m (2'-3')	9900	23	7.7	3500	5.7

*ppt = parts per thousand

Soil salinity concentrations did not reveal a well-defined gradient along the River, as was found with the chloride data. Although the plant community at transect 3 contained both freshwater and saltwater-tolerant species, soil salinities were comparable to those at unimpacted sites (transects 1 and 2). However, chloride concentrations at transect 3 (67-130 mg/L), where some red mangrove were present, were higher than in areas inhabited by strictly freshwater vegetation. These data indicate that soil chloride concentration, rather than salinity, may be a better parameter to use to characterize the salinity gradient along upstream portions of the Northwest Fork. A distinct chloride gradient was detected, associated with proximity to the

Jupiter Inlet. However, elevated salinity levels were found only at transect 4 sampling sites, an area that has been impacted by elevated salinity levels for many decades.

Results from this study indicate that "background" salinity levels are very low (0.1-0.2 ppt) in unimpacted areas. This study also suggests that salinity is not retained in the soils for long periods of time. At transect 3, an area was affected by elevated salinity conditions during the most recent drought (1999-2001), salinity was comparable to the pristine transects 1 and 2.

It is important to understand that the scope of this sampling effort was narrow and interpretation or application of the results are limited. This preliminary study does not address potential changes in soil salinity attributed to seasonal hydrological patterns (dry season vs. wet season), droughts, duration of exposure to a salinity concentration, salinity memory (ability to retain sodium or chloride), spatial distribution along the river corridor, and vertical distribution within the soil profile (which affects shallow or deeply rooted plants differently). Results of this study can be useful to design a more comprehensive soil salinity sampling effort.

The results of this reconnaissance investigation were inconclusive. District staff had speculated that (1) soil salinity levels might serve as a reasonable indicator of past salinity conditions within the river that could be linked to the species composition of river vegetation communities, and (2) these results would show a salinity gradient from downstream to upstream areas. Even though this survey was conducted following one of the most extensive droughts recorded in South Florida, results of the survey showed no clear trend and suggest that soil salinity levels may be highly transitory in response to river flow. Based on these results, soil salinity levels may not be a good long-term indicator of stress to river plant communities.

EFFECTS OF CONSUMPTIVE USES

Two analyses were conducted to quantify the relative effects of consumptive use on surface water and ground water flows to the Loxahatchee Slough and Northwest Fork as follows:

a. A search was conducted of the District Water Use Division's geographical data base to identify all permits, wells and pumps located in the Loxahatchee watershed boundary as well as a buffer area located one-mile outside of the boundary. Results of the data base search are provided in **Appendix O,** listing the major water uses: public water suppliers (PWS), commercial and industrial (IND), golf courses (GOL), landscape irrigation (LAN) and agricultural (AGR) in the watershed and their permitted allocations.

b. In addition, District staff conducted a hydrologic analysis, using output from the Northern Palm Beach County Comprehensive Water Management Plan hydrologic model (MODFLOW), to evaluate the effects of consumptive uses within the basin on the ability to provide flows to the Loxahatchee Slough and River. These results are presented in **Appendix I.**

Based on consideration of the results of these studies and further investigation by the Water Use Division staff, the following summary of impacts was prepared:

Effects of Water Uses on Flows in the Loxahatchee River:

Based on the hydrologic and geologic characteristics of the watershed, not all water uses impact the flows in the Loxahatchee River. Uses of water that have the potential to influence Loxahatchee River flows are identified as follows:

- Direct surface water withdrawals from the River or tributaries
- Direct surface water withdrawals from the C-18 canal upstream of G-92 and S-46
- Groundwater withdrawals that lower the groundwater table under the river, its tributaries or the C-18 canal.

Review of the water use permits issued within the watershed with regard to the above criteria reveals the following:

- No water use permits have been issued that authorize surface water withdrawals directly from the River
- Three water use permits exist that authorize surface water withdrawals directly from the C-18 canal upstream of G-92 and S-46. No water use permits have been issued that authorize surface water withdrawals directly from Hobe Ditch, Cypress Creek or Kitching Creek
- Two permits exist that authorize groundwater drawdowns greater than 0.1 ft beneath the Loxahatchee River or its tributaries
- Four permits exist that authorize groundwater drawdowns greater than 0.1 ft beneath the C-18 canal.

Locations of these projects are shown in **Figure 22.** The dots represent individual wells. Permits typically are issued to landowners or utilities that operate a number of wells on their property. Thus a single permit may be represented by a cluster of dots in close proximity on the map. Impacts are evaluated for each permit and thus consider the combined effects of withdrawals that occur from all of the wells covered by the permit.

The remaining question is, how much do these nine projects affect the flow in the Loxahatchee River? Staff evaluated the Northern Palm Beach County groundwater model as a possible tool to quantify impacts of water use on flow rates in the River. Results of this analysis are presented in **Appendix I**. Several factors limit the ability of this model to accurately estimate surface water flows in the River:

- Although the groundwater model provides summaries of inflows along specific reaches, it is not capable of directly calculating surface water flow rates in canals or rivers. An effort is underway to integrate the groundwater model with a surface water model and to calibrate these models with historical data. Additional work is needed to refine the models and improve the calibration.
- The degree of hydraulic connection between the aquifer and the canal or River have not been measured directly with sufficient precision (i.e. flow rates as low as 1 cfs). The rate of leakage out of or into a canal or river is highly influenced by this factor.

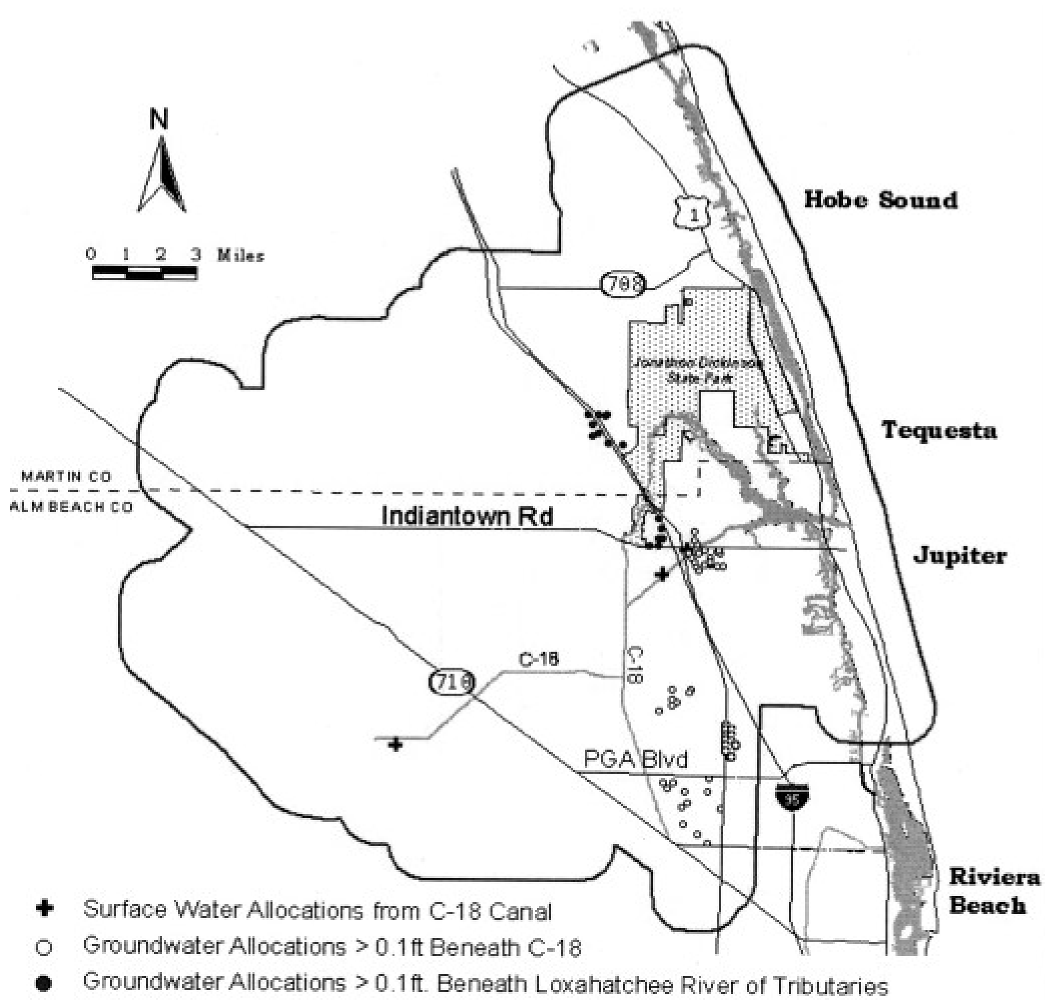


Figure 22. Location of permitted projects with potential to impact flows in the C-18 Canal, Loxahatchee River or tributaries (each permit consists of a cluster of dots that represent individual wells).

- The Northern Palm Beach model only includes the southern portion of the Loxahatchee watershed and hence does not include consumptive use withdrawals in Martin County.
- More data on the timing and amounts of actual water use in the watershed are needed to accurately quantify impacts of withdrawals.

As a result of these limitations, the model has limited capability to predict changes in Loxahatchee River flows associated with consumptive use. However, a qualitative assessment of water uses in the watershed yields the following:

- The three withdrawals from the C-18 Canal include a small nursery, an agriculture property located near the Corbett Wildlife Area and the Jupiter Siphon System. The nursery is only 25 acres and has an average daily allocation of 0.01 mgd. The agricultural project is located approximately nine miles upstream from the G-92 structure and was modified to include water supply from an onsite mine. The Jupiter Siphon System is used occasionally during extreme conditions, to withdraw water from the river and provide direct recharge to the Jupiter wellfield. Such withdrawals are limited and are only allowed to occur during times when the stage in the C-18 Canal is greater than 14.5 ft NGVD during the dry season. As a result, the system has only operated for 3 months during the last five years.

- There is one agricultural project whose allocation can produce a groundwater drawdown greater than 0.1 feet beneath the Loxahatchee River and one agricultural project that has the potential for drawdowns greater than 0.1 feet beneath tributaries to the river.
  - The first project, located in Palm Beach County, has not been used for several years and has been recently acquired by another owner. This project used groundwater that was pumped from wells located adjacent to the Turnpike and moved west to the crops located next to the river. The irrigation method permitted involves a seepage/flood application that raises the groundwater table to about 18 inches below the top of the bed. This raised the water table elevation located next to the River and actually increased ground water base flow to the River when the crops were being irrigated. Changes in the type of use (such as agricultural irrigation to golf course irrigation) would require a modification of the permit.
  - The second agricultural project is located in Martin County. The allocation for this project could produce between 0.2 to 0.3 ft of drawdown beneath portions of Kitchen Creek and Cypress Creek.
- The remaining four projects that cause drawdowns under the C-18 Canal include two golf courses, the Seacoast Utilities and Town of Jupiter Utilities. The range of drawdown for each of these projects beneath portions of C-18 Canal is between 0.2 and 0.3 ft.

The cumulative effect of these withdrawals is analyzed in **Appendix I**. Further information on individual permits is provided in **Appendix O**. While the ability of existing quantitative tools to calculate the impact of consumptive uses on the flow of the Loxahatchee River is limited, estimates based on simple flow net analysis and professional judgment indicate that the dry season impacts on flows that could potentially be delivered to the Northwest Fork are estimated to be less than 5 cfs. See **Appendix I** for further details.

BIOLOGICAL RESULTS

Importance of the Freshwater Floodplain Swamp

The freshwater floodplain swamp community located within the upstream portion of the Northwest Fork of the Loxahatchee River is an important component of the regional ecosystem. The structure of the floodplain swamp community is highly complex, comprised of low understory groundcovers and shrubs, medium height sub-canopy shrubs and hardwoods, and high canopy hardwoods, palms and bald cypress, including a number of cypress tress within the 300-500 year old range. The high canopy supports a wide variety of epiphytic plants such as ferns, bromeliads and orchids. The floodplain swamp community supports a number of important water resource functions for the ecosystem as follows: (1) provides leaf litter and organic detritus that are the basis of the food chain for upstream river system as well as the downstream estuary; (2) helps to stabilize the river shoreline and soils to prevent erosion; (3) provides specialized habitat for many plant and animal species, a number of which are rare, threatened or endangered; (4) maintains and protects water quality in the River; and (5) supports a diverse population of animals, including many that also utilize the surrounding upland and estuarine habitats. Wetland forest communities similar to those found along the upper reaches of the Loxahatchee River support both high wildlife density and diversity (Ewel 1990b).

In downstream reaches of the river, diversity of floodplain vegetation is reduced sharply by the influence of salt water. Mangroves are specifically adapted to live in saline environments, and because of their size, they tend to shade out other competing salt-tolerant wetland species such as cordgrass (*Spartina* spp.). Over time mangrove communities become essentially monocultures and hence have very low vascular plant species diversity. This low vascular plant species diversity, however, is compensated by the fact that mangroves produce large amounts of leaf litter that is used extensively by aquatic organisms as a food source and that many brackish water and marine species of algae and animals thrive in the extensive network of mangrove prop roots.

The long-term decline in the distribution and health of the floodplain swamp community within the mid to upstream portion of the Northwest Fork have been linked to periods of saltwater intrusion during low rainfall periods (Rodis 1973, Alexander and Crook 1975, Russell and McPherson 1984). These periodic episodes of increased salinity appear to be correlated with past hydrologic alterations of the river and its upstream watershed, as well as (potentially) long-term changes in rainfall patterns, climate, and sea level rise. These alterations most notably include the following: (a) the permanent opening of the Jupiter inlet in 1947, (b) dredging activities conducted within the estuary to improve navigation, and (c) construction of the C-18 Canal in 1957-58 which diverted freshwater flows away from the Northwest Fork to the Southwest Fork. Combined, all of these factors have resulted in reducing the amount freshwater flow delivered to River during dry periods and have increased the frequency that the floodplain swamp has been exposed to increased saltwater concentrations. Sufficient fresh water needs to be delivered to the river during dry periods to protect the remaining floodplain swamp community, a Valued Ecosystem Component, from further degradation and loss of natural function.

Because of its ecological importance to the region and surrounding communities, the focus of this report was on establishment of MFL technical criteria for the Northwest Fork to protect the remaining floodplain swamp community against significant harm. Due the lack of recent flow or biological data from the North Fork, and the highly altered nature of the Southwest Fork, these two arms of the Loxahatchee Estuary were not considered for MFL establishment at this time, but may be considered in the future as part of FDEP's MFL Priority List update.

The Effects of Salinity on Cypress Trees

An issue of primary concern during the preparation and review of the previous version of this report (SFWMD 2001) was the effect of salinity on bald cypress trees (*Taxodium distichum*). Because a close relationship between salinity levels and mortality of bald cypress could not be established, SFWMD scientists applied the methods that are used in the present study, which involve an assemblage of freshwater swamp species. However, since cypress trees are a dominant component in the “Wild” portion of the Northwest Fork, effects of salt water on this species are still a primary concern. In addition, the results of this investigation reveal trends and relationships that apply to other predominantly freshwater species. A more detailed treatment of this subject is provided in **Appendix A**.

Concepts to be Considered

Recent changes in the historic distribution of cypress trees along the Northwest Fork of the Loxahatchee River have been well documented (Alexander and Crook, 1975; Rodis 1973; SFWMD, 2002). The mechanisms related to these changes are not entirely understood, but there is a strong relationship between cypress tree die off and increasing levels of salinity within the river (Alexander and Crook, 1975; Rodis 1973). To understand the effects of elevated salinity on cypress trees, two salinity thresholds need to be considered: acute and chronic.

The acute threshold is the salinity level where trees are injured or killed after one exposure event. This may occur during a severe drought or from a surge of sea water pushed upstream during a storm event. Under such conditions, areas that are primarily freshwater systems become inundated with saltwater. As the magnitude of salinity and duration of exposure increase, the potential for injury or death to cypress increases. Effects are often visible within a short time from exposure (i.e. weeks to months).

The chronic threshold is the salinity level where bald cypress are injured or killed after long-term exposure. Unlike the transient drought or storm surge event described above, this threshold is characterized by continuous (or nearly so) exposure to low-level saline conditions. This exposure has the effect of crippling vital biological functions of the tree which can lead to developmental deformities, slowed growth rates, reduced canopy or leaf area, increased parasitism, and perhaps eventual death. Cypress suffering from salt stress are less disease resistant, less competitive ecologically, and less capable of producing viable offspring that are capable of regenerating the forest. Effects are usually only visible after a long period of exposure (i.e. months to years). The chronic threshold level is expected to be lower than the acute threshold level. Furthermore, differences between mature tree and seedling thresholds may be significant.

Of primary consideration in protection of the riverine swamp community is the provision of sufficient freshwater flow to prevent salt water from penetrating upstream. As more water flows through the river, the saltwater interface is pushed further downstream towards the ocean. Another important consideration is the effect of groundwater discharges and seeps to the river floodplain. Groundwater levels in areas adjacent to the river also influence the inland extent of saltwater intrusion. Typically, the depth at which saltwater intrusion occurs is directly related to the elevation of groundwater as shown in **Figure 23.**

Plant physiology, especially relative to root development, is another important factor that determines the response of a species to salinity flux. The depth and extent of root systems, and proximity to the edge of the floodplain both influence the potential for impact from elevated saline conditions.

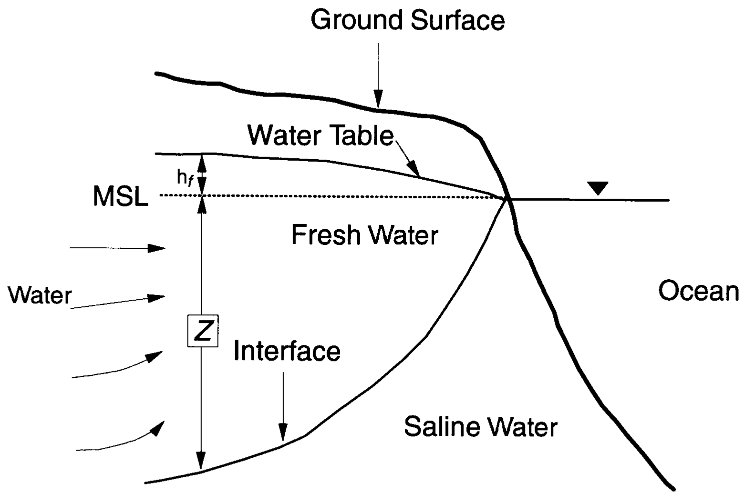


Figure 23. Relationship between water table elevation (h_f) and the depth below ground at which saltwater intrusion occurs (Z). As ground water level increases, the depth at which intrusion occurs also increases.

Tropical tree species (e.g. mangroves) typically develop shallow networks of roots near the soil surface. These species are more influenced by surface water conditions and variations. Temperate and subtropical tree species, including bald cypress, tend to be more deeply rooted and are more influenced by subsurface water quality. Established, mature trees near the edge of the floodplain are less affected by river salinity variations, since groundwater seepage from the uplands can maintain a head of freshwater against the salt water influx. Young saplings near the river channel are more likely to be damaged by periods of increased salinity. Other factors affecting the depth of root penetration include the presence of a hardpan or rock layer and the existence of anoxic conditions.

Literature Review

Rodis (1973) published his observations of the effects of elevated salinity on the cypress forests of the Loxahatchee River. He concluded that the primary cause of environmental problems facing the river was the upstream movement of saltwater, which, in turn, resulted in changes to the flora and fauna in JDSP, and other portions of the river. Results of this study indicated that a minimum continuous flow of 23,000 gallons per minute (50 cfs) was required across the Lainhart Dam to retard further upstream movement of saltwater in the Northwest Fork.

There currently are no salinity threshold studies of cypress trees in the Loxahatchee River Basin. Pezeshki et al. (1987), Allen et al. (1994) and Krauss et al. (1999) performed experiments on bald cypress seedlings from Louisiana and found that acute salinity toxicity effects occur above 2 ppt salinity. None of these experiments adequately covered the salinity range between 0 and 2 ppt. Therefore, a target cannot be determined from these studies for the acute salinity threshold for mature trees or for the chronic threshold for either seedlings or mature trees.

There are apparently no data to determine the relationships among groundwater levels, extent of saltwater penetration from the river to the edge of the floodplain, and depth below ground where saltwater occurs. Several studies have been initiated to determine the salt content and salt gradients in floodplain soils and shallow ground water, but results of these investigations have not been published (Roberts, personal communication; Worth, personal communication). Similarly, there are no data from the Loxahatchee River cypress community concerning the depth of the root zone or the relationship between cypress tree size and depth of root penetration.

Conclusions and Recommendations

- There have been no studies conducted to investigate the relationship between the extent of saltwater migration up the Loxahatchee River and the dieback of bald cypress trees in the floodplain.
- However indirect evidence and observations by a number of authors, indicates that there is a strong correlation between upstream saltwater encroachment and extensive dieoff of bald cypress, replacement of freshwater swamp by mangroves and other salt-tolerant species, and the current distribution of a "stressed" freshwater floodplain vegetation community in which cypress trees appear to be stunted and chlorotic.
- Maintenance of a viable cypress community in the Loxahatchee River floodplain needs to be based on consideration of both acute and chronic effects of salinity exposure.
- Results of studies conducted on Louisiana bald cypress seedlings suggest that exposure at or above 2 ppt salinity concentration may lead to symptoms of acute exposure, such as seedling injury or death. However, there are no indications from the literature on salinity levels that lead to stress or mortality of seedlings in the long term, or for mature trees.
- Additional research is needed to determine effects of salinity on bald cypress trees of different sizes, effects of groundwater interactions, salt content of floodplain soils at different depths and distances from the river, and the depth of cypress root penetration.

River Vegetation Survey Results

In order to develop a database that could be used to analyze river vegetation/salinity trends, a survey was conducted of existing vegetation communities along the river.

Semi-quantitative Survey

A semi-quantitative survey was conducted in November of 2000 and December of 2001 to examine community-based vegetation changes along the Northwest Fork of the Loxahatchee River. A total of 23 sites were surveyed as shown in **Figure 16, Chapter 4.** Measured vegetation parameters included species composition, and abundance. These data were then correlated with distance (in terms of river miles) upstream from the Jupiter Inlet, the primary source of salinity to the river. An additional 10 sites were surveyed in Kitching Creek.

Results from the November 2000 survey identified at least 35 species of vascular plants from 16 floodplain sites in the Northwest Fork (**Table 27**). These data indicate that the total number of plant (vascular macrophytes) species decreases dramatically from upstream freshwater habitats to downstream saltwater-dominated areas **(Figure 24).** These data indicate that a) observed vegetation trends were consistent in both the 2000 and 2001 surveys; b) the number of species increased as a function of distance from the inlet; c) the trend was consistent in both the Northwest Fork and Kitching Creek, and d) the number of species was correlated with salinity.

Table 27. Plant species observed in the Freshwater Segment of the Northwest Fork floodplain during quantitative and semiquantitative sampling periods, November, 2000 and January 2001

Scientific Name	Common Name	Scientific Name	Common Name
Acer rubrum	Red maple	*Osmunda regalis*	Royal fern
Annona glabra	Pond apple	*Persea borbonia*	Red bay
Aster caroliniana	Carolina aster	*Phlebodium aureum*	Golden polypody
Baccaris sp.	Saltbush	*Pleopeltis polypodioides*	Resurrection fern
Blechnum serrulatum	Swamp fern	Polygonum sp.	Swamp smartweed
Boehmeria cylindrica	False nettle	*Pontederia cordata*	Pickerelweed
Carya aquatica	Water hickory	*Quercus laurifolia*	Laurel oak
Crinum americanum	String lily	*Sabal palmetto*	Cabbage palm
Ficus aurea	Golden fig	*Salix caroliniana*	Swamp willow
Fraxinus caroliniana	Pop ash	Smilax sp.	Greenbriar
Hydrocotyl sp.	Water pennywort	*Taxodium distichum*	Baldcypress
Hyptis sp.		*Tillandsia balbisiana*	Air plant
Ilex cassine	Dahoon	*Tillandsia fasciculata*	Stiff-leafed wild pine
Ipomoea alba	Moon flower	*Tillandsia recurvata*	Ball moss
Itea virginica	Virginia willow	*Tillandsia setaceae*	Air plant
Ludwigia repens	Creeping primrose willow	*Tillandsia usneoides*	Spanish moss
Mikania scandens	Climbing hempvine	*Toxicodendron radicans*	Poison ivy
Nephrolepis sp.	Wild Boston fern	*Vitits munsoniana*	Wild grape

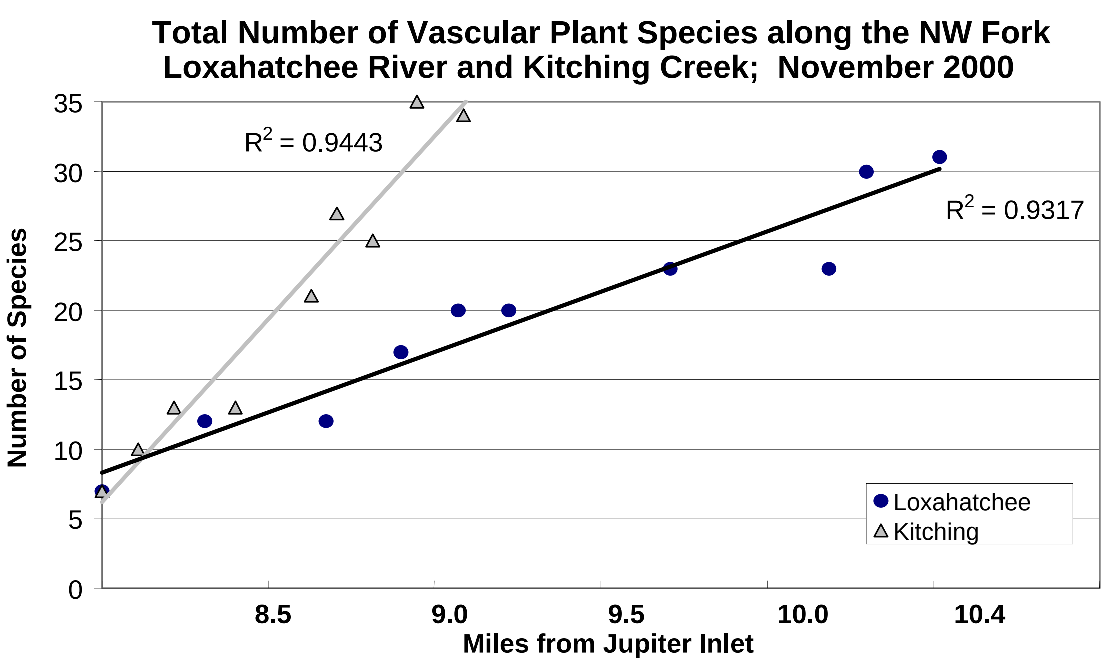


Figure 24. Number of Observed Vascular Plant Species versus river mile, Northwest Fork of the Loxahatchee River and Kitching Creek (November 2000).

Results of the semi-quantitative survey also showed that bald cypress and cabbage palm, as single species, appear to tolerate a wider range of salinity conditions within the river corridor than a number of other common floodplain swamp species. **Table 28** shows the distribution and abundance of common tree species that characterize the river's floodplain swamp forest. This relationship can be described by a linear equation ($R^2 = 0.93$) with upper and lower limits near 35 and 5 species (**Figure 24**). A similar trend was observed along Kitching Creek for data collected during the same period. These results suggest that the distribution of freshwater vegetation along the river is strongly correlated with the existing salinity gradient.

Table 28. Abundance Index*: Results of a semiquantitative vegetation survey at river vegetation sampling locations, Northwest Fork, Loxahatchee River (November 2000/December 2001).

Station Name	7A	7B	7C	V7	8A	8B	V6	8C	V5	8D	9A	9B	V4	9C	V3	10A	10B	V2	10C	V1
River mile	7.3	7.5	7.8	7.95	8.1	8.4	8.55	8.7	8.8	8.9	9.1	9.2	9.3	9.7	9.9	10.1	10.2	10.3	10.4	10.6
bald cypress	0	0	1	1	1	2	1	2	2	3.5	3	3	2	4	4	4	4	4	4	4
cabbage palm	2.5	3	3.5	2	4	3	2	3.5	3.5	3.5	4	3	3	3	3	3	3	2.5	2	3
red mangrove	4	4	4	4	4	4	4	4	4	4	4	4	3	2.5	2	0	0	1	0	0
pond apple	0	0	0	1	0	0	0	3	2	3	3	3	1	3	3.5	3.5	3	3	3.5	3.5
dahoon holly	0	0	0	0	0	0	0	0	0	1	1	1	1	1	2	2	2	3.5	3	2
pop ash	0	0	0	0	0	0	0	0	0	0	0	1	0	2	2	2	2	2	2	2.5
red maple	0	0	0	0	0	0	0	0	0	1	1	1	0	2	1	3	3	3	3.5	3.5
Virginia willow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	2.5	2	3.5
red bay	0	0	0	0	0	0	0	0	0	0	0	0	1.5	0	0	0	1.5	1	0	1.5

* Abundance Index
4 = Highly abundant or dense population (>75% cover), a dominant component of the plant community
3 = Common; widespread and of moderate density but not a dominant component of the plant community
2 = Sparse; widespread and of low density or restricted to localized populations
1 = Two or less individuals; rare
0 = Species not present

A second semi-quantitative survey was repeated in December 2001 at seven additional sites. These results showed a similar trend as reported for the previous survey, with a R^2 of 0.97 reported (**Figure 25**), but exhibited higher total number of species.

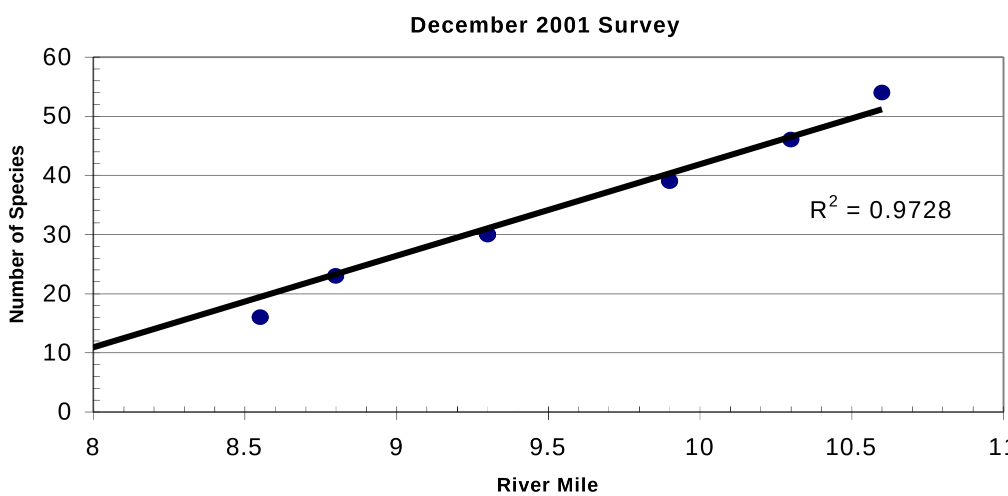


Figure 25. Relationship between total number of vascular plant species and location (river mile) along the Northwest Fork of the Loxahatchee River (December 2001 survey).

Differences in the total number of species observed could be accounted for by differences in rainfall patterns and the number of herbaceous species recorded between the two surveys. Although more species were reported than during the 2000 survey, as perhaps would be expected after a major drought period, the significant positive trend shows that total number of floodplain vascular plant species increases with distance from the inlet and decreases at those stations (with observed higher salinity values) located nearer to the inlet. This relationship provides further evidence that salinity plays an important role in regulating plant community species composition and distribution along the Northwest Fork of the Loxahatchee River. As shown in **Table 28,** the distribution and abundance of red maple, dahoon holly, pop ash, pond apple, red bay, and Virginia willow all appear to be impacted within a very short segment of the river as compared to bald cypress or cabbage palm. As a group, these six freshwater species were limited in their distribution along the river suggesting that they may be more sensitive to long-term changes in salinity as compared to bald cypress, cabbage palm or red mangrove communities.

Table 29 provides a list of these six key species and their generalized salinity tolerances obtained from a review of the literature. The river survey data also indicates that bald cypress, used as a single indicator species, is not the most sensitive indicator of salinity stress within the Northwest Fork of the Loxahatchee River. Based on these relationships, District staff chose the following six species (red maple, pop ash, red bay, Virginia willow, dahoon holly, and pond apple) as indicator species for the selected "valued ecosystem component" (VEC) for the Northwest Fork (see later section of this report entitled, *Proposed VEC for the Northwest Fork of the Loxahatchee River*). In order for a species to maintain itself at a particular location, not only must the plants (trees) survive, but they must also be able to replace themselves over time by successful reproduction. These plants must thus be able to produce viable seeds, the seeds must germinate, and seedlings and saplings must survive to an adult seed-producing stage. These various life stages may have different salinity tolerances.

Table 29. Key species identified along the Northwest Fork and their salinity tolerances.

Species	Saltwater Tolerance
Selected "KEY" Species	
Red maple *(Acer rubrum)*	Freshwater[a]
Pop ash (*Fraxinus caroliniana*)	Freshwater[a]
Virginia willow (*Itea virginica*)	Freshwater[a]
Dahoon holly (*Ilex cassine*)	Freshwater[a]
Red Bay (*Persea borbonia*)	Freshwater[a]
Pond apple (*Annona glabra*)	Freshwater[a]
Other Dominant River Vegetation Species	
Bald cypress (*Taxodium distichum*)	Freshwater to slight salt tolerance[c]
Cabbage palm (*Sabal palmetto*)	Freshwater to slight salt tolerance[b]
Red mangrove (*Rhizophora mangle*)	Salt tolerant[a]

[a] see Tobe, et al. 1998. Tobe, et al. 1998 is a primarily a plant identification manual and gives generalized habitat descriptions rather than specific salinity tolerance of the species listed in the table

[b] Cabbage palm is generally associated with freshwater and coastal swamps

[c] see Allen 1994; Allen et al. 1994, 1997; Conner 1992; Javanshir & Ewel 1993, Pezeshki et al. 1986, 1987, 1990, 1995.

Quantitative Survey

In January 2002, a quantitative vegetation survey was conducted along the Northwest Fork. In this survey District staff selected 9 of the original 23 vegetation sampling sites recording both plant community-based and species-based information. **Figure 16 (Chapter 4)** shows the location of the nine quantitative vegetation-sampling sites that were resurveyed in January 2002.

Eight of these sites (sites V7, 8B, 8D, 9A, 9B, 9C, 10B and V1) were used to compare findings against previously collected semi-quantitative data. Three sites (V1, V3, and V7) were used as model verification sites (**Figure 16, Chapter 4**). The following community-based and species based parameters were measured at each site:

- Presence or absence of selected VEC species
- Number of individuals of VEC species
- Age class of VEC species (mature tree, sapling, seedling, and stump spouts)
- Tree height of VEC species
- Trunk circumference at breast height of VEC species
- Canopy diameter of VEC species

Details regarding sampling methods for the vegetation surveys and field data from vegetation surveys are presented in **Appendix C** of this report.

Number of Adults

Table 30 provides a summary of the total number of adult and saplings tree VEC indicator species recorded at each quantitative vegetation survey site.

Table 30. Number of adults and saplings of selected tree species recorded during the January 2002 quantitative vegetation survey, at eight locations along Northwest Fork.

	Station Name	**V1**	**10B**	**9C**	**9B**	**9A**	**8C**	**8B**	**V7**
	River mile	**10.6**	**10.2**	**9.7**	**9.2**	**9.1**	**8.7**	**8.4**	**7.95**
VEC Indicator Species	**popash**	39	40	35	2	1	0	0	0
	red bay	4	7	6	0	0	0	0	0
	dahoon holly	1	20	5	2	0	0	0	0
	Virginia willow	123	47	35	0	1	0	0	0
	red maple	22	16	10	0	0	0	0	0
	pond apple	17	52	42	13	24	0	0	0
Other Species	**bald cypress**	22	58	33	4	4	4	3	0
	cabbage palm	19	31	43	33	13	11	47	46
	red mangrove	0	1	18	200*	200*	180	200*	200*

* Due to the large number of red mangrove trees present at sites V7 – 9B, values were estimated

Results show that downstream of river mile 9.1 most of the six VEC indicator species were not present in the floodplain swamp. At river mile 9.2 only three VEC indicator species are present; while upstream all six VEC indicator species are present.

Tree Height and Trunk Diameter

Measurement of physical features such as trunk diameter (DBH) and tree height showed a similar trend to that indicated by the numbers of adults and saplings. As one moves downstream from river miles 10.6 to 9.1 there is a trend of both reduced tree height and trunk diameter suggesting these communities have been physiologically stressed due to periodic exposure to increased salinity levels in areas nearer to the Jupiter inlet (**Table 31**).

Table 31. Mean trunk diameter (DBH) and mean tree height of adults at eight river vegetation sampling locations, Northwest Fork of the Loxahatchee River (January 2002)

Station Name	**V1**	**10B**	**9C**	**9B**	**9A**	**8C**	**8B**	**V7**
River mile	**10.6**	**10.2**	**9.7**	**9.2**	**9.1**	**8.7**	**8.4**	**7.95**
Mean Trunk Diameter/Tree Height (in feet)								
VEC Indicator Species								
pond apple	1.8/24	1.0/20	0.4/15	0.3/14	0.5/9	0/0	0/0	0/0
dahoon holly	0.6/28	0.3/17	0.1/12	0.2/13	0/0	0/0	0/0	0/0
pop ash	0.9/19	0.5/19	0.2/13	0.3/14	0.3/11	0/0	0/0	0/0
red maple	1.4/29	0.7/22	0.4/24	0/0	0/0	0/0	0/0	0/0
red bay	0.1/18	0.2/20	0.1/8	0/0	0/0	0/0	0/0	0/0
Other Species								
bald cypress	3.2/43	0.7/23	0.9/32	NA/27	0.3/14	1.0/17	NA/25	0/0
cabbage palm	NA/25	NA/30	NA/24	NA/19	NA/14	NA/11	NA/19	NA/15
red mangrove	0/0	NA/12	NA/9	NA/14	NA/9	NA/9	NA/8	NA/8

NA = data not available; Calculations based on measurement of adult species;
Note: Virginia willow is a shrub and therefore was not measured using the above methods.

Number of Saplings and Seedlings Present

Observations of the number of saplings or seedlings present at each site were important for determining if the community is reproducing and sustainable (**Table 32**). Adults were identified as individuals at canopy height while saplings were less than canopy height, but greater than breast height, and seedlings were those individuals less than breast height. The presence or absence of saplings or seedlings was also considered a more sensitive indicator of the degree that saltwater may impact the community over time. That is, under low salinities it may be possible to sustain adult trees, however seedlings or very young tress may not be able to survive.

Results of the vegetation survey show that very few saplings or seedlings of VEC indicator species are present downstream of river mile 9.2, suggesting that this community can no longer reproduce, is not sustainable, and thus has experienced significant harm (**Table 32**). At river mile 9.7, the number of VEC indicator species saplings and seedlings appear to be reduced in comparison to upstream areas, indicating that this section of the river is currently stressed by periodic exposure to low salinity levels.

Canopy Cover

A primary aspect of forest structure that plays an important role in the ecology of the floodplain swamp is the canopy. Bald cypress' tendency to dominate wetland forests is largely due to their ability to form a high closed canopy, which is particularly evident during the growing season. Within the Wild and Scenic portion of the Loxahatchee River the floodplain swamp

Table 32. Number of saplings and seedlings present at eight river vegetation sampling locations, Northwest Fork of the Loxahatchee River (January 2002).

Station name	**V1**	**10B**	**9C**	**9B**	**9A**	**8C**	**8B**	**V7**
River mile	**10.6**	**10.2**	**9.7**	**9.2**	**9.1**	**8.7**	**8.4**	**7.95**
Number of Seedlings/Saplings Present								
VEC Indicator Species								
pond apple	0/1	0/10	1/3	0/0	1/0	0/0	0/0	0/0
dahoon holly	0/0	7/0	1/0	0/0	0/0	0/0	0/0	0/0
pop ash	6/13	5/3	3/0	0/0	1/0	0/0	0/0	0/0
red maple	1/44	5/38	0/0	0/0	0/0	0/0	0/0	0/0
virginia willow	63/NA	20/NA	9/NA	0/NA	1/NA	0/NA	0/NA	0/NA
Red bay	1/1	3/11	4/0	0/0	0/0	0/0	0/0	0/0
Other Species								
bald cypress	1/0	24/7	5/0	0/0	4/0	0/0	0/0	0/0
cabbage palm	0/0	1/0	0/0	0/0	0/0	0/0	0/0	0/0
red mangrove	0/0	0/0	2/27	NA	NA	NA	NA	NA

NA = data not available, transect inaccessible.

canopy supports a large array of air plants, bromeliads, and orchids, many of which are federally threatened or endangered species (FDEP and SFWMD 2000). The canopy plays a critical role in the life cycles of many birds, reptiles, and insects. The canopy also regulates the microclimate of the forest, controlling humidity, light quality, rainfall distribution and other physical parameters that can have profound influences on plant growth.

In this study, tree canopy areas within various tree height classes were calculated from tree canopy diameter measurements (see **Appendix C** for methods). **Figure 26** shows striking changes in canopy cover area for the six selected VEC indicator species associated with distance (river mile) upstream from the Jupiter Inlet. Major changes in canopy cover were measured between river miles 9.7 and 9.2 indicating a change in the floodplain swamp forest structure between these two sites. Upstream (at river miles 10.2 and 10.6), the floodplain forest appears as a complex structure with a high canopy dominated by bald cypress (between 35–60 ft. in height) and a secondary canopy dominated by mixed hardwoods, bald cypress, and pond apple (between 15-30 ft. in height) (**Figure 26**). Some shrubby species are found below the secondary canopy, at less than 10 ft in height. A short distance downstream at river mile 9.7, the structure of floodplain forest shows a decrease in the area of the high canopy strata. At river mile 9.2 the high canopy has been virtually eliminated and has been replaced by a low canopy dominated by red mangroves approximately 15 ft above the ground surface. These changes in forest structure can have profound effects on microclimate, ecological function, and species composition (both flora and fauna) of the floodplain swamp forest.

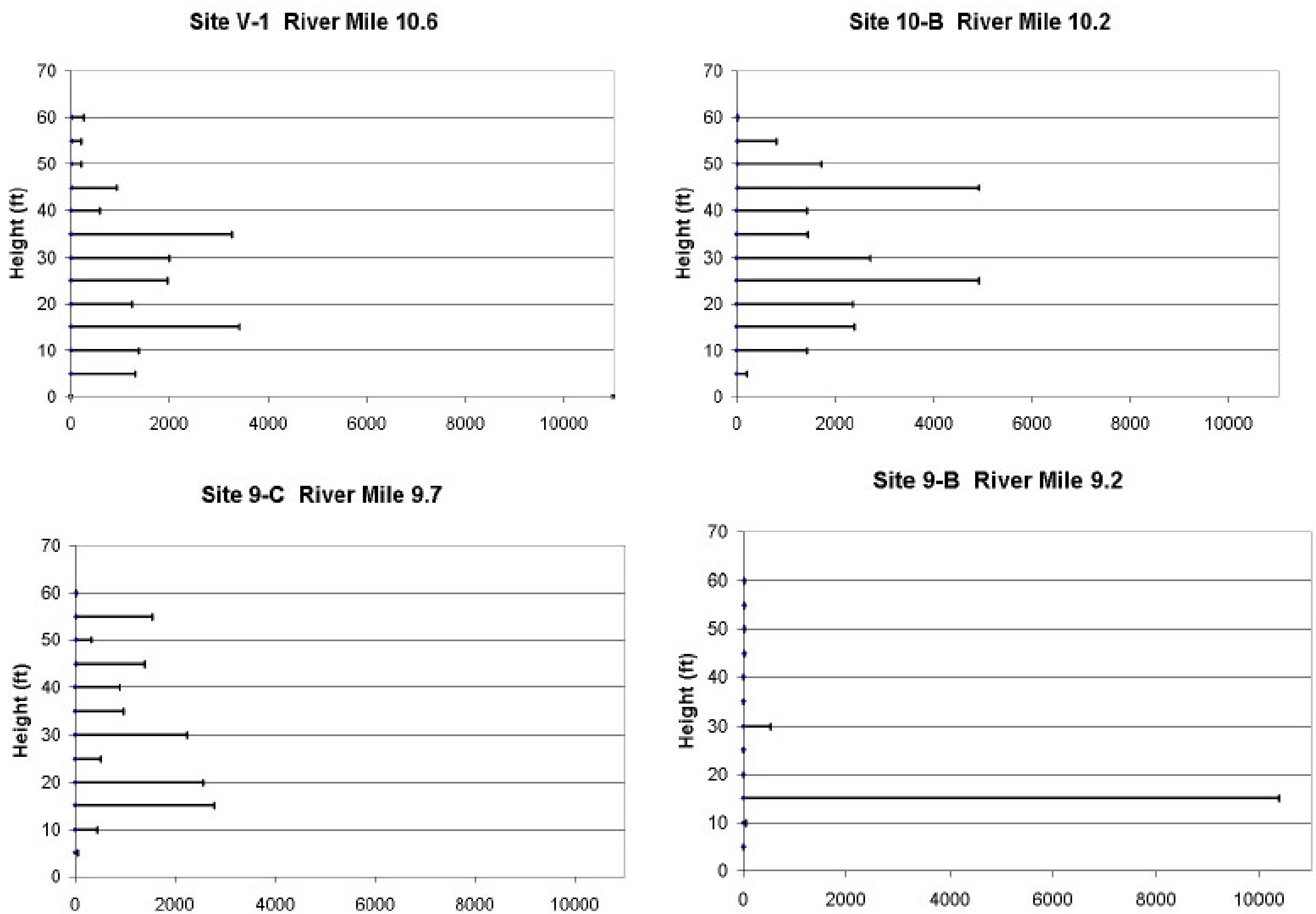


Figure 26. Total Forest Canopy Area Within Height Classes for four sites along the Northwest Fork of the Loxahatchee River.

Vegetation Changes along the Northwest Fork Since 1985

A baseline or reference point must be identified as a basis to establish an MFL. The SFWMD staff selected the condition of the river at the time that Northwest Fork was designated as a "Wild and Scenic River," in 1985. This point was chosen because the river management Plan (SFWMD, 2002) recognized the values of the river at that time and identified the need to protect and enhance these resources. In addition, several types of information are available to provide a description of the condition of the resource at that time.

A review of reports and documentation of vegetation communities along the Northwest Fork was conducted in order to determine the extent of vegetation communities when the River was federally designated as "Wild & Scenic". This information is also useful to determine if the vegetation is still changing when compared with the current (2002) vegetation surveys (see **Figure B-9, Figure B-10** in **Appendix B** and **Table 1** in **Chapter 2**). Reports that were reviewed include the Final Wild and Scenic River Study Environmental Impact Statement (EIS)(United States Department of the Interior/National Park Service, 1984) and the Loxahatchee River National Wild and Scenic River Management Plan (FDEP & SFWMD, 2000).

The EIS provides a map of river vegetation (**Figure 27-A**) and generally describes the vegetation of the river from its source upstream of Indiantown Rd. to the mouth of the Jupiter Inlet. Vegetation was described as a canopied cypress river-swamp community from Indiantown Rd. to the Trapper Nelson Interpretive Site. Downstream of Trapper Nelson's the vegetation changed and was described as mangrove-dominated swamp with dead cypress trees at river mile 9.2. At river mile 10.1, the first mangroves are found and most cypress trees appeared to be stressed. Current vegetation studies indicate that the area of stressed freshwater swamp hardwoods and cypress begins further downstream, near river mile 9.7.

It is not known why there is a discrepancy between the location of the "stressed" area at river mile 10.1 during 1984 and at river mile 9.7 during 2002, however a couple of explanations are plausible. It may be possible that observations were made at different times of the year or different criteria were used to identify "stress." Other explanations may include differences in vegetation sampling methodology, that increased rainfall and flows to the Northwest Fork during the 1990's have led to some recovery of the swamp forest in the area around river mile 10.1 or that measurements of river mile locations differed significantly.

The River Management Plan (FDEP & SFWMD, 2000) also provides a description and map of vegetation along the NW Fork (**Figure 27-B**), based on a survey conducted by the Florida Park Service in 1993 (FDNR 1994). This document indicates that the cypress community "solidly flanks the river and its tributaries upstream from about river mile 9.5 [SFWMD river mile 10.1], and is the dominant species to above river mile 9 [SFWMD river mile 9.2]. The mangrove community solidly lines the river downstream from river mile 9 [SFWMD river mile 9.2]. . . dead cypress trees tower above the red mangroves for one or two miles downstream from this point, evidence of the extent of freshwater vegetation that existed before changes in the upstream movement of salt water."

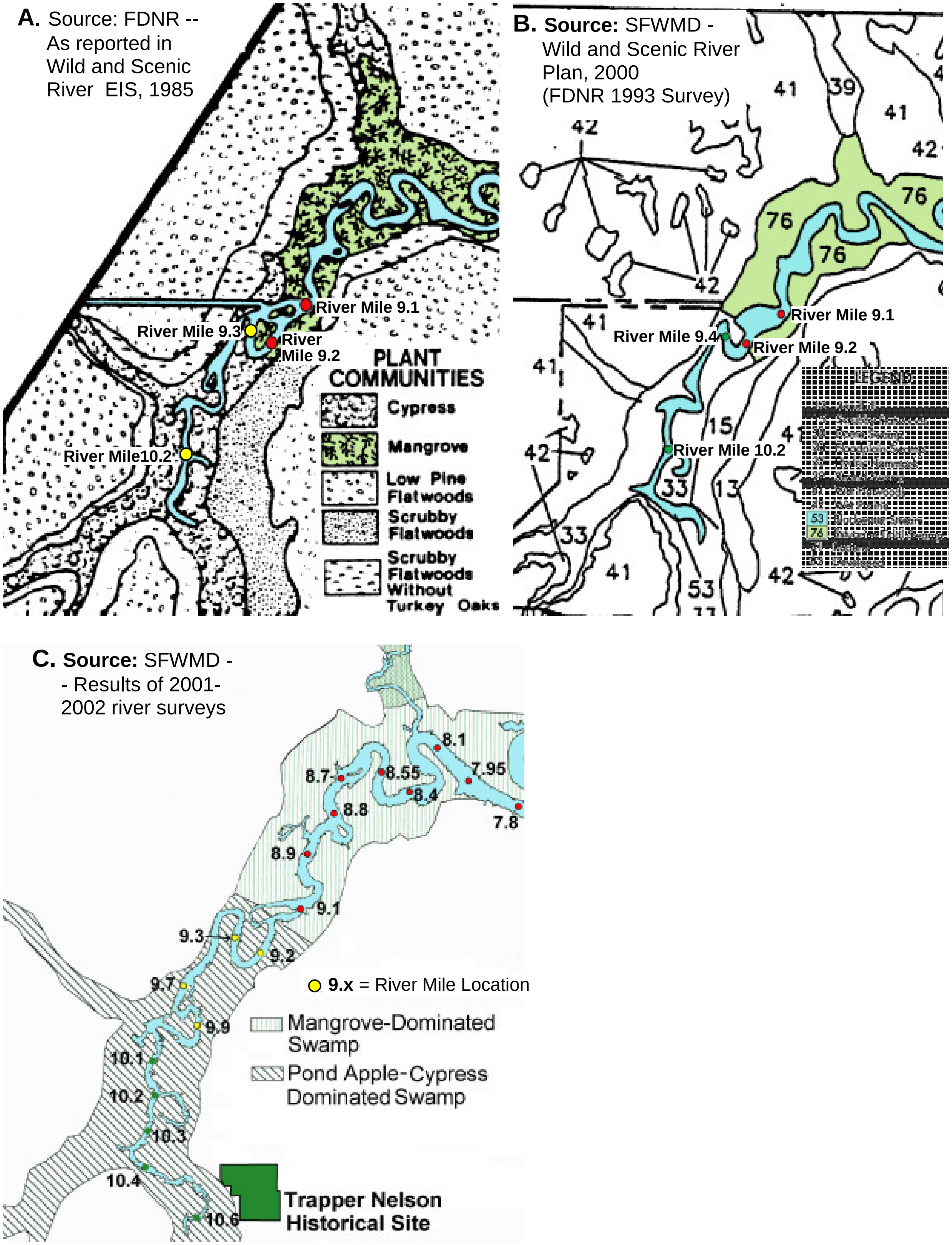


Figure 27. Maps showing results of vegetation surveys along the Northwest Fork, 1985-2000. River mile locations determined by SFWMD during 2000 surveys.

This observation is in line with vegetation data collected along the Northwest Fork in studies from 2000-2002 (**Table 32** and **Figure 27-C**), which indicates that the vegetation zones classified by SFWMD as “pond apple-cypress dominated”, and “mangrove-dominated” closely correspond to the same locations that were identified as “floodplain swamp” and “estuarine tidal swamp in the 1993 surveys and as “cypress” and “mangrove” in the 1985 survey, respectively. Based on this comparison of vegetation community descriptions from 1985 and 2002, it can be inferred that there has been little change in the distribution of freshwater and salt-tolerant vegetation in this section of the river since the mid-1980’s.

However, it is quite possible that there has been a visibly slight, but continuing, decline in the extent of the freshwater community, especially since there is no information on the *health* of the VEC species or the impacts to seedling germination and survival. The information presented primarily supports the conclusion that changes in the extent of cypress and other major tree species seems to have stabilized. As was noted earlier in the report, canopy species may take longer to respond to stress than the rest of the floodplain community, so that substantial changes may have occurred in the herbaceous species, seedlings and saplings during this period.

Other Factors Considered that May Affect Vegetation Distribution

The vegetation survey data collected along the Northwest Fork of the Loxahatchee River documents that a gradient of change occurs, from a freshwater-dominated floodplain swamp to a saltwater-tolerant red mangrove community. These observed changes appear to be highly correlated with distance from the Jupiter inlet and the salinity gradient that exists along the Northwest Fork. We also considered other factors that may explain the current distribution of river vegetation species found along the Northwest Fork. These include possible changes in fire frequency, excessive flooding, and the effects of drought. A review of the literature relative to bald cypress and aerial photography/GIS studies of long-term vegetation changes in the basin as presented in this report indicates that none of these factors can account for the overall pattern of vegetation change observed during the past half-century.

Fire frequency in the river floodplain is generally low, primarily because the soils are saturated most of the year, which retards the spread of fire. Furthermore, dry fuel in the floodplain swamp is sparse, and rapid decomposition rates and frequent flood events tend to clear away fuel. Bald cypress and mixed hardwood forests thrive in both fire free habitats and in occasionally burned areas (see Gunderson 1984, Ewel 1990a). Bald cypress have been found to recolonize after fire, if a local seed source is available (Gunderson 1984).

Excessive or prolonged flooding of the floodplain along the Northwest Fork is unlikely, especially since historic water tables have been reduced and hydroperiods shortened over the past century (see Aerial Photography/GIS studies, **Appendix B**). In spite of this, flooding may be more frequent along downstream segments where tidal action is a dominant hydrological force. However, bald cypress have been found to grow naturally in flooded swamps and lakes 90-100 m from the shoreline, some in water 1-3 m or more deep and at time of floods, the depth may be greater for short intervals (Brown 1984, Lugo and Brown 1984). Conversely, bald cypress are successfully grown in moist soils as well as in much drier landscape situations where flooding never or rarely occurs. Drought would induce short-term restrictions on growth of bald cypress, but would not explain the pattern of loss we have observed along the River. If either of these factors (prolonged flood or drought) had a major influence on the loss of bald cypress and mixed hardwoods along the Northwest Fork, it would be expected to cause widespread loss across the floodplain, rather than only along a front that is closely associated with distance from the inlet.

Effects of Freshwater Inflows on the Loxahatchee Estuary

Major Features of the Estuary

Physical and biological features of the estuary are summarized on pages 26-39. The North Fork portion of the estuary is very small in extent and has very limited resources due to several factors. The lower reaches have been extensively bulkheaded and filled, effectively eliminating important shoreline habitat. In addition, large areas of the bottom consist of soft mud or ooze that is not conducive to supporting estuarine benthic communities. The upper reaches within Jonathon Dickinson State Park in this section of the North Fork Loxahatchee River have steep shorelines that do not support significant amounts of marsh or swamp shoreline vegetation.

The Southwest Fork is very small in size and has limited resources, due to extensive bulkheading and development of the shoreline and the relatively frequent, large-volume discharges of freshwater from S-46 that result in scouring of the substrate and rapid and extreme changes of the salinity regime.

None of the resources or issues in the North Fork or Southwest Fork of the estuary were considered to have a significant function that would be impacted by low flow conditions. In contrast, the resources of the Northwest Fork, Central Embayment and adjacent coastal waters are considered to be sensitive to high flow events. When discharges on the order of 2,000 to 3,000 cfs occur through the S-46 structure into the Southwest Fork, the entire estuary can become freshwater, which has significant adverse effects on marine life, especially seagrasses and benthic macroinvertebrates. These types of high discharge events also result in displacement and loss of habitat for fishes that prefer more saline conditions.

By contrast, the Northwest Fork of the estuary comprises the largest area of brackish water environment. The mud and sand substrates support a variety of benthic communities that are adapted to a changing salinity environment, high turbidity and low light levels in the water column. Significant numbers of oysters live on the bottom and attached to mangroves beginning about river mile 4.0 and extending upstream to approximately river mile 7 (see **Figure 2**). Due to the connection between persistent freshwater and marine environments, the Northwest Fork has the highest quality estuarine conditions within the system and the resources that most need to be protected from significant harm.

Effects of High Rates of Freshwater Discharge

Resources in the Loxahatchee Estuary are more at risk due to the effects of high rates of freshwater discharge than the effects of low flow. During periods of high discharge, on the order of 1,200 cfs may be discharged from the Northwest Fork and 2,000 to 3,000 or more cfs may be discharged from the Southwest Fork. Under such conditions, the entire estuary and adjacent waters are converted to fresh water in a relatively short period of time (hours or days). This has significant adverse effects on marine life in these areas, especially benthic organisms such as seagrasses and oysters, due to rapid and extreme salinity change, siltation and high turbidity, but also results in displacement of freshwater species (fishes, amphibians and reptiles) downstream into areas that will subsequently revert back to marine conditions. The effects of such discharge events may persist for months or years before full recovery can occur.

Effects of Low Rates of Freshwater Discharge

During periods of low flow, saltwater intrudes upstream within the Northwest Fork, as noted throughout this document. Salinity conditions in the estuary were monitored in 1981 during a low flow period, when flow from the Northwest Fork equaled 9 cfs (Russell and McPherson 1984). Data collected during this period indicated that salinities from the inlet through the central embayment were above 35 ppt. Salinities at the surface of the Northwest Fork of the estuary and along the bottom of the upper end of the Northwest Fork, extending up to river mile 4.1, exhibited salinities in the range from 30-35 ppt (see data from Russell and McPherson 1984, presented in **Appendix F**, **page F-6**). Further upstream, in the Northwest Fork near Kitching Creek, salinities were recorded within the range of 20-25 ppt (see **Appendix F**, page **F-7**).

Importance of Maintaining Low-Salinity Conditions

An important aspect of protecting the estuarine character of this system is to maintain an oligohaline (low salinity less than 5ppt) zone. Such low-salinity environments provide important habitat for a wide variety of plants and animals that utilize this resource (SFWMD 2002, Estevez 1999). Assessment of fisheries resources in the estuary, indicate that many such organisms are present in the Loxahatchee River system, including mullet, seatrout, snook, tarpon, blue crabs and shrimp. In other systems (such as the St. Lucie and Caloosahatchee estuaries) it has been demonstrated that a complete loss of oligohaline habitats during the winter and spring months (dry season) has a significant adverse effect on many organisms that utilize this zone during their early life history stages. In some cases, these impacts may last for two years or more, (SFWMD 2001, SFWMD 2002).

PROPOSED VEC FOR THE NORTHWEST FORK

Rationale for VEC Selection

The SFWMD Loxahatchee River research program supports application of a resource-based management strategy defined as the "Valued Ecosystem Component" (VEC) approach. This evaluation methodology is similar to a program developed as part of the National Estuary Program (USEPA 1987). For the purposes of this study, the VEC approach is based on the concept that management goals for the Northwest Fork of the Loxahatchee River can best be achieved by providing suitable environmental conditions that will support certain key species, or key groups of species, that inhabit the system. In some instances the VEC represents those species that are most sensitive to the environmental factor of interest. Protection of these species assumes protection of the entire community. A VEC can be defined as a species, community or set of environmental conditions and associated biological communities that are considered to be critical for maintaining the ecological sustainability of the Northwest Fork's floodplain swamp community.

Based on the results of a vegetation survey of the Northwest Fork of the river (presented previously in this chapter), District staff propose that the freshwater floodplain swamp is the VEC for the Northwest Fork of the Loxahatchee River. In order to monitor the "health" of this VEC, a group of six key woody vegetation species that characterize the upstream floodplain swamp forest were selected to represent the VEC for the purpose of establishing a MFL for the Northwest Fork of the Loxahatchee River. Impacts to the VEC indicator species beyond a critical level are considered to constitute significant harm to the floodplain swamp community. The VEC approach was applied to the Northwest Fork of the Loxahatchee River based on the following relationships:

Results of two river vegetation surveys showed that the bald cypress community is not a sensitive indicator of salinity stress within the Northwest Fork of the Loxahatchee River.

- These results showed that six "key" woody vegetation species (red maple, pop ash, red bay, Virginia willow, Dahoon holly, and pond apple), which are characteristic of the floodplain swamp, appear to be more responsive to long-term changes in river salinity than cypress, cabbage palm or red mangrove communities, and therefore qualify as a more sensitive indicator of the VEC for the Northwest Fork of the Loxahatchee River.
- These six species have physiological characteristics that play important functional roles in the forest ecology. These species are also more sensitive to salinity stress than bald cypress and can be useful in inferring the overall health of the freshwater floodplain swamp. These characteristics also make them useful indicators of long-term salinity conditions.
- Based on these relationships, District staff selected the six species listed in **Table 29** as VEC indicator species for the Northwest Fork of the Loxahatchee River.

Species Selected as Representative of the Proposed VEC

"Key" species as defined in this study refer to those selected from the results of the river survey and a corresponding literature review (**Table 29**) of vegetation salinity tolerances. Key species were selected based on their ability to measure responses within the "two-year or more" timeframe that is the basis for significant harm. The criteria for selection of these key species were as follows:

- Species that play important roles in freshwater swamp ecology by providing food, substrate or habitat for other species and thus are useful indicators of long-term ecosystem health.
- Species that are widely distributed within the floodplain corridor and in South Florida freshwater swamps (i.e. not found only in localized populations). This criterion is used to ensure that observed trends are most likely not due to natural variability that could account

for uneven distributions.

- Species that are significant components of the local riverine swamp community in terms of density and physical forest structure. This criterion was intended to exclude minor (rare) species and to select those that were primary constituents of forest structure, and whose overall abundance can be reliably measured by reasonable sample sizes.
- Terrestrial species that are rooted in the soil substrate (i.e. not floating or epiphytic). This excludes aquatics, which may reflect only short-term (transient) salinity conditions.
- Species that are relatively long lived (more than 10 years, i.e. generally woody or tree species), which are more reliable indicators of long-term conditions. Herbaceous species were excluded, as they typically have shorter life spans (less than 10 years).
- Species that occupy different ecological niches and have different functional roles in the freshwater swamp (i.e. canopy, sub-canopy, shrubby). A decline in one or more of these functional roles can have ecological consequences, such as impacts to wildlife.
- Species that are copious producers of differing seed types (e.g. berries, samaras, etc.) that are readily spread (e.g. air-borne, water-borne, bird-dispersed) throughout the area. This helps to ensure that an observed decline in seedling or sapling numbers is not related to localized seed production or species-specific dispersal characteristics.
- Species that represent a range of saltwater tolerance and sensitivities (i.e. obligate freshwater species, saltwater tolerant species, and transitional species). This characteristic will help to document the range of salinities and changes along the Northwest Fork.

Information gathered from the vegetation survey indicated that a group of nine species would fit the criteria described above. These species are listed in **Table 29** along with their relative salinity tolerances obtained from a review of the available literature.

As the District and other agencies proceed with restoration efforts for the Loxahatchee River other key indicator species and criteria will need to be developed. Thus, the canopy species could be included as indicator of the very long-term conditions associated with recovery of damaged floodplain community structure and herbaceous species could be included as indicators of the effectiveness of short-term hydrologic changes. All strata should eventually be analyzed during vegetation surveys to give a more complete picture of health of the river's plant communities. More detailed studies will be needed that include a larger assortment of species. Additionally, as the District refines the restoration efforts and MFL analysis to include other segments of the ecosystem, indicators for invertebrate and vertebrate populations may also need to be identified

Summary

- Overall, the vegetation survey data collected along the Northwest Fork of the Loxahatchee River shows that a gradient of change exists, from a freshwater-dominated floodplain swamp to a saltwater-tolerant red mangrove swamp.
- Results of quantitative and semi-quantitative surveys showed declines in number of VEC

indicator species, number of individuals, canopy area, tree height, tree trunk diameter, and the number of seedlings and saplings present at river vegetation sampling sites located closer to the Jupiter inlet, which is the source of salinity for the Northwest Fork.

- Quantitative survey results also showed that locations at and above river mile 10.2 have a full canopy cover and contain reproducing populations of cypress and all six VEC indicator species that are characteristic of the floodplain swamp community. From these data, District staff concluded that this area of the river currently represents an unharmed, healthy, sustainable floodplain swamp community.
- Results of semi-quantitative survey indicate that a healthy floodplain swamp community probably continues to exist downstream to river mile 9.8
- At river mile 9.7, although all six VEC indicator species were present, there were observed reductions in canopy cover, a decline in the mean height and trunk diameter of VEC tree species, and a reduction in the number of seedlings and saplings present. These results suggest that several functional characteristics of the floodplain swamp at this location in the river have been, or currently are, stressed by periodic exposure to low salinity levels.
- The most significant result of this study shows that downstream of river mile 9.1 all six VEC indicator species were eliminated from the floodplain and replaced by saltwater-tolerant mangroves. A short distance upstream at river mile 9.2, no VEC saplings or seedlings were present and only three out of the six VEC species remained as part of the floodplain swamp forest. In addition, the high canopy has been virtually eliminated and replaced by a low canopy dominated by red mangroves at river mile 9.2.
- These observed changes in species composition, forest structure, and reproduction capabilities strongly indicate that a major change has occurred to the floodplain swamp forest community that can affect the microclimate, ecological function, and species composition of both flora and fauna within the Northwest Fork. For these reasons, river mile 9.2 was selected as the baseline location in the river where significant harm occurs.

APPLICATION OF MODELING TOOLS

Analysis of the Simulated Long-term Salinity Record

Since long-term salinity records do not exist for each vegetation sampling site it was necessary to develop a method for estimating or "hindcasting" a 30-year salinity time series for the river. This was accomplished through the use of a hydrodynamic model developed for the Loxahatchee River and estuary. Development, application and calibration of the hydrodynamic/salinity model is provided in **Chapter 4 – Methods** and in **Appendix E** of this document. Results of the simulated 30-year time series, for each vegetation monitoring site, are shown in **Appendix H**. Sample outputs of these data are shown in **Figure 28** for stations at river miles 10.2 and 9.2 respectively. From these time series basic statistical measures (mean, standard deviation, median, mode, 90th percentile distribution limits, and maximum daily salinity concentrations) were determined for each vegetation sampling site.

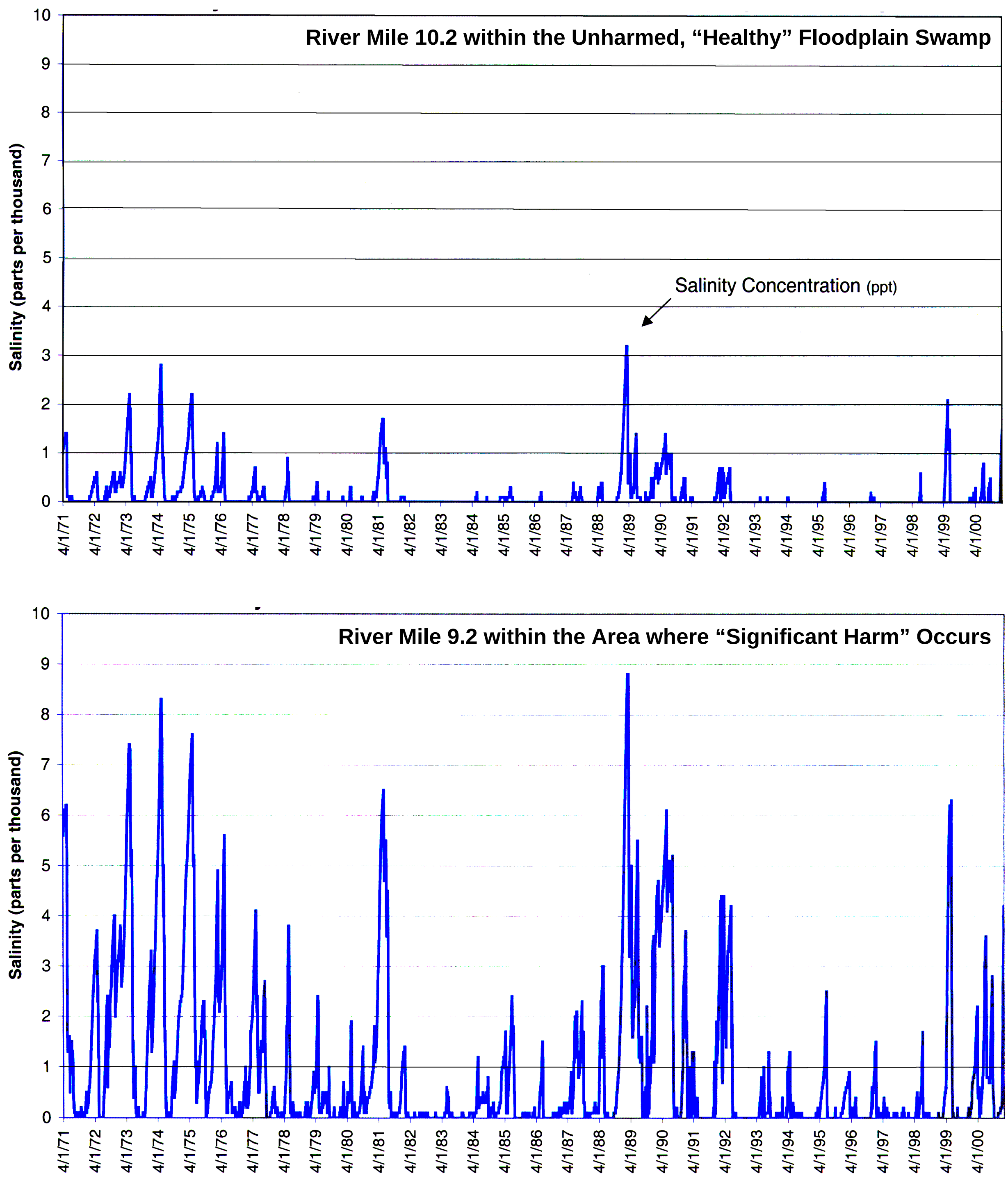


Figure 28. Simulated salinity time series generated from the hydrodynamic/salinity model developed for the Loxahatchee River showing the salinity regime (expressed as estimated mean daily salinity) at river miles 10.2 and 9.2, Northwest Fork of the Loxahatchee River.

The simulated salinity data were also analyzed in terms that are more relevant to the biology of the floodplain swamp community, i.e., the degree of exposure to low salinity conditions in terms of magnitude, event duration and time between events. It was assumed that some "threshold" level of salinity concentration, duration and return frequency exists that, when exceeded, causes an impact to a plant community. For example, along upstream segments of the Northwest Fork, a salinity event may occur at or above a specific threshold level for a number of days at a particular site. This event is followed by a period of time where freshwater conditions return and recovery from the salinity event occurs. To capture this salinity event-recovery cycle and the net effect it may have on the freshwater plant community, the long-term salinity data were examined in terms of salinity event duration (*Ds*) and elapsed time between events (*Db*) for a particular threshold.

Exposure to Different Salinity Concentrations at Particular Locations

Summary statistics were calculated for selected stations between river mile 7.8 and river mile 10.2, based on the output from the long-term modeling run (**Table 33**). The salinity average, standard deviation, upper maximum salinity and upper 90% confidence limit were determined for each station for the 30-year simulation period. The 90th percentile limit shows the level of salinity exposure that might be expected to occur during extreme events. For example, within the unharmed, healthy floodplain swamp community (river mile 10.2), salinities ranged from 0-3 ppt with a mean of 0.15. The upper 90th percentile of the salinity distribution at mile 10.2 was 0.65 ppt (i.e. 90% of the time, the average daily salinities at this location are below 0.65 ppt). At the stressed station (river mile 9.7), salinities ranged from 0-6 ppt with a mean of 0.5 and an upper 90 percentile limit of 1.7 ppt. At the significantly harmed station (river mile 9.2), salinity ranged from 0-9 ppt with a mean of 0.97 and 90% limit of 2.9 ppt.

Table 33. Summary statistics of estimated mean daily salinity concentrations for the 30-Year simulation period (1971-2001) for seven river vegetation sampling sites.

Site Name	River Mile	Salinity (ppt)			
		Mean	Standard Dev. (SD)	Upper 90% limit (Mean +1.28?SD)	Maximum Predicted
7-C (WQ Sta. #64)	7.8	6.2	5.2	13	21
8-B	8.4	3.7	4.1	8.9	18
WQ Sta. #65	8.6	2.8	3.4	7.1	16
8-D	8.9	1.8	2.6	5.2	14
9-B	9.2	1.0	1.6	2.9	9
9-C	9.7	0.48	0.94	1.7	6
10-B	10.2	0.15	0.39	0.65	3

Duration and Frequency of Exposure

Calculations of average salinity concentrations and ranges provided an estimate of the degree of exposure that vegetation communities may have experienced over time. These values, however, do not give an adequate indication of the amount of stress that occurs to a biological community. To provide a better description of exposure, the duration of a particular event and the amount of time that elapsed between events (recovery period) were determined. Although the duration of exposure and the amount of time needed for recovery to occur are unknown for these species, general criteria, for application at the community level, were inferred from available data. **Table 34** shows the mean duration of salinity events (*Ds*) and the mean time between salinity events (*Db*) at or above the selected threshold values for the modeled period.

Table 34. Salinity Event Duration (days) and Time Between Events (days), based on Simulated Salinity "Threshold" Levels, at Seven Sites along the Northwest Fork of the Loxahatchee River.

Site	River Mile	Mean Duration (*Ds*) and Elapsed Time Between (*Db*) Salinity Events									
		Salinity c 1ppt		Salinity c 2ppt		Salinity c 3ppt		Salinity c 4ppt		Salinity c 5ppt	
		Ds	*Db*	*Ds*	*Db*	*Ds*	*Db*	*Ds*	*Db*	*Ds*	*Db*
7C (WQ #64)	7.8	157	14	76	20	50	26	44	33	44	43
8B	8.4	83	23	49	39	52	62	48	77	45	94
WQ #65	8.6	67	30	68	70	58	85	56	111	40	124
8D	8.9	54	52	47	90	46	130	37	144	35	191
9B	9.2	55	143	46	207	45	344	41	504	29	612
9C	9.7	38	189	40	455	34	874	20	1800	22	5422
10B	10.2	31	576	22	2157	13	10899	0	10912	0	10912

For this analysis, the mean daily salinity level, as predicted by the model, was treated as a threshold rather than an average. For example, salinity at river mile 9.2 was plotted as a function of time, as shown in **Figure 28**. The number and duration of events when mean daily salinity equaled or exceeded 2.0 ppt and the elapsed time from one event to the next were determined. Salinity-exposure events increase in magnitude, occur more frequently, and last longer as one moves downstream. At the unharmed station 10B (river mile 10.2), salinity intrusion events with daily mean salinity above 1 ppt concentration and about 30 days duration, were estimated to occur once every 576 days (1.6 years). Daily mean salinities above 2 ppt occur for 22 days every 2157 days (5.9 years). Salinities as high as 3 ppt occurred once in the period of record (10,899 days or about 30 years). At the stressed station (river mile 9.7), daily mean salinities exceeded 1 ppt for approximately five weeks, twice per year; salinities above 2 ppt occurred for 40-days, less than once a year; and salinities exceeded 3 ppt for approximately one month every 2.4 years. At station 9B (river mile 9.2), where significant harm has been observed, salinities exceed 1 ppt approximately four months per year. Salinities above 2 ppt occurred for 46-day periods, about twice a year. Salinities exceeded 3 ppt for approximately 45 days every year (**Table 34**).

Effects of Flow from Lainhart Dam on Salinity Conditions in the River

Based on results from the hydrodynamic/salinity model a relationship between flow and salinity was established for each of the seven vegetation sampling sites located along the Northwest Fork. **Table 35** provides output from the model showing the amount of river flow at Lainhart Dam that is required to maintain mean daily salinity values at different points along the river. Details of the methods and graphical results of these analyses are provided in **Appendix H.** For example at river mile 9.2, a flow of approximately 35 cfs from the Lainhart Dam is sufficient to maintain an mean daily salinity of 1.9 ppt, whereas downstream at river mile 8.4, the amount of flow required to maintain the same average salinity is about 65 cfs (**Table 35**).

Table 35. Flow required from Lainhart Dam to maintain mean daily salinity levels at selected river miles.

Flow (cfs)	Mean Tide Salinity levels (ppt)							
	RM 10.2	**RM 9.7**	**RM 9.4**	**RM 9.2**	**RM 8.9**	**RM 8.6**	**RM 8.4**	**RM 7.7**
200	0.10*	0.10	0.10	0.10	0.11	0.12	0.13	0.21
150	0.10	0.10	0.11	0.11	0.12	0.15	0.19	0.39
100	0.10	0.11	0.12	0.14	0.20	0.34	0.47	1.5
85	0.10	0.12	0.14	0.18	0.29	0.54	0.87	2.3
65	0.11	0.17	0.2	0.34	0.66	1.3	1.9	4.2
55	0.1	0.3	0.4	0.6	1.1	2.0	2.8	5.5
50	0.14	0.30	0.5	0.8	1.3	2.3	3.2	6.2
45	0.2	0.4	0.7	1.1	1.8	2.9	4.0	7.1
40	0.19	0.57	0.9	1.4	2.2	3.5	4.7	8.0
35	0.3	0.9	1.3	1.9	2.9	4.4	5.7	9.2
30	0.34	1.15	1.8	2.5	3.6	5.3	6.7	10
20	0.78	2.34	3.3	4.2	5.6	7.7	9.3	13
10	2.01	4.67	5.9	7.2	8.8	11	13	17

* Values represent mean daily salinity levels, vertically averaged for the entire water column
Source: Output from the SFWMD Hydrodynamic Salinity Model

Flow vs. Salinity Relationships

When actual measured salinity data are graphed against measure flow across Lainhart Dam, a significant amount of "scatter," occurs (see **Appendix D** figures). Field measurements were collected primarily during low flow periods using a Hydrolab® Datasonde Model 3 electronic recording device. Salinity measurements were collected from a depth of about 1 meter above the river bottom at half-hour intervals over periods of 15-30 days (Dent and Ridler 1997). These data were later retrieved from the device, reviewed, and edited to record the maximum daily salinity value for each day.

In contrast, the model output represents a daily-averaged and vertically-averaged concentration. Because of these differences, it is not surprising that the observed frequency distribution of low-flow events over Lainhart Dam, as presented in **Table 24,** does not agree exactly with the frequency distribution of salinity events derived from the long-term model, as shown in **Tables 34** and **35.** Based on the observed data in **Table 24**, for example, under current (1990 to 2001) conditions, flows drop below 35 cfs for 15 days every two months. This is somewhat comparable to the prediction that salinities will exceed 2 ppt for 46 days every 6.8 months at station 9.2 (**Table 35**), since the latter estimate approximately represents a three-times longer time span over which the data were aggregated (6 months vs 2 months).

Comparison between Modeled Data and Observed Data

Differences between model and observed results also occur due to the built-in response time of the model to changes in flow. In addition, there is relatively good daily flow data from only one of the structures and tributaries that provide flow to the river. Discharges from other tributaries, on average, seem to be relatively predictable percentages of the flow from Lainhart Dam. However, they may vary considerably on a daily basis due to local conditions, resulting in a wide range of salinity values associated with a particular flow value for Lainhart Dam. The salinity data are of limited duration and are often incomplete.

Due to the limited number of continuous data sets available, salinities calculated from the calibrated and verified model were used as the basis to analyze long-term trends. The model provides a more consistent estimate of salinity, can account for some of the known sources of variability in the data (tidal cycles), and can be used to simulate how the system would perform under a wider range of hydrologic conditions that better represent the inter-annual patterns and cycles of flood and drought that occur in South Florida. However, the model may not provide a very accurate representation of conditions in the river at any particular point in time. The assumption was made that such errors are random so that model does provide accurate predictions of salinity averages and trends over long time periods.

The peer review panel cited a concern that systematic errors may have been incorporated in the analysis, due to structural or management changes in the system that have occurred during the period of record. Such alterations may have affected the basic flow-salinity relationships, and thus could bias our long-term flow and salinity estimates at particular stations. An additional analysis was therefore conducted to compare salinity vs flow relationships at different points along the river, using data collected from different time periods (see **Figure 29**).

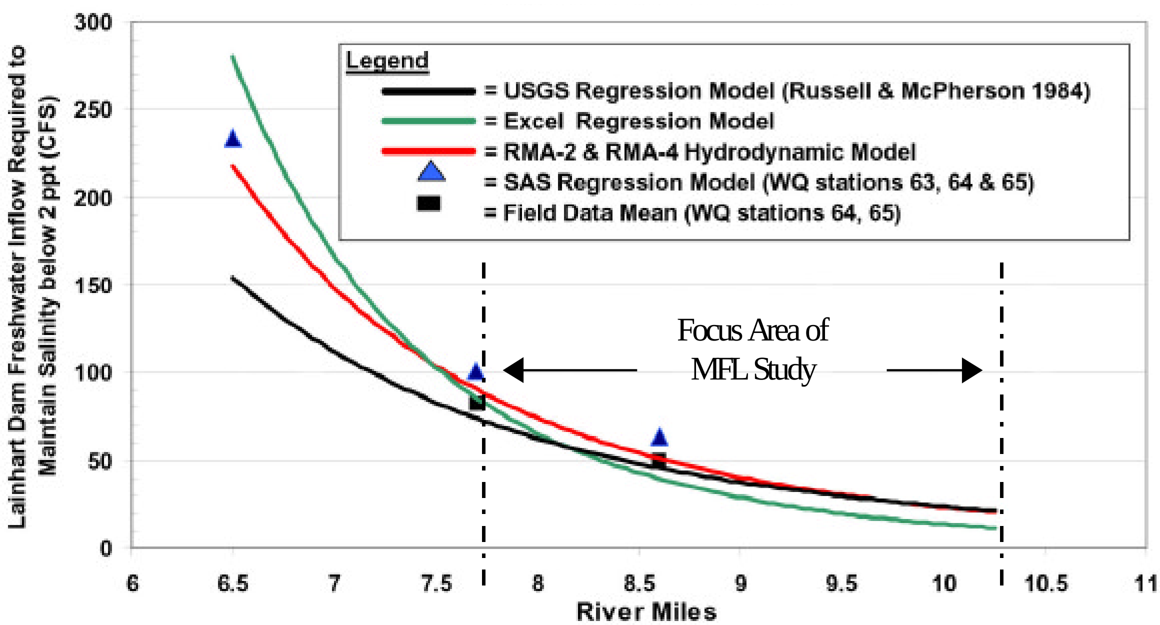


Figure 29. Comparison of Hydrodynamic Model with Regression Analyses of Field Data.

The data generated by the hydrodynamic/salinity model, based on the 30-year period of record, were compared to data collected in the early 1980s by the USGS (Russell and McPherson 1984) and two different statistical analyses of data that were collected in the late 1980s through 1995. Data collected during the early 1980's (Russell and McPherson 1984), represents a period prior to a number of structural changes that occurred in the late 1980's. The results of this comparison (**Figure 29**) indicate that the flow-salinity relationships predicted by the model are similar to those derived directly from field data, using three different analytical methods. There was especially good agreement among the methods in the upstream portion of the river, from river mile 7.8 to river mile 10.2, the area of primary concern for this study. It was therefore concluded that recent structural changes in the river watershed have not had a significant effect on flow-salinity relationships in the river.

Summary of Technical Results

- Long-term flow records for the Loxahatchee River indicate that average flows during the dry season (October 16-May 14) are 70 cfs. During extremely dry conditions, such as those that existed during the 1980-81 and 1989-90 droughts, dry season flows from Lainhart Dam averaged between 26-35 cfs (**Table 24**).
- Examination of the flow record for Lainhart Dam from 1977 to 2001 indicates that increased rainfall and improvements to the G-92 structure in 1987, have increased average flow to the river from 55 cfs to 106 cfs (**Figure 19**). Also the occurrence of flows below 35 cfs has been reduced from 34 percent of the time (1971-1989) to 25 percent of the time (1990-2001) (**Table 25**). These changes can be attributed to a combination of changes in weather patterns and improved management practices.
- In spite of thee benefits, there has been little or no improvement in flows to the river during very dry periods. Review of flow duration curves developed for the Lainhart Dam shows that about 10% of the time, flows are reduced to about 14 cfs over the 30 year period of record (**Figure 20**).
- Results of a river vegetation survey identified six woody vegetation species (red maple, pop ash, dahoon holly, pond apple, Virginia willow and red bay), which predominantly occur in fresh water (**Table 30**), as useful indicators of long-term salinity changes within the river. These six species were selected as indicators for the Valued Ecosystem Component for the Northwest Fork.
- Results of vegetation surveys indicated that a unharmed, healthy floodplain swamp community exists and river mile 10.2, a “stressed” community exists at river mile 9.7, and those communities that remain at river mile 9.2 has been significantly harmed (**Tables 31-33, Figure 26**).
- Comparison of vegetation along the river based on aerial photography, indicates that floodplain vegetation in the upstream areas of the river changed significantly between 1940 and 1995 (**Appendix B**). Results presented in **Chapter 2** and **Figure 31** suggest that there was very little change in river vegetation patterns between 1985 and 1995 and that the improved hydrologic conditions may have stabilized or slowed the trend of river floodplain degradation.
- Since long-term salinity records did not exist for the each vegetation site sampled along the Northwest Fork of the river, a hydrodynamic/salinity model was used to simulate a long-term (30 years) time series of salinity conditions at each site. For each time series, descriptive statistics (mean, standard deviation, 90th percentile, maximum) were developed to characterize salinity regimes at each vegetation sampling site (**Table 34).**
- The data were also expressed in terms of the amount of time that salinities of different levels occurred at each station and the return frequency between salinity exposure events during the 30 year simulation (**Table 35**).
- Results showed that at river mile 10.2 (within the unharmed, healthy floodplain swamp

community) salinities ranged from 0 up to 3 parts per thousand (ppt) with a mean salinity of 0.15 ppt and a 90th percentile of 0.65 ppt during the 30 year simulation. These data indicate that this portion of the river is a freshwater system except during low flow periods when mean daily salinities may exceed 2 ppt for 20 days every six years. Salinity exceeded 3 ppt only once, for a 13-day period, during the 30-year simulation period.

- Downstream at river mile 9.7 (the stressed floodplain swamp community) daily mean salinity levels ranged from 0 up to 6 ppt with a mean salinity of 0.5 ppt and 90th percentile limit of 1.7 ppt during the 30 year simulation. This represents about a three-fold increase in mean salinity as compared to the healthy floodplain swamp community located at river mile 10.2. Salinities at river mile 9.7 exceeded 2 ppt for an average of 40 days, once every 1.25 years.
- Further downstream at river mile 9.2 (the significantly harmed site) salinity levels ranged from 0 to 9 ppt with a mean salinity of 0.97 ppt and 90th percentile limit of 2.9 ppt recorded over the 30 year simulation. Overall, this represents about a six-fold increase in mean salinity as compared to the site at river mile 10.2. At this site, salinity levels exceeded 2 ppt for an average of 46 days, with a return interval of about seven months.
- A flow/salinity relationship was established for each of the seven vegetation sampling sites, based on output of a hydrodynamic/salinity model (**Table 35**). These data show the amount of flow (as measured at the Lainhart Dam) required to maintain average salinity conditions at different points located along the river. These data may also be used to estimate the flows required to maintain desired salinity conditions at different locations on the Northwest Fork.

Application of the River Vegetation/Salinity (SAVELOX) Model

Using the vegetation survey results and the salinity time series generated from the hydrodynamic model, correlation analyses were used to examine vegetation trends relative to salinity event duration. From these data, a river vegetation/salinity model (SAVELOX) was developed using an empirical approach to extrapolate vegetation parameter response given a set of long-term salinity conditions (see **Chapter 4**). The model formulas were based upon the correlation between measured vegetation parameters (i.e. abundance, height of adults, canopy cover, etc.) and a calculated salinity ratio *Ds/Db* at those sites where both computed salinity and vegetation survey data existed.

SAVELOX Model Results

Relationships between vegetation trends and long-term salinity conditions along the Northwest Fork were determined (**Table 36**) and expressed as relational formulas that were the basis for the SAVELOX model. A predicted value for a given vegetation parameter was calculated from the following user input: 1) selection of a mean salinity event threshold ($\geq$1 ppt, $\geq$2 ppt, or $\geq$3 ppt); and 2) long-term mean salinity event duration and mean time between salinity event for a location along the Northwest Fork. The model output is a predicted value for a vegetation parameter at a location along the Northwest Fork. Model output was verified using additional intermediate site vegetation data collected along the Northwest Fork (V-1, V-2, V-3, etc., **Figure 16, Chapter 4**) which were not used in development of the formulas.

Table 36. Estimated Salinity Event Ratio (*Ds/Db*) at a 2 ppt Threshold Associated with a Decline of Measured Freshwater Vegetation Parameters.

Species	**Abundance Index**		**No. of Adults Per Site[4]**		**Canopy Coverage (Adults)**		**Mean Height (Adults)**		**Mean DBH (Adults)**		**No. of Juveniles Per Site[4]**	
	Dec[1]	**NP[2]**	**Dec**	**NP**	**Dec**	**<5%**	**Dec**	**NP**	**Dec**	**NP**	**Dec**	**NP**
Bald Cypress	0.28	5.00[5]	0.13	5.00[5]	0.13	0.38	N/A	5.00[5]	N/A	5.00[5]	0.13	0.52
V. Willow	0.13	0.13	0.13	0.28	N/A	N/A	N/A	0.28	N/A	N/A	0.13	0.28
Dahoon	0.13	0.52	0.13	0.33	N/A	N/A	0.13	0.33	0.13	0.33	0.13	0.28
Pop Ash	0.28	0.52	0.28	0.52	0.13	0.28	0.28	0.52	0.13	0.52	0.28	0.28
Pond Apple	1.26	1.26	0.28	1.22	0.13	0.60	0.28	1.22	0.28	0.60	0.28	0.28
Red Maple	0.13	0.75	0.28	0.28	0.13	0.28	0.28	0.28	0.13	0.28	0.13	0.13

[1] Dec = Most downstream point of the river where the vegetation parameter (Ds/Db) was observed to decline below background levels; where a drop in the value was first noted (moving from upstream to downstream)
[2] NP = Most downstream point of the river where the vegetation parameter was either no longer present, where the value first reached zero, or where there were no individuals found (moving from upstream to downstream)
[3] N/A = not able to be determined from the data
[4] Based upon combined totals from both plots surveyed at a site
[5] Indicates an estimated value

Table 36 shows the salinity ratio threshold associated with a decline in or a value of zero for each measured vegetation parameter for several key species. Using the SAVELOX model, this information can be expanded to include salinity event magnitude (threshold >1 ppt, >2 ppt, or >3 ppt), duration, frequency, location (expressed as river mile) and the corresponding estimated minimum flow over Lainhart Dam required to keep salinity below the threshold value. An example of SAVELOX model results are shown for red maple in **Table 37**.

Table 37. Output of the SAVELOX Model: Mean Salinity Event >2 ppt Duration (days), Mean Time Between Events (days), and Flow (cfs*) associated with community vegetation parameter changes in Red Maple (*Acer rubrum*).

Red Maple					
Vegetation Parameter	**Change in Parameter**	**River Mile**	**Event >2 ppt Duration (days)**	**Event >2 ppt Frequency (days)**	**Lainhart Flow (cfs)***
Abundance Index	Decline[1]	9.7	42	320	30
	Not Present[2]	8.7	60	76	65
Number of Adults Per Site	Decline	9.2	44	157	40
	Not Present	9.2	44	157	40
Canopy Coverage (Adults)	Decline	9.7	42	320	30
	Not Present	9.2	44	157	40
Mean Tree Height (Adults)	Decline	9.2	44	157	40
	Not Present	9.2	44	157	40
Mean DBH (Adults)	Decline	9.7	42	320	30
	Not Present	9.2	44	157	40
Number of Juveniles Per Site	Decline	9.7	42	320	30
	Not Present	9.7	42	320	30

CFS = cubic feet per second

1 Decline = Most downstream point of the river where the vegetation parameter was observed to decline below background levels; where a drop in the value was first noted (moving from upstream to downstream)
[2] Not Present = Most downstream point of the river where the vegetation parameter was either no longer present, where the value first reached zero, or where there were no individuals found (moving from upstream to downstream)

Based on these model results and outputs, it is possible to predict the future distribution of the six VEC species along the Northwest Fork, based on the following:

- The model provides the capability to analyze future water management scenarios that predict hydrologic conditions and flow patterns in the river to determine the resulting salinity regime.

- Based on empirical data derived from healthy stressed and damaged plant communities that presently exist on the river, the model can be used to predict the downstream distribution limits (in river miles) of the healthy freshwater floodplain swamp community or any of its component species.
- In addition, it can be used to determine areas where the freshwater swamp community or its component species will be stressed, and locations where significant harm occurs to this community.
- The model can also be used to predict what flow conditions are necessary to protect or restore these species and the floodplain community.

DEVELOPMENT OF RESOURCE PROTECTION CRITERIA.

Results of the quantitative data from the river vegetation survey have shown that a relatively non-impacted, “healthy”, sustainable floodplain swamp community exists at river mile 10.2. Results of the semi-quantitative sampling indicate that these plant communities remain healthy as far downstream as river mile 9.9.

It should be noted that although there is a direct correlation between presence, abundance and health of “freshwater” forest species and distance from the inlet and that there is a corresponding inverse correlation with salinity concentrations in the river, these correlations do not prove a cause-effect relationship. Specific data on salt tolerances of these six species would be required to establish that salt water exposure was responsible for changes in vegetation along the river channel. Such evidence has not yet been attained and District staff have had to rely on general information that is provide in the literature such as that shown in **Table 29.** Nevertheless, it appears, based at least on empirical evidence from this particular river system, that salinity can at least be considered as a surrogate for stress factors that presently limit the downstream distribution of the floodplain swamp community along the Northwest Fork.

The salinity conditions that occur at river mile 10.2 are essentially those of a freshwater system, except during dry periods when mean daily salinities may increase up to 2 ppt (**Figure 28**). Model simulations show that such elevated salinity conditions have occurred, on average, for periods of about 20 days, once every six years (**Table 34)**. Review of these data indicate that salinity conditions that exist at river mile 10.2 provide a viable and sustainable freshwater floodplain swamp community. More strenuous conditions in terms of magnitude, frequency or duration of salinity exposure, such as those experienced downstream at station 9.7, lead to stress of the freshwater swamp community. Exposure to more severe salinity conditions, such as those that occur at station 9.2, have resulted in significant harm to the floodplain swamp community.

Although there may be a basis to define a “minimum” flow for the river based on a “maximum allowable salinity event,” the ability of plant communities to survive such periodic impacts depends on the health of the community prior to exposure. Since the resource to be protected is a freshwater plant community, the preferred condition would be to not allow any salt water to enter this system. If the community is healthy, by virtue of not having been exposed to salt water for a long period, it can tolerate occasional salinity stress. Likewise if the stress period is followed by a long period when no salt is present, the community can effectively recover.

By contrast, if salinity stress occurs frequently, the community will become increasingly damaged, will not have time to recover and will continue to degrade. This progressive damage may occur due to the direct effects of salt toxicity and/or secondary effects such as a) reduced resistance to insects and diseases, b) competition by more salt-tolerant species such as mangroves, and c) reduced growth and reproductive success. In summary, a robust freshwater floodplain swamp community that has a history of non-exposure to salinity intrusion is better able to survive an occasional increase in salt content than a community that has been stressed by frequent exposure to elevated (although perhaps non-lethal) salinity conditions.

Repeated low-level salinity stress may be sufficient to prevent seed germination and/or to kill newly-sprouted seedlings and saplings of freshwater species without killing the adult plants. In this case, the plant “community” may continue to exist for some time, but without recruitment of new individuals. In this case, the community is not sustainable and will eventually die out and be replaced by saltwater-tolerant species.

The MFL is based on the amount of flow that is required to protect a primarily freshwater system from significant harm when exposed to short-duration, infrequent events that have limited allowable salinity concentrations. Several different salinity criteria were examined as a basis to ensure that the resource was adequately protected. The purpose of this effort was to determine parameters that could be effectively measured in the field, derived from field data or from model simulations and that could be empirically linked to resource impacts.

Based on the analyses and considerations described above, SFWMD staff conclude that to continue to protect the habitat values, species composition, and canopy structure of the existing healthy floodplain swamp community that exists at station 10B (river mile 10.2) and extends downstream to river mile 9.9, average salinity conditions, as determined by the model, should be maintained at or below 0.15 ppt. Daily mean salinity should not be allowed to exceed 1 ppt more than 5 percent of the time (40 days per year), 2 ppt more than 1 percent of the time (30 days in four years) and should not exceed 3 ppt more than 20 days in 10 years (see **Tables 33 and 34).** This indicates that to provide adequate protection for the resource, a range of flow, duration and frequency criteria can be defined for this station as represented in the first line of **Table 38.** A number of previous authors have identified the 2 ppt threshold as being an effective indicator of saltwater contamination because this concentration is significantly higher than background concentrations of salts that might be derived from other sources such as runoff or mineralized groundwater flow. Previous studies have shown generally good correlation between measured values and the locations of the 2 ppt isohaline contours that were predicted by the hydrodynamic model for this river system.

Although a daily mean concentration of 2 ppt is easily estimated from the hydrodynamic/salinity model, it is not clear how this predicted mean salinity relates to the actual range of salinity conditions that may be experienced at a particular location during a 24-hour period. The SFWMD is in the process of upgrading the Loxahatchee River hydrodynamic model to a three dimensional model and establishing a more effective monitoring program in the river to address this issue.

Table 38. Various Salinity parameters that can be used to protect the resource.

River Mile	Approximate Flows (cfs)* needed to maintain salinity concentrations:				
	Mean = 0.15 ppt	Mean = 0.3 ppt	Salinity ≥ 1ppt Not to exceed 31 days/1.6 yr**	Salinity ≥ 2ppt Not to exceed 22 days/5.9yr	Salinity ≥ 3 ppt Not to exceed 14 days/10yr
10.2	50	**35**	20	10	5
9.7	80	50	**32**	25	15
9.2	100	70	47	**35**	**22**
8.9	140	85	60	42	**27**
8.6	150	120	75	55	42
8.35	200	130	80	65	52

* Flows obtained from Table 35 for a given salinity value at a given station location

** Occurrence frequency and duration were obtained from Table 34: for example for 1ppt salinity at station 10.2 *Ds* = 31 days and *Db* = 576 days or 1.6 years; Likewise at 2-ppt salinity, *Ds* =22 days and *Db*=2157 days or 5.9 years

Previous studies have also shown that salinity concentrations in the river are stratified (i.e. low salinity or fresh water is present at the top of the water column and higher salinity water is located at the bottom). Since the two-dimensional model represents a "vertically averaged" salinity, a predicted daily average value of 2 ppt at a particular point in the river is assumed to represent salinity values that range from perhaps 4 ppt at the bottom of the river channel to near fresh water conditions at the surface. Also, since the salinity represents a daily average, there may be a considerable variation at a given point between high tide and low tide conditions, so that a daily average bottom salinity of 4 ppt could potentially represent a low tide bottom salinity of 0 ppt and a high tide bottom salinity of 8 ppt. Salinities of above 7 ppt have been measured in the river upstream of mile marker 10 during an extreme drought condition (Russell and McPherson 1984). Modeling results presented in this study indicate that average salinities as high as 3.5 ppt may occur at this location during an extreme low flow condition.

Data from this study suggest that the 2 ppt isohaline (representing a maximum of perhaps 4 ppt salinity at the bottom of the water column) may have particular relevance to the protection of the freshwater floodplain swamp community. This level is exceeded only about once every 6 years in healthy communities such as those documented at river mile 10.2. This low rate of occurrence is reflective of historical regional rainfall patterns and based on model results is apparently sufficient enough to allow the community to recover to a healthy condition between events. Salinity exposure is sufficiently infrequent enough to allow seeds to germinate successfully and grow beyond the most sensitive life stages.

In contrast, a daily mean salinity of 2 ppt is exceeded about once every year in the "stressed" communities (river mile 9.7), and is exceeded about once every 160 days in communities that have experienced significant harm (river mile 9.2) (**Table 34).** These relatively low levels of exposure are apparently sufficient enough to result in loss of canopy cover, reduced growth, prevention of successful seed germination and subsequent survival of VEC indicator species. Data collected in this study, and information compiled from literature reviews of the salinity tolerance of freshwater vegetation also suggest that seedlings and saplings characteristic of freshwater floodplain swamp communities may be more acutely sensitive to salt concentrations between 3 and 6 ppt. This sensitivity is indicated by a loss of saplings and seedlings of VEC species at river mile 9.7. Exposure to mean daily salinities above 3 ppt occurs approximately once every 2.5 years (34 days out 29 months) at river mile 9.7.

Definitions of No Harm, Stressed and Significant Harm

Based on results of the above field studies, modeling, and data analyses, the following criteria were developed to define a non-impacted, healthy, sustainable floodplain swamp community (the "No Harm" condition) for the Northwest Fork of the Loxahatchee River as well as various other degrees of impacts -- "stressed" and "significant harm" -- as discussed below.

No Harm

The area of the river that characterizes the "no harm" condition is typified by those vegetation communities that were documented in quantitative studies to occur at river mile 10.2.

- All six VEC indicator species are present within the floodplain swamp community.
- The floodplain swamp consists of a high canopy of bald cypress and mixed hardwoods, approximately 35 - 60 ft. in height; a subcanopy of mixed hardwoods, 15-30 ft. in height, and an understory of more than 30 species of vascular plant species.
- Seedlings, saplings and adults of the six VEC species are present, indicating that the community is reproducing and sustainable.
- Results showed that at river mile 10.2, located within the unharmed, healthy floodplain swamp community, mean daily salinity levels ranged from 0 up to 3 parts per thousand (ppt) with a mean daily salinity of 0.15 ppt and a 90th percentile limit of 0.65 ppt during the 30 year simulation. This portion of the river is essentially a freshwater system except during low flow periods when salinities may exceed 1 ppt for 30 days once every two years, and 2 ppt for about 20 days, once every six years.

Stressed

At river mile 9.7, the floodplain swamp has been identified as "stressed" in response to elevated salinity concentrations experienced during low flow conditions. This community is characterized as follows:

- Most of the six VEC indicator species are present, however they are reduced in abundance, tree height, and trunk diameter.
- The number of other plant species is reduced, especially the number of herbaceous species.
- A measurable change in the floodplain forest canopy structure is observed
- Although seedlings and saplings are present, they are reduced in number.
- The long-term salinity record at river mile 9.7 shows that during drought periods this area of the river has been exposed to more frequent occurrences of saline conditions as compared to the "no harm" condition.

- Daily mean salinity levels predicted by the model ranged from 0 up to 6 ppt with a mean salinity of 0.5 ppt and 90th percentile limit of 1.7 ppt during the 30 year simulation. This represents about a three-fold increase in salinity as compared to river mile 10.2. At river mile 9.7 salinity levels exceeded 1 ppt for about 40 days, twice a year, and exceeded 2 ppt about 40 days about once a year.

Significant Harm

Significant harm is defined as *the temporary loss of water resource functions which result from a change in surface or ground water hydrology, that takes more than two years to recover, but which is considered less severe than serious harm* (Chapter 40E-8, F.A.C.). Based on the data presented in this report, significant harm has occurred when:

- Two or more of the six VEC species are no longer present within the floodplain swamp landscape. Based on the results of the river vegetation survey, three of these key species (red bay, Virginia willow, and red maple) are no longer present at river mile 9.2.
- The total number of species present is reduced by about one-third as compared to values recorded upstream of river mile 10.2.
- The floodplain swamp high canopy is no longer present and has been replaced by a low canopy dominated by saltwater tolerant mangroves.
- Seedlings of the six VEC species are no longer present indicating this area can no longer support a reproducing floodplain swamp community.
- At river mile 9.2, daily mean salinity levels ranged from 0 up to 9 parts per thousand (ppt) with a mean salinity of 0.97 ppt and a 90th percentile limit of 2.9 ppt during the 30 year simulation. Overall this represents about a six-fold increase in mean salinity as compared to river mile 10.2. At this site salinity levels exceeded 1 ppt for about 55 days, twice a year and exceeded 2 ppt for 45 days for about once a year.
- Based on these data, river mile 9.2 represents the point in the river where significant harm occurs. Upstream of this point both healthy and salinity "stressed" floodplain vegetation communities continue to exist. Downstream of river mile 9.2 the freshwater dominated floodplain swamp and its associated high canopy are no longer present and have been replaced by saltwater tolerant red mangrove communities with a few remaining stands of bald cypress and cabbage palm trees.

Proposed Minimum Flow Criteria

Basis of Proposed Criteria

<u>Protection from Harm</u>

Based on the results of this study, the flow/salinity regime recorded upstream at river mile 10.2 currently supports an unharmed, healthy, sustainable floodplain swamp community. It is the District's intention to reproduce this salinity regime downstream at river mile 9.2, the point in the river where significant harm has been shown to occur. Using relationships developed from output of a hydrodynamic/salinity model (**Table 38),** a flow regime is needed that will provide essentially freshwater conditions (long-term average salinities of 0.1 to 0.2 ppt) at river mile 9.2.

Protection from Significant Harm

However during very dry periods, Lainhart Dam flows may be substantially reduced as upstream sources are depleted. Under such dry conditions, sufficient flow should be provided to the river to prevent the salinity regime at river mile 9.2 from exceeding 2 ppt for any longer time than has occurred within the “healthy” floodplain swamp community. Such events should not last for more than 20 consecutive days duration, and not occur more often than once every six years, in order not to exceed the salinity regime recorded upstream at river mile 10.2. Review of the flow/salinity relationships shown in **Table 38** indicates that in order to maintain mean daily salinity below 2 ppt at river mile 9.2, the Lainhart Dam needs to provide a minimum flow of at least 35-cfs to the Northwest Fork of the river.

In summary, proposed minimum flow criteria for the Loxahatchee River and Estuary were based on the following:

- Results of this study indicate that sufficient quantities of fresh water from the Lainhart Dam are required to protect the floodplain swamp and associated bald cypress habitat against significant harm. This community has been identified as a valued ecosystem component (VEC) for the Wild and Scenic portion of the Northwest Fork of the Loxahatchee River.
- Research conducted by the SFWMD identified locations on the river where both “healthy” and “stressed” floodplain communities exist (at river miles 10.2 and 9.7, respectively), and identified downstream locations where significant harm to this community is presently occurring (river mile 9.2).
- In order to protect the remaining healthy and stressed floodplain swamp community and the area that currently is experiencing significant harm, sufficient flow should be provided from the Lainhart Dam whenever possible to maintain essentially freshwater conditions in the river upstream of river mile 9.2.
- Modeling results indicate that flows below 35 cubic feet per second from Lainhart Dam cause salinities in excess of 2 ppt to occur at sites where remaining stressed and harmed plant communities exist along the Northwest Fork of the Loxahatchee River. Frequent exposure to salinity levels in excess of 2 ppt was associated with damage to freshwater vegetation.
- During periods of regional drought, due to the limited storage capacity of the basin, it may not be possible to maintain fresh water conditions at river mile 9.2 or to meet the 35-cfs flow criterion at all times. In order to prevent damage or stress from occurring to the floodplain swamp community at river mile 10.2 and significant harm from occurring at river mile 9.2, freshwater flows should not decline below a discharge rate of 35 cfs at the Lainhart Dam for a period of more than 20 consecutive days, more often than once every six years.

Technical Criteria

Based on the above information, SFWMD staff propose the following MFL criteria for the Northwest Fork of the Loxahatchee River:

A MFL violation occurs within the Northwest Fork of the Loxahatchee River when an exceedance, as defined herein, occurs more than once every six years. An "exceedance" occurs when Lainhart Dam flows to the Northwest Fork of the Loxahatchee River decline below 35 cfs for more than 20 consecutive days within any given calendar year.*

* A flow of 35 cfs is equivalent to a recorded stage of 10.68 ft. NGVD as measured upstream of the Lainhart Dam at the SFWMD gage named "LNHRT W".

Effects of the Proposed MFL on Salinity Conditions in the Estuary

To assess the potential impact that the proposed MFL may have on estuarine resources, the following evaluations were based on a literature review and a review of output from the hydrodynamic/salinity model.

Although the extent of the oligohaline zone is reduced considerably in the Loxahatchee River during very dry periods, low-salinity conditions still persist within the river for several miles downstream of the Masten Dam within the Wild and Scenic portion of the River. Loss of a year class of important species is not likely to occur. With the proposed MFL of 35 cfs in place, and the projects to achieve this flow constructed, flows to the river will remain at or above 35 cfs for about 94% of the time (see **Table 43**, Chapter 6). The effects of a 35 cfs flow on the estuary have been previously analyzed as shown in **Appendix F**. Flows in the range from 30-60 cfs were sustained during 1981 (Russell and McPherson 1984) and salinity conditions in the estuary were measured at high and low tides (see **Figure F-3** in **Appendix F**). Although this was not a rigorous study of the effects of such discharges, it provides an indication of likely effects. These results also showed that, in general, salinities throughout most of the estuarine portion of the system were in the range of 30-35 ppt on the bottom and at high tide. During low tides, salinities at the top of the water column in the Northwest Fork and on the bottom in the upper reaches of the Northwest Fork declined to 25-30 ppt. Although it was not measured in the report, observations by District staff and local citizens, indicate that under conditions of low discharge and daily tidal exchange, water clarity generally improves throughout the estuary. Such conditions are beneficial for seagrass communities that live in the central embayment and, at the same time, do not cause undue harm to the oyster communities that form reefs and live on mangrove roots in the Northwest Fork in the vicinity of river mile 6.6 by the JD Park boat ramp.

Estuary Resources that need Protection

An effort was made to characterize the significant biological resources that exist in the estuarine portion of the Loxahatchee system (Chapter 2 pages 26-36). These included primarily mangrove swamp communities, other saltwater marsh vegetation, seagrasses and marine algae, fishes, macroinvertebrates and manatees. Our present (very limited) understanding of the relationships between these system components and freshwater inflows was also described. The Loxahatchee estuary covers the entire range from a primarily marine environment near the inlet and into the central embayment to a completely freshwater environment in the upper reaches of the Northwest Fork.

Effects of the Proposed MFL on Estuarine Organisms

More detailed studies of estuarine organisms and their relationships to freshwater discharges are warranted. Presently the District has engaged a fisheries expert on estuarine fish, to perform a more detailed assessment of estuarine resources in the Loxahatchee River and develop a recommended species list, monitoring, and research needs, to address these concerns.

From the information reviewed it appears that the MFL proposed for the Northwest Fork should not have any significant adverse effects on the estuary and may in fact be beneficial rather than harmful to these resources. In general, species diversity of benthic communities increases as a function of proximity to the inlet (Dent et al., 1998). Under very low flow conditions (see **Appendix F, Figure F-4**), most of the estuary becomes a marine system (30-35 ppt salinities). If these low flow/high salinity conditions persist for several weeks or months, seagrass communities may tend to expand upstream, providing more habitat and food for marine and estuarine fishes and invertebrates, additional stabilization of soft mud bottom communities and provide additional food for manatees. There may be some mortality occurring in oyster communities at the upper end of the Northwest Fork and some associated recruitment occurring further upstream.

The upper reaches of the Northwest Fork still contain extensive areas of habitat suitable for oysters, as well as oligohaline and freshwater habitat. Extreme fluctuations in salinity, associated with periodic low flow events, are not conducive to the development of extensive oyster communities. Oysters are very beneficial to coastal estuaries such as the Loxahatchee River because they tend to stabilize bottom sediments, filter suspended materials from the water column and provide an extensive surface area and substrate for colonization of other organisms.

The proposed MFL is anticipated to improve over current conditions in the estuary by providing for a more extensive and stable oligohaline zone (less than 5 ppt salinity) upstream in the river between river miles 9.2 and 8.5 or so, than occurs at present. Conditions that are more conducive to the growth of oysters on mangrove roots and the formation of oyster reefs or bars (15-25 ppt salinity) are expected to occur in the vicinity of river mile 6 along the river. At the same time, these flows are not expected to adversely affect the marine communities in the central embayment, especially the Johnson' seagrass community that exists near the railroad bridge.

Effects of Proposed MFL on Floodplain Hydrology

Floodplain Transect Analyses To assess the potential effects of the proposed MFL on the upstream floodplain swamp, District staff conducted the following analyses which are provided in detail within Appendix N. District staff utilized a series of soil elevation and surface water measurements within the Wild and Scenic portion of the Loxahatchee River (Figure 30). Field surveys were conducted by SFWMD survey staff at four transect locations from December 1983-April 1984. These data provided measured soil elevations (feet NGVD) across each floodplain transect (SFWMD survey staff field notes). Transects 1 and 2 were located between Indiantown

Rd. and the Florida Turnpike/I-95 bridges. Transects 4 and 5 were located between the Florida Turnpike/I-95 bridges and the Trapper Nelson's interpretive site located in Jonathan Dickinson State Park (**Figure 30**).

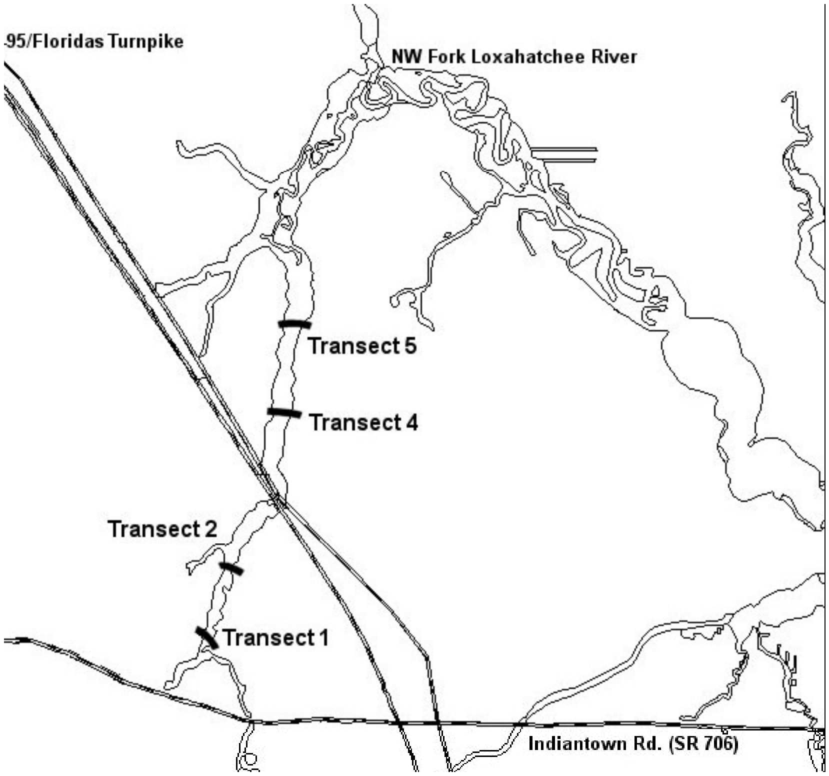


Figure 30. Location of the transect sites along the upper NW Fork of the Loxahatchee River.

In addition to the soil elevation measurements, stage recorders were placed at each transect to record daily water stage data from 1984-1990. These data were extracted from the District's DBHydro database and utilized in these analyses. The soil elevation data was placed into an Excel spreadsheet to develop profiles of each transect. (see **Appendix N, Figures N-2a** to **N-2d).**

Transect survey results are presented in **Table 39**. Results show that the mean floodplain elevations ranged from 9.9 ft. to 2.3 ft NGVD from Transect 1 downstream to Transect 5 indicating an elevation difference of about 7 feet. Similar results are shown for the river channel where the elevation change between upstream and downstream sites was about 6 ft. (**Table 39**).

Table 39. Transect Lengths and Approximate Floodplain Elevations (NGVD) at each Transect

	Transect 1	Transect 2	Transect 4	Transect 5
Total Transect Length (ft)	470	560	520	670
– Upland (ft)	30	90	90	20
– Floodplain Swamp (ft)	360	430	400	580
– River Channel (ft)	80	40	30	70
Floodplain-Upland Ecotone (NGVD)	12.4 – 14.6	8.0 – 11.9	4.8	2.1 – 5.6
Floodplain-Channel Ecotone (NGVD)	8.2	6.9	2.7	2.0
Channel Bottom (NGVD)	1.4	3.2	-3.2	-2.2
Mean Floodplain Elevation (NGVD)	9.9	8.2	4.0	2.3

In contrast, elevations recorded within the upland-floodplain swamp ecotone between opposing sides of the river at three of the transects were inconsistent and highly variable. This may be related to the magnitude of freshwater seepage available from upland areas flanking the floodplain. Review of transect profiles as illustrated in the example provided in **Figure 31** indicates the floodplain is not flat, but undulates along an elevation that varies between 1.0 to 1.5 ft. from the river channel to the edge of the floodplain.

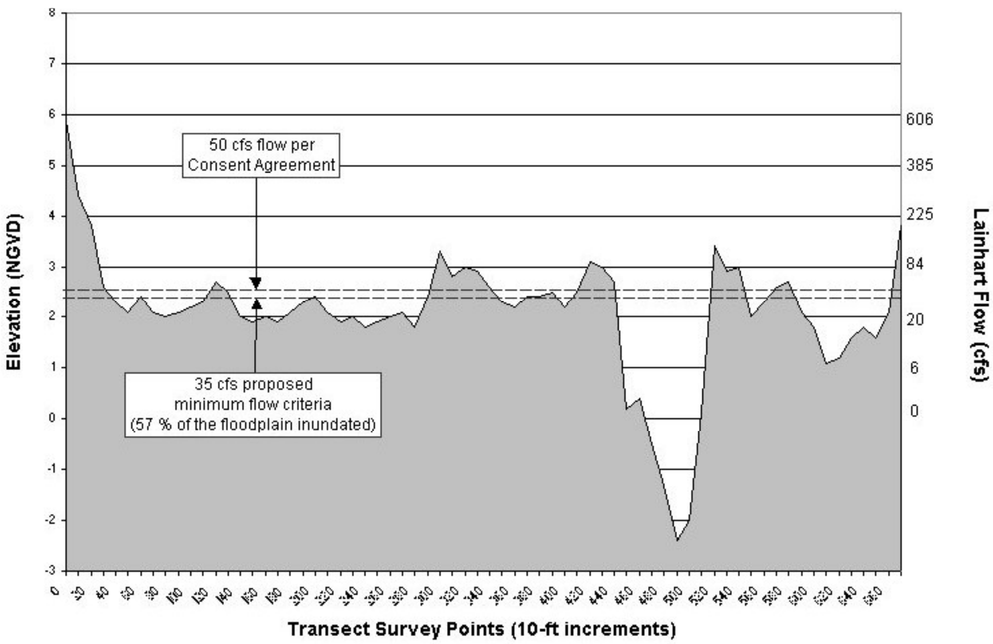


Figure 31. Transect 5 profile across the floodplain, upper NW Fork of the Loxahatchee River.

Figure 32 provides a hydrograph of surface water levels recorded along each transect from 1984-1990 as well as Lainhart Dam flows for the same time period. From a comparison of the mean difference between daily stage measurements recorded at each transect and those recorded at Lainhart Dam, a relationship was developed (**Table 40)** between Lainhart Dam stage and water level stages recorded at each transect. Daily stage measurements at Lainhart Dam were also used to calculate flows. These daily stage (flow) measurements and average transect elevation data (**Table 40**) were used to provide an estimate of the percent of the floodplain that could be expected to be inundated at a given flow magnitude. This relationship is shown in **Table 40.**

Table 40 . Mean (standard deviation) difference between the Lainhart Dam water levels and those recorded downstream at each transect location (in feet NGVD).

Transect Name	Transect 1	Transect 2	Transect 4	Transect 5
Station Id.	LOX.R1_G	LOX.R2_G	LOX.R3_G	LOX.R4_G
Mean (STD)	0.78 (0.28)	3.04 (0.37)	6.12 (0.42)	8.33 (0.38)

Based on these data, a minimum flow of 35 cfs recorded at the Lainhart Dam would inundate more than 50% of the floodplain on average (**Table 41)**. In contrast, nearly 95% of the floodplain is inundated under a flow regime of 300 cfs, while flows of less than 10 cfs would be required to allow surface water to fully receded from the floodplain (**Table 41).**

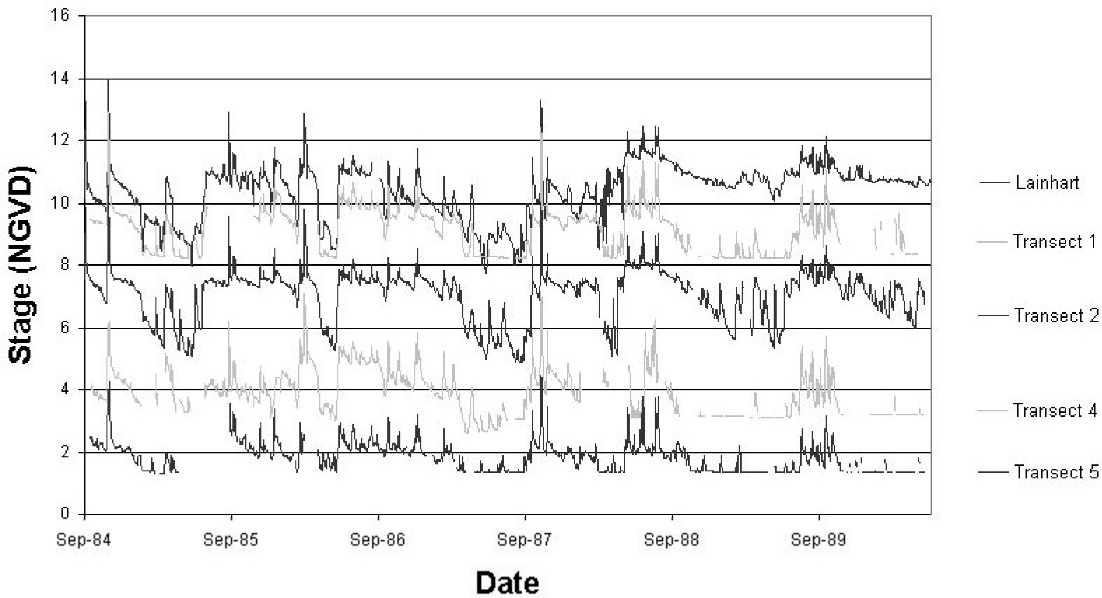


Figure 32. Daily Stage hydrographs for the four transects sites and Lainhart Dam (1984-1990)

Table 41 . Percent of floodplain inundation related to flows over Lainhart Dam (excluding uplands and river channel).

	Lainhart Dam Flows (cubic feet/second)								
	10cfs	25cfs	35 cfs	48cfs	65cfs	75cfs	100cfs	200cfs	300cfs
Transect 1	14**	44	61	61	64	64	69	78	86
Transect 2*	0	7	16	40	49	53	74	86	91
Transect 4	25	58	75	93	95	95	100	100	100
Transect 5	5	43	57	71	81	83	93	98	100
Average (Transects 1, 4, & 5)	15	48	64	75	80	81	87	92	95
Average (all transects)	11	38	52	66	72	74	84	91	94

*= This transect is located just downstream of the Masten Dam and is heavily influenced by this structure
** = Percent of transect inundated at a given Lainhart Dam flow

Providing a dry season flow regime that would inundate more than 50% of the floodplain would provide protection from the effects of over-drainage. In addition, water levels maintained within this range would also (a) provide aquatic refugia for aquatic invertebrates, amphibians and fish species to survive during dry periods, (b) reduce the possibility for invasion by Melaleuca, Brazilian pepper and Old World climbing fern, and (c) reduce the frequency of severe fires that could impact the remaining floodplain swamp forest. Overall, these results indicate that a minimum flow regime of 35 cfs would have no adverse impact on the upstream floodplain swamp. For more details regarding these analyses are in **Appendix N**.

Effects of the Proposed MFL on Navigation and Recreation

When flows over the Lainhart Dam are less than 35 cfs, navigation and recreational uses of the Northwest Fork become impaired. Access to the river by recreational boaters, fishermen, canoeists and kayakers becomes limited and at times, is restricted. Due to many fallen trees, littoral areas and shoals that are exposed or contain only a few inches of water, thereby creating conditions that limit navigation and recreational use of the resource.

CHAPTER 6 -- MFL RECOVERY AND PREVENTION PLAN AND RESEARCH NEEDS

INTRODUCTION AND OVERVIEW

MFL Recovery and Prevention Strategy

Section 373.0361, F.S. requires that each regional water supply plan be based on at least a 20-year planning horizon and include (a) water supply and water resource development components, (b) a funding strategy for water resource development projects, (c) MFLs established within the planning region for identified priority water bodies, (d) development of a MFL recovery and prevention strategy, and (e) technical data and information supporting the plan.

Section 373.0421, F.S., requires that once the MFL technical criteria have been established, the Districts must develop and expeditiously implement a recovery and prevention strategy for those water bodies that are currently exceeding, or are expected to exceed, the MFL criteria within the 20-year planning time frame. Section 373.0421(2), F.S., provides the following, in relevant part:

> *The recovery or prevention strategy shall include phasing or a timetable which will allow for the provision of sufficient water supplies for all existing and projected reasonable-beneficial uses, including development of additional water supplies and implementation of conservation and other efficiency measures concurrent with, to the extent practical, and to offset, reductions in permitted withdrawals, consistent with the provisions of this chapter.*

Implementation Policies

Historical information provided in this report indicates that, over the past 10 years, the proposed minimum flow level (35 cfs) is exceeded approximately 25% of the time under current conditions. These low flow conditions occur frequently, such that an exceedance of the MFL criterion (flow less than 35 cfs for 20 consecutive days duration) occurred 34 times in 31 years or approximately once each year.

Review of existing information indicates the proposed MFL cannot be achieved immediately because of a lack of water conveyance infrastructure and regional storage facilities. These storage and infrastructure shortfalls will be overcome through construction of water resource and water supply development projects, improved conveyance facilities, and improved operational strategies that will provide increased storage and water delivery capabilities. Planning and regulatory efforts will, therefore, include a programmed recovery process that will be implemented over time to improve water supply and distribution to protect water resources and functions. The MFL Recovery Plan for the Northwest Fork of the Loxahatchee River includes many of the features that were developed for the *Northern Palm Beach County Comprehensive Water Management Plan* (NPBCCWMP) (SFWMD, 2002), the *Lower East Coast Regional Water Supply Plan* (SFWMD 2000c), and the *Comprehensive Everglades Restoration Plan* (CERP) (USACE and SFWMD 1999). Appropriate technical analyses are also being conducted to determine the future water supply implications of the proposed MFL technical criteria on urban and agricultural water users in the Loxahatchee River watershed. These results will be integrated into future updates of the *Lower East Coast Regional Water Supply Plan*, with appropriate implementation measures developed consistent with Section 373.0421 F.S. The Loxahatchee River MFL recovery plan consists of capital, regulatory and operational components.

Implementation Process

The SFWMD recognizes that additional water is necessary within the Loxahatchee River watershed to meet human and environment needs, today and in the future. The intent of the District, through its planning, capital improvement, operations, and regulatory programs, is to ensure that these requirements are met in an equitable manner. A cooperative effort is underway by FDEP, SFWMD, and other agencies, with public participation, to develop practical restoration goals and objectives for the Loxahatchee River. In the meantime, the minimum flow criteria for the Northwest Fork that are proposed in this document will be achieved through a combination of structural improvements, enhanced operational protocols and regulatory activities.

The LECRWSP identified that additional planning was required to identify the amount of water needed to meet present and future demands within the SFWMD and develop sources as necessary to meet these needs. The goal of these planning efforts is to ensure that sufficient water is available for natural systems and consumptive uses during a 1-in-10 year drought condition. Projects that are described as part of the MFL Recovery Plan were developed in the *Lower East Coast Regional Water Supply Plan* (SFWMD 2000), the *Northern Palm Beach County Comprehensive Water Management Plan* (SFWMD 2002) and the *Comprehensive Everglades Restoration Plan* (USACE and SFWMD 1999) provide the facilities that are needed to meet or exceed the MFL criteria and may be sufficient to meet restoration requirements, once these have been identified. However, construction of these facilities will not be fully functional for several years.

The SFWMD has improved its operational protocols for the river during the past twenty years to ensure that increasing amounts of water are delivered to the Northwest Fork. These improved operations will continue to be implemented and will be enhanced as additional water becomes available.

The SFWMD, through its regulatory program, will ensure that groundwater and surface water resources are protected from harm and that appropriate water shortage plans are in place to protect water resources from harm and serious harm.

Finally, an adaptive management approach to resource management is proposed. Data collected from ongoing research and monitoring efforts will be used to measure system performance in achieving the proposed criteria and ecosystem responses. The criteria will be modified periodically, if necessary, to ensure that the goal of these efforts—to protect water resources from significant harm—is achieved.

MANAGEMENT TARGETS

The following resource management targets, which relate to providing increased flows to the Northwest Fork of the Loxahatchee River, are contained in the NPBCCWMP (SFWMD 2002):

- Provide supplemental water to maintain up to 65 cubic feet per second (cfs) flow over the Lainhart Dam to the Northwest Fork of the River (this flow target was established in the NPBCCWMP without specifying duration or frequency).
- Provide supplemental water to the Loxahatchee Slough (headwaters of the Loxahatchee River) sufficient to improve hydroperiods within this wetland area.
- Improve the timing and volume of flows provided from the other tributaries that discharge into the Northwest Fork.
- It is the intent of the District, as outlined in the NPBCCWMP, to meet current and projected future (2020) public, agricultural and industrial water supply; flood control; and environmental resource protection needs in northern Palm Beach County.
- The NPBCCWMP identifies nine major projects for improving conveyance and increasing storage in the basin to provide more water to the Slough and meet the 65-cfs flow target for the Lainhart Dam (**see Table 42**).

Table 42. Major NPBCCWMP projects, cost, benefits and completion schedule for projects that will provide additional water for the Loxahatchee slough and river.

Project Description	**Cost** ($ Millions)	**Benefit**	**Date**
L-8 reservoir Pilot study & reservoir testing	$3.5	Demonstrates reservoir feasibility of adding 3,500 ac-ft. of storage to system	2001
Northlake Blvd. Improvements (a) maintain 3, 72 inch culverts by 2002 (b) construct G-161 structure by 2005	$0.1 $1.2	Culvert maintenance provides 50 cfs to slough; G-161 adds up to 150 cfs to slough	2002 2005
C-2 Pump station (M-canal)	$4.0	Adds up to 270 cfs conveyance to WPBWCA & slough	2005
M-canal widening	$3.0	Provides up to 450 cfs of conveyance capacity to WPBWCA & Lox. Slough	2005
Construct Loxahatchee Slough Structure (G-160)	$3.6	Adds 5,000 ac-ft. of storage to basin	2006
Grassy Waters Preserve perimeter canal improvements	TBD	Provides additional route to move water from WPBWCA to slough	TBD
Install pumps to capture J.W. Corbett WMA runoff for storage in Lox. Slough	TBD	Adds additional water to slough	TBD
Construct 10, 5MGD ASR wells	$15	Increase basin storage and reduces competition for water during dry season	2010
Construct L-8 reservoir(s)	?	Adds 48,000 ac-ft of additional storage capacity	2018

Source: SFWMD 2002

In this document, it was determined that significant harm occurs to the river floodplain community when representative species that comprise this community fail to reproduce and survive to maturity, leading to a reduction in species diversity and alteration of the canopy structure. Once such changes have occurred, it may take many years for the forest structure to recover after proper hydrologic conditions have been reestablished. A baseline for protection of existing resources was defined as the condition of the floodplain vegetation communities in 1985, at the time that the Northwest Fork was designated as a Wild and Scenic River. Based on these considerations, the SFWMD identified three possible MFL management targets for this system, that could be used to protect existing resources against significant harm.

- Determine the downstream-most location of the existing "healthy" floodplain community where the critical species are successfully reproducing and the canopy structure is complete. Identify the conditions of salinity and flow that are needed to protect this community from significant harm.

- Determine the downstream-most location of a stressed but essentially intact floodplain community where canopy structure has been impacted but most of the species are still present but may not be reproducing. Identify the flow conditions needed to create a salinity exposure that is comparable to salinity conditions at the "healthy" community site and thus protect this stressed region from significant harm.
- Determine the downstream-most location of the remaining cypress community. Protect this community from significant harm by providing flows and salinity conditions that will ensure that this community remains viable by promoting recruitment, growth and maturity of new trees.

These MFL management targets do not necessarily represent a water reservation for the river or the amount of water needed to achieve restoration. Restoration efforts may also define a different baseline condition, or time period, for the River as the basis for management planning. It is expected that ongoing studies between the SFWMD, FDEP and other agencies will develop additional management targets for restoration of the Loxahatchee River.

SFWMD staff initially attempted to develop MFL criteria based on protection of the cypress community (SFWMD 2001). However, results of a scientific peer review determined that there was insufficient technical information available to support the proposed MFL. This revised (2002) proposal is based on the second MFL target shown above as a more appropriate and scientifically-defensible basis to protect resources of the Northwest Fork from significant harm. New restoration flow targets will likely be developed as part of the cooperative effort between FDEP, SFWMD and other agencies to develop a practical restoration plan for the Loxahatchee River. The MFL criteria may need to be revised when these targets have been defined.

Phased Recovery Plan

Structural components of the recovery and prevention plan will be implemented in the form of a list of projects. The list will include the timing, funding requirements, and expected benefits for each project. The relevant water resource development projects and anticipated completion dates for phasing in these projects were identified in the NPBCCWMP (SFWMD, 2002) and are summarized in the next section. These projects will provide additional water to meet the proposed MFL target and water reservations. Many of the proposed projects provide flood protection and water supply benefits as well as environmental benefits to the Loxahatchee River and watershed. The amount of water that each project contributes to improving flows to the river will be determined during the design phase. Whenever possible, efforts will be made to expedite projects that provide critical storage needs or water delivery capabilities to the River.

The Loxahatchee River is an Outstanding Florida Water body and is afforded the highest protection pursuant to 62-302.700, Florida Administrative Code. As such, no degradation of water quality is permitted to occur as a result of any projects that are implemented to restore the river and all discharges to the Loxahatchee River shall meet state water quality standards. In addition, project components of CERP, pursuant to 373.1502(3)(B)(2), F.S., (Comprehensive Everglades Restoration Plan Recovery Act) shall not contribute to violations of the state water quality standards.

Operational Protocols

The SFWMD will continue to implement existing operational protocols for facilities in this basin to meet requirements for flood control, water supply, environmental resources and water quality. In addition, the District will provide the MFL flow of 35 cfs and continue to provide flows of 50 cfs or greater from the Lainhart Dam to the Northwest Fork whenever water is available, consistent with the operational protocol currently in place. The determination of water availability is made by the SFWMD based on rainfall conditions (Florida Wildlife Federation vs. SFWMD, 1982). The SFWMD will also attempt to minimize occurrences of flows less than 35 cfs, in accord with the recovery strategy. Once facilities are constructed to connect the Loxahatchee Slough to the regional water delivery system, the District will have the ability to provide additional water to reduce or prevent exceedance of MFL criteria.

Regulatory Components

The regulatory component for the Loxahatchee River considers specific modifications that are needed to address issuance of Consumptive Use, and Environmental Resource Permits in this watershed. In addition, the strategy addresses implementation of water shortages and development of water reservations. Specific provisions regarding the regulatory components of the recovery and prevention for the Loxahatchee River are discussed beginning on page 165.

PHASED RECOVERY PLAN

The following provides a summary of the District's proposed phased MFL Recovery Plan for the Loxahatchee River and Estuary. Major features of Phases 1-2, to be completed by 2006 are shown in **Figure 33.**

Phase 1 (2002)

District staff will work to identify specific improvements that can be implemented during the next year to improve conveyance capacity by 20 to 50 cfs to the Northwest Fork during dry conditions, when water is available. The ability to provide water from the City of West Palm Beach's Water Catchment Area (Grassy Waters Preserve) to the Northwest Fork of the Loxahatchee River, without significantly lowering the stage within the Grassy Waters Preserve, is severely limited by the City's current pumping and conveyance capacity from the L-8 Canal into the M-Canal (and subsequently into the Grassy Waters Preserve). Based on recent observations and depending on the severity of the dry conditions (normal dry season versus drought) the influent capacity only exceeds demands by 10 to 20 cfs. During this period the District will work with the City of West Palm Beach, Palm Beach County and DOT to:

- Install new culverts under the entrance road into the Grassy Waters Preserve Southern Nature Center.
- Perform maintenance consisting of removal of exotic vegetation, maintenance excavation and grading to clear out obstructions and allow approximately 20 cfs of flow from the eastern perimeter canal of the Grassy Waters Preserve to the three western 72-inch diameter culverts under North Lake Boulevard.

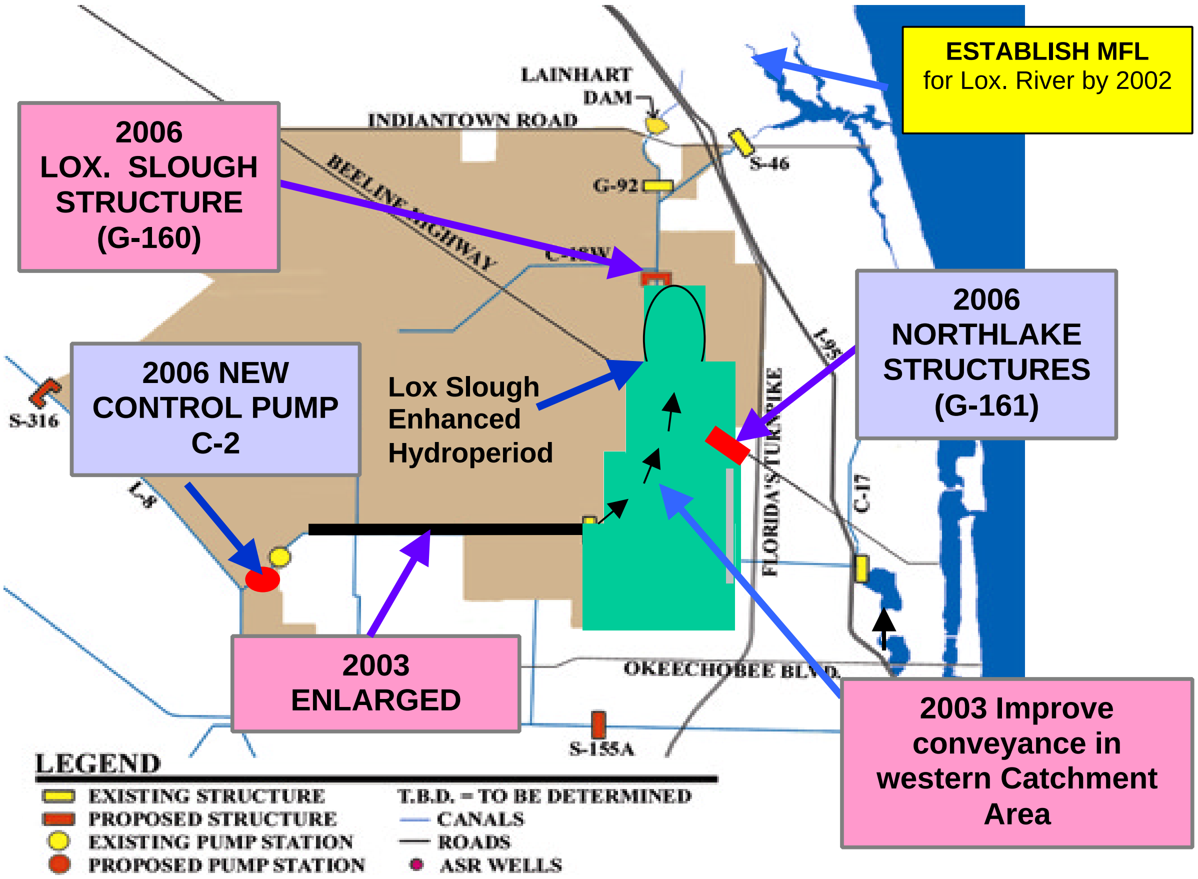


Figure 33. Loxahatchee MFL Recovery Plan, Phases 1-3 (by 2006) (From: Northern Palm Beach County Comprehensive Water Supply Plan).

- Evaluate the constraints imposed by ground surface elevations, existing roads, existing buildings, and existing control structures on the ability to route water from the north side of North Lake Boulevard (at the existing three 72-inch diameter culverts and eastward) to the box culverts under the Bee Line Highway (SR 710). This includes evaluating both the constraints and conditions of Control 5 (controls flow of water from North Side of North Lake Boulevard to the East).
- Complete the L-8 Reservoir Pilot study

Phase 2 - Five Years (2002 through 2006)

Implement improvements to enhance flow capacity during both dry and wet conditions:

- Obtain permit and construct Loxahatchee Slough structure (G-160) to provide additional capacity, as described in the Northern Palm Beach County Comprehensive Water Management Plan (SFWMD 2002), to improve hydrologic conditions in the Slough and store water for discharge to the Northwest Fork during the dry season.
- Install a new C-2 pump station and increase M-Canal conveyance capacity from L-8 basin to Grassy Waters Preserve by 450 cfs.
- As required, modify existing structures to provide conveyance and water quality

enhancement (North of North Lake Boulevard) including:

- Construct a spreader swale north and parallel to North Lake Boulevard
- Remove, breach, or construct additional culverts through berms or other obstructions
- Install new structures along Northlake Blvd (G-161) to provide up to 150 cfs to the Loxahatchee Slough and Northwest Fork. This will require building a structure and/or constructing an enhanced flow way and preferential flow path as needed, to accommodate dry and normal wet weather flows, as well as large storm water events to maintain the required level of drainage and flood protection, without significantly damaging the flow way area.

- As part of the Comprehensive Everglades Restoration Plan process, complete project management plans (PMP) and project implementation reports (PIR) for water supply projects that will provide addition flow and water storage capacity for the Loxahatchee watershed.

Phase 3 - Five Years (2011-2014)

Implement improvements that will substantially increase the sub-regional conveyance and storage capacities and provide the water distribution system required by both the CERP and the Lower East Coast Regional Water Supply plan (LECRWSP).

- Construct Grassy Waters Preserve perimeter canal improvements (2011)
- Consider installation of pumps, as described in the NPBCCWMP, to capture runoff from the J.W. Corbett Wildlife Management Area for storage within Loxahatchee Slough.
- Construct the L-8 reservoir to add 48,000 ac-ft of storage capacity to the water management system (2014)

Phase 4 - CERP (2002 through 2021)

Improvements to complete the development of sub-regional storage capacity to meet the year 2050 needs.

- Construct 10, 5-MGD local Aquifer Storage and Recovery (ASR) wells (50 MGD total injection capacity) to increase basin storage and reduce competition for surface water

Summary of Project Costs and Benefits

The costs and benefits of the nine key projects for increasing storage within the basin and reconnecting the Loxahatchee Slough and Northwest Fork of the Loxahatchee River with the regional water supply system as described in the NPBCCWMP (SFWMD 2002) are summarized in **Table 42**. These projects also represent the District's proposed "MFL Recovery Plan" that are designed to meet the proposed MFL (35-cfs) over the next 5 years, and ultimately meet the District's proposed target flows (65-cfs) by year 2018. The total cost for implementing these projects is estimated at approximately $39 million.

Water Delivery Benefits of Proposed Projects

Table 43 provides a summary of output from these model simulations showing the relative improvements over time in the District's ability to meet both the 35-cfs and 65-cfs flow targets based on implementing these projects. The amount of water produced by these projects over time is represented in **Figure 34.**

Table 43. MFL Recovery Program showing incremental improvements in the District's ability to meet the proposed 35 cfs flow target (based on output from NPBCCWMP models*).

Desired Flow target	1995 Base Case Without Improvements			2006 with G-160 + G-161 in place			2018 with LEC Plan and CERP Projects constructed		
	% time below target	No. Events	Avg. Duration (days)	% time below target	No. Events	Avg. Duration (days)	% time below target	No. Events	Avg. Duration (days)
65 cfs	59	389	5	30	155	6	0.8	4	6
50 cfs	54	273	5	19	138	5	0.6	3	6
35 cfs	49	296	5	6	35	5	0	0	0
20 cfs	44	256	6	1	15	2	0	0	0
10 cfs	20	177	4	<0.1	1	1	0	0	0
5 cfs	6	146	3	0	0	0	0	0	0
2 cfs	5	130	2	0	0	0	0	0	0

*The models are spreadsheet based (Excel) consisting of 3 linked workbooks: the Southern L-8 Basin model, the Grassy Waters Preserve Model, and the Loxahatchee Slough model. Model input includes an 8 year POR (1985-1992) for rainfall and ET, a 65 cfs flow target for the NW Fork of the Loxahatchee River, defined hydroperiod targets for the Loxahatchee Slough and Grassy Waters Preserve, and future water supply demand for the area. For details, the reader is referred to Volume II, Technical Support Document, Northern Palm Beach County Comprehensive Water Supply Management Plan (SFWMD 2002).

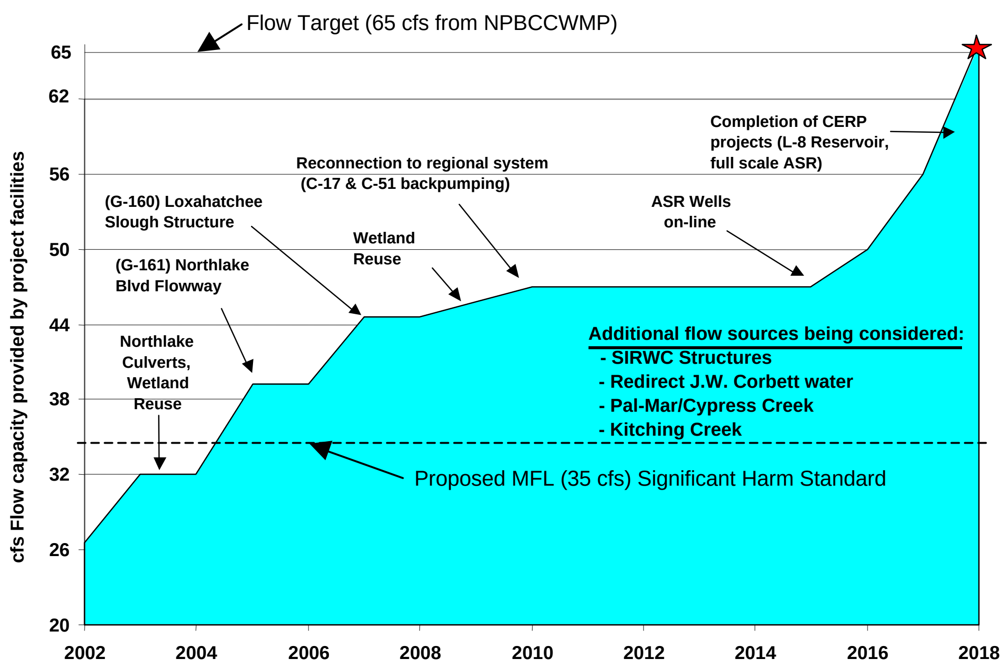


Figure 34. Conceptual representation of increase in flows to the Northwest Fork as projects in the NPBCCWMP and CERP are completed

EVALUATE OPTIONS TO OBTAIN WATER FROM OTHER BASINS

Pal-Mar/Cypress Creek and Hobe Groves

Cypress Creek/Pal-Mar and the Groves are two of the seven sub-basins in the Loxahatchee River watershed. These two basins occupy approximately 63 square miles (40,500 acres) in Martin and Palm Beach Counties. Cypress Creek and Hobe Groves Ditch discharge surface water from these basins to the Northwest Fork. The Cypress Creek/Pal-Mar Basin is made up of 86% native uplands and wetlands. A little over 10,000 acres of native uplands and wetlands are in public ownership in the Hungry Land Wildlife and Environmental Area. The majority of runoff from this basin moves through overland flow from west to east then discharges into the Ranch Colony Canal and Cypress Creek. The eastern portion of the basin has been significantly altered to accommodate agricultural and residential land uses. Citrus groves are the predominant land use in the Groves Basin, which is drained by the Hobe Groves Ditch and the Federation Canal.

Four agencies -- the SFWMD, Florida Fish and Wildlife Conservation Commission, the Florida Department of Environmental Protection and Martin County -- have teamed together, using SFWMD funds, to initiate a study of these areas. Many water resource related problems have been identified such as; (1) upstream movement of salt water in the Northwest Fork of the Loxahatchee River, (2) sediment loading in Cypress Creek and the Loxahatchee River, (3) flooding in Ranch Colony during severe storms, and (4) overdrainage in the Pal-Mar wetlands.

A set of models that represent the hydrologic and hydraulic processes in the Cypress Creek/Pal-Mar and the Groves Basins will be developed. The models will provide a basis for potential solutions to the current problems of the area, such as a) optimal management of the wetlands on the Pal-Mar property, b) possible diversion of flow from the C-44 Canal through Pal-Mar to supplement flow to the Northwest Fork; and c) identification and management of discharges from the Groves and Cypress Creek to the Northwest Fork.

Kitching Creek

Three projects are being considered by Martin County as follows, to provide additional water in this basin that could potentially improve groundwater and surface water flows to the Northwest Fork.

1. Kitching Creek Water Quality Improvement Project

The Kitching Creek Water Quality Improvement Project will enhance surface water flows to the Northwest Fork by raising average wetland water levels by as much as 2 feet over an area exceeding 1,000 acres located north of the Northwest Fork. Water table elevations in these wetland areas will be increased by a similar amount and will serve to increase the groundwater contribution to the Northwest Fork. These water management improvements are located in the vicinity of 138th Street and Bridge Road in Martin County, and extend south toward Jonathan Dickinson State Park. Benefits of this alternative are (a) rehydration of wetlands, (b) water quality improvement, (c) reduction of flood levels, and (d) return of portions of Kitching Creek to its predevelopment flow way (Earth Tech 2000).

This part of the overall project redirects Kitching Creek flows that currently travel to Jenkins Ditch and cause erosion and flooding. The flows will be redirected to the southwest through wetlands and into Kitching Creek's predevelopment flow way and to a wetland system located south of 138th Street. Flooding is reduced along 138th Street, Powerline Road, and Kitching Creek Road. These water management measures are accomplished by blocking existing culverts under Bridge Road and installing new culverts in different locations, possible re-engineering of a portion of Bridge Road, regrading existing drainage ditches and low quality wetlands to provide shallow, wide flow ways, installation of stormwater treatment ponds, and installation of berms and other water control structures.

2. Kitching Creek East Tributary Diversion Berm

This water management improvement project is located in the vicinity of the intersection 138th Street and Powerline Avenue located in Martin County. Benefits of this alternative are rehydration of wetlands, reduction of erosion, and reduction of flooding. This portion of the project creates a diversion that redirects flows into the predevelopment flow way of Wilson Creek and away from populated areas along Powerline Avenue and Kitching Creek Road. This diversion is accomplished by blocking existing culverts at the intersection of Powerline Avenue and Bridge Road, installing a new culvert under Bridge Road east of the intersection, and providing a 2-ft. high berm to direct the water southeast toward Wilson Creek, within Jonathan Dickinson State Park.

3. Flora Avenue Area Improvements

Flora Avenue water management improvements extend approximately 8,000 feet southward from the intersection of Flora Avenue and Bridge Road. Benefits of this project component are improvements in the water quality flowing into Jonathan Dickinson State Park property south and east of Flora Avenue and decreasing the level of flooding of Flora Avenue residences and businesses. Reduced flooding along Flora Avenue will be accomplished by raising an approximate 2000-ft section of the roadway and providing a new water quality structure adjacent to Flora Avenue. Stormwater from developed areas along the road will be routed to detention ponds for attenuation and sediment removal prior to discharge to Jonathan Dickinson State Park.

OPERATIONAL PROTOCOLS

Interim Operating Procedures

During the next several years, while facilities are being constructed and more detailed operational plans for these facilities are being developed, the SFWMD will continue to operate regional facilities in the manner that has been used during the past decade (1990 to 2001). During this period, discharges to the Northwest Fork have improved considerably relative to deliveries that were provided during the 1970's and 1980's. The average amount of water delivered to the Northwest Fork via the Lainhart Dam increased from an annual average of 55-74 cfs in the 1970's and 1980's to an average flow of 106 cfs during 1990-2001 (see **Figure 19**, Chapter 5). These increases occurred due to G-92 conveyance and telemetry improvements and increased rainfall amounts experienced in the basin (**Figure 4**, Chapter 2). The result has been that the distribution of plant communities along the river has not changed significantly since 1984 **(Figure 27,** Chapter 5).

In addition, the District will continue provide flows of 50 cfs or greater from the Lainhart Dam to the Northwest Fork of the River whenever possible, consistent with the operational protocol currently in place. The determination of water availability is made by the SFWMD based on rainfall conditions (Florida Wildlife Federation vs. SFWMD, 1982). Generally, water is discharged from the C-18 through the diversion structure at G-92 depending on the relationship between water levels in the C-18 and the Northwest Fork at Indiantown Road. Water is diverted to the C-14 when (a) flows in the C-14 fall below 50 cfs; and (b) when levels in the C-18 exceed 12.5 feet NGVD (normal canal stage is 14.5 feet NGVD).

Examination of the historical record indicates, on average, that Lainhart Dam flows delivered to the Northwest Fork are generally above 50 cfs as shown in **Table 23** where the overall average dry season flow is 70 cfs for the period of record of 1971-2001. Average dry season flows may be as low as 26 cfs during major regional droughts such as occurred in 1989-90 (**Table 23**) and these problems cannot be fixed until additional storage and conveyance facilities are constructed within the basin. The District will increase the amount of water released to the Loxahatchee River, to eventually achieve the 65 cfs management target that was identified in the NPBCCWM Plan, as projects identified in that plan are completed.

Development of New Operational Protocols

Once the necessary facilities have been constructed to provide a connection between the Loxahatchee Slough and the regional water delivery system, the District will have the ability to deliver water to reduce or prevent the MFL criteria from being exceeded. Operational guidelines necessary for implementation of water supply deliveries to achieve MFLs, in concert with meeting other required water demands, will be identified as these facilities are designed and constructed.

DESIGN AND OPERATIONAL ISSUES SUGGESTED FOR CONSIDERATION BY CONCERNED CITIZENS AND OTHER AGENCIES

A number of additional issues and concerns have been identified by the public and other agencies that need to be considered as part of future research and monitoring efforts, regulatory activities, CERP, and regional water supply planning processes. For the most part, these issues are beyond the scope of the MFL process for the Northwest Fork, but need to be considered by other related activities as they move forward. The issues are identified in **Table 44**, along with those activities or processes that should be used to address these concerns.

REGULATORY COMPONENTS OF THE MFL RECOVERY AND PREVENTION STRATEGY

The overall goal of the District's consumptive use permitting program as it relates to the Loxahatchee River is to regulate the amount of water withdrawn from the river, its tributaries (C-18, Cypress Creek, Hobe Grove Ditch, and Kitching Creek), and the surficial aquifer adjacent to the river consistent with the District rules governing consumptive uses that may influence a MFL water body in recovery (Rule 40E-8 F.A.C.). The regulatory component will apply to consumptive use applications for renewals, new uses, and modifications to existing permits that influence the MFL water body. A major objective of the District's Regulatory Program is to protect the Northwest Fork from unacceptable consumptive use impacts while the capital and operational components of the Recovery Plan are implemented. In addition to the MFL Recovery Plan, a restoration effort will be underway with leadership from FDEP to define a practical restoration goal for the River. Regulatory considerations must be consistent with the

Recovery Plan in support of the restoration effort and will include protecting reserved water supplies from consumptive uses and continuing to impose water quality protection criteria on projects that will discharge water to the Northwest Fork of the Loxahatchee River.

Consumptive Use Provisions/MFL

During the period while the new water conveyance and storage facilities are being constructed, the District intends to issue and renew Consumptive Use Permits (CUP) in a manner that will balance the needs of the environment with the needs for public and agricultural water supply. CUP applications that propose to withdraw water directly or indirectly from the Loxahatchee watershed, that meet the conditions for permit issuance in Part II of Chapter 373,.

Table 44. Loxahatchee River design and operational issues and ongoing or future activities that should address these concerns.

Design/Operational Issue	Process or Activity to Address this Issue
Whether MFL's need to be established for all tributaries to the Loxahatchee River	Cypress Creek, Hobe Grove Ditch and Kitching Creek were added to the MFL Priority List
Determine the amount of water from the L-8 Reservoir that will be available for the Northwest Fork	Reservations of water; development of operational protocols for facilities
Potential purchase of agricultural lands that could be used as reservoirs	LEC and UEC Water Supply Planning Process; determination of restoration needs; CERP and RECOVER processes
Consider the purchase additional lands in the C-18, Pal-Mar or other basins for use as reservoirs or STAs	LEC and UEC Water Supply Planning Process; CERP and RECOVER processes
Use the Reese/Gildan flow-ways and shallow lakes as a reservoir (bleed down only to control)	Development of operational protocols for facilities
Examine opportunities to use water from local developments, with appropriate treatment to meet OFW standards, to enhance flows to the Northwest Fork.	Surface water management/ERP permitting
Send water from Corbett Area to the C-18 Canal for the Northwest Fork	CERP planning process; reservations of water; development of operational protocols for facilities
Increase storage on the Dupuis Reserve to be sent to the Northwest Fork	CERP planning process; reservations of water; development of operational protocols for facilities
Create a reservoir in the C-51 Basin to be sent north to the Northwest Fork	CERP planning process; reservations of water; development of operational protocols for facilities; NPBCCWMP/ LECRWSP Implementation)
Establish a hydrologic connection from the C-44 Basin through Pal-Mar to provide for storage, treatment and discharge of water into the Northwest Fork.	CERP and RECOVER processes; IRL feasibility Study; UEC Water Supply Planning process
Develop facilities needed to store water in the Kitching Creek basin	CERP planning and RECOVER processes; UEC Water Supply Planning process)
Allocate water from new storage facilities for use by the Northwest Fork, depending on availability	NPBCCWMP Implementation; CERP process; reservations of water; development of operational protocols for facilities
Build future reservoirs should be built on disturbed properties rather than pristine lands	LEC and UEC Water Supply and CERP processes
The benefits and impacts of salinity barriers should compared with the benefits and impacts of constructing reservoirs	Determination of restoration water needs; LEC and UEC Water Supply Planning; and CERP planning

F.S., the District's Water Use **Basis of Review**, and Rule 40E-20, F.A.C as applicable, and are consistent with the approved recovery and prevention strategies under Section 373.0421, F.S., will be permitted. These permit applications will be reviewed based on the recovery and prevention strategy approved at the time of permit application review.

Existing or proposed consumptive uses that influence the Loxahatchee River shall be regulated consistent with the provisions contained in District rules 40E-2, 40E-8, 40E-20 and 40E-21 F.A.C., for MFL water bodies under recovery. Copies of these rules can be obtained by mail from the SFWMD or downloaded from the SFWMD website at www.sfwmd.gov. A copy of the MFL rule, Ch. 40E-8 F.A.C., is included in **Appendix L**.

Specific MFL criteria regarding the Loxahatchee River will be formally incorporated into the District rules by Governing Board action consistent with rule making procedures. These criteria will include the following:

1. The definition of the Loxahatchee River: The area of the water body where the MFL criteria will apply (e.g. the River bed that occurs between specific mile markers that are defined in the rule).
2. The MFL criteria consisting of the threshold flow rate, the location of the flow measuring point, the maximum duration that the flow may fall below without exceeding the criteria, and the return frequency beyond which will result in significant harm (e.g. [as currently proposed] 'a flow of less than 35 cfs which persists for more than 20 consecutive days and occurs more frequently than once every 6 years).
3. A reference to the approved recovery plan (included in this document).

These three parts of the rules will help define where the special CUP criteria will apply and identify the elements of the recovery plan that address project water available for recovery. In addition these rule criteria establish under what conditions MFL recovery plan provisions apply versus when other prevention and restoration criteria apply.

Water Shortage Plan Implementation

Water shortage rules for the Loxahatchee basin should be substantially the same as those currently set forth in Chapter 40E-21. If necessary to prevent the MFL criteria from being exceeded, demand management cutbacks for recovery during drought conditions will be identified, to the extent that water withdrawals are causing the MFL exceedance (e.g., phased water shortage restrictions to prevent significant or serious harm). When a drought occurs, the SFWMD will rely upon the Water Shortage Plan to address regional water availability. Water shortage restrictions will be imposed as required by District rules, on the direct or indirect withdrawals from a MFL water body. Water shortage cuttbacks will be imposed if a MFL exceedance occurs or is projected to occur during climatic conditions more severe than a 1-in-10 year drought, to the extent that consumptive uses contribute to such an exceedance.

During such drought circumstances, the District will equitably distribute available supplies to prevent serious harm to the water resources, pursuant to Sections 373.175 and 373.246, F.S., and the District's Water Shortage Plan, Chapter 40E-21, F.A.C. The Water Shortage Plan utilizes a phased cutback approach with the severity of use restrictions increasing commensurate with increased potential for serious harm to the water resources. The water shortage rules implementing the recovery strategy for the Loxahatchee will be similar to those that apply to other recovery areas, such as the Everglades and Caloosahatchee Estuary.

Restoration Components for the Northwest Fork

In addition to the MFL, rules that protect the Loxahatchee River from further withdrawals that would cause significant harm, water supplies developed for restoration of flows to the Northwest Fork must also be protected. The first step in this process is to determine the desired flow regime that is need in the river to achieve restoration. As new water sources are developed, steps must be taken to ensure that the water to meet restoration needs for the benefit of fish and wildlife is available for that purpose. This will be accomplished through the adoption of water reservations. As contemplated in the *Lower East Coast Regional Water Supply Plan* (SFWMD, 2000c), an initial reservation of existing flows would be established by rule. This initial reservation would consist of variable flows, which would be determined by the existing basin configuration, its response to rain and drought, and the need to protect fish and wildlife. Existing legal uses are protected from the reservations in so far as they are not contrary to the public interest. As new water resources development projects are constructed and operated, the amount of water made available for restoration from that project will be added to the reservation while the remaining portion of the project water made available for consumptive use will be available for allocation.

Environmental resource permits are required when land use changes result in discharge of storm water for flood protection or otherwise impact environmentally sensitive lands. The rules governing these permits are contained in SFWMD rules 40E-4 F.A.C. Within these rules are special criteria relating to the water quality of storm waters discharging to Outstanding Florida Waters (contained in Ch. 62-302 F.A.C.). These higher levels of treatment requirements and permit protections are applied to new projects which discharge to the Loxahatchee River, which has been established as an Outstanding Florida Water (OFW).

In addition to enhanced water quality standards for waters that discharge to the River, environmental resource/surface water permits address drainage. Currently, each project is developed such that the rate of discharge that occurred off the land prior to development is equivalent to the rate of discharge after the project. These "pre-versus-post" criteria can also be applied to the volume stored on the project. Within the Loxahatchee watershed, where additional storage is needed, volume-based criteria could be beneficial to the Loxahatchee River. However, the expense of providing this extra storage is significant and may not be cost-effective. An evaluation of a "pre-versus-post" volume permit criteria for lands that discharge to the Loxahatchee River or its tributaries should be undertaken to determine if the cost of implementing these criteria would produce beneficial improvements to the hydrology of the Northwest Fork. Additional hydrologic watershed analyses will be needed to establish the technical basis for adopting new permitting criteria designed to achieve the goal of improving the timing and distribution of inflows to the Northwest Fork.

Water Reservations

Legal Description

Section 373.223(4), F.S., provides the following in relevant part:

The governing board or the department, by regulation, may reserve from use by permit applicants, water in such locations and quantities, and for such seasons of the year, as in its judgment may be required for the *protection of fish and wildlife or the public health and safety*.

The statute also provides that reservations are subject to periodic review based on changed conditions. This provides flexibility to account for changes in implementation strategies and contingency plans during the next 20 years. A specific level of protection is also provided to existing legal users when establishing reservations. Existing legal users are protected insofar as they are "not contrary to the public interest" (Section 373.223(4), F.S.).

Development and Implementation

Water reservations for the Loxahatchee River will be developed and implemented consistent with reservations for the other restoration areas covered by the CERP. Currently, the policy and technical approach for CERP reservations is under development. The first reservation of existing water for the Loxahatchee River which has been historically delivered to the river and identified for the protection fish and wildlife resources is anticipated to be made by the end of 2004. The appropriate timing, depth, distribution and volume of these deliveries needed to protect the resource will be jointly developed by SFWMD and FDEP technical staff.

ADAPTIVE MANAGEMENT OF THE LOXAHATCHEE RIVER AND ESTUARY

Based on best available information, a minimum flow has been proposed for the Northwest Fork, with the understanding that more information is needed to refine assumptions used in criteria development. Ongoing and proposed research and monitoring efforts in the Loxahatchee River, estuary and watershed are designed to provide data to fill gaps in our understanding of the ecosystem. Research and monitoring efforts will be targeted to the VEC approach, based on the freshwater floodplain community, as presently proposed, and potentially to consider other resources in the river and estuary. This information will be incorporated into the next generation of hydrodynamic, salinity, watershed and ecological models now under development. Improved models will provide SFWMD staff with an opportunity to reevaluate the proposed criteria and refine the Northwest Fork MFLs in accordance with regional water supply plan development and implementation activities

Research Needs

The criteria developed in this document should be used as the basis for SFWMD rule development and to incorporate monitoring of the MFL criteria as a factor to be considered in the issuance of Consumptive Use Permits, both individually and cumulatively, within the LEC Planning Area and, more specifically, within the Northern Palm Beach County water supply planning area.

The following provides a summary of proposed research projects needed to refine or verify the proposed MFL criteria for the Loxahatchee River and estuary. In addition, the Loxahatchee River Environmental Control District has recommended research and/or continued monitoring of submerged aquatic vegetation, macroinvertebrates, nutrients, trophic state, and dissolved oxygen in the upper reach of the Northwest Fork. In the development of this document, District staff relied primarily on existing monitoring and research data to identify technical relationships among flow, salinity and observed impacts to the river's biological resources. The research projects listed below are proposed over the next several years to collectively evaluate and/or refine the proposed MFL flow target and duration criteria as necessary.

These criteria will need to be reviewed, and perhaps revised, as: 1) additional data becomes available through future research and monitoring projects; 2) prevention and recovery strategies are implemented; 3) environmental conditions may change over time (i.e. due to sea level rise or climate change), or 4) additional experience is gained through refined modeling. The following additional research and monitoring projects should be considered for future refinement of the MFL criteria for the Loxahatchee River. These studies have also been specifically identified by Loxahatchee regulatory agencies and interest groups, as necessary for future management efforts:

- **Refine MFL Criteria.** Develop a 3 year research plan that will (a) evaluate and or refine the proposed MFL flow target and develop a new target as necessary, (b) refine the proposed minimum duration criteria, and (c) identify other potential VECs in the river and estuary to complement the use of floodplain vegetation. Develop a research plan that will provide a science-based estimate the number of days that water levels may remain below the proposed MFL without impacting the upstream communities. A major focus of this research will be to identify a science-based estimated number of days that surface water flows in the Northwest Fork can remain below the proposed minimum flow without causing significant harm to the upstream river and floodplain communities. The proposed projects will also provide information that can be utilized by regulatory agencies to make informed decisions regarding the effects of the existing and proposed modified hydrologic regimes, on the natural system of the River, and potential future management efforts.
- **Salinity Barrier Feasibility Analysis.** Model the feasibility of installing a salinity barrier within the Northwest Fork to prevent saltwater intrusion of the upstream river system during dry periods (2002) and determine the effects of such a barrier on biological resources, salinity and water quality. The barrier may be permanent, temporary, fixed or adjustable. If the feasibility study warrants construction of a barrier, engineering plans for construction of the barrier will be developed (2003). Several meetings were held in 1975 concerning the feasibility of a salinity barrier. Drawings were completed regarding the proposed structure, and all but the final design are available at the District 5 Administration Office Florida State Parks.
- **River Restoration.** In cooperation with FDEP, develop a practical restoration plan for the Loxahatchee River and estuary that addresses ecosystem management goals and objectives of the Wild and Scenic River, Jonathan Dickinson State Park and aquatic preserves in the estuary and adjacent waterways. An open public process that involves all of the major agencies, environmental interests and the public will be developed and used to determine the appropriate enhancement goals for the River. The practical restoration plan should be based on rainfall-based water delivery system model for the Loxahatchee watershed that develops surface water flow requirements from all major tributaries and groundwater inflow. Appropriate restoration targets that re developed in this process will be included as CERP projects are designed and developed.
- **Estuary Research.** A major assumption in the development of the MFL was the use of the Valued Ecosystem Component (VEC) method to establish the MFL based on protection of upstream freshwater communities. Additional information is needed to determine the effect of the proposed minimum flow regime on the nursery function and extent of oligohaline habitat as well as other downstream estuarine or marine species. During the

next fiscal year, District staff will review and analyze existing water quality and biological data collected from the river to elucidate relationships between river flow and biological response. Additional monitoring may also be necessary to measure the effect of the proposed MFL on these resources, and the results of these studies may necessitate future adjustments to the MFL.

- **Watershed Modeling.** Develop a watershed management plan, incorporating elements of this report, the *Wild and Scenic River Management Plan* (SFWMD 2002) and the *Watershed Action Plan* (FDEP, 1998) for all tributaries that drain into the Loxahatchee River system, including determination of whether MFLs should be established for these tributaries and/or groundwater inflows. This plan will be initiated by expanding the current Basin Assessment and Hydraulic/Hydrologic Study of Cypress Creek/Pal–Mar and the Groves project to develop a Cypress Creek Basin watershed model, that could be utilized for other drainage basins within the Loxahatchee Watershed. This watershed modeling effort would be the first step to: 1) develop a sub-regional hydrologic model that addresses existing Water Use Permits for the Loxahatchee Watershed and their effect on providing minimum flows for the Northwest Fork; 2) provide hydrologic studies of drainage basins that discharge to the Loxahatchee River, to determine which basin is the best source of water to provide minimum flows to the River and Estuary; and 3) determine the relationship between the Northwest Fork, Loxahatchee Slough and the surficial aquifer.

Monitoring Program

- **Ground Water/Soil Salinity Monitoring.** Develop a research program that will investigate the relationship between the movement of saltwater into the cypress forest floodplain groundwater system, quantify and map soil salinity within the river floodplain, establish river wetland plant species salinity and duration tolerances, install water quality monitoring wells and fund a groundwater quality monitoring program within the cypress forest floodplain that will measure groundwater salinity in relationship to Northwest Fork flows.

Groundwater and soil monitoring stations should be established within the floodplain of the Northwest Fork to identify locations of saline groundwater and soil, and to quantify the amount of saline contamination. Data collected from this monitoring will be specifically correlated with other river monitoring and research data (i.e. flow data and surface water, salinity data, vegetative data) to refine the relationships between flow, salinity and the cypress wetland community.

In addition, efforts will be increased to monitor groundwater levels during dry periods as part of the current saltwater intrusion monitoring program. These data can be used as a basis to implement water restrictions when it can be measurably shown that a particular consumptive use has the potential to impact the resource.

The purpose of these efforts is to collect additional data that can be used to a) provide better estimates of groundwater flow to the river at critical points in the watershed, b) refine the interactive groundwater/surface water model that is presently being developed, and c) identify "hot spots" that could potentially impact the slough or the river during dry periods.

Upon adoption of the proposed MFL, the SFWMD would initiate a review of the existing monitoring network, add monitoring stations where deemed appropriate, and establish performance measures that can be used to determine whether observed changes in ground water condition during declared drought periods are having significant effects on the Loxahatchee River.

As part of this monitoring program, SFWMD staff may also review pumpage data provided by major users for major wells and wellfields. These data provide a means to determine whether water restrictions are needed within the basin or whether utilities or other uses should implement cutbacks or shift withdrawals away from problem areas.

- **River Corridor Vegetation Monitoring.** The SFWMD will develop a research and monitoring program to more thoroughly investigate the relationship between the upstream movement of the saltwater wedge and adverse impacts to the floodplain community on the Northwest Fork and Kitching Creek. The program will establish permanent vegetation transects to document and identify vegetative species salinity level and duration tolerances; how different salinities affect physiology; growth and recruitment; and the short-term and long-term change(s) in relation to flow and salinity. The feasibility of using tree ring analysis to determine historical salinity conditions in the river will be evaluated. Data collected from this monitoring will be specifically correlated with other monitoring data (i.e. flow, surface water, groundwater, soil, and salinity data) to refine the relationships between flow, salinity and freshwater wetland communities in the Northwest Fork
- **Tributary Flow Monitoring.** Additional water level and flow monitoring needs to implemented within the basin to provide additional data for the models and to document the effectiveness of SFWMD management actions in terms of maintaining appropriate flows to the river. Besides monitoring of levels and flows at G-92 and Lainhart Dam, water flows and levels should be monitored at other points along the river, including flows and upstream and downstream levels at control structures on Cypress Creek and Hobe Grove ditch, water level and flow data for Kitching Creek near the confluence with the Northwest Fork and perhaps at one or two other locations in the main stream of the River between river mile 6 and river mile 9.

  As part of the MFL monitoring network, install real-time flow monitoring gages for each major tributary that drains into the Northwest Fork of the river. Gages are already operational for G-92 and the Lainhart Dam. Additional telemetry gages may need to be installed to monitor flows from Cypress Creek, Hobe Grove Ditch, Kitching Creek and Jupiter Farms

  Flows at the Lainhart Dam currently fall below the proposed significant harm standard of 35 cfs about 25% of the time (on average 6-7 events/yr. with an average duration of 15 days). Water management structures (culverts/riser boards) that provide surface water hydrologic connections between the river/slough and adjacent properties may have to be closed during critical periods to avoid over drainage of Loxahatchee Slough. Monitoring is needed to determine whether the MFL criteria are being achieved and how much additional flow can be provided that will help meet restoration goals and objectives for the river.

- **Water Quality Monitoring.** Monitor salinity at the (i) the confluence of Kitching Creek and the Northwest Fork of the river (river mile 8.1) and (ii) at a site located approximately one mile up river (river mile 9.1), or whatever point is most appropriate as agreed to by FDEP and SFWMD staff. Expand routine water quality monitoring network to include

Loxahatchee River tributaries and address water quality monitoring needs associated with river restoration and determination/monitoring of Total Maximum Daily Loads for critical parameters.

Adaptive Management Operational Strategy

A possible interim operational strategy for releasing water from G-92 to downstream areas of the Northwest Fork, during the next four years before additional storage facilities are online, might include the following components:

Components

a. During dry periods, data provided from water level gages, flow data and salinity monitoring data can be used by SFWMD operations staff to release water from G-92 only as needed to provide supplemental flow to the river as needed to maintain salinity at the desired level

b. If significant flows are occurring from other tributaries, flows from G-92 could be reduced proportionally. Such a reduction in flow will allow additional water to be effectively stored in the Loxahatchee Slough to be released later in the dry season.

c. During extremely dry periods, flows from G-92 will be managed to maximize the time that flows above 35 cfs can be delivered to the Northwest Fork (this may extend the time that Phase I and Phase II restrictions are imposed and may reduce the likelihood and duration of Phase III restrictions).

Benefits

- The proposed basin-wide MFL research monitoring program and the installation of additional real-time monitoring gages will provide additional data required to model the performance of this watershed, manage and conserve water during drought periods and protect the Northwest Fork against significant harm.
- Provides information needed to assess the ability of operational and regulatory strategies to protect the resource.
- Provides additional incentives to move forward with Loxahatchee Slough, Grassy Waters Preserve and L-8 Basin improvements.
- Provides additional time and data necessary to identify restoration needs and develop plans.
- Implementation of the proposed adaptive management strategy is especially important during the next four years, while additional facilities are being constructed to store and deliver more water.

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GLOSSARY

1995 Base Case A model simulation that provides an understanding of the how the 1995 water management system with 1995 land use and demands responds to historic (1965-1995) climatic conditions.

1-in-10 Year Drought A drought of such intensity, that it is expected to have a return frequency of once in 10 years. This means that there is only a ten percent chance that less than this amount of rain will fall in any given year.

1-in-10 Year Level of Certainty Probability that the needs for reasonable-beneficial uses of water will be fully met during a 1-in-10 year drought.

2020 Base Case A model simulation which provides information of how the 1995 water management system would respond to anticipated future operations and demands under historic (1965-1995) climatic conditions with currently authorized restoration projects implemented, but without Restudy features.

2020 with Restudy A model simulation which provides information on how the water management system will perform with the implementation of the Restudy projects that would be completed by 2020 along with 2020 demands and operating criteria.

Achievable Restoration Goal The level of restoration can be achieved given the physical, structural, ecological (and cultural) constraints of the system.

Acre-Foot The volume of water that would cover one acre to a depth of one foot; 43,560 cubic feet; 1,233.5 cubic meters; 325,872 gallons.

Agricultural Field Scale Irrigation Requirements Simulation (AFSIRS) A simple water budget model for estimating irrigation demands that estimates demand based on basin specific data.

Agricultural Self-Supplied Water Demand The water used to irrigate crops, to water cattle, and for aquaculture (fish production), that is not supplied by a public water utility.

Anoxic Denotes the absence of oxygen

Aquatic Preserve Water bodies, as described in the aquatic preserve Act (Ch 258 F.S.) and administered under rules in Ch. 16Q-21 and 16Q-20 F.A.C., that are set aside by the state to be maintained in essentially natural or existing condition, for protection of fish and wildlife and public recreation so that their aesthetic biological and scientific values may endure for the enjoyment of future generations.

Aquifer A portion of a geologic formation or formations that yield water in sufficient quantities to be a supply source.

Aquifer System A heterogeneous body of intercalated permeable and less permeable material that acts as a water-yielding hydraulic unit of regional extent.

Aquifer Storage and Recovery (ASR) The injection of freshwater into a confined aquifer during times when supply exceeds demand (wet season), and recovering it during times when there is a supply deficit (dry season).

Available Supply The maximum amount of reliable water supply including surface water, ground water and purchases under secure contracts.

Average-day Demand A water system's average daily use based on total annual water production (total annual gallons or cubic feet divided by 365).

Average Irrigation Requirement Irrigation requirement under average rainfall as calculated by the District's modified Blaney-Criddle model.

Average Rainfall Year A year having rainfall with a 50 percent probability of being exceeded over a twelve-month period.

Backpumping The practice of pumping water that is leaving the area back into a surface water reservoir.

Baseline Condition (see *Reference Condition*)

Basin (Ground Water) A hydrologic unit containing one large aquifer or several connecting and interconnecting aquifers.

Basin (Surface Water) A tract of land drained by a surface water body or its tributaries.

Bathymetry The measurement of water depth at various places in a body of water.

Benthos/Benthic Macroscopic organisms that live on or in the bottom substrate, such as clams and worms (contrast to plankton and nekton).

Best Management Practices (BMPs) Agricultural management activities designed to achieve an important goal, such as reducing farm runoff, or optimizing water use.

Biscayne Aquifer A portion of the Surficial Aquifer System, which provides most of the fresh water for public water supply and agriculture within Miami-Dade, Broward, and southeastern Palm Beach County. It is highly susceptible to contamination due to its high permeability and proximity to land surface in many locations.

Brackish Water with a chloride level greater than 250 mg/L and less than 19,000 mg/L.

C&SF Project Comprehensive Review Study (Restudy) A five-year study effort that looked at modifying the current C&SF Project to restore the greater Everglades and South Florida ecosystem while providing for the other water-related needs of the region. The study concluded with the Comprehensive Plan being presented to the congress on July 1, 1999. The recommendations made within the Restudy, that is, structural and operational modifications to the C&SF Project, are being further refined and will be implemented in the Comprehensive Everglades Restoration Plan (CERP).

Central and Southern Florida Project for Flood Control and Other Purposes (C&SF Project) A complete system of canals, storage areas, and water control structures spanning the area from Lake Okeechobee to both the east and west coasts, and from Orlando south to the Everglades designed and constructed during the 1950s by the U.S. Army Corps of Engineers (USACE) to provide flood control and improve navigation and recreation.

Class I through V Surface Water Quality Standards As defined by Chapter 62-302.400 Florida Administrative Code, all surface waters in Florida have been classified according to designated use as follows:

Class I	Potable water supplies
Class II	Shellfish propagation or harvesting
Class III	Recreation, propagation, and maintenance of a healthy, well-balanced population of fish and wildlife
Class IV	Agricultural water supplies
Class V	Navigation, utility, and industrial use

Commercial and Industrial Self-Supplied Water Demand Water used by commercial and industrial operations using over 0.1 million gallons per day.

Comprehensive Everglades Restoration Plan (CERP) The implementation of recommendations made within the Restudy, that is, structural and operational modifications to the C&SF Project are being further refined and will be implemented through this plan.

Cone of Influence The area around a producing well which will be affected by its operation.

Consumptive Use Use that reduces an amount of water in the source from which it is withdrawn.

Consumptive Use Permit A permit issued by the SFWMD allowing utilities to withdraw ground water for consumptive use.

Control Structure A man-made structure designed to regulate the level/flow of water in a canal (e.g., weirs, dams).

Demand The quantity of water needed to be withdrawn to fulfill a requirement.

Desalination A process which treats saline water to remove chlorides and dissolved solids.

District Water Management Plan (DWMP) Regional water resource plan developed by the District under Section 373.036, F.S.

Districtwide Water Supply Assessment (DWSA) This document includes water demand assessments and projections, and descriptions of the surface water and ground water resources within each of the SFWMD's four planning areas.

Domestic Self-Supplied Water Demand The water used by households whose primary source of water is private wells and water treatment facilities with pumpages of less than 0.5 mgd.

Domestic Use Use of water for the individual personal household purposes of drinking, bathing, cooking, or sanitation.

Drainage District A locally constituted drainage, water management or water control distict that is created by special act of the legislature and authorized under Ch. 298 F.S., to constrict, complete, operate, maintain, repair and replace any and all works necessary to implement an adopted water control plan

Drawdown The drawdown at a given point is the distance the water level is dropped.

Environmental Resource Permit (ERP) A SFWMD permit issued under authority of Chapter 40E-4 F.A.C. to ensure that land development projects do not cause adverse environmental, water quality or water quantity impacts.

Epiphytes Plants that derive their moisture and nutrients from the air and rain and usually grow on other plants.

Estuary A water passage where the ocean or sea meets a river.

Eutrophication The gradual increase in nutrients in a body of water. Natural eutrophication is a gradual process, but human activities may greatly accelerate the process.

Evapotranspiration Water losses from the surface of soils (evaporation) and plants (transpiration).

Everglades Agricultural Area (EAA) The area of histosols (muck) predominantly to the Southeast of Lake Okeechobee which is used for agricultural production.

Everglades Construction Project The foundation for the largest ecosystem restoration program in the history of Florida. It is composed of 12 interrelated construction projects located between Lake Okeechobee and the Everglades, including over 47,000 acres of Stormwater Treatment Areas (STAs).

Exotic Nuisance Plant Species A non-native species which tends to out-compete native species and becomes quickly established, especially in areas of disturbance or where the normal hydroperiod has been altered.

Florida Department of Agricultural and Consumer Services (FDACS) FDACS communicates the needs of the agricultural industry to the Legislature, the FDEP, and the water management districts, and ensures participation of agriculture in the development and implementation of water policy decisions. FDACS also oversees Florida's soil and water conservation districts, which coordinate closely with the federal Natural Resources Conservation Service (NRCS).

Florida Department of Environmental Protection (FDEP) The District operates under the general supervisory authority of the FDEP which includes budgetary oversight. FDEP was created by the merger of several former departments including primarily the Florida Department of Natural Resources (FDNR) and the Florida Department of Environmental Regulation (FDER).

Floridan Aquifer System (FAS) A multiple-use aquifer system composed of the upper Floridan and lower Floridan aquifers. It is the principal source of water supply north of Lake Okeechobee and the upper Floridan aquifer is used for drinking water supply in parts of Martin and St. Lucie counties. From Jupiter to south Miami, water from the Floridan Aquifer System is mineralized (total dissolved solids are greater than 1,000 mg/L) along coastal areas and in southern Florida.

Flatwoods (Pine) Natural communities that occur on level land and are characterized by a dominant overstory of slash pine. Depending upon soil drainage characteristics and position in the landscape, pine flatwoods habitats can exhibit xeric to moderately wet conditions.

Florida Water Plan State-level water resource plan developed by the FDEP under Section 373.036, F.S. **F.S.** Florida Statutes.

FY Fiscal Year; the District's fiscal year begins on October 1 and ends on September 30 the following year.

Food Web The totality of interacting food chains in an ecological community.

Geographic Informations Systems (GIS) Mapping The abstract representation of natural (or cultural) features of a landscape into a digital database, geographic information system.

Governing Board Governing Board of the South Florida Water Management District.

Ground Water Water beneath the surface of the ground, whether or not flowing through known and definite channels.

Ground Water Heads Elevation of water table.

Harm *(Term will be defined during proposed rule development process)* An adverse impact to water resources or the environment that is generally temporary and short-lived, especially when the recovery from the adverse impact is possible within a period of time of several months to several years, or less.

Hectare A unit of measure in the metric system equal to 10,000 square meters (2.47 acres).

Hydropattern The pattern of inundation or saturation of an ecosystem.

Hydroperiod The frequency and duration of inundation or saturation of an ecosystem. In the context of characterizing wetlands, the term hydroperiod describes that length of time during the year that the substrate is either saturated or covered with water.

Hypoxic A deficiency of oxygen reaching the tissues of the body.

Incremental Simulations Model simulations performed to understand how the system would perform with partial completion of the Restudy projects and if the ability to meet the 1-in-10 year level of certainty criteria improves over time.

Indicator Region A grouping of model grid cells within the SFWMM consisting of similar vegetation cover and soil type. By grouping cells, the uncertainty of evaluating results from a single two by two, square mile grid cell that represents a single water management gage is reduced.

Infiltration The movement of water through the soil surface into the soil under the forces of gravity and capillarity.

Inorganic Relating to or composed of chemical compounds other than plant or animal origin.

Irrigation The application of water to crops, and other plants by artificial means.

Irrigation Efficiency The average percent of total water pumped or delivered for use that is delivered to the root zone of a plant.

Isohaline Zone Transition between the saltier mesohaline and the fresher oligohaline habitats; in this document it has a salinity of 5 parts per thousand and defines the downstream extent of viable oligohaline habitat under low flow situations.

Kriging A technique for interpolating nonstationary spatial phenomena which can be applied to such diverse hydrologic problems as interpolation of piezometric heads and transmissivities estimated from hydrogeologic surveys and estimation of mean areal precipitation accumulations. It can also be used in hydrologic network design because of its ability to estimate streamflow values using existing stations (Lo, 1992).

Lagoon A body of water separated from the ocean by barrier islands, with limited exchange with the ocean through inlets.

Lake Okeechobee This lake measures 730 square miles and is the second largest freshwater lake wholly within the United States.

Leakance Movement of water between aquifers or aquifer systems.

Leak Detection Systematic method to survey the distribution system and pinpoint the exact locations of hidden underground leaks.

Levee An embankment to prevent flooding, or a continuous dike or ridge for confining the irrigation areas of land to be flooded.

Level of Certainty Probability that the demands for reasonable-beneficial uses of water will be fully met for a specified period of time (generally taken to be one year) and for a specified condition of water availability, (generally taken to be a drought event of a specified return frequency). For the purpose of preparing regional water supply plans, the goal associated with identifying the water supply demands of existing and future reasonable beneficial uses is based upon meeting those demands for a drought event with a 1-in-10 year return frequency.

Marsh A frequently or continually inundated wetland characterized by emergent herbaceous vegetation adapted to saturated soil conditions.

MODFLOW A fine-scale model code created by the U.S. Geological Survey. The District uses it for subregional and ground water modeling. A number of additional modules or components can be added to this model to deal with surface water features such as streams, wetlands, etc.

Mesohaline Term to characterize waters with salinity of 5 to 18 parts per thousand, due to ocean-derived salts.

Minimum Flows and Levels (MFLs) The point at which further withdrawals would cause significant harm to the water resources/ecology of the area.

National Geodetic Vertical Datum (NGVD) A nationally established references for elevation data.

Natural Resources Conservation Service (NRCS) An agency of the U.S. Department of Agriculture (USDA) that provides technical assistance for soil and water conservation, natural resource surveys, and community resource protection.

Nekton Macroscopic organisms swimming actively in water, such as fish (contrast to plankton).

NGVD National Geodetic Vertical Datum, a nationally established references for elevation data relative to sea level.

Oligohaline Low salinity region of an estuary where fresh and saline waters meet; salinity range is typically 0.5 to 5.0 parts per thousand.

Oligosaline Term to characterize water with salinity of 0.5 to 5.0 parts per thousand, due to land-derived salts.

One-in-Ten Year Drought Event A drought of such intensity, that it is expected to have a return frequency of 10 years (see Level of Certainty).

Organics Being composed of or containing matter of, plant and animal origin.

Overhead Sprinkler Irrigation A pressurized system, where water is applied through a variety of outlet sprinkler heads or nozzles. Pressure is used to spread water droplets above the crop canopy to simulate rainfall.

Outstanding Florida Waters (OFW) A special category of water bodies within the state that have been defined by FDEP, based on Section 403.0619270 Florida Statutes, to be worthy of special protection because of their natural attributes.

Per Capita Use Total use divided by the total population served.

Permeability Defines the ability of a rock or sediment to transmit fluid.

Phytoplankton The floating, usually minute, plant life of a body of water

Point Source Any discernible, confined and discrete conveyance from which pollutants are or may be discharged, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft. This term does not include agricultural storm water discharges and return flows from irrigated agriculture.

Potable Water Water that is safe for human consumption.

Potentiometric Head The level to which water will rise when a well is pierced in a confined aquifer.

Potentiometric Surface An imaginary surface representing the total head of ground water.

Process Water Water used for nonpotable industrial usage, e.g., mixing cement.

Projection Period The period over which projections are made. In the case of this document, the 25 year period from 1995 to 2020.

Public Water Supply Demand All potable water supplied by regional water treatment facilities with pumpage of 0.5 million gallons per day (mgd) or more to all customers, not just residential.

Public Water Supply (PWS) Utilities Utilities that provide potable water for public use.

Rationing Mandatory water-use restrictions sometimes used under drought or other emergency conditions.

Reasonable-Beneficial Use Use of water in such quantity as is necessary for economic and efficient utilization for a purpose and in a manner which is both reasonable and consistent with the public interest.

Reclaimed Water Water that has received at least secondary treatment and basic disinfection and is reused after flowing out of a domestic wastewater treatment facility.

RECOVER A comprehensive monitoring and adaptive assessment program formed to perform the following for the Comprehensive Everglades Restoration Program: REstoration, COordination, and VERification.

Recreational Self-Supplied Water Demand The water used for landscape and golf course irrigation. The landscape subcategory includes water used for parks, cemeteries, and other irrigation applications greater than 0.1 million gallons per day. The golf course subcategory includes those operations not supplied by a public water supply or regional reuse facility.

Reduced Threshold Areas (RTAs) Areas established by the District for which the threshold separating a General Permit from an Individual Permit has been lowered from the maximum limit of 100,000 GPD to 20,000 GPD. These areas are typically resource- depleted areas where there have been an established history of substandard water quality, saline water movement into ground or surface water bodies, or the lack of water availability to meet projected needs of a region.

Reference Condition. A representation of historic conditions that previously existed in the Loxahatchee River watershed. In this case, the reference condition is based on District staff's interpretation of a set of historical aerial photography and previous vegetation studies that describe the distribution of plant communities along the Northwest Fork at the time that the Loxahatchee was designated as a Wild and Scenic River (1985).

Regional Water Supply Plan Detailed water supply plan developed by the District under Ch. 373.0361, F.S.

Reservation of Water (see Water Reservation)

Reservoir A man-made or natural lake where water is stored.

Residential Self-Supplied Water Demand The water used by households whose primary source of water is private wells and water treatment facilities with pumpages of less than 0.5 million gallons per day.

Restoration Vision. A narrative description of the desired distribution and extent of the physical components and ecological communities that constitute a restored ecosystem (compare to *achievable restoration*)

Restudy Shortened name for C&SF Restudy.

Retrofitting The replacement of existing water fixtures, appliances and devices with more efficient fixtures, appliances and devices for the purpose of water conservation.

Reuse The deliberate application of water that has received at least secondary treatment, in compliance with the Florida Department of Environmental Protection and water management district rules, for a beneficial purpose.

Reverse Osmosis (RO) Common process used to produce deionized water from municipal water.

RMA-2 Model RMA-2 is a two dimensional depth averaged finite element hydrodynamic numerical model that was developed by Resource Management Associates, Inc. The program has been applied to calculate water levels and flow distribution around islands; flow at bridges, in contracting and expanding reaches, into and out of hydropower plants, at river junctions, circulation and transport in water bodies with wetlands; and general water levels and flow patterns in rivers, reservoirs, and estuaries.

RMA-4 Model The water quality model, RMA-4, is designed to simulate the depth-average advection-diffusion process in an aquatic environment. The model is used for investigating the physical processes of migration and mixing of a soluble substance in reservoirs, rivers, bays, estuaries and coastal zones.

Saline Water Water with a chloride concentration greater than 250 mg/L, but less than 19,000 mg/L.

Saline Water Interface The hypothetical surface of chloride concentration between fresh water and saline water, where the chloride concentration is 250 mg/L at each point on the surface.

Saline Water Intrusion or Saltwater Water Intrusion This occurs when more dense saline water moves laterally inland from the coast, or moves vertically upward, to replace fresher water in an aquifer.

Salinity The total quantity of dissolved salts in sea water, measured by weight in parts per thousand and generally estimated by determining the concentration of dissolved chlorides or electrical conductivity of the water sample.

Sapling Juvenile tree that is shorter than canopy height, but taller than breast height

SAVELOX Model SAlinity and VEgetation model for the LOXahatchee. A model developed by SFWMD to estimate vegetation response to a given set of long-term salinity condiitons.

Sea Water Water which has a chloride concentration equal to or greater than 19,000 mg/L.

Seedling Juvenile tree shorter than breast height

Seepage Irrigation Systems Irrigation systems which convey water through open ditches. Water is either applied to the soil surface (possibly in furrows) and held for a period of time to allow infiltration, or is applied to the soil subsurface by raising the water table to wet the root zone.

Semi-Confining Layers Layers with little or no horizontal flow that can store ground water and also transmit it slowly from one aquifer to another. The rate of vertical flow is dependent on the head differential between the semi-confining beds and those above and below them, as well as the vertical permeability of the sediments.

Sensitivity Analysis An analysis of alternative results based on variations in assumptions (a "what if" analysis).

Serious Harm (*Term will be defined during proposed rule development process)* An extremely adverse impact to water resources or the environment that is either permanent or very long-term in duration. Serious harm is generally considered to be more intense than significant harm.

Significant Harm *(Term will be defined during proposed rule development process)* An adverse impact to water resources or the environment, relating to an established minimum flow or level for a water body; generally temporary but not necessarily short-lived, especially when the period of recovery from the adverse impact exceeds several months to several years in duration; more intense than harm, but less intense than serious harm. St. Lucie Estuary significant harm occurs when freshwater flows to the estuary are less than the rate of evaporation for a period of two consecutive months during the dry season for two or more years in succession.

Slough A channel in which water moves sluggishly, or a place of deep muck, mud or mire. Sloughs are wetland habitats that serve as channels for water draining off surrounding uplands and/or wetlands.

South Florida Water Management Model (SFWMM) An integrated surface water- ground water model that simulates the hydrology and associated water management schemes in the majority of South Florida using climatic data from January 1, 1965, through December 31, 1995. The model simulates the major components of the hydrologic cycle and the current and numerous proposed water management control structures and associated operating rules. It also simulates current and proposed water shortage policies for the different subregions in the system.

Stage The elevation of the surface of a surface water body.

Standard Project Flood (SPF) A mathematically derived set of hydrologic conditions for a region that defines the water levels that can be expected to occur in a basin during an extreme rainfall event, taking into account all pertinent conditions of location, meteorology, hydrology, and topography.

Storm Water Surface water resulting from rainfall that does not percolate into the ground or evaporate.

Stormwater Treatment Area (STA) A system of large treatment wetlands that use naturally occurring biological processes to reduce the levels of phosphorus from agricultural runoff prior to it being released to the Everglades.

Stump Sprouts Damaged adult trees that have resprouted from a trunk

Subregional Ground Water Model A computer model that is used to simulate impacts on a smaller scale than the SFWMM, such as effects within public water supply service areas and impacts of individual wellfields.

Subsidence An example of subsidence is the lowering of the soil level caused by the shrinkage of organic layers. This shrinkage is due to biochemical oxidation.

Supply-Side Management The conservation of water in Lake Okeechobee to ensure that water demands are met while reducing the risk of serious or significant harm to natural systems.

Surface Water Water that flows, falls, or collects above the surface of the earth.

Surficial Aquifer System (SAS) The SAS is the major source of water in the LEC Planning Area. It is unconfined, consisting of varying amounts of limestone and sediments that extend from the land surface to the top of an intermediate confining unit.

SWIM Plan Surface Water Improvement and Management Plan, prepared according to Ch. 373, F. S.

Tidal Rivers Water bodies that receive fresh water from areas other than runoff (from the upstream watershed), are flushed to some extent during a tidal cycle, and are subject to saltwater intrusion from downstream areas.

Total Maximum Daily Load (TMDL) The level of loading to a body of water that will protect uses and maintain compliance with water quality standards (defined in the Clean Water Act).

Transmissivity A term used to indicate the rate at which water can be transmitted through a unit width of aquifer under a unit hydraulic gradient. It is a function of the permeability and thickness of the aquifer, and is used to judge its production potential.

Turbidity The measure of suspended material in a liquid.

Uplands An area with a hydrologic regime that is not sufficiently wet to support vegetation typically adapted to life in saturated soil conditions; nonwetland.

Valued Ecosystem Component (VEC) A resource-based management strategy similar to a program developed by the EPA as part of the National Estuary Program. For the purposes of this study, the VEC approach is based on the concept that management goals for the Northwest Fork of the Loxahatchee River can best be achieved by providing suitable environmental conditions that will support certain key species, or key groups of species, that inhabit the system.

Vertical Migration The vertical movement of oil, gas, contaminants, water, or other liquids through porous and permeable rock.

Wastewater The combination of liquid and waterborne discharges from residences, commercial buildings, industrial plants and institutions together with any ground water, surface runoff or leachate that may be present.

Water Budget An accounting of total water use or projected water use for a given location or activity.

Water Conservation Any beneficial reduction in water losses, wastes, or use.

Water Conservation Areas (WCAs) That part of the original Everglades ecosystem that is now diked and hydrologically controlled for flood control and water supply purposes. These are located in the western portions of Miami-Dade, Broward, and Palm Beach counties, and preserve a total of 1,337 square miles, or about 50 percent of the original Everglades.

Water Control District (see Drainage District)

Water Resource Development The formulation and implementation of regional water resource management strategies, including: the collection and evaluation of surface water and ground water data; structural and nonstructural programs to protect and manage the water resource; the development of regional water resource implementation programs; the construction, operation, and maintenance of major public works facilities to provide for flood control, surface and underground water storage, and ground water recharge augmentation; and, related technical assistance to local governments and to government-owned and privately owned water utilities.

Water Reservations State law on water reservations, in Section 373.223(4), F.S., defines water reservations as follows: "The governing board or the department, by regulation, may reserve from use by permit applicants, water in such locations and quantities, and for such seasons of the year, as in its judgment may be required for the protection of fish and wildlife or the public health and safety. Such reservations shall be subject to periodic review and revision in the light of changed conditions. However, all presently existing legal uses of water shall be protected so long as such use is not contrary to the public interest."

Watershed The drainage area from which all surface water drains to a common receiving water body system.

Water Shortage Declaration Water shortage declarations can be made by the District's Governing Board pursuant to Rule 40E-21.231, Florida Administrative Code, which states "If there is a possibility that insufficient water will be available within a source class to meet the estimated present and anticipated user demands from that source, or to protect the water resource from serious harm, the Governing Board may declare a water shortage for the affected source class." Estimates of the percent reduction in demand required to match available supply is required and identifies which phase of drought restriction is implemented. A gradual progression in severity of restriction is implemented through increasing phases. Once declared, the District is required to notify permitted users by mail of the restrictions and to publish restrictions in area newspapers.

Water Supply Development The planning, design, construction, operation, and maintenance of public or private facilities for water collection, production, treatment, transmission, or distribution for sale, resale, or end use.

Water Supply Plan District plans that provide an evaluation of available water supply and projected demands, at the regional scale. The planning process projects future demand for 20 years and develops strategies to meet identified needs.

Weir A barrier placed in a stream to control the flow and cause it to fall over a crest. Weirs with known hydraulic characteristics are used to measure flow in open channels.

Wetlands Areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support a prevalence of vegetation typically adapted for life in saturated soil conditions.

Wild and Scenic River A river as designated under the authority of the of Public Law 90-542, the wild an Scenic Rivers Act as amended, as a means to preserve selected free-flowing rivers in their natural condition and protect the water quality of such rivers. The Loxahatchee River was federally-designated as the first Wild and Scenic River in Florida on May 17, 1985.

Xeriscape™ Landscaping that involves seven principles: proper planning and design; soil analysis and improvement; practical turf areas; appropriate plant selection; efficient irrigation; mulching; and appropriate maintenance.

LIST OF APPENDICES