Work Plan: Water Quality Monitoring and Modeling for the A.R.M. Loxahatchee National Wildlife Refuge: 2004-2006

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Summary

In FY04, Congress specifically appropriated $1,000,000 to the Arthur R. Marshall Loxahatchee National Wildlife Refuge for water quality monitoring and modeling. This work plan outlines the studies that will be conducted in three areas that will improve the scientific understanding of water quality issues in the refuge and will provide information that can be incorporated into water management decisions for better protection of refuge resources. A draft of the work plan was developed by refuge staff and provided to State, other Federal, and Tribal partners for review and comment in February 2004. This version incorporates comments received in February and March 2004.

The three areas of the plan are: increased monthly water quality sampling sites, similar to current monthly sampling; conductivity transects to provide a better understanding of how and when water from the canals moves into the interior marsh; application of hydrodynamic and water quality modeling to the refuge.

These three areas are consistent with long-term goals identified in the refuge's 15 year Comprehensive Conservation Plan (USFWS 2000) and recommendations made by the Technical Oversight Committee for addressing exceedances observed in interim phosphorus levels within the refuge.

Three existing monitoring networks (monthly compliance monitoring, monitoring at inflow and outflow structures, and 11 stations along two transects in the southwest) operated by the South Florida Water Management District (SFWMD) regularly monitor water quality within the refuge. The current marsh network is estimated to cover approximately 60% of the refuge, leaving 40% of the marsh uncharacterized. The uncharacterized areas of greatest concern are those between the canals and existing stations and in the immediate vicinity of existing or proposed structures (STA-1E and STA-1W for example). The additional monthly sampling will focus on these uncharacterized areas. Forty additional stations will be sampled starting as early as May 2004. Thirty of the sample sites will be located on six transects extending from the canal to 4 km into the interior. Ten additional points will be located in the northwest and southeast. Data collected at these stations will include parameters consistent with the existing Everglades Protection Area (EVPA) sampling.

Much of the Everglades, including the refuge, developed as a rainfall-driven system with surface waters low in nutrients and inorganic ions such as chloride, sodium, and calcium (low conductivity). Information from the refuge and other wetlands indicates that changes in major ions may cause undesirable ecological changes in flora and fauna. It is known that canal water has high conductivity compared to the marsh interior (1000 µS vs, 100 µS, respectively) and there is concern that increases in canal water intrusion into the refuge interior may cause negative ecological consequences. Four to six transects outfitted with data sondes set to collect conductivity and temperature data at hourly intervals will be established in March-May 2004 near locations where water may flow into the marsh in order to documents changes in conductivity adjacent to the canals and in response to water management operations. This information can then be used to refine operations when possible, to minimize canal water intrusion into the interior. Synoptic sampling also will be conducted around the transects when water stages are at specified conditions in order to better understand canal water intrusion.

The goal of the modeling portion of this project is to provide support for refuge management decisions and planning related to water control operations, water supply, and water quality. Calibration and verification using historic and new monitoring data will be used to characterize the applicability, credibility, and uncertainty of the model or models implemented. Scenario analyses will be performed providing detailed projections of the consequences on hydrology and water quality of various management alternatives. Finally, the refuge will be provided with a model that will be maintained to support future management decisions, and provide a foundation for future model development, monitoring planning, and ecological studies.

The information collected during these studies will help resource managers identify potential threats to refuge resources, keep unimpacted areas from becoming impacted, maximize the potential for the recover of impacted areas, and better understand the hydrology and ecology of the refuge.

Acknowledgement

This plan has benefited from numerous technical comments, suggestions, and reviews from colleagues working on Everglades science and management. Their contribution is gratefully acknowledged.

Introduction

<u>Refuge *Comprehensive Conservation Plan*</u>
A multi-year effort was undertaken in the late 1990s to develop a comprehensive 15-year plan for the refuge. The final plan, titled *Arthur R. Marshall Loxahatchee National Wildlife Refuge Comprehensive Conservation Plan*, or CCP, was approved in 2000 after incorporating revisions that followed extensive review by the public, the State of Florida, and other federal agencies (USFWS 2000). The plan identifies long-term goals for the refuge including the need to have a better understanding of the extent and potential influence of canal water intruding into the relatively unimpacted refuge interior. The CCP describes activities such as increased water quality monitoring, and development of a hydrodynamic and water quality model to aid in refuge management decisions, and to provide a better understanding of the potential impacts of altered Everglades hydrology on the ecosystem. In 2003, these goals were further defined in the *Arthur R. Marshall Loxahatchee National Wildlife Refuge Water Quality Monitoring Plan* (USFWS 2003). Specifically, the CCP identified these goals relevant to this project:

> *Goal 1 (Wildlife Habitat and Population Management):*
> Restore and conserve the natural diversity, abundance, and ecological function of refuge flora and fauna.

1. Continue to partner with the South Florida Water Management District and the Army Corps of Engineers to restore and maintain healthy water regimes and appropriate hydropatterns for 143,238 acres (Water Conservation Area 1) of the refuge as part of the northern Everglades.
    - Evaluate and monitor hydrologic conditions on the refuge
    - Review and improve the existing hydrologic model for the refuge to more closely predict wildlife population and vegetative community response to changes in water levels and water delivery
    - Assess the impacts of the previous, current, and future water regulation schedules regarding quality, quantity, delivery, and timing of water on native and exotic and invasive species and habitats.

2. Expand water quality monitoring to include pesticides, fertilizers, and elemental contaminant levels in the cypress swamp, compartments, Strazulla Marsh, below inflow water structures, and other pertinent locations.
    - Continue to monitor nutrient levels and add new monitoring sites at all water inflows to the refuge not currently being monitored.

- Develop a Water Quality Monitoring Plan by 2002 (USFWS 2003).

8. Manage and maintain diverse native habitats and viable wildlife populations consistent with sound biological principles and other objectives of this plan.
    - Identify habitat needs through data collection and analyses.
    - Monitor changes and trends in wildlife, fish, and habitat.

To address these CCP goals and initiate related plan activities, this Work Plan presents a combination of projects totaling approximately $1M for:

- a 2-year enhanced monitoring study of water quality
- a new monitoring network recording conductivity at a number of fixed sites
- evaluation of current conductivity patterns near surface water inflows
- a 2-year monitoring study mapping refuge conductivity patterns
- development and application of a hydrodynamic/water quality model of the refuge

Current budget projections by major project are summarized below:

Project	Total Project Cost
1: Water quality sampling	$366,170
2: Conductivity mapping	$285,018
3: Modeling	$325,000
Support for other efforts (USGS)	73,150
TOTAL	$1,049,338

The research effort by the USGS cited above will address hydrological and ecological questions outside the scope of the projects described here. Funding for these other projects will primarily come from the USGS. Costs budgeted above for the USGS project cover only FWS staff time for sampling assistance and airboat operational costs.

These project activities are critical to help resource managers:

- Identify potential threats to refuge resources
- Keep unimpacted areas from becoming impacted
- Maximize the potential for the recovery of impacted areas
- Better understand the hydrology and ecology of the refuge

Management information needs that these projects will support include:

- When canal stages are below typical interior marsh elevation, what are the impacts of water supply release on interior surface water and groundwater conditions?
- How does selection of relative flow through each of the S-10 gates (gates A, C, D, and E) affect water flow and water quality within the interior?

- When water supply releases from the eastern refuge boundary are made-up by water deliveries, what is the optimal pattern of structure operations? Should we continue to require that all make-up water first be provided prior to water supply releases?
- During water year 2003 , the Everglades Consolidated Report (Weaver and Payne 2004) states that "sulfate concentrations at interior marsh stations in the Refuge (median = 11.0 mg/L) were substantially elevated above both the long-term, historic median (3.6 mg/L) and the previous water year (2.3 mg/L)." What operational or environmental conditions are causing this apparent increased impingement of canal water into the interior?
- How will reduced water supply demands from the refuge that are anticipated to result from the CERP Site 1 Reservoir and Hillsboro ASR projects improve water quality within the refuge and change interior water flow patterns?
- How will the "Loxahatchee National Wildlife Refuge Internal Canal Structures" (CERP project KK) change water flows, hydroperiods, and water quality within the refuge?
- How will changes in refuge inflow timing resulting from planned CERP water storage projects upstream of the refuge change projected water flows, hydroperiods, and water quality within the refuge?
- If there are potential negative impacts of pump, structure, or STA operations, how can they be minimized/eliminated?
- What impacts of STA-1E on refuge water quality and ecological resources are projected?
- What factors contribute to consent decree exceedances?
- How can exceedances to the interim and long-term limits be eliminated?

<u>Previous Study: Florida Cooperative Fish and Wildlife Research Unit, 1990</u>
In 1990 researchers at the University of Florida Cooperative Fish and Wildlife Research Unit reported on a multi-year study of the refuge that included extensive spatial water quality sampling, data analysis, land cover analysis, and a hydrodynamic model of the refuge (Richardson et al. 1990). For over a decade, this study has provided the only comprehensive information to support many of the refuge management decisions and plans. This study provided a foundation supporting the initial CERP plan and the refuge CCP. Numerous changes in inflow volumes and water quality have occurred since the report was issued, and there is a clear need to now revisit questions addressed by Richardson *et al.* as well as new questions not anticipated in their study.

<u>Potential influence of future projects</u>
New projects include Storm Water Treatment Area 1 East (STA-1E) and several Comprehensive Everglades Restoration Plan (CERP) projects (US Army Corps of Engineers and South Florida Water Management District 1999) that will come on line in the next two to ten years. Schedules for the Everglades Construction Project (ECP) and non-ECP projects can be found in the 2004 Everglades Consolidated Report (SFWMD 2004). For a complete list of CERP project starting dates see http://www.evergladesplan.org/pm/projects/project_list.cfm. Many of these projects

could change timing of flows into the refuge, location of inflows, and water flow patterns within the refuge resulting in changes in the movement of high-phosphorus and high-conductivity water into the refuge interior. Such intrusions would likely result in significant changes to refuge flora and fauna. An understanding of what controls these processes in the refuge interior is critical to understanding potential benefits and impacts of future CERP projects.

Monitoring downstream of STA discharges has been identified as critical to determine whether there is intrusion of contaminated water into the refuge interior from STA operations. Currently, no monitoring is being conducted immediately downstream from STA-1W discharges, and the permitting process has not been concluded for any potential STA-1E discharge monitoring.

Complementary recommendations of the Technical Oversight Committee

The 1991 Federal Settlement Agreement (Case No. 88-1886-CIV-HOEVELER) specified interim and long-term concentration levels for phosphorus (P) in the Arthur R. Marshall Loxahatchee National Wildlife Refuge (refuge). Interim levels have been in effect in the refuge since February 1999. Geometric mean concentrations at consent decree compliance sites within the refuge have been larger than the calculated interim levels in nine monthly sampling sets since February 1999. The long-term levels that go into effect December 31, 2006 are more stringent than interim levels and there is concern that the frequency of geometric means being above applicable levels will increase. To date, there is not a clear consensus on the causes of these exceedances and hypotheses for their occurrence range from natural variation to the movement of high phosphorus water from the canals into the interior.

The Technical Oversight Committee (TOC) originated from the Settlement Agreement as a mechanism for technical review and conflict resolution to support the Everglades Program begun by the Agreement and continued in the 1994 Everglades Forever Act (373.4592 F.S.). At the July 24, 2003 meeting of the TOC, the committee discussed the occurrence of the most recent exceedance of Settlement Agreement interim phosphorus levels within the refuge. Resulting from this discussion, the TOC unanimously agreed to forward recommendations to the consent decree principals dealing with (A) Controlling Phosphorus loads to the refuge, (B) Enhancing Monitoring of the refuge, and (C) Modeling of the refuge (http://www.sfwmd.gov/org/ema/toc/archives_mtgs.html). Implementing these recommendations will improve understanding and help provide a better consensus on the factors responsible for any future exceedances. Practical and cost-effective management plans that protect the resource and eliminate exceedances can be developed. These actions parallel those previously identified by the refuge in the CCP described above.

Work plan structure

This work plan is divided into three sections corresponding to separate but closely related projects:

I. Collection of additional water quality samples at new sampling sites between the canals and the existing interior marsh network.

II. Determination of conductivity patterns from canals into the interior marsh adjacent to discharge locations.

III. Development and application of a hydrodynamic/water quality model for the refuge.

Each section is designed as a single project or series of smaller projects that together will begin to address the questions outlined above. Each project has the following information:

Title of project/subproject
Project dates
Background
Objectives
Tasks
Results and implications
Resources needed
Project schedule
Implementation

I. Collection of additional water quality samples between the canals and the existing monthly sampling network

Project dates: 2004-2006

Background:
Three existing monitoring networks operated by the South Florida Water Management District regularly monitor water quality within the refuge (Figure 1):

- Monthly compliance monitoring is performed at 14 stations that are located in the marsh interior. These stations, designated as LOX3-LOX16, are the basis of the Settlement Agreement compliance tests.

- Volume of flow and water quality are monitored at inflow and outflow structures (G-300, G-301, G-251, G-310, S-10E, S-10D, S-10C, S-10A, S-39, G-94A, G-94B, G-94C, G-94D, and Acme #1 PS). Data from these sites are used to compute cumulative mass (loads) of phosphorus and other materials passing through the structures, but are also valuable in characterizing the water quality of the boundary canal waters impacting the refuge wetlands.

- Eleven stations along two transects (X0-X4, Y4, and Z0-Z4) in the southwestern refuge are monitored monthly to characterize water quality across the phosphorus-enriched impacted region of the refuge. These transect stations are designated as the X and Z transects, with one added interior site designated Y4 located between the most interior X and Z sites.

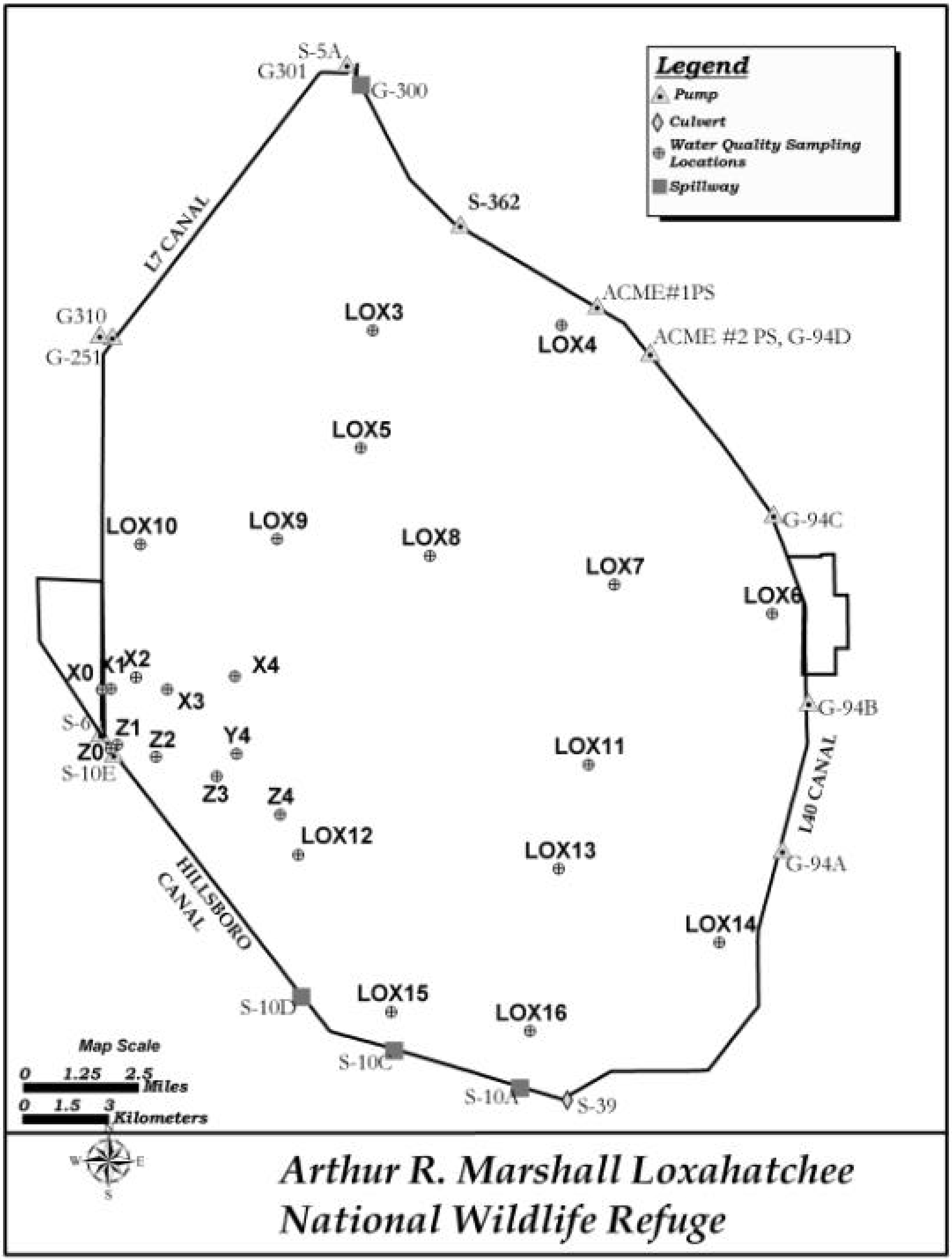

Figure 1: Map showing stations where existing water quality (and supporting information) is monitored.

Objective:
The objective of the proposed 2-year monitoring study is to support management decision-making related to water quantity, timing of inflows, and water quality, through the development and implementation of an enhanced monitoring network that increases the spatial coverage of water quality samples, especially in areas adjacent to discharges and the rim canal.

This work will also provide data in support of the modeling effort described in Section III (*Hydrodynamic and water quality modeling*) below.

Tasks:
Initial, year-one monitoring may occupy as many as 40 additional stations. This spatial density will be modified in the second project year using an adaptive process that will include consultation with other interested parties.

Task 1: Establish spatial pattern for additional stations
Location of additional monitoring sites is being determined through analysis of past data from the existing marsh monitoring stations, topography, current conductivity sampling collected monthly by refuge staff, and conductivity sampling conducted during February 2004 by SFWMD staff (Sue Newman), and other relevant studies (Childers et al. 2003; Richardson et al. 1990; Scheidt et al. 2000). Twenty-eight of the new stations will be located along transects, two will be at (or near) the old LOX1 and LOX2 sites and 10 will be between existing stations and the canal (Figure 2). The number and location of sample sites will be adaptively modified as data become available in order to reduce redundancy and maximize the value of the information collected.

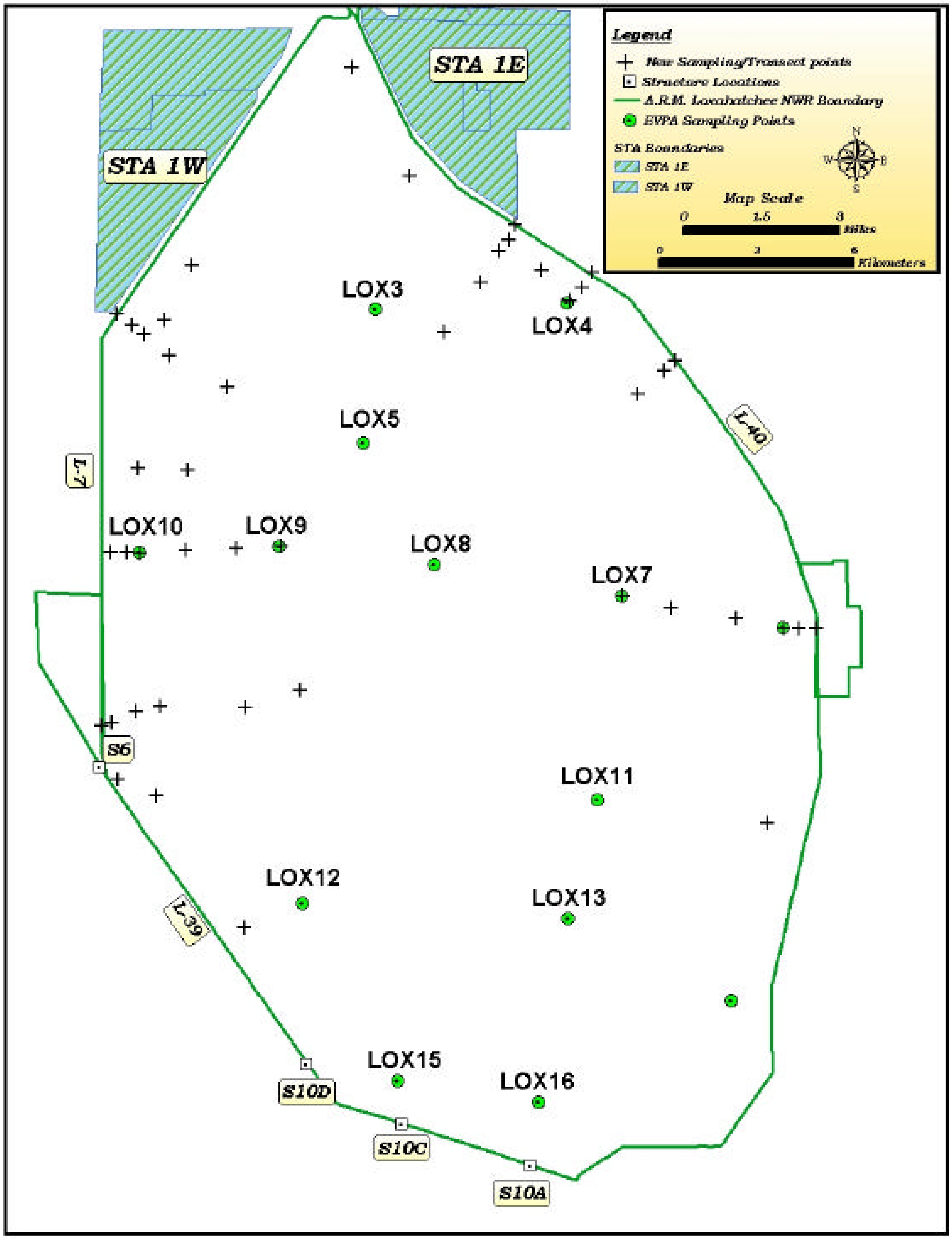

Figure 2. Proposed location of new sampling locations and transects (indicated with crosses) and existing compliance stations (circles).

Samples will be analyzed for the same suite of parameters currently monitored at refuge interior (LOX) sites for the first three months. Data will be reviewed at that point and the list of parameters reduced as appropriate. Where appropriate, compatibility with anticipated future monitoring by CERP (Adaptive Assessment Team 2003) and other projects (including a recent USGS project by Paul McCormick) will be considered in selecting and modifying sample site locations.

Task 2: Implement sampling at new stations

PVC pipe will be placed at each new sampling location and each new station will be assigned an identification number that is consistent with other samples taken in the refuge. Sampling will be conducted via helicopter and follow procedures defined in the South Florida Water Management District's Water Quality Sampling protocol (SFWMD 2002). When practical, this monthly sampling will occur on days just prior to sampling of the current interior (LOX) sites in order to maximize the compatibility of the two sampling efforts (Table 1).

Table 1. Dates of sampling for A.R.M. Loxahatchee NWR enhanced water quality monthly sampling and SFWMD EVPA sampling during 2004

Month	A.R.M. Lox sampling	EVPA
April	5-8 (station setup)	19-20
May	10-13	17-18
June	7-10	14-15
July	19-22	12-13
August	2-5	9-10
September	13-16	20-21
October	4-7	18-19
November	1-4	15-16
December	6-9	13-14

Task 3: Sample analysis

Samples will be analyzed according to accepted procedures for analyzing other water quality samples in the Everglades. For the best ability to examine results from this project with the existing monitoring, described above, it is desirable for the samples to be analyzed by a lab participating in the Everglades laboratory round-robin, and most optimally be analyzed by the same lab that is currently doing the existing 14-station network (SFWMD).

Task 4: Develop QA/QC for sample collection, analysis, and management

An overall QA/QC document will be adopted and/or developed for all aspects of the sample collection and analysis. Protocols will be consistent with other Everglades monitoring efforts.

Task 5: Quarterly summary report

Quarterly summary reports will be prepared that present all of the raw data and simple parametric statistics over the reporting period. Narrative in the report will cite any other available water quality sampling data for that period. Report narrative will integrate the findings with information on STA operation, water level conditions, and other water management activities that occur during the reporting period. The report will be prepared and distributed to all interested parties.

Task 6: Annual report
The first annual report will summarize and synthesize the water quality data from this and other studies and make recommendations on which stations to retain in year 2 for continued monitoring. The year-two annual report will synthesize year 1 and 2 data in the context of water management and present a discussion of monitoring needs incompletely met by this study. The annual reports will, as far as possible, analyze spatial and temporal patterns and hypothesize underlying causes.

Results and implications: These data will provide information that will be used to characterize currently unmonitored areas of the marsh, further illustrate patterns of water quality on a gradient from the canal into the interior, and provide information that may help to explain patterns of exceedances.

Resources needed:

Water Quality Sampling (from the air)	Year 1	Year 2	Total
Helicopter (40 stations- 10 per day- 4 hours flight time, once a month using FWS ship)	$67,200		$67,200
Helicopter (30 stations- 10 per day- 4 hours flight time, once a month-using FWS ship)		$50,400	$50,400
Sample analysis estimate from SFWMD for suite analyzed for 14 stations plus 25% for QA/QC	$112,040	$84,030	$196,070
Staff time based on Bruce's estimates for his and Camille's time for EVPA flights ($15000 for 2.5 days each each month)	$30,000	$22,500	$52,500
	$209,240	$156,930	$ 366,170

Project schedule:

January-March 2004	Analyze existing data and select additional sites
January-May 2004	Work out contract agreement with laboratory for sample analysis and reporting
January-March 2004	Work out arrangements for helicopter
April 2004	Develop project QA/QC plan

May 2004	Begin sampling
Aug, Nov 2004, Feb2005	Quarterly reports due
May 2005	Annual report due with recommendation on reduction/changes to sampling sites
Aug, Nov 2005, Feb 2006	Quarterly reports due
May 2006	Final report due with recommendations on long-term monitoring sites

Implementation:
In order to implement this project, helicopter time, sample collection personnel, and a sample analysis lab must be identified and the appropriate contractual mechanisms must be put in place.

Helicopter time is expected to be available through the use of the FWS helicopter based at Merritt Island, Florida. The details of getting this ship assigned for refuge use 4 days each month will need to be worked out.

Monthly sampling can be conducted by personnel who already work at the refuge (0.13 FTEs/year), but whose positions are unfunded or only partially funded for FY04/FY05.

Someone will need to be assigned/hired to write the quarterly and annual reports. Ideally, this could be the same person who is responsible for the Data sondes network and coordination with the ecological studies and modeling efforts.

A contract with a laboratory for analysis of samples needs to be developed prior to any sampling. This contract should include number of samples, what will be analyzed, when results will be available, storage of data (in DBHYDRO if available to this project), and QA/QC information. The laboratory must meet QA and detection limits compatible with Everglades water quality sampling currently underway.

II. Determination of conductivity patterns from canals into the interior marsh adjacent to discharge locations

Project dates: 2004-2006

Background:
Much of the Everglades developed over the past 5000 years as a rainfall-driven system with surface waters low in nutrients and inorganic ions such as chloride, sodium, and calcium. This ion-depleted or "soft-water" condition was undoubtedly a major determinant of historic ecosystem structure and function. The ecological impacts associated with increased surface-water phosphorus (P) concentrations in the Everglades are by now well recognized (Payne and Weaver 2004). The ecological effects of elevated inorganic ion concentrations in the Everglades are also well established but less widely recognized.

Information from the refuge and other wetlands indicates that increases in the concentration of major inorganic ions may elicit undesirable ecological changes in the Everglades biota and should be avoided. Canal construction and associated wetland drainage and soil loss during the last century disrupted both the surface and groundwater hydrology of south Florida and initiated a slow but persistent movement of ancient seawater from the Floridian aquifer and into canals and subsided lands surrounding the remnant Everglades (Flora and Rosendahl 1982). These hydrologic changes have increased concentrations of major ions in surface waters by several-fold across large portions of the Everglades that are affected by canal discharges (Flora and Rosendahl 1982).

The refuge represents one of the last vestiges of the historic soft-water Everglades (Richardson et al. 1990). This condition is evidenced by the low conductivity (a simple but accurate measure of major ion concentrations, in the refuge an excellent estimate of chloride concentration can be made from conductivity) of surface water in the marsh interior (100 μS) compared with that in the canal surrounding the refuge (1000-1500 μS). Low-conductivity waters in the refuge interior are associated with a characteristic soft-water periphyton community, wetland plant species that may also be adapted to the soft-water conditions, and lower rates of key ecosystem processes (e.g., decomposition) than in areas of the Everglades impacted by canal discharges (Browder et al. 1991; Browder et al. 1994; Gleason 1974; Swift and Nicholas 1987). These effects continue to be a subject of study (S. Newman, pers. com.). While it has long been known that the fringes of the refuge are affected by high conductivity canal water, recent evidence indicates a trend towards increased intrusion of this water into the refuge interior with likely impacts of water chemistry on sensitive biota (Childers et al. 2003; Walker and Kadlec 2003; Weaver and Payne 2004). In addition, Weaver and Payne 2004 noted elevated sulfate concentrations for WY2003 and suggested that the values could be related to unusually high flows and discharges into the refuge from STA1-W. Both scientists and managers have expressed concern over the spread of such impacts and their relationship to water management structures and operations.

Factors controlling the extent of canal-water intrusion into the refuge interior are not well understood, but may be related to both natural hydrologic changes and water management activities. For example, several major pump stations control water flow and stage in the canal surrounding the refuge. Recent changes in the location and schedule of these pumping activities may be promoting increased intrusion of canal water into the marsh interior (http://www.sfwmd.gov/org/ema/toc/archives/docs/refuge_compliance.pdf). Additional water management changes associated with Everglades restoration have the potential to further exacerbate this problem. It is also possible that water management strategies could be altered in the future to alleviate, rather than exacerbate, water quality problems. Therefore, it is critical that causal relationships between water management activities and canal water intrusion into the refuge be developed quickly to ensure that current and proposed restoration programs do not result in the degradation of water quality within the refuge. These relationships can only be determined by monitoring surface-water conductivity across the refuge.

Restoration efforts associated with the Everglades Construction Project and the Comprehensive Everglades Restoration Plan include proposed changes in the location and operation of water control structures that regulate canal flows and stages around the outer rim of the refuge and other construction projects that may increase movement of canal water across the refuge in some areas, and decrease it in others. In addition to conveying existing sources of water into the refuge, the creation of Stormwater Treatment Area 1E (STA-1E) in the northeast corner of the refuge will introduce 100,000 acre-feet of new water into the Everglades Protection Area through discharges into the rim canals of the refuge. This new water, composed of treated water from a combination of agricultural and urban runoff basins, exhibits high conductivity relative to interior marsh locations. Current (though limited) water quality modeling tools suggest that more than 6,000 acres of interior marsh might be impacted by higher-than-background levels of phosphorus-rich water from STA-1E discharges, with a greater area of impact from dissolved constituents that are not taken up as rapidly as phosphorus. Treatment of Acme B basin Stormwater by STA-1E and the reduction of backwater flooding from the L-40 due to diversion of inflow from the S-6 pump may in some measure reduce these impacts.

As the refuge is an Outstanding Florida Water body (with anti-degradation provisions), it is important to characterize potential impacts of new sources of water with high conductivity levels. In order to assess current impacts of STA-1W and potential impacts of STA-1E discharges, baseline conductivity maps of this area of the refuge interior need to be developed for a series of different hydrological and water management conditions.

Objectives:

The proposed investigation has three primary objectives:

1. Document the spatial and temporal extent of intrusion of high conductivity canal water into the refuge under different hydrologic conditions with emphasis on areas directly interior from STA-1E and STA-1W;
2. Develop foundation for permanent monitoring adjacent to STA-1E prior to initiation of discharge;

3. Relate changes in the extent of intrusion to water management activities affecting canal stages and flows into the refuge.
4. Determine the influence of natural meteorological events and hydrologic mechanisms on intrusion of high conductivity canal water.

This work will also provide data supporting the modeling effort described in Section III (*Hydrodynamic and water quality modeling*) below.

Tasks:

Task 1: Network for long-term monitoring of conductivity patterns
Transects to collect conductivity data will be established adjacent to STA-1E, STA-1W discharges, and adjacent to the SFWMD's X transect and extending to a new "X5" location in the southwest portion of the refuge. A fourth and fifth transect will be located on the east side of the refuge near ACME 1 and ACME 2 (G-94D) . These stations will allow for continuous monitoring of surface-water conductivity in the marsh (17 stations) and the rim canal (4 stations). A field datalogger and conductivity probe will be mounted to a pole at each station with the probe's sensor secured 10 cm above the sediment surface. Dataloggers will record site conductivity as frequently as required (possibly hourly) to insure that even the most rapidly changing transients are well characterized. Each station will be visited two weeks after installation and then on a monthly or bimonthly basis to download accumulated data and perform calibration and routine maintenance.

These loggers will be arranged in transects generally perpendicular to the canal to measure the rate and extent of canal water intrusion into the refuge (Figure 2). Generally, transects span the area from the canal to a relatively pristine area in the interior. Locations of transects were selected by examining historic and current information and correspond to sites selected for monthly sampling (see *Collection of additional water quality samples* section above). Depth recorders will be co-located with the four marsh data sondes near STA-1E, and with a minimum of two depth recorders on the other transects.

In times when the northern transects are dry, the data sondes will be moved to transects 1-km either north or south of existing transects in order to maximize data collection.

Task 2: Synoptic sampling around STA-1E and STA-1W discharges
The northeast region of the refuge near the STA-1E discharge pump station (including the existing LOX3 and LOX4 stations) and the northwest region of the refuge near the STA-1W discharge pump station will be sampled with a modified square grid to develop a series of synoptic conductivity maps. The maps will be developed initially with a sampling grid starting at the canal and extending 5 km toward the interior at a resolution of no less than 500 m. The grid will include the areas where the data sondes transects are located.

Sampling will occur under various conditions and will include times when average canal stage is above average marsh stage, when average marsh stage is above canal stage, and when there is no difference in stages. It is anticipated that this sampling would take place 4-6 times per year. Analysis of existing conductivity data taken during airboat surveys by refuge personnel indicates that conductivity in the northeastern portion of the refuge has been fairly low and stable (about 200 µS) since September 2003. Initial synoptic sampling will occur when conductivity at the currently monitored stations begins to increase. A two-person crew will sample each grid via airboat or helicopter in a 2-day window to get a "snapshot" picture of water column conductivity. Samples will be taken with a hand-held, temperature-compensated probe. The probe will be inserted mid-depth into the water column and the conductivity measured when the values equilibrate. At the beginning and end of each day, all conductivity meters will be calibrated using known standards.

After examining the data for quality assurance/quality control (e.g., outlier removal), a spatial map of surface water conductivity levels at the stations sampled will be generated. Appropriate geostatistical approaches will be explored to develop contoured maps.

A similar sampling grid is currently envisioned for conductivity mapping of the region downstream of STA-1W.

Both the SFWMD and the USGS have ongoing monitoring programs that will provide the necessary hydrologic information (e.g., marsh and canal stage, pumping volumes and duration) to identify events and relate changes in marsh conductivity to changes in canal flows and stages. These data will be retrieved and used in combination with conductivity data to evaluate the strength of statistical relationships between specific water management activities and canal water intrusion into different parts of the refuge.

Results and implications:
Previous data (mostly point samples) collected by refuge staff and SFWMD indicate that high conductivity water can intrude more than 4 km into the refuge in certain locations (Walker and Kadlec 2003). Assuming a 4-km wide impacted zone circumscribing the refuge, over half of the refuge may currently be affected by potentially harmful increases in constituents related to surface-water conductivity. The monitoring proposed here will allow refuge staff to conduct a more accurate assessment of the extent of exposure and the frequency of occurrence of different conductivity levels throughout the refuge. Analysis of these data in relationship to hydrological information will indicate hydrologic conditions and water management activities that promote intrusion of canal water into the refuge and, therefore, will suggest management solutions to this potentially serious environmental problem.

This monitoring project will not identify conductivity levels that are associated with significant ecological change in the refuge. This determination is critical to quantifying the ecological effects of canal-water intrusion into the marsh. This question will be addressed by complementary studies by other parties including the USGS.

Intrusion of high conductivity canal water is one of the most widespread water quality changes that human activities have on the refuge, and this project will identify the spatial and temporal extent of this intrusion. Furthermore, by providing an understanding of key hydrologic conditions that affect canal-water intrusion, the results of this work will allow refuge staff to work with the SFWMD and the Army Corp of Engineers to identify and implement alternative water management strategies that minimize flows of canal waters into the marsh while still achieving other water management objectives. Restoration efforts associated with the Everglades Construction Project and the Comprehensive Everglades Restoration Plan (CERP) include proposed changes in the location and operation of water control structures that regulate canal flows and stages around the outer rim of the refuge and other construction projects that may increase movement of canal water across the refuge. An improved understanding of the factors governing interactions between canal waters and the marsh is critical in order to predict the effects of these activities on canal-water intrusion and to modify them accordingly to minimize water quality impacts to the refuge.

Resources needed:

Determination of Conductivity Patterns	Year 1	Year 2	Total
Determination of Conductivity Patterns			
Helicopter time for 8 days each, FWS ship	$ 22,400	$22,400	$44,800
Staff time- GS 7 for ground and aerial sampling (0.5 FTE + benefits)	$ 20,000	$ 20,000	$40,000
Staff time- GS 11 for project coordination/data analysis and report writing (0.50 FTE plus benefits)	$ 29,375	$29,375	$58,750
Conductivity meters	$10,000		$10,000
Hydrolabs (not covered by CESI request) order 1 (16 Hydrolabs)	$18,568		$18,568
Data sondes Order 2 (15 data sondes)	$67,500		$67,500
Field computer for downloading data	$5,000		$5,000
Office computer for GS11	$3,000		$3,000
Supplies (Field and office)	$5,000	$3,000	$8,000
Depth recorders (15)	$15,000		$15,000
Airboat time for monthly checks of data sonde network ($200/day includes fuel and maintenance)	$7,200	$7,200	$14,400
	$203,043	**$81,975**	**$285,018**

Note: The CESI program previously provided funding for purchase of some of the Hydrolab conductivity dataloggers to be used in this study. Cost in this budget is for additional units.

Project schedule:

January-March 2004	Analyze existing data and determine locations for initial transects and design of synoptic sampling grid including criteria for an event
January-March 2004	Work out arrangements for helicopter
January-February 2004	Develop position description for GS11 ecologist/hydrologist and GS7 BioTech and send to regional office
January-April 2004	Order conductivity meters and field computer
March 2004	Install data sondes
February 2004-	Watch for events and conduct event sampling as water moves into the interior (events will include natural fluctuations in water levels due to rainfall, and fluctuations caused by water management, e.g., discharges from STA-1E)
March 2004-March 2006	Monthly data sondes downloads
May 2004	GS7, GS11 on board
Aug, Nov, Feb,	Quarterly reports on conductivity data and synoptic sampling due (corresponds with reports for other water quality sampling)
May 2005 and May 2006	Annual and final report due

Implementation:

In order to implement this project, helicopter time must be secured. Helicopter time may be available through the use of the FWS helicopter based at Merritt Island. The details of getting this ship assigned for refuge use will need to be worked out. Ideally, four days would be needed in a row; however, two sets of two days within two weeks probably would work. Less than one weeks notice might be all we could give for event sampling.

Two additional personnel are needed for this project: one 0.5 FTE time GS7 for sampling and one 0.5 FTE time GS11 for project coordination, data analysis, and report writing. The GS11 would also prepare the reports for the additional water quality sampling and be responsible for ensuring that the additional sampling, conductivity sampling, and ecological studies were coordinated and on schedule. The refuge will have to develop a position description and get it approved and advertised through the Atlanta regional office.

III. Hydrodynamic and water quality modeling

Project dates: 2004-2006

Background:
The Arthur R. Marshall Loxahatchee National Wildlife Refuge is impacted by altered hydrology, impingement of high-conductivity canal water into the interior marsh, and elevated concentrations of nutrients, particularly phosphorus. A priority for the refuge is to better understand and minimize these impacts. Hydrodynamic and water quality models have the potential to provide needed management and scientific support related to these concerns. Information developed in the enhanced water quality monitoring project and conductivity project will be of value in model development and evaluation.

Although previous efforts directed at modeling hydrology and water quality of the refuge (alone or as a part of the greater Everglades) have been of value (Fitz and Sklar 1999; Lin 1979; Lin and Gregg 1988; MacVicar and Lindahl 2000; MacVicar et al. 1984; Munson et al. 2002; Raghunathan et al. 2001; Richardson et al. 1990; Welter 2002), none of the these past modeling efforts adequately address current refuge needs. This project will build upon the understanding and experience of previous modeling studies to implement a working model that will address refuge needs. In order to minimize cost and ensure timely completion, it is anticipated that this project will not develop new computer modeling computer programs, but will utilize available computer programs (likely with some modification) for hydrodynamic and water quality modeling.

This modeling project shares some objectives with other Federal projects. Effort will be made throughout this project to maximize cooperation and information exchange with other Federal projects that are developing models of similar ecosystems. The Restoration Coordination and Verification (RECOVER) Water Quality Team has compiled a listing of 67 project related modeling efforts related to the Comprehensive Everglades Restoration Plan (CERP) implementation (Water Quality Team 2002b). The Water Quality Team has also inventoried some of the available water quality models of potential vale to CERP project teams in their project level water quality assessments (Water Quality Team 2002a). The CERP Everglades Agricultural Area (EAA) storage reservoir project design team has inventoried available models for analysis of hydrodynamics and phosphorus removal in proposed water storage reservoirs (Kimberly-Horn and Associates 2002; Kimberly-Horn and Associates 2003). These reservoirs are expected to often have little water or be dry. Several of the hydrology and water quality models considered by this team may also be applicable to refuge modeling. Support for water quality model review and selection has also been developed by the Southwest Florida Feasibility Study through contracted assistance (Ash Engineering and Engineering and Applied Science 2003). Model selection support documents produced by these and other teams and contractors will be consulted during this project model selection task.

This project also will build on the understanding of phosphorus dynamics in South Florida wetlands that has been established through the development of the DMSTA model (Walker and Kadlec 2002). The US DOI has primarily funded development of DMSTA. DMSTA has been calibrated or tested using data from over seventy wetland sites in South Florida. Initial modeling of phosphorus in this project will use kinetics and parameter ranges established by DMSTA modeling.

Throughout this project, the modeling team will maintain communication and collaboration with the SFWMD Interagency Modeling Center, as well as with other DOI teams monitoring and modeling the Everglades. The modeling team will, where possible, build on previous and continuing modeling efforts (*e.g.* RSM and ELM) relevant to the refuge. The modeling team will make available all final documents, reports, data files, and final model input and output files to any interested parties.

This modeling project will also provide a better understanding and support the development of a consensus on causes of historic and future exceedances of Settlement Agreement mandated phosphorus concentration levels. This project is consistent with recommendations of the Technical Oversight Committee (TOC).

This modeling project will also interact with other efforts to assess flows and water quality in the refuge. In particular, interaction and cooperation with efforts by the SFWMD, the EPD, and the USACOE will be actively pursued.

Concerns have been expressed related to discharge from STA-1E affecting distribution and transport of L-40 Canal sediments. The modeling project described here is not intended to completely satisfy modeling needs related to the highly-enriched canal sediments and sediment mobilization on the L-40 Canal. The modeling planned here is not intended to address near-field flow (momentum dominated flow) near the outfall, and will not likely provide a temporal resolution appropriate to resolve these canal issues. This project can, however, provide support for specialized canal modeling by compiling much of the data needed, and providing appropriate boundary conditions.

Objectives:
The goal of this modeling is to provide best available technical support for management decisions related to refuge inflow and outflow quantity, timing, and quality. This modeling effort will provide projections of water movement and water quality resulting under alternative scenarios of structure operation, STA performance, and structural changes within the refuge.

Model Design Specifications:
It is inappropriate in the project planning stage to conclusively define specifics of model design; early modeling tasks will include refinement of objectives and data inventory, followed by selection of the model or models and determination of appropriate temporal and spatial scales (Ambrose et al. 1990). However, while recognizing the need for flexibility of implementation and the likelihood of needing to set model specifications within a framework of conflicting objectives, it is of value to discuss likely model

specifications within this planning framework. Model specifications include temporal and spatial resolution, computational speed and efficiency, and finally, selection of modeling program or programs. The following paragraphs describe a number of model specifications that must be considered during implementation of the modeling project.

Period of record

The minimum period that must be simulated in order to obtain a reliable calibration, verification, or alternative scenario analysis depends on processes being studied. Ideally, calibration takes place only after the model has simulated a sufficiently long time to be independent of initial conditions (ICs). One approach that has been used in some model calibrations is to cycle the model repeatedly through the calibration interval until independence is achieved. Alternatively, other approaches may be used. In general, the time required for model hydrodynamics to be independent of the ICs is shorter than for conservative transport, which, in turn, is shorter than the time for components that have significant stationary storage (such as phosphorus).

The calibration and verification period should also cover a sufficient variety of environmental conditions to adequately test the model. Events of unusually low and high water, for example, should be included in the selected period to exhibit the model's predictive capabilities within such extremes.

Temporal resolution

Required model temporal resolution is dependent on computational stability and accuracy constraints, data constraints, processes being modeled, and modeling objectives. Stage and inflow data are most conveniently available as daily average values, and it is likely that the model will, at least initially, be implemented using daily values for precipitation, stage, and flow boundaries. Some model runs could be made using input time-series that include periods of more frequent, perhaps hourly, functions to test adequacy of the daily average functions or to examine more rapid responses to inputs.

Spatial resolution

Appropriate spatial scale depends on model objectives and model structure. Some models incorporate features that occur within single model elements. Candidate models, for example, may allow specification of vertically variable storage near the soil surface to accommodate topography at a scale smaller than the model element size. Models may also use a rill elevation or ponding depth to simulate effects of smaller scale topography on flow. Models with these "micro-topography" features may provide improved stability and performance, or require lower spatial resolution.

Spatial resolution may also be constrained by availability of spatial data. Recent USGS topographic studies of the refuge will provide elevations on a 400-meter grid spacing; plant cover mapping on a 50-meter grid spacing will be available from a SFWMD study that should be completed no later than fall 2004. Spatial information on soil properties and soil depth will be less easily estimated, and may need to be assumed to be uniform within specified zones.

Spatial scale is also constrained by model performance and stability requirements. Often, model run-time will increase rapidly as element size is reduced. Previous modeling using the RSM/HSE model (Welter 2002) employed an unstructured triangular mesh with 16,292 cells that were typically 650 feet on each side. This design allowed incorporation of larger tree islands, and avoided excessive run times.

Candidate Models

There are numerous reports available inventorying available models that potentially could be selected in this study. On a national scale, USEPA has compiled a guidance on available models and model selection (Shoemaker et al. 1997). A number of Florida agencies, RECOVER committees, and CERP project teams (including the RECOVER Model Development Refinement Team, Southwest Florida Feasibility Study PDT, and the CERP Decompartmentalization Project) have separately reviewed models available for application in South Florida ecosystems (Ash Engineering and Engineering and Applied Science 2003; Kimberly-Horn and Associates 2002; Kimberly-Horn and Associates 2003). Workshops sponsored by the SFWMD have also inventoried and reviewed available models (SFWMD 2001; Sheer 2000).

In listing, reviewing, and selecting candidate models, it is important to realize that each model is likely to have some deficiencies in terms of the project objectives. In selecting the best models for our uses, it will be essential to estimate the impact of these deficiencies and the potential cost of correcting problems. It is likely that ultimately no single model will best fulfill all needs. Therefore, following an initial screening of models to select all feasible choices, a model should be selected for first implementation. This in no way excludes the possibility of using alternative models in the future as needs change, alternative computer programs mature, and our experience and understanding of the system grows. Indeed, it would be beneficial to understanding uncertainty and improving credibility to have more than one model available. Because of developments in computer software, use of pre-processor programs, and standardization of file formats, many of the candidate models can be efficiently implemented using data and coverages developed for other models.

A preliminary and incomplete list of beneficial model properties that may be considered in selection include:

1. General
   a. Documentation should be clear and complete. Documentation should include theoretical foundations, computer system requirements, input file format, output format, use of pre and post processors, examples, and model testing or quality assurance.
   b. Model user interface should be intuitive and easy-to-use.
   c. Model training and technical support should be available.
   d. Model should be widely applied and accepted, supported by peer reviewed publications, and model peer review.

   e. Model should uses common file formats or provide processors that convert common to/from such formats (*e.g.* shape files, DSS format, spreadsheet compatible formats).
   f. The model should be typically robust and stable, and clearly identify when instability has occurred and the cause of the instability.
   g. Model run time for models of the complexity anticipated here should be reasonable.
   h. Model code should be generally available to all interested parties.
2. Hydrodynamics
   a. Models should support overland flow and flow in channels.
   b. Model formulation must adequately address reversing flow and backwater conditions in both overland and channel flow.
   c. Model formulation must adequately address overbank flow.
   d. Coupling of ground water and surface water components should be as "seamless" as possible.
   e. Frequent wetting and drying of cells should not present problems within the model.
3. Reactive transport (water quality)
   a. Mass should be demonstrated to be locally and globally conserved.
   b. Both advective and dispersive transport should be available for both overland and canal flow.
   c. The model should support both linear (first order) and non-linear user-defined reactions.
   d. The model should allow individual constituents to optionally be transported or stationary.

Tasks:
This project will involve ten tasks divided into two phases. Phase 1 will collect and organize the information needed to support model implementation, and Phase 2 will perform the model implementation and application. Although the deliverable information from Phase 1 will be necessary for completion of Phase 2, some of the tasks in Phase 2 can be initiated prior to completion of all tasks in Phase 1. Task scheduling will be designed to minimize overall project completion time within the constraints of total personnel resources available.

Documentation is a vital part of any modeling, and will be incorporated as a requirement for every task and contract deliverable. Metadata documentation requirements will also be established to assure that sources of data and transformations of data are available to future users and reviewers. All project documentation and modeling will be made available to interested parties. At this time, there is no facility available to the refuge to make these documents and files directly available on-line through a dedicated web page. This information will, at a minimum, be provided through email requests to the investigators.

PHASE I: PREPARATION OF DATA
<u>Task 1: Data acquisition and processing</u>

All data sets used for modeling will be accompanied by documentation of data source, and changes or transformations performed on data. As far as possible, all data will be maintained in formats that will facilitate data sharing between models and studies.

1.1: Select candidate constituents for modeling

There are a number of reasons that a particular water quality constituent might be selected for modeling: (1) Constituents that are of direct interest or directly affect performance measures must be modeled; (2) Constituents that are assumed to directly affect those in the first category must also be simulated; and, (3) Other constituents that add to the model quality assurance or credibility of calibration by providing added constraint or testing should be modeled. Modeling additional constituents reduces the likelihood that the model is "under-constrained" by the calibration data. At a minimum, a conservative constituent, probably chloride, and total phosphorus will be selected for modeling.

1.2: Select period-of-record

An ideal period-of-record (POR) covers a large number of years with periods of extreme meteorological and hydrological conditions that adequately calibrate and test model performance. It is also of value to have a POR that includes major structural changes (*e.g.* diversion of S-6 pump, STA-1E operation) because this further tests the models ability to project such changes. It is desirable to select a POR ending as close as practical to the present. The period of record for model calibration and possible verification should consider data availability, and quality. This task will require a preliminary review of data from various sources.

1.3: Types of data

A number of classes of data must be compiled to support model development. Many of these datasets are spatial (e.g., elevation), some are time series for specific sites (e.g., TP at monitoring sites), and some are both temporally and spatially variable (e.g., rainfall). Data sources must be identified for all data types required.

1.4: Geographic data – elevation, base map –

Most past and current modeling efforts have used soil surface elevation values collected under by the Florida Coop Fisheries and Wildlife Unit (Richardson et al. 1990). Newer topographic data may become available in time to be used in this study. Canal cross-section data have been measured by IFAS (Daroub et al. 2002)

1.5: Hydraulic data – stages and structure flows –

Stage observations and flows are publicly available through the SFWMD DBHYDRO database system. Other sources include refuge observations, and discharger reports.

1.6: Meteorological data – rainfall, temperature, ET –

Rainfall and temperature data recorded at nearby stations are available through DBHYDRO. ET observations within the refuge have been performed by the USGS over limited time periods, and these data can be used to test equations that predict ET from other meteorological parameters.

1.7: Water quality data – inflow, within, and outflow –
Water quality data are available in DBHYDRO, and from other sources.

1.8: Procure and QA all data
There are a number of potential data sources. All procured data must undergo quality assurance checks. Datasets must also be accompanied with metadata descriptions that document sources and all modifications made following procurement. Documentation must be adequate to allow efficient and consistent future extension of dataset POR. Data from the other sections of this work plan will be incorporated into this task.

1.9: Format data as required
Data will need to be organized and placed in proper database or format for use in model input and calibration. Data sources and transformations and transformations will be clearly documented.

<u>Task 2: Develop boundary condition time series</u>
Flows and concentrations of all modeled constituents at every inflow structure (boundary conditions or BCs) must be estimated and compiled into time-series datasets. Time series will also be developed for all outflow structures. This is not necessarily a trivial task. Improvement of estimation of complete time-series from measurements taken at single times (grab samples) or from composite samples has been identified as a significant source of model uncertainty in the ELM calibration (Fitz 2003, Water Quality Team presentation). This task should include investigation of alternative approaches and selection of the optimal technique. The task also includes using this technique to provide BC estimates for model implementation.

<u>Task 3: Develop daily water/material budgets for all structures and simple models</u>
Using time series of flow and concentration, historic daily loads for every structure will be calculated over the selected POR. This calculation will be performed for all candidate constituents identified in Task 1, including budgets (daily totals) for net inflow and net outflow flow and load of each constituent. These daily budgets will be combined into seasonal and annual budgets over the POR for each constituent. Trends in load and retained load (inflow minus outflow load) will be examined. Simple net refuge mass balance models will be developed.

PHASE II: MODEL IMPLEMENTATION
<u>Task 4: Selection of model(s)</u>
Model objectives, needs, and required specifications will be developed. Available models will be reviewed. Based on an objective evaluation of how well existing models meet project needs, available models will be screened to reduce the list of candidate models. A report will be developed and provided to an independent committee tasked with recommending model or models selected for implementation. This independent committee will be made up of three or more experts selected by DOI. In order to maintain

their complete independence, DOI funding of costs for committee members' participation will be contracted separately from modeling support contract(s).

Task 5: Model implementation

The selected model(s) computer programming will likely require alteration to adequately model selected constituents and meet model objectives. This task will therefore involve computer code modification and testing. The model will then be implemented using datasets developed in preceding Tasks 1 and 2.

Task 6: Model calibration and verification

A preliminary calibration of the hydrodynamic model will be performed using observed stage from refuge interior and canal sites. Calibration of mass transport using a relatively conservative constituent (*e.g.*, chloride) may then require additional adjustment of hydrodynamic model parameters. Within the refuge, chloride concentration may be accurately estimated from conductivity. Initial conductivity mapping data will be used in model calibration. Calibration of other reactive water quality constituents should not make further adjustment of the hydrodynamic calibration. Preliminary water quality observations acquired in the monitoring phase of this project will be directly or indirectly used for calibration. At a minimum, calibration statistics reported by the SFWMD for the SFWMM and ELM will be reported (bias, RMS error, r^2, and efficiency). Reporting will discuss the adequacy of calibration and verification, implications on model uncertainty, and possible mechanisms causing degraded calibration statistics. Effectiveness of calibration will be quantitatively measured and reported. At the completion of this task, the working model will be installed on a USFWS computer, and training provided to USFWS staff sufficient to allow independent model runs to be performed by the USFWS staff.

Task 7: Scenario analysis

Alternative management strategies will be defined and simulated. Performance measures and simple statistics, as well as spatial mapping, will be used in comparison of alternatives. Examples of scenarios that may be simulated include:

- Given a projected inflow condition project the temporal and spatial pattern of water depths. Determine the area of the refuge that will have suitable conditions for wading bird foraging and estimate duration.
- Analyze benefits and impacts of revisions to the refuge regulation schedule. This may include changing zone boundary stages or the sequence in which water supply make-up water is delivered.
- Analyze the effect of changing relative flow through the S-10 structures for water delivery to WCA-2. It is conjectured that water quality benefits are maximized by gate openings that minimize the east-west canal stage difference across the refuge.
- Analyze the benefit of balancing inflows between STA-1E and STA-1W. Is it important to, as far as practical, synchronize discharge to minimize canal intrusion?
- Estimate the long-term impact on interior chloride concentration resulting from discharge by the STAs.

- Test changes in hydroperiod and water quality resulting from possible alternative designs for CERP project KK, the "Loxahatchee National Wildlife Refuge Internal Canal Structures."
- Estimate water quality improvement at interior stations that would result from meeting 10 ppb P concentration at all inflows.
- Explore other operational changes that reduce the impact of external loads on interior stations.

Task 8: Documentation

Full documentation of all tasks of this project is required. Publications in peer-reviewed journals will be encouraged and supported. However, peer reviewed publications do not substitute for detailed project reporting and exhaustive review by DOI staff and management, SFWMD/COE staff, and consultants familiar with the system and project. The standard for project reporting is that a professional without specific knowledge of this site or project could implement every task of the project using only project reports and without need to consult the modeling staff. Although a final report and final documentation will be deliverables, documentation will be required throughout the project as an essential part of every task and deliverable.

Task 9: Archive of program and all other files

All programs, input and output datasets, and reports will be centrally archived in electronic form. This task will proceed at the same time as preceding tasks. Resources necessary for completion of this task are included in these preceding tasks.

Task 10: Model maintenance for use

This task extends beyond the funded end of the project. It involves program maintenance to support future changes in programming environments, and extension of datasets to include newly acquired monitoring data.

Results and implications:

Resources needed:

It is estimated that total project cost will not exceed $325,000 and will require 4.5 FTEs (an FTE is defined here to be a full time equivalent effort for one year) of additional effort by staff dedicated to this modeling project over a planned 25-month period.

The task resource chart presented below provides estimates of additional personnel requirements and personnel costs required to complete this project. Cost estimates are crude and can be considerably refined following decisions on methods for personnel procurement. Resources estimated here do not include the cost and effort of current federal employees for project management, oversight, and review.

Prior to initiation of the project, a more detailed timeline and milestone chart will be developed, and a detailed project deliverable list will be formulated. These milestones and deliverable requirements will be used in project management.

Task resource chart

Task	Months	FTEs	Cost* $1000
1	3	0.50	30
2	6	1.00	60
3	3	0.50	30
4	1	0.50	30
5	3	0.50	30
6	4	0.68	40
7	2	0.33	20
8	3	0.50	30
Total	25	4.51	$270

*Assumes $60,000 per FTE.

Assuming $55,000 for equipment, supplies and software, travel, training, technical support, and contingency, total project cost is estimated to be $325,000. Project is anticipated to require 2.5 years for completion.

Project schedule:
Scheduling of all tasks will depend in part on availability of personnel.

January 2004- March 2004	Investigate contracting alternatives.
April 2004- March 2005	Phase I: Preparation of data.
June 2004- February 2006	Phase II: Model implementation.

Implementation:
It is anticipated that some personnel resources (including contract administration, oversight, and/or direct project participation) will be required from existing federal staff. Resource estimates presented above do not include this cost or effort.

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