# A.R.M. Loxahatchee National Wildlife Refuge

# Enhanced Monitoring and Modeling Program – 2nd Annual Report

**LOXA06-008**

# February 2007

## Acknowledgments

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# Acronyms and Abbreviations

| | |
|---|---|
| **ACME** | Special Drainage District |
| **CERP** | Comprehensive Everglades Restoration Plan |
| **cfs** | cubic feet per second |
| **Cl** | chloride |
| **cm** | centimeter |
| **CV** | coefficient of variation |
| **DBHYDRO** | SFWMD's web portal for water quality data |
| **DCS** | depth to consolidated substrate |
| **DOI** | Department of Interior |
| **ENRP** | Everglades Nutrient Removal Project |
| **ET** | evapotranspiration |
| **EVPA** | Federal Consent Decree compliance network for Refuge |
| **FVCOM** | Two-dimensional unstructured finite volume model |
| **km** | kilometer |
| **L** | liter |
| **LOXA** | Refuge's expanded water quality monitoring network |
| **LWDD** | Lake Worth Drainage District |
| **m** | meter |
| **mg** | milligram |
| **Mg** | megagram (metric ton) |
| **MIKE-FLOOD** | Coupled one and two-dimensional finite difference model |
| **mm** | millimeter |
| **msl** | mean sea level |
| **NAD83** | North American Datum of 1983 |
| **NAVD88** | North American Vertical Datum of 1988 |
| **NGVD** | National Geodetic Vertical Datum |
| **NGVD29** | National Geodetic Vertical Datum of 1929 |
| **$NO_x$** | oxides of nitrogen |
| **ppb** | parts per billion (micrograms per liter) |
| **POR** | period of record |
| **RMSE** | root mean square error |
| **s** | second |
| **SFWMD** | South Florida Water Management District |
| **$SO_4$** | sulfate |
| **STA** | Stormwater Treatment Area |
| **TN** | total nitrogen |
| **TP** | total phosphorus |
| **µS** | microSiemen (measure of conductivity) |
| **USACE** | U.S. Army Corps of Engineers |
| **USFWS** | U.S. Fish and Wildlife Service |
| **USGS** | U.S. Geological Survey |
| **WCA** | Water Conservation Area |

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**Section III, Synthesis of Findings**

# Executive Summary

Congress appropriated funds to the U.S. Fish and Wildlife Service in 2004 to develop an enhanced water quality monitoring network and hydrodynamic and water quality models to improve the scientific understanding of water quality in the Arthur R. Marshall Loxahatchee National Wildlife Refuge[1] (Refuge). The network and models provide information that will be used in management decisions to better protect Refuge resources. The enhanced water quality monitoring network complements the existing water quality compliance network created under the 1992 Federal Consent Decree (Case No. 88-1886-CIV-MORENO) by characterizing the water quality of a larger Refuge area, particularly the fringe area potentially impacted by canal water intrusions. The expanded monitoring network, initiated in June, 2004, consists of monthly grab samples collected at 39 canal and marsh stations, and continuous measurements of conductivity along seven transects, four of which extend from the canal near surface water discharge points into the interior. This report focuses on the period from June 2004, through December 2005, but includes data from additional time periods.

Although only a limited range of climatic and hydrological conditions has been experienced during this study, data collected document intrusion of rim canal water into the Refuge interior, adding to a growing information base about canal water impacts to the Refuge. Intrusion of nutrient-rich and high conductivity water from the canal has the potential to negatively impact Refuge plants and animals. Analyses of these data have identified management practices that have the potential to minimize such intrusion.

Based on the water quality data, the Refuge was classified into four geographic zones: (1) canal zone; (2) perimeter zone, located from the canal to 2.5 km (1.6 miles) into the marsh; (3) transition zone, located from 2.5 km (1.6 miles) to 4.5 km (2.8 miles) into the marsh; and (4) interior zone, greater than 4.5 km (2.8 miles) into the marsh. Overall, water quality conditions in the perimeter and transition zones of the Refuge marsh were different from, and more impacted than, the interior zone. The transition zone had instances where canal water penetration may have functionally altered the Refuge ecosystem as supported by a previous study of cattail expansion measurements along a single transect across the Refuge. The perimeter and transition zones combined represent up to 60% of the Refuge interior.

This report concludes that water movement between the canals and the marsh is influenced by the canal-marsh stage difference, structure-controlled water inflow and outflow into perimeter canals, marsh elevation, and rainfall. When inflows to Refuge canals were greater than outflows from Refuge canals and when canal stages were greater than marsh stages, intrusion extended more than 1 km (0.6 miles) into the marsh interior. Even with a minimal difference between the canal and marsh stage and when marsh stage was greater than canal stage, canal water still intruded into the marsh interior. Additionally, this report documents a positive relationship between structure inflows and canal total phosphorus concentrations, reflecting both stormwater treatment area

[1] Public Law 108-108; see House Report No. 108-195, p. 39-41 (2004)

discharges and bypass inflows into the Refuge. When combined with our understanding of the influence of the canal water intrusion into the marsh, these data suggest an impact of high-nutrient water on the Refuge marsh.

A simple water budget model was developed to predict canal compartment and marsh compartment volumes and stages. Statistical analyses demonstrate the applicability of this model to predict temporal variation of water levels in both the marsh and the Refuge perimeter canal. This model already is being used for examining regional water management scenarios. A more complex hydrodynamic model allows examination of Refuge hydrology at a scale of 400 m by 400 m (1312 ft by 1312 feet) – a much higher resolution than the 2-miles by 2-miles hydrodynamic model presently available for the Refuge. Water quality constituents are being incorporated into both models, allowing for both a better understanding of water movement within the marsh and understanding phosphorus levels in the water column. An independent model advisory review panel has provided valuable insights that have been incorporated into the modeling program. Finally, a series of management scenarios has been identified for application of these modeling tools.

This report provides recommendations for specific management practices to minimize the potential of canal water intrusion into the marsh. These recommendations are practical, and could be implemented under the operational structures and rules that presently exist. Other recommendations focus on additional information needs to significantly improve understanding of the Refuge ecosystem for purposes of protecting this valuable remnant of the northern Everglades.

# Section I. Introduction[1]

The Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge), located in Palm Beach County, Florida, includes approximately 58,300 ha (144,000 acres) of northern Everglades habitats (Figure 1). Approximately 57,085 ha (141,000 acres) of interior marsh is Water Conservation Area 1 (WCA-1), an impounded marsh established in the 1950s and 1960s for water supply, flood protection, and wildlife habitat. It is managed by the U.S. Fish and Wildlife Service under a License Agreement with the South Florida Water Management District (SFWMD). The Refuge once was part of the contiguous Everglades that extended from the Kissimmee Chain of Lakes south to Florida Bay. Now, the Refuge interior marsh is impounded and surrounded by agriculture to the north and west, and urban areas and agriculture to the east. Water Conservation Area 2 lies immediately to the south.

The Refuge was established in 1951 under the Migratory Bird Conservation Act of 1929 which states that the Refuge is "…for use as an inviolate sanctuary, or for any other management purposes, for migratory birds." (16 USC. 715d). The Refuge provides habitat for over 300 vertebrate species including the endangered snail kite and wood stork. A current goal of the Refuge is to restore and conserve the natural diversity, abundance and ecological function of Refuge flora and fauna.

Hydrologic inputs once came solely from direct rainfall and overland sheet flow. Today, the Refuge is isolated hydrologically by levees and canals, receives no sheet flow, and inflows now occur as rainfall and discharges into perimeter canals from water management structures (gates and pumps). Water delivered through structures is from runoff from adjacent agricultural and urban areas, and now, in part, is treated by Stormwater Treatment Areas (STA-1W and STA-1E) designed to reduce phosphorus inputs. Untreated water enters from structures on the east side (ACME-1 and ACME-2), or as bypass (untreated) through the G-300 and G-301 at the north end (Figure 1). Water entering through structures and in canals has different characteristics than rainfall or water from natural wetlands and may flow into the marsh under certain canal stages or flow regimes. Hydrologic outflows through structures are for stage regulation and flood protection (S-10 structures and S-39 at the south), and water supply (G-94 structures and S-39 on the east). Evapotranspiration and seepage loss are other sources of water outputs from the Refuge. Location, amount, and timing of inflows and outflows may affect marsh water flow, depths, and nutrient and other ion concentrations.

Areas of pristine marsh throughout the Everglades have been impacted to various degrees by water with high nutrients and other constituents. Information from the Refuge and other wetlands indicates that increases in phosphorus and major ions cause undesirable ecological changes in flora and fauna. A large amount of research conducted by state, federal, and private entities has demonstrated the impacts of small increases in total phosphorus concentrations. Changes in Everglades flora and fauna begin to occur at total phosphorus concentrations slightly higher than 10 $\mu g\ L^{-1}$ (10 ppb). Recognition that increases in total phosphorus concentrations have caused changes in Everglades communities led to establishment of legal mandates

[1] Prepared by Laura A. Brandt, Matthew C. Harwell, and Nick Aumen

including a Federal Consent Decree in 1992 that established phosphorus levels and a compliance methodology for the Refuge. Interim levels for the Refuge have been in effect since February 1999 and long-term levels take effect December 31, 2006. In 1994, Florida's Everglades Forever Act (EFA) was passed which led to the establishment of a numeric criterion for total phosphorus.

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. Conductivity was, therefore, naturally low. Conductivity is a field measurement that provides a good surrogate for concentrations of major ions compared to the naturally low conductivity Refuge marsh interior. In addition to elevated phosphorus concentration, canal water has high conductivity. Although there is no appropriate state water quality numerical criterion for conductivity for the northern Everglades, there are concerns that increases in canal water intrusion into the Refuge interior marsh may cause negative ecological consequences because canal water is high in conductivity as well as nutrients.

The highest soil elevation in the refuge interior is approximately 5.6 m (18.5 ft), and the lowest interior elevation is roughly 3.2 m (10.6 ft) (1929 NGVD). The Refuge interior exhibits a general slope in elevation from north to south, with typical wet prairie or slough elevations as high as 5.0 m (16.3 ft) in the north, and as low as 3.9 m (12.5 ft) in the south. Average interior marsh soil surface elevation is approximately 4.6 m (15.0 ft). Historically, water flowed generally from north to south following the natural elevation gradient. Impoundment of the area has altered flow magnitude and direction. Water discharged into the Refuge perimeter canals now either stays in the canals and eventually passes out through discharge structures on the east or south or flows in and out of the marsh from the east and west.

Water levels are managed by the U.S. Army Corps of Engineers and SFWMD under a water regulation schedule. The current schedule (Figure 2) has an upper level of 5.3 m (17.5 ft) msl (1929 NGVD) and a floor of 4.3 m (14 ft) msl. Under this schedule, outflows are determined based on stage and the need for water supply and flood protection.

The marsh is a mosaic of habitats including slough, wet prairie, sawgrass, brush, tree islands, and cattail. Community location and type is determined by elevation, hydrology, and water quality. Hydroperiods near canals in the central and north part of the marsh are shorter than in the center and southern marsh. In general, water depths are shallower in the north and deeper in the south. Hydroperiod and water depth are key factors in determining vegetation patterns in the marsh. Conditions that are drier result in predominance of brush or sawgrass. Areas that are wetter are characterized by slough or open water.

To protect Refuge resources, resource managers must be able to identify potential threats to Refuge resources, keep unimpacted areas from becoming impacted, and maximize the potential for the recovery of impacted areas. Hydrology and water quality information is critical for making management decisions to meet the multiple purposes of the Refuge and for overall Everglades restoration. In 2004, as a result of this recognition, Congress appropriated funds specifically to the Refuge for development of an enhanced water quality monitoring network and hydrodynamic and water quality models. The appropriation was intended to improve the scientific understanding of water quality issues in the Refuge and to provide information for better water management decisions to protect Refuge resources.

A work plan was developed (Brandt et al. 2004) outlining studies to provide scientifically supported management recommendations. The original list of questions is below – these have subsequently been refined since this program was initiated:

- What are the water quality characteristics in the fringe marsh adjacent to inflows?
- Under what operational or environmental conditions does canal water flow (intrude) into the marsh and how far does it intrude?
- How does relative flow through different structures affect water flow and water quality within the interior marsh?
- 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?
- When canal stages are below typical interior marsh elevation, what are the impacts of water supply releases on interior surface water and groundwater conditions?
- 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?
- What factors contribute to water column phosphorus values that are above the limits established in the Consent Decree?
- What can be done to eliminate exceedances to the interim and long-term levels of the Consent Decree?
- What hydroperiods and depths will occur in the marsh under different operational and water management conditions?

Three areas of study were developed to provide information to address the above questions:

1. additional monthly water quality sampling sites;
2. continually monitored conductivity transects to provide a better understanding of how and when water from the canals moves into the interior marsh; and
3. application of hydrodynamic and water quality modeling to the Refuge.

The original extent of the project was two years. However, additional funds have allowed for the continuation of the projects for an additional two years. This report is the second annual report and includes data collected and analyses from June 2004 through December 2005. This report is intended to provide a better understanding of the hydrological and water quality conditions of the Refuge. The intended audience for this report are those interested in tracking the implementation of the project, those interested in the technical details of the work, and resource managers who can use the information as support for future management decisions. Other information about this program can be found at http://sofia.usgs.gov/lox_monitor_model/.

The report is organized into three major sections. Section I (this section) provides background and a summary of overall project implementation written for a general audience. Section II contains three chapters that are written for a technical audience and are stand-alone documents that can be read independent of information elsewhere in the report. These chapters provide a summary of the overall monitoring network, analysis of canal water intrusion, and a summary of the modeling activities to date. Section III provides a summary of the management implications of the technical chapters and discusses unanswered questions and future monitoring and research needs. This synthesis section is written for a diverse audience.

## Literature Cited

Brandt, L. A., Harwell, M. C., and Waldon, M. G., 2004. Work Plan: Water Quality Monitoring and Modeling for the A.R.M. Loxahatchee National Wildlife Refuge. available at http://sofia.usgs.gov/lox_monitor_model/workplans/2004-2006_workplan.html#pdf, Arthur R. Marshall Loxahatchee National Wildlife Refuge, U.S. Fish and Wildlife Service, Boynton Beach, FL.

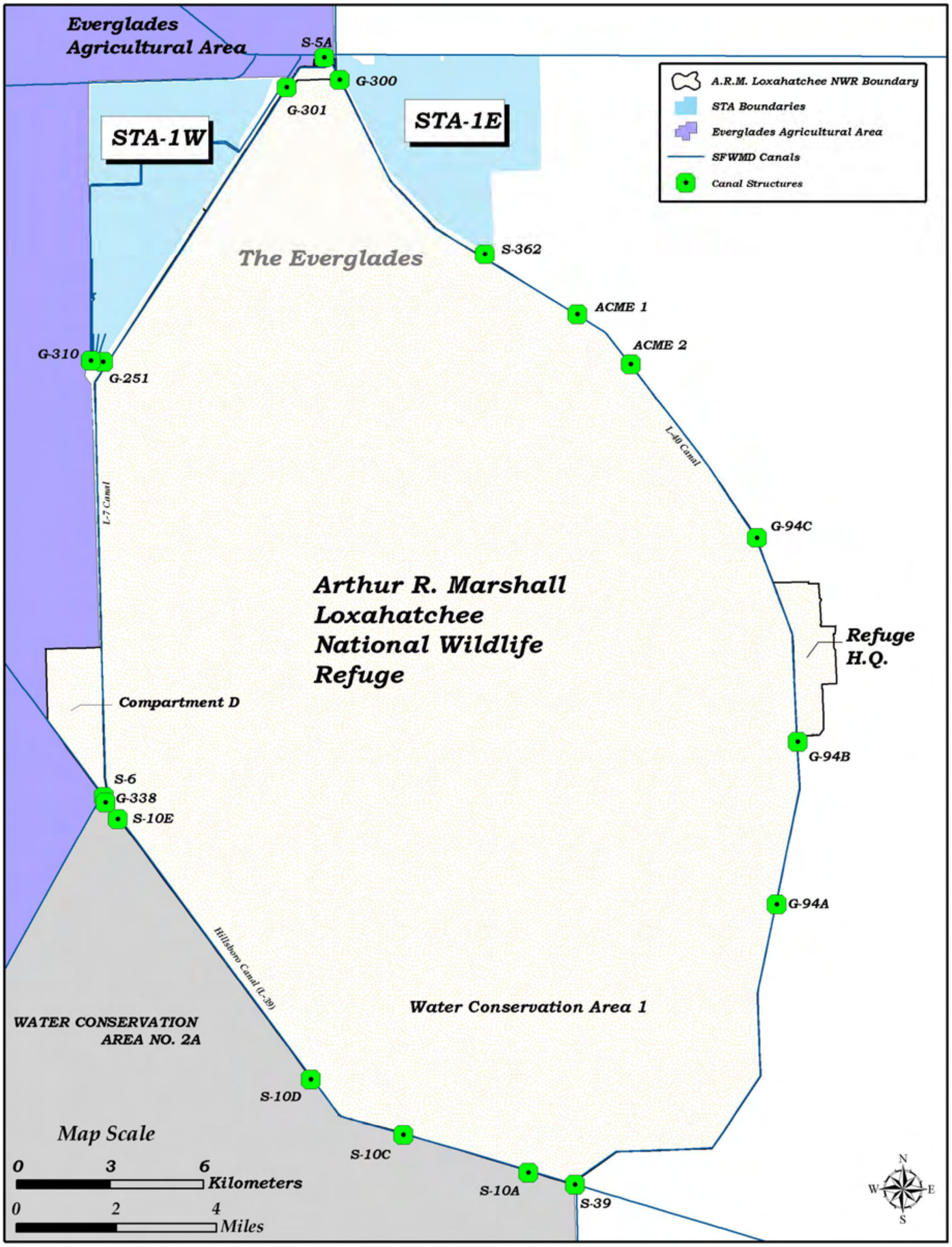
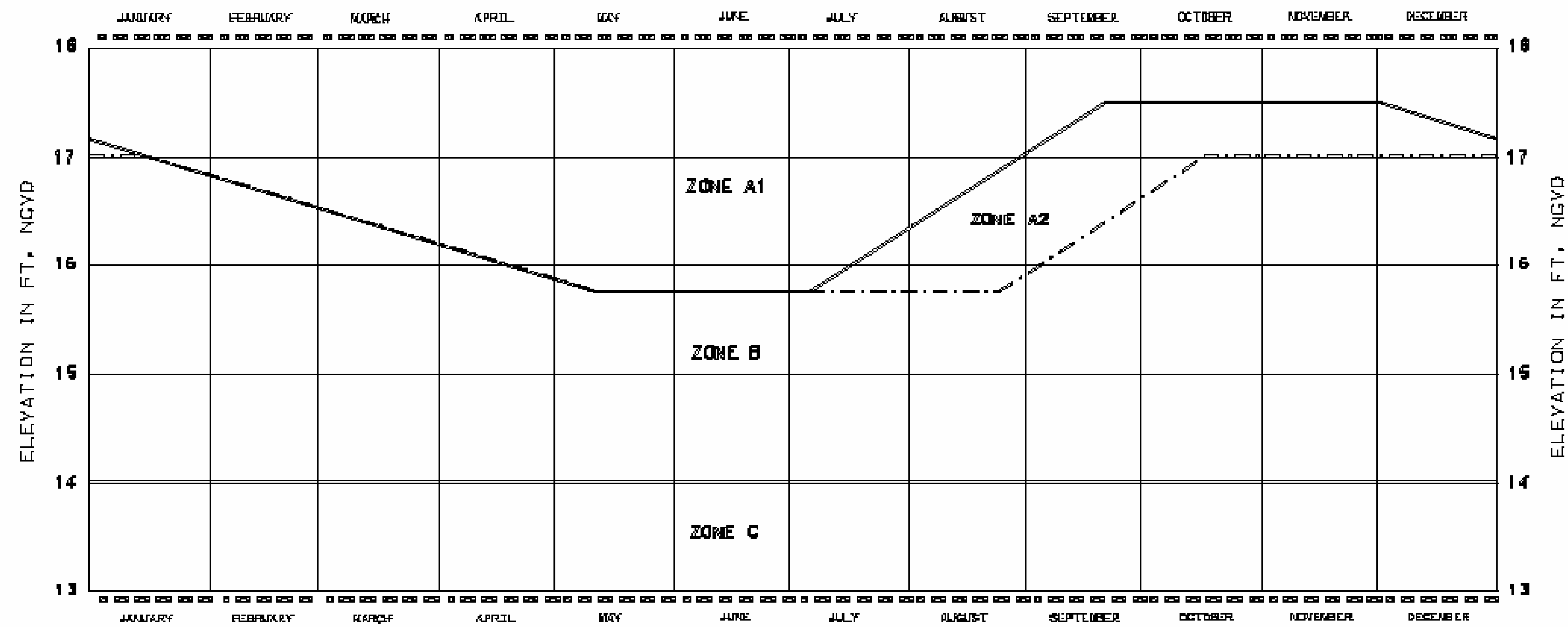



**Figure 1.** The Arthur R. Marshall Loxahatchee National Wildlife Refuge.




| ZONE | RELEASES |
|---|---|
| A1 | UP TO MAXIMUM AT S-10 (AND S-39 WHEN AGREED BETWEEN CORPS AND SFWMD). WATER SUPPLY RELEASES AS NEEDED. |
| A2 | S-10 RELEASES BASED ON CORPS FORECASTS. WATER SUPPLY RELEASES AS NEEDED. IF LAKE OKEECHOBEE STAGE IS ABOVE WCA-1 STAGE OR NO MORE THAN ONE FOOT BELOW WCA-1 STAGE, THEN WATER SUPPLY RELEASES FROM WCA-1 MUST BE PRECEEDED BY AN EQUIVALENT VOLUME OF INFLOW. |
| B | WATER SUPPLY AS NEEDED. IF LAKE OKEECHOBEE STAGE IS ABOVE WCA-1 STAGE OR NO MORE THAN ONE FOOT BELOW WCA-1 STAGE, THEN WATER SUPPLY RELEASES FROM WCA-1 MUST BE PRECEEDED BY AN EQUIVALENT VOLUME OF INFLOW. |
| C | NO NET RELEASES FROM WCA-1. ANY WATER SUPPLY RELEASES MUST BE PRECEEDED BY AN EQUIVALENT VOLUME OF INFLOW. |

| DATES | USE GAGE | CONDITIONS |
|---|---|---|
| 1 JAN - 30 JUN | 1-8 CANAL | ALL |
| 1 JUL - 31 DEC | 1-8 CANAL | EXCEPT AS NOTED BELOW |
| | AVG. 1-7, 1-8T, 1-8 | DURING RISING STAGES WHEN CANAL STAGE EXCEEDS AVERAGE. |

CENTRAL AND SOUTHERN FLORIDA
INTERIM REGULATION SCHEDULE
WATER CONSERVATION AREA NO. 1
DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA
DATED: 03 MAY 1995

**Figure 2.** Water regulation schedule for the Arthur R. Marshall Loxahatchee National Wildlife Refuge. For more information see: USFWS. 2000. Arthur R. Marshall Loxahatchee National Wildlife Refuge Comprehensive Conservation Plan. available at http://loxahatchee.fws.gov, U.S. Fish and Wildlife Service, Boynton Beach, Florida.

# Section II, Chapter 1. Water Quality in the A.R.M. Loxahatchee National Wildlife Refuge: 2004-2005[1]

## Abstract

The Everglades, including the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge), developed as a rainfall-driven system with surface waters low in nutrients and inorganic ions such as chloride, sodium, and calcium, and, therefore, low in conductivity. Canal water intrusion into the Refuge interior may cause negative ecological consequences (i.e., alteration to the periphyton community, displacement of sawgrass by cattails, impaired growth of yellow-eye grass) because canal water is higher in nutrients and other elements. Changes in Everglades flora and fauna occur at total phosphorus (TP) concentrations of 10 ppb and higher. In addition to elevated TP concentrations, canal water has high conductivity compared to the marsh interior. Short pulses of conductivity above conductivity values in rainfall adversely impact Refuge native vegetation in laboratory studies.

In 2004, we initiated an enhanced, 39-site water quality monitoring network to characterize water quality gradients from the perimeter canal into the marsh interior, primarily near discharge sites. This enhanced network supplements an ongoing network that includes 14 sites distributed throughout the middle of the Refuge and that has a long historical record from1978 to the present.

Water management decisions require an understanding of environmental conditions. Because this information comes from a number of sources, a synthesis of relevant environmental conditions such as canal-marsh stage relationships, canal flow, rainfall, and marsh water quality is valuable. The objectives of this study are to document selected environmental conditions and water quality parameters in the Refuge from June 2004 through January 2006.

The Refuge was classified into four geographic zones based upon variability in conductivity data and changes in conductivity as a function of distance into the marsh from the perimeter canal: (1) canal zone; (2) perimeter zone, located from the canal to 2.5 km into the marsh; (3) transition zone, located from 2.5 km to 4.5 km into the marsh; and (4) interior zone, greater than 4.5 km into the marsh. Conductivity variability declined from the perimeter to the interior, with the highest variability in the marsh observed in the perimeter zone and the lowest variability observed in the marsh interior.

Water quality in the perimeter and transition zones of the Refuge marsh was more impacted than in the interior zone. When combined with our understanding of the influence of the canal water intrusion into the marsh (Chapter 2), these data documented continued impact of high-nutrient water into the Refuge marsh.

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[1] Prepared by: Matthew C. Harwell, Donatto Surratt, Dori Barone, Nick Aumen

In general, there was a positive relationship between structure inflows and canal TP concentrations. Canal stations along the STA-1W and the S-6 transects reflect both STA-1W discharges and bypass inflows from G-301. Canal stations along the STA-1E and ACME-1 and ACME-2 transects reflected bypass inflows from G-300. Prolonged inflows from STA-1W resulted in sustained high TP concentrations in the canal for several months at the STA-1W and S-6 transects.

In the perimeter zone, canal and marsh stages increased above 4.86 m (16 ft) msl, water depths increased, and TP, total nitrogen (TN), chloride (Cl), and sulfate ($SO_4$)) increased above average from, January 2004 through December 2005. This period was characterized by high rainfall and canal inflow (>2.47 x $10^8$ $m^3$ $month^{-1}$; 200,000 acre-ft per month) and evapotranspiration and canal outflow were lower than inputs. These high inflow conditions occurred during tropical storms and hurricanes.

In the perimeter zone, average TP concentrations were lower than 15 $\mu g\ L^{-1}$ when water input/output was low, marsh and canal stages were high, and water depth was at least 0.3 m (1 ft). Total phosphorus, TN, and conductivity values increased above average in the perimeter zone when Refuge water losses were higher than water gains and the canal stage dropped below 4.41 m (14.5 ft) msl.

In the transition zone, TP, TN, and conductivity were lower than average when rainfall was low, and canal and marsh stage were similar and above 4.86 m (16.5 ft) msl.

In the interior zone, TP, TN, $SO_4$, and conductivity were close to or below average when canal and marsh stages were greater than 4.86 m (16.5 ft). Conductivity increased three times above rainfall conductivity levels when the canal stage decreased below 4.41 m (14.5 ft) and water depths in the marsh decreased. Total phosphorus, TN, CL, and conductivity increased above average in the interior zone when rains were high, the marsh stage was above 4.92 m (16.2 ft) msl, and the canal stage dropped below 4.71 m (15.5 ft) msl in association with a tropical storm. The increases in these water column constituents were associated with suspension of floc into the water column.

Rainfall in 2005 was lower than historic levels. The Refuge had fairly small inflow volumes in 2005, reflecting water management alterations (e.g., addition of the G-341 for water diversion away from STA-1W) and drier conditions. The results here suggest that the frequency, magnitude, and extent of canal water intrusion into the interior were reduced during 2005 relative to previous years.

Floc, a layer of low bulk-density detrital material covering the marsh sediment surface throughout most of the Everglades, may be a significant component of marsh TP dynamics. The floc layer in the northern Refuge was thinner than in the southern Refuge, where the marsh generally stays inundated throughout the year. Floc thickness was generally more variable in the perimeter zone than in the interior of the Refuge, suggesting a greater influence of water movement in the perimeter zone on suspension of floc into the water column.

Previous efforts to characterize water quality in the Refuge included transect research or synoptic mapping exercises. The surface water quality data presented here reveals the perimeter zone as a portion of the Refuge exposed to nutrient and ion-enriched canal water conditions sufficient to alter the marsh ecology. Additionally, the transition zone experiences canal water penetration and elevated nutrient and ion levels. These conditions of elevated nutrients and other elements have the potential to functionally alter the Refuge ecosystem as supported by a previous study of cattail expansion measurements along a single transect across the Refuge.

## Introduction

The Everglades, including the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge), developed as a rainfall-driven system with surface waters low in nutrients and inorganic ions such as chloride, sodium, and calcium, and, therefore, low in conductivity. Areas of pristine marsh throughout the Everglades have been impacted to various degrees by intrusion of water with high nutrients and other constituents. Information from the Refuge and other wetlands indicates that changes in total phosphorus (TP) and major ions can cause undesirable ecological changes in flora and fauna. For example, Childers et al. (2003) documented changes in vegetation and soil TP patterns in the Refuge.
A large amount of research conducted by state, federal, and private entities has demonstrated the impacts of small increases in TP concentrations. Changes in Everglades flora and fauna occur at TP concentrations at 10 ppb and above (Payne and Weaver 2004).

In addition to elevated TP concentrations, canal water has high conductivity compared to the naturally low conductivity marsh interior. Conductivity is a simple field measurement that provides a surrogate for concentration of major ions. Conductivity acts as a moderately conservative tracer of canal water; there are few biological or chemical processes in the surface water that significantly alter conductivity. Increases in canal water intrusion into the Refuge interior (see Chapter 2) may cause negative ecological consequences because canal water is higher in nutrients and other ionic constituents. Available information indicates a correlative relationship between canal water mineral gradients and periphyton (Gleason et al. 1975) and plant species composition (Childers et al. 2003, McCormick and Crawford 2006).

Prior to June 2004, water quality in the Refuge interior was monitored primarily using the 1992 Federal Consent Decree (Case No. 88-1886-CIV-MORENO) compliance network (EVPA). These 14 stations (Figure 1-1), monitored since 1978, characterize the central region of the interior marsh, leaving a relatively large region uncharacterized, predominantly in the outer, impacted fringe of the wetland.

In June 2004, the Refuge began the establishment of an enhanced water quality monitoring network (LOXA) intended to improve the scientific understanding of water quality in the Refuge and to provide information that can be incorporated into water management decisions to better protect Refuge resources (Brandt et al. 2004). The enhanced monthly sampling focuses on the areas uncharacterized by the EVPA that are near surface water discharge sites (Figure 1-1).

Real-time water management decisions influencing water in the perimeter canals require an understanding of current environmental conditions and past trends. Because this information comes from a number of sources, a synthesis of relevant environmental conditions (canal-marsh stage relationships, canal flow, rainfall, and marsh water quality) is valuable for management purposes. Therefore, the objectives of this chapter are to provide a general descriptive summary of environmental conditions, including selected water quality parameters, in the Refuge from 2004-2005. This chapter presents the following: characterization of water quality and related environmental parameters in the canal, perimeter, transition, and interior regions of the Refuge marsh; and characterization of external environmental conditions, including canal water stage, water movement in perimeter canals, rainfall, and evapotranspiration.

## Methods

Sample collection

Surface water grab samples were collected monthly as part of two monitoring networks (EVPA and LOXA) encompassing a total of 48 marsh stations and 5 stations in the perimeter canals. Water samples were collected in different weeks of the same month and generally over a series of consecutive days for each project. Marsh stations are accessed by float helicopter and sampled by wading out into the marsh to collect 3 to 4 L of water and to make in-situ water quality measurements (temperature, conductivity, dissolved oxygen, pH, and total depth) using a portable data logger (SFWMD 2006).

Total depth (depth of clear water column not including detrital materials overlaying the marsh soil surface) was first measured from the helicopter pontoon to make an estimate of the water depth, and a final measurement was taken in the area of the sample. Samples and in-situ measurements were collected from helicopter pontoons for canal stations. Samples were collected in a manner so as not to disturb the detritus particles coating the marsh soil surface, nor introduce sediment or plant-associated particles into the water column. Samples were not collected when water levels dropped below 10 cm (0.33 ft) and only a small volume of water was collected when water levels are between 10 – 20 cm (0.33 and 0.66 ft) (SFWMD 2006).

Samples were stored on ice and transported to the laboratory for filtration and preservation within 4 hr. of collection. The sequence of sample collection to sample analysis is conducted under a well-documented chain of custody. Samples were transferred to an analytical laboratory for individual analysis after being filtered (if necessary) and preserved (SFWMD, 2005), while maintaining compliance of holding time restrictions. Water quality samples were analyzed by the South Florida Water Management District (SFWMD) for samples collected from January 2004 through December 2005. Analytical methods used, SFWMD lab certification, and QA/QC compliance information are available at SFWMD (2006), and directly from the SFWMD. Original data are available on the SFWMD's DBHYDRO web portal at http://www.sfwmd.gov/org/ema/dbhydro/index.html.

Water Quality Parameters Assessed

Twenty-nine parameters were analyzed for samples collected from water greater than 10 cm (0.66 ft) in depth (Table 1-1). Only TP Cl, and $SO_4$ are analyzed for smaller volumes collected between 10-20 cm (0.33 and 0.66 ft). When values were below the minimum detection limits, a value of one-half of the minimum detection limit was applied (Weaver and Payne 2006). No reported TP or Cl values were below the detection limit, while TN (summed NOx and total kjeldahl nitrogen), and $SO_4$ were reported below the detection limits of 25.6% and 9.3%, respectively.

Stage, flow, rainfall, wet deposition chemistry, and evapotranspiration (ET) data were downloaded from the SFWMD data web portal, DBHYDRO. Data from the USGS 1-7 stage gage (Figure 1-1) were used as estimates of marsh stage values, as this gage was situated in the middle of the Refuge. Canal stage data from the headwater gage of the G-94C outflow spillway structure (Figure 1-1) were used because the 1-8C canal gage had periods of missing data. Refuge inflow and outflow were aggregated as the total daily average flow. Inflow records for ACME-1, ACME-2, G-310, G-251, S-362, G-300, and G-301 were used for daily average inflow into the canals; outflow records at G-300, G-301, G-94A, G-94B, G-94C, S-10A, S-10C, S-10D, and S-39 were used for daily average outflow out of the canals (Figure 1-1). Daily rainfall data were averaged from the G-300, S-6, S-39, S-5A weather stations (Figure 1-1). Wet deposition of TP, TN, CL, and $SO_4$ was estimated from the ENRWET site located in Stormwater Treatment Area (STA) 1W, northwest of the Refuge. Contamination occurring during wet deposition sample collection has been noted as an issue for data precision and accuracy (Walker and Jewell 1997, Redfield 2002). Therefore, we present median values to reduce some of the bias associated with potential sample contamination. Evapotranspiration was measured from the STA-1W weather gage. Seepage was not considered here.

Marsh water quality was characterized using monthly values for TP, TN, conductivity, Cl, and $SO_4$, depth of clear water (Tdepth), and depth to consolidated substrate (DCS). The geometric mean of TP concentrations for the entire marsh network (all 53 stations) also is summarized (Appendix 1-1). Gaps in data for any parameter were treated as missing data. Flagged data from DBHYDRO were not used in these analyses presented here. For additional information on flagged data for the period of record analyzed here, refer to DBHYDRO. When parametric analyses were appropriate, we used them and when they were not appropriate, we applied non-parametric approaches (Mayer 2005). For example, we presented nutrient and ion concentrations as averages to give a perspective of water quality conditions that flora and fauna were exposed to over the period of record. Alternatively, because of the skewed nature of the data, we performed non-parametric statistical tests. For example, we applied the Mann-Whitney U test to compare conductivity amongst canal and marsh zones.

Technical disagreements exist over the validity of some of the May and June 2005 water quality data, with extensive discussion of this topic occurring at the Technical Oversight Committee in October 2005 (c.f., Waldon 2005). The State of Florida flagged some of these data due to their belief that sampling error resulted in unusually high values of some parameters. However, we believe that there was no sampling error, and that further analysis of these two months of data is needed. Rather than including a detailed examination of these issues in this report, we will present a technical analyses and interpretation of both EVPA and LOXA data in a subsequent report. The intent of this analysis is solely to gain a better understanding of the Refuge ecology and unusual events.

Floc

In the Everglades, the term "floc" refers to a layer of low bulk-density detrital material covering the marsh sediment surface (Corstanje et al. 2006). Floc consists mostly of decaying macrophyte tissue, soil particles, algae, and microbes (DeBusk et al. 2001). A layer of floc typically occurs across much of the Refuge marsh. The spatial distribution and thickness of floc is generally not well studied, and factors controlling floc depth have not been thoroughly investigated.

We characterize patterns of floc depth observed during water quality sampling for both the Refuge enhanced (LOXA) and compliance (EVPA) sampling. We calculated the thickness of the floc by taking the difference between the clear water column depth and the depth of the water column from the surface down to the consolidated substrate (DCS minus Tdepth) (Waldon 2005). We examined floc thickness in the Refuge by dividing the monitoring stations into two groups, northern and southern Refuge (Figure 1-1), because the southern Refuge consistently has longer hydroperiods and deeper water than the northern Refuge (USFWS 2000).

Zone Classification

The Refuge interior was classified into several geographic zones based upon conductivity data variability (range of $5^{th}$ and $95^{th}$ percentiles) and changes in median conductivity as a function of distance from the perimeter canal (Figure 1-2; Table 1-2). This classification was a function of conductivity versus distance from canal at all marsh sites June 2004 and December 2005 (Figure 1-2). For the analyses presented here, the following zones were identified:

- Canal: sites located in the canal
- Perimeter: sites located from the canal to 2.5 km (1.6 miles) into the marsh
- Transition: sites located from 2.5 km to 4.5 km (1.6 to 2.8 miles) into the marsh
- Interior: sites located greater than 4.5 km (2.8 miles) into the marsh

Conductivity variability declined across the zones and the conductivity in each zone was significantly different (Mann-Whitney U, $p<0.001$) with the highest variability observed in the perimeter zone and the lowest variability observed in the canal (Figure 1-2, Table 1-3). The lower variability in the canal probably was a result of consistently high conductivity water being introduced into the canals, while the low variability in the transition and interior zones reflects mostly a rainfall-driven area. The mixing of high conductivity canal water with low conductivity interior waters most likely was responsible for the higher conductivity variability in the perimeter zone. Identification of these four zones is based on water quality characteristics only, and does not necessarily reflect the ecological status of the marsh. Water quality data from each zone also were examined and summarized for comparison between zones.

## Results and Discussion

Water Quality Summary Statistics

*Depth of clear water column:* Depth of clear water column (Tdepth) varied over time, with generally similar relationships among zones over time (Figure 1-3). In general, Tdepth in the interior zone was lower than the other marsh zones. From April 2005 to July 2005, there was a period of small, abrupt changes in Tdepth in all marsh zones. The range of depth of clear water was the greatest in the perimeter and transition zones and approximately twice that of the interior zone.

*Depth to consolidated substrate:* Depth to consolidated substrate (DCS) is a measure of the total water column (clear water and any bottom floc layer). As with depth of clear water column, DCS varied over time, with generally similar relationships among zones over time (Figure 1-4). In general, DCS in the perimeter zone was higher than the other marsh zones during the dry season. In the rainy season, DCS was not consistently higher for any of the marsh zones. As with Tdepth, from April 2005 to July 2005, there was a period of small, abrupt changes in DCS in all marsh zones.

*Floc:* Floc thickness throughout the marsh was 13 ± 11 cm (5.1 ± 4.3 inches) (mean and 1 standard deviation) and ranged from 0 to 85 cm (0 - 33.5 inches). Floc thickness constituted 29% of DCS, but was highly variable and not well-predicted by DCS (Figure 1-5). In general, floc thickness was more variable in the perimeter zone, particularly in the southern area of the Refuge, than in the transition and interior zones (Figures 1-6 and 1-7). The coefficient of variation (CV) in floc depth for the northern area of the Refuge was 74%, and 77% for the southern Refuge area.

In the northern area of the Refuge, floc thickness was 10 ± 8 cm (4.0 ± 3.0 inches) (Figure 1-6). Floc in the northern area of the Refuge is less variable than in the southern area, with an average floc thickness of 17.5 ±1 3.5 cm (6.9 ± 5.3 inches) (Figure 1-7), and individual measurements ranging from 0 to 19 inches. Two isolated instances at two highly disturbed southern sites had values above the range (26.4 inches in September 2005 and 33.5 inches in December 2005). The southern area generally stays inundated throughout the year.

Floc thickness in the northern area was greatest between September and December in both 2004 and 2005. In 2004, between September and December, the maximum thickness of floc in the northern area was 37.1 cm (14.6 inches; 55% of DCS) (Figure 1-6), and the maximum thickness of floc in the southern area was 43.9 cm (17.3 inches; 49% of DCS) (Figure 1-7). In 2005, during the same set of months, the northern floc maximum thickness was 40 cm (15.8 inches; 74% of DCS) and the southern floc maximum thickness was 85 cm (33.5 inches; 85% of DCS).

*TP:* Flow-weighted-mean TP (Goforth et al. 2005, Pietro et al. 2006, Pietro et al. 2007) entering the Refuge from STA-1W (G-310 and G-251) increased dramatically between

2004 and 2005 (Figure 1-8), rising from an average level of 60 µg $L^{-1}$ in 2004 to 107 µg $L^{-1}$ in 2005.

In general, TP at the canal sites reflected the increases of the STA discharges. Inflow TP concentrations increased just before the fall 2004 hurricanes, with increases also observed in the canal and perimeter zones. Perimeter zone TP concentrations were generally higher than interior values (Table 1-4). From February through April 2005, there was a period of small, abrupt changes in TP in the transition zone (Figure 1-8).

*TN:* There were no clear distinctions in TN data between marsh zones. In general, canal TN concentrations were slightly higher than the marsh (Figure 1-9). In June and July 2004, transition zone TN was elevated above canal TN concentrations. Additionally, both the perimeter and interior zone TN concentrations were elevated above canal and transition zone TN concentrations in August 2004. These higher marsh TN concentrations relative to the canal TN concentrations suggest that canal water intrusion was not the source of the marsh TN for the months of June through July and August 2004.

*Conductivity:* Conductivity showed a clear delineation between canal, perimeter, and transition zones (Figure 1-10), and formed the basis for the characterization of zones (Figure 1-2). In general, conductivity values in the perimeter zone tracked conductivity in the canal zone. Variability in monthly data was highest in the canal and perimeter zone, with less variability in the transition and interior zones (Table 1-3).

*Cl:* Chloride showed a clear delineation between canal, perimeter, and transition zones, with strong similarities to conductivity (Figure 1-11). In general, Cl in the perimeter zone tracked conductivity in the canal zone. As with conductivity, overall variability in monthly Cl data was highest in the canal and perimeter zone, with less variability in the transition and interior zones (Table 1-4).

*$SO_4$:* Sulfate concentrations were different in canal, perimeter, and transition zones (Figure 1-12). Sulfate in the perimeter zone tracked some of the higher $SO_4$ concentrations in the canals, but had less of a pattern than conductivity and Cl. Transition and interior zones were characterized by fairly uniform low $SO_4$ concentrations (Table 1-4). Sulfate concentrations were reduced to or below detection limits in the interior zone, most likely because of higher $SO_4$ reduction.

Descriptive statistics tables for all the water quality parameters analyzed for the Refuge's LOXA and EVPA monitoring sites (January 2004 to December 2005) are presented in Appendix 1-1.

Atmospheric Deposition Chemistry

Median wet deposition TP in 2004 (7 µg $L^{-1}$) was lower than in 2005 (8 µg $L^{-1}$) and lower than the long-term historical (1999-2005) median concentration of 17 µg $L^{-1}$. Median TN wet deposition in 2004 (0.4 mg $L^{-1}$) and 2005 (0.3 mg $L^{-1}$) were lower than the historic

TN (0.8 mg $L^{-1}$) wet deposition concentration. Median CL wet deposition in 2004 (0.9 mg $L^{-1}$) was slightly lower than 2005 (1.0 mg $L^{-1}$) and historic (2.1 mg $L^{-1}$) CL wet deposition concentrations. Median $SO_4$ wet deposition concentrations for 2004 (0.8 mg $L^{-1}$) and 2005 (0.8 mg $L^{-1}$) were slightly lower than the historic median (1.2 mg $L^{-1}$). Ranges and other summary statistics for wet deposition TP, TN, CL, and $SO_4$ are presented in Table 1-5.

Marsh and Canal Stages

Variability in the marsh stages in 2004 and 2005 was much lower than variability from 1999 to 2005 (Figure 1-13). Marsh stage was above canal stage for the majority of 2004 and 2005 (Figure 1-13). Average 2004 canal stage based on the G-94C gage was 4.80 m (15.8 ft) with a range of 4.07 to 5.29 m (13.4 to 17.4 ft), and in 2005, the average was 4.89 m (16.1 ft) and stage ranged between 4.59 and 5.17 m (15.1 and 17.0 ft). In the marsh, average stage based on the 1-7 gage for 2004 was 4.99 m (16.4 ft) with a range of 4.71 to 5.29 m (15.5 to 17.4 ft), and in 2005, the average was 4.96 m (16.3 ft) with a range of 4.77 to 5.17 m (15.7 to 17.0 ft). Canal stage was sporadically higher than marsh stage from August to November 2004, most of March 2005, and consistently from November through December 2005. Although the 1-7 marsh stage gage serves as a good indicator of marsh stages, care must be taken when estimating the stage near the perimeter and in the more northern and southern regions of the marsh, because of the gentle downward elevation slope from the northern to the southern areas of the marsh. For example, intrusion conditions can occur in the south when mean stages seem to preclude it. Detailed analyses of marsh and canal stage relationships can be found in Chapter 2.

Net Flow in Canals

Net flow in the perimeter canals is defined by the inflow structures in the northern region of the Refuge, and the outflow structures in the southern and eastern regions (Figure 1-1). Positive net flow values reflect higher inflow to the canals (northern region of the L-40 and L-7) relative to outflow from the canals (L-39 and southern region of the L-40), while negative net flow values reflect higher outflow from the Refuge canals relative to inflow to the Refuge canals. In 2004, average inflow to the perimeter canals was 18,322 L $s^{-1}$ (648 cfs) and ranged between 0 and 173,266 L $s^{-1}$ (0 and 6,128 cfs). Average outflow was 17,672 L $s^{-1}$ (625 cfs) with a range of 0 and 116,971 L $s^{-1}$ (0 to 4,137 cfs) in 2004. Average net flow was slightly positive at 650 L $s^{-1}$ (23 cfs) and ranged between 0 and 75,634 L $s^{-1}$ (0 and 2,675 cfs) during 2004 (Figure 1-14). In 2005, average inflow was 10,829 L $s^{-1}$ (383 cfs) with a range of 0 to 17,672 L $s^{-1}$ (0 to 4,137 cfs). Average outflow in 2005 was 8,454 L $s^{-1}$ (299 cfs) with a range of 0 to 78,970 L $s^{-1}$ (0 to 2,793 cfs). The average net flow in 2005 was slightly positive at 2,375 L $s^{-1}$ (84 cfs) with a range of 0 to 98,027 L $s^{-1}$ (0 to 3,467 cfs) (Figure 1-14).

In 2004, inflow and outflow were balanced from April to May and again from November to February. Net flow was moderately positive in July and highly positive in August. Net flow was moderately negative in March and highly negative in October.

In 2005, inflow and outflow were balanced in February, May, and December. Net flow was slightly positive in January and August, moderately positive in September, and highly positive in March and October. Net flow was moderately negative in April and highly negative in July.

In general, highly positive net flow preceded highly negative net flow. In 2004, there was an overall negative net flow for the Refuge at the end of the dry season (March through June) (Figure 1-14). The largest period of positive net flow in 2004 occurred from July to October. July through August 2004 had positive net flow and the positive net flows in September 2004 were related to water management operations associated with Hurricanes Francis and Jeanne (Figure 1-14). October 2004 was characterized by high negative net flows. The late dry season negative net flow observed in 2004 also occurred in 2005, but to a lesser extent. May and June 2005 had large rain inflows (35 cm; 13.8 inches) combined (Figure 1-17), followed by high negative net flows (Figure 1-16). October through mid-November 2005 was characterized by positive net flows (Figure 1-14), and the net flow conditions were influenced by Hurricane Wilma in late October.

Average monthly canal net flow for the historic record (October 1999 to December 2005) ranged between -7,634 to 14,703 L $s^{-1}$ (-270 to 520 cfs) (Figure 1-15). The 2004 (-15,551 to 37,888 L $s^{-1}$; -550 to 1340 cfs) and 2005 (-12,723 to 18,378 L $s^{-1}$; -450 to 650 cfs) ranges and patterns were more variable than the historical range and patterns. Overall, daily variability was high for the period between October 1999 and December 2005 (Figure 1-15).

Historically, inflow and outflow monthly averages generally were balanced (absolute difference less than 2,827 L $s^{-1}$; 100 cfs) from October to March when rainfall was low. Net flow was slightly positive (2,827 to 5,655 L $s^{-1}$; 100 to 200 cfs) in June, while net flow historically was slightly negative in April. Net flow was highly positive (> 11,311 L $s^{-1}$; 400 cfs) in August and a moderately positive (5,655 to 11,311 L $s^{-1}$; 200 to 400 cfs) dominance in September.

Neither the 2004 or 2005 patterns of net flow (Figure 1-14) followed the historic net flow pattern (Figure 1-15). January, February, May, and December were similar when comparing 2005, 2004, and the historic period, although the magnitudes of net flow were slightly different. The increase in inflow, relative to outflow, beginning in late July and lasting through late August/early September, was reflected in the 2004 net flow record, and both patterns followed the increased and sustained rainfall beginning in July and lasting through October (Figure 1-15). This pattern was not observed in 2005. In 2005 rainfall increases were delayed until August (Figure 1-16) and the increases in inflows, relative to outflow, were also delayed until August, reaching the maximum in October.

<u>Rainfall</u>

Rainfall patterns were very different between 2004 and 2005 (Figure 1-16). The average monthly rainfall in 2004 was 90 mm (3.5 inches) with a range of 15 mm (0.6 inches) in December to 308 mm (12.1 inches) in September. In 2005, the average was 101 mm (4.0 inches) with a range of 15 mm (0.6) inches in December) to 224 mm (8.8 inches) in June. The 2004 average was 17% below the historic average while the 2005 average was 3% lower. The monthly average historic rainfall ranged from a low of 38 mm (1.5 inches) in December to a high of 188 mm (7.4 inches) in June.

Cumulative rainfall for 2004 and 2005 was 1067 mm (41.6 inches) and 1229 mm (48.4 inches), respectively, relative to annual historic rainfall of 1273 mm (50.1 inches). Historic rainfall data from January 1956 to December 2005 were aggregated from available weather stations (Table 1-6). The spatial variability of rainfall is high (Abtew et al. 2006). Because of the large area of the Refuge, there is the potential for areas in the north to experience greater rainfall than the south, the east more than the west, and vice versa (Harwell et al. 2005; Abtew et al. 2006).

Evapotranspiration

Evapotranspiration (ET) in South Florida is driven primarily by solar radiation, while vegetation type, wind speed, atmospheric pressure, temperature, and humidity play smaller roles (Abtew et al. 2006). Measurements of ET near the Refuge are limited to one station northwest of the Refuge; however, it is important to note that ET varies spatially across the Everglades (Abtew et al. 2006). Cumulative ET for 2004 (1321 mm; 52 inches) and 2005 (1270 mm; 50 inches) was comparable to annual historic rainfall (1320 mm; 52 inches) and the general patterns of ET were similar from year to year. The average monthly ET in 2004 was 109 mm (4.3 inches) with a range of 69 mm (2.7 inches) (December) to 160 (6.3 inches) (May), and in 2005 the average was 104 mm(4.1 inches) with a range of 76 mm (3.0 inches in December to 137 mm (5.4 inches) in April. The 2004 average was exactly the same as the historic average, while the 2005 average ET was 4% lower (Figure 1-17). The monthly average historic ET ranged from 74 mm (2.9 inches) in December to 150 mm (5.9 inches) in May.

A cyclic pattern was observed for ET. From October to February, ET was lower than 10 cm (4 inches). In March and again between August and September, ET was between 102 and 127 mm (4 and 5 inches). From April to July, ET was greater than 127 mm (5 inches), except for June, when ET dropped to lower levels and rapidly increased above 127 mm (5 inches) by July. ET was highest during the spring and summer months when the solar radiation was greatest and lowest in the fall and winter months when solar radiation was lowest.

Overall Hydrologic Inputs and Outputs

Inputs and outputs were highest from June through October during the 2004-2005 (Figure 1-18), and are similar to patterns from October 1999 to December 2005 (Figure 1-19). One to two months of high inputs generally were followed by higher outputs. During high input, outflow was higher than inflow, rainfall, and ET. Historically, rainfall from June through September ranged from 8.63 x $10^7$ to 1.11 x $10^8$ $m^3$ $month^{-1}$ (70,000 to 90,000 acre-ft per month), and during this period the rainfall was greater than inputs and canal outflow (Figure 1-20). Inflows ranged from 8.02 x $10^7$ to 8.63 x $10^7$ $m^3$ $month^{-1}$ (65,000 to 70,000 acre-ft per month) during high rainfall months and were slightly lower than rainfall, but slightly higher than outflows which were 3.70 x $10^7$ to 8.63 x $10^7$ $m^3$ $month^{-1}$ (30,000 to 70,000 acre-ft per month) (Figure 1-18). Rainfall, inflows, and outflows were lowest from November through April, with occasional spikes in rainfall in March (Figure 1-20). Historically, ET showed a declining pattern over the period June to December and made up only a small portion of the output (Figure 1-19).

From August to October 2004, inflow and outflow were higher than rainfall and ET (Figure 1-20). In September, inflow (2.34 x $10^8$ $m^3$; 190,000 acre-ft) and outflow (2.34 x $10^8$ $m^3$; 190,000 acre-ft) were the highest. This pattern of high inflow and outflow in 2004 was consistent with the historic pattern, while the remainder of 2004 had relatively lower values in rainfall, inflows, and outflows compared to the historic record. Rainfall and inflow spiked in March and June 2005 and in June 2005, outflow also increased above historic levels. The remainder of 2005 showed lower rainfall, inflow, and outflow compared to the historic record (Figure 1-19).

Evapotranspiration ranged 3.95 x $10^7$ to 1.01 x $10^8$ $m^3$ $month^{-1}$ (32,000 to 82,000 acre-ft per month) from October 1999 to December 2005 (Figure 1-20). From November through February, ET was greater than outputs and inputs, as outputs and inputs were at their lowest. During these periods, ET often was the largest loss of water for the Refuge. Unlike previous years, 2005 ET was higher than rainfall, inflow, and outflow through May, with the exception of March, when rainfall was the largest source of water. When rainfall was high in June 2005, ET decreased rapidly and increased just as rapidly by July when rainfall was lower than in June.

Environmental Characteristics by Zone

We characterized water quality by zone through description of monthly environmental conditions. Initial interpretations of potential mechanisms explaining monthly water quality grab samples are limited in scope, in part, because monthly samples were not collected on the same date. Additional efforts examining monthly water quality grab samples with continuous measurements of conductivity along transects (Chapter 2) will provide more information about the influence of canal water intrusion on water quality in the Refuge marsh. Select water quality parameters (analyzed from January 2004 to December 2005) by zone are presented in Appendix 1-2.

*Canal Zone*

Time series plots generally show a good correspondence between structure discharges and canal TP concentrations; an example of a typical pattern is shown in Figure 1-21. Prolonged inflows from STA-1W resulted in sustained high canal TP for several months at the STA-1W canal station (Figure 1-21). This pattern was also observed in the canal station on the S-6 transect (Appendix 1-3) even though the STA-1W canal station is more than 10 km from the S-6 canal station (Figure 1-1). Determining whether this reflected a consistent pattern will require a longer period of canal station monitoring.

Time series plots of structure inflows versus TP and conductivity for the five LOXA canal stations (Figure 1-1) are presented in Appendix 1-3. For canal stations along the STA-1W and S-6 transects, these relationships reflected both STA-1W discharges and bypass inflows from G-301 (Figure 1-1). For canal stations along the STA-1E, ACME-1, and ACME-2 transects, these relationships primarily reflected bypass inflows from G-300 (Figure 1-1).

Conductivity, Cl, and $SO_4$ appeared to follow similar patterns to each other in the canal zone (Figure 1-22). Cl and conductivity patterns were strongly correlated ($R^2$ = 0.87, n=91, p<0.01), while the conductivity to $SO_4$ correlation ($R^2$ = 0.80, n=83, p<0.01) and the Cl to $SO_4$ correlation were weaker ($R^2$ = 0.62, n=83, p<0.01). There were no obvious direct relationships between conductivity, Cl, or $SO_4$ from inflow or outflow structures to water volumes from those structures.

Canal zone TP in October 2004 was greater than 400 $\mu g\ L^{-1}$ and more than 3 times higher than the average canal TP concentration. Wet deposition TP was minimal and likely did not influence the higher October 2004 canal water column concentration. TP loads in September 2004 (19 Mg; metric-tons) and October (13 Mg) discharged from the STA-1W structure were higher than average (3 Mg) and the elevated TP concentration in the canal in October were associated with these higher loads from STA-1W. The TP loads were associated with higher September ($1.54 \times 10^8\ m^3\ month^{-1}$; 125,000 acre-ft per month) and October ($8.26 \times 10^7\ m^3\ month^{-1}$; 67,000 acre-ft per month) 2004 canal inflows than average ($2.84 \times 10^7\ m^3\ month^{-1}$ 23,000 acre-ft per month) canal inflows. Higher inflow conditions were driven by structure operations related to Hurricanes Frances and Jeanne.

*Perimeter Zone (0 to 2.5 km; 0 to 1.6 miles)*

Water depths increased to greater than 30 cm (12 inches) when water inputs (rainfall plus canal inflow; Figure 1-18) were greater than $2.47 \times 10^8\ m^3$ (200,000 acre-ft) while water outputs (ET plus canal water outflow; Figure 1-18) were lower for any month. Conductivity, Cl, TP, TN, and $SO_4$ (Figure 1-23) all increased above average values when water input was high and marsh and canal stages were similar and higher than 4.86 m (16 ft) msl (Figure 1-13). These high water input conditions were most prevalent from August to October 2004, during Tropical Storms Rita and Tammy and Hurricane Wilma.

Water depth increased to above 38 cm (15 inches) and TP concentrations decreased below 15 $\mu g\ L^{-1}$ (Figure 1-23) when water inputs and outputs were lower than $1.23 \times 10^8\ m^3$ (100,000 acre-ft) (Figure 1-18) and canal and marsh stages were similar and above 5.02 m (16.5 ft) msl. These low water input/output (Figure 1-18) and high stage conditions (Figure 1-13) were prevalent from January to March 2004 and again from November to December 2005.

Canal stage dropped below 4.41 m (14.5 ft) msl (Figure 1-13) and water depth (Figure 1-23) in the marsh dropped to the lowest when inflow was minimal, ET was more than double rainfall, and outflow was twice inflow (Figure 1-18). Total phosphorus, conductivity, and TN (Figure 1-23) increased above average under these low canal stage and shallow marsh water depth conditions. Low input and low canal stage conditions were prevalent in April and June 2004. Low canal stage continued through mid-July 2004, but water depth dropped below the 10 cm (0.33 ft) minimum sample collection depth, so samples were not collected. Evapotranspiration had the strongest influence on the water column in April and June 2004, removing more than $1.76 \times 10^8$ $m^3$ (143,000 acre-ft) (Figure 1-18) of water from the Refuge over the two months. The increases in TP, conductivity, and TN potentially were associated with evaporation concentrating the water column.

Other water quality parameters for the perimeter zone are presented in Appendix 1-2.

*Transition Zone (2.5 to 4.5 km; 1.6 to 2.8 miles)*
Water depth ranged 30 to 102 cm (12 to 40 inches) (Figure 1-24) when canal and marsh stages were similar and above 5.10 m (16.5 ft) msl (Figure 1-13). TP and TN were below average in the higher water depths. The water column in the marsh tended to be more clear (particulate matter settled to the bottom) when winds were moderate, rainfall was low, canal and marsh stages were high. High canal and marsh stages with low rainfall and moderate wind speeds were prevalent from January to March 2004 and again in November and December 2005.

TP, TN, Cl, conductivity, and $SO_4$ were moderately elevated in the transition zone, when the Tdepth decreased below 13 cm (5 inches). Lower Tdepths occurred from June through July 2004 and March 2005. Canal stages were much lower than marsh stages and inflow and outflow were low while rainfall was moderate and balanced with ET during the periods June through July 2004 and March 2005. We conjecture that the elevated transition zone constituents resulted from low Tdepth, which allowed concentration of constituents in the water column.

Other water quality parameters for the transition zone are presented in Appendix 1-2.

*Interior Zone (> 4.5 km; > 2.8 miles)*
Water depth increased above 30 cm (12 inches) when canal and marsh stages were similar and above 5.01 m (16.5 ft) msl. TP, TN, Cl, and conductivity were close to or below average when these stage and water depth conditions were prevalent. Conductivity (Figure 1-25) increased to more than 3 times rainfall conductivity levels (100-150 $\mu S\ cm^{-1}$) when the canal stage decreased below 4.41 m (14.5 ft) msl. Sulfate (Figure 1-25) increased above average concentration during the large storm events (Tropical Storms Rita and Tammy and Hurricane Wilma) of August to October 2004 Other water quality parameters for the interior zone are presented in Appendix 1-2.

Floc

Developing a better understanding of the spatial and temporal abundance of floc, and the factors that control floc abundance are important for several reasons. First, floc may represent a significant pool for phosphorus (Bachmann et al. 1999). Second, floc is associated with TP uptake and release of phosphorus, and resuspension of floc has been suggested as a source of TP to overlaying water columns (Fisher and Reddy 2001). This resuspension of a portion of the floc layer may be caused by natural events or disturbance of water during sampling. In either case, TP concentration in the overlying water column may be elevated. Third, even small lateral movements of floc can transport more mass than is transported by advection of the clear water column. As advection of floc has not been quantified, floc may play a significant role in governing TP transport in the Refuge and throughout the Everglades.

To gain perspective on the importance of floc on TP abundance in the Refuge, it is instructive to estimate TP concentration in floc and the overlying clear water column. Average floc bulk density and TP in the Northern Everglades are 22 kg $m^{-3}$ and 632 mg $kg^{-1}$, respectively (Corstanje et al., 2006). Based on the average floc layer thickness reported here, 0.12 m, the typical TP concentration in floc is 1.7 g $m^{-2}$. Assuming floc thickness is 29% of DCS, the clear water column above the floc layer is 28 cm. For a TP water concentration of 0.025 mg $L^{-1}$, areal TP density is 0.0073 g $m^{-2}$. Thus, on an areal basis, there are 230 times more TP mass in the floc layer than in the overlying water. Comparatively minor entrainment of floc into the overlying water would be significant.

## Summary

This chapter describes environmental and water quality monitoring data for the Refuge. The approach of classifying the interior marsh into perimeter, transition, and interior zones provides more insights into how the marsh responds to impacts from canal water penetration than characterization of the marsh only by impacted and unimpacted regions based on soil TP concentrations (used for State of Florida regulatory purposes). Water quality in perimeter and transition zones of the Refuge marsh were different, and more impacted, than in the interior zone. The data document continued impact of high nutrient water on the Refuge marsh. The zone classification used here was based on water chemistry and distance from the canal into the marsh, and alone does not provide information about the ecological status of the marsh.

This chapter functions as a building block for further water quality analyses of gradient transects (Chapter 2) related to water management. Hydrodynamic and water quality modeling tools are being developed (Chapter 3). Previous efforts to characterize the Refuge focused on transect research (Reddy et al. 1998; McCormick et al. 2000; Childers et al. 2003; Chapter 2), or synoptic mapping exercises (Richardson et al. 1990; Scheidt et al. 2000; Stober et al. 2001; Weaver and Payne 2004; Sklar et al. 2005). Here, a zone classification approach used for water quality documented nutrient and ionic conditions in the marsh.

While rainfall and canal water movement significantly influence the perimeter zone chemistry, the exposure to nutrient and ion-enriched canal water conditions is sufficient to alter the ecology of the marsh (Childers et al. 2003; McCormick and Crawford 2006). Both rainfall and canal water movement influence the transition zone chemistry and ecology; however, the impacts to this zone are expected to be different from those in the perimeter zone. These differences in impact are anticipated because the transition zone is farther removed from the influence of canal water inputs. Examples of ecological influences of canal water on this region of the Refuge marsh have been documented in Childers et al. (2003), and experimentally by McCormick and Crawford (2006).

In general, rainfall in the interior zone is the dominant source of water. A secondary source of water to the interior zone may occur as intrusion under the conditions of strong canal inflow coupled with the appropriate canal-marsh stage. If the interior zone were dominated by rainfall and evaporative processes, patterns of nutrient and ion concentrations would be expected to remain relatively consistent through time reflecting biological uptake and release.

Although there was approximately normal rainfall for 2005, the Refuge had a small inflow volume relative to its historical record (October 1999 through December 2005). The small inflow volume, in part, reflects water management changes (e.g., G-341 diversion of waters away from STA-1W; Goforth 2005), and limited use of the STA-1 complex. Chapter 2 documents and characterizes canal water intrusion during 2005; however, the results here provide a preliminary indication that the frequency, magnitude, and extent of canal water intrusion into the interior may have been reduced during 2005 relative to previous years.

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**Table 1-1**. Water quality monitoring parameters for the A.R.M. Loxahatchee National Wildlife Refuge's Enhanced Water Quality Program. Parameter descriptions, IDs, and Methods are as listed in the SFWMD's DBHYDRO database and in SFMWD (2006).

| PARAMETER | ID[1] | Units | MDL | Method |
|---|---|---|---|---|
| ALKALINITY, TOTAL as CACO3 | ALKA | mg $L^{-1}$ | 1 | EPA 310.1 |
| ALKALINE PHOSPHATASE | APA | nM/min mL | 1 | SFWMD 3160.1 |
| CALCIUM | Ca | mg $L^{-1}$ | 0.2 | SM3120B |
| CHLORIDE | Cl | mg $L^{-1}$ | 0.1 | EPA 300.0 |
| COLOR | COLOR | PCU | 1 | SM2120B (MODIFIED) |
| DISSOLVED OXYGEN | DO | mg $L^{-1}$ | 0.01 | FIELD[2] |
| DISSOLVED ORGANIC CARBON | DOC | mg $L^{-1}$ | 1.0 | EPA 415.1 |
| HARDNESS as CACO3 | HARD | mg $L^{-1}$ | 0.1 | SM3120B |
| POTASSIUM | K | mg $L^{-1}$ | 0.1 | SM3120B |
| MAGNESIUM | Mg | mg $L^{-1}$ | 0.1 | SM3120B |
| SODIUM | Na | mg $L^{-1}$ | 0.2 | SM3120B |
| AMMONIUM | $NH_4$ | mg $L^{-1}$ | 0.009 | SM4500-NH3H |
| NITRATE | $NO_3$ | mg $L^{-1}$ | 0.004 | SM4500NO3F |
| NITRITE | $NO_2$ | mg $L^{-1}$ | 0.004 | SM4500NO3F |
| NITRATES and NITRITES as N | NOX | mg $L^{-1}$ | 0.006 | SM4500NO3F |
| PHOSPHATE, ORTHO as P | $OPO_4$ | mg $L^{-1}$ | 0.004 | SM4500PF |
| pH | pH | UNITS | 0.01 | FIELD[2] |
| SILICA | $SiO_2$ | mg $L^{-1}$ | 0.05 | SM4500SID (MODIFIED) |
| SULFATE | $SO_4$ | mg $L^{-1}$ | 0.1 | EPA 300.0 |
| SP CONDUCTANCE | SpCond | $\mu S\ cm^{-1}$ | 0.1 | FIELD[2] |
| KJELDAHL NITROGEN, DISSOLVED | TDKN | mg $L^{-1}$ | 0.05 | EPA 351.2 |
| PHOSPHATE, DISSOLVED as P | $TDPO_4$ | mg $L^{-1}$ | 0.002 | SM4500PF |
| TOTAL DISSOLVED SOLIDS | TDS | mg $L^{-1}$ | 22 | SM2540C |
| TEMPERATURE | TEMP | Deg. C | 0.01 | FIELD[2] |
| KJELDAHL NITROGEN, TOTAL | TKN | mg $L^{-1}$ | 0.05 | EPA 351.2-MOD |
| CARBON, TOTAL ORGANIC | TOC | mg $L^{-1}$ | 1 | EPA 415.1 |
| PHOSPHATE, TOTAL AS P | $TPO_4$ | mg $L^{-1}$ | 0.002 | SM4500PF |
| TOTAL SUSPENDED SOLIDS | TSS | mg $L^{-1}$ | 3 | EPA 160.2 |
| TURBIDITY | TURB | NTU | 0.1 | SM2130B |

[1] ID is the descriptor used in Appendix 1-1
[2] These values reflect the smallest reporting interval from field instruments.

**Table 1-2.** Site distances from canal into the marsh and around the canal with LOXA116 as the starting point (highlighted in table). Sites are grouped by transects and regions of location in the A.R.M. Loxahatchee National Wildlife Refuge (Figure 2-1). The monitoring programs (LOXA and EVPA) and Refuge zone are identified for each site.

| REGION | MONITORING PROGRAM | SITE ID | DISTANCE FROM CANAL (km) | DISTANCE AROUND CANAL (km) | ZONE | PERIOD OF RECORD | REGION | MONITORING PROGRAM | SITE ID | DISTANCE FROM CANAL (km) | DISTANCE AROUND CANAL (km) | ZONE | PERIOD OF RECORD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STA-1W | LOXA | LOXA104 | canal | 12.8 | CANAL | JUN04-DEC05 | S-5A | LOXA | LOXA101 | 0.8 | 27.1 | PERIMETER | JUN04-DEC05 |
| TRANSECT | LOXA | LOXA105 | 0.7 | 12.9 | PERIMETER | JUN04-DEC05 | AREA | LOXA | LOXA140 | 0.9 | 30.8 | PERIMETER | JUN04-DEC05 |
| | LOXA | LOXA106 | 1.1 | 13.4 | PERIMETER | JUN04-DEC05 | | | | | | | |
| | LOXA | LOXA107 | 2.2 | 14.4 | PERIMETER | JUN04-DEC05 | STA-1E | LOXA | LOXA135 | canal | 33.8 | CANAL | JUN04-DEC05 |
| | LOXA | LOXA108 | 3.9 | 11.1 | TRANSITION | JUN04-DEC05 | TRANSECT | LOXA | LOXA136 | 0.6 | 34.0 | PERIMETER | JUN04-DEC05 |
| | | | | | | | | LOXA | LOXA137 | 1.1 | 34.1 | PERIMETER | JUN04-DEC05 |
| STA-1W | LOXA | LOXA102 | 1.3 | 14.0 | PERIMETER | JUN04-DEC05 | | LOXA | LOXA138 | 2.1 | 34.8 | PERIMETER | JUN04-DEC05 |
| AREA | LOXA | LOXA103 | 1.0 | 15.7 | PERIMETER | JUN04-DEC05 | | LOXA | LOXA139 | 3.9 | 36.2 | TRANSITION | JUN04-DEC05 |
| | LOXA | LOXA109 | 1.3 | 8.0 | PERIMETER | JUN04-DEC05 | | | | | | | |
| | LOXA | LOXA110 | 2.7 | 8.3 | TRANSITION | JUN04-DEC05 | | | | | | | |
| | EVPA | LOX3 | 4.6 | 36.3 | INTERIOR | JAN04-DEC05 | STA-1E | LOXA | LOXA134 | 0.8 | 35.4 | PERIMETER | JUN04-DEC05 |
| | | | | | | | AREA | LOXA | LOXA140 | 0.9 | 30.8 | PERIMETER | JUN04-DEC05 |
| S-6 | LOXA | LOXA115 | canal | 0.1 | CANAL | JUN04-DEC05 | | EVPA | LOX3 | 4.6 | 36.3 | INTERIOR | JAN04-DEC05 |
| TRANSECT | LOXA | LOXA116 | 0.4 | 0.0 | PERIMETER | JUN04-DEC05 | | | | | | | |
| | LOXA | LOXA117 | 0.9 | 0.5 | PERIMETER | JUN04-DEC05 | ACME 1 | LOXA | LOXA132 | canal | 36.7 | CANAL | JUN04-DEC05 |
| | LOXA | LOXA118 | 1.8 | 1.3 | PERIMETER | JUN04-DEC05 | TRANSECT | LOXA | LOXA133 | 0.6 | 36.7 | PERIMETER | JUN04-DEC05 |
| | LOXA | LOXA119 | 4.3 | 3.2 | TRANSITION | JUN04-DEC05 | | EVPA | LOX4 | 1.2 | 36.7 | PERIMETER | JAN04-DEC05 |
| | LOXA | LOXA120 | 6.1 | 5.2 | INTERIOR | JUN04-DEC05 | | | | | | | |
| | | | | | | | ACME 2 | LOXA | LOXA129 | canal | 40.5 | CANAL | JUN04-DEC05 |
| S-6 | LOXA | LOXA121 | 0.1 | 91.6 | PERIMETER | JUN04-DEC05 | TRANSECT | LOXA | LOXA130 | 0.5 | 40.6 | PERIMETER | JUN04-DEC05 |
| AREA | LOXA | LOXA122 | 0.9 | 90.6 | PERIMETER | JUN04-DEC05 | | LOXA | LOXA131 | 1.5 | 41.2 | PERIMETER | JUN04-DEC05 |
| SOUTH | LOXA | LOXA123 | 0.9 | 85.6 | PERIMETER | JUN04-DEC05 | CENTRAL | LOXA | LOXA112 | 1.6 | 5.0 | PERIMETER | JUN04-DEC05 |
| AREA | LOXA | LOXA124 | 1.3 | 56.8 | PERIMETER | JUN04-DEC05 | TRANSECT | EVPA | LOX10 | 1.2 | 5.5 | PERIMETER | JAN04-DEC05 |
| | EVPA | LOX11 | 6.6 | 61.5 | INTERIOR | JAN04-DEC05 | | LOXA | LOXA111 | 3.1 | 5.4 | TRANSITION | JUN04-DEC05 |
| | EVPA | LOX12 | 2.7 | 85.8 | TRANSITION | JAN04-DEC05 | | LOXA | LOXA113 | 3.8 | 5.6 | TRANSITION | JUN04-DEC05 |
| | EVPA | LOX13 | 6.6 | 63.6 | INTERIOR | JAN04-DEC05 | | LOXA | LOXA114 | 4.4 | 6.0 | TRANSITION | JUN04-DEC05 |
| | EVPA | LOX14 | 1.2 | 62.6 | PERIMETER | JAN04-DEC05 | | LOXA | LOXA128 | 5.1 | 6.4 | INTERIOR | JUN04-DEC05 |
| | EVPA | LOX15 | 1.2 | 78.0 | PERIMETER | JAN04-DEC05 | | EVPA | LOX7 | 5.5 | 47.4 | INTERIOR | JAN04-DEC05 |
| | EVPA | LOX16 | 2.0 | 74.4 | PERIMETER | JAN04-DEC05 | | EVPA | LOX8 | 9.7 | 48.4 | INTERIOR | JAN04-DEC05 |
| | | | | | | | | EVPA | LOX9 | 5.5 | 7.4 | INTERIOR | JAN04-DEC05 |
| OTHER | EVPA | LOX5 | 8.1 | 11.6 | INTERIOR | JAN04-DEC05 | | LOXA | LOXA127 | 3.1 | 50.0 | TRANSITION | JUN04-DEC05 |
| | | | | | | | | EVPA | LOX6 | 1.1 | 50.8 | PERIMETER | JAN04-DEC05 |
| | | | | | | | | LOXA | LOXA126 | 0.4 | 50.5 | PERIMETER | JUN04-DEC05 |

**Table 1-3.** Conductivity summary statistics for the zone classifications. The four zones were the marsh boundary canal, perimeter (canal to 2.5 km (1.6 miles) into the marsh), transition (2.5 to 4.5 km (1.6 to 2.8 miles) into the marsh), and interior zone (>4.5 km (< 2.8 miles) into the marsh).

| Zone Classification Summary Statistics | Canal | Perimeter | Transition | Interior |
|---|---|---|---|---|
| Number of samples | 90 | 424 | 121 | 131 |
| Mean | 821 | 390 | 166 | 122 |
| Standard deviation | 235 | 226 | 65 | 46 |
| Coefficient of variation | 29% | 58% | 39% | 38% |
| Median | 823 | 319 | 147 | 115 |
| 25th percentile | 669 | 215 | 117 | 97 |
| 75th percentile | 947 | 526 | 195 | 134 |

**Table 1-4**. Summary statistics for TP, TN, conductivity, Cl, $SO_4$, and Tdepth classified by zone from January 2004 - December 2005. Summary statistics are based on monthly arithmetic means for each zone.

| | Canal Zone[A] | | | | | | | Perimeter Zone[B] | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameters** | Mean | Median | Minimum | Maximum | n | 25 percentile | 75 percentile | Mean | Median | Minimum | Maximum | n | 25 percentile | 75 percentile |
| Total Phosphorus ($\mu g\ L^{-1}$) | 113 | 77 | 53 | 499 | 88 | 62 | 97 | 20 | 11 | 6 | 26 | 429 | 9 | 14 |
| Specific Conductivity ($\mu S\ cm^{-1}$) | 820 | 730 | 482 | 1054 | 90 | 622 | 866 | 365 | 329 | 166 | 651 | 424 | 222 | 383 |
| Chloride ($mg\ L^{-1}$) | 105 | 94 | 48 | 130 | 91 | 80 | 117 | 51 | 47 | 20 | 92 | 417 | 36 | 57 |
| Sulfate ($mg\ L^{-1}$) | 44 | 36.6 | 7.9 | 90.0 | 90 | 16.0 | 49.1 | 11 | 2.3 | 0.9 | 43.2 | 414 | 1.8 | 4.3 |
| Tdepth (inches) | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 12 | 10 | 0 | 28 | 551 | 5 | 15 |
| Total Nitrogen ($mg\ L^{-1}$) | 2 | 2.2 | 1.5 | 5.2 | 75 | 1.9 | 2.3 | 1 | 1.3 | 1.0 | 2.3 | 264 | 1.1 | 1.4 |

| | Transition Zone[C] | | | | | | | Interior Zone[D] | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameters** | Mean | Median | Minimum | Maximum | n | 25 percentile | 75 percentile | Mean | Median | Minimum | Maximum | n | 25 percentile | 75 percentile |
| Total Phosphorus ($\mu g\ L^{-1}$) | 14 | 9 | 5 | 52 | 128 | 7 | 15 | 15 | 9 | 7 | 102 | 142 | 8 | 13 |
| Specific Conductivity ($\mu S\ cm^{-1}$) | 200 | 191 | 109 | 332 | 121 | 121 | 264 | 144 | 118 | 76 | 430 | 131 | 103 | 157 |
| Chloride ($mg\ L^{-1}$) | 31 | 29 | 15 | 55 | 119 | 18 | 41 | 24 | 23 | 14 | 38 | 123 | 18 | 28 |
| Sulfate ($mg\ L^{-1}$) | 1 | 1.1 | 0.2 | 3.2 | 117 | 0.5 | 1.4 | 0.2 | 0.1 | 0.1 | 0.4 | 123 | 0.1 | 0.2 |
| Tdepth (inches) | 12 | 10 | 2 | 39 | 166 | 4 | 12 | 9 | 8 | 0 | 20 | 188 | 4 | 12 |
| Total Nitrogen ($mg\ L^{-1}$) | 2 | 1.2 | 0.0 | 8.7 | 67 | 0.9 | 1.6 | 2 | 1.3 | 1.0 | 8.4 | 95 | 1.1 | 1.6 |

[A] All stations analyzed from the LOXA monitoring network from June 2004 to December 2005.

[B] Analysis from January to May 2004 based on 6 EVPA monitoring network stations; from June 2004 to December 2005 based on 6 EVPA sites and 24 LOXA monitoring network stations.

[C] Analysis from January to May 2004 based on 1 EVPA monitoring network station; from June 2004 to December 2005 based on 1 EVPA site and 8 LOXA monitoring network stations.

[D] Analysis from January to May 2004 based on 7 EVPA monitoring network stations; from June 2004 to December 2005 based on 7 EVPA sites and 2 LOXA monitoring network stations.

**Table 1-5.** Summary statistics for wet deposition TP, TN, Cl, and $SO_4$ for 2004, 2005, and for the period 1999-2005.

| Atmospheric Deposition Chemistry | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Year** | **n** | **Mean** | **Std** | **Max** | **Min** | **C.V.** | **Median** |
| TP ($\mu g\ L^{-1}$) | 2004 | 12 | 33.3 | 77.8 | 276.0 | 2.0 | 2.3 | 6.6 |
| | 2005 | 10 | 14.7 | 17.7 | 58.0 | 2.0 | 1.2 | 8.0 |
| | *1999-2005 | 163 | 19.2 | 11.8 | 52.8 | 7.7 | 0.6 | 17.3 |
| TN ($mg\ L^{-1}$) | 2004 | 11 | 0.5 | 0.3 | 1.3 | 0.2 | 0.7 | 0.4 |
| | 2005 | 10 | 0.3 | 0.2 | 0.8 | 0.2 | 0.5 | 0.3 |
| | *1999-2005 | 99 | 0.8 | 0.2 | 1.1 | 0.5 | 0.2 | 0.8 |
| CL ($mg\ L^{-1}$) | 2004 | 11 | 1.1 | 1.0 | 3.0 | 0.2 | 0.9 | 0.9 |
| | 2005 | 11 | 2.1 | 3.1 | 11.3 | 0.5 | 1.5 | 1.0 |
| | *1999-2005 | 146 | 2.0 | 0.6 | 3.2 | 1.2 | 0.3 | 2.1 |
| SO4 ($mg\ L^{-1}$) | 2004 | 11 | 1.1 | 0.7 | 3.0 | 0.6 | 0.6 | 0.8 |
| | 2005 | 11 | 1.0 | 0.6 | 2.4 | 0.6 | 0.6 | 0.8 |
| | *1999-2005 | 130 | 1.3 | 0.3 | 1.9 | 0.9 | 0.2 | 1.2 |

C.V. = coefficient of variation
Max = maximum
Min = minimum
n = number samples
* parameter specific summary statistics for the period 1999-2005 were aggregated to annual monthly values and then aggregated again to 12 months for comparison to 2004 and 2005

**Table 1-6**. Weather station and initial operation dates used for analyses. Historical rainfall was determined from available data for each gage from the operation date to December 2005.

| Weather Station ID | Initial Operation Date |
|---|---|
| S-5A | 1956 |
| S-39 | 1963 |
| S-6 | 1960 |
| G-300 | 2004 |
| STA-1W | 1999 |

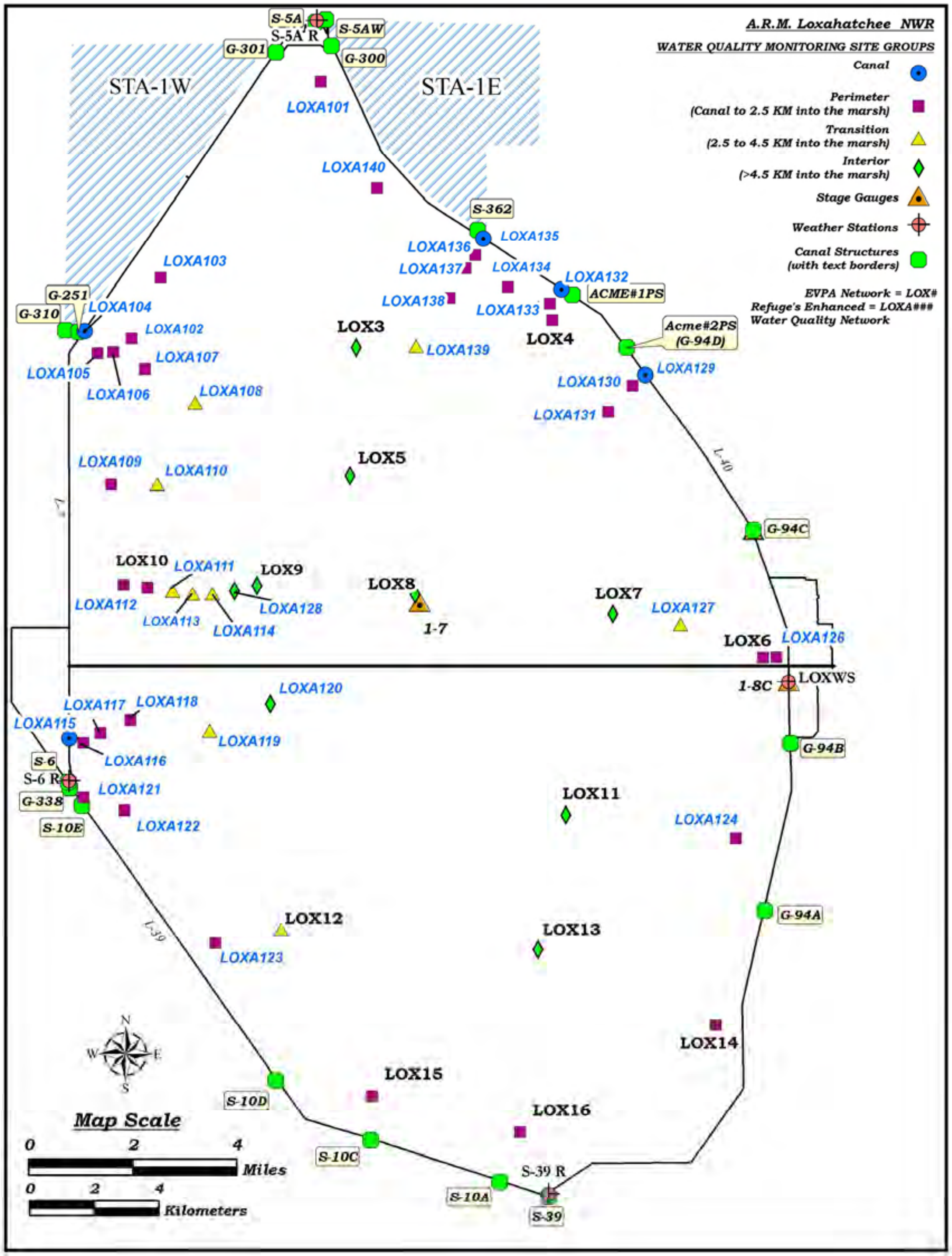



**Figure 1-1**. Water quality stations in the A.R.M. Loxahatchee National Wildlife Refuge classified by zone (canal, perimeter, transition, interior). The line across the middle of the Refuge delineates the northern and southern regions used for analysis of floc data.

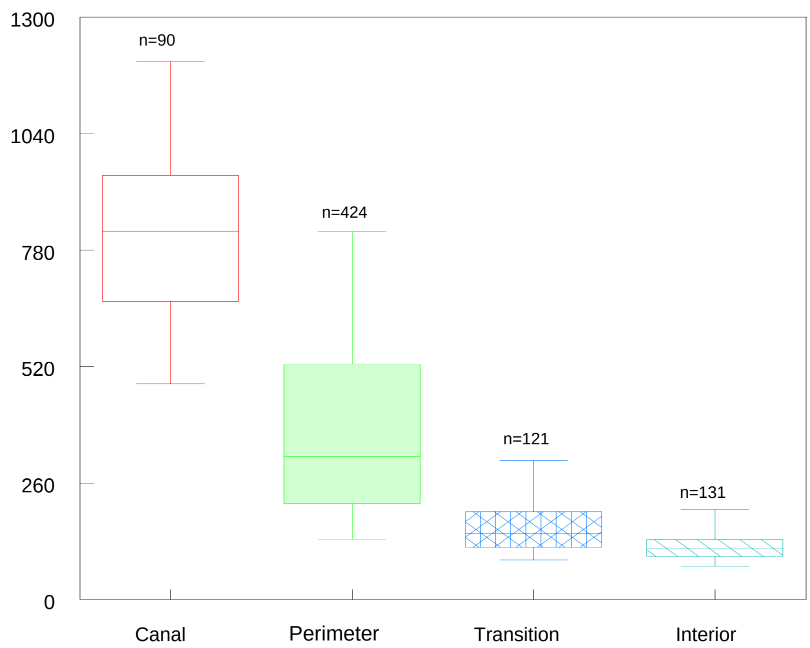



**Figure 1-2**. Box-whisker plot showing conductivity verses distance to canal for the four zones: boundary canal; perimeter (from canal to 2.5 km (1.6 miles) into marsh; transition (2.5 to 4.5 km (1.6 to 2.8 miles) into marsh); interior (more than 4.5 km (> 2.8 miles) into marsh). The horizontal line in each box is the median, the top and bottom of the box represents the 75$^{th}$ and 25$^{th}$ percentile, respectively, and the whiskers define the 5$^{th}$ and 95$^{th}$ percentile observations.

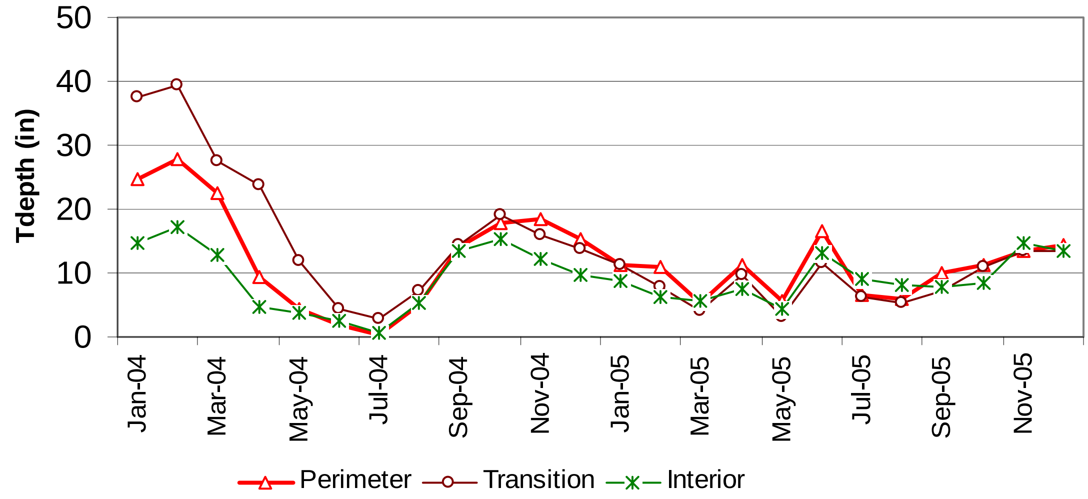



**Figure 1-3**. Clear water column depth (Tdepth in inches; arithmetic mean of all stations in each zone) over time in the different marsh zones of the Refuge interior. Zones described in Figure 1-2.

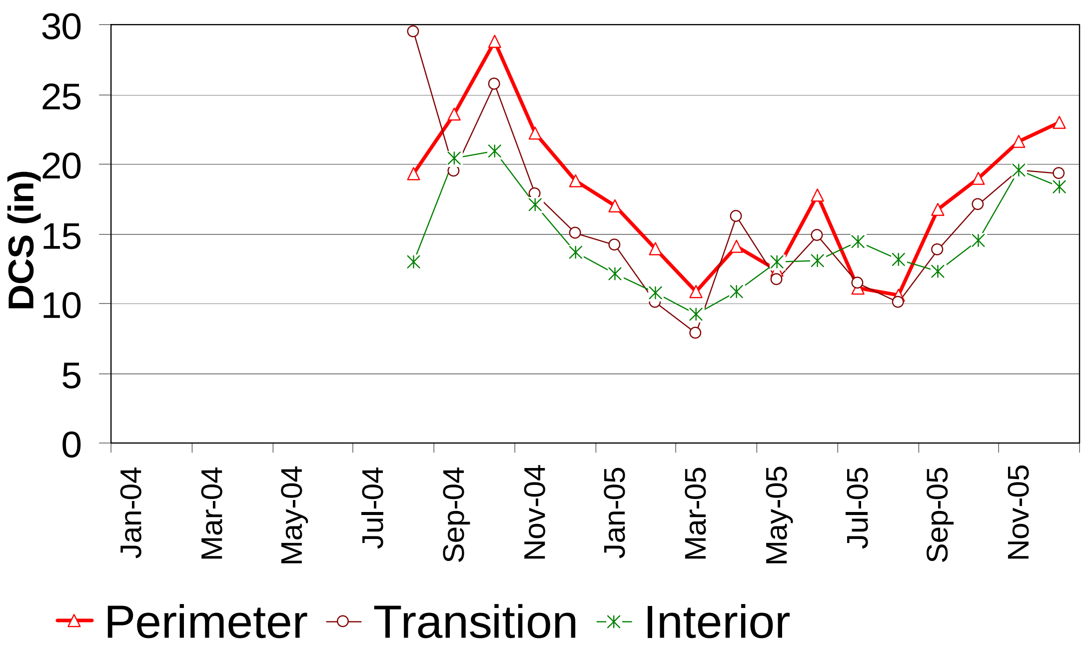



**Figure 1-4**. Depth to consolidated substrate (DCS in inches; arithmetic mean of all stations in each zone) over time in the different marsh zones of the Refuge interior. Zones described in Figure 1-2.

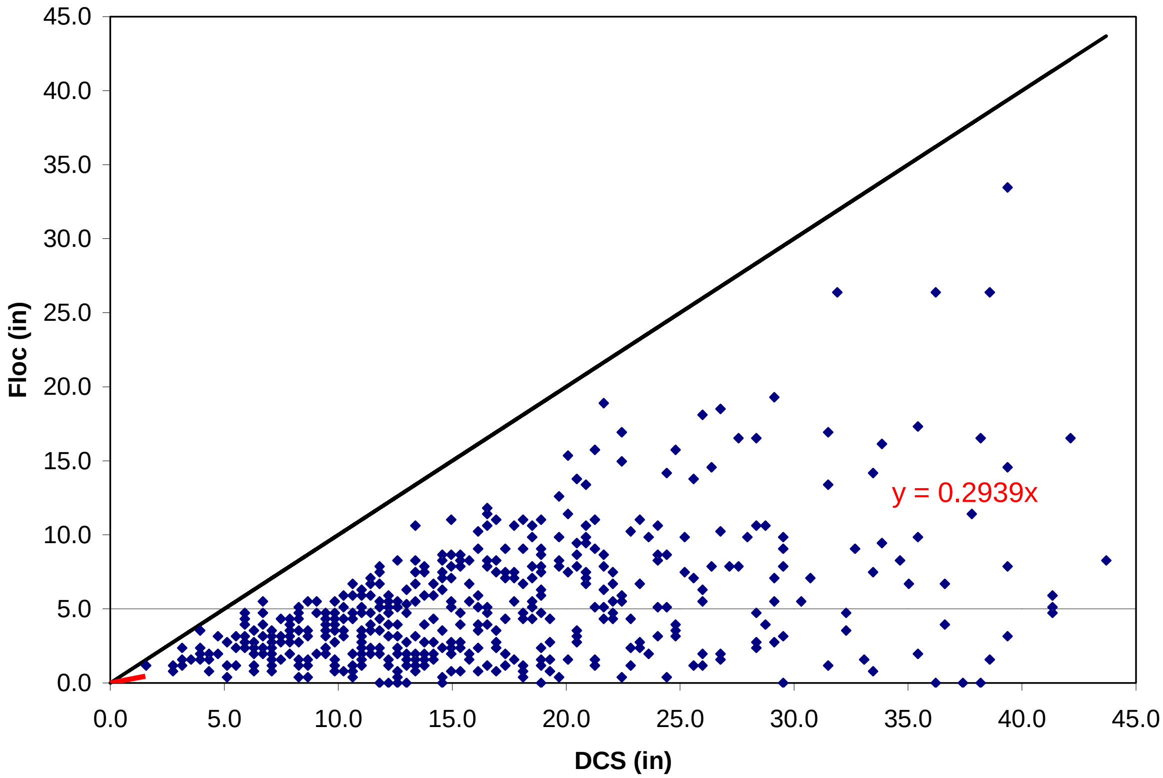



**Figure 1-5**. Floc depth plotted versus depth to consolidated sediment for all available observations. The solid line is a 1:1 ratio at which floc occupies the entire DCS column. The dashed line is a trend line with origin at zero.

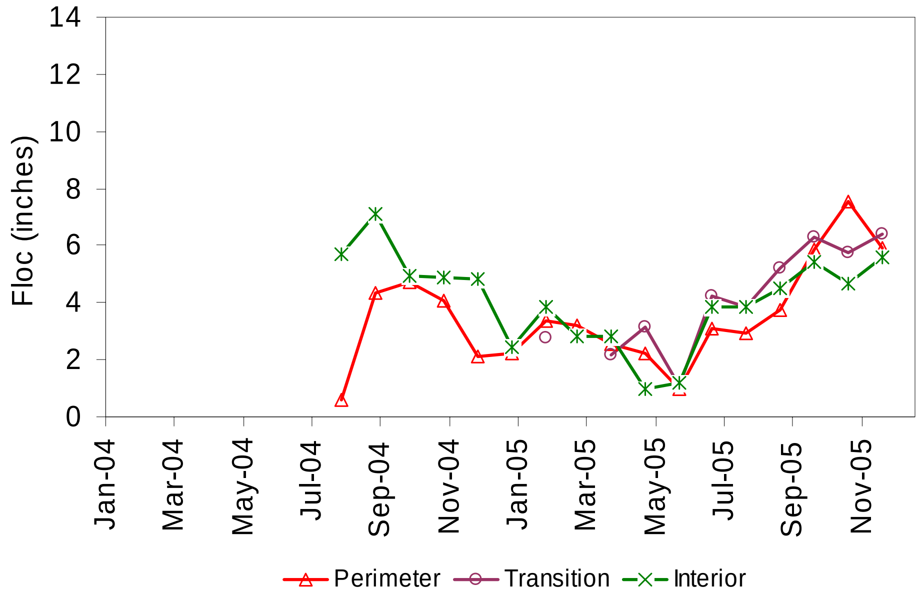



**Figure 1-6**. Depth of floc (inches; arithmetic mean of all stations in each zone) over time in the different marsh zones of the northern Refuge. Zones described in Figure 1-2; northern Refuge identified in Figure 1-1.

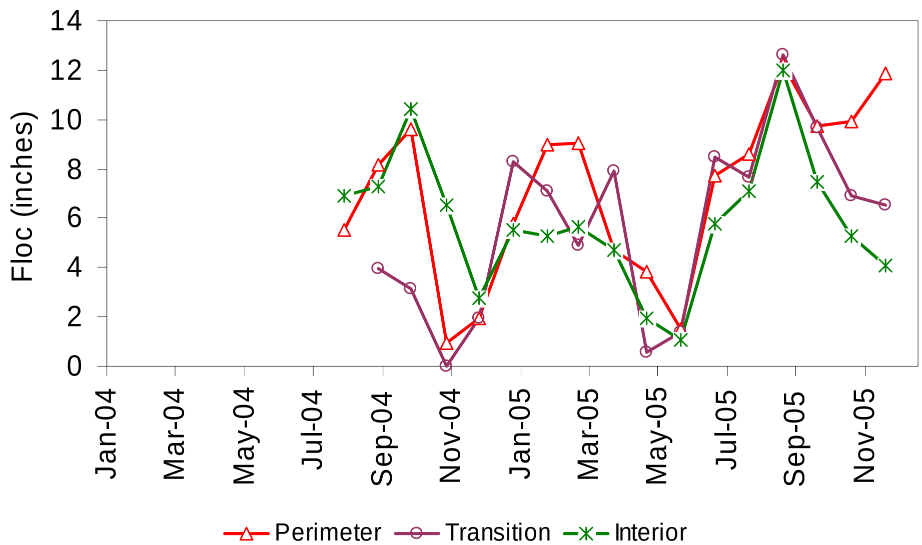
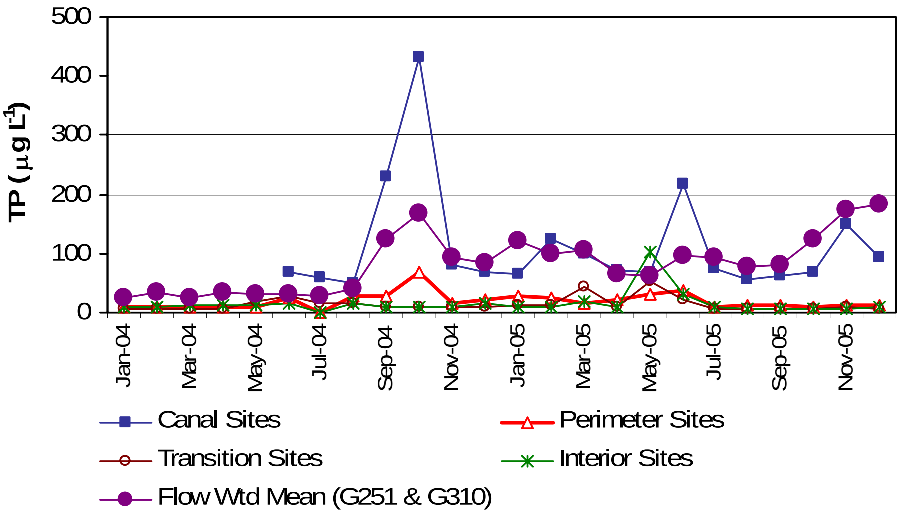



**Figure 1-7**. Depth of floc (inches; arithmetic mean of all stations in each zone) over time in the different marsh zones of the southern Refuge. Zones described in Figure 1-2; southern Refuge identified in Figure 1-1.

(a)




(b)

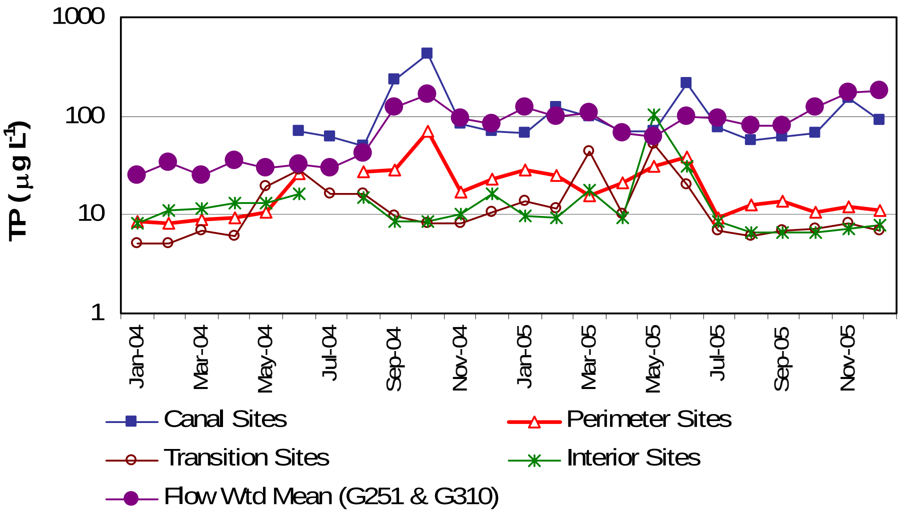



**Figure 1-8**. TP (µg $L^{-1}$) over time in the inflow structures, canals, and different marsh zones of the Refuge interior (arithmetic mean of all stations in each zone). Data presented on (a) normal scale, and (b) log scale; Zones described in Figure 1-2. Monthly values are summarized in Appendix 1-2. May and June 2005 not interpreted in this report (see Methods).

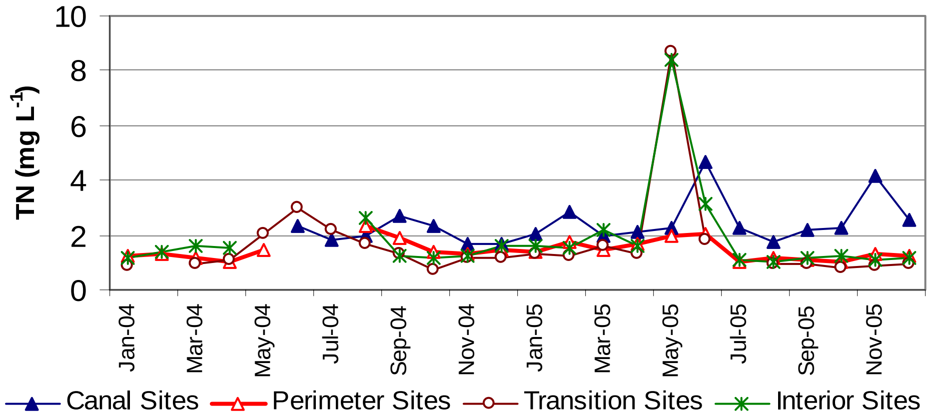



**Figure 1-9**. TN (mg $L^{-1}$; arithmetic mean of all stations in each zone) over time in canals, and different marsh zones of the Refuge interior. Zones described in Figure 1-2. May and June 2005 not interpreted in this report (see Methods).

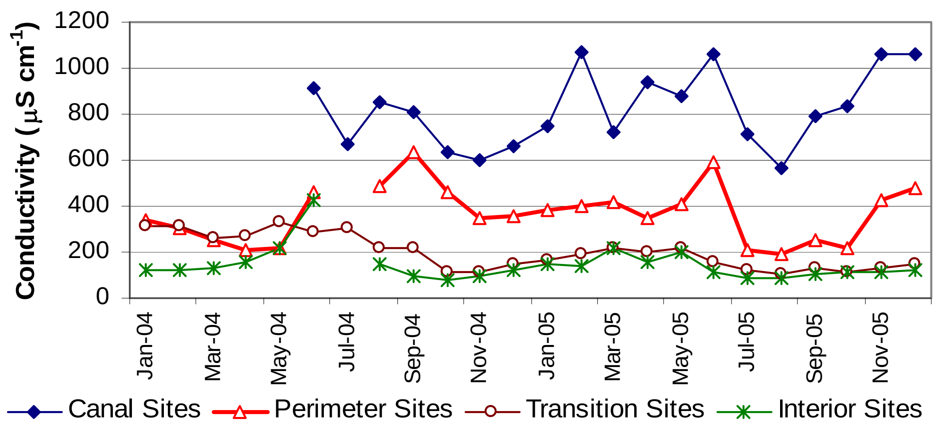



**Figure 1-10**. Conductivity (µS $cm^{-1}$; arithmetic mean of all stations in each zone) over time in canals, and different marsh zones of the Refuge interior. Zones described in Figure 1-2. May and June 2005 not interpreted in this report (see Methods).

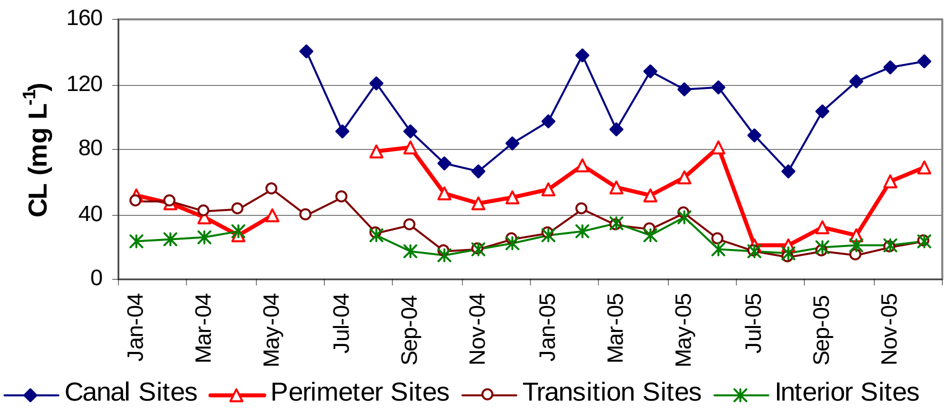



**Figure 1-11**. Chloride concentration (mg $L^{-1}$; arithmetic mean of all stations in each zone) over time in canals, and different marsh zones of the Refuge interior. Zones described in Figure 1-2. May and June 2005 not interpreted in this report (see Methods).

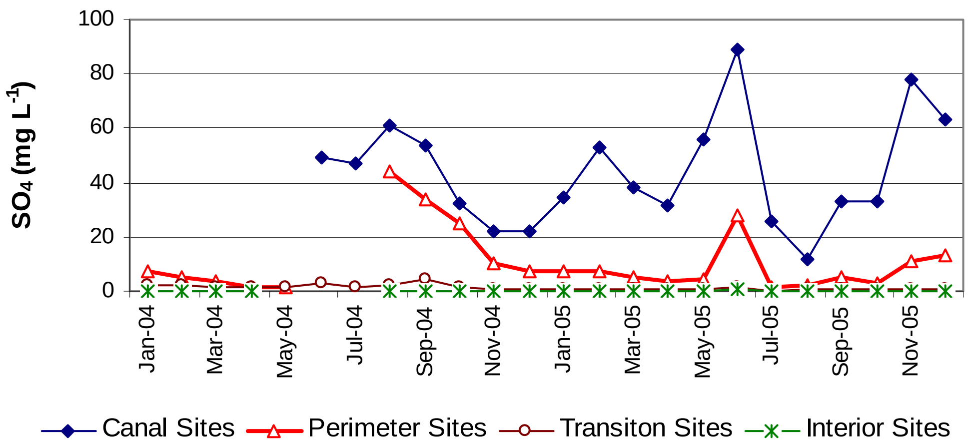
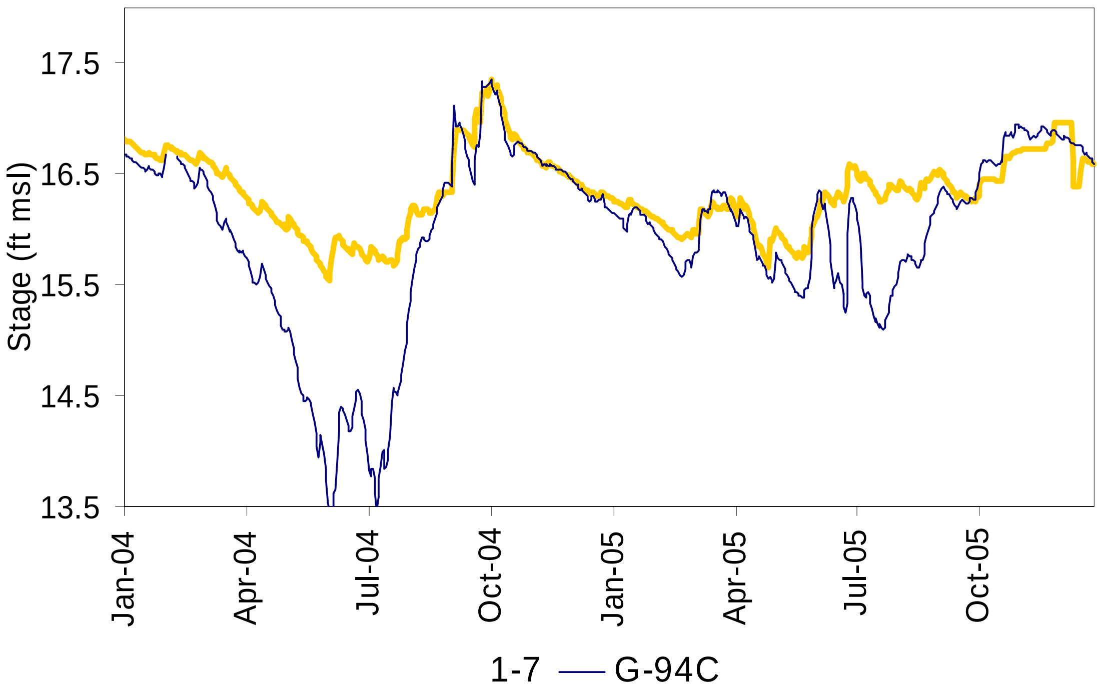



**Figure 1-12**. Sulfate concentration (mg $L^{-1}$; arithmetic mean of all stations in each zone) over time in canals, and different marsh zones of the Refuge interior. Zones described in Figure 1-2. May and June 2005 not interpreted in this report (see Methods).

(a)




(b)

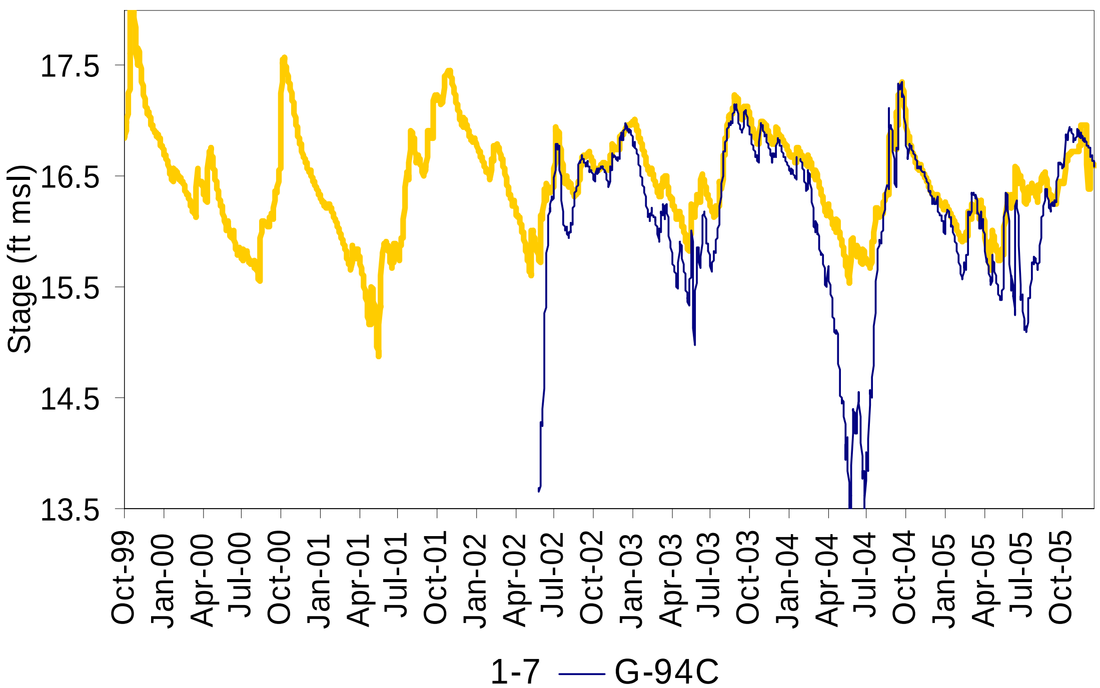



**Figure 1-13**. Marsh (1-7: thick line) and canal (G-94C: thin line) stages reported in feet for (a) the analysis period in this report – January 2004 to December 2005; (b) historical period (1999-2005; note no data available for G-94C prior to June 2002). For reference, the marsh soil stage at the 1-7 gage is approximately 15.6 ft msl (Waldon 2006).

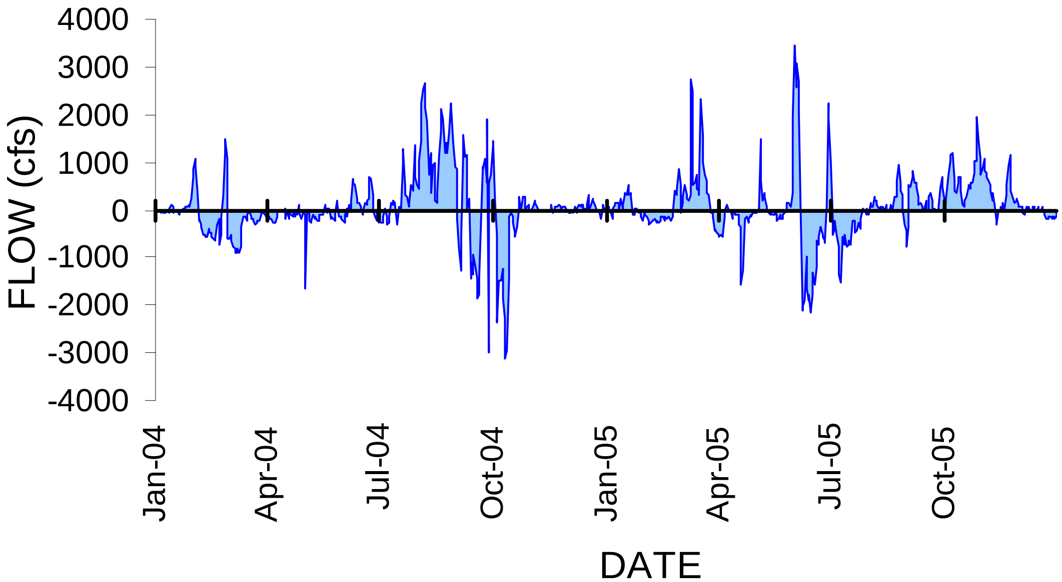



**Figure 1-14**. Daily average net flows (calculated as the difference between inflow and outflow from all structures) for the Refuge from January 2004 to December 2005. Positive values indicate net inflow and negative values indicate net outflow.

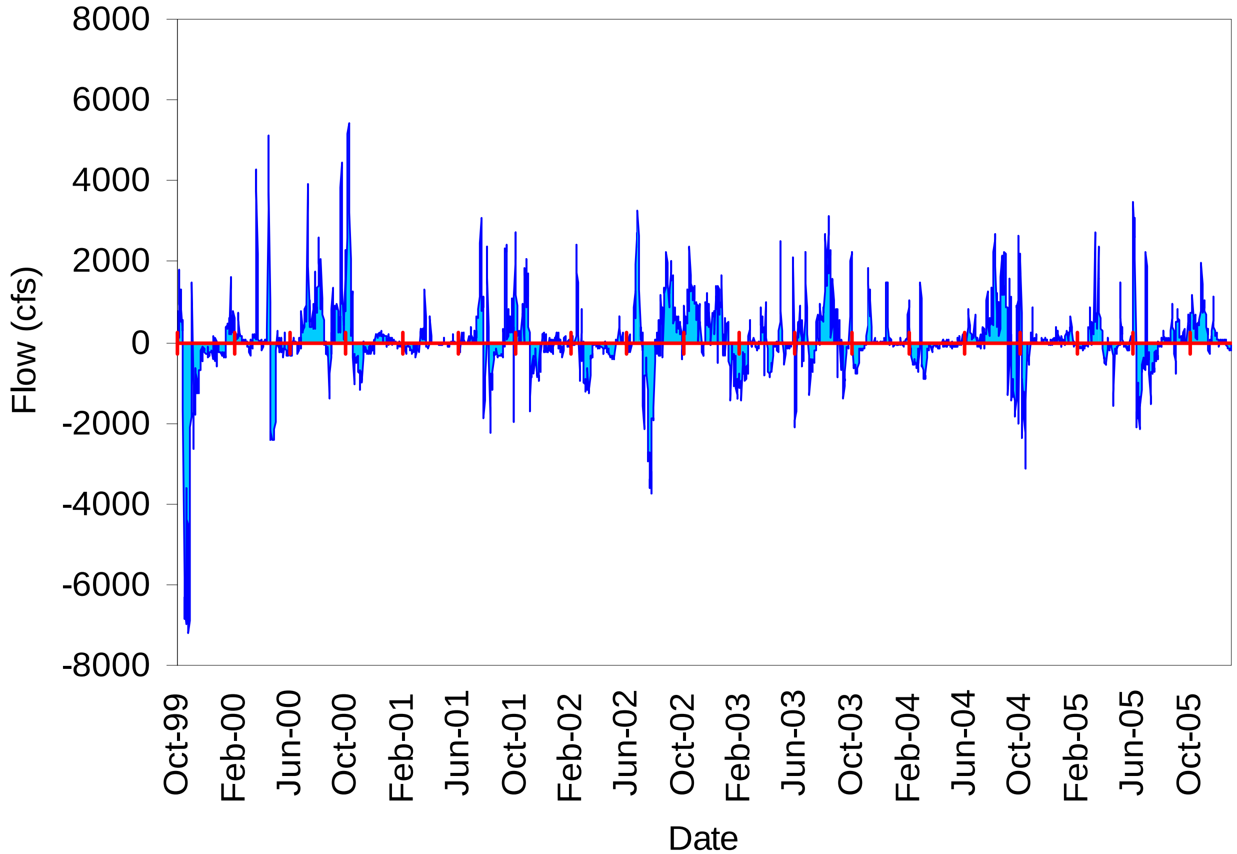



**Figure 1-15**. Daily average net flows (calculated as the difference between inflow and outflow from all structures) for the Refuge from January 1999 to December 2005. Positive values indicate net inflow and negative values indicate net outflow.

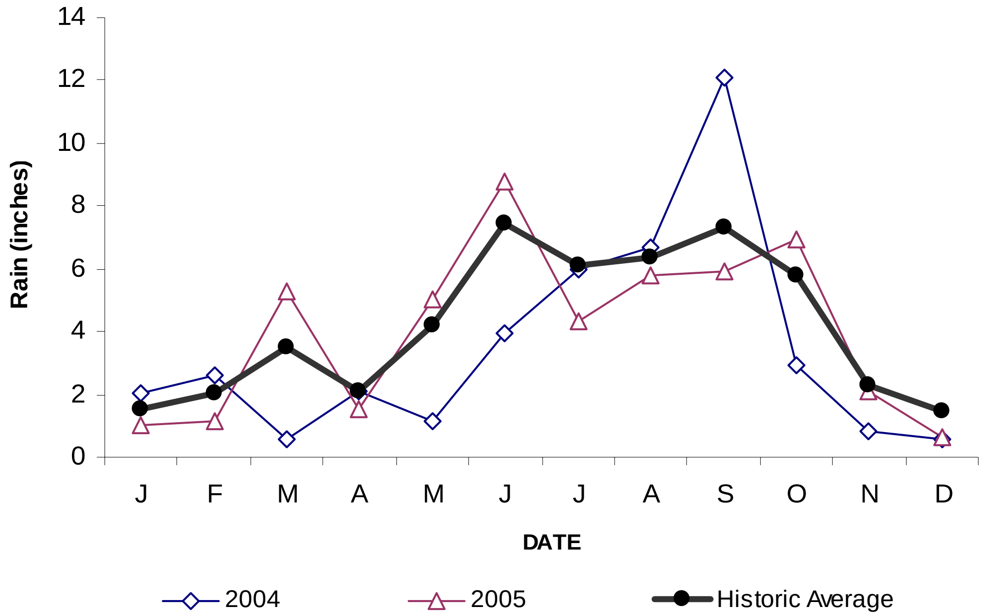



**Figure 1-16**. Monthly rainfall for 2004 (diamonds) and 2005 (triangles) recorded at different stations around the Refuge. The thick line (circles) is the historic average for all the sites used in determining the rainfall for the Refuge (station locations shown in Figure 1-1; period of record presented in Table 1-4). May and June 2005 not interpreted in this report (see Methods).

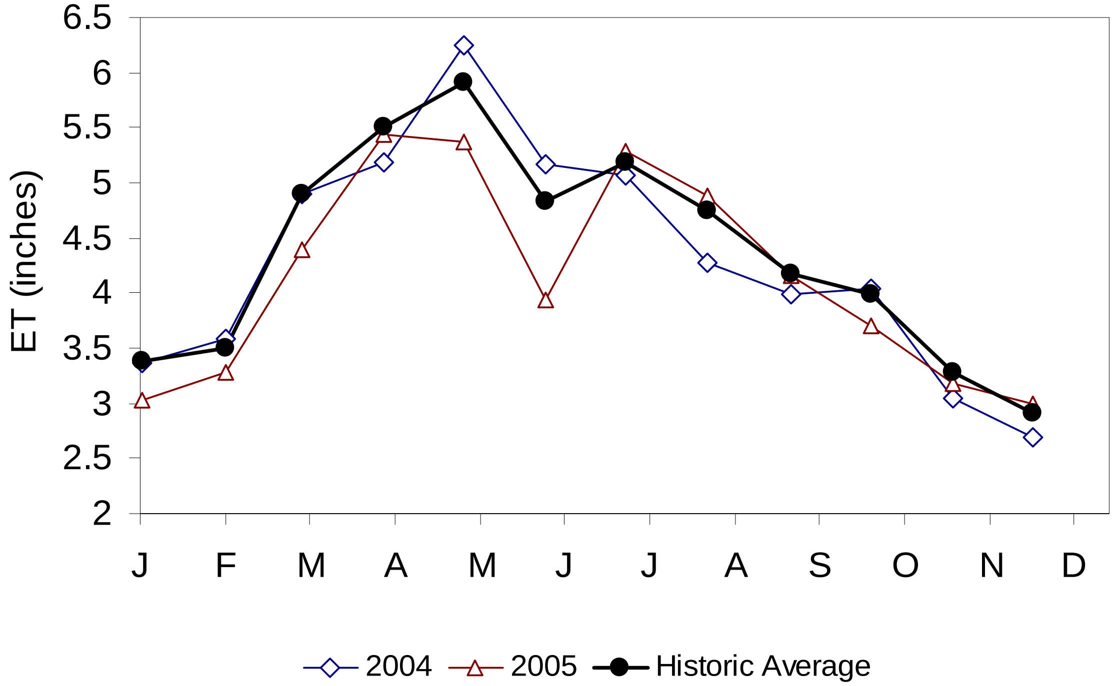



**Figure 1-17**. Monthly ET for 2004 (diamonds) and 2005 (triangles) recorded at different stations around the Refuge. The thick line (circles) is the historic average of ET measured at the STA-1W weather gage between October 1999 and December 2005. May and June 2005 not interpreted in this report (see Methods).

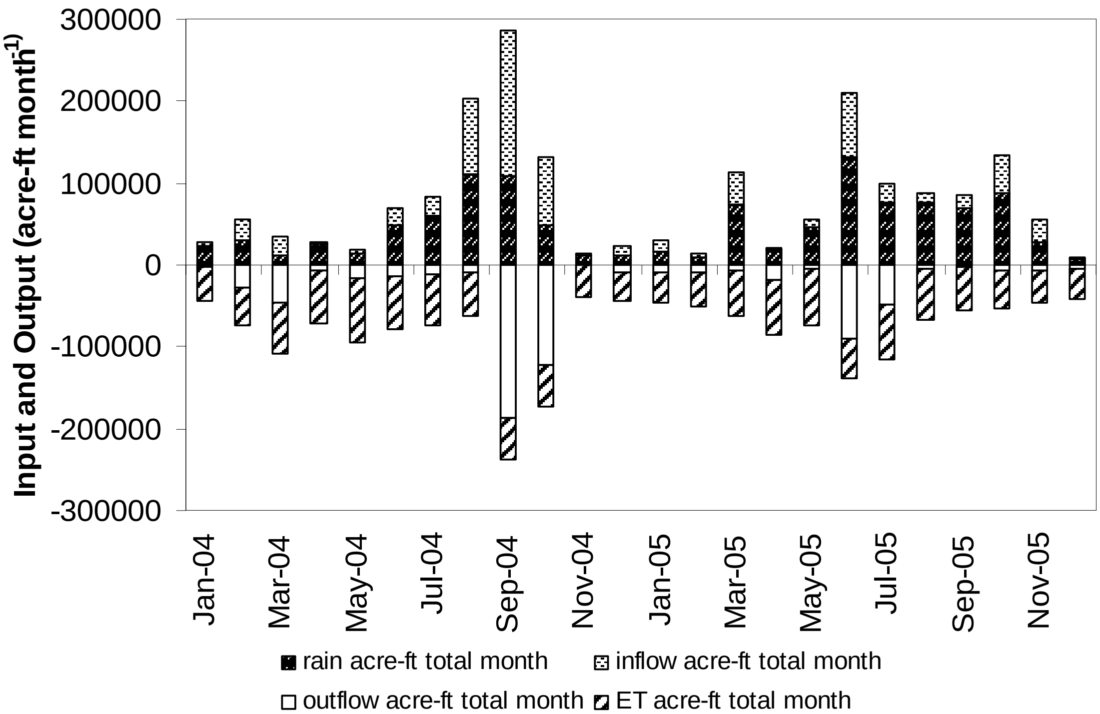



**Figure 1-18**. Total monthly water inputs (rainfall and canal inflows) and outputs (evapotranspiration and canal outflows) for the Refuge from January 2004 to December 2005. Rainfall was the average of four weather stations (S-5A, S-6, LOXWS, and the S-39) summed for each month. Canal inflows were the daily sum from all the inflow structures (STA-1W: G-251 and G-310, STA-1E: S-362, bypass: G-300 and G-310, and ACME-1 and ACME-2) summed over each month. Evapotranspiration was the monthly total determined from the STA-1W weather station. Canal outflows were the daily sum from all the outflow structures (bypass: G-300 and G-301), S-10A, S-10C, S-10D, G-94A, G-94B, ACME-1, and ACME-2) summed over each month.

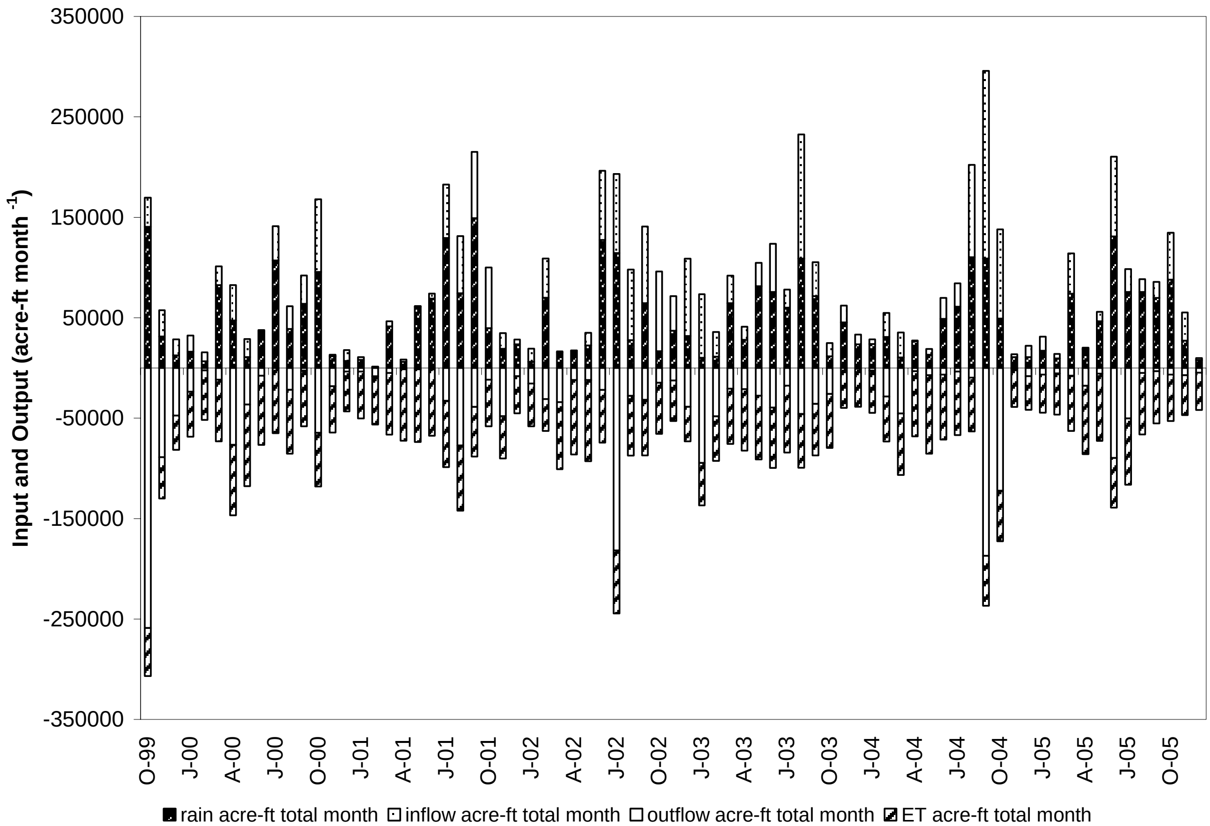



**Figure 1-19**. Total monthly water inputs (rainfall and canal inflows) and outputs (evapotranspiration and canal outflows) for the Refuge from October 1999 to December 2005. Data sources described in Figure 1-18.

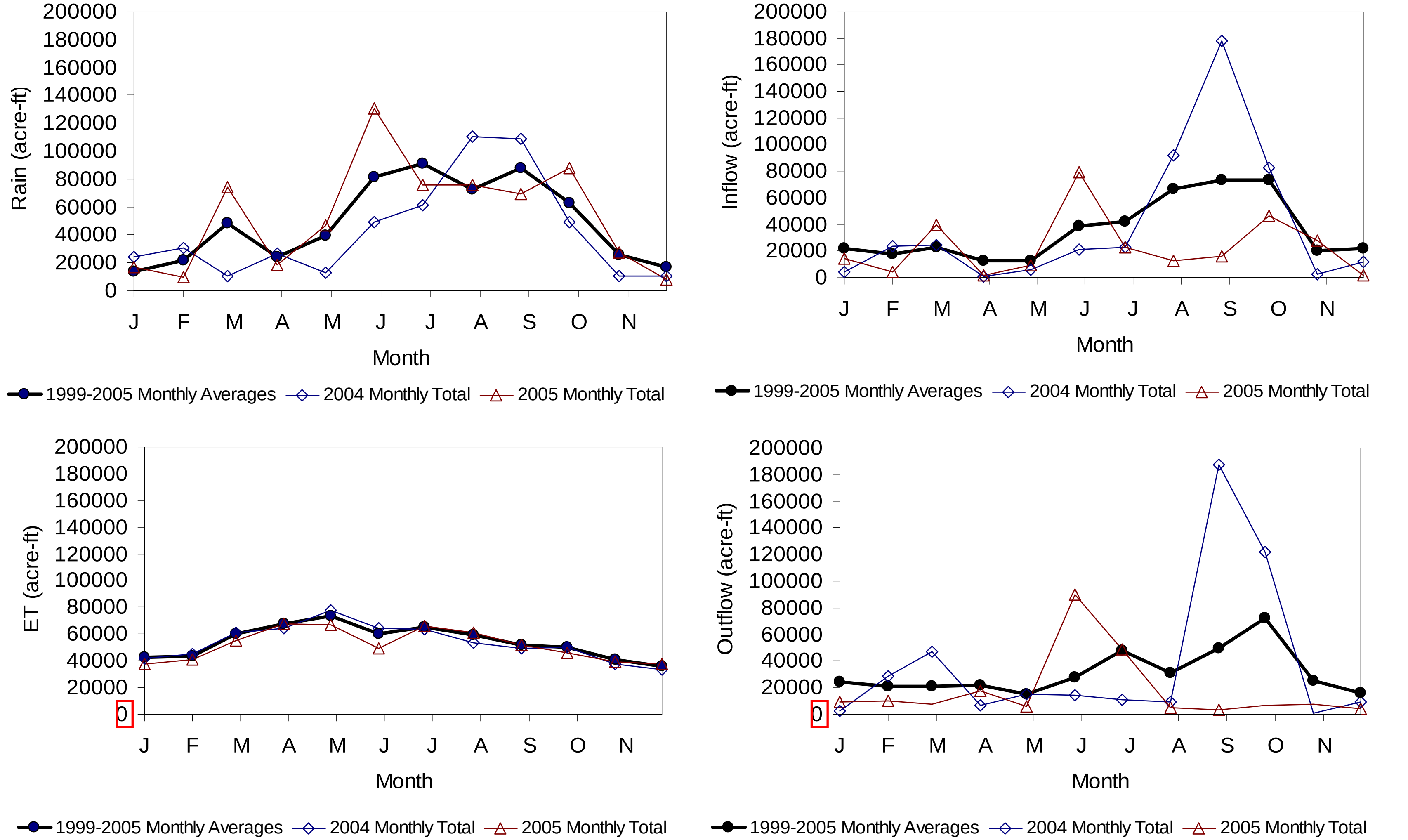



**Figure 1-20.** Monthly rainfall (top left), ET (bottom left), inflows (top right), and outflows (bottom right), measured in acre-feet, for 2004 (diamonds) and 2005 (triangles). The thick line (circles) is the historic monthly average for 1999-2005.

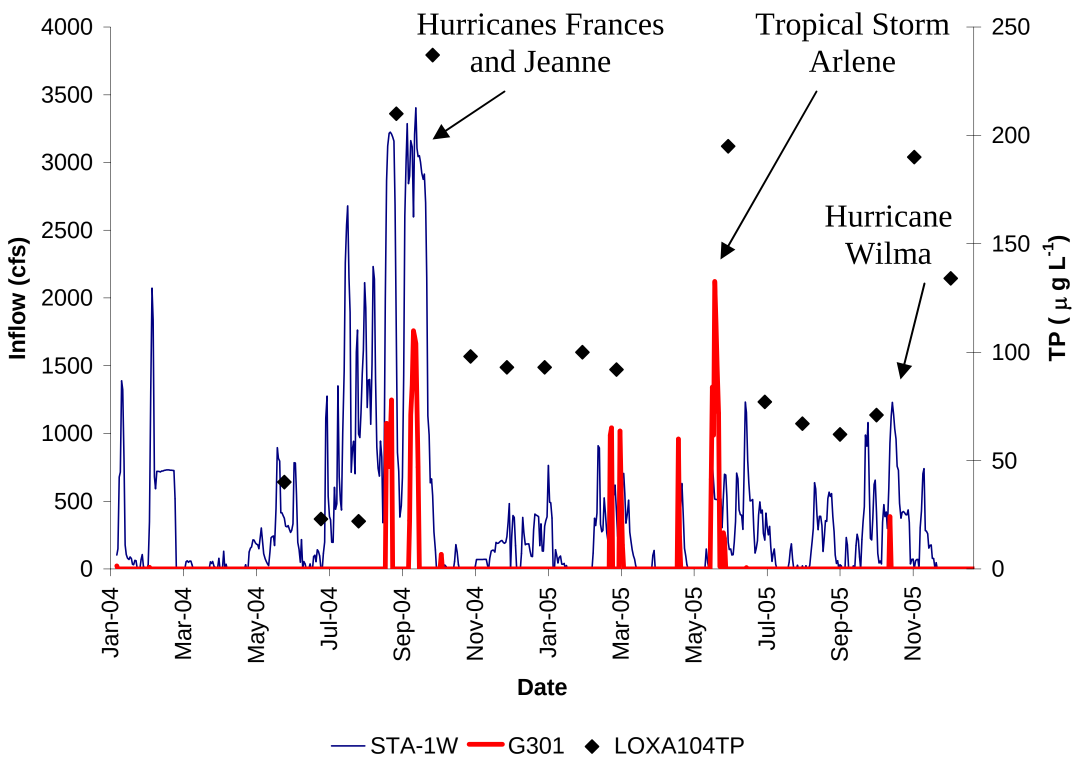



**Figure 1-21**. Time series of structure discharges with corresponding canal water TP values for the canal station located on the STA-1W transect (LOXA104). STA-1W discharges are from G-310 and G-251; untreated bypass inflows are from G-301 (Figure 1-1). May and June 2005 not interpreted in this report (see Methods).

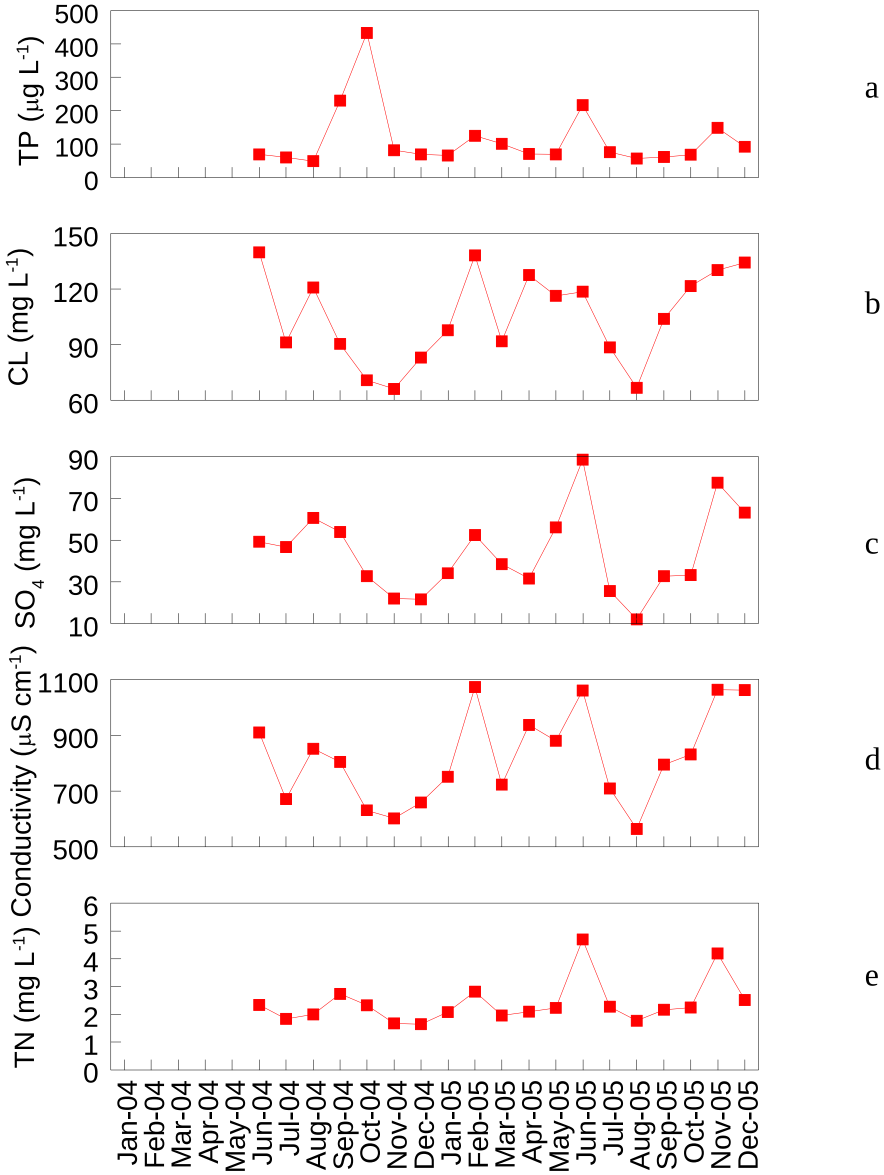



**Figure 1-22**. (a) TP, (b) Cl, (c) $SO_4$, (d) conductivity, and (e) TN monthly arithmetic means for sites in the canal zone. May and June 2005 not interpreted in this report (see Methods).

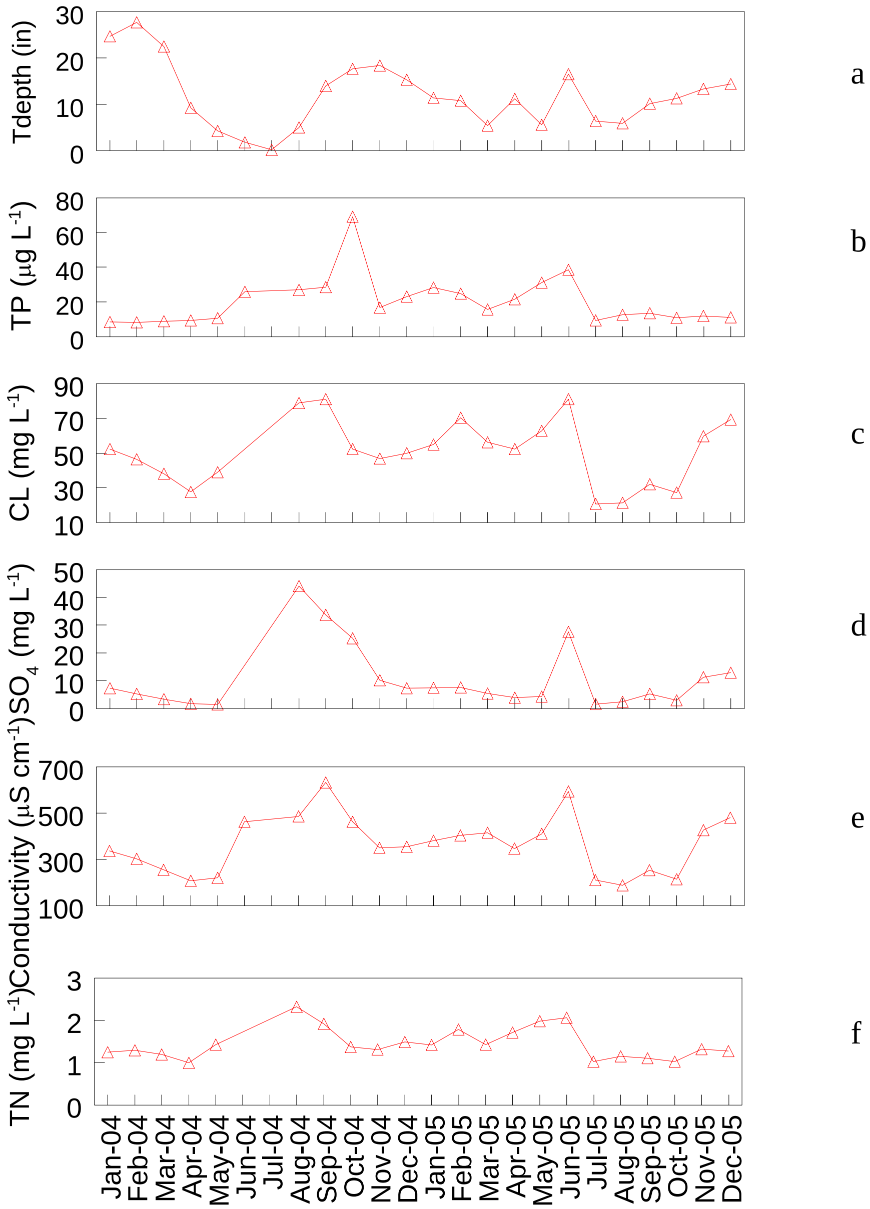



**Figure 1-23**. (a) Tdepth, (b) TP, (c) Cl, (d) $SO_4$, (e) conductivity, and (f) TN monthly arithmetic mean of parameters for sites in perimeter zone. May and June 2005 not interpreted in this report (see Methods).

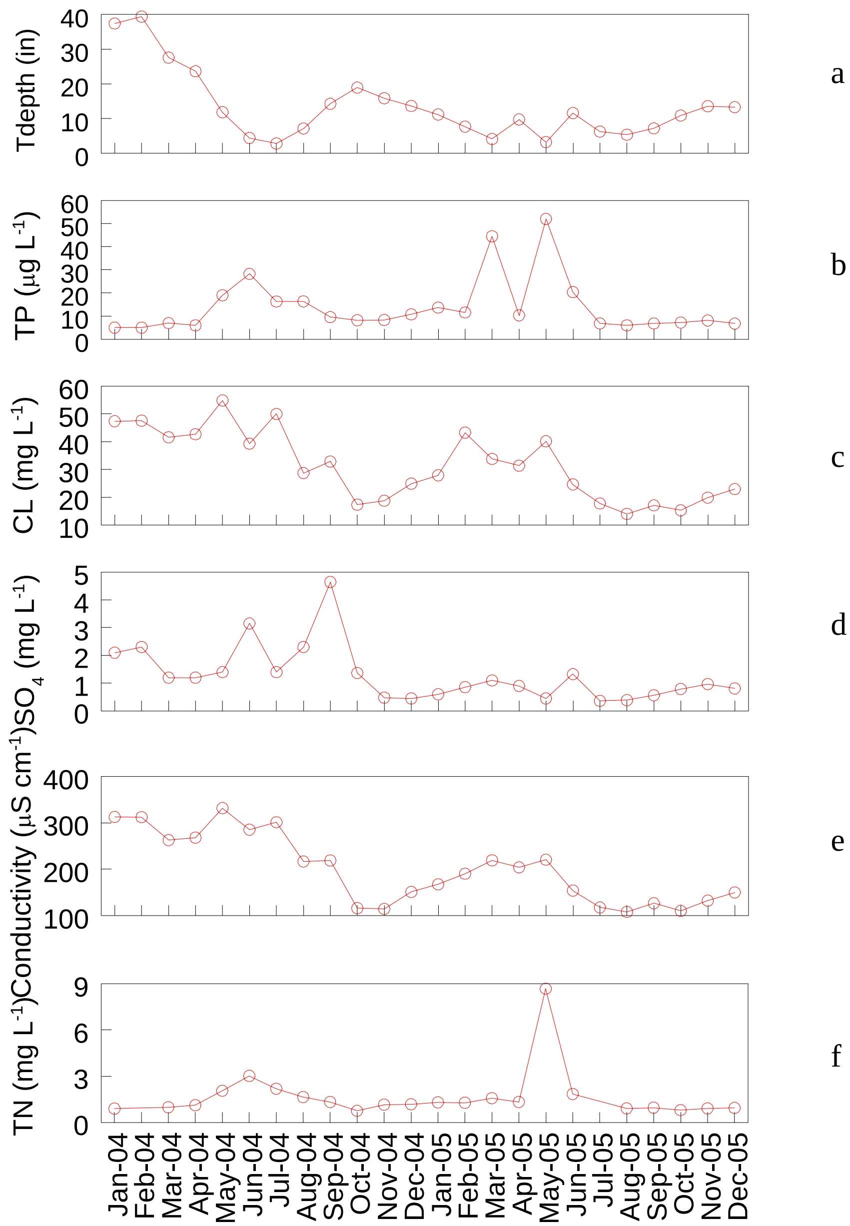



**Figure 1-24.** (a) Tdepth, (b) TP, (c) Cl, (d) SO4, (e) conductivity, and (f) TN monthly arithmetic mean of parameters for sites in the transition zone. May and June 2005 not interpreted in this report (see Methods).

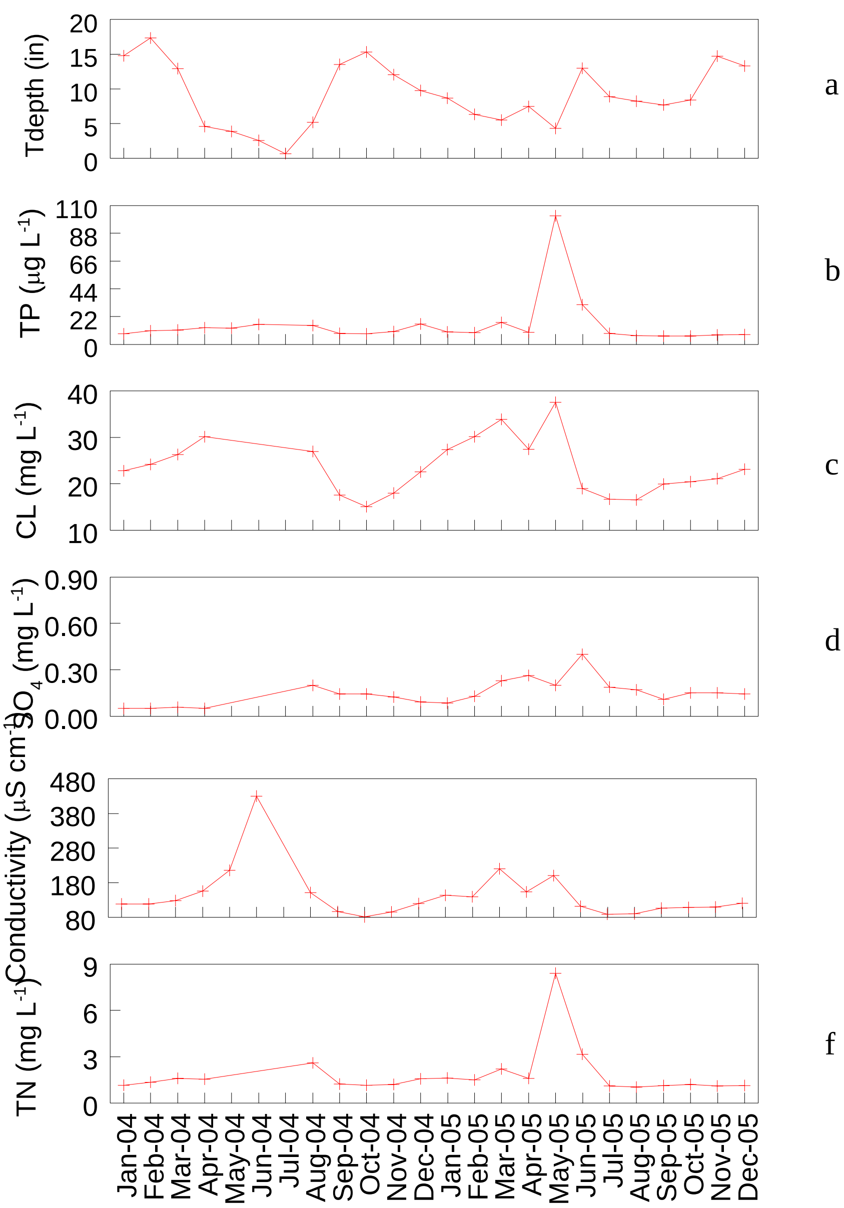



**Figure 1-25**. (a) Tdepth, (b) TP, (c) Cl, (d) SO4, (e) conductivity, and (f) TN monthly arithmetic mean of parameters for sites in the interior zone. May and June 2005 not interpreted in this report (see Methods).

# Section II, Chapter 2. Transect Conductivity Monitoring: Canal Water Intrusion[1]


## Abstract

The Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge) developed as a rainfall-driven system and is part of the continuous Greater Everglades ecosystem. Presently, the Refuge is impounded by canals that deliver nutrient and ion-enriched waters south from the Everglades Agricultural Area, as well as from Lake Okeechobee and urban drainage. These waters intrude into the interior of the Refuge and cause ecosystem alterations including sawgrass stands converted to cattail stands. The Refuge is one of the last remaining pristine areas of the Everglades. Therefore, ecosystem protection is an important management goal and intrusion of nutrient and ion-enriched waters to the marsh is a potential threat to this goal.

Thirty-two conductivity monitors (sondes) were deployed in the Refuge. Sondes were deployed along six transects perpendicular to the perimeter canal. Additional sondes also were deployed at sites perpendicular to the main transects to document conductivity parallel to the canal alignment within the marsh. Sondes continuously collected temperature and conductivity data hourly.

We found a strong relationship between canal water inflow pulses and water column conductivity up to 1 km (0.62 miles) into the marsh interior. Beyond 1 km (0.62 miles) into the marsh, the relationship was less obvious, most likely a result of varying lag times associated with canal water intrusion into more interior marsh areas.

We used location of the 300, 350 and 500 $\mu S\ cm^{-1}$ conductivity isopleths as indicators of canal water intrusion into the marsh. The 300, 350 and 500 $\mu S\ cm^{-1}$ conductivity levels were determined through interpolating conductivity between sites that bracket each of the three conductivity values. Each transect had different magnitudes of canal water intrusion into the marsh. The west side of the Refuge generally experienced greater canal water intrusion. In general, for both sides of the Refuge, canal water intruded into the marsh between 0.1 and 5 km (0.06 to 3.1 miles) from November 2004 to January 2006. The areas most sensitive to canal water movement (in or out of the Refuge) were those with marsh sediment elevations lower than 4.4 meters (m) (14.6 ft) mean sea level (msl), particularly when these areas were lower in elevation than adjacent areas.

Water movement between the marsh and the canals was influenced by canal-marsh stage difference, structure-controlled water inflow to and outflow from perimeter canals, marsh elevation, and rainfall. Little water movement occurred across the canal-interior gradient when the canal-marsh stage difference was small, canal flow was low, and rainfall was nominal. However, even a small pulse of water (<11, 309 $L\ s^{-1}$ (<400 cfs) discharged into the canal under these conditions resulted in movement of the 300 $\mu S\ cm^{-1}$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[1] Prepared by: Donatto Surratt, Michael G. Waldon, Matthew C. Harwell, Nick Aumen

conductivity isopleth into the marsh. When marsh stage was much higher than canal stage and outflow was minimal, water from the marsh interior pushed toward the perimeter canals. Rainfall also had an impact on water movement toward the canals from the marsh when marsh stage was greater than canal stage and inflow into canals was minimal.

We examined intrusion under two scenarios of structure operations – high inflow with low outflow, and high inflow with high outflow. During or after storm events leading to high inflow and low outflow conditions, even if marsh stage was greater than canal stage, canal water could extend more than 1.5 km (0.93 miles) into the marsh interior. With increasing pulses of water to the perimeter canals, canal water intrusion could easily extend up to 3.9 km (2.4 miles) into the marsh. Under high inflow and much higher outflow conditions (3 and 4 times greater outflow than inflow), water from the marsh interior moved toward the canals, reducing the distance of canal water intrusion by 40% from 0.6 to 1 km (0.37 to 0.62 miles).

Canal water was always observed in the marsh. Higher intrusion on the west side was associated with higher inflows along western canals. With positive net flow (more water entering the canals then released from the canals) into the Refuge, and when canal stage was greater than marsh stage, canal water intrusion extended more than 2.5 km (1.6 miles) into the marsh. When canal stages were greater than marsh stages, intrusion extended to greater than 1 km (0.62 miles) into the marsh. Movement of water from the marsh interior toward the canals was much greater when the marsh stage was much greater than canal stage. Even with a minimal difference between canal and marsh stage, canal water still intruded into the marsh interior.

High outflow events from the canals, regardless of location, were associated with movement of water from the marsh interior toward the canals. Storms and resulting management operations impacted canal water intrusion. Refuge outflow structures typically are opened in anticipation of storm events. Opening these structures drew down the canals, and pulled marsh water from the interior towards the canals. Additionally, water often was pumped from adjacent urban areas into the perimeter canals in anticipation of storm events, raising the canal stage and allowing water to intrude into the marsh interior.

## Introduction

The majority of the Arthur R. Marshall National Wildlife Refuge (Refuge) overlays Water Conservation Area-1 (WCA-1; Figure 2-1). The Refuge is a 58,320-hectare (144,000-acre) remnant of northern Everglades wetland habitat (USFWS 2000). Historically, rainfall and sheet flow were the primary source of water to this area. Since completion of its construction in the early 1960s, WCA-1 has been ringed by perimeter levees and associated borrow canals. These levees and canals are designated:

- L-40 (eastern perimeter levee and canal)
- L-7 (northwestern perimeter levee and canal)
- L-39 (southwestern perimeter levee and canal)

The Refuge is relatively flat with a north/south slope estimated to be 4.0 cm per km (2.5 inches per mile) (Richardson et al. 1990). The average marsh elevation for the Refuge is 4.65 m msl (15.0 feet mean sea-level ) (NGVD 1929), with a range from 5.62 m msl (18.5 ft) in the northern part to 3.22 m msl (10.6 ft) in the southern part. During inflow to the Refuge canals, canal stage on the east and west can be different by 0.15 m (0.5 ft) or more depending on water stage and rate of inflow, but otherwise tends to be nearly flat around the entire Refuge perimeter (Waldon 2006).

In the Refuge, the perimeter levee borrow canals were placed on the interior side of the levees, most likely to reduce potential problems downstream of the S-5A pump station. At the time of construction, the S-5A was one of the world's largest pumping facilities (Anonymous 1955), and there may have been concern that forcing its outflow across the wetland would result in the tailwater head overtopping nearby levees.

Inflow pump stations are controlled by the South Florida Water Management District (SFWMD) and the Village of Wellington, and outflow structures are controlled by the SFWMD and the U.S. Army Corp of Engineers (USACE), under the guidance of a water regulation schedule (USACE 1992; USACE 1994; USFWS 2000). The Lake Worth Drainage District (LWDD) and the Village of Wellington also manage some outflow structures.

Water deliveries to the Refuge were made up of both treated and untreated water for the period of record (POR), from November 2004 to January 2006. Untreated waters came from the Everglades Agricultural Area (EAA), the L-8 basin east of the EAA, and Lake Okeechobee via bypass structures (G-300 and G-301) or the Village of Wellington via the ACME-1 and ACME-2 water control structures (Figure 2-1). Treated waters came from the EAA, the L-8 basin, and Lake Okeechobee via stormwater treatment areas (STAs). Both untreated and treated water were higher in nutrients and other ions than water in the Refuge interior (Chapter 1). The STAs were designed to filter nutrients from enriched waters.

Water high in nutrient and mineral content is pumped into the Refuge perimeter canals from stormwater runoff and other sources. There is a concern that when canal stages are greater than marsh stages, enriched water from perimeter canals may intrude into the Refuge interior, resulting in eutrophication and elevated ion concentrations in the Refuge wetlands (Swift 1981; Swift 1984; Richardson et al. 1990; McCormick and Crawford 2006). When canal water levels are below 4.71 m (15.5 ft) msl (Figure 2-2), it has been thought that little exchange of water between the canals and marsh occurs (Sylvester 2004). The difference between canal and marsh stages had been assumed to be the driving factor for canal water intrusion into the marsh A gradient of surface water with elevated nutrient and mineral content with concentrations ranging from higher values near canals to lower values in the most interior regions of the Refuge exists (Richardson et al. 1990; Stober et al. 1998; Scheidt et al. 2000; Stober et al. 2001; Harwell et al. 2005). The primary source of these elevated concentrations in the fringe wetlands is hypothesized to be canal water flowing toward the Refuge interior.

Temperature-compensated conductivity (specific conductance) is used here as a conservative tracer of canal water. Typically, there are no biological or chemical processes in the surface water that significantly alter conductivity (Kadlec and Knight 1996). Commonly used conservative tracers, including total dissolved solids and Cl, generally are found to be proportional to conductivity (APHA 1992; Surratt 2005), thus conductivity can be considered as if it were a concentration following a linear mixing relationship analogous to constituent concentrations.

While water movement is the driving process of non-conservative (reactive) constituent transport, water movement alone is not adequate for a complete understanding of reactive material transport. The related concepts of retention, retardation, and adsorption/desorption are widely recognized for their significance in altering reactive constituent transport relative to water and conservative constituent movement (Woerman et al. 1998; Meals et al. 1999; He and Mankin 2002; Field 2003).

Previous studies have employed a variety of techniques to visualize, identify, and understand the spatial pattern of surface water concentrations in the Refuge and linkage of these patterns to canal water intrusion. One simple approach that avoids bias of interpolation or extrapolation is mapping site concentrations using colors or size to indicate concentration (e.g., Weaver and Payne 2004; Weaver and Payne 2006).

McPherson et al. (1976), reported conductivity and nutrient concentrations at various distances from Refuge canals, and attempted to quantify intrusion by sampling before and after pumping events. The authors reported canal conductivity values similar to those we observed, but median monthly TP concentration from July 1972 to July 1974 at the S-5A and S-6 pump stations were 50 $\mu g\ L^{-1}$ (50 ppb), much lower than we observed. Impact of intrusion was observed by these authors through quantifying patterns of conductivity along their transects. Time series studies along Refuge transects have improved our understanding of temporal and spatial patterns (Reddy et al. 1998; McCormick et al. 2000; Childers et al. 2003; Iricanin 2005).

Investigators also have used computer-automated contouring to visualize patterns of surface water concentrations in the Refuge (Richardson et al. 1990; Scheidt et al. 2000;

Stober et al. 2001; Weaver and Payne 2004; Sklar et al. 2005). These studies generate a surface, often depicted by contours of constant concentration levels (termed isopleths) over a 2-dimensional map of the Refuge. Contour generation is, at times, problematic, generating patterns that are artifacts of the algorithm selected, and interpolations that are dependent on arrangement of site locations. Some common problems with automated contour-generating algorithms are:

1. Contour interpolation typically uses a distance-weighting formula to interpolate values at unmonitored locations. This interpolation can be problematic when there is a linear feature such as a mountain ridge or stream channel. In the case of the Refuge, there is a ridge of elevated conductivity along the perimeter canal.

2. Conductivity generally is high near the canal and drops rapidly moving toward the Refuge interior. Along the canal at corners, contouring algorithms that do not take into account canal location will not interpolate corners in the contours conforming to the canal. Thus, at convex corners, contour lines often move away from the canal line. Because this extrapolation is in areas without actual observations, correct interpolation is unknown.

The site locations and methods of spatial analysis presented in this chapter were intended to minimize these problems with contouring of conductivity data. Site locations primarily were along transects (Figure 2-1). This transect approach reduced the impact of the first problem described above. Contouring also was limited to plots using a transformed coordinates system (distance around perimeter canal and distance from canal). The use of this transformed coordinate system eliminated artifacts of interpolation at corners described in the second problem above where a geographic coordinate system would be used.

The objective of this study was to understand canal water intrusion into the marsh by:

a) Describing and qualitatively examining conductivity patterns,
b) Examining conductivity changes along transects at selected times, and
c) Examining specific effects of water inflow or outflow on transect conductivity

Analyses presented here include examination of conductivity time-series graphs, distance of water movement across the canal-marsh interior gradient, and mapping of this movement relative to distance from the canals and positions around the canal. Baselines describing conductivity patterns under neutral conditions are defined as a part of these analyses. This approach is analogous to ecological analyses using neutral models (Taylor 1979; Gardner and Walters 2001). All of the analysis methods applied in this paper were limited to the northern portion of the Refuge because of the lack of sondes in the southern portion of the Refuge.

## Methods

<u>Data acquisition and monitoring</u>

*Marsh Zone Characterization*. The Refuge was divided into the canal and three marsh zones for purposes of characterizing water quality across the Refuge. The perimeter, transition, and interior zones were the three zones identified based on the decreasing conductivity variability from the canal to the interior zone. The perimeter zone was demarcated as from the canal to 2.5 km (1.6 miles) into the marsh; the transition zone was from 2.5 to 4.5 km (1.6 to 2.8 miles) into the marsh; and the interior zone was greater than 4.5 km (2.8 miles) into the marsh from the canal.

*Sonde Data.* Thirty-two conductivity monitors (sondes) were deployed (Table 2-1) along six transects (STA-1W, STA-1E, ACME-1, ACME-2, S-6, and Central; Figure 2-1) from the canal to 9 km (5.6 miles) into the marsh interior. The period of record (POR) analyzed in this chapter is from November 2004 to January 2006 (Table 2-2). Ten sondes (Yellow Springs Instruments; YSI Series 6MLX; www.ysi.com) were deployed on the central transect, and 22 sondes (Hydrolab Inc.; Mini Sonde 4a; www.hydrolab.com) were deployed at sites other than the central transect. Sondes recorded hourly water temperature and temperature-compensated conductivity. Sondes were adjusted to a fixed elevation 10 cm above the floc surface.

Sondes were visited monthly to download data, then cleaned and recalibrated before redeployment. Sampling and calibration procedures followed those in the Refuge field sampling manual (SFWMD 2005; USFWS 2005). Post-deployment precision checks were made upon retrieval by using calibration standards specific to the water column specific conductivity. Sonde conductivity readings beyond 10% of the continuing calibration (post-calibration) value were excluded. Conductivity was not measured when water levels were below 10 cm (4 inches). Because conductivity variability over a single day typically was small (Harwell et al. 2005), only daily instantaneous values taken at midnight were used in the analyses presented in this report.

Average, standard deviations, minimum, and maximum summary statistics were reported for the non-transformed data presentation, while the rank-based Mann-Whitney statistical test was applied for data comparisons. Statistics presented in this chapter reflect midnight values for all days data were available from the sondes.

Stage, flow, and rainfall data were downloaded from the SFWMD data web portal, DBHYDRO (http://www.sfwmd.gov/org/ema/dbhydro/).

*Stage Data.* Data from the USGS 1-7 stage gage were applied as estimates of marsh stage, because only the northern area of the Refuge was characterized in this report (Figure 2-1). It should be noted that while stage values at the 1-7 are useful as stage indicators for the interior marsh, stage values do vary north to south in the Refuge (Waldon 2006). Canal stages were characterized using the headwater gage of the G-94C spillway structure located on the L-40 Canal (east side of the Refuge). It has been previously assumed that when canal water levels are below 4.7 m (15.5 ft) msl, little exchange of water between the canals and marsh occurs (Sylvester, 2004). Variability in the canal-marsh stage difference relative to the canal stage increases above 4.56 m (15 ft) msl (Figure 2-2). This higher variability may correspond to intrusion events just below canal stages of 4.7 m (15.5 ft) msl.

Stages within the Refuge tend to be flat under high water conditions (Richardson et al. 1990). Examination of high-water stages also reveals small inconsistencies among the Refuge gage datums (Waldon 2006). Therefore, the G-94C gage readings were adjusted by adding 2.83 cm (0.093 ft) and the adjustment was derived during high-water conditions >5.15 m (17 ft) msl in order to equalize stage readings.

For uniformity purposes, we used the G-94C stage gage for these analyses, although discharges did occur through this structure over the POR. When water is flowing out of this structure, the headwaters have the potential to be depressed and the tail waters could mound, causing a non-uniform distribution of stage in the canal. There is a potential that the canal-marsh stage differences associated with the G-94C reported here may have been impacted by mounding or depression, which could alter the magnitude of the stage difference used in our analysis; however, this potential mounding did not impact the overall interpretations of canal water intrusion into the marsh.

*Flow Data.* Daily inflow and outflow rates ($m^3 s^{-1}$) ($ft^3 s^{-1}$, cfs) were used in this study. Inflow records for ACME-1, ACME-2, G-310, G-251, S-362, G-300, and G-301 were summed for daily average inflow; outflow records at G-300, G-301, G-94A, G-94B, G-94C, S-10A, S-10C, S-10D, and S-39 were used for daily average outflow (Figure 2-1). Net flow was determined as the difference between inflow to the canals and outflow from the canals. Positive net flow occurred when inflow to the canals was greater than outflow from the canals and negative net flow occurred when outflow from the canals was greater than inflow to the canals.

*Rainfall Data.* Data from the S-6, S-39, LOXWS and S-5A weather stations were used in this analysis (Figure 2-1). Daily rain records were averaged for the four weather stations. Groundwater seepage and evapotranspiration (ET) play nontrivial roles in the overall Refuge water budget (Meselhe et al. 2006). Because groundwater seepage is relatively small and less variable than rainfall and pumped inflows, groundwater seepage was not considered in this analysis. Evapotranspiration effects on canal water intrusion were considered for two specific examples across two transects and presented in the caveat section. Water depth in the marsh also was considered for these examples.

<u>Mathematical and graphical analysis</u>

Data exploration and analyses were performed using three complementary methods.

*Method 1 - Time-series conductivity transect analysis:* Time-series data were graphed and visually examined for each monitoring site. Inspection of hourly time-series indicated that conductivity variation over a single day was small. Therefore, all time-series analyses reported here used daily sub-samplings of hourly series for each day.

*Method 2 - Distance of intrusion:* In the first approach, we determined the general level of intrusion by generating conductivity isopleths (contour lines between points of similar value) along four conductivity transects (STA-1W, STA-1E, ACME-2, and S-6). In the second approach, we used a set of baseline conditions to track the magnitude of water movement under difference Refuge operation scenarios (e.g., canal stage higher than marsh stage, inflow higher than outflow, etc).

Approach 1. Transect interpolated canal water intrusion

Distance of intrusion was interpolated for the 500 and 350 µS $cm^{-1}$ conductivity levels along each transect. These selected conductivity levels are between the canal and the marsh interior values, and are used to track canal water intrusion into the rainfall-driven marsh interior. Further, tracking these conductivity levels allowed us to track water movement from the transition and interior zones towards the perimeter zone and canals. The 500 and 350 µS $cm^{-1}$ conductivity levels were chosen as reference values for ecological reasons. Preliminary results from an experimental study testing the impact of full concentration (1000 µS $cm^{-1}$) and 50% canal water conductivity dilution (500 µS $cm^{-1}$) indicate that canal water diluted to 50% impacts growth and development of native Refuge plants (e.g., *Xyris ambigua*) (McCormick and Crawford 2006). The 350 µS $cm^{-1}$ value was chosen because other experimental research document changes in the soft-water periphyton community from the Refuge interior with exposure to water with conductivity in this range (300 to 400 µS $cm^{-1}$) (Sklar et al. 2005).

The specific location of the 500 and 350 µS $cm^{-1}$ isopleths on each transect was estimated by linear interpolation. Using the actual values at each site along a transect into the interior, Equation 1 was used to estimate the isopleths.

SAMPLE CALCULATION FOR A HYPOTHETICAL EXAMPLE:

At a specific time, the following conductivity values were recorded:

- Site 1 - Canal 850 µS $cm^{-1}$
- Site 2 - 600 m into the marsh 700 µS $cm^{-1}$
- Site 3 - 1000 m into the marsh 450 µS $cm^{-1}$
- Site 4 - 2000 m into the marsh 280 µS $cm^{-1}$

To calculate the distance for the 500 µS $cm^{-1}$ location, *X* is linearly interpolated between Sites 2 and 3 from Equation 1:

$$x_1 = x_0 + \left( \frac{(y_2 - y_{target})(x_0 - x_2)}{(y_2 - y_0)} \right) , \qquad \textbf{(1)}$$

where:

$x_0$ = distance into the marsh of lower conductivity measurement
$y_0$ = lower conductivity measurement
$x_2$ = distance into the marsh of higher conductivity measurement
$y_2$ = higher conductivity measurement
$x_1$ = interpolated distance into the marsh of target conductivity
$y_{target}$ = target conductivity

The calculation in this example is:

*X* = 600 m + [(700-500 µS $cm^{-1}$)(1000-600 m)/(700-450 µS $cm^{-1}$)] = 920 m

In the unusual cases when transect conductivities did not have a pair of sites bracketing the desired value, no distance of the isopleth was interpolated.

Approach 2. Water movement across the canal-interior gradient

We developed a conductivity baseline from which to measure the magnitude of canal water movement across each canal-interior transect. The ideal baseline would be established during a period of time when canal and marsh stages were equal, net flow for the canal system was zero, and rainfall was zero. Conductivity data from a date having conditions similar to these ideal conditions were plotted versus distance from the nearest canal. A simple exponential trend model was fit to the data set and the generated model was applied as the baseline for comparisons (Figure 2-3 presents a conceptual model of the processes used for producing these analyses).

Four scenarios defined by natural and management conditions were selected for comparison against the baseline using simple exponential trends for each scenario. Each scenario was defined by various canal-marsh configurations (e.g., canal-marsh stage difference, greater inflow and outflow situations, and low and high rainfall conditions). It was anticipated that water column constituent (nutrients and other ions) intrusion into the marsh from canal water pulses would be attenuated by mechanisms such as dilution and dispersion. The range of variability for water column constituent attenuation was unknown. To account for some of this variability, we used five-day (the analysis date, plus the four days prior) average net flow and total rainfall to characterize each analyzed period. The values for selected five-day periods were used to capture the influence of conditions that may have contributed to intrusion on the analyzed date. Additional period lengths (e.g., 2, 10, and 15 days) were considered for the pre-analysis dates; however, because the range in variability of water column constituent attenuation was large, the use of the other periods did not differ. In order to reduce rainfall effects, periods when the five-day total rainfall was near zero were selected, with the exception of one example when rainfall was as high as 5.1 mm (0.2 inches). This exception was included to show the impact of water release from the canals coupled with a greater magnitude of rainfall on movement of water across the canal-interior gradient.

We compared the baseline to the exponential trend lines from each scenario using simple difference analysis (Figure 2-3). The amount of difference between the baseline and each scenario as a function of distance into the marsh was then averaged to characterize the magnitude of water movement across the canal-interior gradient for each scenario.

Finally, we identified areas of the marsh with higher and lower water movement by plotting the exponential trend lines from each scenario as a function of distance from the canal into the marsh interior. This approach allowed us to determine the zones where water movement was most evident under the condition for each setting.

*Method 3 - Distance of Intrusion: A transformed coordinate system approach*: The interpolated distance of canal water intrusion calculated in the previous method were plotted as a function of distance of intrusion into the marsh versus distance around the perimeter canal, going clockwise from LOXA116 (western Refuge) to LOXA126 (eastern Refuge; Figure 2-4) – we refer to this as a transformed coordinate system approach. This characterization was done using conductivity contours generated from the conductivity data. The southern region of the Refuge was not characterized for these analyses, because of the lack of sondes in the south (Figure 2-1). Intrusion patterns were compared to specific base conditions to better visualize pattern changes along transects.

We selected periods of alternating canal-marsh stage relations (e.g., canal stage greater than marsh stage and vice-versa) and hydrologic natural drivers (e.g., tropical storm and hurricane events) for this analysis. Stage relationships and storm events were considered for conditions of: (1) high canal water inflow with little outflow ($I_H$-$O_L$) and (2) high canal inflow with high outflow ($I_H$-$O_H$) rates of 19,792 L $s^{-1}$ (700 cfs) or greater. The first flow scenario was selected to partially determine the impacts of water supply release on the interior marsh surface water. The second flow scenario was selected to partially determine the impact of relative flow through each of the S-10 gates (Figure 2-1; gates A, C, and D) on water flow and water quality within the marsh interior. We also examined periods of structure operations surrounding these two selected periods. Low canal water inflow and low outflow ($I_L$-$O_L$) and moderate (5,654 – 14,137 L $s^{-1}$; 200-500 cfs) canal water inflow and low outflow ($I_M$-$O_L$) operations were the other conditions analyzed.

For the $I_H$-$O_L$ flow conditions from October to November 2005, we selected five time-snapshots that bracketed Hurricane Rita, Tropical Storm Tammy, and Hurricane Wilma. We used the pre-Rita time-snapshot as the reference condition for comparisons. For the $I_H$-$O_H$ flow conditions from late May to early July 2005, we selected three time-snapshots that bracketed Tropical Storm Arlene and one large unnamed rain event. We used the pre-Arlene time-snapshot as the reference condition for comparisons.

We also compared the 500 µS $cm^{-1}$ isopleth from this transformed coordinate system analysis approach to the 500 µS $cm^{-1}$ average extent of intrusion. The average extent of intrusion was determined in Method 2 – Approach 1 (Table 2-4**)**.

## Results and Discussion

<u>Conditions during the study period</u>

Average stage at the G-94C headwater stage gage was 4.94 m (16.26 ft) msl with a range of 4.61 (15.18 ft) to 5.18 (17.04 ft) msl. The average stage at the G-94C was similar to the G-94C average stage – 4.93 m (16.23 ft) msl for the period June 2002 through January 2006. The range of stages at the G-94C, particularly in 2005, was smaller than the range (4.11 m (13.52 ft) to 5.30 m (17.45 ft) msl).

Stage gage 1-7 was used to represent water elevation in the Refuge interior. The gage is located near the middle of the Refuge (Figure 2-1). Because only one gage was used, and because there likely are water elevation differences across the Refuge area, readings from this one gage probably do not reflect actual water elevations everywhere in the Refuge. Average stage at the 1-7 stage gage was 4.96 m (16.33 ft) msl with a range of 4.76 (15.65 ft) to 5.16 (16.96 ft) msl. The average stage at the1-7 gage was slightly lower than the 1-7 gage average stage 5.00 m (16.46 ft) msl for the period June 2002 through January 2006. Also, the range of stages at the 1-7 gage was smaller than the range from June 2002 through January 2006 4.72 (15.53 ft) to 5.27 (17.35 ft) msl.

The canal stage exceeded the marsh stage by a maximum of 14.5 cm (0.48 ft), while marsh stage exceeded canal stage by a maximum of 0.33 m (1.08 ft). The marsh stage was higher than the canal stage more frequently and for longer duration over the POR. Average stage difference was 2.4 cm (0.08 ft) with marsh stage greater than canal stage and marsh stage higher than canal stage 50% of the time. Given potential differences in stage gage datum survey errors, small stage differences may not reflect actual difference between water levels in marsh and canals.

Average stage difference was higher for the marsh by 7 cm (0.23 ft) from June 2002 through January 2006 (Figure 1-13). The canal stage exceeded the marsh stage by a maximum of 15 cm (0.48 ft), while the marsh stage exceeded the canal stage by a maximum of 0.675 m (2.22 ft) over the period June 2002 to January 2006. Over this period of time, marsh stage exceeded canal stage 67% of the time. In all four years, 2002 through 2005, the marsh stage was much greater than the canal stage in June. Decreases in the canal stage in June were the cause of the large stage difference, particularly once the marsh water level decreased to a level similar to the marsh soil elevation. After the marsh water level and marsh soil elevation were similar, short canal outflow pulses (days to a week) at moderate discharge rates rapidly reduced the canal stage.

Canal stage variability (3% coefficient of variation) was lower than canal stage variability from June 2002 to January 2006 (5% coefficient of variation). The range in canal and marsh stage difference was lower than the range from June 2002 to January 2006. Average inflow rates (4, 920 ± 8229 L $s^{-1}$;174 ± 291 cfs); mean ± 1 standard deviation) were much lower than average inflows for the period June 2002 to January 2006 (17,700 ± 25,786 L $s^{-1}$; 626 ± 912 cfs). It appears that reduced inflows resulting from management changes (e.g., use of the G-341 to divert water away from STA-1W to STA-2; increased diversion of water from the L-8 canal to tide, Goforth 2005) and lower rainfall decreased canal stage variability, reducing the canal-marsh stage difference.

Rainfall in the Refuge from November 2004 to January 2006 averaged 1080 mm $yr^{-1}$ (42.5 inches per year) (6.55 x $10^8$ $m^3$ $yr^{-1}$; 531,250 acre-ft per year). Rainfall contributed 69 % of the total volume of water entering the area (Figure 2-5)). This amount of rainfall is lower than average (1186 mm $yr^{-1}$; 46.7 inches per year from 1970 to 1986) (Richardson et al. 1990) and 1153 mm $yr^{-1}$ (45.7 inches per year) from 2000 to 2005. Lower rainfall is notable because it is greater than the inflow volume (1.76 x $10^8$ $m^3$ $yr^{-1}$; 142,500 acre-ft per year) from STA-1W; 2.93 x $10^7$ $m^3$ $yr^{-1}$ (23,750 acre-ft per year) from STA-1E; 1.54 x $10^7$ $m^3$ $yr^{-1}$ (12,500 acre-ft per year) from ACME-1; 1.39 x $10^7$ $m^3$ $yr^{-1}$ (11,250 acre-ft per year) from ACME-2; and 5.55 x $10^7$ $m^3$ $yr^{-1}$ (45,000 acre-ft per year) from the bypass structures. The higher rainfall volume relative to the canal inflow possibly was a result of unusual rainfall patterns, but is more likely caused by limited treatment capacity of STA-1W resulting from treatment cells being offline for repairs and optimization.

Conductivity in the interior zone during 2005 was typically less than 150 μS $cm^{-1}$, while at canal sites it generally ranged from 700-1000 μS $cm^{-1}$.

<u>Method 1 – Time-series conductivity transect analysis</u>

The STA-1W transect incorporates a set of sondes that extend from the northwest marsh perimeter canals to an intermediate area within the marsh transition zone (Figure 2-1). Sondes along this transect include LOXA104 (canal), LOXA105 (0.7 km; 0.43 miles), LOXA106 (1.1 km; 0.68 miles), LOXA107 (2.2 km; 1.36 miles), and LOXA108 (3.9 km; 2.42 miles).

Canal (LOXA104) inflows and outflows and conductivity (Figure 2-6) were highly variable from day to day. Increases in canal conductivity in this area of the canal were evident shortly (< 5 days) after spikes (>14,137 L $s^{-1}$; 500 cfs) in canal water inflows.

Alternatively, reduced canal conductivity levels in this area of the canal were evident shortly after spikes in outflow from the canal. In general, conductivity at the LOXA104 canal site increased over the analyzed period by 1.2 $\mu S\ cm^{-1}\ d^{-1}$ from 690 $\mu S\ cm^{-1}$ in November 2004 to 1,220 $\mu S\ cm^{-1}$ in mid-January 2006. A conductivity increase over the same time periods also was observed from the STA-1W (G-310) and the G-301 bypass discharge structures on the west side of the Refuge. Conductivity at the G-310 structure increased from a median of 892 $\mu S\ cm^{-1}$ from November 2004 through April 2005 to a median of 1302 $\mu S\ cm^{-1}$ from August through January 2006. Conductivity at the G-301 structure increased from a median of 815 $\mu S\ cm^{-1}$for the period November 2004 through April 2005 to a median of 1065 $\mu S\ cm^{-1}$ from August through January 2006. These increased levels of discharge from the water control structures have increased conductivity levels in the canal over the period examined.

In general, when the canal and marsh stages were similar and moderate to high inflow rates occurred for short periods (< 6 days), conductivity across the STA-1W transect increased above average levels. For example, conductivity from the canal to 1.1 km (0.68 miles) into the marsh was elevated above the average conductivity (Table 2-3) for 5 to 7 days in early June 2005. In early June, the conductivity ranged from 1,040 to 1,120 $\mu S\ cm^{-1}$ in the canal at LOXA104, 720 to 990 $\mu S\ cm^{-1}$ at 0.7 km (0.43 miles), and 520 to 660 $\mu S\ cm^{-1}$ at 1.1 km (0.68 miles). The canal stage was greater than the marsh stage by an average of 6.7 ± 1.8 cm (0.22 ± 0.06 ft) (mean ± 1 standard deviation) and as much as 9.0 cm (0.3 ft) for 6 to 7 days. Inflow (115,925 $L\ s^{-1}$; 4,100 cfs) and outflow rates (73,513 $L\ s^{-1}$; 2,600 cfs) spiked to the highest observed rates. The inflow spike started 7 to 8 days before the outflows spiked. This inflow spike pushed the high conductivity (1,100 $\mu S\ cm^{-1}$) canal waters into the marsh at least 1.1 km (0.68 miles) where conductivity was observed at the highest values.

When the canal stage was lowered by more than 21.3 cm (0.7 ft) over a few weeks, water from the marsh interior moved towards the canal and, through dilution and dispersion, reduced the conductivity levels in the perimeter and transition zones (see Method 2: Distance of Intrusion; Approach 2). For example, canal conductivity in mid-July sharply dropped below 500 $\mu S\ cm^{-1}$ and conductivity in the marsh at 1.1 km (0.68 miles) (<190 $\mu S\ cm^{-1}$) and 2.2 km (1.36 miles) (<170 $\mu S\ cm^{-1}$) both dropped below average conductivity (Table 2-3) for these areas. Conductivity at 2.2 km (1.36 miles) remained at these levels through mid-September, while at 1.1 km (0.68 miles), conductivity increased slightly, but remained below 300 $\mu S\ cm^{-1}$ through mid-October 2005. The marsh stage was greater than the canal stage by 21.3 cm (0.7 ft) or more for the period mid-July through August 2005, while inflows and outflow were mostly lower than 14,137 $L\ s^{-1}$ (500 cfs). In late August 2005, inflows and outflows increased above 19,792 $L\ s^{-1}$ (700 cfs) for several weeks into September 2005. The flow increases were associated with a relative increase in conductivity at 1.1 km (0.68 miles) to just below 300 $\mu S\ cm^{-1}$.

When both canal and marsh stages were maintained above 5.0 m (16.5 ft) msl for a week or more, pulses of high rate inflow pushed canal water into the marsh and increased marsh conductivity. For example, conductivity in the canal (LOXA104 – 1,400 $\mu S\ cm^{-1}$)

and at 0.7 km (0.43 miles) (1,000 μS $cm^{-1}$) in mid-December 2005, spiked to some of the highest values observed. Canal stage was approximately 12.2 cm (0.4 ft) greater than marsh stage in mid-December 2005, but from early October to late November 2005, canal stage averaged 7.9 ± 0.1.2 cm (0.26 ± 0.04 ft) higher than marsh stage. Marsh stage was higher than canal stage < 1.52 cm (< 0.05 ft) in early December 2005. Canal inflows and outflows were low in December 2005, but inflows were greater than 14,137 L $s^{-1}$ (500 cfs) from late September to early December 2005. Canal outflows rarely were observed and were substantially lower than inflows from late September to early December 2005. The high (21,295 to 56,548 L $s^{-1}$ (750 to 2,000 cfs) and sustained (> 15 days) inflow rates coupled with the canal stage higher than the marsh stage were conditions when conductivity across the STA-1W transect was elevated above average, representative of a diluted canal water conductivity signature.

The STA-1E transect incorporates a set of sondes that extend from the northeast marsh perimeter canals to an intermediate area within the perimeter zone (Figure 2-1) of the marsh. Sondes along this transect include LOXA135 (canal), LOXA136 (0.6 km; 0.37 miles), LOXA137 (1.1 km; 0.68 miles), LOXA138 (2.1 km; 1.30 miles), and LOXA139 (3.9 km; 2.42 miles).

Median conductivity at LOXA135 (776 μS $cm^{-1}$,) was lower than the average conductivity at LOXA104 (983 μS $cm^{-1}$). The difference was linked to the greater water discharge from STA-1W to the L-7 canal compared to discharge from STA-1E. STA-1W discharged 2.22 x $10^8$ $m^3$ $yr^{-1}$ (180,000 acre-ft) of water, while STA-1E discharged 3.82 x $10^7$ $m^3$ $yr^{-1}$ (31,000 acre-ft). However, discharge from the structures does not necessarily remain in the vicinity of the discharge structures. Waters from each structure, once introduced to the canals, has the potential to move around the entire perimeter canal system, not just south along each canal.

The STA-1E discharge structure is less than 0.2 km (0.12 miles) from LOXA135. However, the length of time before a STA-1E discharge spike (> 14,137 L $s^{-1}$; 500 cfs) was observed at LOXA135, using conductivity as an indicator, was highly variable. Conductivity in the canal at LOXA135 (Figure 2-7), similar to canal inflow, was highly variable. Large inflow spikes (> 56,548 L $s^{-1}$; 2,000 cfs) preceded spikes in canal (LOXA135) conductivity by 1 to 3 days. Large outflow spikes (> 28,742 L $s^{-1}$; 1,000 cfs) preceded decreases in canal (LOXA135) conductivity by 1 to 5 days.

Conductivity across the STA-1E transect was stable when the difference between the canal and marsh stages was small and inflows/outflows were maintained at low to moderate rates. Short (< 5 days) pulses of high canal water inflow did not increase marsh conductivity when canal and marsh stage were both above 4.86 m (16 ft) msl. For example, conductivity at interior sites, relative to the LOXA135 canal conductivity, was less variable and less responsive to small canal inflow oscillations. Interior conductivity ranged from 500 μS $cm^{-1}$ at 0.6 km (0.37 miles) to 100 μS $cm^{-1}$ at 3.9 km (2.42 miles), while canal-marsh stage difference was less than 6.0 cm (0.2 ft). These conductivity levels were evident in the marsh from November 2004 to January 2005, mid-March through April 2005, and again from November 2005 to January 2006.

Rapid (< 15 days) increase of approximately 0.3 m (1 ft) in canal stage from below to above marsh stages, associated with high inflow rates, resulted in elevated conductivity readings in the marsh at least 1.1 km (0.68 miles) in from the canal. These rapid changes at high inflow rates were experienced in the marsh (indicated by elevated conductivity) within days of the high flow event. Conductivity from the canal (LOXA135) to 1.1 km (0.68 miles) into the marsh was elevated above the average conductivity (Table 2-3) for 7 to 9 days in early June 2005. In early June, the conductivity ranged from 815 to 1,150 $\mu$S $cm^{-1}$ in the canal at LOXA135, 480 to 860 $\mu$S $cm^{-1}$ at 0.6 km (0.37 miles), and 370 to 660 $\mu$S $cm^{-1}$ at 1.1 km (0.68 miles). The canal stage was greater than the marsh stage by an average of 5.2 ± 1.5 cm (0.17 ± 0.05 ft) and as much as 8.8 cm (0.29 ft) for 6 to 7 days during this same period. Inflow (115,925 L $s^{-1}$; 4,100 cfs) and outflow (73,513 L $s^{-1}$; 2,600 cfs) spiked to the highest observed rates. The inflow spike started 7 to 8 days before the outflow spike. This inflow spike pushed high conductivity (1,100 $\mu$S $cm^{-1}$) canal waters into the marsh at least 1.1 km (0.68 miles), where conductivity was observed at the highest values.

Regardless of inflow rates, conductivity across the STA-1E transect was lowest when there was a large difference between canal and marsh stages and when marsh stage was greater. Conductivity in the canal and the interior decreased below average conductivities (Table 2-3) across the canal-interior gradient when the marsh stage became greater than the canal stage by more than 12.1 cm (0.4 ft). The canal-marsh stage difference condition lasted from mid-July through August 2005 and the decreases in conductivity across the canal-interior gradients was observed for an extended period of time between July and October 2005, even when inflow rates were high as 28,247 L $s^{-1}$ (1,000 cfs). Even though the stage difference decreased half-way into the low conductivity period, moderate inflows did not increase the conductivity until the canal stage increased above the marsh stage for several weeks.

The ACME-2 transect incorporates a set of sondes that extend from the northeast (south of STA-1E transect) marsh perimeter canals to an intermediate area within the perimeter zone of the marsh (Figure 2-1). The sondes along this transect include LOXA129 (canal), LOXA130 (0.5 km; 0.31 miles), and LOXA131 (1.5 km; 0.93 miles).

Conductivity in the L-40 Canal (LOXA129; Figure 2-8) was variable. The relationship between inflow volumes and conductivity variation at the LOXA129 canal site was not straight forward. We conjecture that the lack of obvious relationship was a result of two confounding factors. First, water in the canal on the east side of the Refuge was often mixed with discharges from STA-1E, the bypass structures (G-300 and G-301), and the two ACME structures. Water discharged from these structures was from different source basins having a diversity of land uses (agricultural, municipal, or a mixture of the two), and generally carried different minerals and nutrient loads. Because of the complexity of mixing in the Refuge L-40 Canal, we were not able to directly link conductivity at the LOXA129 canal site to individual discharge structures with the available information. Second, we hypothesized that water flowing along the L-40 canal from the discharge structures often were mixed and diluted by water flowing out of the marsh interior into the canal. Water moving out of the marsh to the canals was more evident in areas of relatively lower marsh sediment elevation, such as the ACME-2 transect. The introduction of marsh water into the canal may have diluted the canal water, reducing the conductivity levels in the canal. These diluted and mixed waters ultimately produced a different conductivity signal than that observed at any of the structures.

In the canal, conductivity at LOXA129 (672 $\mu S\ cm^{-1}$) was lower than LOXA135 (Table 2-3). LOXA135 was situated north of the ACME structures and LOXA129 was situated south of the ACME structures. LOXA135 and LOXA129 were separated by 5.6 km (3.48 miles). Again, we conjecture that the temporal difference in conductivity between the two sites was driven by marsh water dilution and mixing of STA-1E and bypass waters with ACME structure discharges.

Similar to the STA-1E transect, conductivity levels in the marsh across the ACME-2 transect were stable when the canal and marsh stages were similar and inflow/outflow rates were maintained at low to moderate rates. Unlike the STA-1E transect, when inflow rates were high, conductivity increased in the marsh across the ACME-2 transect, even though the canal and marsh stages were similar. For example, conductivity spiked in the canal (1,400 $\mu S\ cm^{-1}$) and at 0.5 km (0.31 miles) (700 $\mu S\ cm^{-1}$) into the marsh interior in late March 2005. The inflow spiked to 76,340 $L\ s^{-1}$ (2,700 cfs) in late March 2005, while the canal stage was 5.2 ± 1.82 m (0.17 ± 0.06 ft) higher than the marsh stage and rainfall was minimal (< 0.28 $L\ s^{-1}$; 0.01 cfs). The stage difference coupled with the high inflow spike and low rainfall were conditions conducive for elevated marsh conductivity, representative of a diluted canal water signature.

Even when the marsh stage was much higher than the canal stage, if inflow was high, conductivity across the ACME-2 transect often was elevated above average. For example, conductivity across the ACME-2 canal-interior gradient increased above average (Table 2-3) at each site in late May 2005. Conductivity increased to 860 $\mu S\ cm^{-1}$ in the canal (LOXA129), 660 $\mu S\ cm^{-1}$ at 0.5 km (0.31 miles) into the marsh interior, and 570 $\mu S\ cm^{-1}$ at 1.5 km (0.93 miles) into the marsh interior. The marsh stage was 7.6 cm (0.25 ft) higher than the canal stage, while inflows were as high as 115,925 $L\ s^{-1}$ (4,100 cfs) and rainfall was less than 5.1 mm (0.2 inches). The high rate of canal water inflow to the Refuge was enough to push water into the marsh interior regardless of the canal-marsh stage gradient.

In general, the ACME-2 transect was more sensitive to inflow spikes, relative to the STA-1E transect, mostly because of the lower perimeter topography across the ACME-2 transect from 4.38 (14.4 ft) to 4.44 m (14.6 ft) msl) relative to the STA-1E transect from 4.62 (15.2 ft) to 4.80 m (15.8 ft) msl. Further, conductivity in the interior along the ACME-2 transect was near the upper conductivity range when absolute canal-marsh stage difference was less than 6.1 cm (0.2 ft) and inflows to the canals were greater than outflow for two or more weeks. Alternatively, conductivity in the interior was closer to the lower conductivity range when the marsh stage was higher than the canal stage by at least 9.1 cm (0.3 ft).

The S-6 transect incorporates a set of sondes that extend from the southwest marsh perimeter canal to an intermediate area within the interior marsh zone (Figure 2-1). Sondes along this transect include LOXA115 (canal), LOXA116 (0.4 km; 0.25 miles), LOXA117 (0.9 km; 0.56 miles), LOXA118 (1.8 km;1.12 miles), LOXA119 (4.3 km; 2.67 miles), and LOXA120 (6.1 km; 3.79 miles).

The relationship between inflow volumes and conductivity at the LOXA115 canal site was not related directly. We believe that the lack of an obvious relationship was a result of lag-time between the STA-1W structure and the LOXA115 canal site, which are separated by 13 km (8.07 miles). The time for water discharged from the STA-1W structure to reach the LOXA115 canal site ranged between 2 and 5 days based on conductivity signals measured at the structure and canal site. Conductivity at LOXA115 (950 $\mu S\ cm^{-1}$) was significantly lower than LOXA104, likely because of mixing of water from the marsh with canal water as canal water moved south to LOXA115. Water moving from the marsh towards the canals was most evident when the canal stage was much lower (0.15 to 0.30 m; 0.5 to 1 ft) than the marsh stage. That stage configuration occurred only a few times and the small number of times when water was moving from the marsh to the canals explained why the average difference between the two sites, although statistically significant, was small.

The S-6 transect was more sensitive to inflow spikes than the STA-1W transect. The greater sensitivity to canal water across the S-6 transect relative to the STA-1W transect was because of the lower elevation (4.13 to 4.32 m; 13.6 to 14.2 ft msl) across the S-6 relative to the elevation across the STA-1W (4.53 to 4.65 m; 14.9 to 15.3 ft msl). The lower elevation reduced the physical impedance to canal water movement into the marsh allowing water from the canal to move into the marsh easier in these lower elevation areas.

Conductivity spikes across the S-6 transect generally occurred days to a week after high rates of canal inflow. For example, conductivity spikes above average (Table 2-3) were observed in the canal (1,220 $\mu S\ cm^{-1}$) and at 0.4 km (0.25 miles) (1,030 $\mu S\ cm^{-1}$) and 0.9 km (0.56 miles) (670 $\mu S\ cm^{-1}$) into the marsh in late March 2005. These spikes in conductivity occurred when the canal stage was 5.17 cm (0.17 ft) higher than the marsh stage and inflows were as high as 76, 340 L $s^{-1}$ (2,700 cfs). Conductivity spikes were observed in the canal (1,360 $\mu S\ cm^{-1}$) and the marsh at 0.4 km (0.25 miles) (1,150 $\mu S\ cm^{-1}$), 0.9 km (0.56 miles) (890 $\mu S\ cm^{-1}$), and at 1.8 km (1.12 miles) (520 $\mu S\ cm^{-1}$) during early November 2005. These spikes in conductivity occurred when the canal stage was more than 6.1 cm (0.2 ft) greater than marsh stages and inflows were high as 65,031 L $s^{-1}$ (2,300 cfs).

In general, when the marsh stage was much greater than the canal stage for several weeks, inflows had little impact on the interior sites and conductivity in the marsh remained below average. Conductivity levels from late July to early August 2004 in the canal (330 $\mu S\ cm^{-1}$) and in the marsh at 0.4 km (0.25 miles) (180 $\mu S\ cm^{-1}$) and 1.8 km (1.12 miles) (100 $\mu S\ cm^{-1}$) were the lowest levels observed. This period, late July to early August 2005, was characterized with marsh stages more than 0.30 m (1 ft) higher than the canal stage and low inflows and outflows. The much higher marsh stage relative to the canal stage coupled with the low inflows and sporadic rainfall were conditions conducive for the observed low conductivity marsh water movement toward the canals.

In general for all the transects, when the marsh stage was maintained above the canal stage by more than 6.1 cm (0.2 ft), short duration, high-flow rate canal inflow events had little impact on conductivity in the marsh. Alternatively, when the absolute stage difference was less than 6.1 cm (0.2 ft), high conductivity was observed across each transect, particularly when net flow was positive. Finally, areas of lower marsh elevation were more sensitive to canal inflows than areas with higher elevation.

<u>Method 2 – Distance of Intrusion</u>

Approach 1 - Transect interpolated canal water intrusion

Time-series canal water intrusion into the marsh interior was characterized (Table 2-4) for four transects – two transects on the east side of the Refuge (STA-1E and ACME-2) and two on the west side of the Refuge (S-6 and STA-1W).

Canal water intrusion is the movement of high conductivity canal water into the marsh interior. Generally, intrusion is driven by conditions of high canal inflow and canal stages greater than marsh stages. Alternatively, movement of lower conductivity marsh water towards the canals generally is driven by (1) high rainfall events diluting the conductivity in the interior and/or creating a hydraulic gradient toward the canal; (2) high outflow events pulling water from the marsh interior towards the canals; or (3) a combination of 1 and 2.

Along the STA-1W transect (Figure 2-10c; Table 2-4), the average extent of canal water intrusion for the 500 $\mu S\ cm^{-1}$ isopleth was 0.8 ± 0.4 km (0.50 ± 0.25 miles) (mean ± 1 standard deviation), while for the 350 $\mu S\ cm^{-1}$ isopleth it was 1.2 ± 0.5 km (0.75 ± 0.31 miles). The 500 $\mu S\ cm^{-1}$ isopleth maximum intrusion was 2.7 km (1.68 miles) on August 26, 2005, which reduced to 0.8 km (0.50 miles) by August 27, 2005. For the 350 $\mu S\ cm^{-1}$ isopleth, maximum intrusion was 3.5 (2.17 miles) on August 25, 2005, which reduced to 1 km (0.62 miles) by August 27, 2005. Canal stage was lower than marsh stage by an average of 17.0 ± 2.43 cm (0.55 ± 0.08 ft); net flow was negative and averaged 14,957 L $s^{-1}$ (529 cfs) from August 22 to 26; and rainfall averaged 6.4 mm $d^{-1}$ (0.25 inches per day) which equals $3.85 \times 10^6\ m^3\ d^{-1}$ (3,123 acre-ft per day) over the same period. The high inflow rates (15,550 to 28,247 L $s^{-1}$; 550 to 1,000 cfs) from August 22 to 26 were high enough to push water into the marsh regardless of the observed canal-marsh stage difference.

On July 13, 2005, the 350 $\mu S\ cm^{-1}$, minimum intrusion was 0.3 km (0.18 miles). This small intrusion event was generally influenced by water moving from the marsh interior towards the canals, which reduced the extent higher conductivity canal water could intrude into the marsh. Both the 500 $\mu S\ cm^{-1}$ and 350 $\mu S\ cm^{-1}$ isopleths consistently declined from June 4, 2005 to the observed minimum dates (July 11 and 13). Canal and marsh stages were similar prior to June 9. Canal stage dropped by at least 0.27 m (0.9 ft) between June 10 and 27 and again between July 1 and 11. Between July 1 and 11, net flow was negative at 14,900 L $s^{-1}$ (527 cfs). Rainfall averaged 7.6 mm $d^{-1}$ (0.3 inches per day) from July 1 to 11 and we suspect this rainfall event raised the water level in the marsh. Increased differences between the marsh and canal stages and high canal water discharge from the Refuge pushed low conductivity water from the marsh towards the canals.

Along the STA-1E transect (Figure 2-10d; Table 2-4), average extent of canal water intrusion for the 500 $\mu S\ cm^{-1}$ conductivity isopleth was 0.5 ± 0.1 km (0.31 ± 0.6 miles), while for the 350 $\mu S\ cm^{-1}$ isopleth it was 0.9 ± 0.2 km (0.56 ± 0.3 miles). The 500 $\mu S\ cm^{-1}$ isopleth maximum intrusion was 0.7 km (0.44 miles) on November 9, 2005. The 350 $\mu S\ cm^{-1}$ isopleth maximum intrusion was 1.3 km (0.80 miles) on November 4, 2005. These maximum intrusions were associated with positive net flow of 24,599 L $s^{-1}$ (870 cfs) over two days. The high inflow preceded the maximum intrusion by four days. Canal stage was 8.5 cm (0.28 ft) higher than marsh stage and both were higher than 5.07 m (16.7 ft) msl, leading to the intrusion event.

The 500 $\mu S\ cm^{-1}$ isopleth minimum intrusion was less than 1 m (3.28 ft) on September 3, 2005. The marsh stage exceeded the canal stage by 7.60 ± 0.90 cm (0.25 ± 0.03 ft) and both were higher than 4.86 m (16 ft) msl for the five-day average (September 3 and 4 days prior). Net flow was negative with a range of 8,765 to 21,488 L $s^{-1}$ (310 to 760 cfs) and rainfall was 6.35 ± 0.76 mm $d^{-1}$ (0.25 ± 0.03 inches per day) which equals $5.12 \times 10^7 \pm 9.93 \times 10^5\ m^3\ d^{-1}$ (4,148 ± 805 acre-ft per day) for the five-day average. The higher marsh stage relative to the canal stage coupled with negative net flow and high rainfall conditions were important contributors to this period of low intrusion.

The 350 $\mu S\ cm^{-1}$ isopleth minimum intrusion was 20 m (65.6 ft) on August 18, 2005. Net flow was negative and less than 1,130 L $s^{-1}$ (40 cfs) over the four days leading to this event. The marsh stages were higher than the canal stage by more than 0.18 m (0.6 ft) over four weeks preceding August 18. Outflow dominated water movement in the canal for most of July, while low inflow rates (< 2,827 L $s^{-1}$; 100 cfs) in early August did not balance the extended period of high outflow. Rainfall for the two weeks leading to August 18 averaged 4.56 ± 2.43 cm $d^{-1}$ (0.15 ± 0.08 ft per day) which equals $2.29 \times 10^6 \pm 1.16 \times 10^6\ m^3\ d^{-1}$ (1,861 ± 938 acre-ft per day). These extended periods of hydrologic conditions maintained the low observed intrusion in mid-August 2005.

Along the ACME-2 transect (Figure 2-10e; Table 2-4), average extent of canal water intrusion for the 500 $\mu S\ cm^{-1}$ isopleth was 0.7 ± 0.3 km (0.44 ± 0.19 miles), while for the 350 $\mu S\ cm^{-1}$ isopleth it was 0.9 ± 0.4 km (0.56 ± 0.25 miles). The 500 $\mu S\ cm^{-1}$ isopleth maximum intrusion was 1.4 km (0.87 miles) on May 17, 2005. The marsh stage exceeded the canal stage by an average of 5.77 ± 1.8 cm (0.19 ± 0.06 ft) on May 17 and 13 days prior. Average inflow exceeded average outflow for these 14 days by 5,655 L $s^{-1}$ (200 cfs). Rainfall decreased substantially over the 12 days from 4.32 mm $d^{-1}$ (0.17 inches per day) between May 5 and 7 down to less than 0.2 mm $d^{-1}$ (0.01 inches per day) between May 9 and 17. The low canal-marsh stage difference, coupled with small influxes of canal water inflow and low rainfall, were conditions conducive for the maximum observed intrusion on the ACME-2 transect.

The 350 $\mu S\ cm^{-1}$ isopleth maximum intrusion was 1.5 km (0.93 miles) on April 13, 2005. Absolute canal-marsh stage difference never exceeded 7.6 cm (0.25 ft) from March 19 to April 13. Average inflow exceeded average outflow by 4,806 $L\ s^{-1}$ (170 cfs) for the same 27 days. Rainfall was sporadic for the 27 days, averaging 3.05 ± 3.56 mm $d^{-1}$ (0.12 ± 0.14 inches per day); 1.86 x $10^6$ ± 2.07 x $10^6$ $m^3\ d^{-1}$ (1,512 ± 1680 acre-ft per day); and less than 0.25 mm $d^{-1}$ (0.01 inches) a few days before April 13. These conditions of small canal-marsh stage difference, low inflows, and low rainfall were conducive for the maximum intrusion event along the ACME-2 transect.

The 350 $\mu S\ cm^{-1}$ isopleth minimum intrusion was 40 m (131.2 ft) on August 21, 2005. The marsh stage was 15.2 to 30.4 cm (0.5 to 1 ft) greater than the canal stage through mid to late August, and at the end of July 2005, net flow was negative and approximately 11,310 $L\ s^{-1}$ (400 cfs). Average rainfall, from July 20 to August 21, was 3.56 ± 2.23 mm $d^{-1}$ (0.14 ± 0.09 inches per day) which equals 2.09 x $10^6$ ± 1.49 x $10^6$ $m^3\ d^{-1}$ (1,693 ± 1206 acre-ft per day). The extensive and prolonged difference between the marsh stage and canal stages coupled with the observed outflow and rainfall were conducive for low conductivity water movement from the marsh interior toward the canals.

The ACME-2 transect was more sensitive to canal water movement than the STA-1E transect. This sensitivity was estimated quantitatively based on a combination of conductivity variability across transects and qualitatively based on a transect-specific comparison of time-series conductivity spikes versus inflow from the eastern inflow structures. Coefficients of variation for the 350 and 500 $\mu S\ cm^{-1}$ isopleth along the ACME-2 transect were 45% and 52%, respectively. Coefficients of variation for the 350 and 500 $\mu S\ cm^{-1}$ isopleth along the STA-1E transect were 35% and 38%, respectively, and these coefficients of variation were lower than those along the ACME-2 transect. Variability across both transects was much higher than variability (22%) of conductivity from the STA-1E discharge structure. The patterns of conductivity spikes between the STA-1E and ACME-2 transects were offset by 1 to 3 days and the spikes occurred at the STA-1E transect first. We believe that the large difference in conductivity variability may have been caused by canal water dilution with marsh water when the canal stage was much lower than the marsh stage, mixing of water from different structures that discharge into the L-40 canal, differences in vegetative resistance between the two transects, and/or topographic difference between the two transects.

Along the S-6 transect (Figure 2-10f; Table 2-4), average extent of canal water intrusion at the 500 $\mu S\ cm^{-1}$ isopleth was 0.9 ± 0.6 km (0.56 ± 0.37 miles) and for the 350 $\mu S\ cm^{-1}$ isopleth it was 1.5 ± 1.0 km (0.93 ± 0.37 miles). The 500 $\mu S\ cm^{-1}$ isopleth maximum intrusion was 2.1 km (1.30 ± 0.37 miles) on November 16, 2005. The 350 $\mu S\ cm^{-1}$ maximum intrusion was 3.7 km (2.30 miles) on November 16, 2005. The canal stage consistently was higher than the marsh stage by an average of 8.2 ± 1.5 cm (0.27 ± 0.05 ft), from November 1 to 16. Inflow exceeded outflow by 14, 250 $L\ s^{-1}$ (504 cfs) for these 15 days. Average rainfall for the 15 days was low at 1.82 ± 2.13 cm $d^{-1}$ (0.06 ± 0.07 ft per day) which equals 9.84 x $10^5$ ± 1.12 x $10^6$ $m^3$ $d^{-1}$ (798 ± 909 acre-ft per day). These conditions when the canal stages were higher than the marsh stages, coupled with continued moderate inflow fluxes and low rainfall, were conducive to the substantial intrusion event in November 2005.

The 500 µS $cm^{-1}$ isopleth minimum intrusion was 3 m (9.8 ft) on August 3, 2005, which was a considerable reduction from 20 m (65.6 ft) intrusion observed a few weeks earlier (on July 19, 2005). The 350 µS $cm^{-1}$ isopleth minimum intrusion was 1 m (3.28 ft) on August 11, 2005. Marsh stage exceeded canal stage by more than 0.24 m (0.8 ft) from July 19 to August 3, 2005. Outflow exceeded inflow by 7,069 L $s^{-1}$ (250 cfs) for the same 15 days. Rainfall, 4.06 ± 3.05 mm $d^{-1}$ (0.16 ± 0.12 ft per day) or 2.47 x $10^6$ ± 1.78 x $10^6$ $m^3$ $d^{-1}$ (2,000 ± 1,440 acre-ft per day), for the 15 days was substantial. These prolonged higher marsh stages relative to canal stages, coupled with higher outflows and substantial rainfall, were conditions conducive for the smaller intrusion observed in August 2005.

The S-6 transect was more sensitive to canal water movement than the STA-1W transect. Coefficients of variation for the 350 and 500 µS $cm^{-1}$ isopleth along the S-6 transect were 65% and 65%, respectively. Coefficients of variation for the 350 and 500 µS $cm^{-1}$ isopleth along the STA-1W transect were 45% and 46%, respectively, and these coefficients of variation were lower than those along the S-6 transect. Variability across both transects was much higher than variability (20%) of conductivity from the STA-1W discharge structure. The patterns of conductivity spikes between the STA-1W and S-6 transects were offset between 2 to 5 days and the spikes occurred at the STA-1W first. We conjecture that the large difference in conductivity variability was driven mostly by the lag-time of canal water movement from the STA-1W transect south to the S-6 transect, which allowed sporadic marsh water mixing with canal waters, particularly when the canal stage was much lower than the marsh stage.

Approach 2 - Water movement across the canal-interior gradient

<u>Baseline Conditions – December 7, 2004.</u> The marsh stage was 1.52 cm (0.6 inches) higher than the canal stage; five-day average net flow was negative at a rate of 394 L $s^{-1}$ (14 cfs); and five-day total rainfall was much less than 3.0 mm (0.01 inches) (< 1.60 x $10^5$ $m^3$; 130 acre-ft) on December 7, 2004, the date selected for the baseline conditions. No date in the POR met all three desired conditions for the baseline. However, the magnitude by which each baseline condition was offset was negligible and comparison hydrologic conditions (scenarios) were significantly greater with the exception of rainfall. Periods when rainfall was low were selected for most of the scenarios to minimize the impact of natural drivers (e.g., hurricanes and tropical storms) on intrusion, specifically because we wanted to understand how structure operation (canal water inflow/outflow) impacts water movement across the canal-interior gradient.

<u>Scenario 1 – March 23, 2005</u>. The Scenario 1 conductivity front, relative to the baseline conditions, intruded into the marsh by an average of 1.7 km (1.05 miles), with a range of 0.9 to 3.1 km (0.56 to 1.93 miles) (Table 2-5). Water movement was greatest in the

interior zone and lowest in the perimeter zone. The canal stage was 7.0 cm (0.23 ft) higher than the marsh stage; inflow was 19,000 L $s^{-1}$ (672 cfs) higher than outflow per day for the five-day average; and the five-day total rainfall was 0.5 mm (0.02 inches) (Table 2-6). The higher canal stage relative to marsh stage, moderate to high inflow, and low rainfall were conducive for the observed intrusion event.

Scenario 2 – November 12, 2005. The Scenario 2 conductivity front, relative to the baseline conditions, intruded into the marsh an average of 0.5 km (0.31 miles), with a range of 0 to 0.8 km (0 to 0.50 miles) (Table 2-5). Water movement was greatest in the perimeter zone, lower in the transition zone, and even lower in the interior zone. The canal stage was 7.9 cm (0.26 ft) higher then the marsh stage; outflow was 4,694 L $s^{-1}$ (166 cfs) higher than inflows per day over the five days; and there was no rain for the five-day total rainfall (Table 2-6). Generally, when the canal-marsh stage gradient is higher on the canal side, canal water can intrude into the marsh. Alternatively, when outflows dominate the canal water budget, lower conductivity marsh water moves towards the canals. In this case, when the canal stage was higher than the marsh stage and outflow was greater than inflow, canal water intruded, while lower conductivity water moved towards the canal.

Scenario 3 – April 17, 2005. The Scenario 3 conductivity front, relative to the baseline conditions, intruded into the marsh an average of 0.5 km (0.31 miles), with a range of 0.1 to 1.2 km (0.06 to 0.75 miles) (Table 2-5). Water movement was greatest in the interior zone and lowest in the perimeter zone. The marsh stage was 0.61 cm (0.2 inches) higher than the canal stage; outflow per day average was 2,658 L $s^{-1}$ (94 cfs) higher than inflow over the five days; and there was no rain (Table 2-6). Although these conditions where conducive for the intrusion, the conductivity front in this scenario, particularly in the perimeter zone, was similar to the conductivity front for the baseline conditions.

Scenario 4 – July 21, 2005. The Scenario 4 conductivity front, relative to the baseline conditions, moved towards the canal an average of 1.1 km (0.68 miles), with a range of 0.5 to 1.4 km (0.31 to 0.87 miles) (Table 2-5). Water movement from the interior towards the canal was greatest in the perimeter zone and lower in the transition zone. The marsh stage was 0.32 m (1.05) ft greater than the canal stage; per day average outflow was 13,854 L $s^{-1}$ (490 cfs) higher than inflows for the five days; and the five-day total rainfall was 5.08 mm (0.2 inches) ($3.08 \times 10^6$ $m^3$; 2,500 acre-ft) (Table 2-6). When the marsh stage was significantly higher (>0.30 m; 1 ft) than the canal stage; net flow was negative and approximately 14,137 L $s^{-1}$ (500 cfs), and rainfall was low but consistent, water from the interior pushed out towards the canals.

Method 3 - Distance of Intrusion: A transformed coordinate system

A high inflow and low outflow ($I_H$-$O_L$) canal structure operation was observed between October and November 2005, and a high inflow and high outflow ($I_H$-$O_H$) canal structure operation was observed between late May and late June 2005. Structures were operated in a $I_H$-$O_L$ configuration before and during two tropical storms and one hurricane. The $I_H$-$O_H$ operation was implemented before and during one tropical storm and two unnamed large rainfall events. Snapshots in time of conductivity isopleths were produced before and after selected weather events to examine water movement within the marsh and between the canals and the marsh. Hydrologic conditions (i.e., canal-marsh stage difference, net flow, and rainfall) for each scenario were characterized with respect to water movement across the canal-interior gradient (Table 2-7).

Refuge inflows for the period of $I_H$-$O_L$ flows (October to November 2005) were from rainfall (44%; 1.21 x $10^6$ $m^3$ $d^{-1}$; 983 acre-ft per day) and discharges from STA-1W (38%; 1.05 x $10^6$ $m^3$ $d^{-1}$; 850 acre-ft per day), STA-1E (13%; 3.58 x $10^5$ $m^3 d^{-1}$; 290 acre-ft per day), ACME-1 (2%; 6.91 x $10^4$ $m^3$ $d^{-1}$; 56 acre-ft per day), ACME-2 (2%; 4.81 x $10^4$ $m^3$ $d^{-1}$; 39 acre-ft per day) and, occasionally, the STA bypass structures G-300 and G-301 (< 1%; 1.60 x $10^4$ $m^3$ $d^{-1}$;13 acre-ft per day). Refuge outflow from the structures was 2.79 x $10^5$ $m^3$ $d^{-1}$ (226 acre-ft per day), while evapotranspiration (2.64 x $10^6$ $m^3$ $d^{-1}$; 2,144 acre-ft per day) and groundwater seepage accounted for the remainder of water removal from the Refuge. Outflows were through S-39 (66%) in the southeast and the G-94 (34%) water control structures (D, C, B, and A) along the east.

Refuge inflows for the period of $I_H$-$O_H$ flows (late May to late June 2005) were from rainfall (39%; 1.72 x $10^6$ $m^3$ $d^{-1}$; 1,396 acre-ft per day) and discharges from STA-1W (25%; 1.09 x $10^6$ $m^3$ $d^{-1}$; 888 acre-ft per day), STA-1E (2%; 1.11 x $10^5$ $m^3$ $d^{-1}$; 90 acre-ft per day), ACME-1 (4%; 1.94 x $10^5$ $m^3$ $d^{-1}$; 157 acre-ft per day), ACME-2 (4%; 1.73 x $10^5$ $m^3$ $d^{-1}$; 140 acre-ft per day) and the bypass structures (26%; 1.15 x $10^6$ $m^3$ $d^{-1}$; 931 acre-ft per day). Refuge outflows from structures removed 3.08 x $10^6$ $m^3$ $d^{-1}$ (2,496 acre-ft per day), while evapotranspiration removed 3.29 x $10^6$ $m^3$ $d^{-1}$ (2,669 acre-ft per day). Eighty-six percent of water removal occurred through the S-10 structures and the S-39 accounted for 14%.

$I_H$-$O_L$ Structure operation – Canal water intrusion

Pre-Hurricane Rita – September 18, 2005. Intrusion, on September 18, 2005 (pre-Hurricane Rita), was greatest in the west and north areas of the Refuge (Figure 2-11). Intrusion observed for this pre-Rita structure operation ($I_L$-$O_L$) was applied as a reference point in the following analysis.

The 300 $\mu S\ cm^{-1}$ isopleth intruded 1 km (0.62 miles) in the west and the northwest areas of the Refuge near the S-6 and STA-1W transects and 0.6 km (0.37 miles) in the northeast near the STA-1E, ACME-1, and ACME-2 transects. No intrusion was observed in the eastern-most area of the Refuge near the central transect. Intrusion of the 500 $\mu S\ cm^{-1}$ isopleth followed the intrusion pattern of the 300 $\mu S\ cm^{-1}$ isopleth. The 500 $\mu S\ cm^{-1}$ isopleth intruded 0.6 km (0.37 miles) in the west and northwest areas of the Refuge and 0.4 km (0.25 miles) in the northeast area of the Refuge. Intrusion across the characterized area of the Refuge, following the 500 $\mu S\ cm^{-1}$ isopleths, was less extensive than average intrusion for the 500 $\mu S\ cm^{-1}$ isopleths (Table 2-4) along all transects.

On September 18, the canal stage 4.95 m (16.29 ft) msl was slightly lower than the marsh stage 4.96 m (16.31 ft) msl. On September 18 and four days prior, average canal water inflow rates were low: 311 L $s^{-1}$ (11 cfs) (STA-1W), 367 L $s^{-1}$ (13 cfs) (STA-1E), and 537 L $s^{-1}$ (19 cfs) of untreated through the ACME structures. No outflows were observed for the five-day period. Rainfall for this pre-Rita period was less than 0.3 mm (0.01 inches) per day.

Similar to previous observation, when the marsh stage was even slightly higher than the canal stage and inflows were low, the hydrologic conditions were conducive to a less than average extent of intrusion.

Post-Rita/Pre-Tropical Storm Tammy – September 27, 2005. Structures were operated as $I_L$-$O_L$ for the post-Rita/pre-Tropical Storm Tammy period (September 27, 2005). Intrusion was identical to the pre-Rita intrusion pattern across the characterized zone of the Refuge with the exception of the most eastern area of the Refuge (Figure 2-12). Intrusion, following the 300 μS $cm^{-1}$ isopleth, in the most eastern area of the Refuge increased to 0.4 km (0.25 miles) after Rita.

Differences between the canal 4.96 m (16.33 ft) msl and the marsh 4.95 m (16.28 ft) msl stages decreased after Rita. Five-day average inflow was low at 113 L $s^{-1}$ (4 cfs) (STA-1W) and 792 L $s^{-1}$ (28 cfs) (STA-1E). Five-day average outflows were nominal at 170 L $s^{-1}$ (6 cfs) (G-94). Five-day average rainfall was 3.6 mm (0.14 inches) per day (2.16 x $10^6$ $m^3$ $d^{-1}$; 1,750 acre-ft per day).

Fifty-five percent of the inflow was through the structures on the east side of the Refuge. The canal stage increased by 1.22 cm (0.04 ft), while the marsh stage decreased by 0.91 cm (0.03 ft) by the end of Hurricane Rita. The low but consistent inflow of 2,827 L $s^{-1}$ (100 cfs) over the period from September 18 to 27, coupled with the minimal canal-marsh stage difference, were conditions conducive for the observed intrusion increase in the east area of the Refuge.

Post-Tammy/Pre-Hurricane Wilma – October 17, 2005. Structures were operated as $I_M$-$O_L$ for the post-Tammy/pre-Hurricane Wilma period (October 17, 2005). Intrusion was greatest on the west side of the Refuge (Figure 2-13). In the middle of the Refuge, going from both north to south and east to west (2.5 to 6 km; 1.56 to 3.73 miles into the marsh), conductivity was at the expected rainfall-driven level of 100 μS $cm^{-1}$. Intrusion along the 300 and 500 μS $cm^{-1}$ isopleths, relative to the pre-Tammy/post-Rita period, was higher across the characterized zone. The 300 μS $cm^{-1}$ isopleth intruded 3.4 km (2.11 miles) in the west, 1.2 km (0.75 miles) in the northwest, 0.5 km (0.31 miles) in the northeast, and 1.4 km (0.87 miles) in the east. The 500 μS $cm^{-1}$ isopleth pattern did not follow the 300 μS $cm^{-1}$ isopleth in the west and east areas of the Refuge. The 500 μS $cm^{-1}$ isopleth intruded 1 km (0.62 miles) in the west, 0.8 km (0.50 miles) in the northwest, and 0.2 km (0.12 miles) in the northeast and east areas of the Refuge.

Intrusion in the west area of the Refuge, following the 500 μS $cm^{-1}$ isopleths, was greater than the average intrusion for the 500 μS $cm^{-1}$ conductivity levels (Table 2-4) along the S-6 transect. Intrusion, following the 500 μS $cm^{-1}$ isopleths, across the remainder of the characterized zone was near or below average intrusion for the STA-1W, STA-1E, and ACME-2 transect.

Canal stage 5.07 m (16.68 ft) msl was higher than the marsh stage 5.0 m (16.45 ft) msl. Structures were operated as moderate inflow (11,197 L $s^{-1}$; 396 cfs) and no outflow over the five-day period. Ninety-four percent of the inflow (10,490 L $s^{-1}$; 371 cfs) entered the Refuge through STA-1W and the remaining 6% entered the Refuge through STA-1E. Rainfall for the five-day average was less than 0.3 mm (0.01 inches) per day.

The extended period of higher inflows (through Tropical Storm Tammy – 56,549 L $s^{-1}$; 2,000 cfs for 3-4 days) with lower rainfall was conducive for the observed canal water intrusion, particularly in the west area of the Refuge.

<u>Hurricane Wilma – October 25, 2005</u>. Structures were operated as $I_H$-$O_L$ for the Hurricane Wilma period (October 25, 2005). Patterns of intrusion during Hurricane Wilma were very similar to the post-Tammy/pre-Wilma pattern, except both the conductivity fronts intruded further into the marsh across most of the characterized zone (Figure 2-14). The 100 $\mu$S $cm^{-1}$ isopleth was 5.6 to 6 km (3.47 to 3.73 miles) into the marsh in the west, 3.6 km (2.23 miles) in the northwest and northeast, and 3.1 km (1.93 miles) in the east. The 300 $\mu$S $cm^{-1}$ isopleth intruded 3.6 km (2.23 miles) in the west, 0.2 km (0.12 miles) more than in the post-Tammy/pre-Wilma period. Intrusion, following the 300 $\mu$S $cm^{-1}$ isopleth, in the northwest and northeast areas of the Refuge extended 1.2 km (0.75 miles) into the marsh, 0.4 km (0.25 miles) more than in the post-Tammy/pre-Wilma period. Intrusion in the east was 1.2 km (0.75 miles), 0.2 km (0.12 miles) less than the post-Tammy/pre-Wilma period. The 500 $\mu$S $cm^{-1}$ isopleth intruded 1.2 km in the west, 0.8 km in the northwest, and 0.4 km (0.25 miles) in the northeast. Intrusion at the 500 $\mu$S $cm^{-1}$ conductivity level was not evident in the east area of the Refuge.

Intrusion in the west, following the 500 $\mu$S $cm^{-1}$ isopleth, was more extensive than the average intrusion (Table 2-4) along the S-6 transect. Intrusion, following the 500 $\mu$S $cm^{-1}$ isopleths, across the remainder of the characterized zone was near or below the 500 $\mu$S $cm^{-1}$ conductivity level average intrusion for the STA-1W, STA-1E, and ACME-2 transect.

The canal stage 5.16 m (16.98 ft) msl was higher than the marsh 5.06 m (16.66 ft) msl stage. Inflow was 16,456 L $s^{-1}$ (582 cfs) and outflow was 509 L $s^{-1}$ (18 cfs) for the five-day average. Rainfall (17.5 mm, 0.69 inches per day) was substantially higher than the previous periods reported as part of our analysis.

The length of time and volume of rainfall were conducive for pushing low conductivity water from the marsh toward the canal into the transition zone. Low outflow rates on the east side of the Refuge may have contributed to the extent of interior water movement towards the canal, particularly in the east area of the Refuge. However, the high inflow rates were conducive for the observed extended intrusion of canal water into the marsh, particularly in the west area of the marsh.

Post-Hurricane Wilma – November 15, 2005. Structures were operated as $I_M$-$O_L$ for the post-Hurricane Wilma period (November 15, 2005). Patterns of intrusion evident in the post-Wilma condition were like no other pattern observed (Figure 2-15). The 100 $\mu$S cm$^{-1}$ isopleth was no longer present, indicating no values in the characterized zone below 100 $\mu$S cm$^{-1}$ Thus, few areas of the Refuge characterized by the network had natural rainfall conductivity levels during this period. Conductivity along the 300 $\mu$S cm$^{-1}$ isopleth intruded 5 km (3.11 miles) in the west, 1.6 to 1.8 km (0.99 to 1.12 miles) in the northwest and northeast, and 0.6 km (0.37 miles) in the east. Intrusion, following the 500 $\mu$S cm$^{-1}$ isopleth, was 3.6 km (2.23 miles) in the west and 1.4 km (0.88 miles) in the northwest and northeast areas of the Refuge. The 500 $\mu$S cm$^{-1}$ isopleth was not present in the east region of the Refuge. Intrusion across the characterized zone of the Refuge, following the 500 $\mu$S cm$^{-1}$ isopleths, was greater than the average intrusion for the 500 $\mu$S cm$^{-1}$ conductivity level (Table 2-4) along the S-6, STA-1W, STA-1E, and ACME-2 transects.

The canal stage 5.15 m (16.93 ft) msl was higher than the marsh stage 5.08 m (16.72 ft) msl. Five-day structure operation was moderate inflow (7,464 L s$^{-1}$; 264 cfs) and low outflow (2,601 L s$^{-1}$; 92 cfs). Rainfall was 2.28 mm d$^{-1}$ (0.09 inches per day) for the five days. Inflow was high, 113,098 L s$^{-1}$ (4,000 cfs), following the rainfall from Hurricane Wilma. These high and prolonged inflows coupled with much lower outflows and rainfall were conditions conducive for the observed extensive canal water intrusion.

$I_H$-$O_H$ Structure operation – Canal water intrusion

Pre-Tropical Storm Arlene – May 30, 2005. Structures were operated as $I_L$-$O_L$ for the pre-Tropical Storm Arlene period (May 30, 2005). Intrusion on May 30, 2005 (pre-Tropical Storm Arlene) was greatest in the west area of the Refuge and lowest in the northeast area (Figure 2-16). The 300 $\mu$S cm$^{-1}$ isopleth intruded 2.9 km (1.80 miles) in the west, 1.8 km (1.12 miles) in the northwest, 1.1 km (0.68 miles) in the northeast, and 2.4 to 2.6 km (1.50 to 1.61 miles) in the east. Intrusion of the 500 $\mu$S cm$^{-1}$ isopleth was 0.9 km (0.56 miles) in the west and northwest and 0.4 to 0.6 km (0.25 to 0.37 miles) in the northeast. The 500 $\mu$S cm$^{-1}$ isopleth was not present in the east area of the Refuge.

In the west and northwest, intrusion, following the 500 $\mu$S cm$^{-1}$ isopleth, was greater than average intrusion (Table 2-4) for the 500 $\mu$S cm$^{-1}$ conductivity level along the S-6 and STA-1W transect, while the 500 $\mu$S cm$^{-1}$ isopleth intrusion was below average for the STA-1E and ACME-2 transects.

The marsh stage 4.80 m (15.79 ft) msl was higher than the canal stage 4.73 m (15.58 ft msl). Structures were operated as low inflow (2,120 L s$^{-1}$; 75 cfs) and no outflow for the five-days. Rainfall (5.84 mm d$^{-1}$, 0.23 inches per day) was substantial and was consistent since May 22.

Canal water intrusion was evident across the characterized zone, even under these conditions of high and sustained rainfalls coupled with low inflow, low canal stage, and marsh stage higher than canal stage. Interestingly, the 100 μS $cm^{-1}$ isopleth was not present, although rainfall was moderate to high and prolonged.

Post-Arlene/Pre-unnamed storm event – June 17, 2005. Structures were operated as $I_H$-$O_H$ for the post-Arlene/pre-unnamed storm period (September 27, 2005). Intrusion, on June 17, 2005 (post-Arlene/pre-unnamed storm event), was uniform across the characterized zone of the Refuge (Figure 2-17). The 300 μS $cm^{-1}$ isopleth intruded 1.2 km (0.75 miles) in the west, northwest, and northeast. Intrusion of the 300 μS $cm^{-1}$ isopleth was 1.5 km (0.93 miles) in the northeast and east areas of the Refuge characterized zone. The 500 μS $cm^{-1}$ isopleth intruded 0.6 km (0.37 miles) in the west, northwest, and northeast, but the 500 μS $cm^{-1}$ isopleth was not present in the east.

Intrusion in the northwest, northeast, and east areas of the Refuge, following the 300 μS $cm^{-1}$ isopleths, was greater than the average intrusion for the 350 μS $cm^{-1}$ conductivity level along the STA-1W, STA-1E, and ACME-2 transects. Across the characterized zone of the Refuge, following the 500 μS $cm^{-1}$ isopleths, the intrusion extent was lower than average (Table 2-4) along the S-6, STA-1, STA-1E, and ACME-2 transects.

The marsh stage 4.93 m (16.23 ft) msl was higher than the canal stage 4.76 m (15.69 ft) msl. Inflow was 12,695 L $s^{-1}$ (449 cfs) and outflow at 63,278 L $s^{-1}$ (2,238 cfs) over the five days. Rainfall was 1.8 mm (0.07 inches) per day and low for the five days.

Intrusion was observed in this scenario, although outflows were much higher than inflows. Intrusion was greatest in the east area of the Refuge, even though 76% of the inflow came in on the west side of the Refuge through STA-1W. This higher intrusion in the east may reflect more water being drawn from the marsh towards the canals on the west side of the Refuge as the S-10 spillway structures released large volumes of water during this period. This movement of water from the lower conductivity interior marsh toward the canals may have diluted the higher conductivity waters in the perimeter area in the west.

Post-unnamed storm event – June 27, 2005. Structures were operated as $I_H$-$O_H$ for the post-unnamed storm period (June 27, 2005). Intrusion on June 27, 2005 (post-unnamed storm event) was greatest near the discharge structures and lowest in the west and east (Figure 2-18). The 300 μS $cm^{-1}$ isopleth intruded 0.4 km (0.25 miles) in the west and 0.9 to 1.2 km (0.56 to 0.75 miles) in the northwest and northeast. The 300 μS $cm^{-1}$ level was not evident in the east. Intrusion of the 500 μS $cm^{-1}$ isopleth ranged 0.3 to 0.6 km (0.18 to 0.37 miles) across the Refuge in the characterized zone, except in the east where it was not present.

Intrusion across the characterized zone of the Refuge, following the 500 μS $cm^{-1}$ isopleths, was lower than average intrusion for the 500 μS $cm^{-1}$ conductivity level (Table 2-4) along the S-6, STA-1W, STA-1E, and ACME-2 transects.

The marsh stage, 4.96 m (16.30 ft) msl, was higher than the canal stage, 4.66 m (15.34 ft) msl. Inflow was 18,294 L $s^{-1}$ (647 cfs) and outflow at 45,013 L $s^{-1}$ (1,572 cfs) over the five days. Rainfall was 3.1 mm (0.12 inches) per day for the five days.

The structure operation, $I_H$-$O_H$, coupled with the moderate rainfall in this scenario, was conducive for minimal to moderate intrusion, particularly with respect to the 500 μS $cm^{-1}$ isopleth. Comparison of the 500 μS $cm^{-1}$ isopleth in this scenario to previous scenarios shows that the conditions in this scenario were conducive for the lowest extent of canal water intrusion relative to the 500 μS $cm^{-1}$ isopleth. However, these conditions still caused intrusion even though the canal stage was below 4.71 m (15.5 ft) msl.

Caveats

The range of conditions during the sampling period was limited, which limited our analysis approach when trying to understand conditions driving water quality in the Refuge. Neither unusually high nor low stages occurred and rainfall was the dominant source of water. Pumped inflow was lower than normal, most likely because there were no large discharge events from STA-1E and because discharge from STA-1W was moderate with part of the STA offline or impaired.

Because the interior marsh stage was determined using data from only one stage gage in the middle of the marsh, actual stage values may differ in different regions of the Refuge. This possibility is likely, given the differences in bottom elevation from north to south and the possibility of water mounding near surface water inputs. This type of difference may help explain why intrusion is occurring even when marsh stages are higher than canal stages.

Some judgment is necessary in the interpretation of conductivity values or other conservative constituent concentrations, because they depend on a complex set of environmental, hydrological, and topographic factors. Although we hypothesize that the major factor influencing conductivity is mass transport, evaporation and precipitation also can alter these values. For example, rainfall of 5.1 cm (2 inches) onto a 9.9 cm (3.9-inch) water column would be expected to dilute conductivity to roughly two-thirds of the original value. Thus, a large rain event, especially when marsh water depths are relatively shallow, can result in an overestimation of water movement from the marsh interior towards the canals.

Evaporation concentrates dissolved constituents and may cause an overestimation of canal water intrusion. To examine the impact of rainfall and evapotranspiration (ET) on intrusion, we looked at two examples of intrusion presented in this report. We examined ET with respect to high rainfall and low water depth (August 25, 2005; STA-1W transect) and low rainfall and high water depth (November 16, 2005; S-6 transect).

To determine the impacts of rainfall and ET on intrusion, several steps were used. First, we added the net rainfall (difference between total rainfall and ET) to the total water depth for each period. The potential conductivity values associated with the change in volume resulting from the addition of net rainfall using a simple mass balance approach was then calculated. Next, the percent difference between the actual conductivity level (350 $\mu S\ cm^{-1}$) and the estimated conductivity level was used to determine the upper and lower limits of the conductivity range associated with the contribution of net rainfall. We determined the distance into the marsh of the upper and lower limits of each conductivity range by interpolation, as presented in the methods section. These minimum and maximum distances of intrusion represent the variability of intrusion distance that could be caused by rainfall and ET for the high and low water depths examples examined here.

Intrusion of the 350 $\mu S\ cm^{-1}$ isopleth on August 25, 2005 extended to 3.5 km (2.17 miles) into the marsh, water depth was 10.6 cm (0.35 ft), and total net rainfall for the period August 22 – 26, 2005 was 21 mm (0.8 inches) with 15.2 mm (0.6 inches) ET and 36.5 mm (1.4 inches) actual rainfall. The addition of net rainfall to the water column increased the water depth to 12.7 cm (5.0 inches) and the range of conductivity associated with this change was 292 to 420 $\mu S\ cm^{-1}$. Intrusion for these conductivity values ranged between 3.8 and 3.1 (2.36 and 1.93 miles), respectively.

Intrusion of the 350 $\mu S\ cm^{-1}$ isopleth on November 11, 2005 extended to 3.7 km (2.30 miles) into the marsh, water depth was 0.72 m (2.38 ft), and total net rainfall for the period November 1 – 16, 2005 was 27.3 mm (1.1 inches) with 45.6 mm (1.8 inches) ET and 18.2 mm (6.7 inches) actual rainfall. The amount decreased the water depth to 0.7 m (2.29 ft) and the range of conductivity associated with this change was 337 to 364 $\mu S\ cm^{-1}$. Intrusion for these conductivity values ranged between 3.9 and 3.6 km (2.42 and 2.23 miles), respectively.

Using these examples, we demonstrated that effects of rainfall and ET are greater when water depths are low. The extent of how much the effect of rainfall and ET may influence the distance of intrusion ranges between 2 and 12%. In the examples of intrusion described throughout this report, issues with rainfall and ET were minimized by selecting periods with little or no rain, and selecting periods sufficiently short to minimize the influence of evapotranspiration. The reader should be aware, however, that some scenarios examined here had high rainfall by design.

## Summary

We have characterized canal water intrusion into the Refuge marsh at different locations and under different scenarios using a number of approaches. Water movement between the canal and marsh were influenced by a combination of canal and marsh stage differences, inflow and outflow rates, and rainfall conditions. Conductivity along transects, generating and using the 300, 350, and 500 $\mu S\ cm^{-1}$ isopleths provided valuable reference points for characterizing when and where canal water intruded into the interior. In all scenarios examined, the 300 and 350 $\mu S\ cm^{-1}$ isopleths extend further into the marsh interior than the 500 $\mu S\ cm^{-1}$ isopleth. These conductivity levels were selected because they have been documented to impact the biotic communities of the Refuge (Sklar et al., 2005, McCormick and Crawford, 2006).

Combined, these different approaches suggest frequent and sometimes persistent intrusion of canal water between 0.5 and 2.5 km (0.31 to 1.56 miles) into the Refuge interior. Areas most susceptible to intrusion are on the west side of the Refuge where canal water intrusion was shown to extend 5 km (3.10 miles) under certain conditions. The areas most sensitive to canal water movement (in or out of the Refuge) were those with marsh sediment elevations lower than 4.43 m (14.6 ft) msl, particularly when these areas were lower in elevation than adjacent areas.

When the canal stage is higher than the marsh stage, intrusion occurred under all conditions of inflow and outflow. Intrusion of the 350 $\mu S\ cm^{-1}$ conductivity level extended more than 0.4 km (0.25 miles) into the marsh whenever the canal stage was higher than the marsh stage.

Even if canal stages are below or near 4.71 (15.5 ft) msl and the marsh stage is held above 4.71 m (15.5 ft) msl, canal water still can intrude into the marsh. Under this canal-marsh stage relationship, the 300 $\mu S\ cm^{-1}$ conductivity level intruded 1 to 3 km (0.62 to 1.86 miles) into the marsh. It has been assumed previously that when canal water levels are below 4.71 m (15.5 ft) msl, little exchange of water between the canals and marsh occurs (Sylvester, 2004). Variability in canal – marsh stage difference relative to the canal stage increases above 4.56 m (15 ft) msl (Figure 2-2). This higher variability may correspond to intrusion events that occur just below a canal stage of 4.71 m (15.5 ft) msl. Even though the relation between canal-marsh stage difference and canal stage shows canal water did not enter into the Refuge until the canal stage increased to greater than 4.86 m (16 ft) msl (Figure 2-2), simply considering the stage difference alone was not sufficient to determine when canal water would intrude into the marsh, particularly in the case when canal stages were slightly below 4.71 m (15.5 ft) msl. Our findings do not support the assumption that canal water does not intrude into the marsh when the canal stage is lower than 4.71 m (15.5 ft) msl. Under conditions when the canal stage is slightly below or near 4.71 m (15.5 ft) msl, we found intrusion to a greater extent than the overall extent of average intrusion from November 2004 to January 2006.

Regardless of how much higher the marsh stage is relative to the canal stage, canal water intrusion still can occur. Intrusion was least in the area of the Refuge monitored when the marsh stage was more than 0.30 m (1 ft) higher than the canal stage. Although the canal stage was much lower than the marsh stage, the range of intrusion for the 300 and 350 $\mu S\ cm^{-1}$ levels of conductivity still extended 0.2 to 0.9 km (0.12 to 0.56 miles) into the marsh. Further, when the marsh stage was higher than the canal stage for extended periods of time (>10 days), low duration pulses (<5 days) of high inflows did not increase canal water intrusion. Instead, canal water conductivity decreased. The decrease in canal water conductivity appeared to be a result of lower conductivity marsh water pushing towards the canal and mixing with the higher conductivity canal water.

When the marsh stage is less than 6 cm (2.4 inches) higher than the canal stage, canal water intrusion still can occur if even low inflow rates occur. Intrusion of the 300 µS cm$^{-1}$ isopleth under this canal-marsh stage relationship extended between 0.6 and 1 km (0.37 to 0.62 miles) into the marsh, except in the eastern area of the marsh where the 300 μS cm$^{-1}$ conductivity level was not observed.

When inflows are introduced to the Refuge on the west side at a higher rate than on the east side, intrusion can be higher in the west than in eastern areas of the marsh. Inflows were higher on the west side of the Refuge, similar to the extent of canal water intrusion.

When water is removed from the Refuge through the S-10 structures, intrusion can be reduced on the west side of the Refuge while intrusion on the east side of the Refuge may be less affected. When outflows from the Refuge were above 33,929 L s$^{-1}$ (1,200 cfs) and inflows were lower than 18,378 L s$^{-1}$ (650 cfs), the magnitude of intrusion across the Refuge decreased. The reduction mostly occurred in the western areas of the Refuge, while the eastern areas of the Refuge were affected less. The magnitude of intrusion decreased in the eastern areas below the magnitude of intrusion in the western areas of the marsh following 20 days of this type of structure operation.

When both rainfall and inflows were high, intrusion across the Refuge was substantially different. We documented that high inflow, even though high rainfall conditions were present, allowed extensive intrusion in the western areas of the marsh. Alternatively, in the east area of the Refuge, intrusion seemed to be moderated by these high rainfall conditions.

Intrusion can be extensive or minimal, depending on the configuration of structure operations (inflow and outflow conditions). We documented that when the structures were operated as high inflow and low outflow after a large rain event, intrusion extended 5 km (3.10 miles) in some areas of the Refuge. Alternatively, when the structures were operated as high inflow and higher outflow following a large rainfall event, intrusion was below average across the Refuge.

This study addressed the following two management questions: (1) Under what operational or environmental conditions does canal water flow (intrude) into the marsh and how far does it intrude? (2) How does relative flow through different structures affect water flow and water quality within the interior marsh? Further work on measuring canal water intrusion will be valuable for identifying how to minimize/eliminate potential negative impacts of pump, structure, or STA operations on the Refuge interior. Additional efforts examining monthly water quality grab samples with continuous measurements of conductivity along transects will provide more information about the influence of canal water intrusion on water quality in the Refuge marsh. In particular, collection of additional data across a wider range of climatic and hydrologic conditions will be valuable. Future efforts to examine explicit mechanisms should incorporate information from the hydrodynamic and water quality modeling tools presently being developed.

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**Table 2-1**. Site distances from the canal into the marsh and around the canal with LOXA116 as the starting point (highlighted in table). Sites are grouped by transects and regions of location in the A.R.M. Loxahatchee National Wildlife Refuge (Figure 2-1).

| REGION | SITE ID | DISTANCE FROM CANAL (km) | DISTANCE AROUND CANAL (km) |
|---|---|---|---|
| STA-1W TRANSECT | LOXA104 | canal | 12.8 |
| | LOXA105 | 0.7 | 12.9 |
| | LOXA106 | 1.1 | 13.4 |
| | LOXA107 | 2.2 | 14.4 |
| | LOXA108 | 3.9 | 11.1 |
| STA-1W AREA | LOXA102 | 1.3 | 14.0 |
| | LOXA103 | 1.0 | 15.7 |
| | LOXA109 | 1.3 | 8.0 |
| | LOXA110 | 2.7 | 8.3 |
| | LOX3 | 4.6 | 36.3 |
| S-6 TRANSECT | LOXA115 | canal | 0.1 |
| | LOXA116 | 0.4 | 0.0 |
| | LOXA117 | 0.9 | 0.5 |
| | LOXA118 | 1.8 | 1.3 |
| | LOXA119 | 4.3 | 3.2 |
| | LOXA120 | 6.1 | 5.2 |
| S-6 AREA | LOXA121 | 0.1 | 91.6 |
| | LOXA122 | 0.9 | 90.6 |
| SOUTH AREA | LOXA123 | 0.9 | 85.6 |
| | LOXA124 | 1.3 | 56.8 |
| | LOX11 | 6.6 | 61.5 |
| | LOX12 | 2.7 | 85.8 |
| | LOX13 | 6.6 | 63.6 |
| | LOX14 | 1.2 | 62.6 |
| | LOX15 | 1.2 | 78.0 |
| | LOX16 | 2.0 | 74.4 |
| OTHER | LOX5 | 8.1 | 11.6 |

| REGION | SITE ID | DISTANCE FROM CANAL (km) | DISTANCE AROUND CANAL (km) |
|---|---|---|---|
| S-5A AREA | LOXA101 | 0.8 | 27.1 |
| | LOXA140 | 0.9 | 30.8 |
| STA-1E TRANSECT | LOXA135 | canal | 33.8 |
| | LOXA136 | 0.6 | 34.0 |
| | LOXA137 | 1.1 | 34.1 |
| | LOXA138 | 2.1 | 34.8 |
| | LOXA139 | 3.9 | 36.2 |
| STA-1E AREA | LOXA134 | 0.8 | 35.4 |
| | LOXA140 | 0.9 | 30.8 |
| | LOX3 | 4.6 | 36.3 |
| ACME 1 TRANSECT | LOXA132 | canal | 36.7 |
| | LOXA133 | 0.6 | 36.7 |
| | LOX4 | 1.2 | 36.7 |
| ACME 2 TRANSECT | LOXA129 | canal | 40.5 |
| | LOXA130 | 0.5 | 40.6 |
| | LOXA131 | 1.5 | 41.2 |
| CENTRAL TRANSECT | LOXA112 | 1.6 | 5.0 |
| | LOX10 | 1.2 | 5.5 |
| | LOXA111 | 3.1 | 5.4 |
| | LOXA113 | 3.8 | 5.6 |
| | LOXA114 | 4.4 | 6.0 |
| | LOXA128 | 5.1 | 6.4 |
| | LOX7 | 5.5 | 47.4 |
| | LOX8 | 9.7 | 48.4 |
| | LOX9 | 5.5 | 7.4 |
| | LOXA127 | 3.1 | 50.0 |
| | LOX6 | 1.1 | 50.8 |
| | LOXA126 | 0.4 | 50.5 |

**Table 2-2**. Months in which conductivity sondes were deployed over the period of study.

| | 2004 | | | | | | | | | | 2005 | | | | | | | | | | | | 2006 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site ID | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D | J |
| LOXA104 | | | | X | X | X | X | X | X | | X | X | X | X | X | X | X | X | X | X | | | X |
| LOXA105 | | | | | | | | | | X | X | X | X | X | X | X | X | | | | | | X |
| LOXA106 | | | | | | | | | | X | X | X | X | X | X | X | X | X | X | X | X | | X |
| LOXA107 | | | | | | | | | | X | X | X | X | X | X | X | X | X | X | X | X | | X |
| LOXA108 | X | | | | | | | | | X | X | X | X | X | X | X | X | X | X | X | X | | X |
| LOXA111 | | | | | | | | | | | | | | | X | | X | X | X | X | X | | X |
| LOXA112 | | | | | | | | | | | X | X | X | X | X | | X | X | X | X | X | | X |
| LOXA113 | | | | | | | | | | | X | X | X | X | X | | X | X | X | X | X | | X |
| LOXA115 | X | X | X | X | | | | X | X | X | X | X | X | X | X | X | X | X | X | | | | X |
| LOXA116 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | |
| LOXA117 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | |
| LOXA118 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | |
| LOXA119 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | |
| LOXA120 | | | | | | | | | | | | X | X | X | X | X | X | X | X | X | X | | |
| LOXA126 | | | | | | | | | | X | X | X | X | X | X | X | X | X | X | X | X | | X |
| LOXA127 | | | | | | | | | | X | X | X | X | X | X | | X | X | X | X | X | | X |
| LOXA129 | | | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | X |
| LOXA130 | | | | | | | | | | | X | X | X | X | X | X | X | X | X | X | X | | X |
| LOXA131 | | | | | | | | | | | X | X | X | X | X | X | X | X | X | X | X | | X |
| LOXA132 | | | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | X |
| LOXA133 | | | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | X |
| LOXA135 | X | X | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | X |
| LOXA136 | X | X | | X | X | X | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | X |
| LOXA137 | X | X | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | X |
| LOXA138 | X | X | | X | X | X | X | X | X | | X | X | X | X | X | | | X | X | X | X | | X |
| LOXA139 | X | X | | X | X | | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | X |
| LOX4 | | | | X | X | | | | | X | X | X | X | X | X | X | X | X | X | X | X | | X |
| LOX6 | | | | | | | | | | X | X | X | X | X | X | X | | X | X | X | | | X |
| LOX7 | | | | | | | | | | X | X | X | X | X | X | | X | X | X | X | | | X |
| LOX8 | | | | | | | | | | | X | X | X | X | X | | | | | X | X | | X |
| LOX9 | | | | | | | | | | | X | X | X | X | X | X | | X | | X | | | X |
| LOX10 | | | | | | | | | | X | X | X | X | X | X | | X | X | | X | | | X |

**Table 2-3.** Summary statistics and distance from the canal for time-series conductivity data along four transects (STA-1W, STA-1E, ACME-2, and S-6).

| Transect | Site | Distance from Canal (km) | Conductivity ($\mu S\ cm^{-1}$) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Average | Standard Deviation | Minimum | Maximum | Median | 25th Percentile | 75th Percentile |
| *STA-1W* | LOXA104 | 0.0 | 970 | 230 | 270 | 1500 | 985 | 768 | 1135 |
| | LOXA105 | 0.7 | 530 | 160 | 60 | 990 | 498 | 454 | 557 |
| | LOXA106 | 1.1 | 320 | 90 | 100 | 660 | 325 | 255 | 375 |
| | LOXA107 | 2.2 | 260 | 30 | 105 | 340 | 285 | 241 | 306 |
| | LOXA108 | 3.9 | 190 | 30 | 140 | 360 | 188 | 173 | 208 |
| *STA-1E* | LOXA135 | 0.0 | 790 | 190 | 37 | 1440 | 777 | 637 | 911 |
| | LOXA136 | 0.6 | 390 | 110 | 160 | 860 | 402 | 357 | 438 |
| | LOXA137 | 1.1 | 260 | 90 | 100 | 660 | 274 | 169 | 324 |
| | LOXA138 | 2.1 | 190 | 50 | 120 | 330 | 183 | 157 | 215 |
| | LOXA139 | 3.9 | 130 | 60 | 60 | 390 | 109 | 96 | 146 |
| *ACME-2* | LOXA129 | 0.0 | 680 | 170 | 290 | 1400 | 673 | 555 | 785 |
| | LOXA130 | 0.5 | 440 | 160 | 160 | 720 | 503 | 247 | 567 |
| | LOXA131 | 1.5 | 280 | 110 | 100 | 570 | 272 | 181 | 375 |
| *S-6* | LOXA115 | 0.0 | 930 | 250 | 330 | 1510 | 950 | 719 | 1117 |
| | LOXA116 | 0.4 | 640 | 270 | 180 | 1230 | 607 | 505 | 826 |
| | LOXA117 | 0.9 | 430 | 160 | 140 | 890 | 406 | 385 | 457 |
| | LOXA118 | 1.8 | 230 | 90 | 90 | 530 | 249 | 145 | 284 |
| | LOXA119 | 4.3 | 170 | 30 | 100 | 280 | 178 | 149 | 190 |
| | LOXA120 | 6.1 | 130 | 40 | 70 | 220 | 120 | 102 | 157 |

**Table 2-4**. Summary of intrusion events using (A) the 500 μS $cm^{-1}$ and (B) 350 μS $cm^{-1}$ isopleths for four transects (STA-1W, STA-1E, ACME-2, and S-6).

A

| Transect | Average 500 μS $cm^{-1}$ Instrusion (km) | Maximum 500 μS $cm^{-1}$ Intrusion (km) | Date | Canal-Marsh Stage Difference | Canal-Marsh Stage Difference (ft) | Net Inflow (cfs) | Hypothesized Cause For Intrusion Event |
|---|---|---|---|---|---|---|---|
| STA-1W | 0.8±0.36 | 2.7 | 8/26/2005 | Marsh > Canal | 0.64 | 529 | Extended high inflow |
| STA-1E | 0.49±0.1 | 0.73 | 11/9/2005 | Canal > Marsh | 0.18 | 870 | High inflow and canal stage > marsh stage |
| ACME-2 | 0.65±0.32 | 1.4 | 5/17/2005 | Marsh > Canal | 0.29 | 1500 | Extended high inflow |
| S-6 | 0.85±0.55 | 2.49 | 11/30/2005 | Canal > Marsh | 0.2 | 115 | Moderate inflow and canal > marsh stage |

B

| Transect | Average 350 μS $cm^{-1}$ Instrusion (km) | Maximum 350 μS $cm^{-1}$ Intrusion (km) | Date | Canal-Marsh Stage Difference | Canal-Marsh Stage Difference (ft) | Net Inflow (cfs) | Hypothesized Cause For Intrusion Event |
|---|---|---|---|---|---|---|---|
| STA-1W | 1.16±0.5 | 3.5 | 8/25/2005 | Marsh > Canal | 0.64 | 529 | Extended high inflow |
| STA-1E | 0.89±0.16 | 1.3 | 11/4/2005 | Canal > Marsh | 0.18 | 870 | High inflow and canal stage > marsh stage |
| ACME-2 | 0.86±0.4 | 1.53 | 4/13/2005 | Canal > Marsh | 0.14 | 2100 | Extended high inflow |
| S-6 | 1.5±0.95 | 3.92 | 11/30/2005 | Canal > Marsh | 0.2 | 115 | Moderate inflow and canal > marsh stage |

**Table 2-5**. Intrusion distance for each of the four scenarios. The zone columns identify areas of the Refuge where the water movement was greatest or least for each scenario.

| Scenario | Average Intrusion (km) | Maximum Intrusion (km) | Zone | Minimum Intrusion (km) | Zone |
|---|---|---|---|---|---|
| 1 | 1.7 | 3.1 | Interior | 0.9 | Perimeter |
| 2 | 0.5 | 0.8 | Perimeter | 0 | Interior |
| 3 | 0.5 | 1.2 | Interior | 0.1 | Perimeter |
| 4 | 1.1 | 1.4 | Perimeter | 0.5 | Interior |

**Table 2-6**. Canal/marsh stage relationships, net water movement in the canals, and rainfall conditions for the four scenarios.

| Scenario | Stage Relationship | Canal-Marsh (ft) | Flow (cfs) | Rainfall (in) |
|---|---|---|---|---|
| 1 | Canal > Marsh | 0.16 | Inflow (672) | 0.02 |
| 2 | Canal > Marsh | 0.14 | Outflow (166) | 0 |
| 3 | Marsh > Canal | 0.12 | Outflow (94) | 0 |
| 4 | Marsh > Canal | 1.15 | Outflow (489) | 0.2 |

**Table 2-7**. Conditions associated with the storm event-driven distance of intrusion analysis approach. Flows were reported as the average cubic feet per second (cfs) for the analysis date and four days prior. Rainfall was reported as average inches per day for the analysis data and four days prior.

| | Structure Operation | Canal Stage (ft msl) | Marsh Stage (ft msl) | STA-1W Inflow (cfs) | STA-1E Inflow (cfs) | ACMEs Inflow (cfs) | G-94C Outflow (cfs) | S-10s Outfolw (cfs) | S-39 Outflow (cfs) | Rain (inches d-1) |
|---|---|---|---|---|---|---|---|---|---|---|
| pre-Rita | $I_L$-$O_L$ | 16.19 | 16.31 | 11 | 13 | 19 | 0 | 0 | 0 | <0.01 |
| pre-Tammy | $I_L$-$O_L$ | 16.23 | 16.28 | 4 | 28 | 0 | 6 | 0 | 0 | 0.14 |
| pre-Wilma | $I_M$-$O_L$ | 16.59 | 16.45 | 371 | 25 | 0 | 0 | 0 | 0 | <0.01 |
| Wilma | $I_H$-$O_L$ | 16.89 | 16.66 | 435 | 87 | 60 | 18 | 0 | 0 | 0.69 |
| post-Wilma | $I_M$-$O_L$ | 16.84 | 16.72 | 104 | 142 | 18 | 92 | 0 | 0 | 0.09 |
| pre-Arlene | $I_L$-$O_L$ | 15.49 | 15.79 | 40 | 0 | 35 | 0 | 0 | 0 | 0.23 |
| post-Arlene | $I_H$-$O_H$ | 15.59 | 16.23 | 342 | 43 | 64 | 0 | 1872 | 364 | 0.07 |
| post-unnamed rain event | $I_H$-$O_H$ | 15.25 | 16.3 | 438 | 125 | 104 | 0 | 1220 | 352 | 0.12 |

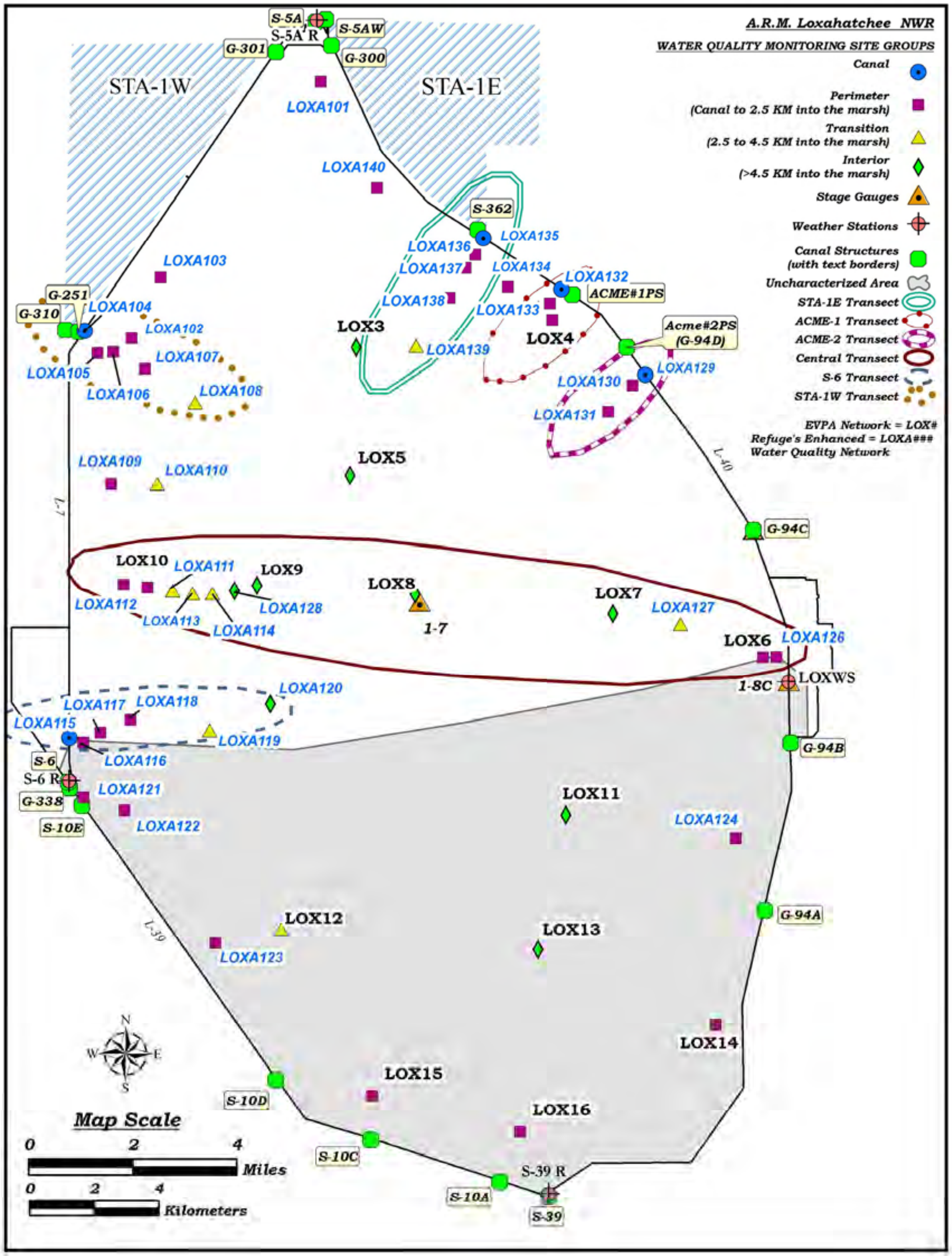


**Figure 2-1.** Map of the LOXA and EVPA water quality monitoring sites, inflow and outflow structures, and canal and marsh stage gages used in this report. The sites are classified into the canal and three marsh zones (see legend). The non-shaded area represents the area of the Refuge that was characterized for conductivity in this report.

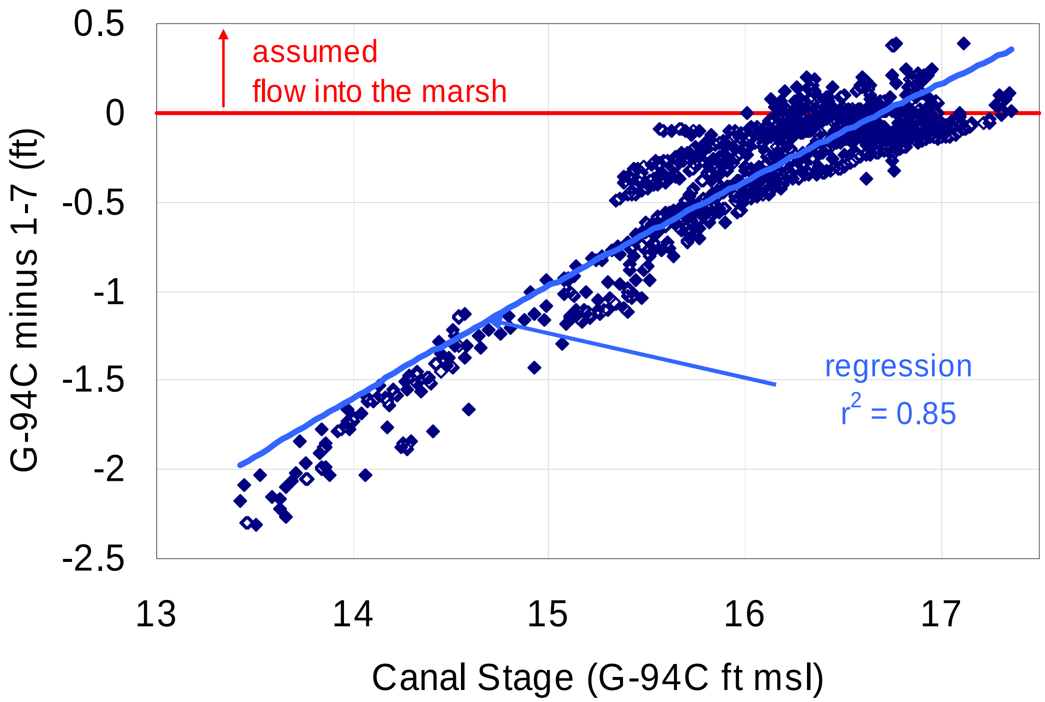


**Figure 2-2**. Canal (G-94C) and marsh (1-7) stage difference verses canal stage at the (G-94C). Positive values on the stage difference (y) axis represent canal stages greater than marsh stages and negative values represented marsh stages greater than canal stages. The difference between the canal and marsh stages historically was assumed to be the driving force for canal water intrusion into the marsh. Above the solid horizontal line, canal water was anticipated to intrude into the marsh. The diagonal line represents the logarithmic trend fit for the stage difference relative to the canal stage.

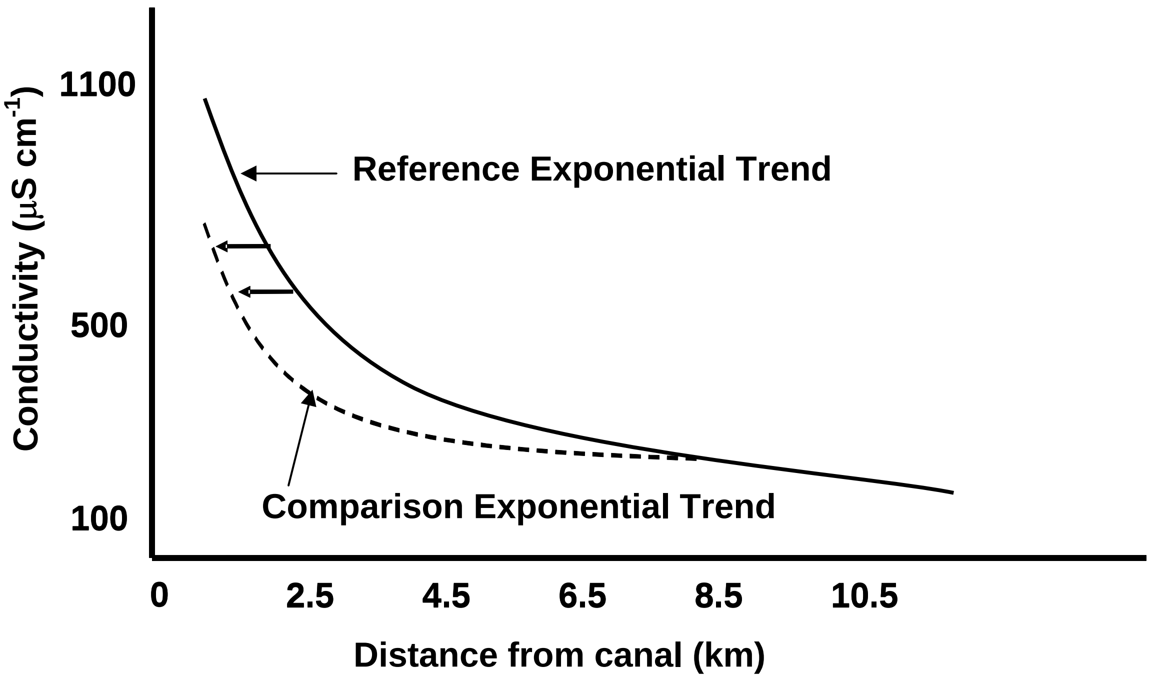


**Figure 2-3**. Example of the models applied to determine magnitude of water movement across the canal-interior gradient for deployed sondes across the Refuge's enhanced water quality monitoring network. Exponential trends were fit to the data for both the baseline date (solid line) and the comparison scenario dates (dashed line). The differences between these sets of models were determined and the average differences were calculated.

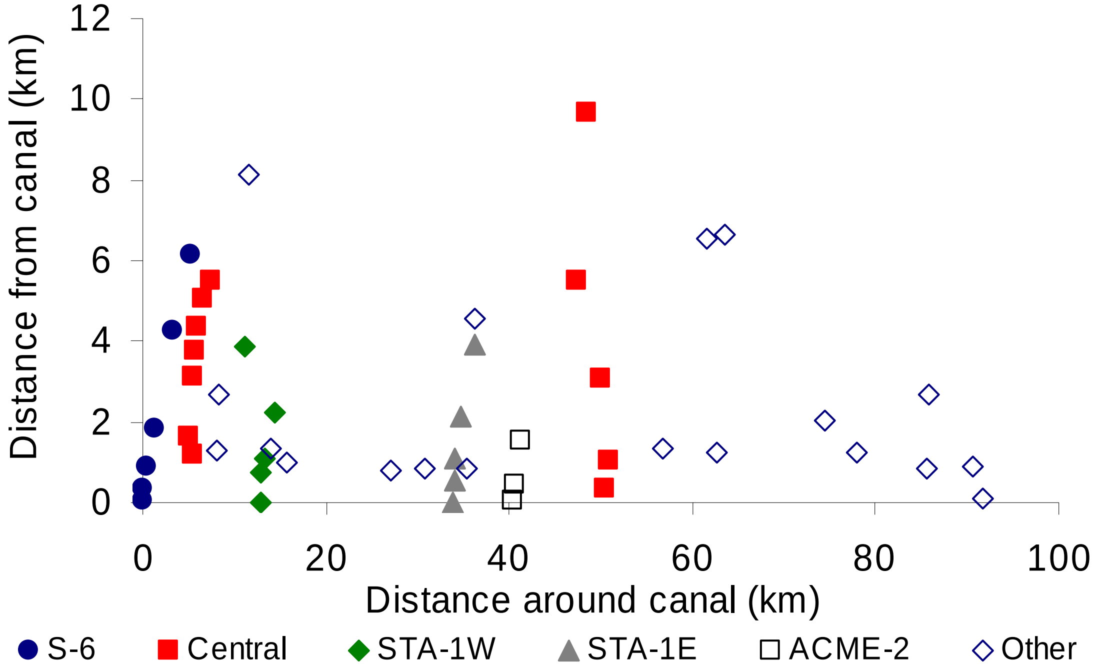


**Figure 2-4**. Monitoring site and sonde deployment locations plotted as the shortest distance in to the marsh from the canal, and clockwise distance around the perimeter canal (0 km at the LOXA116). Transects are identified in Table 2-3.

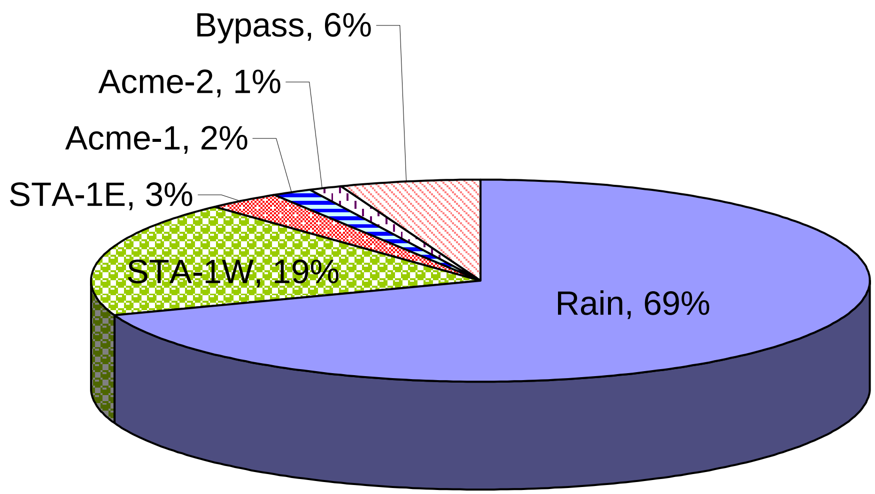


**Figure 2-5**. Estimated average percent of total inflow over the study period, November, 2004 to January, 2006. Total average inflow from all represented sources (structures and rainfall) was 61.2 inches per year. Rain is the average of rainfall at stations S-5A, LOXWS, S-39, and S-6.

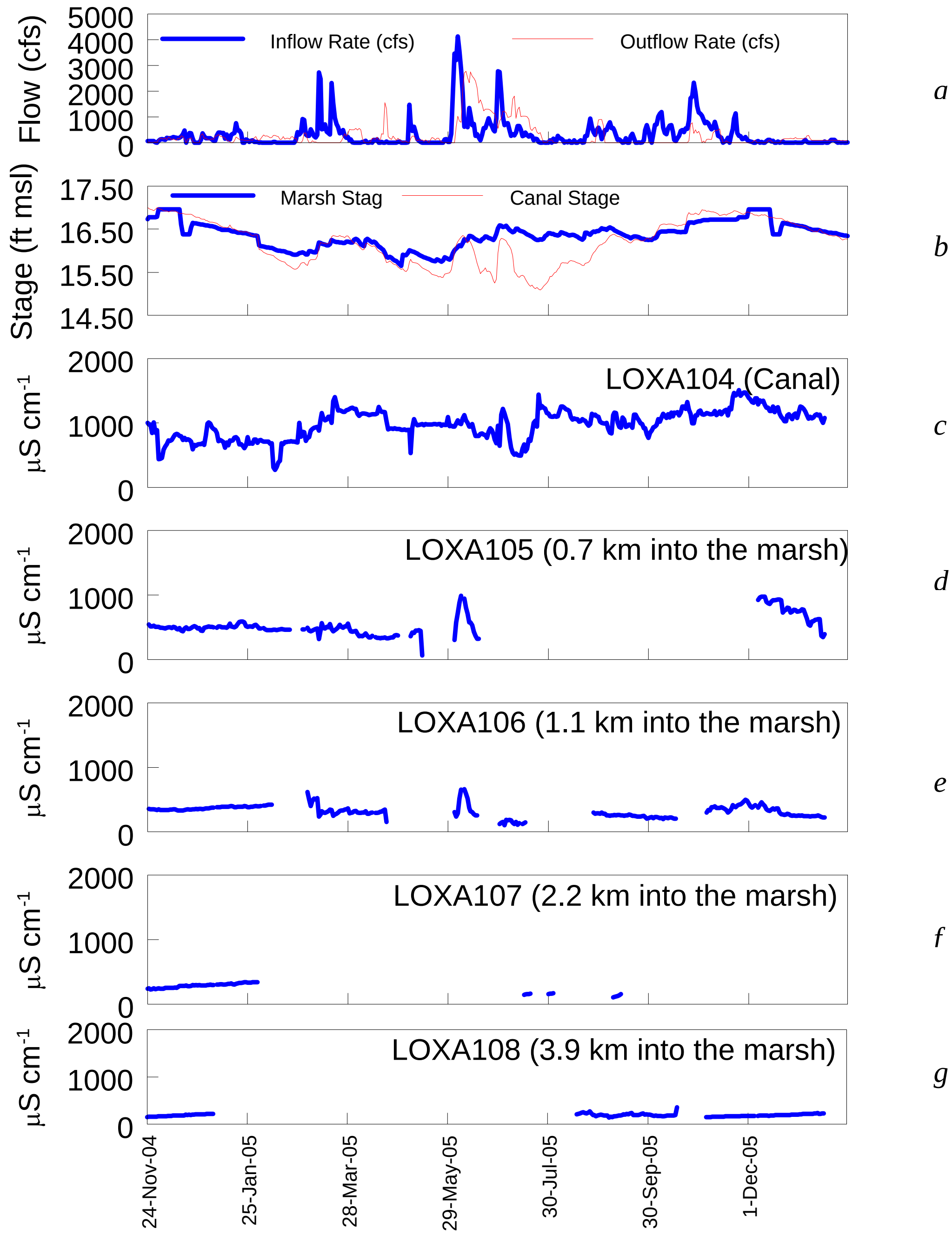


**Figure 2-6.** *a*) Inflow and outflow rates (cfs) summed for all structures across the POR (November 2004 to January 2006). *b*) Marsh (thick line) and canal (thin line) stage reading from the 1-7 and G-94C stage gages, respectively. Panels *c-g* are the time-series of daily (midnight) conductivity values from the STA-1W transect - *c*) LOXA104 canal site, *d*) LOXA105 0.7 km into the marsh, *e*) LOXA106 1.1 km into the marsh, *f*) LOXA107 2.2 km into the marsh, and *g*) LOXA108 3.9 km into the marsh.

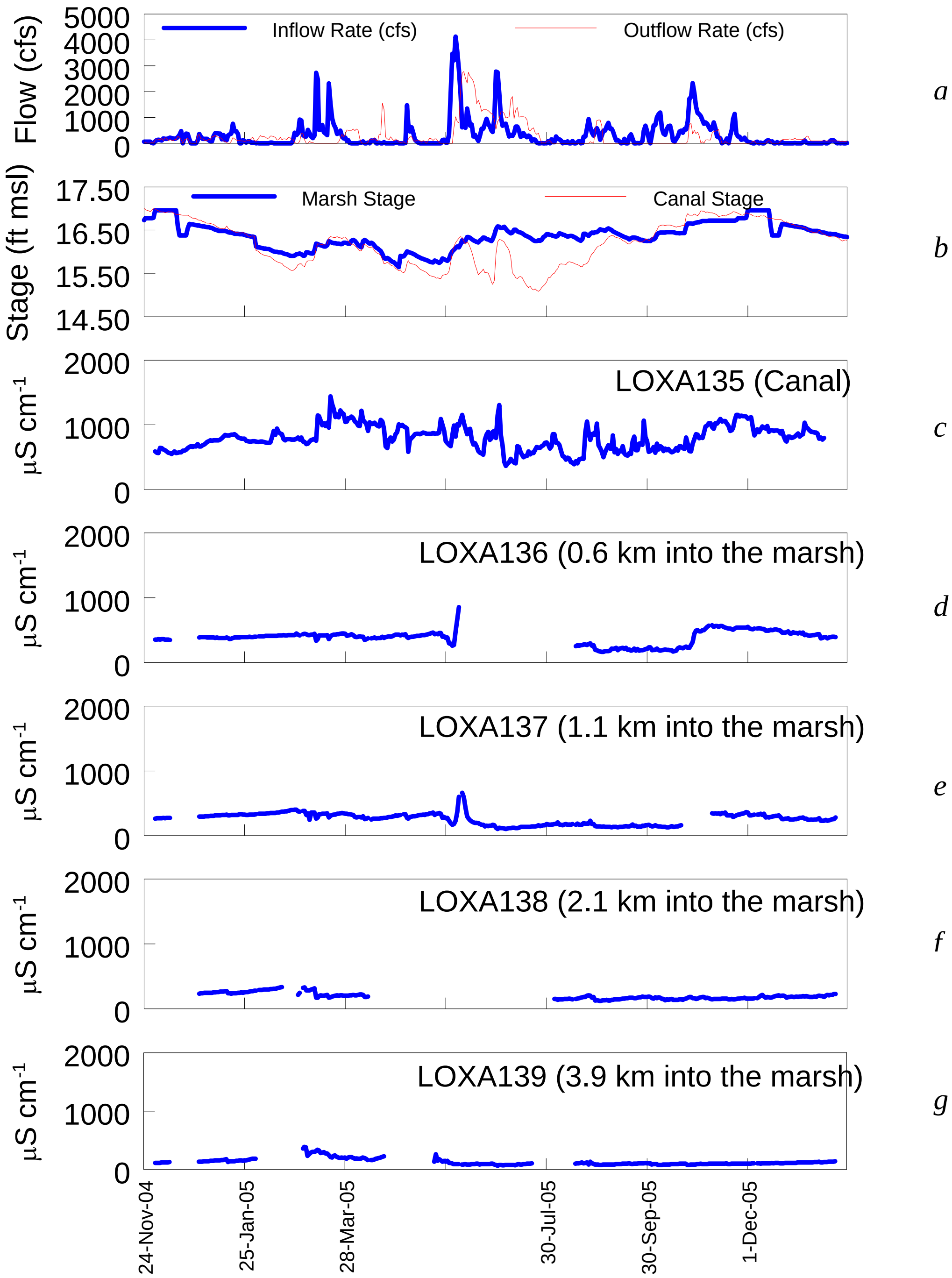


**Figure 2-7.** *a*) Inflow and outflow rates (cfs) summed for all structures across the POR (November 2004 to January 2006). *b*) Marsh (thick line) and canal (thin line) stage reading from the 1-7 and G-94C stage gages, respectively. Panels *c*-*g* are the time-series of daily (midnight) conductivity values from the STA-1E transect - *c*) LOXA135 canal site, *d*) LOXA136 0.6 km into the marsh, *e*) LOXA137 1.0 km into the marsh, *f*) LOXA138 2.1 km into the marsh, and *g*) LOXA139 3.9 km into the marsh.

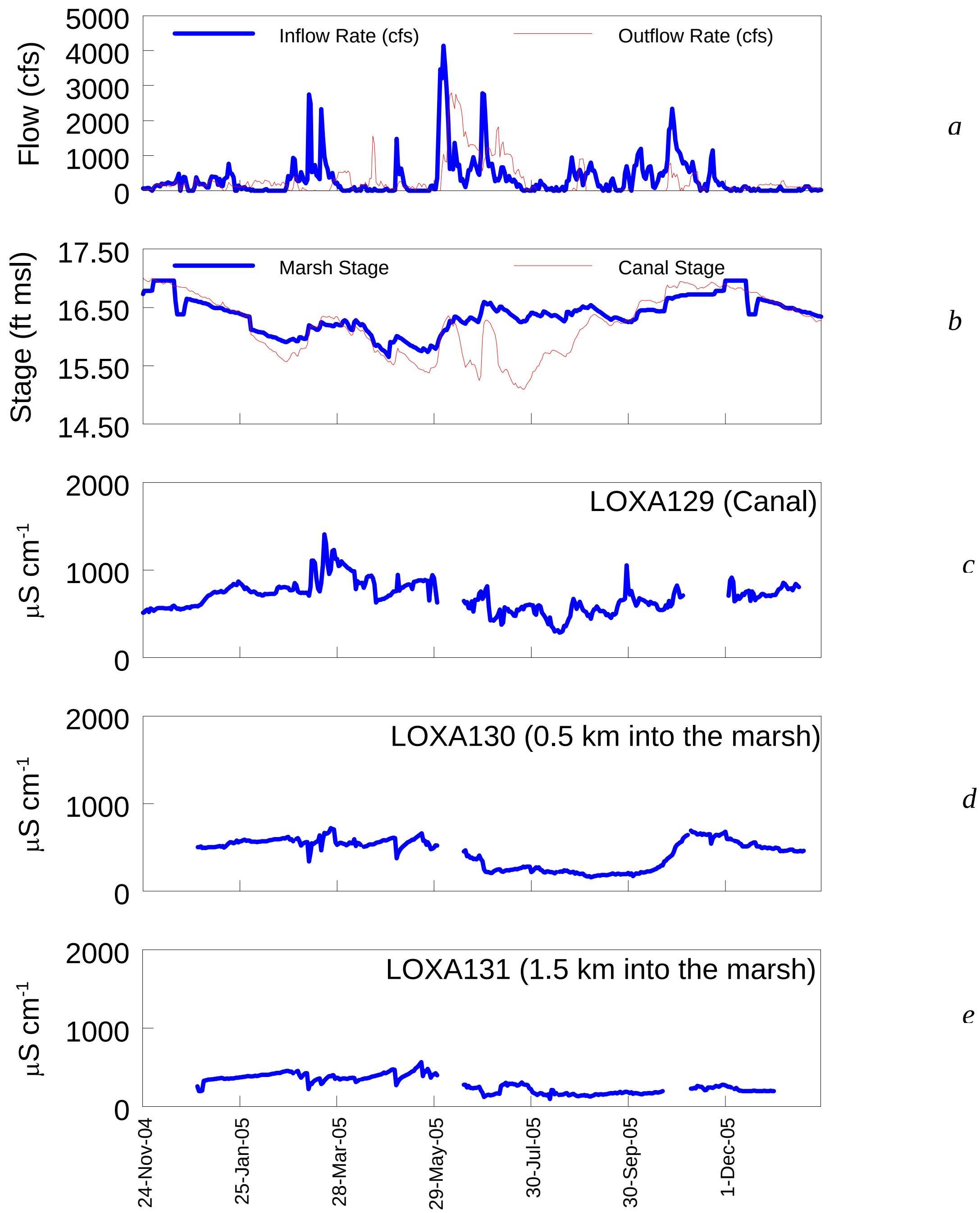


**Figure 2-8.** *a*) Inflow and outflow rates (cfs) summed for all structures across the POR (November 2004 to January 2006). *b*) Marsh (thick line) and canal (thin line) stage reading from the 1-7 and G-94C stage gages, respectively. Panels *c-e* are the time-series of daily (midnight) conductivity values from the ACME-2 transect - *c*) LOXA129 canal site, *d*) LOXA130 0.5 km into the marsh, and *e*) LOXA131 1.5 km into the marsh.

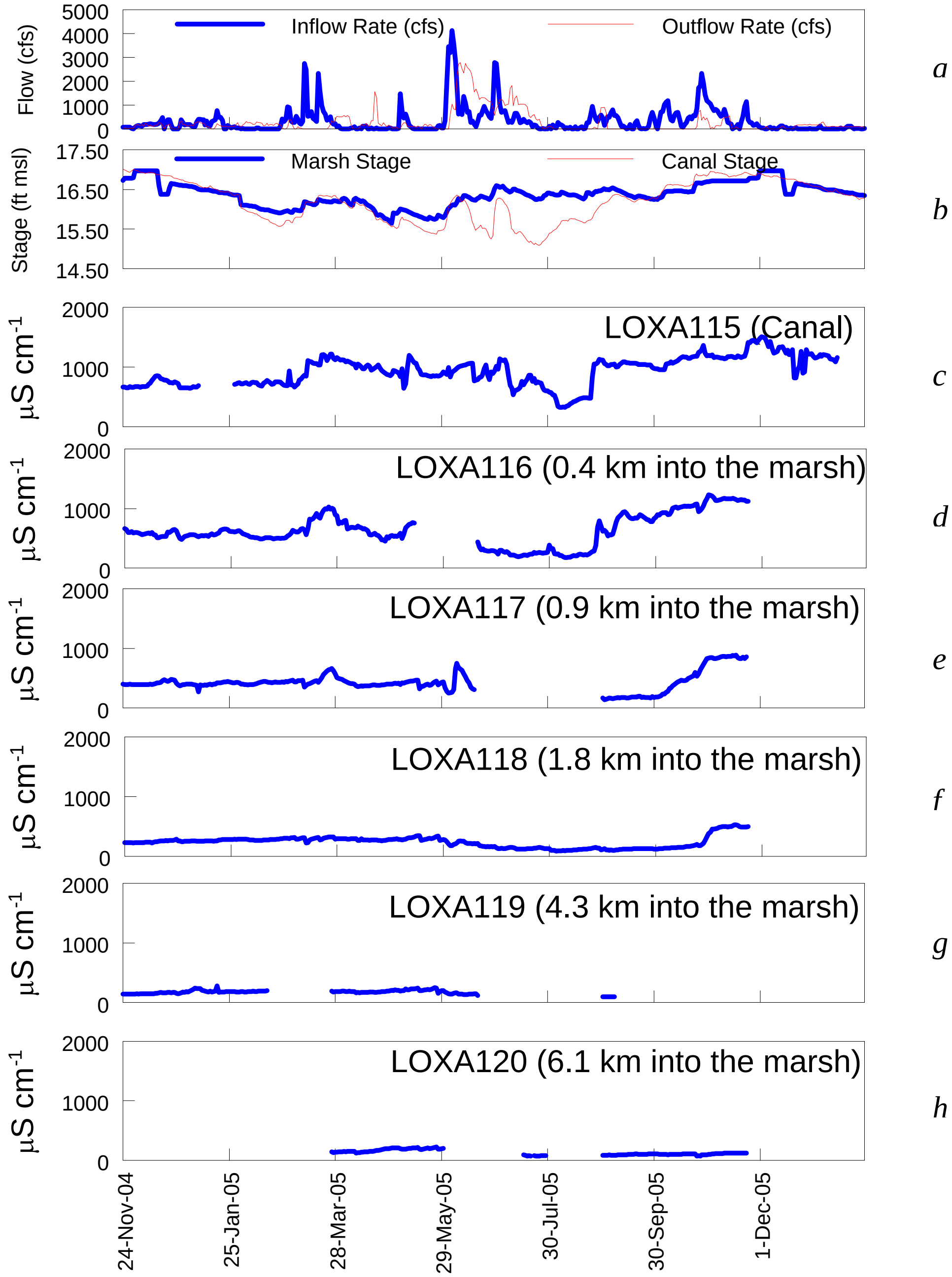


**Figure 2-9.** *a*) Inflow and outflow rates (cfs) summed for all structures across the POR (November 2004 to January 2006). *b*) Marsh (thick line) and canal (thin line) stage reading from the 1-7 and G-94C stage gages, respectively. Panels *c*-*h* are the time-series of daily (midnight) conductivity values from the S-6 transect - *c*) LOXA115 – canal site, *d*) LOXA116 – 0.4 km into the marsh, *e*) LOXA117 – 0.9 km into the marsh, *f*) LOXA118 – 1.8 km into the marsh, *g*) LOXA119 – 4.3 km into the marsh, and *h*) LOXA120 – 6.1 km into the marsh.

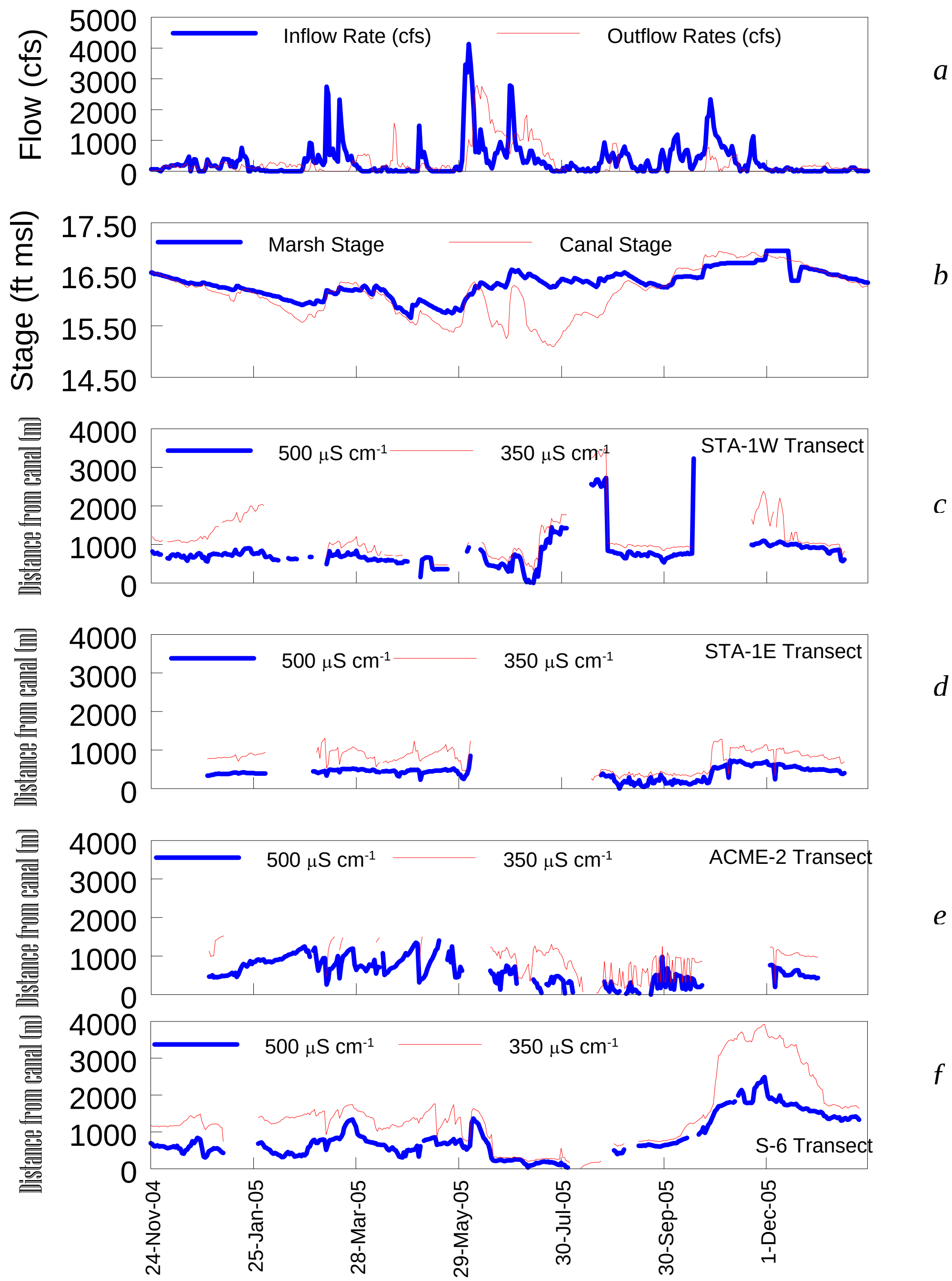


**Figure 2-10.** *a*) Inflow and outflow rates (cfs) summed for all structures across the POR (November 2004 to January 2006). *b*) Canal (G-94C) and marsh (1-7) stage levels (feet mean sea level). The 350 µS $cm^{-1}$ and 500 µS $cm^{-1}$ conductivity isopleths used to track canal water movement into and out of the marsh interior for: *c*) STA-1W, *d*) STA-1E, *e*) ACME-2, and *f*) S-6 transects.

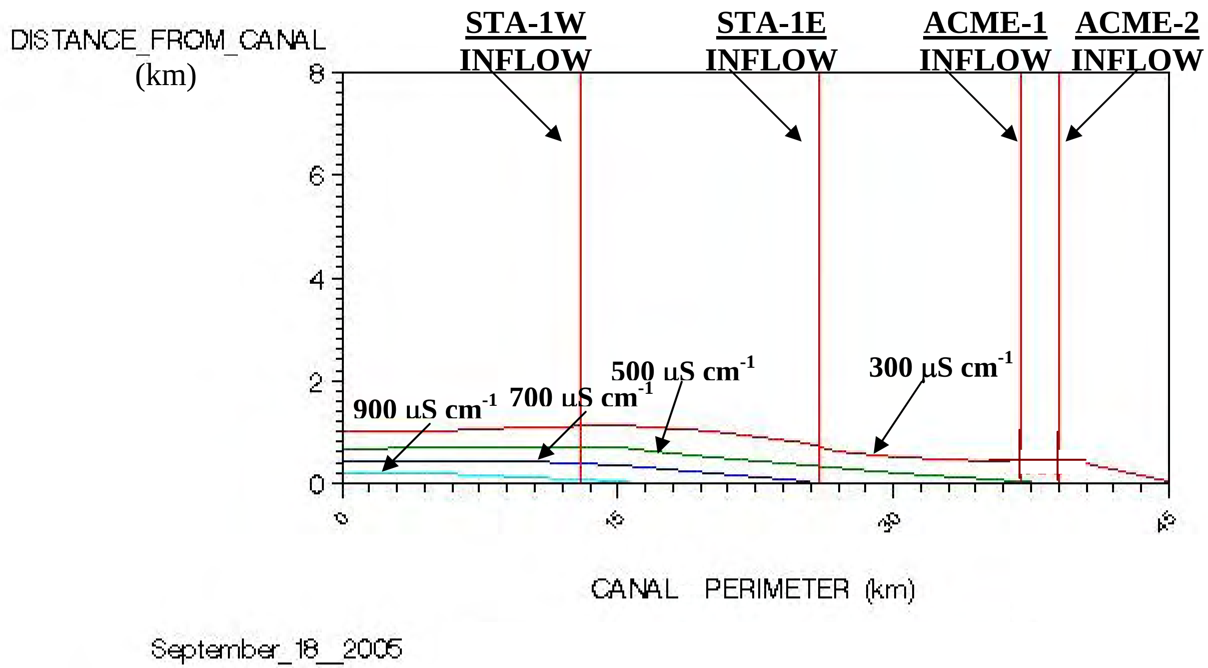


**Figure 2-11**. Pre-Hurricane Rita conductivity contours for the canal and interior of the Refuge. Data were plotted from the mid-west perimeter of the Refuge (0 km on the x-axis) to the mid-east perimeter of the Refuge (46 km on the x-axis) (Figure 2-1). The y-axis represents the distance into the marsh from the canal for each conductivity sonde site. The locations of each inflow and outflow structure (vertical lines) around the canal are shown as they are potential locations of canal water movement into and out of the marsh.

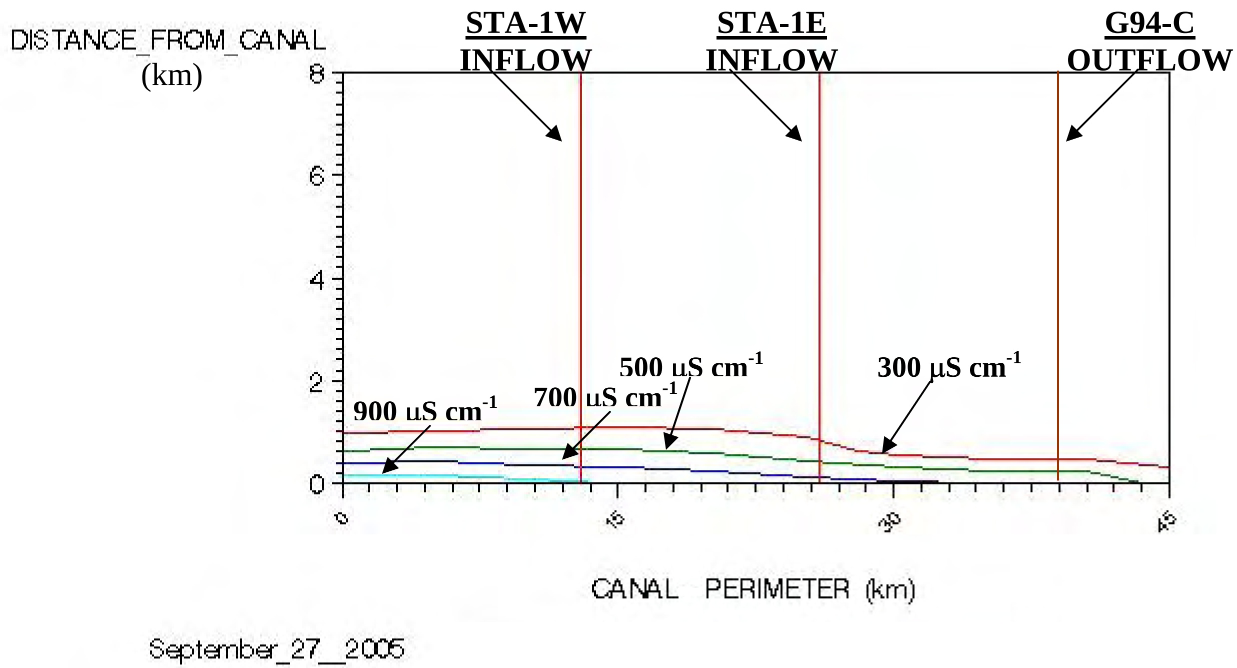


**Figure 2-12**. Post-Hurricane Rita and pre-Tropical Storm Tammy and conductivity contours for the canal and interior of the Refuge. Data were plotted from the mid-west perimeter of the Refuge (0 km on the x-axis) to the mid-east perimeter of the Refuge (46 km on the x-axis). The y-axis represents the distance into the marsh from the canal for each conductivity sonde site established in the Refuge (marsh and canals). The distance for each inflow and outflow structure (vertical lines) around the canal also was plotted to provide the locality of expected water movement into the marsh.

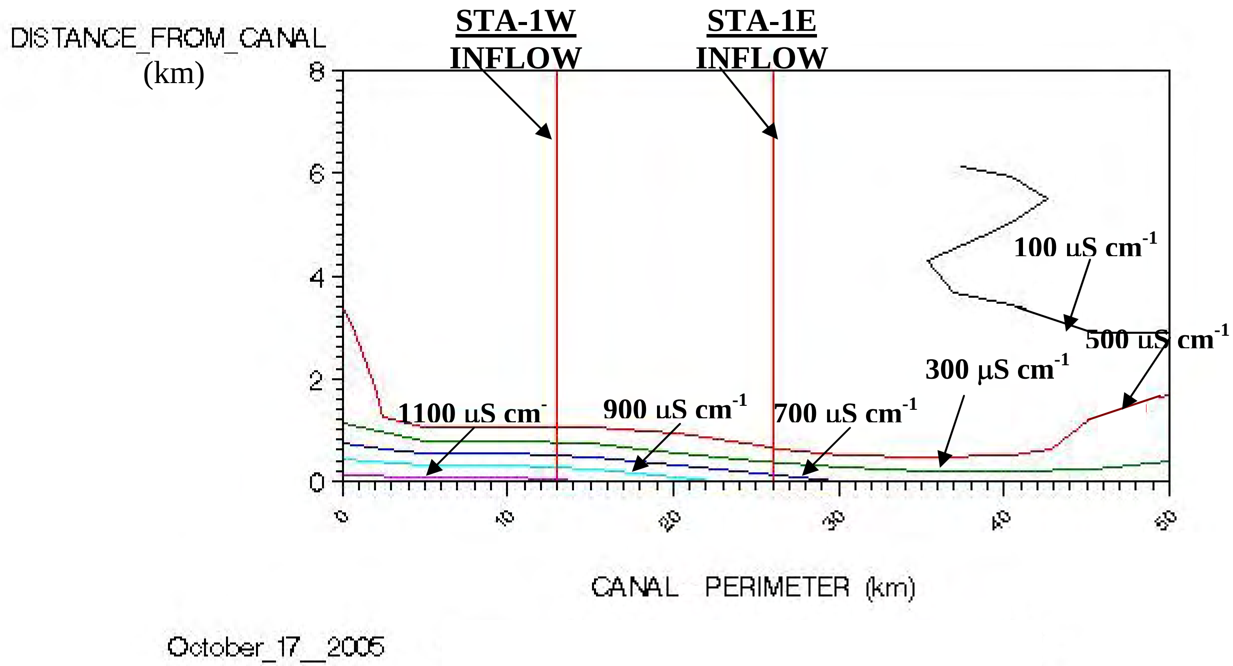


**Figure 2-13**. Post-Tropical Storm Tammy and pre-Hurricane Wilma and conductivity contours for the canal and interior of the Refuge. Data were plotted from the mid-west perimeter of the Refuge (0 km on the x-axis) to the mid-east perimeter of the Refuge (46 km on the x-axis). The y-axis represents the distance into the marsh from the canal for each conductivity sonde site established in the Refuge (marsh and canals). The distance for each inflow and outflow structure (vertical lines) around the canal also was plotted to provide the locality of expected water movement into the marsh.

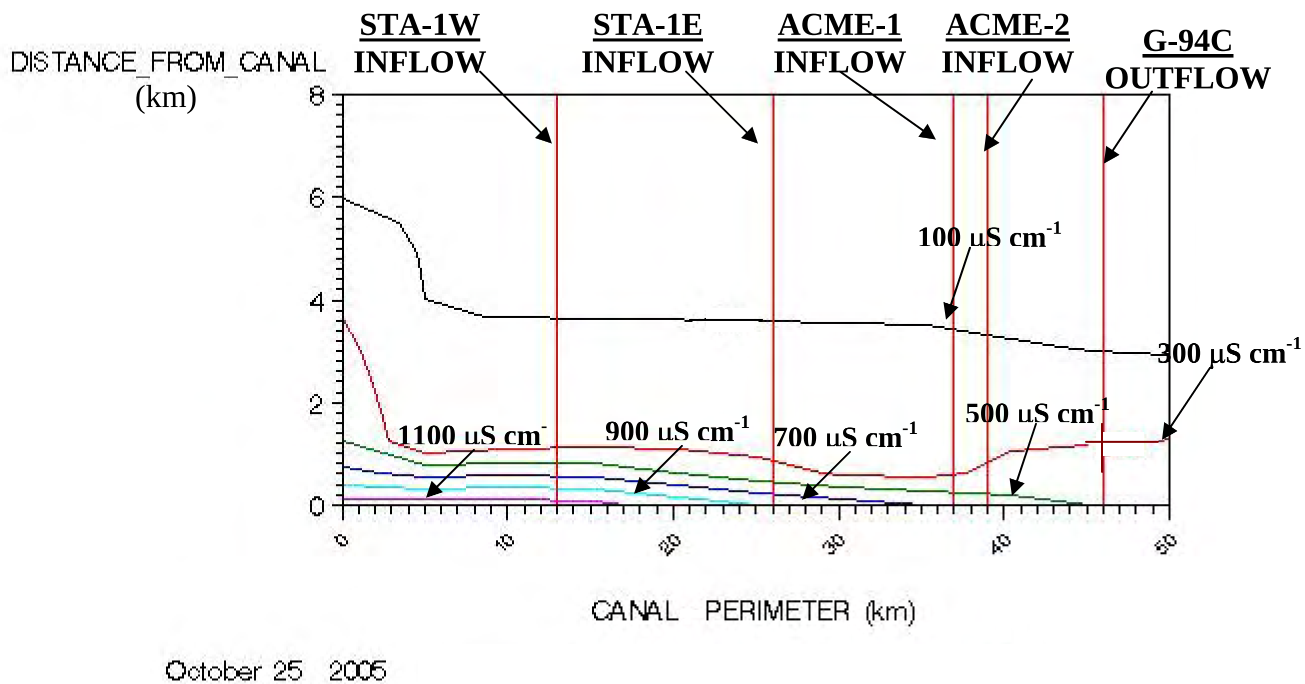


**Figure 2-14**. Hurricane Wilma conductivity contours for the canal and interior of the Refuge. Data were plotted from the mid-west perimeter of the Refuge (0 km on the x-axis) to the mid-east perimeter of the Refuge (46 km on the x-axis). The y-axis represents the distance into the marsh from the canal for each conductivity sonde site established in the Refuge (marsh and canals). The distance for each inflow and outflow structure (vertical lines) around the canal also was plotted to provide the locality of expected water movement into the marsh.

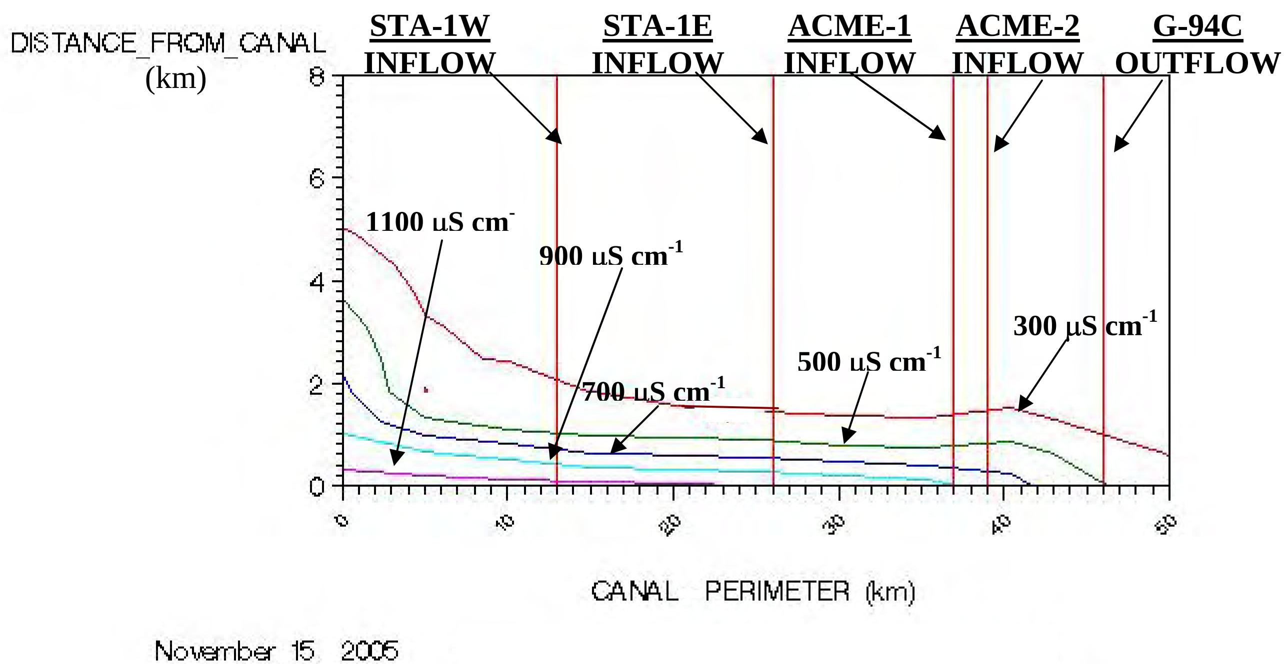


**Figure 2-15**. Post-Hurricane Wilma conductivity contours for the canal and interior of the Refuge. Data were plotted from the mid-west perimeter of the Refuge (0 km on the x-axis) to the mid-east perimeter of the Refuge (46 km on the x-axis). The y-axis represents the distance into the marsh from the canal for each conductivity sonde site established in the Refuge (marsh and canals). The distance for each inflow and outflow structure (vertical lines) around the canal also was plotted to provide the locality of expected water movement into the marsh.

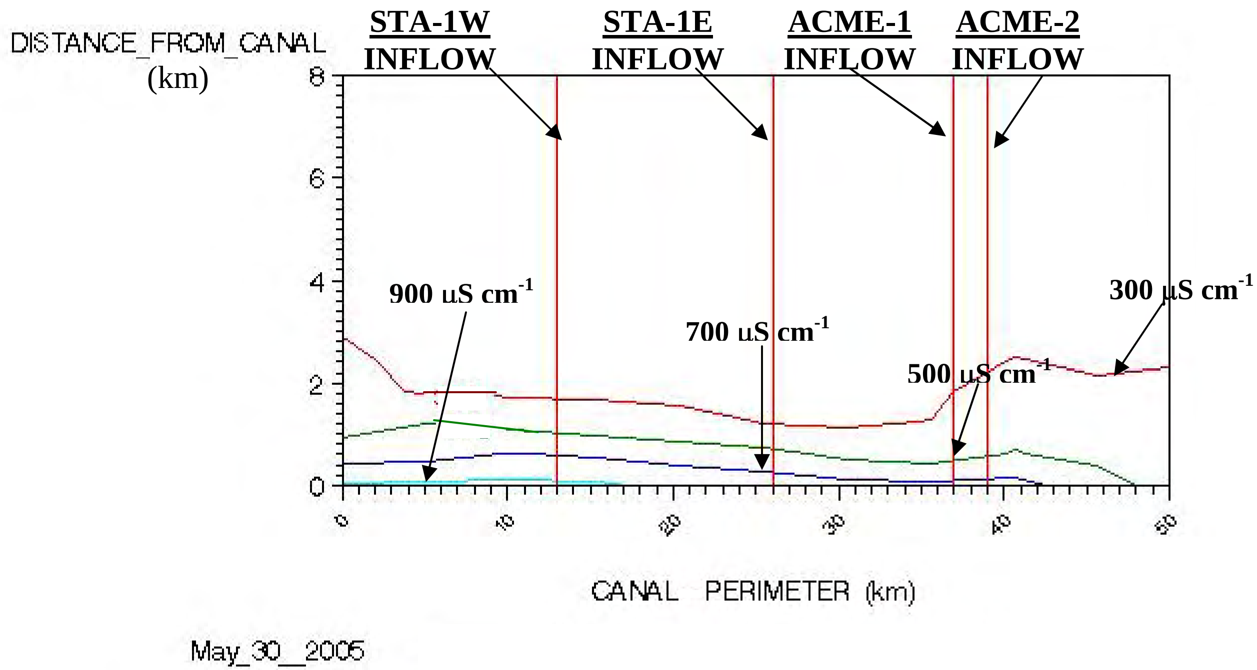


**Figure 2-16**. Pre-Tropical Storm Arlene conductivity contours for the canal and interior of the Refuge. Data were plotted from the mid-west perimeter of the Refuge (0 km on the x-axis) to the mid-east perimeter of the Refuge (46 km on the x-axis). The y-axis represents the distance into the marsh from the canal for each conductivity sonde site established in the Refuge (marsh and canals). The distance for each inflow and outflow structure (vertical lines) around the canal also was plotted to provide the locality of expected water movement into the marsh.

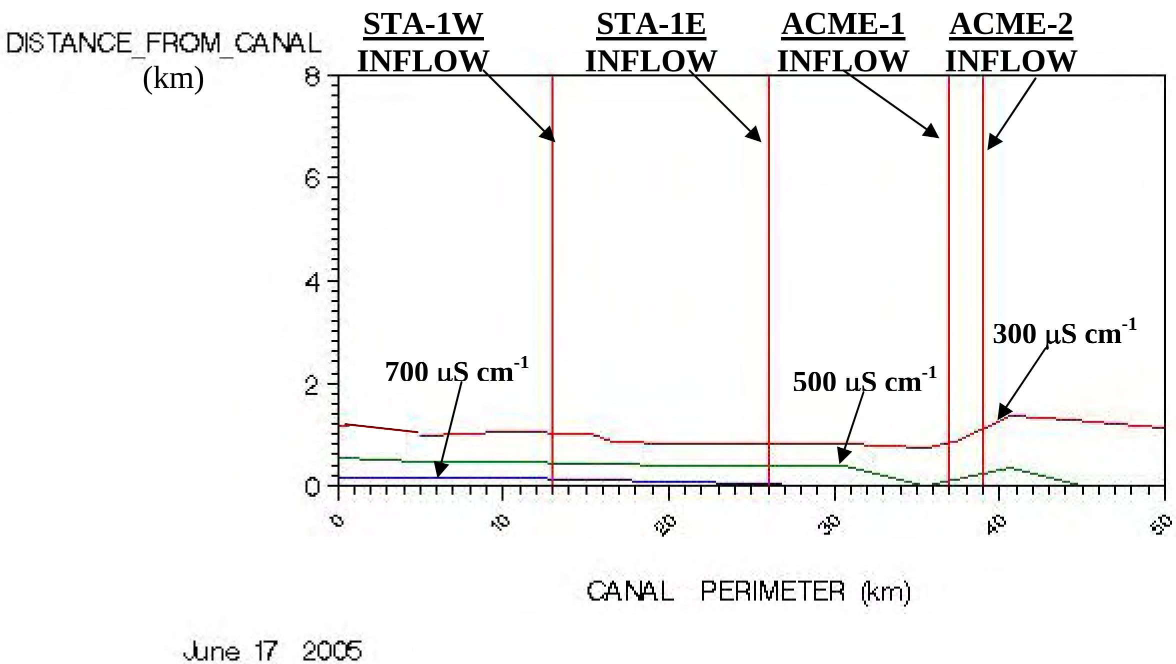


**Figure 2-17**. Post-Tropical Storm Arlene and pre-unnamed rain event and conductivity contours for the canal and interior of the Refuge. Data were plotted from the mid-west perimeter of the Refuge (0 km on the x-axis) to the mid-east perimeter of the Refuge (46 km on the x-axis). The y-axis represents the distance into the marsh from the canal for each conductivity sonde site established in the Refuge (marsh and canals). The distance for each inflow and outflow structure (vertical lines) around the canal also was plotted to provide the locality of expected water movement into the marsh.

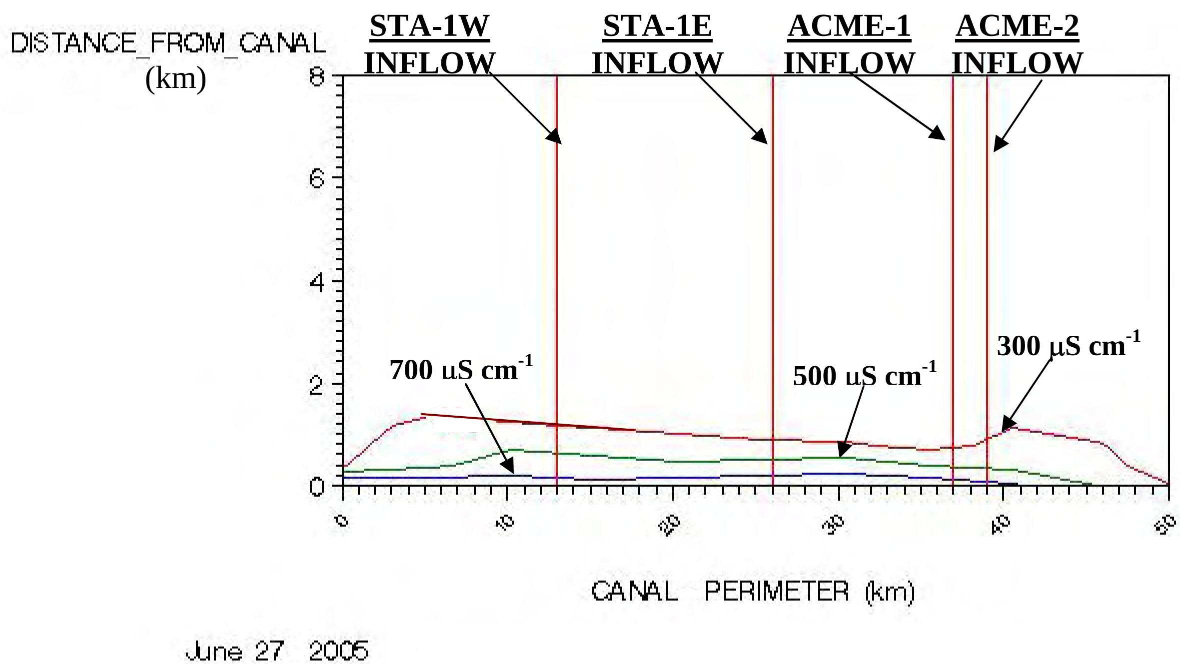


**Figure 2-18**. Post-unnamed rain event conductivity contours for the canal and interior of the Refuge. Data were plotted from the mid-west perimeter of the Refuge (0 km on the x-axis) to the mid-east perimeter of the Refuge (46 km on the x-axis). The y-axis represents the distance into the marsh from the canal for each conductivity sonde site established in the Refuge (marsh and canals). The distance for each inflow and outflow structure (vertical lines) around the canal also was plotted to provide the locality of expected water movement into the marsh.

# Section II, Chapter 3. Hydrodynamic and Water Quality Modeling[1]


## Abstract

Hydrodynamic, hydrologic and water budget models coupled with water quality and mass balance models are valuable tools that provide predictions of water movement and water constituent concentrations. When fully calibrated and validated for a given site, the specific model or models provide information valuable for answering questions on the hydrologic, hydrodynamic, and water quality conditions occurring under present conditions and management rules, and how these processes would be altered by different structural changes and management scenarios. Predictions of hydrologic and water quality conditions can, in turn, support predictions of ecologic processes and conditions if the relationship of ecologic indicators to hydrology and water quality are known. The necessary complexity and spatial dimensionality of a model are case-specific and are dependent on the specific ecological system under study and the nature of the questions being addressed. Special care must therefore be given to select models that best accomplish a set of goals and objectives.

This chapter is a status report on an ongoing project to model water and water quality in the Arthur R. Marshall Loxahatchee National Wildlife Refuge. It provides a snapshot of modeling approaches and results presently available. All information in this chapter is preliminary and will be superseded in future reporting.

We document the development of water budget and hydrodynamic models that will be used to provide a quantitative framework for management decisions related to inflow and outflow quantities, timing, and water quality. The period from January 1995 to December 2004 was selected for initial model development, calibration, and validation. This period was deemed to have representative dry and wet years, is of sufficient length to test model performance, and covers a period when data are most complete and credible.

A simple water budget model was developed as a 2-compartment (double-box) model that predicts canal compartment and marsh compartment volumes and stages. This model, implemented in an Excel workbook, was calibrated for the 5-year period of record between January 1995 and December 1999, and validated with data for the 5-year period of record between January 2000 and December 2004. Statistical analyses demonstrate the applicability of this model to predict temporal variation of water levels in both the marsh and the Refuge perimeter canal. Future efforts to link a simplified water quality model to the water budget model are planned.


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Selection of complex computer models for the hydrodynamic and water quality simulations was another early task. Eighteen potential models, and 11 other models with components that were potentially useful as resources, were initially reviewed. Of these, six models were selected for final consideration. Some of the models not selected for final consideration were, nonetheless, listed as potential resources of modeling approaches or formulations.

Of the six models, two were further evaluated by setting up test cases and performing test runs for the Refuge. One model is a two-dimensional unstructured finite volume model, FVCOM, and the second is a coupled one and two-dimensional finite difference model, MIKE-FLOOD. These models are being used to predict spatial and temporal distribution of water inside the Refuge, and the preliminary results show agreement between observed and predicted stages at specific locations. Efforts are now underway to model the transport of a conservative tracer constituent, dissolved chloride (Cl). The quality of the Cl calibration will test the ability of the model to simulate transport and dispersion within the marsh. Constrained by the hydrodynamic and chloride calibrations, the dynamics of total phosphorus (TP) in the Refuge will then be modeled.

Because the modeling project began at the same time as the Refuge enhanced water quality monitoring project, data from the enhanced project were not available for the period-of-record selected for use in this model development. The improved understanding of processes at work on the Refuge that has come out of the enhanced monitoring project has helped shape the current model. Data obtained by the enhanced water quality monitoring project will be of value in future model improvement and evaluation.

Future applications of the completed model will examine the impacts, both positive and negative, of management and structural alternatives. The complex hydrological and water quality models could, for example, examine operational strategies that would minimize intrusion of canal water into the Refuge interior. An understanding of any ecological tradeoff between an optimal hydrologic regimen and avoidance of intrusion of the currently high-nutrient canal water is a priority need for management in the short-term until the water quality of Stormwater Treatment Area (STA) effluent is good enough to cause no harm to Refuge flora and fauna.

## Introduction

Changes in water quantity, timing, distribution and quality are introducing negative impacts to the Everglades ecosystem (Harwell et al. 1996; USFWS 2000). Historically, water would sheet flow across the Everglades, but now, water flows through canals and structures, and through a series of water storage areas (Water Conservation Areas, WCA) and finally on to the Everglades National Park. The Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge), which includes WCA-1, is an area of 58,320 hectares (144,000 acres), and is a remnant of the northern Everglades. The Refuge is bordered on the northwest by drained agricultural land, the Everglades Agricultural Area (EAA), and mainly by an urban development at the east. Water Conservation Area-2A is located to the southwest of the Refuge.

A priority for the Refuge is to better understand and minimize nutrient-related and hydrological impacts. Changes in natural timing of water levels in the Refuge affect wading birds feeding patterns, apple snail reproductive output, and alligator nesting. Similarly, changes in patterns of water depths impact aquatic vegetation and tree islands. During the dry season, lower water levels increase the potential for fire damage to vegetation, soils and wildlife (USFWS 2000).

Along with changes in water quantity and timing, water quality changes define important threats to the Everglades ecosystem. The Refuge is impacted by canal water intrusion into the interior marsh carrying elevated concentrations of dissolved minerals and nutrients, particularly phosphorus (P). High nutrient concentrations in runoff, specifically total phosphorus (TP) from agricultural areas causes proliferation of cattails, and other undesirable plant species that negatively affect the ecosystem balance. In the Everglades nutrient enrichment and increased mineral concentration have caused deteriorated ecological conditions (Swift 1981; Flora and Rosendahl 1982; Swift 1984; Swift and Nicholas 1987; Nearhoof 1992; Doren et al. 1997; McCormick et al. 2000; Childers et al. 2002; McCormick et al. 2002; Gaiser et al. 2005; McCormick and Crawford 2006). The Refuge continues to be eutrophied by the influx of high nutrient runoff (USFWS 2000).

Although previous efforts directed at modeling hydrology and water quality of the Refuge have been of value (Lin 1979; MacVicar et al. 1984; Lin and Gregg 1988; Richardson et al. 1990; Fitz and Sklar 1999; MacVicar and Lindahl 2000; Raghunathan et al. 2001; Munson et al. 2002; Welter 2002). None of these modeling efforts adequately address current Refuge needs. The Refuge is impacted by changes in water flow and stage (Brandt et al. 2000; USFWS 2000), excessive nutrient loading (Newman et al. 1997; USFWS 2000), and altered dissolved mineral concentrations including chloride (Swift 1981; Swift 1984; Swift and Nicholas 1987; Browder et al. 1991; Browder et al. 1994; McCormick and Crawford 2006). Hydrodynamic and water quality models have the potential to provide needed management and scientific support related to these concerns.

The goal of this modeling (Brandt et al. 2004) is to provide best available technical support for management decisions related to Refuge inflow and outflow water quantity, timing, and quality. We will develop a water budget model and a two-dimensional hydrodynamic and water quality model for the Refuge that will provide a quantitative framework for these management decisions. We also will predict water movement and water quality resulting under alternative operation scenarios, Stormwater Treatment Area (STA) performance, climatic variation, and structural changes within the Refuge.

Models can assist managers in decision-making, but alone are not sufficient. Objectives and alternatives must be first be defined before alternatives can be compared. When fully calibrated and validated, the models described here should assist in answering questions and provide information such as the questions listed below (Brandt et al. 2004):

- What is the impact of different management scenarios on the water distribution inside the Refuge?
- What is the impact of the management scenarios on the hydroperiod?
- Does the water depth (duration and frequency) satisfy the needs of plant communities and associated wildlife?
- What are the spatial and temporal distributions of phosphorus concentrations within the Refuge?
- What are the impacts of management decisions and strategies on the water quality?
- What are the impacts of alternative regulation schedules on the water quantity (stage) and quality (TP, Cl, and possibly other constituents) in the Refuge?
- How does (and what are the effects of) surface and ground water interactions in the Refuge?
- What was the impact of moving the location of inflows?
- How do new STA design alternatives impact the Refuge hydrology and water quality?

The reader should note that these models will provide a necessary tool supporting investigation of these questions, but, for most questions, these Refuge models are not sufficient alone to answer these questions. Questions related to ecological change require a definition of how water quality and quantity impact Refuge communities. For example, the models may predict water depths and flows, and nutrient concentrations, but prediction of changes in distribution of species such as cattail or sawgrass may require further research, assumptions, or modeling. Similarly, the Refuge models cannot predict how projects outside the model boundary (WCA-1) will affect Refuge inflow quantity and quality, or water demands for discharge from the Refuge. Project analyses using the Refuge models will necessarily require predictions from other models of project-related impacts to the Refuge model boundaries. For example, analyses of impacts to the Refuge from the EAA Feasibility Study alternatives (A.D.A. Engineering and SFWMD 2005) require specification of quantity and quality of inflow to the Refuge under each alternative scenario.

There are four major components in the Refuge modeling effort:

I. Independent technical review
II. Data compilation, processing, and initial analysis
III. Simplified modeling approach
IV. Fully-dynamic (complex) modeling approach

This chapter is a status report on each of the following tasks.

## Independent Technical Review

A technical review panel was assembled to ensure that the modeling effort of the Refuge will follow accepted scientific and technically sound methodologies. The panel review provides credibility and validation that the numerical modeling tools developed as part of this effort are reliable for management decisions and planning.

Under a cooperative agreement with Tennessee Technological University, an independent technical panel of experts was selected and convened. The panel reviewed the modeling project documents, and recommended revisions to the model or models. The panel also is tasked to provide any other technical comments or recommendations that they feel are appropriate and are of value in improving the modeling project. The panel is charged with answering specific questions compiled by Dr. Vincent Neary, the principal investigator. This independent panel is made up of three experts, including Dr. Neary. This panel is being funded through a separate cooperative agreement from the modeling support agreement in order to eliminate any perceived conflicts of interest. Panel members selected by Dr. Neary are: Dr. John A. McCorquodale, University of New Orleans, and Dr. Malcolm L. Spaulding, University of Rhode Island. Further information is available at the advisory panel homepage:
http://sofia.usgs.gov/lox_monitor_model/advisorypanel/index.html

## Data Compilation, Processing, and Initial Analysis

Most of the effort required to implement a model is expended in data identification, compilation, and processing. Initial modeling team efforts focused on compiling and evaluating data required for modeling purposes (Meselhe et al. 2005). Datasets are spatially variable (e.g., elevation), and some are both temporally and spatially variable such as all meteorological, hydrologic, and water quality parameters. The types of data that have been compiled and evaluated include:

- Marsh elevation data and canal cross-section elevations
- Hydrologic data: water level and discharges through hydraulic structures
- Meteorological data: rainfall, temperature, evapotranspiration (ET), and wind

- Water quality data: concentrations of the parameters of interest.

Meselhe et al. (2005) presented a detailed description of the data acquisition and processing for the Refuge modeling effort. They described the selection of the water quality constituents to be modeled, the selection of periods of records for calibration and validation, the sources of the data, the compilation process, and quality assurance. They also identify additional data that are needed, and recommend needed additional monitoring. It is important to note that the information presented below for the temporally variable data is based on the selected period of record (POR) for calibration and validation of the model, namely from January 1995 to December 2004.

Marsh Elevation and Canal Cross Section Data

The Refuge interior marsh elevation generally is very flat. The latest marsh elevation data for the Refuge are available from the United States Geological Survey (USGS) on a 400 by 400 meter (m) (1312 by 1322 ft) grid. According to (Desmond 2003), the horizontal positions were established by GPS observations and are referenced to the North American Datum of 1983 (NAD83). The horizontal accuracy is +/- 15 centimeters (cm) (6 inches). Similarly, the elevation data have a vertical accuracy specification of +/- 15 cm (6 inches) relative to the North American Vertical Datum of 1988 (NAVD88). Desmond (2003) indicated that the vertical accuracy of the elevation data was determined based on the requirements for use as input to hydrologic models. Because the Refuge water level data are based on the National Geodetic Vertical Datum (NGVD29), the USGS's elevation data were converted from the NAVD88 to the NGVD29 (Figure 3-1).

Desmond (2003) reports that highest soil elevation in the Refuge interior is approximately 5.62 m (18.5 ft), and that lowest interior elevation is roughly 3.22 m (10.6 ft) (NGVD 1929). The Refuge interior exhibits a general slope in elevation from north to south, with typical wet prairie or slough elevations as high as 5.00 m (16.3 ft) in the north, and as low as 3.80 m (12.5 ft) in the south (Richardson et al., 1990). Average interior marsh soil surface elevation is approximately 4.56 m (15.0 ft). The Refuge is bordered by the L-7 and L-39 Canals to the west and the L-40 Canal to the east. For the western canals, the sediment surface elevations range between 2.13 and - 0.46 m (7.0 and -1.5 ft) NGVD29, and between 2.03 and – 1.73 m (6.7 and -5.7 ft) NGVD29 for the L-40 canal. The top width ranges between 37 and 62 m (120 and 205 ft) for the western canals, and between 27 and 53 m (88 and 173 ft) for the L-40 canal. The perimeter canal cross-section elevation data were collected by the University of Florida's Institute of Food and Agricultural Sciences (IFAS). Sediment samples and cross section elevations were taken approximately at 1600 m (1.0 mile) resolution (Daroub et al. 2002).

Water Level Data

*Interior Station Stages:* The water level data were obtained at the SFWMD's Environmental Data Base (DBHYDRO) website (www.sfwmd.gov/org/ema/dbhydro/). There are 5 active continuous recording stations inside the Refuge, two of them in operation just after mid-2001. These 5 stations are operated by the USGS and are referred as 1-7, 1-9, 1-8T, Lox North and Lox South (Figure 3-2). Additionally, site 1-8C is located in the perimeter canal. Historic daily average water level data from 1954 to 2005 are available at USGS sites 1-7, 1-9, and 1-8C, with earliest data collected by the US Army Corps of Engineers. The stage-monitoring site 1-8T has water level measurements since 1979. Water level data from recently installed USGS sites Lox North and Lox South are available beginning in 2001.

For the POR (January 1995-December 2004), the daily means of water levels for the interior stations (1-7, 1-8T, and 1-9) range between 5.03 and 4.94 m (16.55 and 16.26 ft) NGVD29, and the maximum and minimum daily average stages are 5.51 and 4.24 m (18.12 and 13.94 ft) NGVD29, respectively. For gage 1-8C (located in the perimeter canal), the mean of daily average water level is 4.96 m (16.31 ft) NGVD29, and the maximum and minimum daily average stages are 5.53 and 3.67 m (18.19 and 12.06 ft) NGVD29, respectively. Gage Lox North presents a higher average stage (5.09 m; 16.73 ft NGVD29) than the rest of the stations, and gage Lox South has a lower average stage (4.89 m; 16.10 ft NGVD29). These stations only have data for the period from 2001 to December 2004.

Other stage data are available at inflow and outflow structures. It is important to recognize that these structure-site water level observations are at times impacted by local influence of structure flows (Lin and Gregg 1988; Waldon 2006). Head-water and tail-water stage data, for the hydraulic structures associated with the Refuge, are also available from the DBHYDRO website. It is important to note that some of 19 hydraulic structures were constructed during the POR (Figure 3-3). Structures G-301 and G-300 started operating in August 1999. Structure G-310 started operating on July 2000, and data for the S-362 station are available only after October 2004.

The means of daily average water levels in the perimeter canal at structures range from 4.89 to 4.84 m (16.28 to 15.93 ft) NGVD29.

<u>Flow Data</u>

There are 19 hydraulic structures associated with the water management of the Refuge. These structures are shown in Figure 3-3. Details on structures operation and water management of the Refuge (Figure 3-3) are in USFWS (2000) and Meselhe et al. (2005). The pump stations, S-6, S-5A, G-310, G-251, S-362, Acme-1, and Acme-2 (G-94D) are or were all sources of Refuge inflow. Gated structures S-10E, S-10D, S-10C, S-10A, S-39, G-94C, G-94A, and G-94B are Refuge outflows. Bidirectional flow may occur at gate S-5AS, G-338, G-301, and G-300. Positive flow at these structures indicates an inflow; negative flow at these structures indicates an outflow. No significant flow has occurred through gate G-338, and only one inflow event occurred at gate G-94C during the POR examined here.

Not all of the 19 structures were in operation during the complete POR (Waldon 2005). For example, the S-5A pump station discharged directly into the Refuge until August 1999, when it was diverted to the western stormwater treatment area (STA-1W).

Similarly, structure S-5AS and the S-6 pump were diverted away from the Refuge in June 1999 and May 2001, respectively. Structures G-301 and G-300 started operating in August 1999. Structure G-310 started operating in May 1999.

Based on the POR and according to the management structures' operation, pumping stations G-310, S-6 and S-5A present the highest mean of daily average inflows, with a flow close to 11,310 L $s^{-1}$ (400 cfs). The maximum recorded daily average discharge is equal to135,123 L $s^{-1}$ (4,779 cfs) through pumping station S-5A. Meanwhile, stations G-310 and S-6 show maximum daily average discharges equal to 91,177 L $s^{-1}$ (3,224 cfs) and 82,561 L $s^{-1}$ (2,920 cfs), respectively. Structures S-39 and S-10D present the highest mean of daily average outflows from the Refuge with a flow close to 5,089 L $s^{-1}$ (180 cfs). Structures S-10C and S-10A have an mean of daily average discharge (outflow) close to 4,100 L $s^{-1}$ (145 cfs). The maximum recorded daily average outflow from the Refuge is 139,138 L $s^{-1}$ (4,921 cfs) through spillway S-10A. The yearly average inflow to the Refuge was 7.14 x $10^8$ $m^3$ (579,038 acre-ft) and the yearly average outflow was 7.11 x $10^8$ $m^3$ (576,141 acre-ft).

Rainfall Data

Daily rainfall data are available at different locations inside and close to the Refuge. There are 5 daily rainfall stations inside the Refuge: 5A, S-6, S-39, WCA1ME, LOXWS and one station located at the former Everglades Nutrients Removal Project (ENRP) within STA-1W, which is located adjacent to the northwestern boundary of the Refuge. These six rainfall measurement stations are operated by the SFWMD and data are available from the DBHYDRO website. There are also 10 rain gages located adjacent to the Refuge (Figure 3-4). Stations S-5A, S-6, and S-39 have daily average rainfall measurements since 1956, 1960, and 1963, respectively. The weather station WCA1ME has rainfall measurements since 1994, and weather stations LOXWS and ENRP have measurements since 1996. Ten additional rain gages are located in and near the Village of Wellington adjacent to the Refuge in the Acme Drainage District's northern Basin A, and southern Basin B (Figure 3-4). Daily rainfall measurements from these gages are available since January 1997. Gage 10 (PS-2) was added to this rain gage network in April 2000, and its daily rainfall data are available since then. The annual average rainfall for the Refuge is 1321 mm (52.1 inches) for the POR between 1995 and 2004.

Evaporation and Potential Evapotranspiration Data

Evapotranspiration (ET) data for the Refuge are available from the ENRP (STA-1W) site; these data are available from the DBHYDRO website. Pan evaporation and potential evapotranspiration are available from stations S-5A and LOXWS, respectively (Figure 3-4). Annual average ET from the STA-1W station is equal to 1321 mm (52 inches).

## Refuge Modeling – Overview

It is a priority for the Refuge to ensure an appropriate water regulation schedule and structure operations that will produce maximum benefits for flood control, water supply, and fish and wildlife. It is also a priority to better understand and to minimize the impact of excessive nutrient loading. The main goal of this modeling effort is to provide a quantitative framework for management decisions related to water quality, quantity and timing. This goal is being accomplished through the development of two analytical tools: (a) a simple water budget-mass balance model, and (b) a complex hydrodynamic-water quality model.

## Simplified Modeling

The simplified water budget model will predict temporal variations of water levels in the canal and in the marsh based on user-specified inflow and outflow conditions of the boundary hydraulic structures. Quantifying components of the Refuge's water budget is important, particularly seepage. There are no measurements of overall seepage rate in the Refuge. The simplified model was used to estimate seepage rates based on water balance. Uncertainty in the estimate of seepage caused by uncertainty in other processes such as ET, will need to be considered when applying the seepage estimate.

This simplified box-model is computationally efficient and can perform decadal simulations in minutes. This feature allows the Refuge managers to assess various management strategies quickly and efficiently, at least on a preliminary basis. The simplified model will allow rapid testing of model sensitivity to parameters, and support quick tests of a broader suite of management scenarios than can feasibly be examined and verified using the more complex model.

The box-model is set up such that the interior marsh is considered as a unit. Spatial differences can not be discerned between, for example, the northern and southern portion of the interior marsh. The box-model would, rather, provide an averaged water level and constituent concentration for the entire interior marsh and for the perimeter canal. Spatial variations within the marsh and the perimeter canal will be available from the fully dynamic model.

### Water budget modeling

A double box (2-compartment) water budget model was developed for the Refuge (Figure 3-5). This model predicts canal and marsh stages from observed inflow, outflow, precipitation, and evapotranspiration.

The simple modeling technique used here is reminiscent of the classical hydrological methods of level pool routing (Chow et al. 1988) or cubature (Rantz 1982). The model evolved from a water and constituent mass model initiated by Walker (unpublished) that helped lay the ground work for our current model. Significant modifications were introduced in order to fit the needs of using the model as a management and analysis tool. Major modifications to the original Walker (unpublished) model are: (1) the new model predicts canal and marsh stages instead of outflows; (2) seepage was included in the balance; (3) additional stations were used in the precipitation analysis; and (4) reduction factors were introduced in the evapotranspiration calculations based on the marsh depth. These modifications more readily allow assessment of the impact of operation of the boundary structures on the water level and constituents concentrations in the interior marsh and the perimeter canal.

The following equations where used to determine the canal ($E_T$) and the marsh stage ($E_M$):

Canal Stage: $$\frac{dE_T}{dt} = P - ET - G_T + (Q_E - Q_{MI} - Q_{RO}) / A_C \qquad (1)$$

Marsh Stage: $$\frac{dE_M}{dt} = P - ET - G_M + Q_{MI} / A_M \qquad (2)$$

where $E_T$ is the average stage in the perimeter canal, $E_M$ is the average stage in the marsh; $A_C$ and $A_M$ are the perimeter canal and marsh areas, respectively; $P$ is the precipitation; $ET$ is the evapotranspiration; $G_T$ and $G_M$ are the seepage in the canal and marsh respectively; $Q_E$ is the external inflow to the perimeter canal, $Q_{RO}$ if the outflow from the perimeter canal; and $Q_{MI}$ is the flow from the perimeter canal to the marsh.

Spatially averaged precipitation was used in this simplified model. Observed evapotranspiration data were obtained from the DBHYDRO website for a single station located near the Refuge interior, site ENRP. Evapotranspiration at sites that go dry for even a few weeks out of the year exhibit considerably lower annual ET water loss (German 1999). As the marsh stage approaches the average sediment elevation used in the model, actual ET is reduced below the observed value. Data were modified to estimate actual ET using the following equation:

$$ET = f_{ET}\, ET_{obs} \qquad (3)$$

where $ET_{obs}$ is the evapotranspiration reported for a fully wetted wetland; $f_{ET} = Maximum(f_{ET\min}, Minimum(1, \frac{H}{H_{ET}}))$; $f_{ETmin}$ is the minimum reduction of ET because of shallow depth = 20%; $H$ is the marsh water depth in meters so that $H = Maximum(0, E_M - E_0)$; $E_0$ is the marshwater surface elevation; $E_0$ is the marsh ground elevation = 4.57 m, the average elevation of the Refuge interior (Desmond 2003; Meselhe et al. 2005); and $H_{ET}$ is the depth below which ET is reduced = 0.25 m (0.82 ft). Using a linear reduction in ET over a small depth range as depth approaches zero is expected to achieve more stable results than simple switching at zero depth (personal communication, Sorab Panday 2004). Some other models, including SWAT (Arnold et al. 1998) and MODHMS (http://modhms.com) use a similar approach.

The rate of loss of groundwater recharge in the canal or marsh is calculated from the head difference between the Refuge and boundary area (Lin and Gregg 1988):

$$G_i = r_{seep}(E_i - E_B) \tag{4}$$

where $i = t \text{ or } m$ for canal or marsh, respectively; $r_{seep}$ is the seepage rate constant = 0.06 and 0.000004 $d^{-1}$ in the canal and marsh, respectively; and $E_B$ is the boundary water surface elevation = 3.5 m (11.48 ft). The flow from the canal to the marsh was calculated based on the "power law model" (Kadlec and Knight 1996):

$$Q_{MI} = CH^3(E_T - E_M) \tag{5}$$

where $C = 10^7\, BW / R = 2\pi 10^7\, B$ = 1.88x$10^9$ $m^{-1}d^{-1}$; $H = Maximum(0, E_M - E_0)$ ; $W$ is the average marsh perimeter = 81.5 km (50.6 miles); $R$ is the average radius of the marsh = 13.0 km (6.5 miles) (this value was obtained assuming an approximated circular geometry; and $B$ is a calibrated transport coefficient = 30 $m^{-1}d^{-1}$ (98.4 ft per day)).

Differential equations for canal and marsh stage are calculated using the Euler numerical integration method with a one-day time step. This method provides a fast solution and is easily implemented using the available daily average time-series data. However, one problem with this technique is that when net canal flow is large, stage change over one day is so large that the assumption of "small" change in the integration algorithm is not satisfied. This problem can result in failure of convergence and instability. A heuristic approach is used to stabilize the solution that is otherwise unstable at times. This heuristic approach limits the magnitude of the canal stage, and maintains conservation of water volume by shifting flow directly to the marsh. Such an approach is reasonable because under these conditions flow between the marsh and canal is likely being underestimated by the Eulerian method with a daily time-step. Denoting the revised stage derivative with an asterisk, this heuristic scheme is

$$\frac{dE_T^*}{dt} = \frac{dE_T}{dt} \qquad when \left|\frac{dE_T}{dt}\right| \le E'_{T\max}$$

$$\frac{dE_T^*}{dt} = \frac{\left(\frac{dE_T}{dt}\right)}{\left|\frac{dE_T}{dt}\right|} E'_{T\max} \qquad when \left|\frac{dE_T}{dt}\right| > E'_{T\max} \tag{6}$$

where $E'_{Tmax}$ is equal to 0.10 m/day.

The additional flow into the marsh, $Q_{MI}^*$, is

$$Q_{MI}^* = \left(\frac{dE_T}{dt} - \frac{dE_T^*}{dt}\right) A_C \tag{7}$$

and,

$$\frac{dE_M^*}{dt} = \frac{dE_M}{dt} + \frac{Q_{MI}^*}{A_M} \qquad (8)$$

The water budget model was calibrated using the period from 1995 to 1999, and validated with the data from 2000 to 2004. The major calibration parameter is the transport coefficient (*B*) in Eq. 5, and it was found that a value equal to 30 $m^{-1}d^{-1}$ ( 98.4 ft $d^{-1}$) produced the best agreement between observed and predicted values. Observed and predicted values are in good agreement (Figure 3-6 and Figure 3-7).

Bias, root mean square error (RMSE), correlation coefficient (R), variance reduction, and the Nash Sutcliffe efficiency (Nash and Sutcliffe 1970) were performed for the calibration and validation periods (Table 1). These statistics have been used to evaluate other South Florida models (Fitz et al. 2002; SFWMD 2003). Bias is the difference between the average of the model prediction and the paired average observed values (i.e., average model error or residual). RMSE is a weighted average of the absolute value of the model error. Variance reduction is one minus the ratio of the variance of the model residual to the variance of the observed data. The correlation coefficient measures the tendency of the model and observed data to rise and fall together. Finally, efficiency reflects both model bias and reduction of variance. It therefore has the value of combining these independent criteria into a single goodness-of-fit measure. Efficiency has a maximum value of one, corresponding to a perfect fit. A value of zero indicates that the model predicts no better than simply using the average observed value. Negative efficiency values are often considered to indicate that a model is not useful as a predictive tool. Nash Sutcliffe efficiency can be problematic when applied to observations with limited variation about their mean value.

Observed and predicted stages for the marsh are in better agreement than the observed and predicted values for the canal. Some reasons for this variation include: (1) the area for the perimeter canal was assumed constant; (2) the variability of the water level is greater in the canal than in the marsh; (3) the emphasis during the calibration was to match the observed marsh stages with the model prediction; and (4) water supply delivery flows through G-94A, G-94B, and G-94C, prior to 2000, were unavailable, and set to zero.

<u>Simplified nutrient and chloride load modeling</u>

Daily inflow and outflow loads of TP and Cl were estimated from daily average discharge and concentration data for the period from 1995-2004. Estimated daily loads will be used to force a simplified compartmental (box) model that is being coupled to the water budget model flow's predictions. The model will be used to predict temporal variations of TP and Cl in the marsh and in the perimeter canal. The model will be used to identify the best method for filling the daily information based on available data. Daily loads also are being aggregated into calendar year and water year totals. The aggregated water year loads will be compared with similar values presented by the SFWMD.

## Fully-Dynamic (Complex) Modeling

Model prediction of spatial variations of flow conditions (stage, velocity) and constituent concentrations can only be obtained by a spatially explicit (two-dimensional) numerical model. Such features are not available in the box-model, and it is necessary to use a dynamic spatially variable numerical model. The complex dynamic model is being implemented to simulate the same period as the simple box model, calendar years 1995 through 2004.

### Model Selection

Eighteen models or combination of models were considered as candidates for this modeling effort (Meselhe et al. 2006a). Available models had to meet one or more of the following criteria:

- Capabilities for simulating hydrodynamics and transport processes.
- Capabilities for simulating water quality processes.
- Available and documented through manuals, publications and/or user guides.

A standardized model information and evaluation sheet was prepared for each of the 18 candidate models.

Preliminary evaluation led to identifying the following models as primary candidate models (Meselhe et al. 2006a):

- FVCOM
- MIKE FLOOD
- Wetlands/WASP 6 - EFDC
- TELEMAC
- H3D
- GEMSS

### Hydrodynamic modeling

It was hoped initially that one model would be clearly superior in all desired features. However, none of these models ranked highest in all features. Two models, MIKE FLOOD and FVCOM, were therefore selected for preliminary implementation and testing. The fully dynamic models FVCOM and MIKE FLOOD were selected.

FVCOM is an unstructured, finite-volume, three-dimensional model consisting of momentum, continuity, temperature, salinity, and density equations closed physically and mathematically using the Mellor and Yamada level 2.5 turbulent closure sub-model

(Mellor and Yamada 1982). The finite-volume method used in this model combines the advantages of a finite element method for geometric flexibility and a finite-difference method for simple discrete computation (Chen et al. 2004).

MIKE FLOOD is a widely-used, user-friendly, proprietary suite of linked modeling modules. It includes a complete hydrodynamic model, with an implicit ADI finite difference scheme of $2^{nd}$ order accuracy. It dynamically links MIKE 11 (DHI Water & Environment 2005b) for rivers hydraulics with MIKE 21 for surface water modeling. MIKE 21 uses a structured Cartesian grid within a suite of modeling programs that include hydrodynamic (DHI Water & Environment 2005d), advection/dispersion (DHI Water & Environment 2005c), and ecological modeling (DHI Water & Environment 2005a) modules.

The two-dimensional hydrodynamic simulations were performed forcing the model with the inflows and outflows from the hydraulic structures and precipitation and evaporation as meteorological forcing. The same spatially invariant precipitation and evapotranspiration time series that were used in the simplified model were applied initially in the more complex models. The seepage loss was estimated using a similar approach to the one presented by Eq. 4.

*FVCOM*

An unstructured triangular mesh was generated for the Refuge using the MATISSE software (distributed by the Canadian Hydraulics Centre). This grid consisted of 12,190 nodes and 22,848 elements. The smaller element sizes are about 25 m (82 ft), within and adjacent to the perimeter canal; and the larger element edges are about 650 m (2130 ft), on the central portion of the Refuge. This grid was refined at different locations, allowing for a good representation of the perimeter canal, and to capture the tree islands (Figure 3-8).

In its current form, the model-predicted water levels are in very good agreement with the observed values (Figure 3-9; Table 2). Some issues have emerged that may limit application of FVCOM for the full range of Refuge applications. These issues include (1) computer run-time with the FVCOM model can be impractical, and (2) there were difficulties in obtaining a copy of the water quality module of FVCOM. Revisions to the FVCOM model are available, and the use of the model may be pursued in the future, especially for higher resolution individual storm-event modeling.

*MIKE FLOOD*

A structured-Cartesian grid was created for the Refuge using the MIKE ZERO software (DHI Water & Environment 2005e). This grid consists of 57 cells in the west to east direction and 90 cells in the south to north direction. The grid spacing is 400 m x 400 m (1312 ft x 1312 ft). This spacing is consistent with available topographic data. A canal model was set up using the canal cross-sectional data described above. The distance between these cross sections is approximately 1600 m (1 mile); additional cross sections were interpolated each 400 m (0.25 miles). Figure 3-10 shows the Cartesian grid developed for the Refuge.

The MIKE FLOOD model is being calibrated for the period of record that goes from January 2000 to December 2004. Preliminary results show good agreement between observed and predicted water levels at specific locations (Table 2). Efforts are underway to calibrate the transport subroutine using Cl as conservative tracer, and to model the dynamics of TP in the Refuge using the ECO Lab software (DHI Water & Environment 2005a).

Water quality modeling

The TP model will build on the understanding of P dynamics in South Florida wetlands that has been established through the development of the DMSTA model (Walker and Kadlec 2002). The DMSTA model has been calibrated or tested using data from over 70 wetland sites in South Florida, the most relevant of which is WCA-2A. Initial modeling of P will use kinetics and parameter ranges established by DMSTA modeling. Chloride will be modeled as a conservative constituent and TP will be modeled using the DMSTA differential equations using the DHI ECO Lab software to link the MIKE FLOOD advection dispersion module results to the constituent dynamics.

The water quality model will aid in the understanding of how different structure operations and management scenarios (structural alterations, management decisions, strategies, and regulations) affect the water quality in the Refuge. The model will help to identify how water quality may be altered and how the spatial and temporal distribution of TP inside the Refuge may be altered given a particular management scenario.

## Model Application

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. The complex model will be used for this purpose.
- Analyze benefits and impacts of revisions to the Refuge regulation schedule. This analysis may include changing zone boundary stages or the sequence in which water supply make-up water is delivered. The simplified and the complex models will be used for this purpose.
- Analyze changing the temporal and spatial distribution of outflow for water delivery to WCA-2 and the urban areas to the east. It is conjectured that water quality benefits are maximized by gate openings that minimize the east-west canal stage difference across the Refuge. The simplified and the complex models will be used for this purpose.

- 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 water intrusion? The complex model will be used for this purpose.
- Test operational alternatives for pumps and outflow structures to find ways to reduce effluent intrusion. The simplified and the complex models will be used for this purpose.
- Estimate the long-term impact on interior Cl concentration resulting from discharge by the STAs. The simplified and the complex models will be used for this purpose.
- Test changes in hydroperiod and water quality resulting from possible alternative designs for CERP project KK, the “Loxahatchee National Wildlife Refuge Internal Canal Structures.” The complex model will be used for this purpose.
- Estimate water quality improvement at interior stations that would result from meeting 10 ppb TP concentration at all inflows. The simplified and the complex models will be used for this purpose.
- Estimate the long-term impact (spatial extent) on interior TP concentration resulting from discharges by the STAs that exceed 10 ppb (e.g., STA-1W outflow of 100 ppb). The complex hydrodynamic and water quality models will be used for this purpose.
- Estimate the spatial impact of STA bypass (untreated water) on the Refuge.
- Analyze the benefit of diverting part or all urban water supply flows around the Refuge.
- Explore other operational changes that reduce the impact of external loads on interior stations. The simplified and the complex models will be used for this purpose.

## Summary

Initial efforts of this Refuge project worked to identify existing models that could be applied quickly, with little or no modification, and using available data. The implementation of the selected models is underway, and has demonstrated the feasibility of modeling Refuge stage with the selected models and approaches.

The tools developed here will provide spatial and temporal variation of flow conditions (stage and velocity), and constituent transport and transformation within the marsh and in the perimeter canal. These models will provide a valuable tool supporting Refuge management.

These tools are not regional models and can not project the response of the natural system outside the Refuge’s boundaries to any management alterations. Influences such as stages and flows outside the model boundary may influence conditions inside the Refuge. The model can provide detailed information about the response of the Refuge to regional management changes and alterations. However, the impact of regional changes on the Refuge model boundary conditions must be assumed or obtained from regional modeling efforts (e.g., the SFWMM). The hydrodynamic model is not designed to accurately project stage and flow near flowing structures. The limit of this restriction is difficult to quantify, but needs to be considered in application of modeling results. The user must therefore also be cognizant of this model limitation.

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**Table 1**. Statistical parameters for Double Box Water Budget Model.

| | Marsh Model Statistics | | Canal Model Statistics | |
|---|---|---|---|---|
| Statistical Parameter | Calibration | Validation | Calibration | Validation |
| Bias (ft) | -0.095 | -0.315 | 0.005 | -0.316 |
| RMSE (ft) | 0.264 | 0.380 | 0.423 | 0.558 |
| Variance Reduction | 0.719 | 0.811 | 0.653 | 0.753 |
| R (Correl Coef) | 0.887 | 0.913 | 0.808 | 0.868 |
| Nash-Sutcliffe Eff | 0.762 | 0.609 | 0.440 | 0.594 |

**Table 2**. Statistical parameters for marsh stages – hydrodynamic model.

| | Marsh Model Statistics |
|---|---|
| Statistical Parameter | Hydrodynamic Model Calibration |
| Bias (ft) | -0.034 |
| RMSE (ft) | 0.167 |
| Variance reduction | 0.934 |
| R (Correl Coef) | 0.978 |
| Nash-Sutcliffe Eff | 0.901 |

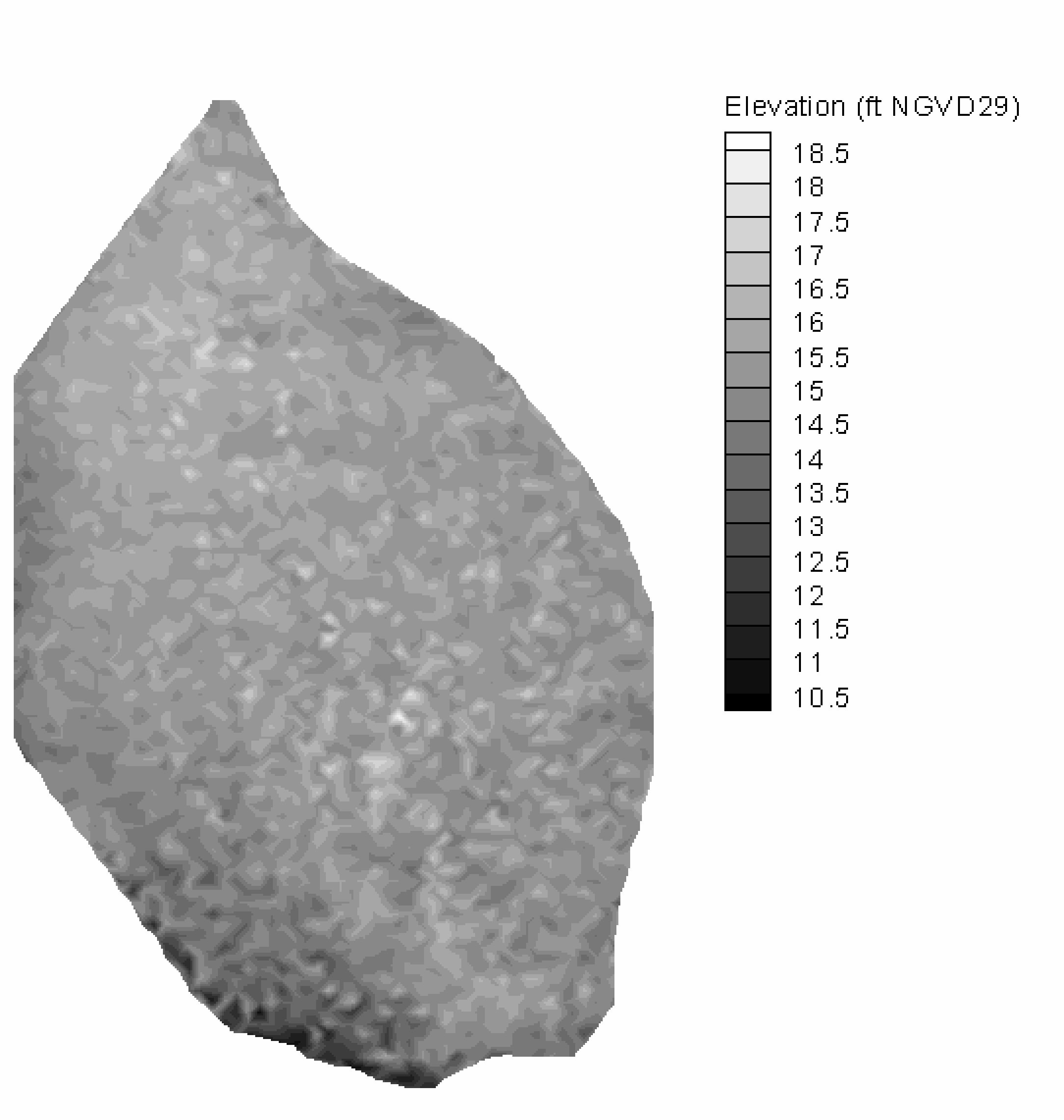


**Figure 3-1**. A.R.M. Loxahatchee National Wildlife Refuge 2003 USGS elevation data.

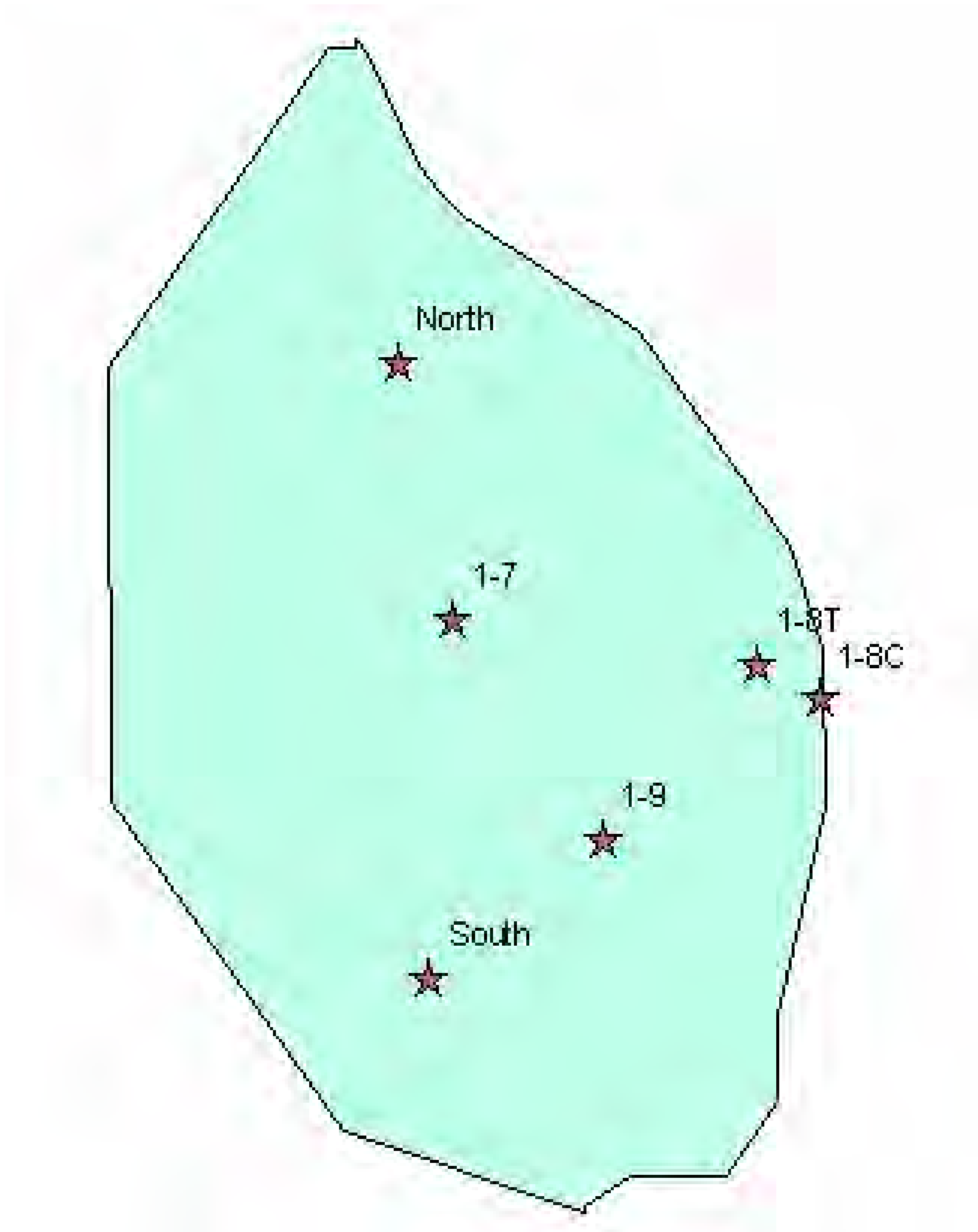


**Figure 3-2**. USGS water level monitoring stations.

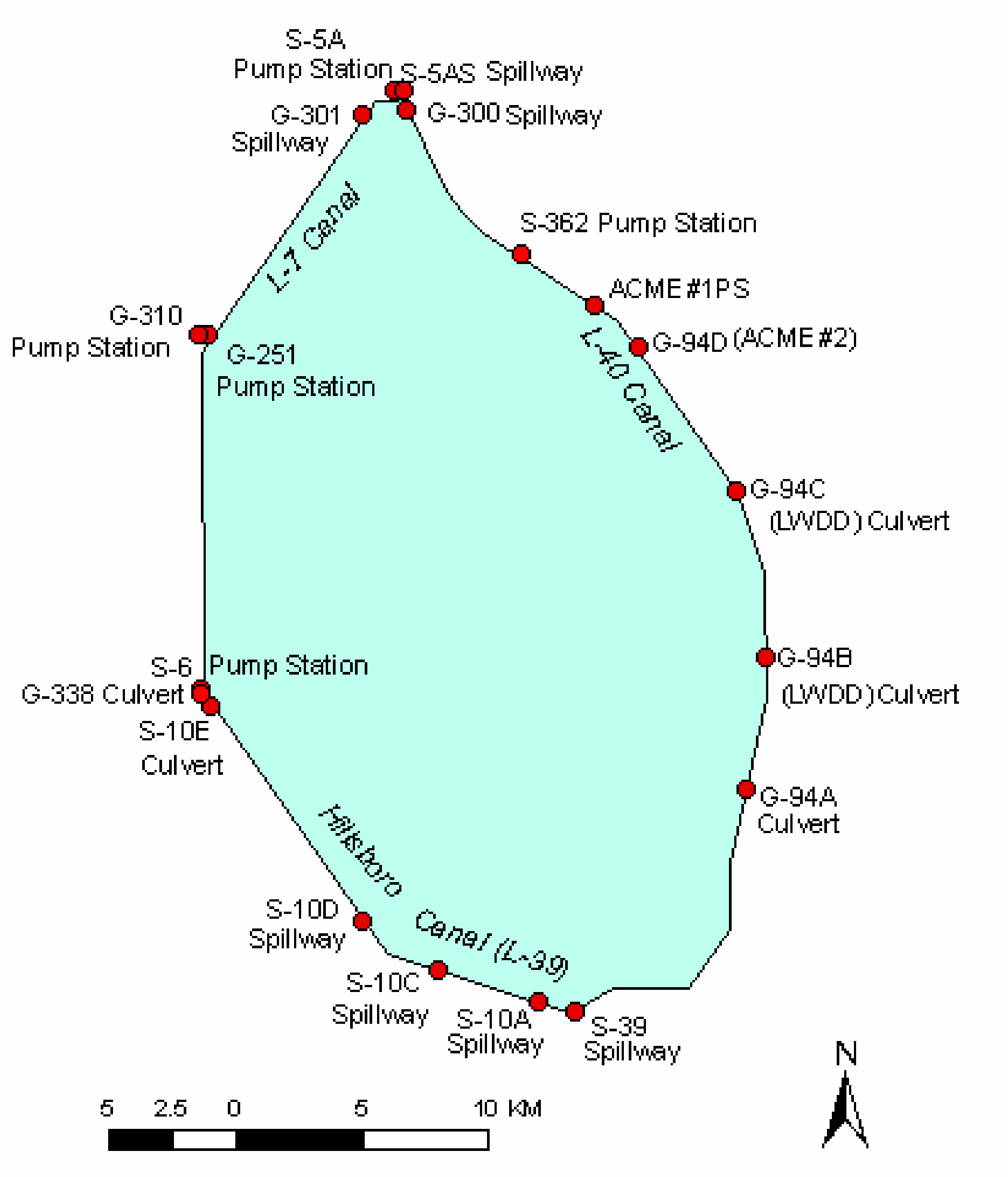


**Figure 3-3**. Location of hydraulic structures in the Refuge.

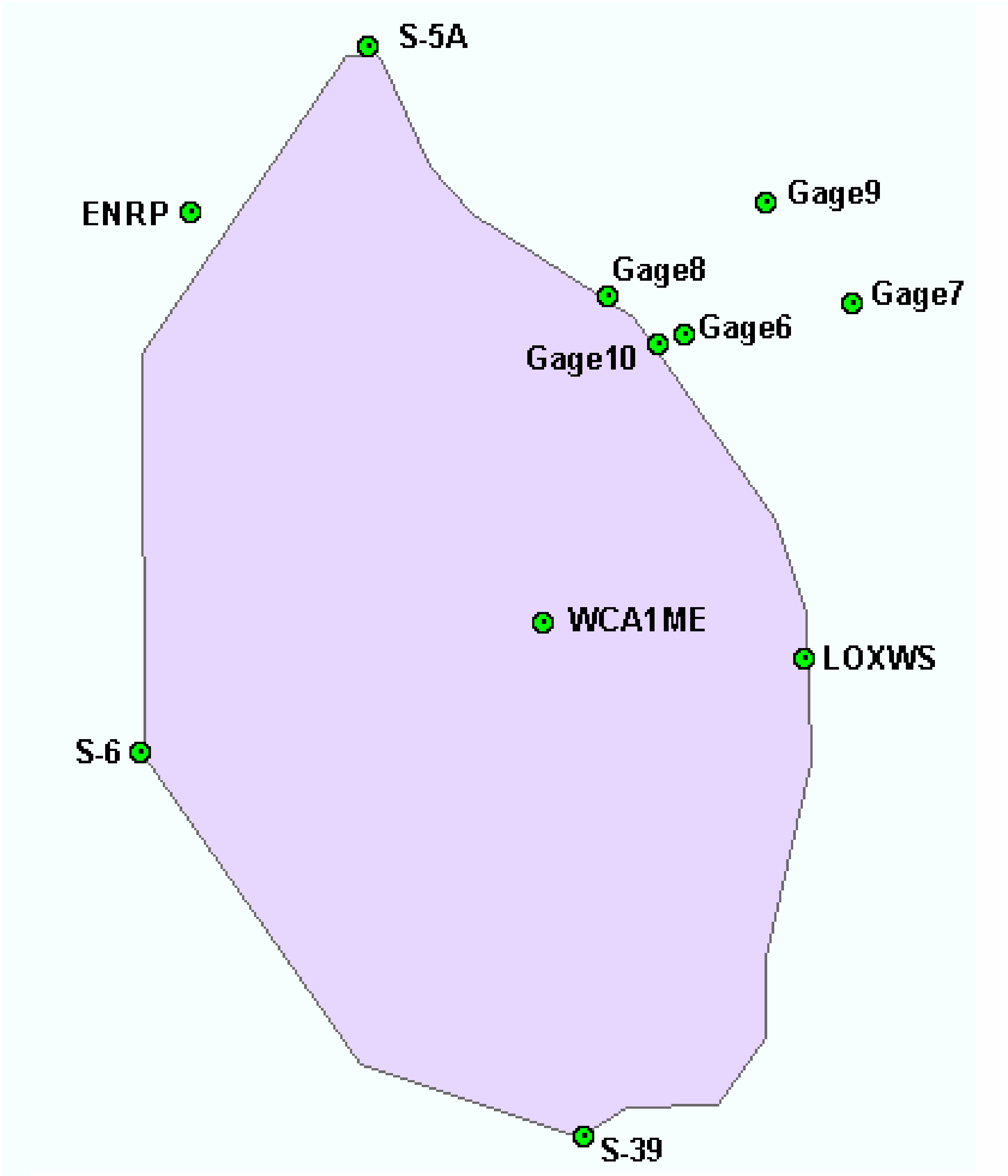


**Figure 3-4**. Location of rain gages and weather stations.

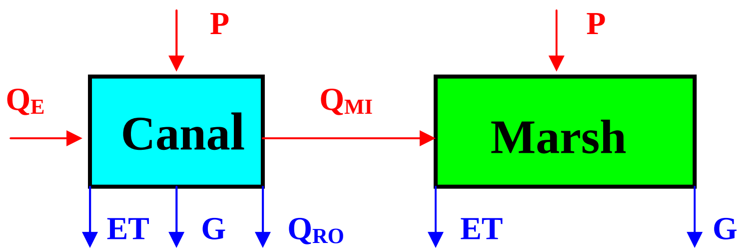


**Figure 3-5**. Sketch of the Water Budget Double Box Model.

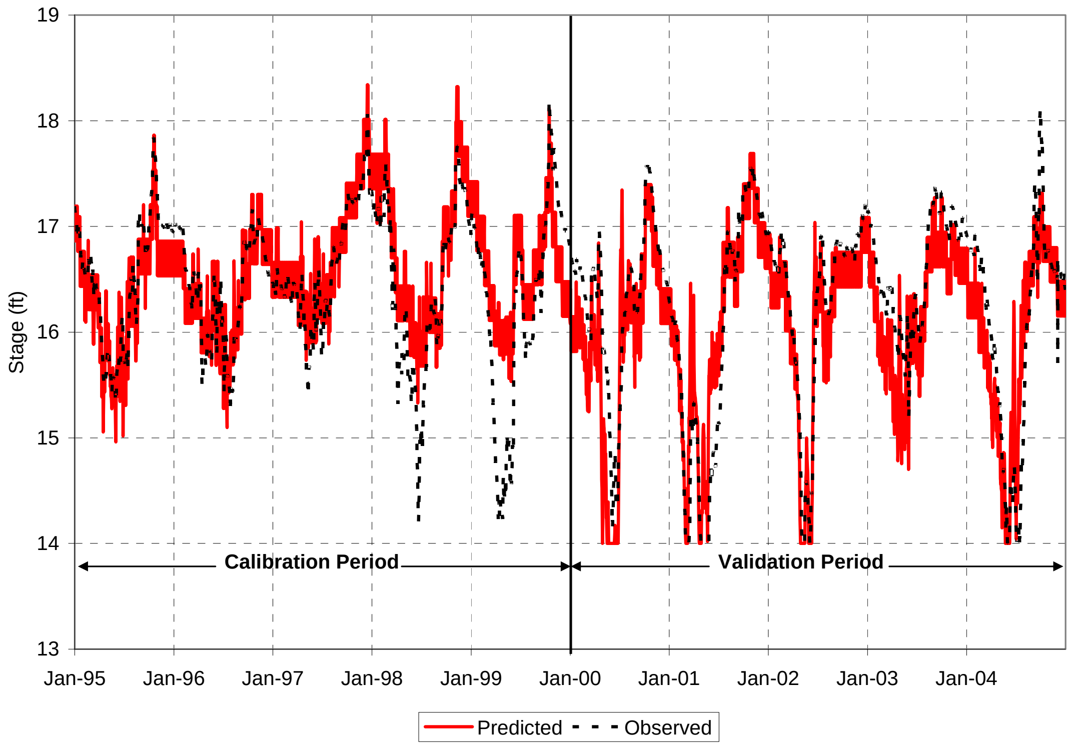


**Figure 3-6**. Observed vs. predicted canal stages for the calibration and validation periods.

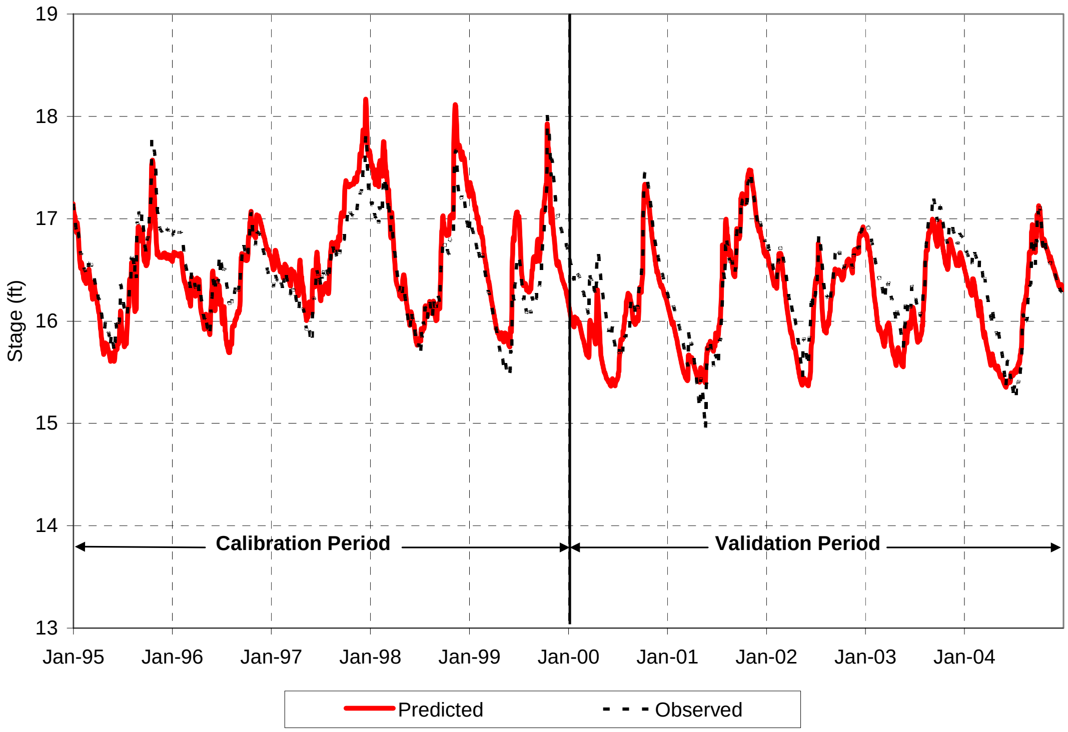


**Figure 3-7**. Observed vs. predicted marsh stages for the calibration and validation periods.

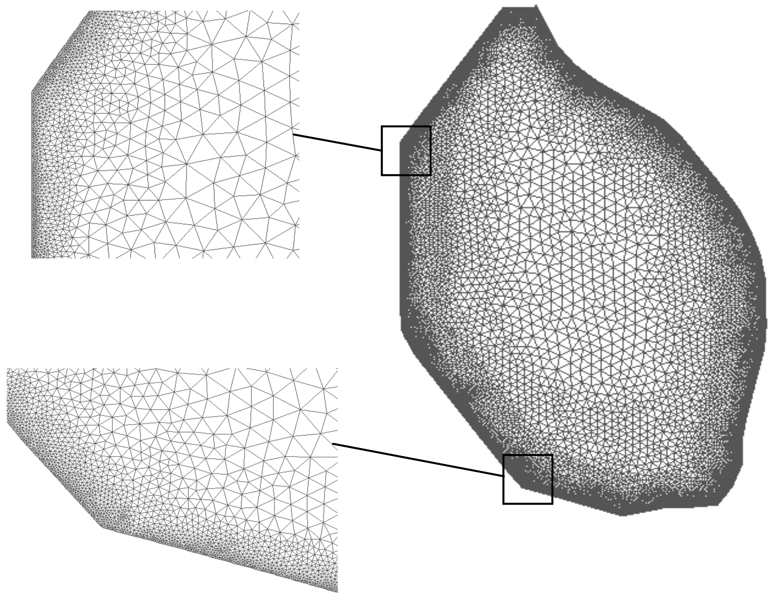

**Figure 3-8**. Unstructured grid for the A.R.M. Loxahatchee National Wildlife Refuge.

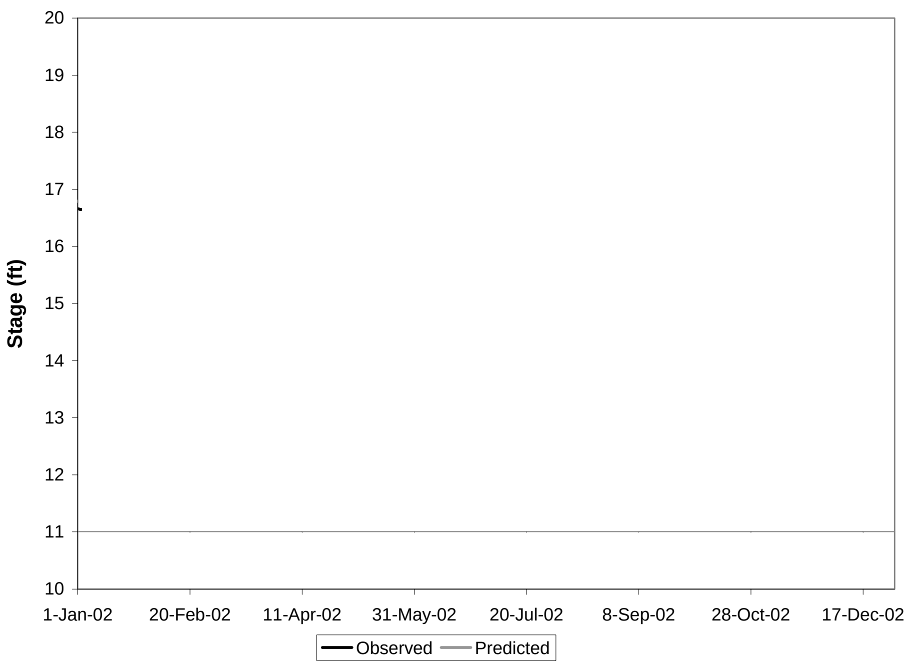


**Figure 3-9**. Observed vs. predicted marsh stage for the hydrodynamic model (Gage South).

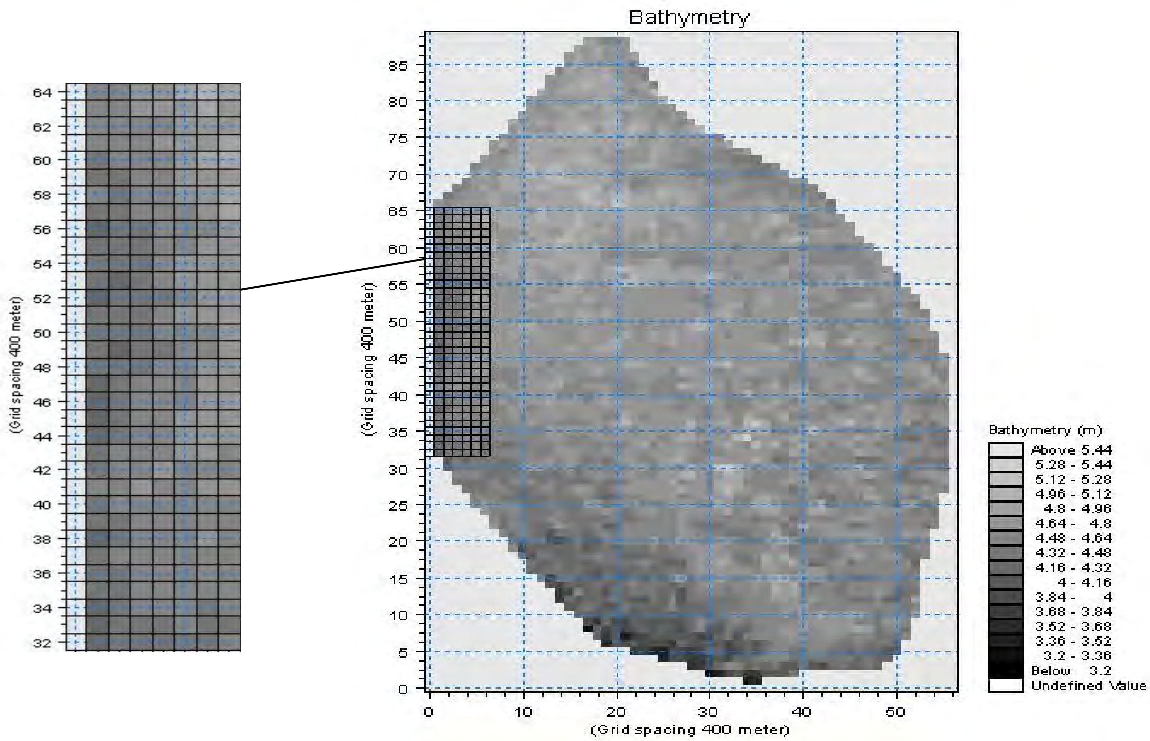


**Figure 3-10**. Structured-cartesian grid of the Refuge.

# Section III. Synthesis of Findings, Preliminary Management Recommendations, and Future Monitoring and Research[1]

## Introduction

The general purposes of the Refuge's water quality monitoring and modeling program are to improve the scientific understanding of Refuge water quality and to provide an improved scientific foundation for water management decisions to protect Refuge resources. In this program, we: (1) improved the spatial coverage and extent of water quality monitoring to better characterize the entire marsh; (2) documented changes in marsh conductivity along transects from the canals to the interior in response to water management, and; (3) applied modeling tools for support of Refuge management decisions and planning related to water management operations, water supply, and water quality.

In Section I of this report, we outlined a series of management decisions for which additional scientific information was necessary. Section II provided the technical details of studies conducted to address some of those needs. In Section III, we provide a synthesis of the information presented in Section II in the context of management decision support. In addition, we discuss additional information necessary to improve our scientific understanding of Refuge water quality issues.

The overarching management question for the Refuge is how do we protect Refuge resources? In Section I, we posed three general questions:

- What are the water quality characteristics in the fringe marsh adjacent to inflows?
- What are the projected impacts of STA-1E on Refuge water quality and ecological resources?
- What hydropatterns will occur in the marsh under different operational and water management conditions?

In addition to these more general questions, there is a more specific question that addresses both protection of Refuge resources and meeting legal requirements: What can be done to eliminate exceedances of the interim and long-term levels of the Consent Decree? The question might be more appropriately phrased: What can be done to eliminate exceedances of the interim and long-term levels of the Consent Decree while protecting the ecological integrity of the Refuge? Our goal is not just to eliminate water quality exceedances, but also to achieve water quality that is needed to protect Refuge resources.

Given these complex issues, this program focused on: (1) an improved understanding of phosphorus dynamics; and (2) understanding how to modify operations to minimize or eliminate canal water intrusion into the marsh. Ultimately, we expect the hydrodynamic and water quality models to be vital tools toward eliminating water quality exceedances without negatively impacting Refuge hydrology.

[1] Prepared by Matthew C. Harwell, Laura A. Brandt, Nick Aumen

## Water Quality Characteristics of the Fringe Marsh

The fringe marsh (called the perimeter zone in this report) extends from the canal up to 2.5 km (1.6 miles) into the Refuge marsh (Section II, Chapter 1). This classification was based upon conductivity data variability and changes in overall conductivity with perpendicular distance from the perimeter canal into the marsh interior. The transition zone was defined similarly, and extends from 2.5 to 4.5 km (1.6 to 2.8 miles) into the marsh. Finally, the interior zone was defined as the marsh area farther than 4.5 km (2.8 miles) from the perimeter canals.

In general, water quality data demonstrate that the perimeter zone is subject to canal water intrusion. In addition, canal water occasionally is observed in the transition zone. These findings are of concern because the perimeter and transition zones represent as much as 61% of the total Refuge area, and this area may be exposed to poor water quality and resulting ecological impacts. Perimeter zone conductivity is driven partly by differences between canal and marsh stages. Conductivity in the perimeter zone (average of 365 $\mu S\ cm^{-1}$) consistently is greater than conductivity in the Refuge's soft water interior (144 $\mu S\ cm^{-1}$). Average TP concentrations in the perimeter zone (20 $\mu g\ L^{-1}$, or ppb) were lower than canal concentrations (113 $\mu g\ L^{-1}$), but higher than the transition (14 $\mu g\ L^{-1}$) and interior zones (15 $\mu g\ L^{-1}$). Total phosphorus concentrations in the perimeter zone consistently were above 10 $\mu g\ L^{-1}$ from June 2004 until June 2005, but near 10 $\mu g\ L^{-1}$ from July 2005 until December 2005. One factor that may have contributed to these recent lower concentrations was the decreased Refuge inflows driven by limited STA discharges (discussed in Chapter 2).

Average values of other water quality parameters such as Cl and $SO_4$ also show a decreasing gradient from the canal into the interior marsh. Average Cl concentrations in the perimeter zone (51 $mg\ L^{-1}$, or ppm) were approximately one-half of canal concentrations (105 $mg\ L^{-1}$), but approximately twice those observed in the interior marsh (24 $mg\ L^{-1}$). Average $SO_4$ concentrations in the perimeter zone (10.6 $mg\ L^{-1}$) were approximately one-quarter of canal concentrations (43.9 $mg\ L^{-1}$), but one-hundred times those in the interior marsh (0.1 $mg\ L^{-1}$).

## Potential Impacts of STA-1E on Refuge Water Quality and Ecology

Canal water intrusion was documented more than 2 km (1.2 miles) into the marsh near the STA-1E outflow, despite limited discharges during the period of record. These findings are of concern because marsh water quality near the STA-1E outflow is relatively pristine as compared to the marsh water quality near the STA-1W and S-6 outflows.

Potential impacts of hard water on Refuge ecology are not addressed explicitly in this report. However, in a collaborative effort, Dr. Paul McCormick (USGS) is conducting ecological studies of potential hard water impacts (http://sofia.usgs.gov/projects/eco_lox/). It has been established already that Refuge soft-water periphyton are impacted by exposure to hard water (Sklar et al. 2005; Gottlieb et al. 2006). Additional research is documenting impacts of hard water on higher plants living in soft-water conditions. McCormick and Crawford (2006) measured reduced germination rate, growth rates, and biomass in *Xyris* spp. (yellow-eye star grass), an interior slough species. Results such as these increase concerns over potential impacts of agricultural and urban runoff on Refuge resources. However, efforts to minimize intrusion and the associated negative impacts of excess phosphorus would have the additional benefits of minimizing negative impacts of hard water.

## Improved Understanding of Phosphorus Dynamics

A number of mechanisms may contribute to high water column phosphorus concentrations. These mechanisms include canal water intrusion, internal and external loading, atmospheric deposition, planktonic algae, fire, precipitation, wind resuspension of floc, and drought (severe dry-out followed by re-wetting). This study focused on canal water intrusion by addressing two water management questions related to intrusion:

- Under what operational or environmental conditions does canal water intrude into the marsh and how far does it intrude?
- How does relative flow through different structures affect water flow and water quality within the interior marsh?

Significant information has been gained, but there are limitations to the conclusions that can be drawn because of the limited range of climatic and hydrological conditions experienced over the period of record (November 2004 – January 2006). Neither high nor low Refuge stages occurred during the study period and rainfall was the dominant source of water. Surface water inflow was lower than normal, most likely because STA-1W discharge was moderate with part of the STA off-line or impaired, and there were no large discharges from STA-1E. Continued monitoring over a period that includes high and low stages and high inflow conditions is necessary to fully address the questions posed above.

Analysis of intrusion dynamics (Chapter 2) was based on a limited number of events and associated hydrological conditions that were not easy to analyze statistically. Despite these limitations, important insights were gained. Intrusion varies by location and was influenced by canal and marsh stage differences, inflow and outflow rates, and rainfall conditions. There was frequent and persistent intrusion of canal water from 0.5 to 2.5 km (0.3 to 1.6 miles) into the Refuge interior, suggesting that as much as 7 to 37 % of the marsh regularly experiences some influence of canal water. The Refuge area most susceptible to intrusion was on the western side where canal water intrusion was shown to extend 5 km (3.1 miles) into the marsh under certain conditions. The higher west-side intrusion may reflect the generally higher surface water inflows on the west side compared to what was experienced on the east side during the study period, and the west side's low topography.

The relative difference between marsh and canal stages was an important driver of water movement and intrusion. The relative difference was determined by comparing water levels at one interior marsh gage (1-7) and one canal gage (1-8C). Stage data from only one area of the marsh and canal limits our ability to assess relative canal/marsh stage differences at all locations around the canal, but provides a useful way to compare stages. When marsh stage was > 0.2 m (> 0.6 ft) higher than canal stage and net Refuge outflow was small, water from the marsh interior moved toward the canal and intrusion was minimal, approximately 0.5 km (0.3 miles) into the marsh. When marsh stage was > 0.3 m (> 1.0 ft) higher than canal stage, the extent of intrusion was lower, approximately 0.2 km (0.1 miles) into the marsh. When marsh stage was higher than canal stage for more than 10 days, high inflow events > 14,137 L $s^{-1}$ (> 500 cfs) for fewer than 5 days did not significantly increase canal water intrusion.

Under the range of hydrological conditions experienced during the period of record, intrusion always was observed regardless of how much higher marsh stage was compared to canal stage (Chapter 2). When canal stage dropped below 4.7 m (15.5 ft) and marsh stage was 0.1 m (0.3 ft) higher, intrusion occurred from 1 to 3 km (0.6 to 1.9 miles) into the marsh. This finding is significant to water supply management because it has been suggested that when canal water levels are below 4.7 m (15.5 ft), little exchange of water between the canal and marsh occurs (Sylvester, 2004).

When canal stage was higher than marsh stage, intrusion occurred under all conditions of inflow and outflow. Intrusion extended more than 0.4 km (0.2 miles) into the marsh whenever canal stage was > 0.1 m (> 0.2 ft) higher than marsh stage. Even when canal stage was < 0.1 m (< 0.2 ft) higher than marsh stage and inflows and rainfall were low, intrusion occurred. Moderate surface water inflows < 11,310 L $s^{-1}$ (< 400 cfs), low stage difference, and low rainfall conditions resulted in intrusion up to 3.6 km (2.2 miles) into the marsh. When canal stage was > 0.1 m (> 0.2 ft) higher than marsh stage, and with a positive net flow into the Refuge, canal water intrusion extended at least 2.5 km (1.6 miles) into the marsh. When there were high inflow and low outflow conditions following a large rainfall event, intrusion extended 5 km (3.1 miles) into some areas of the Refuge. When inflow and outflow conditions were both high following a large rainfall event, there was less intrusion into the Refuge.

The hydrodynamic and water quality models under development (Section II, Chapter 3) will be used to address the influences of water depths, flow, and water quality under different water management scenarios. Initial development of the water budget model and the Cl mass balance model, has provided insight into mechanisms such as transpiration that affect the phosphorus mass balance model and the dynamic model performance. Because the mass balance models can be run very quickly, a wide range of inputs can be looked at for initial screening purposes. The more-complex dynamic model then can be used to evaluate a subset of those scenarios.

## Preliminary Water Management Recommendations

Water management operations affect patterns of intrusion, suggesting ways to minimize negative impacts by adjusting inflow and outflow rates and locations when possible, depending on relative marsh and canal stages (Chapter 2). Data analyses presented in this report, coupled with future scenario analyses using the models, will allow us to more fully develop water management recommendations. In addition to recommending operational strategies, these data and scenario analyses will provide information to identify potential linkages between canal water intrusion and any future high phosphorus events.

- If there are potential negative impacts of pump, structure, or STA operations, how can they be minimized or eliminated?

- When water supply releases from the eastern Refuge boundary are made up by increased Refuge inflows, what is the optimal pattern of structure operations? Should we continue to require that all make-up water be provided prior to water supply releases?
- When canal stages are below the interior marsh elevation, what are the impacts of water supply releases on interior surface water and groundwater conditions?

Some preliminary water management recommendations to minimize intrusion can be made from the results of the Refuge's enhanced water quality study. Preliminary recommendations based on Chapter 2 include:

- Refuge inflows should be short duration (≤ 5 days) pulses of < 5655 L $s^{-1}$ (< 200 cfs) when absolute canal/marsh stage difference is < 0.1 m (< 0.2 ft) and interior water depths are < 0.2 m (< 0.5 ft).

- Refuge inflow rates can be moderate 5655 to 11,310 L $s^{-1}$ (200 to 400 cfs) for short durations if marsh stage is > 0.2 m (> 0.6 ft) higher than canal stage by and waters depths are < 0.1 m (< 0.3 ft).

- Refuge inflows should be discontinued when the canal stage is > 0.1 m (> 0.2 ft) higher than marsh stage, unless the rainfall or outflow volumes are 3 to 4-times higher than the inflows.

- If Refuge inflows must be extended beyond short-duration pulses, outflow should be greater than inflow and last several days longer.

- If Refuge inflows must be maintained at high rates, the S-10s and S-39 should be opened to create outflow 3 or 4-times higher than inflow.

## Recommendations for Future Monitoring and Research

A number of recommendations for future monitoring and research have been identified as a result of the analyses conducted to date. The recommendations below are not necessarily in priority order.

***Recommendation:*** *Continue the expanded monitoring program long enough to document the water quality response to a full range of wet and dry conditions and high and low discharges. This recommendation likely will require monitoring past the current monitoring end date (September 2007).*

This report summarizes data collected from June 2004 through December 2005. Significant information has been collected on canal water intrusion, water quality characterization of the previously uncharacterized area of the marsh, and on development of modeling tools. The biggest limitation of the data collected to date is that they span a limited range of the water management operations and environmental conditions that the Refuge experiences. In particular, limited data have been collected under conditions when STA-1E is discharging. The only way to address this limitation is to continue the monitoring through both wet and dry years and under a range of water management operations. Currently, field sampling is planned to continue through September 2007, providing an additional 21 months of data; however, there is no guarantee that the complete range of hydrological and water management conditions will be experienced in that sampling window.

We had planned to refine the parameter list and to reduce the number of sampling sites in the second year of the study. The parameter list was refined in 2005 (Surratt 2005), resulting in a reduction of the number of parameters measured. A subsequent analysis was conducted to examine whether there were technical reasons to reduce the number of sampling sites. It was concluded that no stations should be eliminated from the network presently for several reasons. First, the period of record, while long enough for preliminary statistical analysis, did not capture a full range of environmental conditions in the Refuge. Second, sampling sites from the expanded network are being considered for incorporation into the State's Class III water quality monitoring network, which has not yet been finalized. Additionally, downstream monitoring requirements for STA-1W and STA-1E permits have not been finalized and structural modifications to the L-40 are being planned. As such, it is premature to eliminate sampling sites that may provide water quality information critical to these efforts.

***Recommendation:*** *Add at least one more sampling site each to the ACME-1 and ACME-2 transects to monitor potential changes in intrusion resulting from planned diversion and construction projects.*

The use of continuously collected conductivity data to track water movement within the Refuge marsh has proven to be a sensitive, reliable, and cost-effective methodology. The existing transects cover areas immediately adjacent to S-6, STA-1W, STA-1E, and ACME-1 and ACME-2; however, the transects adjacent to ACME-1 and ACME-2 only extend 1.2 and 1.5 km (0.7 and 0.9 miles) into the marsh, respectively. Based on data collected from other transects, these transects should be extended to at least 5 km (3.1 miles) into the marsh to document the potential extent of canal water intrusion. This documentation is important when considering potential changes that may occur with STA-1E discharges and the planned construction of a berm along the marsh perimeter at the outflow of the STA-1E discharge. We suspect that hydraulic changes resulting from the berm will push water farther south of the berm and these waters will then intrude into the marsh near our ACME-1 and ACME-2 transects, which are both too short to monitor the potential full extent of canal water intrusion.

***Recommendation:*** *Add three transect of five sondes each to the sampling program: one in the north just south of S5-A extending 4.5 km (2.8 miles) into the marsh; one in the southwest from S10-D extending 4.5 km (2.8 miles) to LOX16; and one in the southeast from G-94A extending 4.0 km (2.5 miles) to west of LOX14.*

The original work plan focused on establishing sampling stations adjacent to outflows. Because of this focus, two areas of the marsh have not been included – the northern-most and the southern-most regions of the marsh. Based on analyses presented in Chapters 1 and 2 that show how variable intrusion can be in different parts of the marsh, it is apparent that monitoring needs to be extended in these areas. One transect of five stations should extend from the most northern canal edge (just south of the S-5A discharge cell) south to at least 4.5 km (2.8 miles) into the marsh interior. Establishment of this transect is important to understand patterns of intrusion related to bypass through G-300 and G-301. Although this northern area is drier, the limited data available show it to be especially vulnerable to canal water intrusion. Modeling results show that shallower areas are likely to experience greater distances of canal water penetration following increases in canal stage (Waldon 2006).

Two transects should be added in the south. One should extend from L-39 at S-10D to LOX16, 4.5 km (2.8 miles) into the marsh interior. A second transect should be added from L-40, extending from the G-94A culvert to about 4 km (2.5 miles) west of LOX14. These two southern transects would be located in an area that generally has low total phosphorus concentrations and experiences limited intrusion.

Establishing these additional transects will help us ensure that operational and structural changes designed to improve conditions in part of the marsh are not resulting in unintended negative impacts in other parts of the marsh. Additional transects also will provide a better spatial coverage of data for calibrating the models.

***Recommendation:*** *Establish additional grab sample stations between the canal and 0.5 km (0.3 miles) into the marsh, located downstream of inflows.*

Canal water intrusion regularly occurs between the canal and 0.5 km (0.3 miles) into the marsh (Chapters 1 and 2). Currently, only two of the monthly grab sample stations are within this zone and four of the transects analyzed in Chapter 2 do not have stations within this zone There is concern that a lack of stations within this zone will make it more difficult to better characterize spatial and temporal patterns of intrusion. This 0.5 km-wide (0.3 mile-wide) zone represents approximately 7% of the Refuge, and it is important its water quality be well-characterized.

***Recommendation:*** *Include measurements of the physical and chemical characteristics of floc at selected locations and times.*

Floc potentially is a major component of the Refuge's phosphorus budget (Chapter 1). An increased understanding of the physical and chemical characteristics of floc would contribute substantially to our understanding of overall marsh phosphorus dynamics.

- To what degree do weather (e.g., wind, rain) and hydrological factors (e.g., depth, rise or recession rates) affect the resuspension of floc into the clear water column?
- What is the settling rate for floc, and how is it affected by the above factors? How variable is this settling rate?
- Does floc significantly move (advect) with surface water flows? Is floc velocity slower than the velocity of water and dissolved constituents?
- Is the TP concentration in floc interstitial water elevated? If yes, does resuspension and re-settling of the floc result in elevated clear-water TP concentrations?
- What physical and water quality parameters are associated with floc layer thickness?
- Is floc resuspension associated with high TP events?

***Recommendation:*** *Include the Depth to Consolidated Substrate (DCS) in DBHYDRO.*

Our initial investigation of floc layer thickness leads to the conclusion that DCS should be added as a parameter in Everglades water quality databases, including DBHYDRO. At the present time, DCS is measured during water quality sampling in WCA-1 and WCA-2. However, these valuable observations that are required for calculation of floc layer thickness are not entered into DBHYDRO from field notes.

***Recommendation:*** *Establish six additional rain gages within the interior marsh to provide better data for modeling.*

Precipitation has been identified as a factor for which additional information could greatly improve model performance. Precipitation is variable across the Refuge, and model input presently is based on data from rain gages in and around the Refuge. Only five of these stations are in the Refuge, and most of those are either on the east side or along the canals. The addition of six rain gages within the Refuge interior would greatly enhance the spatial coverage of rainfall data and performance of the model.

***Recommendation:*** *Initiate studies to determine ET in different vegetative communities and the relative contribution of evaporation and transpiration to ET values in those communities.*

Evapotranspiration has proven to be a significant factor contributing to variation in model performance. In particular, more information is needed on the variability of ET across different vegetative communities and on the relative contributions of evaporation and transpiration to ET.

***Recommendation:*** *Measure canal velocity and discharge upstream and downstream of STA-1E and STA-1W discharges during periods of medium and high flow, and install continuous velocity monitoring equipment at the 1-8C gage.*

Currently, the model calculates the volume of flow going north and south from each STA discharge site. Information on the actual amount of water and its velocity going north and south during medium and high flows will greatly improve our confidence in model performance, as will continuous data collected at the 1-8C gage.

***Recommendation:*** *Continue to facilitate and support work being conducted by USGS and others on ecological effects of water quality on Refuge communities.*

Research designed to link Refuge water quality and ecological effects is not part of the scope of the expanded monitoring program. Work presently funded and conducted by USGS will help provide some of those linkages, and will be reported separately. In late 2006, a post-doctoral research associate was hired as part of the Refuge's program to support the USGS ecological effects research.

***Recommendation:*** *Conduct Refuge-wide vegetation and sediment phosphorus mapping every five years, and initiate yearly vegetation monitoring at existing water quality sampling stations.*

There are important information gaps that, if filled, would enhance our ability to recommend water management practices that will best protect Refuge resources. For example, we know that vegetation can be negatively impacted by the combined effects of poor water quality and too little or too much water, yet we have very little monitoring data that helps us to tease apart water quality and quantity impacts. Two scales of monitoring trends would help to address this question, one is a large scale across space and time – the entire Refuge every five years, and the other is smaller scale – yearly vegetation monitoring at each station. The SFWMD is working on a Refuge-wide vegetation map using 2003/2004 images. Additionally, the SFWMD has constructed a Refuge-wide sediment phosphorus map. Both of these maps will provide baseline information to which future maps can be compared.

***Recommendation:*** *Develop a Refuge-specific Habitat Suitability Index (HSI) for periphyton. This index will require collection of baseline data as well as evaluation of existing information.*

Habitat suitability indices are another tool that will be helpful in evaluating whether current and future water quality conditions are similar to conditions that occurred historically and to evaluate if no degradation is occurring (as related to the Refuge's Outstanding Florida Waters designation). In particular, the development of a periphyton HSI will provide an ecological tool that, when linked with the hydrologic model, will provide projections on expected ecological responses given different water management scenarios.

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# Appendices

**Appendix 1-1** Summary statistics of water quality data for 2004 (January – December) and 2005 (January – December) for individual EVPA and LOXA stations.

**Appendix 1-2** Summary statistics of monthly water quality data (January 2004 – December 2005) by zone.

**Appendix 1-3** Time series of structure discharges with corresponding water quality conditions of total phosphorus and specific conductivity for the five LOXA canal stations.

# Appendix 1-1

Individual EVPA and LOXA station summary statistics of water quality data for 2004 (January – December) and 2005 (January – December). Where values were below the minimum detection limits, a value of one half of the minimum detection limit is reported (sensu Weaver and Payne 2006).

| Site - Year | STAT | ALK | APA | Ca | Cl | COLOR | D-O | DOC | HARD | K | Mg | N02 | N03 | Na | NH4 | NOX | OPO4 | Ph_F | SiO2 | SO4 | SpC | T_PO4 | TDKN | TDS | TEMP | TKN | TOC | TSS | TURB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | mg/L | nM/minmL | mg/L | mg/L | PCU | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | units | mg/L | mg/L | uS/cm | mg/L | mg/L | mg/L | Deg.C | mg/L | mg/L | mg/L | mg/L |
| | Count | 2 | 1 | 2 | 2 | 2 | 7 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 8 | 2 | 2 | 8 | 7 | 2 | 2 | 8 | 1 | 1 | 2 | 2 |
| | Average | 7.50 | 40.00 | 4.25 | 14.90 | 156.50 | 5.30 | 22.00 | 16.35 | 0.80 | 1.40 | 0.01 | 0.01 | 9.10 | 0.02 | 0.01 | 0.01 | 6.69 | 2.45 | 0.13 | 119.49 | 0.02 | 1.22 | 82.50 | 19.80 | 1.31 | 24.00 | 3.75 | 0.95 |
| LOX3-2004 | StdDev | 0.71 | | 0.07 | 1.13 | 7.78 | 1.77 | 0.00 | 0.49 | 0.00 | 0.00 | 0.00 | 0.01 | 0.14 | 0.00 | 0.00 | 0.00 | 0.86 | 0.43 | 0.11 | 32.55 | 0.01 | 0.11 | 2.12 | 4.52 | | | 3.18 | 0.21 |
| | Min | 7.00 | 40.00 | 4.20 | 14.10 | 151.00 | 3.06 | 22.00 | 16.00 | 0.80 | 1.40 | 0.01 | 0.00 | 9.00 | 0.02 | 0.01 | 0.01 | 5.13 | 2.14 | 0.05 | 74.70 | 0.01 | 1.14 | 81.00 | 14.00 | 1.31 | 24.00 | 1.50 | 0.80 |
| | Max | 8.00 | 40.00 | 4.30 | 15.70 | 162.00 | 7.29 | 22.00 | 16.70 | 0.80 | 1.40 | 0.01 | 0.01 | 9.20 | 0.02 | 0.02 | 0.01 | 7.49 | 2.75 | 0.20 | 165.70 | 0.04 | 1.30 | 84.00 | 25.40 | 1.31 | 24.00 | 6.00 | 1.10 |
| | Count | 0 | 0 | 0 | 3 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 3 | 4 | 4 | 0 | 0 | 5 | 0 | 0 | 0 | 0 |
| | Average | | | | 22.77 | | 5.09 | | | | | | | | | | | 6.32 | | 0.30 | 102.03 | 0.01 | | | 24.24 | | | | |
| LOX3-2005 | StdDev | | | | 1.46 | | 0.99 | | | | | | | | | | | 0.27 | | 0.10 | 15.92 | 0.00 | | | 4.64 | | | | |
| | Min | | | | 21.60 | | 3.81 | | | | | | | | | | | 6.07 | | 0.20 | 78.60 | 0.01 | | | 16.60 | | | | |
| | Max | | | | 24.40 | | 6.19 | | | | | | | | | | | 6.69 | | 0.40 | 114.00 | 0.01 | | | 28.00 | | | | |
| | Count | 7 | 6 | 7 | 7 | 7 | 6 | 7 | 7 | 7 | 7 | 7 | 3 | 7 | 7 | 7 | 7 | 8 | 7 | 7 | 8 | 8 | 7 | 7 | 8 | 7 | 7 | 7 | 7 |
| | Average | 104.00 | 17.33 | 30.73 | 58.80 | 125.43 | 4.25 | 26.14 | 113.60 | 4.61 | 8.94 | 0.00 | 0.00 | 39.57 | 0.01 | 0.00 | 0.01 | 6.68 | 12.29 | 5.47 | 479.50 | 0.02 | 1.24 | 295.14 | 20.85 | 1.52 | 26.71 | 5.21 | 2.81 |
| LOX4-2004 | StdDev | 21.89 | 11.18 | 8.39 | 14.51 | 19.65 | 1.22 | 2.61 | 29.12 | 2.24 | 2.07 | 0.00 | 0.00 | 8.67 | 0.01 | 0.00 | 0.00 | 0.39 | 7.45 | 5.17 | 220.72 | 0.02 | 0.18 | 70.98 | 5.10 | 0.44 | 3.30 | 5.69 | 4.29 |
| | Min | 74.00 | 4.00 | 20.30 | 42.40 | 108.00 | 3.01 | 22.00 | 76.90 | 1.40 | 6.40 | 0.00 | 0.00 | 30.50 | 0.00 | 0.00 | 0.00 | 6.03 | 4.06 | 1.50 | 284.00 | 0.01 | 0.99 | 209.00 | 14.70 | 1.19 | 22.00 | 1.50 | 0.50 |
| | Max | 131.00 | 31.00 | 39.90 | 80.20 | 167.00 | 6.28 | 30.00 | 151.00 | 6.90 | 12.40 | 0.01 | 0.00 | 54.10 | 0.02 | 0.01 | 0.01 | 7.23 | 22.80 | 15.40 | 970.00 | 0.05 | 1.55 | 408.00 | 29.30 | 2.47 | 32.00 | 17.00 | 12.30 |
| | Count | 6 | 5 | 6 | 10 | 6 | 10 | 6 | 6 | 6 | 6 | 6 | 5 | 6 | 6 | 6 | 6 | 10 | 6 | 10 | 9 | 10 | 6 | 6 | 12 | 6 | 6 | 6 | 6 |
| | Average | 92.00 | 14.40 | 28.23 | 54.02 | 133.17 | 4.86 | 27.83 | 103.63 | 4.17 | 8.05 | 0.00 | 0.00 | 38.37 | 0.01 | 0.01 | 0.00 | 6.91 | 7.19 | 1.74 | 332.54 | 0.01 | 1.34 | 273.67 | 24.24 | 1.43 | 28.50 | 3.25 | 0.97 |
| LOX4-2005 | StdDev | 25.65 | 3.78 | 8.23 | 27.33 | 18.94 | 2.21 | 4.62 | 30.55 | 1.97 | 2.42 | 0.00 | 0.00 | 15.14 | 0.01 | 0.00 | 0.00 | 0.36 | 2.52 | 0.85 | 132.38 | 0.01 | 0.28 | 87.25 | 5.75 | 0.42 | 4.97 | 4.29 | 0.27 |
| | Min | 56.00 | 9.00 | 16.70 | 22.10 | 113.00 | 2.19 | 23.00 | 60.30 | 1.40 | 4.50 | 0.00 | 0.00 | 17.40 | 0.00 | 0.00 | 0.00 | 6.52 | 3.81 | 0.80 | 194.30 | 0.01 | 1.03 | 115.00 | 17.30 | 1.02 | 24.00 | 1.50 | 0.60 |
| | Max | 120.00 | 18.00 | 37.80 | 94.50 | 167.00 | 9.00 | 33.00 | 138.00 | 6.60 | 10.70 | 0.01 | 0.01 | 55.20 | 0.03 | 0.01 | 0.01 | 7.80 | 10.20 | 3.20 | 533.00 | 0.03 | 1.62 | 362.00 | 34.40 | 2.01 | 34.00 | 12.00 | 1.40 |
| | Count | 4 | 3 | 4 | 4 | 4 | 6 | 4 | 4 | 4 | 4 | 4 | 2 | 4 | 4 | 4 | 4 | 6 | 4 | 4 | 6 | 6 | 4 | 4 | 6 | 4 | 4 | 4 | 4 |
| | Average | 10.00 | 126.67 | 5.50 | 24.23 | 89.75 | 5.08 | 23.25 | 21.35 | 0.78 | 1.88 | 0.00 | 0.01 | 14.25 | 0.01 | 0.01 | 0.01 | 6.29 | 2.47 | 0.08 | 110.83 | 0.01 | 1.51 | 116.50 | 20.20 | 1.83 | 24.75 | 12.50 | 3.50 |
| LOX5-2004 | StdDev | 3.16 | 70.81 | 1.47 | 7.34 | 52.94 | 1.92 | 1.71 | 5.69 | 0.10 | 0.46 | 0.00 | 0.00 | 4.00 | 0.01 | 0.01 | 0.00 | 0.72 | 0.81 | 0.03 | 24.90 | 0.01 | 0.28 | 32.07 | 4.20 | 0.48 | 2.50 | 10.41 | 2.16 |
| | Min | 7.00 | 45.00 | 4.00 | 15.00 | 36.00 | 2.82 | 21.00 | 15.40 | 0.70 | 1.40 | 0.00 | 0.01 | 9.40 | 0.00 | 0.01 | 0.01 | 5.02 | 1.56 | 0.05 | 73.90 | 0.01 | 1.27 | 83.00 | 15.10 | 1.39 | 22.00 | 4.00 | 0.90 |
| | Max | 14.00 | 171.00 | 7.40 | 30.90 | 141.00 | 7.91 | 25.00 | 28.40 | 0.90 | 2.40 | 0.01 | 0.01 | 18.10 | 0.02 | 0.03 | 0.01 | 6.93 | 3.49 | 0.10 | 141.00 | 0.03 | 1.83 | 150.00 | 25.50 | 2.40 | 28.00 | 27.00 | 6.20 |
| | Count | 0 | 0 | 0 | 5 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 5 | 5 | 5 | 0 | 0 | 6 | 0 | 0 | 0 | 0 |
| | Average | | | | 23.98 | | 5.06 | | | | | | | | | | | 6.18 | | 0.06 | 114.36 | 0.01 | | | 25.52 | | | | |
| LOX5-2005 | StdDev | | | | 2.35 | | 0.43 | | | | | | | | | | | 0.06 | | 0.02 | 9.85 | 0.00 | | | 4.70 | | | | |
| | Min | | | | 20.20 | | 4.39 | | | | | | | | | | | 6.10 | | 0.05 | 98.50 | 0.01 | | | 17.00 | | | | |
| | Max | | | | 26.50 | | 5.57 | | | | | | | | | | | 6.25 | | 0.10 | 124.00 | 0.01 | | | 29.90 | | | | |
| | Count | 8 | 8 | 8 | 8 | 8 | 9 | 8 | 8 | 8 | 8 | 8 | 2 | 8 | 8 | 7 | 8 | 9 | 8 | 8 | 9 | 9 | 8 | 8 | 9 | 8 | 8 | 8 | 8 |
| | Average | 53.50 | 31.25 | 20.56 | 40.85 | 93.00 | 4.02 | 20.25 | 73.83 | 1.96 | 5.46 | 0.00 | 0.02 | 27.13 | 0.18 | 0.01 | 0.00 | 6.89 | 5.83 | 14.70 | 277.43 | 0.01 | 1.50 | 192.25 | 20.68 | 1.59 | 20.25 | 1.50 | 0.55 |
| LOX6-2004 | StdDev | 8.96 | 11.60 | 6.47 | 6.15 | 59.44 | 2.07 | 7.87 | 21.33 | 0.81 | 1.30 | 0.00 | 0.03 | 4.07 | 0.50 | 0.01 | 0.00 | 0.34 | 4.24 | 28.58 | 69.63 | 0.00 | 1.25 | 62.71 | 4.74 | 1.28 | 7.44 | 0.00 | 0.11 |
| | Min | 35.00 | 14.00 | 15.60 | 30.50 | 41.00 | 1.29 | 15.00 | 56.10 | 1.00 | 4.20 | 0.00 | 0.00 | 20.30 | 0.00 | 0.00 | 0.00 | 6.43 | 1.14 | 0.60 | 196.00 | 0.01 | 0.93 | 148.00 | 15.10 | 0.98 | 16.00 | 1.50 | 0.40 |
| | Max | 62.00 | 48.00 | 36.20 | 50.90 | 224.00 | 7.75 | 39.00 | 125.00 | 3.40 | 8.50 | 0.01 | 0.04 | 33.40 | 1.41 | 0.04 | 0.01 | 7.57 | 11.90 | 84.30 | 444.00 | 0.02 | 4.58 | 342.00 | 29.10 | 4.74 | 38.00 | 1.50 | 0.70 |
| | Count | 9 | 9 | 9 | 10 | 9 | 10 | 9 | 9 | 9 | 9 | 9 | 1 | 9 | 9 | 8 | 9 | 10 | 8 | 10 | 9 | 10 | 9 | 9 | 12 | 9 | 9 | 9 | 9 |
| | Average | 51.89 | 50.56 | 17.06 | 36.29 | 72.89 | 4.66 | 17.22 | 61.02 | 1.77 | 4.48 | 0.00 | 0.00 | 22.11 | 0.01 | 0.01 | 0.00 | 6.94 | 5.82 | 1.72 | 243.14 | 0.01 | 1.09 | 159.56 | 23.34 | 1.15 | 17.33 | 1.50 | 0.63 |
| LOX6-2005 | StdDev | 19.04 | 19.59 | 6.17 | 18.16 | 11.13 | 1.66 | 3.60 | 22.72 | 0.79 | 1.79 | 0.00 | | 10.87 | 0.01 | 0.01 | 0.00 | 0.27 | 4.95 | 0.97 | 93.29 | 0.00 | 0.14 | 67.97 | 4.57 | 0.14 | 3.57 | 0.00 | 0.21 |
| | Min | 30.00 | 21.00 | 9.60 | 13.50 | 54.00 | 1.12 | 13.00 | 33.60 | 0.80 | 2.40 | 0.00 | 0.00 | 9.70 | 0.00 | 0.00 | 0.00 | 6.54 | 0.17 | 0.70 | 114.00 | 0.01 | 0.89 | 84.00 | 16.60 | 0.95 | 13.00 | 1.50 | 0.40 |
| | Max | 81.00 | 87.00 | 25.80 | 56.90 | 89.00 | 7.39 | 22.00 | 92.20 | 3.20 | 7.20 | 0.00 | 0.00 | 36.20 | 0.02 | 0.04 | 0.00 | 7.46 | 13.60 | 3.90 | 344.70 | 0.01 | 1.28 | 250.00 | 28.90 | 1.32 | 22.00 | 1.50 | 1.10 |
| | Count | 7 | 6 | 7 | 7 | 7 | 8 | 7 | 7 | 7 | 7 | 7 | 1 | 7 | 7 | 7 | 7 | 10 | 7 | 7 | 10 | 10 | 7 | 7 | 10 | 7 | 7 | 7 | 7 |
| | Average | 13.14 | 44.50 | 6.93 | 24.86 | 100.29 | 4.96 | 22.14 | 24.99 | 0.80 | 1.87 | 0.00 | 0.01 | 14.54 | 0.01 | 0.01 | 0.01 | 6.28 | 4.98 | 0.26 | 140.34 | 0.01 | 1.03 | 124.57 | 21.73 | 1.31 | 22.43 | 4.79 | 1.16 |
| LOX7-2004 | StdDev | 0.90 | 22.88 | 0.57 | 3.95 | 31.10 | 2.77 | 1.95 | 2.37 | 0.31 | 0.25 | 0.00 | | 2.14 | 0.01 | 0.01 | 0.00 | 0.50 | 1.64 | 0.24 | 49.66 | 0.00 | 0.45 | 19.81 | 4.77 | 0.18 | 1.90 | 8.05 | 0.67 |
| | Min | 12.00 | 28.00 | 6.10 | 18.40 | 62.00 | 0.53 | 19.00 | 21.40 | 0.40 | 1.50 | 0.00 | 0.01 | 10.60 | 0.00 | 0.00 | 0.00 | 5.30 | 2.76 | 0.05 | 97.00 | 0.01 | 0.03 | 98.00 | 15.30 | 1.13 | 20.00 | 1.50 | 0.60 |
| | Max | 14.00 | 74.00 | 7.70 | 30.70 | 149.00 | 8.71 | 25.00 | 28.20 | 1.30 | 2.20 | 0.01 | 0.01 | 17.20 | 0.02 | 0.02 | 0.01 | 7.23 | 7.46 | 0.70 | 266.90 | 0.02 | 1.30 | 155.00 | 30.50 | 1.65 | 25.00 | 23.00 | 2.50 |
| | Count | 8 | 7 | 8 | 10 | 8 | 10 | 8 | 8 | 8 | 8 | 8 | 2 | 8 | 8 | 7 | 8 | 10 | 7 | 10 | 9 | 10 | 8 | 8 | 12 | 8 | 8 | 8 | 8 |
| | Average | 11.25 | 38.86 | 6.28 | 26.16 | 90.63 | 3.69 | 19.88 | 23.04 | 0.89 | 1.81 | 0.00 | 0.01 | 13.23 | 0.01 | 0.01 | 0.00 | 6.14 | 4.14 | 0.35 | 127.22 | 0.01 | 1.15 | 114.00 | 24.20 | 1.29 | 20.38 | 1.50 | 0.90 |
| LOX7-2005 | StdDev | 3.28 | 9.99 | 1.65 | 10.76 | 8.67 | 1.70 | 3.76 | 5.96 | 0.33 | 0.46 | 0.00 | 0.01 | 4.05 | 0.00 | 0.01 | 0.00 | 0.17 | 0.65 | 0.12 | 49.72 | 0.01 | 0.18 | 37.34 | 4.64 | 0.30 | 3.62 | 0.00 | 0.24 |
| | Min | 7.00 | 31.00 | 4.40 | 12.50 | 82.00 | 0.97 | 15.00 | 15.80 | 0.50 | 1.20 | 0.00 | 0.00 | 7.80 | 0.00 | 0.00 | 0.00 | 5.98 | 2.97 | 0.20 | 71.00 | 0.01 | 0.86 | 57.00 | 17.50 | 0.90 | 16.00 | 1.50 | 0.60 |
| | Max | 17.00 | 60.00 | 9.00 | 44.10 | 106.00 | 6.77 | 27.00 | 32.70 | 1.50 | 2.50 | 0.00 | 0.02 | 19.20 | 0.02 | 0.02 | 0.00 | 6.52 | 4.82 | 0.60 | 217.00 | 0.02 | 1.44 | 164.00 | 30.40 | 1.76 | 27.00 | 1.50 | 1.20 |
| | Count | 9 | 8 | 9 | 9 | 9 | 8 | 9 | 9 | 9 | 9 | 9 | 4 | 9 | 9 | 9 | 9 | 10 | 9 | 9 | 10 | 10 | 9 | 9 | 10 | 9 | 9 | 9 | 9 |
| | Average | 10.44 | 49.88 | 5.74 | 23.29 | 77.78 | 5.53 | 22.56 | 21.72 | 0.58 | 1.80 | 0.00 | 0.00 | 13.54 | 0.01 | 0.01 | 0.00 | 6.23 | 3.53 | 0.07 | 128.41 | 0.01 | 1.32 | 114.00 | 21.76 | 1.53 | 23.00 | 3.61 | 1.04 |
| LOX8-2004 | StdDev | 2.51 | 13.84 | 1.09 | 6.21 | 29.90 | 2.50 | 3.28 | 3.96 | 0.19 | 0.37 | 0.00 | 0.01 | 3.25 | 0.02 | 0.00 | 0.00 | 0.65 | 0.93 | 0.03 | 53.51 | 0.01 | 0.20 | 34.08 | 4.87 | 0.49 | 3.35 | 5.46 | 0.59 |
| | Min | 8.00 | 30.00 | 4.40 | 15.50 | 47.00 | 1.09 | 18.00 | 16.70 | 0.20 | 1.40 | 0.00 | 0.00 | 9.60 | 0.00 | 0.00 | 0.00 | 5.17 | 2.16 | 0.05 | 79.20 | 0.01 | 1.02 | 77.00 | 14.80 | 1.16 | 19.00 | 1.50 | 0.50 |
| | Max | 16.00 | 69.00 | 7.60 | 36.40 | 135.00 | 8.57 | 30.00 | 28.20 | 0.80 | 2.60 | 0.01 | 0.01 | 19.90 | 0.06 | 0.02 | 0.01 | 7.67 | 5.53 | 0.10 | 260.40 | 0.03 | 1.71 | 188.00 | 30.30 | 2.73 | 31.00 | 18.00 | 2.50 |
| | Count | 10 | 9 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 | 10 | 10 | 10 | 10 | 10 | 9 | 10 | 8 | 10 | 10 | 10 | 12 | 10 | 10 | 10 | 10 |
| | Average | 9.30 | 46.11 | 5.55 | 23.87 | 75.10 | 4.98 | 22.40 | 21.71 | 0.82 | 1.91 | 0.00 | 0.09 | 14.14 | 0.01 | 0.01 | 0.00 | 6.19 | 3.91 | 0.13 | 105.53 | 0.01 | 1.33 | 113.80 | 24.07 | 1.46 | 22.50 | 2.35 | 1.25 |
| LOX8-2005 | StdDev | 2.36 | 10.89 | 1.00 | 7.49 | 12.43 | 1.35 | 4.27 | 3.97 | 0.27 | 0.37 | 0.00 | | 3.85 | 0.00 | 0.03 | 0.00 | 0.19 | 1.77 | 0.12 | 24.81 | 0.00 | 0.21 | 32.91 | 4.81 | 0.33 | 4.17 | 2.69 | 0.75 |
| | Min | 7.00 | 21.00 | 3.90 | 14.40 | 67.00 | 3.04 | 16.00 | 15.40 | 0.60 | 1.40 | 0.00 | 0.09 | 8.90 | 0.00 | 0.00 | 0.00 | 5.90 | 1.70 | 0.05 | 75.00 | 0.01 | 1.01 | 46.00 | 17.60 | 1.11 | 16.00 | 1.50 | 0.50 |
| | Max | 13.00 | 58.00 | 6.80 | 35.90 | 108.00 | 6.93 | 28.00 | 27.20 | 1.40 | 2.50 | 0.01 | 0.09 | 20.00 | 0.01 | 0.09 | 0.01 | 6.47 | 5.94 | 0.40 | 145.50 | 0.02 | 1.64 | 160.00 | 31.10 | 2.09 | 28.00 | 10.00 | 3.10 |

| Site - Year | STAT | ALK | APA | Ca | Cl | COLOR | D-O | DOC | HARD | K | Mg | N02 | N03 | Na | NH4 | NOX | OPO4 | Ph_F | SiO2 | SO4 | SpC | T_PO4 | TDKN | TDS | TEMP | TKN | TOC | TSS | TURB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | mg/L | nM/minmL | mg/L | mg/L | PCU | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | units | mg/L | mg/L | uS/cm | mg/L | mg/L | mg/L | Deg.C | mg/L | mg/L | mg/L | mg/L |
| | Count | 5 | 4 | 5 | 5 | 5 | 6 | 5 | 5 | 5 | 5 | 5 | 1 | 5 | 5 | 5 | 5 | 8 | 5 | 5 | 8 | 8 | 5 | 5 | 8 | 5 | 5 | 5 | 5 |
| | Average | 19.40 | 63.00 | 5.82 | 23.02 | 54.40 | 4.87 | 18.40 | 24.44 | 1.10 | 2.40 | 0.00 | 0.00 | 14.88 | 0.01 | 0.01 | 0.01 | 6.33 | 4.56 | 0.06 | 127.95 | 0.01 | 1.16 | 119.20 | 20.91 | 1.28 | 18.60 | 3.30 | 1.04 |
| LOX9-2004 | StdDev | 8.20 | 15.98 | 1.83 | 7.43 | 20.43 | 2.08 | 2.30 | 7.86 | 0.32 | 0.81 | 0.00 | | 4.85 | 0.00 | 0.01 | 0.00 | 0.56 | 1.51 | 0.02 | 40.67 | 0.00 | 0.23 | 39.10 | 6.03 | 0.20 | 2.07 | 3.25 | 0.65 |
| | Min | 9.00 | 43.00 | 3.80 | 14.30 | 39.00 | 2.64 | 16.00 | 15.30 | 0.60 | 1.40 | 0.00 | 0.00 | 9.00 | 0.00 | 0.00 | 0.01 | 5.16 | 3.01 | 0.05 | 75.50 | 0.01 | 0.89 | 59.00 | 14.20 | 1.06 | 16.00 | 1.50 | 0.50 |
| | Max | 29.00 | 82.00 | 8.40 | 29.80 | 81.00 | 8.09 | 21.00 | 34.80 | 1.40 | 3.30 | 0.00 | 0.00 | 19.50 | 0.01 | 0.02 | 0.01 | 6.92 | 6.92 | 0.10 | 200.00 | 0.02 | 1.46 | 162.00 | 31.70 | 1.57 | 21.00 | 9.00 | 2.10 |
| | Count | 2 | 2 | 2 | 7 | 2 | 7 | 2 | 2 | 2 | 2 | 2 | 0 | 2 | 2 | 2 | 2 | 7 | 2 | 7 | 6 | 7 | 2 | 2 | 8 | 2 | 2 | 2 | 2 |
| | Average | 18.00 | 44.50 | 6.70 | 24.07 | 54.00 | 4.49 | 18.50 | 27.00 | 1.10 | 2.50 | 0.00 | | 15.35 | 0.01 | 0.01 | 0.00 | 6.34 | 5.12 | 0.08 | 123.87 | 0.01 | 1.21 | 139.00 | 25.55 | 1.28 | 19.00 | 1.50 | 0.80 |
| LOX9-2005 | StdDev | 2.83 | 3.54 | 0.00 | 5.05 | 5.66 | 1.08 | 0.71 | 0.00 | 0.14 | 0.00 | 0.00 | | 0.92 | 0.01 | 0.00 | 0.00 | 0.09 | 0.91 | 0.06 | 21.74 | 0.00 | 0.05 | 46.67 | 4.71 | 0.10 | 0.00 | 0.00 | 0.28 |
| | Min | 16.00 | 42.00 | 6.70 | 15.30 | 50.00 | 2.92 | 18.00 | 27.00 | 1.00 | 2.50 | 0.00 | | 14.70 | 0.00 | 0.00 | 0.00 | 6.19 | 4.47 | 0.05 | 85.40 | 0.01 | 1.17 | 106.00 | 18.30 | 1.21 | 19.00 | 1.50 | 0.60 |
| | Max | 20.00 | 47.00 | 6.70 | 30.70 | 58.00 | 5.75 | 19.00 | 27.00 | 1.20 | 2.50 | 0.00 | | 16.00 | 0.02 | 0.01 | 0.00 | 6.42 | 5.76 | 0.20 | 149.00 | 0.01 | 1.24 | 172.00 | 30.10 | 1.35 | 19.00 | 1.50 | 1.00 |
| | Count | 6 | 5 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 2 | 6 | 6 | 6 | 6 | 8 | 6 | 6 | 8 | 8 | 6 | 6 | 8 | 6 | 6 | 6 | 6 |
| | Average | 52.50 | 21.00 | 14.72 | 35.98 | 73.33 | 3.85 | 17.83 | 58.63 | 2.40 | 5.32 | 0.00 | 0.00 | 24.68 | 0.01 | 0.01 | 0.00 | 6.57 | 6.03 | 3.57 | 250.86 | 0.01 | 0.96 | 175.17 | 20.26 | 1.14 | 18.00 | 5.83 | 1.37 |
| LOX10-2004 | StdDev | 19.04 | 7.25 | 5.01 | 15.61 | 25.48 | 1.26 | 1.94 | 21.05 | 0.84 | 2.07 | 0.00 | 0.00 | 10.37 | 0.01 | 0.00 | 0.00 | 0.49 | 4.66 | 3.06 | 112.01 | 0.00 | 0.12 | 48.82 | 5.37 | 0.30 | 2.19 | 8.22 | 1.32 |
| | Min | 29.00 | 13.00 | 8.00 | 16.30 | 48.00 | 2.42 | 15.00 | 30.80 | 1.30 | 2.60 | 0.00 | 0.00 | 11.10 | 0.00 | 0.00 | 0.00 | 5.50 | 0.66 | 0.90 | 111.80 | 0.01 | 0.79 | 95.00 | 13.50 | 0.81 | 15.00 | 1.50 | 0.50 |
| | Max | 74.00 | 31.00 | 20.40 | 54.10 | 105.00 | 6.14 | 20.00 | 82.30 | 3.40 | 7.60 | 0.01 | 0.00 | 35.80 | 0.02 | 0.01 | 0.01 | 7.17 | 13.60 | 9.30 | 443.00 | 0.02 | 1.06 | 224.00 | 28.20 | 1.68 | 21.00 | 22.00 | 4.00 |
| | Count | 3 | 3 | 3 | 9 | 3 | 9 | 3 | 3 | 3 | 3 | 3 | 0 | 3 | 3 | 3 | 3 | 9 | 3 | 9 | 8 | 9 | 3 | 3 | 10 | 3 | 3 | 3 | 3 |
| | Average | 41.67 | 32.33 | 11.97 | 25.47 | 79.67 | 3.78 | 17.00 | 46.50 | 1.33 | 4.03 | 0.00 | | 14.13 | 0.01 | 0.01 | 0.00 | 6.70 | 9.60 | 1.91 | 180.95 | 0.01 | 0.91 | 152.00 | 21.97 | 0.93 | 17.00 | 1.50 | 0.77 |
| LOX10-2005 | StdDev | 3.21 | 13.58 | 1.01 | 10.60 | 9.87 | 1.12 | 1.73 | 4.33 | 0.29 | 0.47 | 0.00 | | 2.18 | 0.00 | 0.01 | 0.00 | 0.20 | 2.43 | 0.44 | 63.41 | 0.00 | 0.06 | 32.05 | 5.04 | 0.03 | 1.73 | 0.00 | 0.15 |
| | Min | 38.00 | 24.00 | 10.80 | 13.60 | 73.00 | 2.33 | 15.00 | 41.50 | 1.00 | 3.50 | 0.00 | | 11.70 | 0.00 | 0.00 | 0.00 | 6.52 | 6.79 | 1.40 | 104.00 | 0.01 | 0.84 | 115.00 | 15.60 | 0.90 | 15.00 | 1.50 | 0.60 |
| | Max | 44.00 | 48.00 | 12.60 | 42.10 | 91.00 | 5.31 | 18.00 | 49.20 | 1.50 | 4.40 | 0.00 | | 15.90 | 0.01 | 0.02 | 0.00 | 7.13 | 11.10 | 2.70 | 276.00 | 0.02 | 0.96 | 171.00 | 28.10 | 0.95 | 18.00 | 1.50 | 0.90 |
| | Count | 7 | 6 | 7 | 7 | 7 | 10 | 7 | 7 | 7 | 7 | 7 | 2 | 7 | 7 | 7 | 7 | 10 | 7 | 7 | 10 | 10 | 7 | 7 | 10 | 7 | 7 | 7 | 7 |
| | Average | 11.29 | 53.00 | 6.53 | 19.04 | 78.00 | 4.21 | 18.43 | 21.91 | 0.26 | 1.37 | 0.00 | 0.00 | 10.76 | 0.02 | 0.01 | 0.00 | 6.50 | 2.90 | 0.06 | 115.60 | 0.01 | 1.00 | 88.43 | 21.39 | 1.18 | 19.00 | 2.50 | 0.79 |
| LOX11-2004 | StdDev | 2.93 | 21.85 | 1.55 | 5.36 | 31.56 | 2.48 | 2.15 | 5.13 | 0.05 | 0.31 | 0.00 | 0.00 | 2.71 | 0.03 | 0.01 | 0.00 | 0.42 | 1.76 | 0.02 | 47.40 | 0.00 | 0.14 | 22.10 | 4.56 | 0.19 | 2.45 | 2.06 | 0.18 |
| | Min | 8.00 | 32.00 | 4.70 | 11.90 | 42.00 | 0.88 | 15.00 | 15.90 | 0.20 | 1.00 | 0.00 | 0.00 | 7.10 | 0.00 | 0.00 | 0.00 | 6.00 | 0.90 | 0.05 | 67.00 | 0.01 | 0.78 | 58.00 | 14.70 | 0.98 | 15.00 | 1.50 | 0.60 |
| | Max | 15.00 | 82.00 | 8.50 | 25.30 | 128.00 | 8.46 | 22.00 | 28.50 | 0.30 | 1.80 | 0.01 | 0.01 | 14.20 | 0.09 | 0.03 | 0.01 | 7.10 | 5.10 | 0.10 | 225.20 | 0.02 | 1.22 | 115.00 | 29.30 | 1.46 | 23.00 | 7.00 | 1.00 |
| | Count | 9 | 9 | 9 | 10 | 9 | 10 | 9 | 9 | 9 | 9 | 9 | 0 | 9 | 9 | 8 | 9 | 10 | 8 | 10 | 6 | 10 | 9 | 9 | 12 | 9 | 9 | 9 | 9 |
| | Average | 10.89 | 52.00 | 6.54 | 21.12 | 66.67 | 3.50 | 19.56 | 22.68 | 0.38 | 1.52 | 0.00 | | 12.33 | 0.01 | 0.01 | 0.00 | 6.08 | 2.28 | 0.10 | 98.63 | 0.01 | 1.07 | 97.78 | 23.72 | 1.35 | 20.00 | 3.06 | 1.11 |
| LOX11-2005 | StdDev | 4.17 | 15.93 | 2.03 | 4.66 | 10.90 | 1.72 | 3.21 | 6.25 | 0.12 | 0.26 | 0.00 | | 2.53 | 0.01 | 0.01 | 0.00 | 0.27 | 1.52 | 0.06 | 20.57 | 0.01 | 0.18 | 39.37 | 4.46 | 0.52 | 3.24 | 3.33 | 0.90 |
| | Min | 5.00 | 27.00 | 3.60 | 14.30 | 54.00 | 1.40 | 14.00 | 13.40 | 0.20 | 1.10 | 0.00 | | 8.30 | 0.00 | 0.00 | 0.00 | 5.72 | 0.34 | 0.05 | 70.00 | 0.01 | 0.83 | 55.00 | 16.80 | 0.92 | 15.00 | 1.50 | 0.50 |
| | Max | 16.00 | 81.00 | 8.70 | 28.50 | 91.00 | 6.24 | 23.00 | 29.40 | 0.60 | 1.80 | 0.00 | | 15.90 | 0.03 | 0.02 | 0.01 | 6.48 | 4.39 | 0.20 | 123.20 | 0.03 | 1.36 | 190.00 | 30.00 | 2.64 | 24.00 | 11.00 | 3.40 |
| | Count | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 1 | 12 | 12 | 11 | 12 | 12 | 12 | 12 | 11 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| | Average | 62.67 | 17.00 | 17.12 | 38.70 | 61.33 | 4.62 | 17.75 | 66.70 | 1.98 | 5.83 | 0.00 | 0.00 | 26.37 | 0.02 | 0.00 | 0.00 | 7.07 | 8.13 | 1.74 | 267.29 | 0.01 | 1.02 | 178.42 | 23.29 | 1.54 | 17.75 | 10.92 | 2.91 |
| LOX12-2004 | StdDev | 12.21 | 7.70 | 3.19 | 11.92 | 18.48 | 2.06 | 3.52 | 12.68 | 0.48 | 1.17 | 0.00 | | 7.44 | 0.02 | 0.00 | 0.00 | 0.37 | 3.67 | 0.72 | 59.04 | 0.01 | 0.24 | 33.55 | 4.76 | 1.01 | 3.31 | 25.85 | 7.13 |
| | Min | 45.00 | 6.00 | 12.50 | 19.90 | 40.00 | 2.01 | 14.00 | 47.60 | 1.40 | 4.00 | 0.00 | 0.00 | 14.50 | 0.00 | 0.00 | 0.00 | 6.69 | 1.77 | 1.10 | 158.10 | 0.01 | 0.81 | 121.00 | 15.80 | 0.88 | 14.00 | 1.50 | 0.40 |
| | Max | 81.00 | 32.00 | 21.30 | 54.90 | 91.00 | 7.91 | 24.00 | 83.40 | 2.60 | 7.30 | 0.00 | 0.00 | 36.00 | 0.08 | 0.02 | 0.01 | 8.02 | 14.90 | 3.30 | 332.10 | 0.05 | 1.48 | 234.00 | 30.20 | 4.18 | 24.00 | 92.00 | 25.50 |
| | Count | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 | 10 | 10 | 9 | 10 | 10 | 9 | 10 | 9 | 10 | 10 | 10 | 12 | 10 | 10 | 10 | 10 |
| | Average | 48.90 | 17.40 | 13.81 | 25.84 | 58.00 | 5.26 | 15.80 | 53.22 | 1.32 | 4.57 | 0.00 | 0.01 | 18.04 | 0.01 | 0.00 | 0.00 | 6.87 | 6.28 | 1.15 | 197.09 | 0.01 | 0.91 | 119.70 | 24.50 | 1.02 | 15.90 | 2.75 | 0.59 |
| LOX12-2005 | StdDev | 14.27 | 6.70 | 3.66 | 7.18 | 9.89 | 1.78 | 2.20 | 14.16 | 0.33 | 1.21 | 0.00 | | 5.07 | 0.00 | 0.00 | 0.00 | 0.33 | 3.16 | 0.53 | 44.03 | 0.00 | 0.07 | 47.63 | 4.44 | 0.20 | 2.02 | 3.95 | 0.15 |
| | Min | 27.00 | 10.00 | 8.10 | 15.80 | 45.00 | 2.73 | 12.00 | 31.10 | 0.80 | 2.70 | 0.00 | 0.01 | 11.00 | 0.00 | 0.00 | 0.00 | 6.38 | 3.21 | 0.40 | 118.00 | 0.01 | 0.76 | 39.00 | 18.10 | 0.80 | 12.00 | 1.50 | 0.30 |
| | Max | 68.00 | 31.00 | 18.60 | 35.20 | 76.00 | 7.49 | 18.00 | 72.40 | 1.80 | 6.30 | 0.00 | 0.01 | 25.00 | 0.02 | 0.01 | 0.00 | 7.22 | 11.40 | 2.20 | 254.20 | 0.02 | 0.99 | 182.00 | 30.50 | 1.57 | 18.00 | 14.00 | 0.80 |
| | Count | 9 | 9 | 9 | 9 | 9 | 10 | 9 | 9 | 9 | 9 | 9 | 3 | 9 | 9 | 9 | 9 | 10 | 9 | 9 | 10 | 10 | 9 | 9 | 10 | 9 | 9 | 9 | 9 |
| | Average | 14.44 | 50.33 | 7.29 | 19.76 | 73.56 | 4.16 | 20.00 | 24.02 | 0.50 | 1.42 | 0.00 | 0.01 | 11.01 | 0.24 | 0.01 | 0.00 | 6.39 | 3.25 | 0.09 | 110.91 | 0.01 | 1.38 | 100.11 | 21.72 | 1.54 | 20.33 | 1.50 | 0.83 |
| LOX13-2004 | StdDev | 4.42 | 17.37 | 1.90 | 6.17 | 32.45 | 2.73 | 6.63 | 6.11 | 0.46 | 0.33 | 0.00 | 0.00 | 2.82 | 0.47 | 0.01 | 0.00 | 0.27 | 2.54 | 0.07 | 35.06 | 0.00 | 0.87 | 31.40 | 4.00 | 0.89 | 6.60 | 0.00 | 0.20 |
| | Min | 12.00 | 28.00 | 5.80 | 14.00 | 36.00 | 0.87 | 16.00 | 18.80 | 0.20 | 1.10 | 0.00 | 0.00 | 8.30 | 0.00 | 0.00 | 0.00 | 6.12 | 0.35 | 0.05 | 79.90 | 0.01 | 0.92 | 73.00 | 15.80 | 0.98 | 16.00 | 1.50 | 0.50 |
| | Max | 26.00 | 78.00 | 12.10 | 34.30 | 121.00 | 8.70 | 37.00 | 39.30 | 1.70 | 2.20 | 0.01 | 0.01 | 17.70 | 1.44 | 0.04 | 0.01 | 6.89 | 8.54 | 0.20 | 186.00 | 0.01 | 3.67 | 179.00 | 28.70 | 3.85 | 37.00 | 1.50 | 1.10 |
| | Count | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 0 | 8 | 8 | 7 | 8 | 8 | 8 | 8 | 4 | 8 | 8 | 8 | 10 | 8 | 8 | 8 | 8 |
| | Average | 12.75 | 53.50 | 7.08 | 19.69 | 63.00 | 4.54 | 18.13 | 23.68 | 0.40 | 1.46 | 0.00 | #DIV/0! | 11.38 | 0.01 | 0.01 | 0.00 | 6.21 | 2.23 | 0.13 | 101.03 | 0.01 | 1.08 | 97.00 | 23.57 | 1.29 | 18.63 | 2.69 | 1.30 |
| LOX13-2005 | StdDev | 3.96 | 20.41 | 1.76 | 3.09 | 10.80 | 1.93 | 2.47 | 5.14 | 0.12 | 0.20 | 0.00 | #DIV/0! | 1.75 | 0.01 | 0.00 | 0.00 | 0.28 | 1.80 | 0.14 | 18.22 | 0.00 | 0.12 | 22.60 | 4.54 | 0.33 | 2.67 | 3.36 | 1.04 |
| | Min | 6.00 | 32.00 | 4.00 | 15.10 | 48.00 | 1.77 | 14.00 | 14.80 | 0.20 | 1.10 | 0.00 | 0.00 | 8.80 | 0.00 | 0.00 | 0.00 | 5.78 | 0.20 | 0.05 | 75.00 | 0.01 | 0.94 | 57.00 | 17.60 | 1.00 | 14.00 | 1.50 | 0.70 |
| | Max | 16.00 | 89.00 | 8.30 | 23.00 | 76.00 | 7.13 | 21.00 | 27.20 | 0.60 | 1.60 | 0.00 | 0.00 | 13.20 | 0.02 | 0.01 | 0.01 | 6.54 | 4.78 | 0.40 | 116.00 | 0.01 | 1.23 | 128.00 | 29.70 | 1.89 | 22.00 | 11.00 | 3.80 |
| | Count | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 3 | 10 | 10 | 9 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| | Average | 47.10 | 17.90 | 16.64 | 35.50 | 81.70 | 3.59 | 18.70 | 59.71 | 1.62 | 4.40 | 0.00 | 0.01 | 22.75 | 0.02 | 0.01 | 0.00 | 6.65 | 4.11 | 5.98 | 228.37 | 0.01 | 0.95 | 165.50 | 21.63 | 1.07 | 18.90 | 1.75 | 0.59 |
| LOX14-2004 | StdDev | 25.16 | 7.68 | 10.12 | 20.45 | 21.92 | 1.70 | 3.92 | 38.85 | 1.76 | 3.29 | 0.00 | 0.00 | 14.31 | 0.03 | 0.02 | 0.00 | 0.21 | 4.28 | 13.40 | 145.56 | 0.00 | 0.27 | 82.32 | 4.14 | 0.33 | 4.01 | 0.79 | 0.25 |
| | Min | 32.00 | 8.00 | 10.50 | 20.50 | 52.00 | 1.65 | 15.00 | 36.90 | 0.60 | 2.50 | 0.00 | 0.00 | 13.00 | 0.00 | 0.00 | 0.00 | 6.32 | 0.71 | 0.60 | 133.00 | 0.01 | 0.77 | 100.00 | 15.70 | 0.79 | 15.00 | 1.50 | 0.30 |
| | Max | 116.00 | 30.00 | 44.80 | 89.80 | 115.00 | 6.23 | 27.00 | 168.00 | 6.50 | 13.60 | 0.01 | 0.01 | 61.20 | 0.09 | 0.06 | 0.01 | 7.02 | 14.90 | 44.00 | 628.00 | 0.01 | 1.63 | 391.00 | 28.80 | 1.72 | 27.00 | 4.00 | 1.10 |
| | Count | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 4 | 10 | 10 | 9 | 10 | 10 | 9 | 10 | 8 | 10 | 10 | 10 | 11 | 10 | 10 | 10 | 10 |
| | Average | 47.70 | 16.10 | 16.21 | 30.91 | 84.20 | 4.31 | 17.60 | 57.26 | 1.37 | 4.08 | 0.00 | 0.01 | 20.24 | 0.01 | 0.01 | 0.00 | 6.71 | 4.92 | 1.94 | 217.53 | 0.01 | 0.87 | 133.30 | 23.81 | 0.98 | 17.70 | 1.95 | 0.50 |
| LOX14-2005 | StdDev | 12.07 | 4.41 | 3.37 | 5.38 | 14.70 | 1.32 | 1.26 | 12.03 | 0.44 | 0.90 | 0.00 | 0.01 | 3.51 | 0.00 | 0.00 | 0.00 | 0.14 | 3.26 | 0.60 | 28.91 | 0.00 | 0.06 | 33.10 | 4.71 | 0.17 | 1.49 | 1.42 | 0.11 |
| | Min | 30.00 | 11.00 | 11.10 | 20.40 | 67.00 | 2.36 | 16.00 | 38.10 | 0.80 | 2.50 | 0.00 | 0.00 | 12.80 | 0.00 | 0.00 | 0.00 | 6.44 | 1.10 | 1.10 | 180.00 | 0.01 | 0.77 | 73.00 | 17.50 | 0.81 | 16.00 | 1.50 | 0.30 |
| | Max | 66.00 | 25.00 | 21.50 | 39.30 | 107.00 | 6.49 | 20.00 | 75.10 | 1.90 | 5.20 | 0.01 | 0.02 | 25.40 | 0.02 | 0.01 | 0.00 | 6.94 | 9.38 | 3.00 | 249.00 | 0.01 | 0.96 | 187.00 | 30.20 | 1.40 | 20.00 | 6.00 | 0.60 |

| Site - Year | STAT | ALK | APA | Ca | Cl | COLOR | D-O | DOC | HARD | K | Mg | N02 | N03 | Na | NH4 | NOX | OPO4 | Ph_F | SiO2 | SO4 | SpC | T_PO4 | TDKN | TDS | TEMP | TKN | TOC | TSS | TURB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | mg/L | nM/minmL | mg/L | mg/L | PCU | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | units | mg/L | mg/L | uS/cm | mg/L | mg/L | mg/L | Deg.C | mg/L | mg/L | mg/L | mg/L |
| | Count | 10 | 10 | 10 | 10 | 10 | 11 | 10 | 10 | 10 | 10 | 10 | 3 | 10 | 10 | 9 | 10 | 11 | 10 | 10 | 11 | 11 | 10 | 10 | 11 | 10 | 10 | 10 | 10 |
| | Average | 107.80 | 15.50 | 31.86 | 63.15 | 60.00 | 4.18 | 20.30 | 124.40 | 3.72 | 10.89 | 0.00 | 0.01 | 43.51 | 0.03 | 0.01 | 0.00 | 7.12 | 9.94 | 17.37 | 462.85 | 0.01 | 1.22 | 297.00 | 22.93 | 1.32 | 20.60 | 1.50 | 0.61 |
| LOX15-2004 | StdDev | 41.68 | 3.81 | 13.02 | 30.38 | 16.97 | 1.63 | 3.77 | 53.45 | 1.99 | 5.15 | 0.00 | 0.00 | 20.49 | 0.02 | 0.01 | 0.00 | 0.29 | 5.43 | 15.92 | 192.06 | 0.01 | 0.21 | 121.35 | 4.53 | 0.20 | 3.95 | 0.00 | 0.10 |
| | Min | 58.00 | 10.00 | 17.20 | 27.90 | 38.00 | 1.37 | 16.00 | 65.40 | 1.80 | 5.40 | 0.00 | 0.01 | 21.10 | 0.00 | 0.00 | 0.00 | 6.54 | 2.23 | 2.10 | 223.00 | 0.00 | 0.96 | 171.00 | 15.50 | 1.16 | 16.00 | 1.50 | 0.50 |
| | Max | 170.00 | 21.00 | 50.00 | 107.00 | 82.00 | 6.14 | 27.00 | 202.00 | 7.20 | 19.30 | 0.00 | 0.01 | 74.40 | 0.07 | 0.02 | 0.01 | 7.46 | 19.30 | 51.70 | 761.00 | 0.03 | 1.63 | 480.00 | 30.10 | 1.82 | 27.00 | 1.50 | 0.80 |
| | Count | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 2 | 10 | 10 | 9 | 10 | 10 | 9 | 10 | 9 | 10 | 10 | 10 | 12 | 10 | 10 | 10 | 10 |
| | Average | 90.60 | 15.60 | 26.95 | 47.04 | 56.70 | 5.30 | 18.80 | 103.00 | 2.72 | 8.68 | 0.00 | 0.02 | 33.22 | 0.02 | 0.01 | 0.00 | 7.20 | 6.83 | 10.95 | 386.48 | 0.01 | 1.15 | 230.60 | 24.94 | 1.23 | 19.20 | 1.50 | 0.59 |
| LOX15-2005 | StdDev | 38.43 | 5.38 | 11.43 | 19.30 | 2.71 | 1.23 | 2.53 | 43.56 | 1.34 | 3.68 | 0.00 | 0.03 | 13.50 | 0.02 | 0.01 | 0.00 | 0.22 | 2.66 | 7.71 | 140.47 | 0.00 | 0.15 | 88.43 | 4.60 | 0.14 | 2.66 | 0.00 | 0.18 |
| | Min | 31.00 | 8.00 | 9.90 | 20.30 | 54.00 | 4.20 | 14.00 | 37.60 | 1.00 | 3.10 | 0.00 | 0.00 | 13.10 | 0.00 | 0.00 | 0.00 | 6.80 | 3.56 | 1.50 | 171.00 | 0.01 | 0.88 | 98.00 | 18.20 | 0.93 | 14.00 | 1.50 | 0.40 |
| | Max | 153.00 | 23.00 | 46.50 | 79.50 | 61.00 | 7.76 | 23.00 | 179.00 | 5.40 | 15.40 | 0.00 | 0.04 | 55.80 | 0.06 | 0.05 | 0.01 | 7.46 | 10.60 | 25.80 | 605.20 | 0.01 | 1.41 | 363.00 | 32.00 | 1.45 | 24.00 | 1.50 | 1.00 |
| | Count | 9 | 9 | 9 | 9 | 9 | 10 | 9 | 9 | 9 | 9 | 9 | 2 | 9 | 8 | 8 | 9 | 10 | 9 | 9 | 10 | 10 | 9 | 9 | 10 | 9 | 9 | 9 | 9 |
| | Average | 42.56 | 17.22 | 14.42 | 34.14 | 85.89 | 2.09 | 17.89 | 54.11 | 1.63 | 4.40 | 0.00 | 0.01 | 22.16 | 0.01 | 0.01 | 0.00 | 6.55 | 5.27 | 5.68 | 207.53 | 0.01 | 0.91 | 158.89 | 21.65 | 0.99 | 18.22 | 1.78 | 0.67 |
| LOX16-2004 | StdDev | 29.08 | 7.87 | 9.91 | 24.86 | 32.77 | 1.42 | 4.62 | 42.48 | 2.02 | 4.35 | 0.00 | 0.00 | 17.93 | 0.01 | 0.01 | 0.00 | 0.23 | 4.97 | 13.76 | 162.55 | 0.00 | 0.28 | 100.35 | 4.08 | 0.34 | 4.68 | 0.83 | 0.37 |
| | Min | 24.00 | 8.00 | 8.20 | 15.00 | 47.00 | 0.33 | 13.00 | 28.00 | 0.30 | 1.80 | 0.00 | 0.00 | 8.90 | 0.00 | 0.00 | 0.00 | 6.22 | 0.38 | 0.20 | 96.80 | 0.01 | 0.68 | 89.00 | 15.40 | 0.72 | 13.00 | 1.50 | 0.40 |
| | Max | 118.00 | 31.00 | 40.20 | 97.20 | 134.00 | 4.65 | 28.00 | 165.00 | 6.80 | 15.80 | 0.01 | 0.01 | 68.20 | 0.02 | 0.02 | 0.01 | 7.02 | 16.90 | 42.30 | 654.00 | 0.02 | 1.62 | 415.00 | 29.00 | 1.83 | 28.00 | 4.00 | 1.30 |
| | Count | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 2 | 10 | 10 | 9 | 10 | 10 | 9 | 10 | 8 | 10 | 10 | 10 | 12 | 10 | 10 | 10 | 10 |
| | Average | 41.40 | 17.30 | 13.67 | 29.13 | 81.40 | 3.41 | 16.90 | 48.88 | 1.04 | 3.57 | 0.00 | 0.00 | 19.04 | 0.01 | 0.01 | 0.00 | 6.54 | 4.27 | 1.09 | 194.91 | 0.01 | 0.84 | 110.80 | 23.98 | 0.92 | 17.20 | 1.65 | 0.59 |
| LOX16-2005 | StdDev | 9.71 | 4.74 | 2.31 | 5.13 | 12.95 | 1.47 | 1.79 | 8.73 | 0.29 | 0.73 | 0.00 | 0.00 | 3.26 | 0.01 | 0.00 | 0.00 | 0.13 | 2.34 | 0.40 | 25.45 | 0.00 | 0.08 | 27.54 | 4.68 | 0.12 | 2.04 | 0.47 | 0.17 |
| | Min | 30.00 | 9.00 | 10.90 | 20.10 | 66.00 | 1.73 | 15.00 | 36.70 | 0.70 | 2.30 | 0.00 | 0.00 | 12.60 | 0.00 | 0.00 | 0.00 | 6.32 | 0.97 | 0.60 | 165.00 | 0.01 | 0.72 | 67.00 | 17.30 | 0.77 | 14.00 | 1.50 | 0.30 |
| | Max | 60.00 | 25.00 | 18.00 | 35.80 | 105.00 | 6.72 | 20.00 | 65.00 | 1.50 | 4.80 | 0.00 | 0.01 | 23.10 | 0.02 | 0.01 | 0.00 | 6.74 | 7.04 | 2.00 | 229.50 | 0.01 | 0.93 | 160.00 | 30.80 | 1.09 | 20.00 | 3.00 | 0.80 |
| | Count | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 2 | 4 | 4 | 3 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| | Average | 173.75 | 3.75 | 54.53 | 73.35 | 165.00 | 0.84 | 30.00 | 199.75 | 8.10 | 15.35 | 0.01 | 0.01 | 51.00 | 0.02 | 0.01 | 0.01 | 7.07 | 27.43 | 24.53 | 629.00 | 0.03 | 1.70 | 427.50 | 23.95 | 1.76 | 33.25 | 1.88 | 0.90 |
| LOXA101-2004 | StdDev | 18.19 | 2.22 | 3.31 | 16.59 | 42.03 | 0.27 | 2.94 | 15.80 | 0.77 | 2.32 | 0.00 | 0.00 | 10.66 | 0.00 | 0.01 | 0.01 | 0.08 | 6.92 | 7.05 | 81.78 | 0.02 | 0.15 | 69.57 | 3.64 | 0.14 | 7.85 | 0.75 | 0.47 |
| | Min | 152.00 | 2.00 | 50.60 | 49.20 | 122.00 | 0.61 | 27.00 | 188.00 | 7.30 | 12.70 | 0.00 | 0.00 | 35.60 | 0.01 | 0.00 | 0.01 | 6.99 | 17.40 | 14.60 | 525.00 | 0.01 | 1.53 | 332.00 | 19.40 | 1.63 | 29.00 | 1.50 | 0.60 |
| | Max | 196.00 | 7.00 | 58.70 | 85.30 | 204.00 | 1.14 | 34.00 | 222.00 | 8.90 | 18.30 | 0.01 | 0.01 | 59.40 | 0.02 | 0.02 | 0.03 | 7.15 | 33.10 | 29.60 | 724.00 | 0.05 | 1.87 | 499.00 | 27.40 | 1.89 | 45.00 | 3.00 | 1.60 |
| | Count | 4 | 4 | 4 | 8 | 4 | 7 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 8 | 4 | 8 | 8 | 8 | 4 | 4 | 8 | 4 | 4 | 4 | 4 |
| | Average | 150.00 | 5.75 | 42.70 | 80.96 | 174.50 | 3.03 | 31.50 | 158.98 | 6.55 | 12.75 | 0.01 | 0.02 | 49.13 | 0.01 | 0.02 | 0.00 | 6.98 | 21.68 | 8.69 | 588.75 | 0.02 | 1.55 | 381.50 | 21.84 | 1.63 | 31.75 | 1.50 | 0.80 |
| LOXA101-2005 | StdDev | 45.84 | 0.96 | 14.81 | 28.59 | 17.64 | 1.40 | 3.11 | 54.63 | 1.87 | 4.33 | 0.00 | 0.02 | 18.81 | 0.00 | 0.02 | 0.00 | 0.22 | 8.81 | 9.14 | 174.44 | 0.02 | 0.30 | 127.18 | 4.61 | 0.38 | 2.63 | 0.00 | 0.29 |
| | Min | 94.00 | 5.00 | 26.80 | 38.90 | 159.00 | 1.65 | 27.00 | 99.90 | 3.80 | 8.00 | 0.01 | 0.00 | 27.10 | 0.01 | 0.01 | 0.00 | 6.63 | 10.20 | 0.90 | 318.00 | 0.01 | 1.23 | 236.00 | 15.80 | 1.31 | 28.00 | 1.50 | 0.50 |
| | Max | 206.00 | 7.00 | 62.60 | 125.00 | 197.00 | 4.93 | 34.00 | 232.00 | 7.90 | 18.50 | 0.01 | 0.05 | 72.80 | 0.02 | 0.06 | 0.01 | 7.24 | 31.00 | 29.20 | 802.00 | 0.06 | 1.96 | 544.00 | 28.40 | 2.18 | 34.00 | 1.50 | 1.10 |
| | Count | 3 | 3 | 3 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 2 | 3 | 3 | 3 | 4 | 4 | 4 | 3 | 3 | 4 | 3 | 3 | 3 | 3 |
| | Average | 150.67 | 7.67 | 48.27 | 64.55 | 158.67 | 1.14 | 29.00 | 182.70 | 6.83 | 15.17 | 0.01 | 0.01 | 52.13 | 0.02 | 0.01 | 0.01 | 6.91 | 26.53 | 25.85 | 522.88 | 0.01 | 1.64 | 400.33 | 23.65 | 1.69 | 34.33 | 1.50 | 1.33 |
| LOXA102-2004 | StdDev | 77.86 | 2.08 | 26.53 | 43.26 | 35.39 | 0.76 | 10.54 | 101.35 | 3.01 | 8.67 | 0.00 | 0.00 | 32.24 | 0.01 | 0.01 | 0.00 | 0.26 | 12.98 | 25.36 | 324.98 | 0.00 | 0.66 | 244.22 | 4.13 | 0.68 | 17.90 | 0.00 | 1.10 |
| | Min | 67.00 | 6.00 | 18.40 | 32.70 | 119.00 | 0.43 | 19.00 | 71.10 | 3.40 | 6.20 | 0.01 | 0.00 | 24.40 | 0.01 | 0.01 | 0.00 | 6.61 | 15.90 | 4.50 | 254.50 | 0.01 | 0.94 | 146.00 | 18.30 | 0.95 | 19.00 | 1.50 | 0.70 |
| | Max | 221.00 | 10.00 | 69.10 | 127.00 | 187.00 | 1.94 | 40.00 | 269.00 | 9.00 | 23.50 | 0.01 | 0.01 | 87.50 | 0.03 | 0.01 | 0.01 | 7.10 | 41.00 | 54.50 | 952.00 | 0.02 | 2.26 | 633.00 | 27.00 | 2.30 | 54.00 | 1.50 | 2.60 |
| | Count | 3 | 3 | 3 | 7 | 3 | 6 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 7 | 3 | 7 | 7 | 7 | 3 | 3 | 7 | 3 | 3 | 3 | 3 |
| | Average | 84.33 | 19.00 | 25.97 | 43.64 | 139.00 | 3.64 | 23.00 | 100.03 | 4.00 | 8.53 | 0.01 | 0.01 | 33.23 | 0.01 | 0.01 | 0.00 | 6.77 | 13.57 | 7.17 | 316.83 | 0.01 | 1.06 | 233.67 | 22.59 | 1.05 | 23.33 | 1.50 | 0.83 |
| LOXA102-2005 | StdDev | 48.23 | 17.58 | 14.43 | 22.28 | 26.51 | 1.29 | 1.73 | 57.25 | 1.59 | 5.10 | 0.00 | 0.00 | 23.77 | 0.00 | 0.00 | 0.00 | 0.18 | 2.15 | 9.59 | 145.97 | 0.00 | 0.34 | 120.44 | 4.77 | 0.35 | 1.53 | 0.00 | 0.21 |
| | Min | 55.00 | 6.00 | 16.80 | 25.50 | 116.00 | 1.66 | 22.00 | 63.40 | 2.80 | 5.20 | 0.00 | 0.00 | 17.70 | 0.00 | 0.01 | 0.00 | 6.55 | 11.90 | 2.30 | 200.20 | 0.01 | 0.86 | 146.00 | 15.60 | 0.84 | 22.00 | 1.50 | 0.60 |
| | Max | 140.00 | 39.00 | 42.60 | 89.90 | 168.00 | 4.84 | 25.00 | 166.00 | 5.80 | 14.40 | 0.01 | 0.01 | 60.60 | 0.01 | 0.02 | 0.01 | 7.04 | 16.00 | 28.80 | 624.00 | 0.02 | 1.46 | 371.00 | 29.30 | 1.45 | 25.00 | 1.50 | 1.00 |
| | Count | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| | Average | 127.75 | 5.75 | 39.95 | 69.63 | 150.00 | 1.15 | 29.25 | 154.05 | 6.15 | 13.18 | 0.01 | 0.00 | 50.00 | 0.01 | 0.01 | 0.01 | 6.93 | 22.86 | 24.95 | 534.80 | 0.01 | 1.54 | 390.50 | 23.28 | 1.58 | 32.75 | 1.50 | 1.08 |
| LOXA103-2004 | StdDev | 70.40 | 3.10 | 24.39 | 36.62 | 37.21 | 0.59 | 7.72 | 92.58 | 2.95 | 7.76 | 0.00 | 0.00 | 24.63 | 0.00 | 0.00 | 0.00 | 0.21 | 13.71 | 24.89 | 299.84 | 0.00 | 0.55 | 194.12 | 4.41 | 0.52 | 14.91 | 0.00 | 0.34 |
| | Min | 62.00 | 3.00 | 17.40 | 37.10 | 111.00 | 0.48 | 22.00 | 68.10 | 3.60 | 6.00 | 0.00 | 0.00 | 27.30 | 0.01 | 0.01 | 0.01 | 6.73 | 8.93 | 3.40 | 257.20 | 0.01 | 0.99 | 227.00 | 17.70 | 1.06 | 21.00 | 1.50 | 0.80 |
| | Max | 200.00 | 10.00 | 61.10 | 118.00 | 194.00 | 1.62 | 40.00 | 240.00 | 9.40 | 21.30 | 0.01 | 0.01 | 81.20 | 0.02 | 0.01 | 0.01 | 7.14 | 39.80 | 49.40 | 873.00 | 0.02 | 2.22 | 618.00 | 27.20 | 2.19 | 54.00 | 1.50 | 1.50 |
| | Count | 3 | 3 | 3 | 8 | 3 | 7 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 8 | 3 | 8 | 8 | 8 | 3 | 3 | 8 | 3 | 3 | 3 | 3 |
| | Average | 106.33 | 4.67 | 31.10 | 50.64 | 176.67 | 3.02 | 31.67 | 120.97 | 4.93 | 10.57 | 0.01 | 0.01 | 43.67 | 0.01 | 0.01 | 0.00 | 6.86 | 16.43 | 6.66 | 346.99 | 0.02 | 1.39 | 324.33 | 21.14 | 1.44 | 32.33 | 1.50 | 0.83 |
| LOXA103-2005 | StdDev | 41.31 | 2.08 | 14.46 | 23.48 | 56.54 | 1.54 | 5.13 | 54.60 | 1.29 | 4.53 | 0.00 | 0.00 | 17.15 | 0.00 | 0.00 | 0.00 | 0.29 | 2.38 | 10.45 | 155.46 | 0.01 | 0.14 | 106.40 | 5.02 | 0.18 | 5.03 | 0.00 | 0.25 |
| | Min | 81.00 | 3.00 | 22.50 | 21.10 | 119.00 | 1.36 | 26.00 | 88.30 | 4.00 | 7.80 | 0.01 | 0.00 | 32.40 | 0.00 | 0.01 | 0.00 | 6.42 | 14.30 | 1.00 | 166.20 | 0.01 | 1.26 | 257.00 | 14.20 | 1.27 | 27.00 | 1.50 | 0.60 |
| | Max | 154.00 | 7.00 | 47.80 | 93.90 | 232.00 | 5.72 | 36.00 | 184.00 | 6.40 | 15.80 | 0.01 | 0.01 | 63.40 | 0.01 | 0.02 | 0.01 | 7.28 | 19.00 | 32.20 | 676.00 | 0.04 | 1.54 | 447.00 | 28.60 | 1.63 | 37.00 | 1.50 | 1.10 |
| | Count | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 6 | 7 | 7 | 7 |
| | Average | 194.00 | 1.07 | 62.50 | 114.00 | 138.00 | 3.70 | 33.00 | 242.00 | 9.03 | 20.91 | 0.02 | 0.09 | 80.13 | 0.12 | 0.10 | 0.08 | 7.62 | 19.60 | 54.73 | 852.86 | 0.10 | 2.06 | 565.71 | 26.80 | 2.23 | 33.14 | 2.36 | 2.87 |
| LOXA104-2004 | StdDev | 18.07 | 0.45 | 12.20 | 32.97 | 58.66 | 1.99 | 6.22 | 28.76 | 2.18 | 2.33 | 0.02 | 0.09 | 22.02 | 0.09 | 0.10 | 0.09 | 0.32 | 3.83 | 11.63 | 99.59 | 0.09 | 0.36 | 53.37 | 2.11 | 0.36 | 5.27 | 1.70 | 2.24 |
| | Min | 161.00 | 0.50 | 42.70 | 80.10 | 86.00 | 0.31 | 27.00 | 202.00 | 7.40 | 16.80 | 0.01 | 0.00 | 58.80 | 0.04 | 0.01 | 0.01 | 7.26 | 11.90 | 34.50 | 713.00 | 0.02 | 1.61 | 475.00 | 22.60 | 1.84 | 28.00 | 1.50 | 1.50 |
| | Max | 214.00 | 2.00 | 77.80 | 175.00 | 218.00 | 6.40 | 46.00 | 281.00 | 13.30 | 23.70 | 0.05 | 0.24 | 121.00 | 0.33 | 0.30 | 0.22 | 8.03 | 22.60 | 68.20 | 1018.00 | 0.24 | 2.57 | 639.00 | 29.10 | 2.72 | 44.00 | 6.00 | 7.90 |
| | Count | 11 | 11 | 11 | 11 | 11 | 9 | 11 | 11 | 11 | 11 | 10 | 10 | 11 | 10 | 10 | 10 | 11 | 10 | 10 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| | Average | 244.18 | 1.95 | 83.15 | 132.66 | 124.73 | 3.99 | 33.91 | 308.09 | 8.75 | 24.42 | 0.03 | 0.32 | 93.28 | 0.12 | 0.35 | 0.06 | 7.61 | 20.25 | 65.24 | 1008.33 | 0.10 | 2.15 | 651.18 | 25.43 | 2.35 | 33.64 | 3.00 | 6.15 |
| LOXA104-2005 | StdDev | 42.79 | 1.31 | 17.74 | 25.65 | 38.39 | 1.77 | 7.38 | 65.21 | 1.47 | 5.23 | 0.04 | 0.38 | 20.04 | 0.21 | 0.41 | 0.05 | 0.20 | 7.03 | 22.76 | 190.29 | 0.05 | 0.59 | 156.41 | 5.09 | 0.55 | 7.78 | 2.16 | 4.22 |
| | Min | 178.00 | 0.50 | 59.90 | 91.70 | 73.00 | 0.89 | 22.00 | 218.00 | 7.30 | 16.60 | 0.00 | 0.00 | 64.10 | 0.01 | 0.00 | 0.01 | 7.16 | 8.53 | 39.10 | 722.00 | 0.06 | 1.32 | 386.00 | 17.70 | 1.55 | 21.00 | 1.50 | 2.20 |
| | Max | 315.00 | 5.00 | 112.00 | 182.00 | 188.00 | 7.19 | 43.00 | 419.00 | 11.50 | 34.00 | 0.11 | 1.26 | 135.00 | 0.70 | 1.32 | 0.16 | 7.89 | 27.80 | 100.00 | 1354.00 | 0.20 | 3.33 | 920.00 | 32.70 | 3.41 | 44.00 | 8.00 | 14.70 |

| Site - Year | STAT | ALK | APA | Ca | Cl | COLOR | D-O | DOC | HARD | K | Mg | N02 | N03 | Na | NH4 | NOX | OPO4 | Ph_F | SiO2 | SO4 | SpC | T_PO4 | TDKN | TDS | TEMP | TKN | TOC | TSS | TURB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | mg/L | nM/minmL | mg/L | mg/L | PCU | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | units | mg/L | mg/L | uS/cm | mg/L | mg/L | mg/L | Deg.C | mg/L | mg/L | mg/L | mg/L |
| | Count | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 2 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 |
| | Average | 173.00 | 1.88 | 59.00 | 76.20 | 174.50 | 0.65 | 30.25 | 215.00 | 7.90 | 16.43 | 0.01 | 0.00 | 53.60 | 0.02 | 0.01 | 0.05 | 6.77 | 23.23 | 40.25 | 662.13 | 0.08 | 1.75 | 458.75 | 23.75 | 2.27 | 30.25 | 1.88 | 2.58 |
| LOXA105-2004 | StdDev | 35.19 | 1.03 | 16.79 | 7.90 | 48.75 | 0.71 | 4.11 | 58.03 | 1.73 | 3.89 | 0.00 | 0.00 | 5.21 | 0.01 | 0.00 | 0.08 | 0.47 | 5.82 | 21.97 | 133.34 | 0.10 | 0.50 | 111.36 | 4.39 | 0.51 | 4.11 | 0.75 | 1.62 |
| | Min | 128.00 | 0.50 | 38.50 | 65.20 | 133.00 | 0.22 | 25.00 | 143.00 | 5.90 | 11.40 | 0.00 | 0.00 | 46.00 | 0.01 | 0.01 | 0.01 | 6.13 | 18.30 | 12.00 | 481.00 | 0.02 | 1.11 | 306.00 | 18.60 | 1.68 | 25.00 | 1.50 | 1.00 |
| | Max | 201.00 | 3.00 | 73.80 | 84.00 | 227.00 | 1.72 | 34.00 | 265.00 | 9.90 | 19.50 | 0.01 | 0.01 | 57.70 | 0.03 | 0.01 | 0.18 | 7.16 | 31.50 | 58.40 | 763.00 | 0.23 | 2.17 | 551.00 | 27.60 | 2.60 | 34.00 | 3.00 | 4.80 |
| | Count | 5 | 5 | 5 | 7 | 5 | 7 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 8 | 5 | 7 | 8 | 7 | 5 | 5 | 8 | 5 | 5 | 5 | 5 |
| | Average | 186.60 | 3.20 | 57.66 | 90.57 | 132.00 | 2.81 | 32.20 | 216.20 | 7.06 | 17.54 | 0.00 | 0.00 | 72.42 | 0.01 | 0.00 | 0.01 | 6.89 | 21.89 | 22.26 | 628.20 | 0.02 | 1.65 | 484.40 | 23.80 | 1.74 | 32.20 | 2.20 | 0.86 |
| LOXA105-2005 | StdDev | 57.16 | 1.64 | 19.68 | 39.23 | 3.54 | 1.55 | 6.22 | 73.75 | 1.35 | 5.93 | 0.00 | 0.00 | 23.55 | 0.02 | 0.00 | 0.00 | 0.16 | 9.04 | 19.45 | 250.79 | 0.01 | 0.41 | 163.96 | 6.87 | 0.34 | 6.50 | 1.57 | 0.15 |
| | Min | 122.00 | 2.00 | 35.30 | 44.80 | 129.00 | 1.32 | 25.00 | 132.00 | 5.50 | 10.70 | 0.00 | 0.00 | 46.60 | 0.00 | 0.00 | 0.00 | 6.62 | 9.85 | 4.90 | 332.80 | 0.01 | 1.17 | 298.00 | 14.70 | 1.31 | 25.00 | 1.50 | 0.70 |
| | Max | 238.00 | 6.00 | 73.60 | 141.00 | 138.00 | 5.30 | 38.00 | 273.00 | 8.30 | 22.10 | 0.01 | 0.00 | 95.80 | 0.04 | 0.01 | 0.01 | 7.15 | 30.60 | 58.90 | 942.10 | 0.04 | 1.98 | 631.00 | 36.40 | 2.03 | 40.00 | 5.00 | 1.10 |
| | Count | 3 | 3 | 3 | 4 | 3 | 4 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 2 | 3 | 4 | 3 | 4 | 4 | 4 | 3 | 3 | 4 | 3 | 3 | 3 | 3 |
| | Average | 160.33 | 4.33 | 53.93 | 63.60 | 178.00 | 0.94 | 29.33 | 199.67 | 7.37 | 15.87 | 0.01 | 0.00 | 50.73 | 0.02 | 0.01 | 0.01 | 6.67 | 25.93 | 29.60 | 549.20 | 0.02 | 1.65 | 450.00 | 23.23 | 1.67 | 29.00 | 1.50 | 1.30 |
| LOXA106-2004 | StdDev | 51.60 | 2.89 | 21.82 | 23.49 | 45.00 | 0.94 | 6.66 | 80.88 | 2.16 | 6.67 | 0.00 | 0.00 | 18.53 | 0.00 | 0.00 | 0.01 | 0.51 | 5.70 | 26.83 | 222.26 | 0.02 | 0.45 | 134.51 | 4.21 | 0.52 | 6.24 | 0.00 | 0.62 |
| | Min | 102.00 | 1.00 | 28.80 | 44.90 | 133.00 | 0.31 | 22.00 | 108.00 | 4.90 | 8.90 | 0.01 | 0.00 | 36.20 | 0.02 | 0.01 | 0.01 | 5.92 | 21.30 | 6.60 | 345.00 | 0.01 | 1.13 | 299.00 | 18.20 | 1.07 | 22.00 | 1.50 | 0.80 |
| | Max | 200.00 | 6.00 | 68.00 | 97.50 | 223.00 | 2.31 | 35.00 | 261.00 | 8.90 | 22.20 | 0.01 | 0.01 | 71.60 | 0.02 | 0.01 | 0.03 | 7.02 | 32.30 | 60.50 | 819.00 | 0.05 | 1.94 | 557.00 | 27.00 | 1.98 | 34.00 | 1.50 | 2.00 |
| | Count | 3 | 3 | 3 | 7 | 3 | 6 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 7 | 3 | 7 | 7 | 7 | 3 | 3 | 7 | 3 | 3 | 3 | 3 |
| | Average | 112.67 | 5.33 | 34.67 | 53.27 | 138.00 | 3.35 | 26.00 | 131.67 | 5.57 | 11.00 | 0.01 | 0.00 | 45.03 | 0.01 | 0.01 | 0.00 | 6.70 | 19.70 | 9.07 | 376.06 | 0.01 | 1.18 | 323.00 | 21.64 | 1.25 | 26.33 | 1.50 | 1.03 |
| LOXA106-2005 | StdDev | 27.59 | 3.21 | 9.83 | 21.80 | 18.03 | 1.35 | 1.00 | 37.23 | 0.60 | 3.16 | 0.00 | 0.00 | 11.82 | 0.00 | 0.00 | 0.00 | 0.14 | 5.41 | 10.56 | 141.11 | 0.00 | 0.13 | 160.59 | 5.21 | 0.20 | 0.58 | 0.00 | 0.06 |
| | Min | 92.00 | 3.00 | 27.20 | 24.20 | 118.00 | 1.91 | 25.00 | 104.00 | 5.00 | 8.70 | 0.00 | 0.00 | 35.10 | 0.00 | 0.00 | 0.00 | 6.53 | 14.80 | 2.60 | 196.70 | 0.01 | 1.08 | 189.00 | 13.80 | 1.09 | 26.00 | 1.50 | 1.00 |
| | Max | 144.00 | 9.00 | 45.80 | 89.50 | 153.00 | 5.70 | 27.00 | 174.00 | 6.20 | 14.60 | 0.01 | 0.01 | 58.10 | 0.01 | 0.01 | 0.01 | 6.91 | 25.50 | 32.30 | 641.00 | 0.02 | 1.33 | 501.00 | 27.50 | 1.47 | 27.00 | 1.50 | 1.10 |
| | Count | 2 | 2 | 2 | 3 | 2 | 4 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 5 | 2 | 3 | 5 | 5 | 2 | 2 | 5 | 2 | 2 | 2 | 2 |
| | Average | 161.50 | 20.50 | 52.55 | 75.50 | 139.50 | 1.21 | 32.50 | 204.00 | 7.75 | 17.70 | 0.01 | 0.01 | 65.50 | 0.01 | 0.01 | 0.01 | 6.62 | 34.85 | 25.30 | 435.06 | 0.01 | 1.76 | 523.00 | 23.94 | 1.77 | 33.00 | 1.50 | 0.55 |
| LOXA107-2004 | StdDev | 14.85 | 9.19 | 9.55 | 33.53 | 17.68 | 1.07 | 0.71 | 35.36 | 0.07 | 2.83 | 0.00 | | 3.25 | 0.00 | 0.01 | 0.00 | 0.35 | 1.48 | 23.75 | 252.47 | 0.00 | 0.03 | 43.84 | 4.30 | 0.02 | 1.41 | 0.00 | 0.07 |
| | Min | 151.00 | 14.00 | 45.80 | 36.80 | 127.00 | 0.22 | 32.00 | 179.00 | 7.70 | 15.70 | 0.01 | 0.01 | 63.20 | 0.01 | 0.01 | 0.01 | 6.07 | 33.80 | 2.50 | 216.30 | 0.01 | 1.74 | 492.00 | 17.90 | 1.75 | 32.00 | 1.50 | 0.50 |
| | Max | 172.00 | 27.00 | 59.30 | 95.90 | 152.00 | 2.58 | 33.00 | 229.00 | 7.80 | 19.70 | 0.01 | 0.01 | 67.80 | 0.02 | 0.01 | 0.01 | 6.96 | 35.90 | 49.90 | 762.00 | 0.02 | 1.78 | 554.00 | 28.00 | 1.78 | 34.00 | 1.50 | 0.60 |
| | Count | 1 | 1 | 1 | 4 | 1 | 4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 4 | 1 | 4 | 4 | 4 | 1 | 1 | 4 | 1 | 1 | 1 | 1 |
| | Average | 50.00 | 8.00 | 15.40 | 25.83 | 156.00 | 3.03 | 22.00 | 60.50 | 2.50 | 5.40 | 0.00 | 0.01 | 21.10 | 0.00 | | 0.01 | 6.64 | 2.47 | 3.95 | 197.18 | 0.01 | 0.91 | 28.00 | 24.30 | 1.29 | 22.00 | 20.00 | 1.40 |
| LOXA107-2005 | StdDev | | | | 3.64 | | 1.26 | | | | | | | | | | | 0.26 | | 4.66 | 30.37 | 0.01 | | | 2.53 | | | | |
| | Min | 50.00 | 8.00 | 15.40 | 21.00 | 156.00 | 1.81 | 22.00 | 60.50 | 2.50 | 5.40 | 0.00 | 0.01 | 21.10 | 0.00 | | 0.01 | 6.42 | 2.47 | 1.00 | 152.70 | 0.01 | 0.91 | 28.00 | 22.00 | 1.29 | 22.00 | 20.00 | 1.40 |
| | Max | 50.00 | 8.00 | 15.40 | 29.30 | 156.00 | 4.35 | 22.00 | 60.50 | 2.50 | 5.40 | 0.00 | 0.01 | 21.10 | 0.00 | | 0.01 | 7.01 | 2.47 | 10.90 | 219.50 | 0.02 | 0.91 | 28.00 | 27.70 | 1.29 | 22.00 | 20.00 | 1.40 |
| | Count | 3 | 2 | 3 | 4 | 3 | 4 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 2 | 3 | 4 | 3 | 4 | 5 | 5 | 3 | 3 | 5 | 3 | 3 | 3 | 3 |
| | Average | 27.67 | 37.50 | 6.90 | 25.80 | 129.33 | 3.75 | 20.67 | 28.37 | 1.87 | 2.73 | 0.01 | 0.00 | 17.17 | 0.01 | 0.01 | 0.01 | 6.45 | 8.52 | 0.31 | 172.80 | 0.01 | 1.09 | 116.67 | 26.86 | 1.22 | 21.00 | 1.50 | 1.73 |
| LOXA108-2004 | StdDev | 7.02 | 16.26 | 1.68 | 6.68 | 18.58 | 2.97 | 2.52 | 6.77 | 0.25 | 0.61 | 0.00 | 0.00 | 3.25 | 0.00 | 0.00 | 0.00 | 0.14 | 2.84 | 0.28 | 62.31 | 0.00 | 0.19 | 21.22 | 4.23 | 0.17 | 1.73 | 0.00 | 1.14 |
| | Min | 21.00 | 26.00 | 5.60 | 19.20 | 108.00 | 1.84 | 18.00 | 22.80 | 1.60 | 2.20 | 0.01 | 0.00 | 15.00 | 0.00 | 0.01 | 0.00 | 6.30 | 5.54 | 0.05 | 121.00 | 0.01 | 0.87 | 102.00 | 21.30 | 1.02 | 20.00 | 1.50 | 0.80 |
| | Max | 35.00 | 49.00 | 8.80 | 33.40 | 142.00 | 8.17 | 23.00 | 35.90 | 2.10 | 3.40 | 0.01 | 0.00 | 20.90 | 0.01 | 0.01 | 0.01 | 6.57 | 11.20 | 0.60 | 274.00 | 0.02 | 1.21 | 141.00 | 32.40 | 1.33 | 23.00 | 1.50 | 3.00 |
| | Count | 1 | 1 | 1 | 4 | 1 | 4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 4 | 4 | 4 | 1 | 1 | 4 | 1 | 1 | 1 | 1 |
| | Average | 31.00 | 4.00 | 9.00 | 31.25 | 175.00 | 3.98 | 29.00 | 36.00 | 1.40 | 3.30 | 0.01 | 0.01 | 23.50 | 0.01 | 0.02 | 0.01 | 6.57 | 0.98 | 0.25 | 191.15 | 0.01 | 1.68 | 87.00 | 23.77 | 2.19 | 28.00 | 9.00 | 3.20 |
| LOXA108-2005 | StdDev | | | | 3.76 | | 1.58 | | | | | | | | | | | 0.24 | | 0.13 | 38.93 | 0.01 | | | 2.09 | | | | |
| | Min | 31.00 | 4.00 | 9.00 | 27.70 | 175.00 | 2.74 | 29.00 | 36.00 | 1.40 | 3.30 | 0.01 | 0.01 | 23.50 | 0.01 | 0.02 | 0.01 | 6.30 | 0.98 | 0.10 | 146.20 | 0.01 | 1.68 | 87.00 | 21.38 | 2.19 | 28.00 | 9.00 | 3.20 |
| | Max | 31.00 | 4.00 | 9.00 | 34.70 | 175.00 | 6.29 | 29.00 | 36.00 | 1.40 | 3.30 | 0.01 | 0.01 | 23.50 | 0.01 | 0.02 | 0.01 | 6.82 | 0.98 | 0.40 | 240.60 | 0.03 | 1.68 | 87.00 | 26.20 | 2.19 | 28.00 | 9.00 | 3.20 |
| | Count | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 1 | 4 | 4 | 3 | 4 | 5 | 4 | 4 | 5 | 5 | 4 | 4 | 5 | 4 | 4 | 4 | 4 |
| | Average | 71.00 | 9.00 | 20.75 | 43.50 | 126.50 | 1.41 | 21.25 | 81.30 | 3.75 | 7.15 | 0.00 | 0.01 | 30.28 | 0.01 | 0.01 | 0.01 | 6.52 | 18.60 | 8.68 | 320.36 | 0.01 | 1.06 | 239.50 | 25.00 | 1.09 | 21.25 | 1.50 | 0.55 |
| LOXA109-2004 | StdDev | 49.58 | 2.94 | 15.55 | 31.46 | 45.18 | 0.73 | 7.93 | 60.60 | 2.93 | 5.23 | 0.00 | | 20.37 | 0.00 | 0.00 | 0.00 | 0.45 | 9.57 | 10.75 | 203.60 | 0.01 | 0.43 | 145.38 | 3.15 | 0.46 | 7.93 | 0.00 | 0.10 |
| | Min | 39.00 | 6.00 | 10.20 | 20.10 | 92.00 | 0.65 | 16.00 | 40.30 | 1.80 | 3.60 | 0.00 | 0.01 | 15.40 | 0.00 | 0.01 | 0.01 | 5.79 | 10.20 | 1.30 | 152.80 | 0.01 | 0.81 | 130.00 | 20.40 | 0.84 | 16.00 | 1.50 | 0.40 |
| | Max | 144.00 | 13.00 | 43.50 | 88.70 | 192.00 | 2.40 | 33.00 | 170.00 | 8.00 | 14.80 | 0.01 | 0.01 | 59.60 | 0.01 | 0.01 | 0.01 | 7.01 | 31.00 | 24.30 | 656.00 | 0.02 | 1.70 | 448.00 | 27.90 | 1.77 | 33.00 | 1.50 | 0.60 |
| | Count | 9 | 9 | 9 | 11 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 6 | 9 | 8 | 7 | 9 | 11 | 9 | 10 | 11 | 11 | 9 | 9 | 11 | 9 | 9 | 9 | 9 |
| | Average | 70.56 | 12.67 | 21.67 | 44.48 | 99.67 | 2.48 | 21.78 | 84.09 | 3.28 | 7.32 | 0.00 | 0.01 | 32.23 | 0.01 | 0.01 | 0.00 | 6.66 | 9.90 | 7.99 | 294.96 | 0.01 | 1.07 | 224.11 | 23.58 | 1.17 | 21.78 | 2.67 | 0.63 |
| LOXA109-2005 | StdDev | 36.24 | 4.42 | 12.67 | 29.05 | 14.92 | 0.91 | 3.63 | 47.82 | 1.78 | 3.98 | 0.00 | 0.00 | 18.08 | 0.01 | 0.00 | 0.00 | 0.14 | 7.12 | 10.26 | 177.54 | 0.01 | 0.20 | 112.50 | 5.13 | 0.25 | 3.49 | 3.50 | 0.14 |
| | Min | 37.00 | 7.00 | 10.80 | 18.00 | 79.00 | 1.07 | 16.00 | 42.10 | 1.60 | 3.70 | 0.00 | 0.00 | 12.20 | 0.00 | 0.00 | 0.00 | 6.43 | 3.02 | 1.60 | 140.60 | 0.01 | 0.84 | 122.00 | 15.80 | 0.86 | 17.00 | 1.50 | 0.50 |
| | Max | 148.00 | 18.00 | 46.30 | 98.40 | 123.00 | 3.65 | 27.00 | 177.00 | 6.50 | 15.00 | 0.01 | 0.01 | 64.40 | 0.02 | 0.01 | 0.01 | 6.86 | 21.60 | 33.40 | 670.00 | 0.03 | 1.35 | 421.00 | 29.20 | 1.63 | 26.00 | 12.00 | 0.90 |
| | Count | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 1 | 4 | 4 | 3 | 4 | 5 | 4 | 4 | 5 | 5 | 4 | 4 | 5 | 4 | 4 | 4 | 4 |
| | Average | 28.25 | 32.67 | 8.03 | 22.80 | 111.00 | 3.09 | 18.75 | 31.93 | 1.68 | 2.90 | 0.00 | 0.00 | 15.88 | 0.01 | 0.01 | 0.01 | 6.36 | 8.52 | 0.98 | 142.22 | 0.01 | 0.98 | 137.25 | 25.36 | 1.08 | 19.25 | 4.25 | 0.93 |
| LOXA110-2004 | StdDev | 7.27 | 16.17 | 2.41 | 6.78 | 36.81 | 1.57 | 4.11 | 9.63 | 0.57 | 0.90 | 0.00 | | 4.17 | 0.01 | 0.00 | 0.00 | 0.32 | 3.91 | 0.90 | 36.53 | 0.00 | 0.18 | 33.35 | 3.10 | 0.25 | 3.40 | 3.28 | 0.38 |
| | Min | 23.00 | 18.00 | 6.20 | 16.60 | 75.00 | 1.47 | 14.00 | 24.60 | 1.30 | 2.20 | 0.00 | 0.00 | 12.80 | 0.00 | 0.00 | 0.00 | 5.81 | 4.35 | 0.40 | 112.10 | 0.01 | 0.71 | 111.00 | 20.50 | 0.72 | 16.00 | 1.50 | 0.60 |
| | Max | 39.00 | 50.00 | 11.40 | 31.80 | 159.00 | 5.20 | 24.00 | 45.60 | 2.50 | 4.20 | 0.01 | 0.00 | 21.80 | 0.02 | 0.01 | 0.01 | 6.58 | 12.80 | 2.30 | 202.00 | 0.02 | 1.12 | 186.00 | 28.10 | 1.30 | 24.00 | 8.00 | 1.30 |
| | Count | 1 | 1 | 1 | 6 | 1 | 6 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 7 | 1 | 6 | 6 | 6 | 1 | 1 | 7 | 1 | 1 | 1 | 1 |
| | Average | 46.00 | 22.00 | 12.90 | 24.92 | 114.00 | 4.98 | 20.00 | 51.50 | 3.00 | 4.70 | 0.00 | 0.00 | 21.20 | 0.00 | | 0.00 | 6.62 | 5.03 | 1.27 | 155.30 | 0.01 | 1.01 | 113.00 | 23.61 | 1.16 | 20.00 | 1.50 | 0.90 |
| LOXA110-2005 | StdDev | | | | 5.09 | | 1.82 | | | | | | | | | | | 0.23 | | 1.27 | 31.39 | 0.01 | | | 4.69 | | | | |
| | Min | 46.00 | 22.00 | 12.90 | 16.80 | 114.00 | 2.79 | 20.00 | 51.50 | 3.00 | 4.70 | 0.00 | 0.00 | 21.20 | 0.00 | | 0.00 | 6.26 | 5.03 | 0.50 | 109.70 | 0.01 | 1.01 | 113.00 | 17.00 | 1.16 | 20.00 | 1.50 | 0.90 |
| | Max | 46.00 | 22.00 | 12.90 | 31.20 | 114.00 | 7.49 | 20.00 | 51.50 | 3.00 | 4.70 | 0.00 | 0.00 | 21.20 | 0.00 | | 0.00 | 6.89 | 5.03 | 3.80 | 204.00 | 0.02 | 1.01 | 113.00 | 28.90 | 1.16 | 20.00 | 1.50 | 0.90 |

| Site - Year | STAT | ALK | APA | Ca | Cl | COLOR | D-O | DOC | HARD | K | Mg | N02 | N03 | Na | NH4 | NOX | OPO4 | Ph_F | SiO2 | SO4 | SpC | T_PO4 | TDKN | TDS | TEMP | TKN | TOC | TSS | TURB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | mg/L | nM/minmL | mg/L | mg/L | PCU | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | units | mg/L | mg/L | uS/cm | mg/L | mg/L | mg/L | Deg.C | mg/L | mg/L | mg/L | mg/L |
| | Count | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 1 | 4 | 4 | 3 | 4 | 5 | 4 | 4 | 5 | 5 | 4 | 4 | 5 | 4 | 4 | 4 | 4 |
| | Average | 36.75 | 26.25 | 12.23 | 27.30 | 99.50 | 2.46 | 17.50 | 47.80 | 2.08 | 4.20 | 0.00 | 0.00 | 18.28 | 0.01 | 0.01 | 0.00 | 6.48 | 9.07 | 5.45 | 204.90 | 0.01 | 0.94 | 143.50 | 24.82 | 1.05 | 18.25 | 2.88 | 0.83 |
| LOXA111-2004 | StdDev | 19.81 | 15.00 | 7.35 | 21.71 | 25.72 | 1.57 | 5.97 | 29.38 | 1.88 | 2.66 | 0.00 | | 13.79 | 0.00 | 0.00 | 0.00 | 0.22 | 6.83 | 9.50 | 122.50 | 0.00 | 0.31 | 95.71 | 3.56 | 0.31 | 5.32 | 2.75 | 0.17 |
| | Min | 23.00 | 11.00 | 6.70 | 12.70 | 69.00 | 1.15 | 12.00 | 25.90 | 1.10 | 2.20 | 0.00 | 0.00 | 9.10 | 0.00 | 0.00 | 0.00 | 6.30 | 4.50 | 0.40 | 96.00 | 0.01 | 0.68 | 59.00 | 19.40 | 0.74 | 14.00 | 1.50 | 0.60 |
| | Max | 65.00 | 45.00 | 23.00 | 59.40 | 125.00 | 4.43 | 26.00 | 90.90 | 4.90 | 8.10 | 0.01 | 0.00 | 38.70 | 0.01 | 0.01 | 0.01 | 6.85 | 19.20 | 19.70 | 382.00 | 0.01 | 1.39 | 281.00 | 27.80 | 1.38 | 26.00 | 7.00 | 1.00 |
| | Count | 5 | 5 | 5 | 7 | 5 | 6 | 5 | 5 | 5 | 5 | 5 | 1 | 5 | 5 | 4 | 5 | 7 | 5 | 7 | 6 | 7 | 5 | 5 | 7 | 5 | 5 | 5 | 5 |
| | Average | 36.20 | 40.40 | 10.54 | 21.60 | 76.60 | 3.37 | 16.80 | 41.34 | 1.34 | 3.64 | 0.00 | 0.01 | 13.98 | 0.01 | 0.00 | 0.00 | 6.52 | 6.88 | 1.27 | 141.63 | 0.01 | 0.88 | 122.20 | 22.57 | 1.11 | 17.00 | 7.50 | 2.06 |
| LOXA111-2005 | StdDev | 4.44 | 3.51 | 1.17 | 7.10 | 13.28 | 0.73 | 1.92 | 4.67 | 0.32 | 0.44 | 0.00 | | 3.51 | 0.01 | 0.00 | 0.00 | 0.16 | 4.19 | 0.44 | 23.16 | 0.01 | 0.09 | 20.95 | 4.60 | 0.42 | 2.00 | 11.07 | 3.10 |
| | Min | 30.00 | 37.00 | 8.80 | 13.20 | 63.00 | 1.91 | 14.00 | 34.50 | 1.10 | 3.00 | 0.00 | 0.01 | 8.90 | 0.00 | 0.00 | 0.00 | 6.32 | 2.19 | 0.70 | 109.20 | 0.01 | 0.74 | 108.00 | 15.90 | 0.79 | 14.00 | 1.50 | 0.50 |
| | Max | 40.00 | 46.00 | 11.60 | 33.40 | 97.00 | 3.78 | 19.00 | 45.80 | 1.90 | 4.10 | 0.00 | 0.01 | 17.50 | 0.03 | 0.01 | 0.01 | 6.82 | 12.50 | 2.10 | 169.10 | 0.02 | 0.96 | 159.00 | 27.80 | 1.79 | 19.00 | 27.00 | 7.60 |
| | Count | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 2 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 5 | 5 | 4 | 4 | 5 | 4 | 4 | 4 | 4 |
| | Average | 65.50 | 17.50 | 19.78 | 39.90 | 104.00 | 2.28 | 20.25 | 77.13 | 3.28 | 6.75 | 0.00 | 0.01 | 27.90 | 0.01 | 0.01 | 0.01 | 6.59 | 13.26 | 9.23 | 289.60 | 0.01 | 1.12 | 225.75 | 25.14 | 1.13 | 21.25 | 3.00 | 0.95 |
| LOXA112-2004 | StdDev | 49.80 | 17.02 | 15.53 | 34.89 | 34.77 | 2.03 | 7.85 | 62.07 | 3.02 | 5.65 | 0.00 | 0.00 | 23.71 | 0.00 | 0.00 | 0.00 | 0.40 | 9.57 | 13.23 | 214.77 | 0.00 | 0.44 | 152.52 | 3.06 | 0.42 | 7.27 | 2.12 | 0.17 |
| | Min | 36.00 | 4.00 | 10.50 | 19.20 | 77.00 | 0.18 | 16.00 | 40.30 | 1.50 | 3.40 | 0.00 | 0.01 | 14.00 | 0.00 | 0.01 | 0.00 | 5.97 | 6.99 | 1.60 | 147.00 | 0.01 | 0.80 | 136.00 | 20.40 | 0.75 | 16.00 | 1.50 | 0.80 |
| | Max | 140.00 | 41.00 | 43.00 | 92.10 | 155.00 | 4.76 | 32.00 | 170.00 | 7.80 | 15.20 | 0.01 | 0.01 | 63.40 | 0.01 | 0.02 | 0.01 | 6.99 | 27.40 | 29.00 | 664.00 | 0.02 | 1.77 | 454.00 | 27.90 | 1.73 | 32.00 | 6.00 | 1.20 |
| | Count | 7 | 7 | 7 | 10 | 7 | 8 | 7 | 7 | 7 | 7 | 7 | 3 | 7 | 7 | 6 | 7 | 10 | 7 | 9 | 10 | 10 | 7 | 7 | 10 | 7 | 7 | 7 | 7 |
| | Average | 53.86 | 21.14 | 16.40 | 34.68 | 89.43 | 3.74 | 20.00 | 62.69 | 2.53 | 5.29 | 0.00 | 0.00 | 20.99 | 0.01 | 0.01 | 0.00 | 6.75 | 7.12 | 3.20 | 240.66 | 0.01 | 1.02 | 161.43 | 23.33 | 1.07 | 19.86 | 2.79 | 0.80 |
| LOXA112-2005 | StdDev | 6.82 | 7.10 | 2.58 | 13.35 | 19.01 | 1.50 | 1.91 | 9.88 | 1.03 | 0.88 | 0.00 | 0.00 | 5.26 | 0.00 | 0.00 | 0.00 | 0.18 | 2.95 | 2.10 | 69.24 | 0.01 | 0.04 | 28.80 | 5.46 | 0.09 | 1.86 | 2.20 | 0.22 |
| | Min | 40.00 | 12.00 | 11.80 | 16.50 | 66.00 | 1.64 | 17.00 | 45.00 | 1.10 | 3.70 | 0.00 | 0.00 | 11.70 | 0.00 | 0.00 | 0.00 | 6.46 | 2.65 | 1.30 | 139.50 | 0.01 | 0.98 | 125.00 | 14.50 | 0.96 | 17.00 | 1.50 | 0.60 |
| | Max | 61.00 | 33.00 | 20.20 | 58.80 | 120.00 | 5.91 | 23.00 | 77.00 | 4.20 | 6.50 | 0.01 | 0.01 | 27.00 | 0.01 | 0.01 | 0.01 | 7.05 | 11.60 | 8.50 | 376.40 | 0.02 | 1.07 | 196.00 | 29.40 | 1.23 | 23.00 | 6.00 | 1.20 |
| | Count | 4 | 3 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 4 | 1 | 4 | 4 | 3 | 4 | 6 | 4 | 4 | 6 | 6 | 4 | 4 | 6 | 4 | 4 | 4 | 4 |
| | Average | 31.75 | 36.33 | 9.18 | 21.95 | 86.00 | 3.09 | 17.50 | 36.08 | 1.60 | 3.20 | 0.00 | 0.01 | 14.75 | 0.01 | 0.01 | 0.01 | 6.47 | 7.39 | 1.68 | 181.55 | 0.01 | 0.81 | 112.75 | 25.25 | 1.07 | 18.00 | 3.50 | 1.05 |
| LOXA113-2004 | StdDev | 13.15 | 8.62 | 4.36 | 13.05 | 24.21 | 1.67 | 5.20 | 17.50 | 0.93 | 1.58 | 0.00 | | 8.49 | 0.01 | 0.00 | 0.00 | 0.36 | 5.36 | 2.62 | 84.81 | 0.00 | 0.54 | 29.41 | 2.55 | 0.27 | 4.08 | 2.61 | 0.59 |
| | Min | 22.00 | 27.00 | 5.80 | 11.40 | 61.00 | 1.18 | 13.00 | 22.70 | 1.10 | 2.00 | 0.00 | 0.01 | 8.20 | 0.00 | 0.00 | 0.00 | 5.87 | 3.74 | 0.20 | 86.00 | 0.01 | 0.03 | 88.00 | 20.70 | 0.69 | 15.00 | 1.50 | 0.50 |
| | Max | 51.00 | 44.00 | 15.50 | 40.60 | 118.00 | 5.35 | 25.00 | 61.50 | 3.00 | 5.50 | 0.01 | 0.01 | 27.00 | 0.02 | 0.01 | 0.01 | 6.90 | 15.30 | 5.60 | 271.00 | 0.01 | 1.25 | 153.00 | 27.70 | 1.33 | 24.00 | 7.00 | 1.70 |
| | Count | 3 | 3 | 3 | 9 | 3 | 7 | 3 | 3 | 3 | 3 | 3 | 1 | 3 | 3 | 2 | 3 | 9 | 3 | 8 | 8 | 9 | 3 | 3 | 9 | 3 | 3 | 3 | 3 |
| | Average | 33.00 | 47.33 | 9.30 | 20.09 | 74.00 | 3.79 | 16.00 | 36.67 | 1.27 | 3.23 | 0.00 | 0.03 | 13.03 | 0.01 | 0.01 | 0.00 | 6.61 | 6.16 | 0.78 | 129.39 | 0.01 | 0.92 | 106.67 | 23.32 | 1.05 | 16.00 | 4.00 | 0.87 |
| LOXA113-2005 | StdDev | 2.00 | 19.86 | 0.17 | 6.67 | 14.00 | 1.52 | 0.00 | 0.40 | 0.29 | 0.06 | 0.00 | | 1.10 | 0.01 | 0.00 | 0.00 | 0.22 | 2.22 | 0.32 | 15.90 | 0.00 | 0.07 | 29.02 | 4.14 | 0.16 | 1.00 | 4.33 | 0.31 |
| | Min | 31.00 | 33.00 | 9.20 | 14.00 | 60.00 | 2.10 | 16.00 | 36.30 | 1.10 | 3.20 | 0.00 | 0.03 | 11.80 | 0.00 | 0.00 | 0.00 | 6.25 | 3.60 | 0.40 | 109.00 | 0.00 | 0.86 | 77.00 | 17.60 | 0.88 | 15.00 | 1.50 | 0.60 |
| | Max | 35.00 | 70.00 | 9.50 | 35.20 | 88.00 | 6.49 | 16.00 | 37.10 | 1.60 | 3.30 | 0.00 | 0.03 | 13.90 | 0.02 | 0.01 | 0.00 | 6.86 | 7.46 | 1.20 | 160.10 | 0.02 | 1.00 | 135.00 | 29.10 | 1.20 | 17.00 | 9.00 | 1.20 |
| | Count | 4 | 3 | 4 | 4 | 4 | 6 | 4 | 4 | 4 | 4 | 4 | 1 | 4 | 4 | 3 | 4 | 7 | 4 | 4 | 7 | 7 | 4 | 4 | 7 | 4 | 4 | 4 | 4 |
| | Average | 24.00 | 43.33 | 7.15 | 17.88 | 95.50 | 3.47 | 18.00 | 28.35 | 1.28 | 2.55 | 0.00 | 0.03 | 12.18 | 0.01 | 0.02 | 0.00 | 6.40 | 5.97 | 0.19 | 166.04 | 0.01 | 0.94 | 115.25 | 25.61 | 1.05 | 18.50 | 2.63 | 0.83 |
| LOXA114-2004 | StdDev | 8.64 | 5.51 | 2.45 | 6.50 | 32.01 | 1.67 | 4.69 | 9.83 | 0.62 | 0.93 | 0.00 | | 4.43 | 0.00 | 0.02 | 0.00 | 0.18 | 3.29 | 0.15 | 74.68 | 0.01 | 0.19 | 18.01 | 2.59 | 0.27 | 4.04 | 2.25 | 0.43 |
| | Min | 16.00 | 38.00 | 5.00 | 10.80 | 75.00 | 1.03 | 13.00 | 19.50 | 0.90 | 1.70 | 0.00 | 0.03 | 7.70 | 0.00 | 0.00 | 0.00 | 6.18 | 3.84 | 0.05 | 76.00 | 0.01 | 0.67 | 99.00 | 20.80 | 0.69 | 15.00 | 1.50 | 0.50 |
| | Max | 36.00 | 49.00 | 10.50 | 25.40 | 143.00 | 5.56 | 24.00 | 41.70 | 2.20 | 3.80 | 0.01 | 0.03 | 17.80 | 0.01 | 0.04 | 0.01 | 6.74 | 10.80 | 0.40 | 277.00 | 0.03 | 1.09 | 135.00 | 28.10 | 1.34 | 24.00 | 6.00 | 1.40 |
| | Count | 4 | 4 | 4 | 8 | 4 | 7 | 4 | 4 | 4 | 4 | 4 | 1 | 4 | 4 | 3 | 4 | 9 | 4 | 7 | 8 | 8 | 4 | 4 | 9 | 4 | 4 | 4 | 4 |
| | Average | 27.25 | 30.75 | 7.90 | 18.50 | 73.00 | 3.30 | 15.75 | 31.60 | 1.23 | 2.90 | 0.00 | 0.03 | 12.10 | 0.01 | 0.00 | 0.00 | 6.55 | 5.56 | 0.44 | 122.65 | 0.01 | 0.84 | 106.50 | 23.68 | 1.08 | 16.25 | 3.63 | 0.75 |
| LOXA114-2005 | StdDev | 1.26 | 6.80 | 0.36 | 3.40 | 6.22 | 1.97 | 0.96 | 1.26 | 0.21 | 0.12 | 0.00 | | 1.40 | 0.00 | 0.00 | 0.00 | 0.30 | 2.74 | 0.29 | 13.08 | 0.01 | 0.07 | 26.65 | 4.06 | 0.45 | 1.26 | 4.25 | 0.57 |
| | Min | 26.00 | 24.00 | 7.60 | 15.90 | 66.00 | 2.15 | 15.00 | 30.50 | 1.00 | 2.80 | 0.00 | 0.03 | 10.30 | 0.00 | 0.00 | 0.00 | 6.26 | 2.94 | 0.20 | 110.50 | 0.01 | 0.76 | 80.00 | 17.04 | 0.81 | 15.00 | 1.50 | 0.40 |
| | Max | 29.00 | 40.00 | 8.40 | 26.20 | 80.00 | 7.63 | 17.00 | 33.40 | 1.50 | 3.00 | 0.00 | 0.03 | 13.40 | 0.01 | 0.00 | 0.00 | 7.18 | 8.39 | 1.00 | 153.00 | 0.03 | 0.90 | 142.00 | 28.10 | 1.75 | 18.00 | 10.00 | 1.60 |
| | Count | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 6 | 7 | 7 | 6 | 7 | 7 | 7 |
| | Average | 187.57 | 1.43 | 62.29 | 106.50 | 134.57 | 3.67 | 31.57 | 238.57 | 8.23 | 20.21 | 0.02 | 0.09 | 75.10 | 0.09 | 0.11 | 0.06 | 7.56 | 19.79 | 53.17 | 821.07 | 0.09 | 1.96 | 529.86 | 26.86 | 2.09 | 31.43 | 5.29 | 5.06 |
| LOXA115-2004 | StdDev | 20.26 | 1.10 | 8.28 | 26.96 | 53.05 | 1.24 | 3.82 | 21.09 | 1.24 | 2.40 | 0.02 | 0.09 | 18.60 | 0.05 | 0.11 | 0.07 | 0.29 | 2.64 | 11.39 | 102.68 | 0.07 | 0.25 | 70.03 | 2.14 | 0.29 | 3.05 | 3.72 | 3.46 |
| | Min | 160.00 | 0.50 | 53.30 | 71.40 | 81.00 | 2.27 | 28.00 | 224.00 | 7.00 | 17.10 | 0.01 | 0.01 | 51.50 | 0.03 | 0.02 | 0.01 | 7.01 | 16.00 | 38.70 | 691.00 | 0.03 | 1.67 | 422.00 | 22.50 | 1.76 | 28.00 | 1.50 | 1.20 |
| | Max | 227.00 | 3.00 | 78.40 | 148.00 | 214.00 | 5.22 | 37.00 | 285.00 | 10.50 | 22.30 | 0.05 | 0.23 | 104.00 | 0.17 | 0.28 | 0.17 | 7.88 | 23.00 | 65.00 | 962.00 | 0.20 | 2.37 | 600.00 | 28.50 | 2.50 | 36.00 | 12.00 | 10.40 |
| | Count | 11 | 11 | 11 | 11 | 11 | 9 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 10 | 10 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| | Average | 218.18 | 1.68 | 74.66 | 116.13 | 113.73 | 4.26 | 30.27 | 277.00 | 7.90 | 22.02 | 0.02 | 0.27 | 82.59 | 0.05 | 0.29 | 0.05 | 7.65 | 18.12 | 59.32 | 907.55 | 0.09 | 1.87 | 580.18 | 25.25 | 2.12 | 30.27 | 3.59 | 5.69 |
| LOXA115-2005 | StdDev | 49.97 | 1.06 | 19.85 | 38.02 | 32.02 | 2.32 | 7.90 | 75.07 | 2.05 | 6.32 | 0.02 | 0.52 | 26.55 | 0.06 | 0.53 | 0.04 | 0.19 | 6.84 | 26.45 | 249.07 | 0.04 | 0.54 | 184.67 | 4.57 | 0.56 | 8.11 | 2.40 | 5.01 |
| | Min | 140.00 | 0.50 | 46.00 | 46.70 | 74.00 | 0.83 | 20.00 | 161.00 | 3.30 | 11.20 | 0.00 | 0.01 | 35.90 | 0.00 | 0.01 | 0.00 | 7.35 | 11.10 | 19.00 | 481.50 | 0.05 | 1.18 | 256.00 | 19.60 | 1.13 | 19.00 | 1.50 | 2.40 |
| | Max | 312.00 | 4.00 | 110.00 | 184.00 | 158.00 | 9.14 | 42.00 | 409.00 | 11.00 | 32.90 | 0.07 | 1.82 | 128.00 | 0.23 | 1.87 | 0.14 | 7.92 | 29.00 | 107.00 | 1338.00 | 0.19 | 2.66 | 878.00 | 31.20 | 2.84 | 43.00 | 8.00 | 18.60 |
| | Count | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 4 | 5 | 5 | 4 | 5 | 5 | 5 |
| | Average | 187.00 | 3.70 | 62.66 | 85.78 | 142.00 | 0.70 | 30.20 | 228.60 | 7.44 | 17.54 | 0.01 | 0.01 | 61.28 | 0.06 | 0.01 | 0.04 | 7.05 | 16.51 | 41.56 | 784.30 | 0.09 | 1.86 | 494.80 | 24.76 | 2.15 | 30.40 | 4.60 | 2.96 |
| LOXA116-2004 | StdDev | 35.14 | 4.18 | 13.06 | 30.57 | 30.11 | 0.49 | 4.60 | 55.36 | 2.12 | 5.64 | 0.00 | 0.00 | 21.17 | 0.06 | 0.00 | 0.07 | 0.25 | 7.09 | 24.67 | 196.42 | 0.07 | 0.30 | 140.52 | 2.23 | 0.20 | 4.04 | 3.90 | 0.59 |
| | Min | 142.00 | 0.50 | 45.40 | 57.00 | 108.00 | 0.34 | 26.00 | 158.00 | 4.10 | 10.70 | 0.01 | 0.00 | 42.60 | 0.01 | 0.01 | 0.01 | 6.74 | 5.85 | 18.40 | 609.00 | 0.04 | 1.51 | 354.00 | 21.30 | 2.00 | 26.00 | 1.50 | 2.00 |
| | Max | 238.00 | 11.00 | 80.90 | 135.00 | 183.00 | 1.52 | 37.00 | 308.00 | 9.50 | 25.80 | 0.01 | 0.01 | 96.10 | 0.16 | 0.02 | 0.16 | 7.25 | 24.60 | 81.00 | 1063.00 | 0.20 | 2.21 | 707.00 | 26.60 | 2.41 | 36.00 | 11.00 | 3.40 |
| | Count | 10 | 10 | 10 | 10 | 10 | 8 | 10 | 10 | 10 | 10 | 10 | 9 | 10 | 10 | 9 | 10 | 9 | 9 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| | Average | 169.10 | 2.40 | 56.46 | 84.99 | 113.10 | 1.79 | 27.40 | 204.58 | 5.55 | 15.45 | 0.00 | 0.00 | 59.68 | 0.05 | 0.01 | 0.00 | 7.16 | 13.09 | 33.65 | 668.40 | 0.04 | 1.51 | 447.50 | 22.84 | 1.80 | 27.40 | 5.25 | 1.67 |
| LOXA116-2005 | StdDev | 68.27 | 1.56 | 25.29 | 47.50 | 12.36 | 0.45 | 6.90 | 93.94 | 2.75 | 7.53 | 0.00 | 0.00 | 32.67 | 0.02 | 0.00 | 0.00 | 0.16 | 8.37 | 29.81 | 321.30 | 0.02 | 0.46 | 239.84 | 5.10 | 0.49 | 7.49 | 5.04 | 0.93 |
| | Min | 66.00 | 0.50 | 21.30 | 17.30 | 96.00 | 1.10 | 17.00 | 74.30 | 1.20 | 5.10 | 0.00 | 0.00 | 14.70 | 0.03 | 0.00 | 0.00 | 6.74 | 3.24 | 4.90 | 209.00 | 0.02 | 0.88 | 130.00 | 15.30 | 1.01 | 16.00 | 1.50 | 0.70 |
| | Max | 273.00 | 5.00 | 96.20 | 157.00 | 138.00 | 2.29 | 38.00 | 349.00 | 9.70 | 27.30 | 0.01 | 0.01 | 112.00 | 0.07 | 0.01 | 0.01 | 7.31 | 26.00 | 89.00 | 1160.00 | 0.06 | 2.35 | 843.00 | 29.00 | 2.42 | 39.00 | 16.00 | 3.20 |

| Site - Year | STAT | ALK | APA | Ca | Cl | COLOR | D-O | DOC | HARD | K | Mg | N02 | N03 | Na | NH4 | NOX | OPO4 | Ph_F | SiO2 | SO4 | SpC | T_PO4 | TDKN | TDS | TEMP | TKN | TOC | TSS | TURB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | mg/L | nM/minmL | mg/L | mg/L | PCU | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | units | mg/L | mg/L | uS/cm | mg/L | mg/L | mg/L | Deg.C | mg/L | mg/L | mg/L | mg/L |
| | Count | 4 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 4 | 2 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 5 | 5 | 3 | 4 | 5 | 3 | 4 | 4 | 4 |
| | Average | 145.50 | 5.75 | 47.80 | 78.85 | 147.75 | 2.17 | 28.25 | 182.50 | 6.25 | 15.30 | 0.01 | 0.00 | 54.90 | 0.01 | 0.01 | 0.01 | 6.95 | 21.03 | 35.75 | 566.64 | 0.02 | 1.63 | 414.25 | 24.26 | 1.65 | 28.25 | 2.13 | 0.85 |
| LOXA117-2004 | StdDev | 48.45 | 2.63 | 17.82 | 34.36 | 16.50 | 2.88 | 7.41 | 72.26 | 2.09 | 6.74 | 0.00 | 0.00 | 24.02 | 0.01 | 0.00 | 0.00 | 0.38 | 6.20 | 25.53 | 248.34 | 0.00 | 0.59 | 176.51 | 2.93 | 0.54 | 7.09 | 1.25 | 0.19 |
| | Min | 105.00 | 2.00 | 32.70 | 51.30 | 126.00 | 0.50 | 22.00 | 123.00 | 4.40 | 9.60 | 0.01 | 0.00 | 34.70 | 0.00 | 0.01 | 0.01 | 6.36 | 15.20 | 13.60 | 367.00 | 0.01 | 1.04 | 248.00 | 19.80 | 1.06 | 22.00 | 1.50 | 0.60 |
| | Max | 205.00 | 8.00 | 69.30 | 123.00 | 162.00 | 7.28 | 38.00 | 271.00 | 8.30 | 23.70 | 0.01 | 0.00 | 85.70 | 0.02 | 0.01 | 0.01 | 7.33 | 29.10 | 68.20 | 939.00 | 0.02 | 2.21 | 628.00 | 27.10 | 2.12 | 37.00 | 4.00 | 1.00 |
| | Count | 3 | 3 | 3 | 10 | 3 | 9 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 10 | 3 | 10 | 10 | 10 | 3 | 3 | 10 | 3 | 3 | 3 | 3 |
| | Average | 151.33 | 6.67 | 48.60 | 65.29 | 118.00 | 2.47 | 27.33 | 180.67 | 5.97 | 14.43 | 0.00 | 0.01 | 59.40 | 0.02 | 0.01 | 0.00 | 6.78 | 16.07 | 15.65 | 475.84 | 0.02 | 1.36 | 430.67 | 22.14 | 1.46 | 27.00 | 1.50 | 1.63 |
| LOXA117-2005 | StdDev | 51.54 | 2.52 | 18.06 | 37.06 | 20.07 | 1.20 | 6.11 | 65.01 | 2.05 | 4.85 | 0.00 | 0.00 | 24.05 | 0.01 | 0.00 | 0.00 | 0.22 | 7.66 | 11.52 | 241.01 | 0.01 | 0.40 | 195.77 | 5.74 | 0.41 | 5.57 | 0.00 | 0.99 |
| | Min | 101.00 | 4.00 | 30.30 | 16.70 | 104.00 | 0.99 | 22.00 | 115.00 | 3.90 | 9.60 | 0.00 | 0.00 | 35.60 | 0.00 | 0.01 | 0.00 | 6.42 | 9.80 | 3.90 | 153.50 | 0.01 | 0.98 | 249.00 | 14.00 | 1.01 | 22.00 | 1.50 | 0.50 |
| | Max | 204.00 | 9.00 | 66.40 | 126.00 | 141.00 | 4.63 | 34.00 | 245.00 | 8.00 | 19.30 | 0.00 | 0.01 | 83.70 | 0.03 | 0.01 | 0.01 | 7.21 | 24.60 | 34.20 | 850.50 | 0.04 | 1.78 | 638.00 | 31.40 | 1.81 | 33.00 | 1.50 | 2.30 |
| | Count | 4 | 4 | 4 | 4 | 4 | 6 | 4 | 4 | 4 | 4 | 4 | 2 | 4 | 4 | 4 | 4 | 6 | 4 | 4 | 6 | 6 | 3 | 4 | 6 | 3 | 4 | 4 | 4 |
| | Average | 87.75 | 20.25 | 27.13 | 47.38 | 110.25 | 2.08 | 21.50 | 103.88 | 3.80 | 8.78 | 0.01 | 0.00 | 33.15 | 0.01 | 0.01 | 0.01 | 6.79 | 14.55 | 14.43 | 352.63 | 0.01 | 1.19 | 230.50 | 25.82 | 1.20 | 21.25 | 1.50 | 0.53 |
| LOXA118-2004 | StdDev | 42.52 | 9.39 | 13.37 | 28.23 | 13.82 | 1.39 | 5.74 | 52.15 | 2.55 | 4.54 | 0.00 | 0.00 | 17.74 | 0.00 | 0.00 | 0.00 | 0.28 | 6.62 | 11.49 | 156.96 | 0.00 | 0.29 | 102.28 | 2.62 | 0.31 | 5.25 | 0.00 | 0.19 |
| | Min | 59.00 | 9.00 | 17.10 | 26.20 | 96.00 | 0.75 | 18.00 | 64.90 | 2.00 | 5.40 | 0.00 | 0.00 | 19.60 | 0.00 | 0.01 | 0.00 | 6.39 | 7.91 | 5.70 | 220.80 | 0.01 | 1.01 | 145.00 | 21.30 | 1.01 | 18.00 | 1.50 | 0.40 |
| | Max | 150.00 | 28.00 | 46.40 | 87.10 | 129.00 | 4.68 | 30.00 | 179.00 | 7.40 | 15.30 | 0.01 | 0.00 | 58.00 | 0.01 | 0.01 | 0.01 | 7.17 | 22.40 | 30.00 | 647.00 | 0.02 | 1.53 | 364.00 | 28.50 | 1.56 | 29.00 | 1.50 | 0.80 |
| | Count | 7 | 7 | 7 | 11 | 7 | 10 | 7 | 7 | 7 | 7 | 7 | 5 | 7 | 7 | 6 | 7 | 10 | 6 | 11 | 10 | 11 | 7 | 7 | 11 | 7 | 7 | 7 | 7 |
| | Average | 68.29 | 10.57 | 21.74 | 34.48 | 99.29 | 3.15 | 19.71 | 81.27 | 2.79 | 6.51 | 0.00 | 0.01 | 25.76 | 0.01 | 0.01 | 0.00 | 6.70 | 9.85 | 5.85 | 265.51 | 0.01 | 0.95 | 180.86 | 23.96 | 1.08 | 19.71 | 8.07 | 0.89 |
| LOXA118-2005 | StdDev | 28.20 | 3.64 | 9.01 | 21.91 | 15.41 | 1.50 | 3.59 | 33.35 | 1.49 | 2.64 | 0.00 | 0.00 | 14.24 | 0.01 | 0.00 | 0.00 | 0.25 | 9.45 | 2.64 | 122.18 | 0.00 | 0.19 | 108.21 | 6.26 | 0.29 | 3.86 | 15.10 | 0.99 |
| | Min | 34.00 | 5.00 | 11.40 | 11.20 | 81.00 | 1.79 | 14.00 | 42.20 | 1.00 | 3.30 | 0.00 | 0.00 | 9.20 | 0.00 | 0.00 | 0.00 | 6.28 | 3.10 | 2.80 | 111.70 | 0.01 | 0.71 | 33.00 | 14.20 | 0.76 | 14.00 | 1.50 | 0.40 |
| | Max | 104.00 | 16.00 | 34.10 | 74.00 | 127.00 | 6.98 | 24.00 | 126.00 | 5.10 | 9.90 | 0.00 | 0.01 | 45.00 | 0.03 | 0.01 | 0.01 | 7.11 | 23.10 | 11.20 | 457.50 | 0.02 | 1.17 | 325.00 | 33.50 | 1.65 | 25.00 | 42.00 | 3.10 |
| | Count | 6 | 5 | 6 | 6 | 6 | 7 | 6 | 6 | 6 | 6 | 6 | 2 | 6 | 6 | 6 | 6 | 7 | 6 | 6 | 6 | 7 | 5 | 6 | 7 | 6 | 6 | 6 | 6 |
| | Average | 37.33 | 32.40 | 10.28 | 21.00 | 74.50 | 3.05 | 15.67 | 40.25 | 1.55 | 3.55 | 0.00 | 0.06 | 14.83 | 0.05 | 0.03 | 0.00 | 6.56 | 7.63 | 1.68 | 176.97 | 0.01 | 0.87 | 124.83 | 26.20 | 0.96 | 16.00 | 1.75 | 0.73 |
| LOXA119-2004 | StdDev | 4.72 | 8.02 | 1.43 | 5.39 | 6.32 | 1.71 | 2.42 | 5.83 | 0.45 | 0.58 | 0.00 | 0.08 | 3.73 | 0.11 | 0.05 | 0.00 | 0.31 | 2.67 | 1.61 | 83.22 | 0.00 | 0.23 | 19.26 | 2.66 | 0.38 | 2.53 | 0.61 | 0.35 |
| | Min | 28.00 | 25.00 | 7.80 | 15.90 | 68.00 | 0.21 | 13.00 | 30.30 | 1.20 | 2.60 | 0.00 | 0.00 | 11.60 | 0.00 | 0.00 | 0.00 | 6.13 | 4.78 | 0.60 | 117.00 | 0.01 | 0.68 | 104.00 | 21.70 | 0.63 | 13.00 | 1.50 | 0.30 |
| | Max | 41.00 | 42.00 | 12.00 | 30.60 | 86.00 | 4.87 | 20.00 | 47.50 | 2.30 | 4.30 | 0.01 | 0.12 | 21.80 | 0.27 | 0.13 | 0.01 | 7.13 | 11.60 | 4.90 | 343.00 | 0.02 | 1.27 | 156.00 | 30.00 | 1.72 | 20.00 | 3.00 | 1.10 |
| | Count | 6 | 6 | 6 | 11 | 6 | 10 | 6 | 6 | 6 | 6 | 6 | 1 | 6 | 6 | 5 | 6 | 10 | 6 | 11 | 9 | 11 | 6 | 6 | 11 | 6 | 6 | 6 | 6 |
| | Average | 37.50 | 22.50 | 10.85 | 19.81 | 73.17 | 5.37 | 15.83 | 42.28 | 1.30 | 3.72 | 0.00 | 0.01 | 13.92 | 0.01 | 0.01 | 0.00 | 6.57 | 5.64 | 1.11 | 144.03 | 0.02 | 0.77 | 112.17 | 24.67 | 2.12 | 16.83 | 16.17 | 1.40 |
| LOXA119-2005 | StdDev | 7.23 | 10.35 | 1.78 | 8.21 | 6.68 | 1.39 | 2.48 | 7.13 | 0.41 | 0.64 | 0.00 | | 4.43 | 0.01 | 0.00 | 0.00 | 0.20 | 2.86 | 0.30 | 44.84 | 0.02 | 0.15 | 27.03 | 6.95 | 3.22 | 3.19 | 34.24 | 2.02 |
| | Min | 28.00 | 13.00 | 8.70 | 11.10 | 63.00 | 2.63 | 13.00 | 33.90 | 0.90 | 3.00 | 0.00 | 0.01 | 8.60 | 0.00 | 0.00 | 0.00 | 6.30 | 3.19 | 0.70 | 92.10 | 0.01 | 0.59 | 76.00 | 13.60 | 0.66 | 13.00 | 1.50 | 0.40 |
| | Max | 49.00 | 42.00 | 13.90 | 35.20 | 81.00 | 7.90 | 20.00 | 54.40 | 1.80 | 4.80 | 0.00 | 0.01 | 21.50 | 0.02 | 0.02 | 0.01 | 6.96 | 10.70 | 1.70 | 225.00 | 0.07 | 1.04 | 156.00 | 35.00 | 8.68 | 22.00 | 86.00 | 5.50 |
| | Count | 5 | 4 | 5 | 5 | 5 | 6 | 5 | 5 | 5 | 5 | 5 | 0 | 5 | 5 | 5 | 5 | 6 | 5 | 5 | 6 | 6 | 4 | 5 | 6 | 5 | 5 | 5 | 5 |
| | Average | 22.00 | 47.25 | 6.48 | 18.34 | 67.60 | 3.49 | 16.20 | 25.88 | 1.12 | 2.38 | 0.00 | | 11.94 | 0.02 | 0.01 | 0.00 | 6.43 | 6.24 | 0.14 | 168.92 | 0.01 | 1.05 | 103.80 | 26.08 | 1.15 | 16.40 | 1.50 | 0.78 |
| LOXA120-2004 | StdDev | 5.57 | 9.29 | 1.32 | 4.53 | 13.46 | 2.12 | 1.48 | 5.18 | 0.36 | 0.44 | 0.00 | | 2.50 | 0.01 | 0.00 | 0.00 | 0.22 | 4.05 | 0.11 | 130.56 | 0.00 | 0.17 | 18.05 | 1.66 | 0.15 | 1.14 | 0.00 | 0.27 |
| | Min | 15.00 | 34.00 | 4.60 | 11.80 | 53.00 | 0.79 | 14.00 | 18.40 | 0.80 | 1.70 | 0.00 | | 8.60 | 0.00 | 0.00 | 0.00 | 6.13 | 2.16 | 0.05 | 83.00 | 0.01 | 0.84 | 78.00 | 23.20 | 0.93 | 15.00 | 1.50 | 0.40 |
| | Max | 29.00 | 55.00 | 8.10 | 23.50 | 84.00 | 6.60 | 18.00 | 31.90 | 1.60 | 2.80 | 0.00 | | 15.00 | 0.03 | 0.01 | 0.01 | 6.63 | 11.50 | 0.30 | 430.00 | 0.02 | 1.23 | 128.00 | 27.90 | 1.30 | 18.00 | 1.50 | 1.00 |
| | Count | 8 | 8 | 8 | 11 | 8 | 10 | 8 | 8 | 8 | 8 | 8 | 0 | 8 | 8 | 8 | 8 | 10 | 7 | 11 | 9 | 10 | 8 | 8 | 11 | 8 | 8 | 8 | 8 |
| | Average | 22.75 | 57.13 | 7.18 | 23.00 | 52.38 | 5.57 | 16.50 | 29.28 | 1.08 | 2.76 | 0.00 | | 13.59 | 0.02 | 0.01 | 0.00 | 6.55 | 6.15 | 0.19 | 133.60 | 0.02 | 1.12 | 106.50 | 25.85 | 2.32 | 16.75 | 33.19 | 3.78 |
| LOXA120-2005 | StdDev | 6.16 | 34.88 | 1.70 | 8.62 | 5.48 | 1.70 | 3.74 | 7.01 | 0.27 | 0.67 | 0.00 | | 3.97 | 0.02 | 0.00 | 0.00 | 0.26 | 2.75 | 0.13 | 47.48 | 0.03 | 0.29 | 43.26 | 5.82 | 2.56 | 3.73 | 55.68 | 6.79 |
| | Min | 16.00 | 33.00 | 5.50 | 13.80 | 43.00 | 2.43 | 13.00 | 22.50 | 0.80 | 2.10 | 0.00 | | 10.60 | 0.00 | 0.00 | 0.00 | 6.09 | 1.32 | 0.05 | 86.00 | 0.00 | 0.96 | 61.00 | 16.70 | 1.00 | 13.00 | 1.50 | 0.40 |
| | Max | 33.00 | 138.00 | 10.60 | 38.00 | 61.00 | 8.47 | 24.00 | 43.40 | 1.50 | 4.10 | 0.00 | | 22.30 | 0.06 | 0.01 | 0.01 | 6.94 | 9.32 | 0.40 | 223.00 | 0.10 | 1.84 | 160.00 | 34.70 | 8.39 | 24.00 | 130.00 | 20.00 |
| | Count | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 3 | 4 | 4 | 4 |
| | Average | 201.00 | 1.13 | 65.60 | 81.58 | 141.25 | 0.61 | 30.75 | 240.00 | 8.48 | 18.48 | 0.01 | 0.01 | 58.15 | 0.03 | 0.01 | 0.04 | 7.02 | 16.61 | 39.60 | 733.35 | 0.11 | 1.73 | 494.25 | 24.23 | 1.91 | 31.25 | 11.88 | 4.93 |
| LOXA121-2004 | StdDev | 25.60 | 0.63 | 9.88 | 10.48 | 17.73 | 0.17 | 1.71 | 37.43 | 0.59 | 3.07 | 0.00 | 0.00 | 6.08 | 0.03 | 0.01 | 0.04 | 0.32 | 5.40 | 10.76 | 95.50 | 0.06 | 0.15 | 51.56 | 2.84 | 0.12 | 1.89 | 20.75 | 6.20 |
| | Min | 175.00 | 0.50 | 52.50 | 70.80 | 124.00 | 0.46 | 29.00 | 191.00 | 7.90 | 14.60 | 0.01 | 0.00 | 52.10 | 0.00 | 0.00 | 0.01 | 6.56 | 8.83 | 24.00 | 622.00 | 0.03 | 1.58 | 435.00 | 20.40 | 1.79 | 30.00 | 1.50 | 1.30 |
| | Max | 236.00 | 2.00 | 76.40 | 95.00 | 166.00 | 0.83 | 33.00 | 282.00 | 9.20 | 22.10 | 0.01 | 0.01 | 66.30 | 0.08 | 0.02 | 0.11 | 7.26 | 20.60 | 48.70 | 852.00 | 0.18 | 1.87 | 558.00 | 26.80 | 2.03 | 34.00 | 43.00 | 14.20 |
| | Count | 1 | 1 | 1 | 5 | 1 | 5 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 5 | 1 | 5 | 6 | 5 | 1 | 1 | 6 | 1 | 1 | 1 | 1 |
| | Average | 216.00 | 3.00 | 73.10 | 107.32 | 100.00 | 0.75 | 31.00 | 268.00 | 7.50 | 20.90 | 0.00 | 0.01 | 71.10 | 0.03 | 0.01 | 0.01 | 7.01 | 15.10 | 47.92 | 757.98 | 0.07 | 1.73 | 503.00 | 21.76 | 2.69 | 31.00 | 22.00 | 3.60 |
| LOXA121-2005 | StdDev | | | | 51.87 | | 0.40 | | | | | | | | | | | 0.09 | | 30.62 | 358.94 | 0.03 | | | 5.53 | | | | |
| | Min | 216.00 | 3.00 | 73.10 | 30.60 | 100.00 | 0.23 | 31.00 | 268.00 | 7.50 | 20.90 | 0.00 | 0.01 | 71.10 | 0.03 | 0.01 | 0.01 | 6.86 | 15.10 | 9.90 | 322.70 | 0.05 | 1.73 | 503.00 | 15.50 | 2.69 | 31.00 | 22.00 | 3.60 |
| | Max | 216.00 | 3.00 | 73.10 | 172.00 | 100.00 | 1.24 | 31.00 | 268.00 | 7.50 | 20.90 | 0.00 | 0.01 | 71.10 | 0.03 | 0.01 | 0.01 | 7.11 | 15.10 | 95.10 | 1252.00 | 0.12 | 1.73 | 503.00 | 27.57 | 2.69 | 31.00 | 22.00 | 3.60 |
| | Count | 4 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 4 | 2 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 5 | 5 | 3 | 4 | 5 | 3 | 4 | 4 | 4 |
| | Average | 187.00 | 11.00 | 62.25 | 97.33 | 131.25 | 1.75 | 31.75 | 236.25 | 6.98 | 19.60 | 0.01 | 0.00 | 68.90 | 0.01 | 0.01 | 0.01 | 7.04 | 21.70 | 46.60 | 726.18 | 0.01 | 1.84 | 516.50 | 25.26 | 1.91 | 32.25 | 1.50 | 0.85 |
| LOXA122-2004 | StdDev | 24.10 | 5.89 | 11.37 | 20.32 | 7.04 | 1.70 | 4.11 | 47.20 | 0.85 | 4.64 | 0.00 | 0.00 | 15.08 | 0.01 | 0.00 | 0.00 | 0.25 | 1.89 | 24.90 | 175.20 | 0.00 | 0.36 | 98.33 | 2.31 | 0.40 | 4.03 | 0.00 | 0.19 |
| | Min | 161.00 | 5.00 | 51.70 | 78.70 | 121.00 | 0.45 | 28.00 | 192.00 | 6.10 | 15.20 | 0.00 | 0.00 | 54.50 | 0.01 | 0.00 | 0.01 | 6.61 | 19.60 | 21.10 | 527.00 | 0.01 | 1.43 | 428.00 | 21.70 | 1.48 | 28.00 | 1.50 | 0.70 |
| | Max | 208.00 | 19.00 | 73.80 | 123.00 | 137.00 | 4.58 | 37.00 | 280.00 | 7.70 | 23.90 | 0.01 | 0.01 | 86.90 | 0.02 | 0.01 | 0.01 | 7.24 | 23.90 | 69.00 | 940.00 | 0.02 | 2.13 | 608.00 | 27.70 | 2.26 | 37.00 | 1.50 | 1.10 |
| | Count | 5 | 5 | 5 | 9 | 5 | 9 | 5 | 5 | 5 | 5 | 5 | 2 | 5 | 5 | 4 | 5 | 10 | 5 | 9 | 11 | 10 | 5 | 5 | 11 | 5 | 5 | 5 | 5 |
| | Average | 185.60 | 7.80 | 57.96 | 72.70 | 104.40 | 2.25 | 26.80 | 206.00 | 5.78 | 14.90 | 0.00 | 0.01 | 55.74 | 0.02 | 0.01 | 0.00 | 7.08 | 15.83 | 12.50 | 567.37 | 0.01 | 1.36 | 421.00 | 23.26 | 1.42 | 27.00 | 1.50 | 0.90 |
| LOXA122-2005 | StdDev | 55.32 | 3.42 | 17.72 | 34.27 | 9.04 | 1.28 | 4.32 | 59.76 | 1.17 | 4.03 | 0.00 | 0.00 | 17.20 | 0.01 | 0.01 | 0.00 | 0.18 | 3.83 | 6.92 | 235.03 | 0.01 | 0.23 | 133.41 | 5.44 | 0.25 | 4.53 | 0.00 | 0.29 |
| | Min | 109.00 | 5.00 | 35.10 | 22.70 | 93.00 | 0.54 | 20.00 | 122.00 | 3.90 | 8.40 | 0.00 | 0.01 | 28.30 | 0.00 | 0.00 | 0.00 | 6.78 | 9.43 | 3.50 | 240.00 | 0.01 | 1.00 | 218.00 | 14.20 | 1.04 | 20.00 | 1.50 | 0.50 |
| | Max | 244.00 | 12.00 | 76.30 | 102.00 | 118.00 | 4.87 | 30.00 | 264.00 | 6.80 | 18.00 | 0.00 | 0.01 | 70.00 | 0.04 | 0.02 | 0.01 | 7.32 | 18.90 | 23.40 | 810.10 | 0.03 | 1.54 | 544.00 | 30.40 | 1.66 | 31.00 | 1.50 | 1.20 |

| Site - Year | STAT | ALK | APA | Ca | Cl | COLOR | D-O | DOC | HARD | K | Mg | N02 | N03 | Na | NH4 | NOX | OPO4 | Ph_F | SiO2 | SO4 | SpC | T_PO4 | TDKN | TDS | TEMP | TKN | TOC | TSS | TURB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | mg/L | nM/minmL | mg/L | mg/L | PCU | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | units | mg/L | mg/L | uS/cm | mg/L | mg/L | mg/L | Deg.C | mg/L | mg/L | mg/L | mg/L |
| LOXA123-2004 | Count | 3 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 4 | 1 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 5 | 5 | 3 | 4 | 5 | 3 | 4 | 4 | 4 |
| | Average | 110.67 | 14.25 | 35.28 | 62.20 | 83.00 | 1.68 | 21.75 | 133.50 | 4.33 | 10.98 | 0.00 | 0.01 | 43.20 | 0.03 | 0.01 | 0.00 | 7.06 | 15.05 | 16.63 | 473.68 | 0.02 | 1.23 | 306.00 | 25.50 | 1.32 | 21.75 | 1.50 | 0.83 |
| | StdDev | 9.07 | 6.40 | 2.93 | 3.35 | 5.35 | 0.97 | 1.50 | 10.47 | 0.17 | 0.82 | 0.00 | | 2.18 | 0.02 | 0.01 | 0.00 | 0.13 | 0.58 | 2.63 | 24.98 | 0.01 | 0.09 | 22.91 | 1.96 | 0.13 | 1.26 | 0.00 | 0.21 |
| | Min | 101.00 | 5.00 | 32.40 | 59.60 | 80.00 | 0.83 | 20.00 | 123.00 | 4.10 | 10.10 | 0.00 | 0.01 | 41.20 | 0.00 | 0.00 | 0.00 | 6.90 | 14.30 | 13.80 | 440.00 | 0.01 | 1.13 | 282.00 | 22.30 | 1.17 | 20.00 | 1.50 | 0.60 |
| | Max | 119.00 | 19.00 | 39.20 | 66.70 | 91.00 | 3.01 | 23.00 | 147.00 | 4.50 | 11.90 | 0.01 | 0.01 | 46.30 | 0.06 | 0.02 | 0.01 | 7.23 | 15.70 | 19.50 | 499.00 | 0.03 | 1.30 | 337.00 | 27.60 | 1.43 | 23.00 | 1.50 | 1.10 |
| LOXA123-2005 | Count | 6 | 6 | 6 | 9 | 6 | 7 | 6 | 6 | 6 | 6 | 6 | 2 | 6 | 6 | 5 | 6 | 8 | 5 | 9 | 9 | 9 | 6 | 6 | 9 | 6 | 6 | 6 | 6 |
| | Average | 142.33 | 13.00 | 44.33 | 65.74 | 82.83 | 1.51 | 25.67 | 167.27 | 4.82 | 13.72 | 0.00 | 0.01 | 55.53 | 0.04 | 0.01 | 0.00 | 7.10 | 14.92 | 17.62 | 493.70 | 0.01 | 1.44 | 359.17 | 23.48 | 1.65 | 26.00 | 5.25 | 1.53 |
| | StdDev | 52.56 | 4.56 | 19.49 | 35.75 | 7.49 | 1.40 | 4.18 | 69.80 | 2.20 | 5.13 | 0.00 | 0.00 | 23.59 | 0.02 | 0.01 | 0.00 | 0.21 | 4.66 | 17.55 | 237.21 | 0.01 | 0.24 | 184.80 | 5.22 | 0.40 | 4.29 | 9.19 | 1.82 |
| | Min | 77.00 | 5.00 | 22.60 | 23.10 | 72.00 | 0.20 | 21.00 | 89.60 | 2.60 | 8.10 | 0.00 | 0.01 | 29.70 | 0.01 | 0.00 | 0.00 | 6.86 | 11.40 | 3.30 | 213.80 | 0.01 | 1.19 | 182.00 | 16.30 | 1.23 | 21.00 | 1.50 | 0.50 |
| | Max | 232.00 | 18.00 | 78.70 | 140.00 | 90.00 | 4.28 | 33.00 | 290.00 | 8.60 | 22.70 | 0.00 | 0.01 | 97.80 | 0.07 | 0.03 | 0.01 | 7.36 | 22.70 | 58.20 | 988.50 | 0.04 | 1.83 | 692.00 | 29.40 | 2.30 | 33.00 | 24.00 | 5.20 |
| LOXA124-2004 | Count | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 1 | 4 | 3 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| | Average | 28.25 | 14.75 | 10.85 | 24.43 | 111.00 | 1.28 | 18.50 | 36.48 | 1.00 | 2.30 | 0.00 | 0.02 | 14.63 | 0.01 | 0.01 | 0.04 | 6.47 | 4.64 | 1.33 | 145.83 | 0.06 | 0.98 | 95.50 | 24.73 | 1.18 | 18.75 | 2.63 | 0.75 |
| | StdDev | 5.56 | 15.95 | 2.06 | 9.21 | 16.21 | 1.26 | 1.73 | 7.57 | 0.67 | 0.62 | 0.00 | | 5.21 | 0.01 | 0.01 | 0.07 | 0.37 | 3.59 | 1.52 | 47.36 | 0.06 | 0.10 | 46.10 | 3.30 | 0.34 | 1.71 | 2.25 | 0.24 |
| | Min | 23.00 | 2.00 | 9.30 | 17.70 | 88.00 | 0.37 | 17.00 | 30.70 | 0.60 | 1.80 | 0.00 | 0.02 | 10.70 | 0.00 | 0.00 | 0.00 | 6.13 | 1.17 | 0.50 | 115.00 | 0.02 | 0.89 | 44.00 | 20.10 | 0.96 | 17.00 | 1.50 | 0.60 |
| | Max | 36.00 | 36.00 | 13.80 | 37.80 | 126.00 | 2.71 | 21.00 | 47.40 | 2.00 | 3.20 | 0.01 | 0.02 | 22.20 | 0.01 | 0.03 | 0.15 | 6.87 | 9.66 | 3.60 | 215.00 | 0.15 | 1.10 | 148.00 | 27.30 | 1.69 | 21.00 | 6.00 | 1.10 |
| LOXA124-2005 | Count | 8 | 7 | 8 | 12 | 8 | 11 | 8 | 8 | 8 | 8 | 8 | 2 | 8 | 8 | 6 | 8 | 12 | 8 | 12 | 11 | 11 | 8 | 8 | 12 | 8 | 8 | 8 | 8 |
| | Average | 34.00 | 10.57 | 12.76 | 26.38 | 83.00 | 2.08 | 17.75 | 44.14 | 1.04 | 3.00 | 0.00 | 0.00 | 16.95 | 0.01 | 0.01 | 0.00 | 6.48 | 4.89 | 1.17 | 171.94 | 0.02 | 0.89 | 117.38 | 21.80 | 1.20 | 17.88 | 4.50 | 0.71 |
| | StdDev | 12.87 | 2.82 | 3.96 | 9.05 | 13.40 | 1.11 | 1.67 | 14.68 | 0.58 | 1.18 | 0.00 | 0.00 | 5.82 | 0.00 | 0.01 | 0.00 | 0.43 | 3.71 | 1.65 | 56.91 | 0.03 | 0.10 | 30.33 | 5.48 | 0.68 | 1.81 | 7.18 | 0.20 |
| | Min | 21.00 | 6.00 | 8.70 | 14.20 | 67.00 | 0.61 | 15.00 | 29.20 | 0.50 | 1.80 | 0.00 | 0.00 | 9.50 | 0.00 | 0.00 | 0.00 | 5.93 | 0.86 | 0.05 | 99.30 | 0.01 | 0.75 | 72.00 | 10.40 | 0.77 | 15.00 | 1.50 | 0.40 |
| | Max | 55.00 | 14.00 | 19.70 | 43.20 | 111.00 | 3.83 | 20.00 | 70.00 | 2.00 | 5.10 | 0.01 | 0.01 | 27.20 | 0.02 | 0.02 | 0.01 | 7.30 | 10.40 | 6.20 | 268.00 | 0.11 | 1.01 | 159.00 | 27.10 | 2.82 | 20.00 | 22.00 | 1.00 |
| LOXA126-2004 | Count | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 2 | 4 | 3 | 4 | 4 | 3 | 4 | 4 | 5 | 5 | 4 | 4 | 5 | 4 | 4 | 4 | 4 |
| | Average | 83.00 | 15.00 | 27.08 | 53.75 | 108.00 | 2.77 | 21.00 | 99.20 | 3.13 | 7.68 | 0.00 | 0.00 | 36.90 | 0.01 | 0.01 | 0.00 | 6.91 | 11.86 | 12.30 | 332.46 | 0.01 | 1.14 | 263.00 | 25.74 | 1.20 | 21.25 | 1.50 | 0.78 |
| | StdDev | 38.75 | 11.53 | 13.25 | 21.98 | 21.65 | 0.97 | 5.35 | 49.31 | 1.52 | 3.96 | 0.00 | 0.00 | 16.39 | 0.00 | 0.00 | 0.00 | 0.22 | 7.34 | 12.47 | 163.99 | 0.01 | 0.32 | 124.63 | 2.84 | 0.33 | 5.25 | 0.00 | 0.33 |
| | Min | 61.00 | 6.00 | 19.30 | 40.90 | 81.00 | 1.67 | 18.00 | 70.40 | 2.20 | 5.40 | 0.00 | 0.00 | 27.40 | 0.00 | 0.00 | 0.00 | 6.77 | 4.97 | 4.20 | 191.00 | 0.01 | 0.91 | 176.00 | 21.10 | 0.93 | 18.00 | 1.50 | 0.40 |
| | Max | 141.00 | 28.00 | 46.90 | 86.50 | 134.00 | 4.03 | 29.00 | 173.00 | 5.40 | 13.60 | 0.01 | 0.01 | 61.40 | 0.01 | 0.01 | 0.01 | 7.16 | 22.20 | 30.70 | 616.00 | 0.03 | 1.60 | 448.00 | 27.70 | 1.68 | 29.00 | 1.50 | 1.10 |
| LOXA126-2005 | Count | 9 | 8 | 9 | 12 | 9 | 11 | 9 | 9 | 9 | 9 | 9 | 1 | 9 | 9 | 7 | 9 | 12 | 9 | 12 | 11 | 11 | 9 | 9 | 12 | 9 | 9 | 9 | 9 |
| | Average | 103.44 | 28.00 | 35.74 | 55.37 | 89.11 | 2.66 | 22.11 | 123.33 | 3.54 | 8.28 | 0.00 | 0.02 | 41.08 | 0.01 | 0.01 | 0.00 | 6.80 | 6.62 | 8.28 | 384.21 | 0.01 | 1.36 | 261.00 | 24.01 | 1.48 | 22.33 | 2.50 | 0.76 |
| | StdDev | 51.72 | 15.88 | 19.69 | 29.56 | 16.61 | 1.32 | 4.62 | 64.56 | 1.60 | 3.83 | 0.00 | | 17.59 | 0.01 | 0.01 | 0.00 | 0.26 | 6.21 | 12.60 | 222.69 | 0.01 | 0.26 | 116.99 | 4.28 | 0.37 | 4.47 | 2.22 | 0.25 |
| | Min | 30.00 | 17.00 | 10.30 | 10.80 | 71.00 | 0.92 | 12.00 | 35.60 | 1.00 | 2.40 | 0.00 | 0.02 | 8.00 | 0.00 | 0.00 | 0.00 | 6.30 | 0.48 | 0.50 | 105.00 | 0.01 | 0.95 | 64.00 | 16.50 | 0.86 | 13.00 | 1.50 | 0.40 |
| | Max | 191.00 | 54.00 | 68.30 | 99.40 | 116.00 | 4.64 | 27.00 | 236.00 | 6.20 | 15.80 | 0.01 | 0.02 | 66.30 | 0.05 | 0.02 | 0.01 | 7.08 | 15.60 | 40.50 | 770.00 | 0.03 | 1.70 | 488.00 | 29.60 | 2.04 | 28.00 | 8.00 | 1.10 |
| LOXA127-2004 | Count | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 2 | 4 | 2 | 4 | 4 | 3 | 4 | 4 | 4 | 5 | 4 | 4 | 5 | 4 | 4 | 4 | 4 |
| | Average | 23.50 | 46.00 | 9.48 | 28.78 | 118.75 | 2.82 | 21.50 | 34.28 | 1.33 | 2.60 | 0.00 | 0.00 | 17.18 | 0.01 | 0.01 | 0.01 | 6.38 | 7.35 | 2.63 | 163.63 | 0.01 | 1.17 | 136.00 | 26.30 | 1.30 | 21.00 | 1.50 | 0.70 |
| | StdDev | 1.29 | 13.11 | 0.64 | 4.09 | 49.99 | 1.64 | 5.80 | 2.05 | 0.30 | 0.12 | 0.00 | 0.00 | 1.85 | 0.00 | 0.00 | 0.00 | 0.16 | 0.80 | 2.37 | 22.92 | 0.01 | 0.23 | 11.40 | 2.73 | 0.38 | 4.97 | 0.00 | 0.18 |
| | Min | 22.00 | 32.00 | 8.70 | 25.10 | 86.00 | 0.83 | 16.00 | 32.00 | 1.00 | 2.50 | 0.00 | 0.00 | 15.90 | 0.00 | 0.01 | 0.00 | 6.24 | 6.32 | 0.40 | 143.00 | 0.01 | 0.91 | 125.00 | 21.50 | 0.93 | 17.00 | 1.50 | 0.50 |
| | Max | 25.00 | 58.00 | 10.10 | 34.60 | 193.00 | 4.55 | 29.00 | 36.20 | 1.70 | 2.70 | 0.01 | 0.00 | 19.90 | 0.01 | 0.01 | 0.01 | 6.56 | 8.26 | 5.50 | 191.00 | 0.03 | 1.45 | 152.00 | 27.80 | 1.80 | 28.00 | 1.50 | 0.90 |
| LOXA127-2005 | Count | 6 | 3 | 6 | 12 | 6 | 11 | 6 | 6 | 5 | 6 | 7 | 1 | 6 | 6 | 5 | 6 | 12 | 6 | 11 | 11 | 11 | 6 | 6 | 12 | 6 | 6 | 6 | 6 |
| | Average | 24.17 | 49.00 | 9.42 | 28.17 | 75.00 | 4.56 | 21.50 | 34.10 | 1.56 | 2.57 | 0.00 | 0.01 | 18.10 | 0.01 | 0.01 | 0.00 | 6.60 | 3.75 | 0.23 | 140.25 | 0.01 | 1.31 | 132.17 | 24.98 | 1.46 | 21.67 | 2.67 | 0.73 |
| | StdDev | 4.26 | 5.00 | 2.15 | 13.95 | 12.84 | 1.11 | 3.62 | 7.40 | 0.58 | 0.48 | 0.00 | | 5.04 | 0.00 | 0.00 | 0.00 | 0.27 | 1.82 | 0.19 | 52.58 | 0.00 | 0.18 | 21.02 | 4.62 | 0.30 | 4.18 | 1.91 | 0.19 |
| | Min | 20.00 | 44.00 | 6.80 | 11.60 | 55.00 | 2.30 | 17.00 | 25.20 | 1.10 | 2.00 | 0.00 | 0.01 | 11.40 | 0.00 | 0.00 | 0.00 | 6.23 | 1.47 | 0.05 | 82.00 | 0.01 | 1.07 | 104.00 | 16.60 | 1.08 | 16.00 | 1.50 | 0.50 |
| | Max | 32.00 | 54.00 | 12.20 | 50.60 | 88.00 | 6.08 | 25.00 | 43.80 | 2.50 | 3.20 | 0.00 | 0.01 | 23.80 | 0.01 | 0.01 | 0.01 | 7.13 | 5.92 | 0.70 | 238.20 | 0.01 | 1.51 | 161.00 | 29.90 | 1.87 | 25.00 | 6.00 | 1.00 |
| LOXA128-2004 | Count | 4 | 3 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 4 | 1 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 5 | 5 | 3 | 4 | 5 | 4 | 4 | 4 | 4 |
| | Average | 28.50 | 77.00 | 5.68 | 16.85 | 79.50 | 3.43 | 17.75 | 22.85 | 1.08 | 2.13 | 0.00 | 0.00 | 10.80 | 0.01 | 0.01 | 0.00 | 6.27 | 4.70 | 0.08 | 112.50 | 0.01 | 0.93 | 99.00 | 25.88 | 1.37 | 18.00 | 4.13 | 1.63 |
| | StdDev | 27.31 | 26.23 | 1.45 | 4.97 | 18.81 | 1.09 | 2.99 | 6.06 | 0.43 | 0.59 | 0.00 | | 3.04 | 0.01 | 0.00 | 0.00 | 0.20 | 3.16 | 0.03 | 37.01 | 0.01 | 0.19 | 14.76 | 2.35 | 0.58 | 3.16 | 5.25 | 1.73 |
| | Min | 10.00 | 49.00 | 3.80 | 10.60 | 60.00 | 2.35 | 14.00 | 15.00 | 0.70 | 1.40 | 0.00 | 0.00 | 7.00 | 0.00 | 0.00 | 0.00 | 6.08 | 2.58 | 0.05 | 65.00 | 0.01 | 0.72 | 79.00 | 22.20 | 0.85 | 14.00 | 1.50 | 0.60 |
| | Max | 69.00 | 101.00 | 7.00 | 21.50 | 105.00 | 5.00 | 21.00 | 28.50 | 1.70 | 2.70 | 0.00 | 0.00 | 13.50 | 0.02 | 0.01 | 0.01 | 6.56 | 9.40 | 0.10 | 163.00 | 0.02 | 1.07 | 112.00 | 28.10 | 2.21 | 21.00 | 12.00 | 4.20 |
| LOXA128-2005 | Count | 3 | 3 | 3 | 7 | 3 | 7 | 3 | 3 | 3 | 3 | 3 | 0 | 3 | 3 | 2 | 3 | 8 | 3 | 7 | 7 | 6 | 3 | 3 | 8 | 3 | 3 | 3 | 3 |
| | Average | 23.67 | 62.33 | 7.00 | 21.33 | 65.33 | 5.06 | 17.00 | 28.37 | 1.30 | 2.67 | 0.00 | | 13.60 | 0.01 | 0.00 | 0.00 | 6.47 | 4.56 | 0.16 | 121.26 | 0.01 | 1.04 | 90.67 | 25.62 | 1.57 | 17.33 | 10.33 | 2.07 |
| | StdDev | 1.53 | 55.14 | 0.44 | 3.64 | 6.66 | 2.03 | 1.00 | 0.92 | 0.26 | 0.06 | 0.00 | | 1.15 | 0.00 | 0.00 | 0.00 | 0.11 | 2.01 | 0.12 | 13.05 | 0.01 | 0.07 | 32.15 | 6.26 | 0.90 | 1.53 | 15.30 | 2.37 |
| | Min | 22.00 | 30.00 | 6.50 | 16.80 | 58.00 | 2.34 | 16.00 | 27.30 | 1.10 | 2.60 | 0.00 | | 12.70 | 0.00 | 0.00 | 0.00 | 6.39 | 2.65 | 0.05 | 107.00 | 0.01 | 0.98 | 54.00 | 17.20 | 1.04 | 16.00 | 1.50 | 0.60 |
| | Max | 25.00 | 126.00 | 7.30 | 28.20 | 71.00 | 7.49 | 18.00 | 28.90 | 1.60 | 2.70 | 0.00 | | 14.90 | 0.01 | 0.00 | 0.00 | 6.74 | 6.66 | 0.40 | 148.30 | 0.03 | 1.12 | 114.00 | 34.20 | 2.61 | 19.00 | 28.00 | 4.80 |
| LOXA129-2004 | Count | 7 | 7 | 7 | 7 | 7 | 6 | 7 | 7 | 7 | 7 | 7 | 5 | 7 | 6 | 6 | 7 | 5 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| | Average | 162.14 | 4.00 | 55.77 | 81.34 | 118.00 | 2.93 | 24.71 | 195.00 | 7.07 | 13.56 | 0.01 | 0.02 | 54.90 | 0.12 | 0.03 | 0.10 | 7.47 | 13.93 | 31.96 | 647.06 | 0.16 | 1.56 | 429.57 | 27.50 | 1.89 | 26.14 | 8.86 | 7.19 |
| | StdDev | 24.92 | 2.08 | 8.63 | 30.39 | 51.47 | 2.44 | 5.22 | 31.83 | 1.60 | 5.24 | 0.01 | 0.02 | 21.25 | 0.11 | 0.02 | 0.16 | 0.38 | 3.70 | 19.93 | 155.74 | 0.16 | 0.37 | 100.23 | 3.04 | 0.42 | 7.17 | 6.38 | 5.08 |
| | Min | 120.00 | 2.00 | 43.50 | 54.00 | 45.00 | 0.38 | 17.00 | 161.00 | 5.20 | 7.90 | 0.00 | 0.00 | 35.30 | 0.01 | 0.01 | 0.01 | 7.17 | 8.81 | 6.60 | 497.40 | 0.06 | 0.99 | 329.00 | 21.90 | 1.41 | 17.00 | 1.50 | 1.80 |
| | Max | 192.00 | 8.00 | 72.30 | 130.00 | 193.00 | 6.11 | 32.00 | 237.00 | 8.90 | 20.70 | 0.02 | 0.04 | 87.40 | 0.31 | 0.06 | 0.43 | 8.01 | 19.90 | 59.00 | 874.00 | 0.50 | 2.10 | 563.00 | 30.60 | 2.40 | 37.00 | 18.00 | 15.60 |
| LOXA129-2005 | Count | 12 | 10 | 12 | 12 | 12 | 11 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 11 | 7 | 11 | 12 | 12 | 12 | 12 | 11 | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| | Average | 191.75 | 2.30 | 68.23 | 91.70 | 125.83 | 3.19 | 27.92 | 230.92 | 6.04 | 14.74 | 0.05 | 0.20 | 62.85 | 0.12 | 0.42 | 0.03 | 7.41 | 11.68 | 32.57 | 737.81 | 0.10 | 1.81 | 475.67 | 24.78 | 2.25 | 28.42 | 9.79 | 7.59 |
| | StdDev | 47.09 | 1.06 | 19.35 | 25.85 | 34.65 | 2.04 | 4.23 | 68.83 | 2.16 | 5.73 | 0.10 | 0.45 | 17.28 | 0.21 | 0.64 | 0.05 | 0.27 | 4.19 | 24.15 | 200.89 | 0.06 | 0.54 | 127.87 | 4.16 | 0.62 | 4.25 | 8.38 | 4.80 |
| | Min | 99.00 | 1.00 | 33.50 | 32.30 | 87.00 | 1.10 | 23.00 | 108.00 | 1.70 | 5.90 | 0.01 | 0.00 | 24.50 | 0.00 | 0.03 | 0.01 | 6.97 | 7.40 | 3.50 | 321.00 | 0.06 | 1.24 | 211.00 | 18.30 | 1.59 | 23.00 | 1.50 | 1.90 |
| | Max | 251.00 | 4.00 | 96.60 | 119.00 | 185.00 | 6.65 | 36.00 | 332.00 | 8.80 | 22.90 | 0.33 | 1.60 | 82.70 | 0.70 | 1.77 | 0.18 | 7.89 | 20.60 | 76.60 | 1002.00 | 0.26 | 3.04 | 652.00 | 30.20 | 3.52 | 38.00 | 32.00 | 19.40 |

| Site - Year | STAT | ALK | APA | Ca | Cl | COLOR | D-O | DOC | HARD | K | Mg | N02 | N03 | Na | NH4 | NOX | OPO4 | Ph_F | SiO2 | SO4 | SpC | T_PO4 | TDKN | TDS | TEMP | TKN | TOC | TSS | TURB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | mg/L | nM/minmL | mg/L | mg/L | PCU | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | units | mg/L | mg/L | uS/cm | mg/L | mg/L | mg/L | Deg.C | mg/L | mg/L | mg/L | mg/L |
| | Count | 4 | 3 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 2 | 4 | 2 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| | Average | 138.25 | 4.17 | 45.83 | 56.30 | 136.00 | 0.85 | 23.75 | 156.50 | 6.45 | 10.23 | 0.00 | 0.00 | 37.48 | 0.01 | 0.01 | 0.05 | 6.98 | 11.92 | 15.98 | 487.00 | 0.07 | 1.33 | 330.25 | 24.93 | 1.48 | 24.25 | 1.50 | 1.05 |
| LOXA130-2004 | StdDev | 28.61 | 3.75 | 11.73 | 17.21 | 44.10 | 0.22 | 6.65 | 43.29 | 1.59 | 3.58 | 0.00 | 0.00 | 11.01 | 0.01 | 0.00 | 0.09 | 0.15 | 4.92 | 17.77 | 122.97 | 0.09 | 0.42 | 97.52 | 3.63 | 0.51 | 7.50 | 0.00 | 0.48 |
| | Min | 112.00 | 0.50 | 39.50 | 30.70 | 111.00 | 0.60 | 16.00 | 128.00 | 5.40 | 6.50 | 0.00 | 0.00 | 21.40 | 0.00 | 0.00 | 0.00 | 6.81 | 6.09 | 3.40 | 348.00 | 0.01 | 0.95 | 217.00 | 20.40 | 1.08 | 16.00 | 1.50 | 0.60 |
| | Max | 179.00 | 8.00 | 63.40 | 66.60 | 202.00 | 1.02 | 32.00 | 221.00 | 8.80 | 15.10 | 0.01 | 0.00 | 45.10 | 0.02 | 0.01 | 0.18 | 7.10 | 17.00 | 42.00 | 647.00 | 0.21 | 1.92 | 454.00 | 28.20 | 2.23 | 34.00 | 1.50 | 1.70 |
| | Count | 11 | 10 | 10 | 12 | 11 | 11 | 11 | 10 | 10 | 10 | 11 | 5 | 10 | 11 | 7 | 11 | 12 | 11 | 12 | 11 | 11 | 11 | 11 | 12 | 11 | 11 | 11 | 11 |
| | Average | 117.64 | 7.60 | 39.66 | 65.34 | 114.82 | 2.25 | 25.18 | 138.03 | 4.70 | 9.46 | 0.00 | 0.01 | 44.15 | 0.01 | 0.00 | 0.00 | 6.76 | 6.36 | 5.87 | 456.01 | 0.02 | 1.39 | 287.27 | 24.30 | 1.55 | 25.45 | 2.41 | 0.96 |
| LOXA130-2005 | StdDev | 47.95 | 2.17 | 16.30 | 32.05 | 14.65 | 1.46 | 5.47 | 56.03 | 2.15 | 3.78 | 0.00 | 0.01 | 19.64 | 0.00 | 0.00 | 0.00 | 0.23 | 5.03 | 8.80 | 205.84 | 0.01 | 0.32 | 117.69 | 4.83 | 0.45 | 5.48 | 2.03 | 0.47 |
| | Min | 49.00 | 3.00 | 16.50 | 17.70 | 98.00 | 0.55 | 17.00 | 56.40 | 1.40 | 3.70 | 0.00 | 0.00 | 13.30 | 0.00 | 0.00 | 0.00 | 6.42 | 1.23 | 1.20 | 171.00 | 0.01 | 0.89 | 115.00 | 16.40 | 0.87 | 17.00 | 1.50 | 0.50 |
| | Max | 185.00 | 11.00 | 63.30 | 102.00 | 148.00 | 4.99 | 31.00 | 221.00 | 7.10 | 15.20 | 0.01 | 0.02 | 69.40 | 0.02 | 0.01 | 0.01 | 7.08 | 16.30 | 30.20 | 757.00 | 0.06 | 1.78 | 479.00 | 30.80 | 2.45 | 32.00 | 7.00 | 2.20 |
| | Count | 4 | 3 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 2 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| | Average | 100.75 | 27.00 | 30.43 | 62.45 | 137.00 | 2.54 | 26.00 | 113.78 | 4.95 | 9.20 | 0.01 | 0.00 | 41.70 | 0.01 | 0.01 | 0.01 | 7.03 | 15.75 | 10.98 | 432.58 | 0.01 | 1.39 | 310.75 | 25.50 | 1.45 | 25.50 | 1.50 | 0.65 |
| LOXA131-2004 | StdDev | 38.08 | 17.06 | 12.00 | 18.27 | 20.20 | 2.28 | 4.08 | 44.45 | 1.74 | 3.50 | 0.00 | 0.00 | 12.52 | 0.01 | 0.00 | 0.00 | 0.07 | 8.09 | 9.83 | 149.85 | 0.00 | 0.17 | 96.15 | 3.12 | 0.21 | 2.65 | 0.00 | 0.24 |
| | Min | 68.00 | 8.00 | 19.40 | 45.30 | 121.00 | 1.15 | 22.00 | 73.10 | 3.40 | 6.00 | 0.00 | 0.00 | 30.30 | 0.00 | 0.01 | 0.01 | 6.96 | 6.18 | 2.20 | 293.30 | 0.01 | 1.23 | 228.00 | 21.00 | 1.22 | 23.00 | 1.50 | 0.40 |
| | Max | 139.00 | 41.00 | 42.30 | 87.50 | 163.00 | 5.17 | 30.00 | 158.00 | 6.60 | 12.80 | 0.01 | 0.01 | 58.60 | 0.02 | 0.01 | 0.01 | 7.09 | 25.10 | 21.50 | 612.00 | 0.01 | 1.59 | 429.00 | 27.80 | 1.67 | 29.00 | 1.50 | 0.90 |
| | Count | 9 | 8 | 9 | 11 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 4 | 9 | 9 | 6 | 9 | 10 | 9 | 11 | 9 | 10 | 9 | 9 | 10 | 9 | 9 | 9 | 9 |
| | Average | 58.22 | 33.63 | 17.96 | 45.22 | 109.56 | 4.05 | 23.00 | 66.41 | 2.77 | 5.22 | 0.00 | 0.00 | 24.87 | 0.01 | 0.01 | 0.00 | 6.82 | 4.52 | 1.43 | 248.76 | 0.01 | 1.34 | 186.44 | 23.80 | 1.46 | 23.22 | 2.89 | 0.72 |
| LOXA131-2005 | StdDev | 15.94 | 13.57 | 4.83 | 24.28 | 12.83 | 0.88 | 5.57 | 18.52 | 1.06 | 1.57 | 0.00 | 0.00 | 11.63 | 0.00 | 0.00 | 0.00 | 0.17 | 3.24 | 0.66 | 93.22 | 0.00 | 0.35 | 54.58 | 4.27 | 0.43 | 5.54 | 4.17 | 0.41 |
| | Min | 33.00 | 19.00 | 11.10 | 15.90 | 93.00 | 2.76 | 17.00 | 40.20 | 1.40 | 3.00 | 0.00 | 0.00 | 11.20 | 0.00 | 0.00 | 0.00 | 6.54 | 0.46 | 0.50 | 137.00 | 0.01 | 0.90 | 104.00 | 16.30 | 0.94 | 18.00 | 1.50 | 0.50 |
| | Max | 76.00 | 58.00 | 24.10 | 81.10 | 128.00 | 5.71 | 32.00 | 90.40 | 4.40 | 7.30 | 0.01 | 0.01 | 42.60 | 0.02 | 0.02 | 0.01 | 7.05 | 8.38 | 2.60 | 383.00 | 0.01 | 1.78 | 271.00 | 29.00 | 2.10 | 32.00 | 14.00 | 1.80 |
| | Count | 6 | 6 | 7 | 7 | 7 | 6 | 7 | 7 | 7 | 7 | 7 | 4 | 7 | 6 | 6 | 7 | 5 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| | Average | 170.33 | 3.33 | 57.57 | 86.14 | 126.86 | 3.29 | 26.29 | 203.14 | 7.33 | 14.41 | 0.01 | 0.03 | 57.64 | 0.14 | 0.03 | 0.12 | 7.56 | 14.51 | 33.93 | 677.31 | 0.17 | 1.64 | 454.57 | 27.66 | 2.00 | 27.00 | 8.00 | 6.66 |
| LOXA132-2004 | StdDev | 25.16 | 1.37 | 8.18 | 26.85 | 62.86 | 3.07 | 5.53 | 28.28 | 2.02 | 5.10 | 0.01 | 0.02 | 18.62 | 0.13 | 0.03 | 0.18 | 0.46 | 3.48 | 18.98 | 136.99 | 0.19 | 0.44 | 88.16 | 3.29 | 0.58 | 8.31 | 6.21 | 4.41 |
| | Min | 130.00 | 2.00 | 46.00 | 50.00 | 50.00 | 0.21 | 18.00 | 170.00 | 5.00 | 7.70 | 0.00 | 0.01 | 32.50 | 0.01 | 0.01 | 0.01 | 7.20 | 10.40 | 8.40 | 520.20 | 0.06 | 1.07 | 368.00 | 21.70 | 1.33 | 18.00 | 1.50 | 1.50 |
| | Max | 203.00 | 5.00 | 71.70 | 124.00 | 220.00 | 8.46 | 33.00 | 252.00 | 10.00 | 20.50 | 0.02 | 0.05 | 82.90 | 0.33 | 0.07 | 0.51 | 8.27 | 19.50 | 56.70 | 853.00 | 0.57 | 2.33 | 563.00 | 31.70 | 2.90 | 43.00 | 18.00 | 13.90 |
| | Count | 12 | 10 | 11 | 12 | 12 | 11 | 11 | 11 | 11 | 11 | 12 | 11 | 11 | 10 | 8 | 11 | 12 | 12 | 12 | 12 | 10 | 11 | 12 | 12 | 11 | 11 | 12 | 12 |
| | Average | 201.00 | 3.90 | 73.25 | 97.03 | 119.83 | 3.71 | 28.18 | 249.55 | 6.68 | 16.15 | 0.05 | 0.26 | 68.38 | 0.16 | 0.43 | 0.04 | 7.48 | 12.25 | 36.00 | 777.48 | 0.10 | 1.90 | 479.17 | 25.04 | 2.28 | 28.91 | 9.63 | 7.84 |
| LOXA132-2005 | StdDev | 41.11 | 2.60 | 18.68 | 22.09 | 36.23 | 2.13 | 5.44 | 67.31 | 1.99 | 6.31 | 0.10 | 0.55 | 15.20 | 0.25 | 0.70 | 0.06 | 0.26 | 4.93 | 25.87 | 173.14 | 0.07 | 0.66 | 128.49 | 4.32 | 0.74 | 5.50 | 7.81 | 4.59 |
| | Min | 135.00 | 1.00 | 42.00 | 59.60 | 86.00 | 1.12 | 23.00 | 140.00 | 3.20 | 7.30 | 0.01 | 0.01 | 41.50 | 0.00 | 0.04 | 0.00 | 7.16 | 6.93 | 5.50 | 474.00 | 0.05 | 1.38 | 286.00 | 18.10 | 1.74 | 24.00 | 1.50 | 3.00 |
| | Max | 264.00 | 9.00 | 104.00 | 124.00 | 190.00 | 7.32 | 39.00 | 360.00 | 9.80 | 27.40 | 0.34 | 1.88 | 89.50 | 0.83 | 2.08 | 0.21 | 8.01 | 24.30 | 90.00 | 1054.00 | 0.29 | 3.50 | 714.00 | 30.20 | 3.90 | 40.00 | 28.00 | 15.40 |
| | Count | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 2 | 4 | 2 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| | Average | 139.75 | 2.50 | 46.45 | 57.95 | 141.50 | 0.78 | 25.25 | 160.50 | 6.58 | 10.83 | 0.01 | 0.00 | 38.73 | 0.01 | 0.01 | 0.08 | 7.06 | 13.30 | 18.00 | 501.20 | 0.17 | 1.53 | 346.00 | 24.73 | 2.62 | 28.25 | 9.00 | 2.23 |
| LOXA133-2004 | StdDev | 34.26 | 1.73 | 14.24 | 16.81 | 51.20 | 0.50 | 6.34 | 51.76 | 1.96 | 4.38 | 0.00 | 0.00 | 11.22 | 0.01 | 0.00 | 0.12 | 0.12 | 5.68 | 19.09 | 125.97 | 0.11 | 0.44 | 113.64 | 3.87 | 0.93 | 10.78 | 4.32 | 0.62 |
| | Min | 120.00 | 1.00 | 36.70 | 33.20 | 106.00 | 0.25 | 18.00 | 132.00 | 5.40 | 6.90 | 0.00 | 0.00 | 22.40 | 0.00 | 0.00 | 0.01 | 6.93 | 6.49 | 4.40 | 384.00 | 0.07 | 1.18 | 244.00 | 19.60 | 1.72 | 20.00 | 5.00 | 1.60 |
| | Max | 191.00 | 5.00 | 67.20 | 69.70 | 215.00 | 1.24 | 33.00 | 238.00 | 9.50 | 17.10 | 0.01 | 0.00 | 46.70 | 0.02 | 0.01 | 0.25 | 7.14 | 19.20 | 46.00 | 680.00 | 0.32 | 2.17 | 506.00 | 28.00 | 3.60 | 44.00 | 15.00 | 2.90 |
| | Count | 1 | 1 | 1 | 5 | 1 | 5 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 6 | 1 | 5 | 6 | 5 | 1 | 1 | 6 | 1 | 1 | 1 | 1 |
| | Average | 190.00 | 3.00 | 65.90 | 71.20 | 126.00 | 1.80 | 31.00 | 238.00 | 6.60 | 17.80 | 0.01 | | 74.30 | 0.12 | 0.00 | 0.06 | 6.85 | 18.00 | 10.26 | 501.07 | 0.10 | 2.05 | 538.00 | 21.35 | 2.54 | 32.00 | 6.00 | 4.50 |
| LOXA133-2005 | StdDev | | | | 30.96 | | 0.83 | | | | | | | | | | | 0.33 | | 17.59 | 196.49 | 0.11 | | | 4.39 | | | | |
| | Min | 190.00 | 3.00 | 65.90 | 22.70 | 126.00 | 0.75 | 31.00 | 238.00 | 6.60 | 17.80 | 0.01 | | 74.30 | 0.12 | 0.00 | 0.06 | 6.43 | 18.00 | 1.10 | 200.00 | 0.02 | 2.05 | 538.00 | 16.97 | 2.54 | 32.00 | 6.00 | 4.50 |
| | Max | 190.00 | 3.00 | 65.90 | 109.00 | 126.00 | 2.69 | 31.00 | 238.00 | 6.60 | 17.80 | 0.01 | | 74.30 | 0.12 | 0.00 | 0.06 | 7.20 | 18.00 | 41.60 | 814.00 | 0.27 | 2.05 | 538.00 | 27.30 | 2.54 | 32.00 | 6.00 | 4.50 |
| | Count | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 2 | 4 | 2 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| | Average | 124.00 | 6.38 | 41.33 | 53.98 | 130.75 | 2.12 | 24.00 | 145.00 | 6.10 | 10.20 | 0.01 | 0.00 | 37.20 | 0.01 | 0.01 | 0.05 | 7.04 | 14.57 | 19.23 | 464.10 | 0.07 | 1.41 | 324.25 | 24.98 | 1.54 | 26.50 | 2.13 | 1.08 |
| LOXA134-2004 | StdDev | 28.44 | 4.64 | 12.42 | 15.11 | 33.76 | 2.34 | 5.03 | 44.79 | 1.22 | 3.90 | 0.00 | 0.00 | 10.95 | 0.00 | 0.00 | 0.09 | 0.04 | 6.16 | 19.39 | 126.63 | 0.10 | 0.31 | 91.30 | 3.54 | 0.32 | 8.89 | 1.25 | 0.40 |
| | Min | 100.00 | 0.50 | 29.70 | 32.10 | 104.00 | 0.22 | 17.00 | 108.00 | 5.20 | 6.90 | 0.00 | 0.00 | 21.70 | 0.01 | 0.00 | 0.01 | 7.00 | 7.27 | 5.10 | 368.00 | 0.02 | 1.01 | 230.00 | 20.00 | 1.14 | 18.00 | 1.50 | 0.60 |
| | Max | 165.00 | 11.00 | 58.10 | 65.30 | 180.00 | 4.73 | 29.00 | 210.00 | 7.90 | 15.80 | 0.01 | 0.00 | 46.90 | 0.01 | 0.01 | 0.19 | 7.08 | 20.20 | 47.90 | 647.00 | 0.22 | 1.78 | 447.00 | 27.80 | 1.92 | 39.00 | 4.00 | 1.50 |
| | Count | 6 | 6 | 6 | 12 | 6 | 11 | 6 | 6 | 6 | 6 | 6 | 4 | 6 | 6 | 5 | 6 | 12 | 6 | 12 | 11 | 11 | 6 | 6 | 12 | 6 | 6 | 6 | 6 |
| | Average | 97.00 | 10.42 | 29.93 | 47.89 | 117.83 | 3.38 | 28.00 | 110.18 | 5.30 | 8.62 | 0.00 | 0.00 | 40.45 | 0.01 | 0.01 | 0.01 | 6.82 | 7.30 | 3.68 | 319.37 | 0.03 | 1.56 | 273.17 | 24.56 | 1.87 | 28.00 | 5.92 | 1.32 |
| LOXA134-2005 | StdDev | 22.48 | 10.48 | 7.74 | 21.90 | 10.96 | 1.69 | 1.90 | 27.48 | 0.76 | 2.04 | 0.00 | 0.00 | 8.37 | 0.01 | 0.00 | 0.00 | 0.26 | 3.84 | 5.50 | 136.67 | 0.02 | 0.22 | 61.43 | 5.09 | 0.30 | 2.28 | 3.04 | 0.40 |
| | Min | 75.00 | 0.50 | 23.80 | 17.30 | 105.00 | 1.20 | 25.00 | 88.40 | 4.40 | 7.00 | 0.00 | 0.00 | 33.30 | 0.00 | 0.00 | 0.00 | 6.40 | 2.78 | 0.60 | 141.20 | 0.01 | 1.21 | 228.00 | 16.30 | 1.40 | 24.00 | 1.50 | 0.80 |
| | Max | 139.00 | 29.00 | 45.10 | 84.30 | 131.00 | 5.63 | 31.00 | 164.00 | 6.60 | 12.60 | 0.01 | 0.01 | 56.20 | 0.03 | 0.01 | 0.01 | 7.25 | 12.40 | 20.70 | 589.00 | 0.07 | 1.86 | 390.00 | 30.40 | 2.26 | 31.00 | 10.00 | 1.90 |
| | Count | 7 | 7 | 7 | 7 | 7 | 6 | 7 | 7 | 7 | 7 | 7 | 6 | 7 | 7 | 6 | 7 | 6 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| | Average | 162.57 | 2.71 | 56.29 | 85.51 | 120.57 | 2.93 | 24.57 | 197.00 | 7.31 | 13.74 | 0.01 | 0.02 | 57.47 | 0.09 | 0.04 | 0.12 | 7.45 | 13.56 | 31.36 | 665.77 | 0.19 | 1.58 | 443.14 | 27.39 | 1.94 | 26.71 | 9.21 | 8.19 |
| LOXA135-2004 | StdDev | 19.71 | 1.98 | 7.40 | 26.06 | 51.67 | 2.47 | 5.00 | 27.37 | 1.89 | 5.21 | 0.01 | 0.03 | 18.44 | 0.08 | 0.04 | 0.19 | 0.33 | 3.90 | 18.44 | 141.58 | 0.22 | 0.35 | 86.62 | 2.82 | 0.41 | 7.20 | 6.42 | 5.42 |
| | Min | 126.00 | 1.00 | 44.80 | 59.60 | 48.00 | 0.13 | 18.00 | 166.00 | 5.30 | 7.60 | 0.00 | 0.00 | 39.60 | 0.01 | 0.00 | 0.01 | 7.10 | 8.19 | 8.30 | 544.00 | 0.05 | 1.03 | 350.00 | 21.90 | 1.49 | 18.00 | 1.50 | 1.80 |
| | Max | 186.00 | 6.00 | 68.00 | 122.00 | 190.00 | 6.40 | 31.00 | 232.00 | 9.90 | 20.60 | 0.03 | 0.07 | 82.90 | 0.26 | 0.10 | 0.54 | 7.98 | 19.70 | 56.20 | 847.00 | 0.65 | 2.18 | 541.00 | 29.90 | 2.64 | 40.00 | 18.00 | 17.20 |
| | Count | 12 | 12 | 12 | 12 | 12 | 10 | 12 | 12 | 12 | 12 | 12 | 11 | 12 | 12 | 11 | 12 | 12 | 12 | 12 | 11 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| | Average | 197.83 | 4.67 | 70.41 | 103.44 | 121.92 | 4.27 | 28.58 | 242.42 | 6.34 | 16.16 | 0.05 | 0.19 | 70.78 | 0.14 | 0.24 | 0.03 | 7.51 | 12.17 | 37.66 | 815.18 | 0.09 | 1.91 | 506.08 | 25.39 | 2.23 | 29.42 | 7.58 | 7.66 |
| LOXA135-2005 | StdDev | 51.82 | 3.37 | 19.66 | 25.61 | 38.37 | 1.96 | 5.55 | 74.73 | 2.15 | 6.88 | 0.08 | 0.31 | 19.05 | 0.26 | 0.37 | 0.05 | 0.33 | 5.79 | 26.47 | 208.03 | 0.05 | 0.67 | 137.03 | 4.38 | 0.67 | 5.82 | 4.21 | 4.80 |
| | Min | 133.00 | 1.00 | 49.90 | 48.10 | 73.00 | 1.20 | 22.00 | 154.00 | 2.90 | 6.50 | 0.00 | 0.01 | 33.20 | 0.00 | 0.02 | 0.00 | 7.09 | 6.66 | 7.90 | 455.20 | 0.04 | 1.31 | 326.00 | 18.40 | 1.63 | 23.00 | 4.00 | 2.30 |
| | Max | 298.00 | 13.00 | 108.00 | 152.00 | 194.00 | 7.38 | 42.00 | 397.00 | 9.80 | 30.80 | 0.24 | 1.09 | 111.00 | 0.94 | 1.26 | 0.18 | 8.11 | 28.10 | 99.00 | 1161.00 | 0.22 | 3.73 | 793.00 | 30.50 | 3.96 | 43.00 | 19.00 | 19.00 |

| Site - Year | STAT | ALK | APA | Ca | Cl | COLOR | D-O | DOC | HARD | K | Mg | N02 | N03 | Na | NH4 | NOX | OPO4 | Ph_F | SiO2 | SO4 | SpC | T_PO4 | TDKN | TDS | TEMP | TKN | TOC | TSS | TURB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | mg/L | nM/minmL | mg/L | mg/L | PCU | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | units | mg/L | mg/L | uS/cm | mg/L | mg/L | mg/L | Deg.C | mg/L | mg/L | mg/L | mg/L |
| | Count | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| | Average | 143.25 | 2.75 | 48.13 | 56.98 | 181.50 | 0.55 | 29.00 | 171.50 | 6.40 | 12.48 | 0.01 | 0.00 | 40.23 | 0.04 | 0.01 | 0.06 | 6.98 | 14.20 | 25.25 | 525.05 | 0.11 | 1.80 | 387.50 | 24.50 | 2.20 | 32.75 | 3.50 | 1.98 |
| LOXA136-2004 | StdDev | 45.06 | 3.07 | 18.99 | 8.13 | 37.54 | 0.23 | 2.94 | 66.56 | 2.56 | 4.63 | 0.00 | 0.00 | 6.07 | 0.03 | 0.00 | 0.09 | 0.24 | 5.98 | 23.73 | 159.77 | 0.09 | 0.31 | 117.11 | 3.69 | 0.28 | 7.89 | 2.35 | 0.80 |
| | Min | 102.00 | 0.50 | 30.60 | 48.30 | 149.00 | 0.29 | 26.00 | 110.00 | 3.80 | 8.20 | 0.01 | 0.00 | 33.80 | 0.02 | 0.01 | 0.01 | 6.77 | 5.48 | 3.10 | 364.00 | 0.04 | 1.52 | 280.00 | 19.70 | 1.85 | 26.00 | 1.50 | 1.10 |
| | Max | 188.00 | 7.00 | 65.20 | 64.40 | 215.00 | 0.69 | 33.00 | 233.00 | 9.50 | 17.10 | 0.01 | 0.00 | 45.70 | 0.09 | 0.01 | 0.19 | 7.21 | 19.00 | 48.00 | 676.00 | 0.24 | 2.14 | 506.00 | 27.40 | 2.53 | 44.00 | 6.00 | 3.00 |
| | Count | 1 | 1 | 1 | 6 | 1 | 5 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 6 | 1 | 5 | 6 | 6 | 1 | 1 | 6 | 1 | 1 | 1 | 1 |
| | Average | 219.00 | 3.00 | 76.30 | 66.45 | 147.00 | 1.51 | 36.00 | 282.00 | 7.40 | 22.30 | 0.01 | | 81.30 | 0.00 | 0.01 | 0.01 | 6.63 | 23.90 | 15.08 | 473.68 | 0.06 | 2.14 | 632.00 | 21.38 | 2.44 | 36.00 | 8.00 | 4.20 |
| LOXA136-2005 | StdDev | | | | 33.04 | | 1.64 | | | | | | | | | | | 0.18 | | 27.44 | 253.15 | 0.05 | | | 4.64 | | | | |
| | Min | 219.00 | 3.00 | 76.30 | 20.70 | 147.00 | 0.45 | 36.00 | 282.00 | 7.40 | 22.30 | 0.01 | | 81.30 | 0.00 | 0.01 | 0.01 | 6.35 | 23.90 | 1.40 | 183.00 | 0.02 | 2.14 | 632.00 | 16.00 | 2.44 | 36.00 | 8.00 | 4.20 |
| | Max | 219.00 | 3.00 | 76.30 | 120.00 | 147.00 | 4.42 | 36.00 | 282.00 | 7.40 | 22.30 | 0.01 | | 81.30 | 0.00 | 0.01 | 0.01 | 6.86 | 23.90 | 64.10 | 934.00 | 0.15 | 2.14 | 632.00 | 27.40 | 2.44 | 36.00 | 8.00 | 4.20 |
| | Count | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| | Average | 117.75 | 4.75 | 39.35 | 49.85 | 165.25 | 0.91 | 26.50 | 142.05 | 5.68 | 10.65 | 0.01 | 0.00 | 35.40 | 0.02 | 0.01 | 0.01 | 6.83 | 12.20 | 21.70 | 443.30 | 0.03 | 1.62 | 314.50 | 24.78 | 1.73 | 30.00 | 1.50 | 1.18 |
| LOXA137-2004 | StdDev | 54.25 | 3.77 | 20.38 | 16.76 | 35.86 | 0.71 | 2.65 | 72.37 | 2.47 | 5.28 | 0.00 | 0.00 | 13.11 | 0.00 | 0.00 | 0.01 | 0.29 | 9.28 | 22.23 | 203.90 | 0.02 | 0.28 | 118.91 | 3.53 | 0.29 | 7.12 | 0.00 | 0.65 |
| | Min | 70.00 | 1.00 | 21.40 | 35.50 | 121.00 | 0.16 | 24.00 | 78.80 | 3.50 | 6.20 | 0.00 | 0.00 | 24.90 | 0.01 | 0.01 | 0.01 | 6.52 | 1.12 | 2.80 | 271.20 | 0.01 | 1.28 | 207.00 | 20.30 | 1.42 | 24.00 | 1.50 | 0.60 |
| | Max | 171.00 | 10.00 | 57.40 | 72.80 | 200.00 | 1.58 | 30.00 | 212.00 | 8.10 | 16.60 | 0.01 | 0.01 | 53.20 | 0.02 | 0.01 | 0.03 | 7.11 | 23.10 | 47.30 | 682.00 | 0.06 | 1.90 | 446.00 | 27.60 | 1.99 | 40.00 | 1.50 | 2.10 |
| | Count | 8 | 8 | 8 | 12 | 8 | 10 | 8 | 8 | 8 | 8 | 8 | 6 | 8 | 8 | 7 | 8 | 12 | 8 | 12 | 11 | 12 | 8 | 8 | 12 | 8 | 8 | 8 | 8 |
| | Average | 70.00 | 19.75 | 22.33 | 41.72 | 121.25 | 3.03 | 25.38 | 82.31 | 2.81 | 6.48 | 0.00 | 0.01 | 26.29 | 0.01 | 0.01 | 0.00 | 6.62 | 8.52 | 3.39 | 302.35 | 0.02 | 1.47 | 184.50 | 24.33 | 1.58 | 25.75 | 2.63 | 0.95 |
| LOXA137-2005 | StdDev | 34.17 | 11.25 | 11.13 | 22.34 | 15.95 | 1.34 | 3.78 | 42.06 | 1.65 | 3.49 | 0.00 | 0.02 | 15.61 | 0.01 | 0.01 | 0.00 | 0.22 | 5.01 | 7.33 | 143.94 | 0.02 | 0.21 | 117.26 | 5.03 | 0.36 | 4.03 | 2.08 | 0.41 |
| | Min | 39.00 | 10.00 | 13.30 | 16.20 | 96.00 | 1.04 | 20.00 | 47.10 | 0.80 | 3.40 | 0.00 | 0.00 | 11.90 | 0.00 | 0.00 | 0.00 | 6.26 | 0.96 | 0.80 | 120.40 | 0.01 | 1.24 | 24.00 | 16.70 | 1.24 | 20.00 | 1.50 | 0.50 |
| | Max | 148.00 | 40.00 | 48.40 | 92.00 | 143.00 | 5.78 | 32.00 | 180.00 | 5.40 | 14.40 | 0.01 | 0.04 | 60.80 | 0.02 | 0.01 | 0.01 | 7.01 | 17.10 | 26.60 | 655.00 | 0.05 | 1.84 | 424.00 | 30.10 | 2.31 | 32.00 | 6.00 | 1.80 |
| | Count | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| | Average | 89.75 | 39.00 | 28.68 | 51.73 | 147.00 | 1.73 | 26.75 | 107.75 | 4.90 | 8.80 | 0.01 | 0.00 | 35.85 | 0.02 | 0.01 | 0.01 | 6.81 | 13.33 | 14.70 | 387.45 | 0.01 | 1.49 | 290.00 | 24.98 | 1.78 | 31.50 | 4.88 | 1.20 |
| LOXA138-2004 | StdDev | 54.01 | 20.35 | 17.15 | 27.55 | 29.34 | 0.76 | 4.35 | 64.41 | 2.95 | 5.23 | 0.00 | 0.00 | 20.18 | 0.00 | 0.00 | 0.00 | 0.33 | 11.42 | 17.21 | 226.96 | 0.00 | 0.16 | 151.94 | 3.76 | 0.32 | 8.70 | 6.75 | 0.80 |
| | Min | 41.00 | 18.00 | 13.10 | 26.20 | 117.00 | 0.99 | 23.00 | 48.90 | 2.20 | 4.00 | 0.00 | 0.00 | 17.00 | 0.02 | 0.01 | 0.01 | 6.49 | 2.73 | 1.50 | 176.80 | 0.01 | 1.32 | 155.00 | 19.80 | 1.49 | 24.00 | 1.50 | 0.70 |
| | Max | 137.00 | 65.00 | 47.70 | 84.80 | 187.00 | 2.50 | 33.00 | 177.00 | 8.10 | 14.00 | 0.01 | 0.00 | 58.30 | 0.02 | 0.01 | 0.01 | 7.11 | 26.30 | 38.00 | 597.00 | 0.02 | 1.69 | 438.00 | 27.90 | 2.07 | 44.00 | 15.00 | 2.40 |
| | Count | 3 | 3 | 3 | 10 | 3 | 8 | 3 | 3 | 3 | 3 | 3 | 1 | 3 | 3 | 3 | 3 | 10 | 3 | 10 | 9 | 10 | 3 | 3 | 10 | 3 | 3 | 3 | 3 |
| | Average | 38.00 | 52.00 | 12.27 | 28.22 | 96.00 | 5.55 | 20.33 | 45.30 | 1.57 | 3.57 | 0.00 | 0.01 | 13.93 | 0.00 | 0.01 | 0.00 | 6.74 | 4.45 | 0.99 | 194.02 | 0.01 | 1.22 | 93.00 | 25.05 | 1.34 | 20.00 | 3.00 | 1.00 |
| LOXA138-2005 | StdDev | 1.73 | 10.54 | 0.15 | 14.57 | 23.90 | 2.34 | 0.58 | 0.66 | 0.21 | 0.06 | 0.00 | | 0.81 | 0.00 | 0.00 | 0.00 | 0.24 | 0.90 | 0.45 | 77.00 | 0.01 | 0.08 | 61.73 | 5.42 | 0.15 | 1.00 | 2.60 | 0.53 |
| | Min | 37.00 | 41.00 | 12.10 | 13.30 | 75.00 | 3.03 | 20.00 | 44.60 | 1.40 | 3.50 | 0.00 | 0.01 | 13.20 | 0.00 | 0.00 | 0.00 | 6.39 | 3.41 | 0.40 | 96.30 | 0.01 | 1.14 | 24.00 | 16.60 | 1.21 | 19.00 | 1.50 | 0.60 |
| | Max | 40.00 | 62.00 | 12.40 | 55.00 | 122.00 | 8.58 | 21.00 | 45.90 | 1.80 | 3.60 | 0.01 | 0.01 | 14.80 | 0.00 | 0.01 | 0.01 | 7.25 | 5.05 | 1.70 | 328.20 | 0.03 | 1.30 | 143.00 | 33.10 | 1.50 | 21.00 | 6.00 | 1.60 |
| | Count | 3 | 3 | 3 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 2 | 3 | 4 | 3 | 4 | 4 | 4 | 3 | 3 | 4 | 3 | 3 | 3 | 3 |
| | Average | 19.67 | 67.00 | 8.73 | 24.10 | 168.67 | 1.48 | 26.00 | 33.17 | 1.57 | 2.77 | 0.01 | 0.00 | 14.53 | 0.02 | 0.01 | 0.01 | 6.27 | 7.04 | 1.76 | 138.88 | 0.01 | 1.47 | 143.67 | 25.25 | 1.62 | 26.33 | 3.00 | 1.57 |
| LOXA139-2004 | StdDev | 4.16 | 47.76 | 2.18 | 5.62 | 37.65 | 0.57 | 6.24 | 7.94 | 0.42 | 0.60 | 0.00 | 0.00 | 3.65 | 0.00 | 0.00 | 0.00 | 0.18 | 1.82 | 2.50 | 34.31 | 0.00 | 0.44 | 36.75 | 3.54 | 0.42 | 4.93 | 2.60 | 1.59 |
| | Min | 15.00 | 36.00 | 6.80 | 17.70 | 144.00 | 0.83 | 21.00 | 26.00 | 1.10 | 2.20 | 0.01 | 0.00 | 10.80 | 0.01 | 0.01 | 0.01 | 6.02 | 5.07 | 0.05 | 100.50 | 0.01 | 1.04 | 120.00 | 20.50 | 1.22 | 23.00 | 1.50 | 0.60 |
| | Max | 23.00 | 122.00 | 11.10 | 31.40 | 212.00 | 1.90 | 33.00 | 41.70 | 1.90 | 3.40 | 0.01 | 0.00 | 18.10 | 0.02 | 0.01 | 0.01 | 6.42 | 8.66 | 5.40 | 184.00 | 0.01 | 1.91 | 186.00 | 28.00 | 2.06 | 32.00 | 6.00 | 3.40 |
| | Count | 1 | 1 | 1 | 7 | 1 | 7 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 8 | 1 | 7 | 7 | 7 | 1 | 1 | 8 | 1 | 1 | 1 | 1 |
| | Average | 21.00 | 75.00 | 6.70 | 16.84 | 146.00 | 5.35 | 21.00 | 25.00 | 0.80 | 2.00 | 0.01 | 0.00 | 9.10 | 0.00 | 0.01 | 0.01 | 6.52 | 1.04 | 0.31 | 116.59 | 0.01 | 1.23 | 90.00 | 26.06 | 1.47 | 21.00 | 6.00 | 1.50 |
| LOXA139-2005 | StdDev | | | | 4.87 | | 2.44 | | | | | | | | | | | 0.23 | | 0.17 | 37.95 | 0.00 | | | 5.36 | | | | |
| | Min | 21.00 | 75.00 | 6.70 | 12.90 | 146.00 | 3.39 | 21.00 | 25.00 | 0.80 | 2.00 | 0.01 | 0.00 | 9.10 | 0.00 | 0.01 | 0.01 | 6.12 | 1.04 | 0.10 | 86.10 | 0.01 | 1.23 | 90.00 | 16.81 | 1.47 | 21.00 | 6.00 | 1.50 |
| | Max | 21.00 | 75.00 | 6.70 | 27.00 | 146.00 | 9.41 | 21.00 | 25.00 | 0.80 | 2.00 | 0.01 | 0.00 | 9.10 | 0.00 | 0.01 | 0.01 | 6.87 | 1.04 | 0.60 | 183.00 | 0.02 | 1.23 | 90.00 | 33.50 | 1.47 | 21.00 | 6.00 | 1.50 |
| | Count | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| | Average | 97.00 | 15.50 | 30.33 | 54.40 | 200.50 | 1.36 | 31.50 | 112.13 | 5.38 | 8.83 | 0.01 | 0.01 | 37.40 | 0.02 | 0.01 | 0.01 | 6.89 | 13.40 | 12.23 | 409.03 | 0.02 | 1.74 | 305.00 | 24.63 | 1.85 | 33.25 | 1.50 | 1.15 |
| LOXA140-2004 | StdDev | 47.71 | 14.73 | 15.11 | 29.05 | 40.99 | 1.02 | 6.19 | 56.15 | 3.14 | 4.58 | 0.00 | 0.00 | 18.99 | 0.00 | 0.00 | 0.00 | 0.20 | 14.11 | 13.62 | 204.77 | 0.01 | 0.36 | 133.43 | 3.45 | 0.50 | 5.74 | 0.00 | 0.41 |
| | Min | 52.00 | 5.00 | 15.80 | 30.20 | 156.00 | 0.22 | 26.00 | 57.70 | 2.70 | 4.40 | 0.01 | 0.00 | 21.70 | 0.01 | 0.01 | 0.01 | 6.72 | 1.90 | 1.70 | 218.10 | 0.01 | 1.40 | 170.00 | 20.00 | 1.34 | 28.00 | 1.50 | 0.80 |
| | Max | 144.00 | 37.00 | 45.70 | 96.30 | 255.00 | 2.20 | 40.00 | 164.00 | 9.00 | 13.40 | 0.01 | 0.01 | 64.70 | 0.02 | 0.02 | 0.01 | 7.15 | 32.10 | 30.70 | 657.00 | 0.03 | 2.24 | 467.00 | 27.60 | 2.53 | 40.00 | 1.50 | 1.60 |
| | Count | 2 | 2 | 2 | 9 | 2 | 7 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 9 | 2 | 9 | 8 | 9 | 2 | 2 | 9 | 2 | 2 | 2 | 2 |
| | Average | 83.00 | 18.50 | 26.50 | 45.03 | 166.50 | 5.70 | 30.00 | 99.65 | 3.45 | 8.10 | 0.01 | 0.00 | 38.55 | 0.01 | 0.01 | 0.01 | 6.87 | 9.96 | 3.14 | 295.01 | 0.02 | 1.63 | 265.50 | 25.33 | 1.82 | 30.50 | 2.25 | 1.05 |
| LOXA140-2005 | StdDev | 65.05 | 6.36 | 19.80 | 22.51 | 4.95 | 2.56 | 7.07 | 75.45 | 3.18 | 6.36 | 0.00 | | 32.46 | 0.00 | 0.00 | 0.00 | 0.21 | 7.98 | 5.81 | 140.37 | 0.01 | 0.62 | 197.28 | 5.97 | 0.71 | 7.78 | 1.06 | 0.35 |
| | Min | 37.00 | 14.00 | 12.50 | 22.80 | 163.00 | 3.11 | 25.00 | 46.30 | 1.20 | 3.60 | 0.01 | 0.00 | 15.60 | 0.01 | 0.00 | 0.00 | 6.69 | 4.31 | 0.70 | 158.20 | 0.01 | 1.19 | 126.00 | 16.10 | 1.31 | 25.00 | 1.50 | 0.80 |
| | Max | 129.00 | 23.00 | 40.50 | 94.70 | 170.00 | 8.70 | 35.00 | 153.00 | 5.70 | 12.60 | 0.01 | 0.00 | 61.50 | 0.01 | 0.01 | 0.01 | 7.37 | 15.60 | 18.60 | 604.00 | 0.04 | 2.07 | 405.00 | 33.20 | 2.32 | 36.00 | 3.00 | 1.30 |

# Appendix 1-2

Summary statistics of monthly water quality data (January 2004 – December 2005) by zone.

**Table A2-1**. EVPA and LOXA sites classified into zones for analyses.

| Zones | Sites |
|---|---|
| Canal Zone | LOXA104, LOXA115, LOXA129, LOXA132, LOXA135 |
| Perimeter Zone (< 2.5 km) | LOX4, LOX6, LOX10, LOX14, LOX15, LOX16 LOXA101, LOXA102, LOXA103, LOXA105, LOXA106, LOXA107, LOXA109, LOXA112, LOXA116, LOXA117, LOXA118, LOXA121, LOXA122, LOXA123, LOXA124, LOXA126, LOXA130, LOXA131, LOXA133, LOXA134, LOXA136, LOXA137, LOXA138, LOXA140 |
| Transition Zone (2.5 – 4.5 km) | LOX12 LOXA108, LOXA110, LOXA111, LOXA113, LOXA114, LOXA119, LOXA127, LOXA139 |
| Interior Zone (> 4.5 km) | LOX3, LOX5, LOX7, LOX8, LOX9, LOX11, LOX13 LOXA120, LOXA128 |

**Table A2-2**. Summary Statistics of monthly water quality data (January 2004 – December 2005) by zone:

A2-2-1: 2004 Arithmetic Mean
A2-2-2: 2005 Arithmetic Mean
A2-2-3: 2004 Geometric Mean
A2-2-4: 2005 Geometric Mean

**Summary Geometric Mean Data By Zone**

(Geo Mean = geometric mean, Count = # of sites, 95% CI Up = 95% upper geometric mean confidence interval,
95% CI Low = 95% lower geometric mean confidence interval)

| | | Jan-04 | Feb-04 | Mar-04 | Apr-04 | May-04 | Jun-04 | Jul-04 | Aug-04 | Sep-04 | Oct-04 | Nov-04 | Dec-04 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Phosphorus (ppb) | Canal -Geo Mean | | | | | | 66.0 | 51.1 | 44.0 | 227.9 | 388.6 | 80.8 | 67.9 |
| | Canal - Count | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| | Canal - 95% CI Up | | | | | | 72.2 | 74.0 | 55.1 | 232.2 | 491.1 | 82.8 | 71.3 |
| | Canal - 95% CI Low | | | | | | 60.4 | 35.3 | 35.1 | 223.7 | 307.6 | 78.9 | 64.6 |
| | Perimeter - Geo Mean | 7.2 | 7.6 | 8.2 | 8.8 | 10.0 | 24.7 | | 20.9 | 19.0 | 26.8 | 12.8 | 14.2 |
| | Perimeter - Count | 6 | 6 | 6 | 4 | 3 | 2 | 0 | 16 | 29 | 30 | 30 | 30 |
| | Perimieter - 95%CI Up | 9.6 | 8.8 | 9.3 | 9.8 | 11.5 | 27.4 | | 33.4 | 36.9 | 169.6 | 20.3 | 28.0 |
| | Perimeter - 95% CI Low | 5.4 | 6.5 | 7.3 | 7.9 | 8.8 | 22.4 | | 13.1 | 9.7 | 4.2 | 8.1 | 7.2 |
| | Transition - Geo Mean | 5.0 | 5.0 | 7.0 | 6.0 | 19.0 | 25.3 | 15.6 | 14.4 | 9.2 | 8.0 | 8.1 | 10.2 |
| | Transition - Count | 1 | 1 | 1 | 1 | 1 | 4 | 3 | 8 | 9 | 9 | 9 | 9 |
| | Transition - 95% CI Up | | | | | | 31.6 | 17.3 | 18.4 | 9.9 | 8.4 | 8.6 | 11.4 |
| | Transition - 95% CI Low | | | | | | 20.3 | 14.1 | 11.3 | 8.6 | 7.7 | 7.6 | 9.2 |
| | Interior - Geo Mean | 8.0 | 9.4 | 10.0 | 11.9 | 12.8 | 16.0 | | 14.0 | 8.4 | 8.2 | 9.4 | 14.3 |
| | Interior - Count | 7 | 7 | 7 | 4 | 5 | 1 | 0 | 7 | 9 | 8 | 9 | 8 |
| | Interior - 95% CI Up | 8.6 | 12.0 | 12.5 | 14.8 | 13.2 | | | 15.8 | 8.9 | 8.6 | 10.6 | 17.9 |
| | Interior - 95% CI Low | 7.3 | 7.3 | 8.1 | 9.6 | 12.5 | | | 12.4 | 8.0 | 7.9 | 8.3 | 11.5 |
| Total Nitrogen (mg/L) | Canal -Geo Mean | | | | | | 2.33 | 1.83 | 2.00 | 2.72 | 2.31 | 1.64 | 1.65 |
| | Canal - Count | 0 | 0 | 0 | 0 | 0 | 5 | 3 | 5 | 5 | 4 | 5 | 3 |
| | Canal - 95% CI Up | | | | | | 2.35 | 1.85 | 2.01 | 2.73 | 2.33 | 1.69 | 1.65 |
| | Canal - 95% CI Low | | | | | | 2.31 | 1.81 | 1.99 | 2.71 | 2.29 | 1.58 | 1.64 |
| | Perimeter - Geo Mean | 1.14 | 1.28 | 1.15 | 0.99 | 1.43 | | | 2.15 | 1.85 | 1.29 | 1.27 | 1.42 |
| | Perimeter - Count | 6 | 2 | 6 | 3 | 2 | 0 | 0 | 6 | 29 | 23 | 26 | 19 |
| | Perimieter - 95%CI Up | 1.35 | 1.29 | 1.23 | 1.01 | 1.43 | | | 2.44 | 1.99 | 1.45 | 1.36 | 1.56 |
| | Perimeter - 95% CI Low | 0.97 | 1.27 | 1.08 | 0.97 | 1.43 | | | 1.90 | 1.71 | 1.14 | 1.18 | 1.30 |
| | Transition - Geo Mean | 0.90 | | 0.98 | 1.12 | 2.06 | 2.79 | 2.19 | 1.44 | 1.29 | 0.75 | 1.13 | 1.16 |
| | Transition - Count | 1 | 0 | 1 | 1 | 1 | 2 | 1 | 2 | 9 | 7 | 5 | 7 |
| | Transition - 95% CI Up | | | | | | 3.29 | | 1.92 | 1.38 | 0.77 | 1.19 | 1.19 |
| | Transition - 95% CI Low | | | | | | 2.35 | | 1.07 | 1.20 | 0.74 | 1.08 | 1.13 |
| | Interior - Geo Mean | 1.15 | 1.33 | 1.57 | 1.52 | | | | 2.34 | 1.22 | 1.15 | 1.21 | 1.56 |
| | Interior - Count | 5 | 6 | 6 | 2 | 0 | 0 | 0 | 3 | 9 | 8 | 6 | 6 |
| | Interior - 95% CI Up | 1.16 | 1.40 | 1.63 | 1.56 | | | | 2.97 | 1.25 | 1.18 | 1.21 | 1.61 |
| | Interior - 95% CI Low | 1.14 | 1.27 | 1.51 | 1.49 | | | | 1.84 | 1.20 | 1.12 | 1.21 | 1.51 |
| Specific Conductivity (uS/cm) | Canal -Geo Mean | | | | | | 908 | 655 | 850 | 802 | 625 | 594 | 649 |
| | Canal - Count | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| | Canal - 95% CI Up | | | | | | 913 | 687 | 853 | 807 | 637 | 609 | 669 |
| | Canal - 95% CI Low | | | | | | 904 | 625 | 848 | 797 | 613 | 580 | 629 |
| | Perimeter - Geo Mean | 302 | 274 | 220 | 186 | 209 | 453 | | 445 | 584 | 400 | 305 | 320 |
| | Perimeter - Count | 6 | 6 | 6 | 4 | 3 | 2 | 0 | 15 | 29 | 30 | 30 | 30 |
| | Perimieter - 95%CI Up | 368 | 332 | 294 | 235 | 234 | 473 | | 534 | 705 | 566 | 404 | 393 |
| | Perimeter - 95% CI Low | 248 | 226 | 165 | 148 | 187 | 434 | | 370 | 485 | 283 | 230 | 261 |
| | Transition - Geo Mean | 313 | 313 | 263 | 268 | 332 | 285 | 298 | 211 | 211 | 113 | 113 | 150 |
| | Transition - Count | 1 | 1 | 1 | 1 | 1 | 3 | 3 | 8 | 8 | 9 | 8 | 9 |
| | Transition - 95% CI Up | | | | | | 286 | 306 | 223 | 226 | 119 | 116 | 153 |
| | Transition - 95% CI Low | | | | | | 284 | 289 | 200 | 196 | 108 | 111 | 147 |
| | Interior - Geo Mean | 118 | 117 | 127 | 154 | 210 | 430 | | 147 | 95 | 80 | 95 | 119 |
| | Interior - Count | 7 | 7 | 7 | 4 | 5 | 1 | 0 | 7 | 9 | 9 | 9 | 8 |
| | Interior - 95% CI Up | 120 | 120 | 130 | 158 | 221 | | | 156 | 98 | 83 | 96 | 120 |
| | Interior - 95% CI Low | 115 | 114 | 125 | 151 | 200 | | | 139 | 92 | 77 | 94 | 117 |
| Chloride (mg/L) | Canal -Geo Mean | | | | | | 138.5 | 87.4 | 120.7 | 89.7 | 70.8 | 64.7 | 81.2 |
| | Canal - Count | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| | Canal - 95% CI Up | | | | | | 141.0 | 95.1 | 120.9 | 91.4 | 71.3 | 68.0 | 85.0 |
| | Canal - 95% CI Low | | | | | | 136.0 | 80.3 | 120.6 | 88.1 | 70.2 | 61.7 | 77.4 |
| | Perimeter - Geo Mean | 47.6 | 42.9 | 33.7 | 24.8 | 38.2 | | | 75.7 | 76.3 | 46.9 | 41.7 | 46.2 |
| | Perimeter - Count | 6 | 6 | 6 | 3 | 2 | 0 | 0 | 6 | 29 | 30 | 29 | 29 |
| | Perimieter - 95%CI Up | 56.5 | 50.0 | 43.0 | 30.7 | 40.2 | | | 82.8 | 87.0 | 59.7 | 53.0 | 54.0 |
| | Perimeter - 95% CI Low | 40.1 | 36.8 | 26.3 | 20.1 | 36.2 | | | 69.2 | 67.0 | 36.9 | 32.9 | 39.6 |
| | Transition - Geo Mean | 47.4 | 47.6 | 41.6 | 42.7 | 54.9 | 38.3 | 50.0 | 27.6 | 31.6 | 16.6 | 18.3 | 24.4 |
| | Transition - Count | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 9 | 9 | 9 | 9 |
| | Transition - 95% CI Up | | | | | | 40.3 | | 29.8 | 34.0 | 18.1 | 19.1 | 25.4 |
| | Transition - 95% CI Low | | | | | | 36.4 | | 25.6 | 29.3 | 15.3 | 17.6 | 23.5 |
| | Interior - Geo Mean | 22.5 | 23.7 | 26.0 | 29.5 | | | | 26.5 | 17.4 | 14.6 | 17.6 | 22.3 |
| | Interior - Count | 5 | 6 | 6 | 2 | 0 | 0 | 0 | 3 | 9 | 9 | 6 | 6 |
| | Interior - 95% CI Up | 23.1 | 24.7 | 26.6 | 30.8 | | | | 27.4 | 17.9 | 15.5 | 18.3 | 22.8 |
| | Interior - 95% CI Low | 21.8 | 22.9 | 25.5 | 28.2 | | | | 25.6 | 16.9 | 13.7 | 17.0 | 21.7 |
| Sulfate (mg/L) | Canal -Geo Mean | | | | | | 48.95 | 44.93 | 60.57 | 53.32 | 30.15 | 18.20 | 15.27 |
| | Canal - Count | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| | Canal - 95% CI Up | | | | | | 49.48 | 48.61 | 60.90 | 54.72 | 35.55 | 26.42 | 31.01 |
| | Canal - 95% CI Low | | | | | | 48.42 | 41.53 | 60.25 | 51.96 | 25.56 | 12.53 | 7.52 |
| | Perimeter - Geo Mean | 2.83 | 2.33 | 1.19 | 0.90 | 1.21 | | | 39.12 | 25.76 | 14.73 | 5.57 | 4.46 |
| | Perimeter - Count | 6 | 6 | 6 | 3 | 2 | 0 | 0 | 6 | 29 | 30 | 29 | 29 |
| | Perimieter - 95%CI Up | 13.42 | 10.13 | 7.31 | 4.13 | 1.64 | | | 50.18 | 52.93 | 76.77 | 19.02 | 11.34 |
| | Perimeter - 95% CI Low | 0.60 | 0.54 | 0.19 | 0.20 | 0.90 | | | 30.49 | 12.53 | 2.83 | 1.63 | 1.75 |
| | Transition - Geo Mean | 2.10 | 2.30 | 1.20 | 1.20 | 1.40 | 2.62 | 1.40 | 2.07 | 2.56 | 0.91 | 0.29 | 0.30 |
| | Transition - Count | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 9 | 9 | 9 | 9 |
| | Transition - 95% CI Up | | | | | | 3.88 | | 2.57 | 9.05 | 1.91 | 1.00 | 0.84 |
| | Transition - 95% CI Low | | | | | | 1.77 | | 1.67 | 0.72 | 0.43 | 0.08 | 0.11 |
| | Interior - Geo Mean | 0.05 | 0.05 | 0.06 | 0.05 | | | | 0.18 | 0.13 | 0.08 | 0.09 | 0.07 |
| | Interior - Count | 5 | 6 | 6 | 2 | 0 | 0 | 0 | 3 | 9 | 9 | 6 | 6 |
| | Interior - 95% CI Up | 0.05 | 0.05 | 0.06 | 0.05 | | | | 0.22 | 0.16 | 0.18 | 0.15 | 0.11 |
| | Interior - 95% CI Low | 0.05 | 0.05 | 0.05 | 0.05 | | | | 0.15 | 0.11 | 0.04 | 0.05 | 0.04 |
| Tdepth (in.) | Perimeter - Geo Mean | 22.6 | 25.5 | 20.8 | 4.9 | 0.4 | 0.2 | 0.0 | 0.0 | 13.2 | 16.8 | 17.2 | 13.8 |
| | Perimeter - Count | 6 | 6 | 6 | 6 | 6 | 27 | 30 | 30 | 29 | 30 | 30 | 29 |
| | Perimieter - 95%CI Up | 27.0 | 30.0 | 24.6 | 29.6 | * | * | * | * | 14.7 | 18.7 | 19.6 | 16.9 |
| | Perimeter - 95% CI Low | 18.9 | 21.7 | 17.6 | 0.8 | * | * | * | * | 11.9 | 15.1 | 15.1 | 11.4 |
| | Transition - Geo Mean | 37.4 | 39.4 | 27.6 | 23.6 | 11.8 | 1.4 | 0.1 | 1.2 | 13.1 | 18.0 | 14.2 | 12.2 |
| | Transition - Count | 1 | 1 | 1 | 1 | 1 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |
| | Transition - 95% CI Up | | | | | | * | * | * | | 19.7 | 17.4 | 14.8 |
| | Transition - 95% CI Low | | | | | | * | * | * | | 16.5 | 11.6 | 10.1 |
| | Interior - Geo Mean | 13.5 | 15.5 | 11.7 | 2.4 | 3.6 | 2.4 | 0.0 | 4.6 | 13.2 | 14.6 | 10.7 | 8.2 |
| | Interior - Count | 7 | 7 | 7 | 6 | 7 | 7 | 9 | 9 | 9 | 8 | 9 | 9 |
| | Interior - 95% CI Up | 16.4 | 19.9 | 14.3 | 9.8 | 4.2 | 2.7 | * | 6.0 | 13.9 | 16.1 | 14.0 | 11.9 |
| | Interior - 95% CI Low | 11.1 | 12.1 | 9.6 | 0.6 | 3.1 | 2.1 | * | 3.6 | 12.5 | 13.2 | 8.2 | 5.7 |

* Indicates that geometric mean confidence intervals could not be calculated because there were values close to zero.

**Summary Geometric Mean Data By Zone**

(Geo Mean = geometric mean, Count = # of sites, 95% CI Up = 95% upper geometric mean confidence interval,
95% CI Low = 95% lower geometric mean confidence interval)

| | | Jan-05 | Feb-05 | Mar-05 | Apr-05 | May-05 | Jun-05 | Jul-05 | Aug-05 | Sep-05 | Oct-05 | Nov-05 | Dec-05 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Phosphorus (ppb) | Canal -Geo Mean | 64.8 | 118.5 | 99.8 | 70.3 | 66.1 | 209.2 | 75.2 | 56.6 | 60.4 | 64.5 | 145.0 | 89.2 |
| | Canal - Count | 5 | 5 | 3 | 3 | 3 | 5 | 5 | 4 | 5 | 5 | 5 | 5 |
| | Canal - 95% CI Up | 67.5 | 131.3 | 100.8 | 70.4 | 72.6 | 225.8 | 76.7 | 57.4 | 61.6 | 71.2 | 152.6 | 95.1 |
| | Canal - 95% CI Low | 62.3 | 107.1 | 98.8 | 70.1 | 60.1 | 193.9 | 73.7 | 55.8 | 59.3 | 58.6 | 137.8 | 83.6 |
| | Perimeter - Geo Mean | 13.6 | 17.7 | 13.7 | 15.4 | 29.6 | 30.0 | 8.4 | 10.1 | 11.3 | 10.1 | 11.0 | 9.6 |
| | Perimeter - Count | 29 | 27 | 14 | 19 | 9 | 23 | 17 | 19 | 29 | 25 | 26 | 30 |
| | Perimieter - 95%CI Up | 34.0 | 32.6 | 16.8 | 26.9 | 32.6 | 47.2 | 10.1 | 14.4 | 15.2 | 11.6 | 12.8 | 11.9 |
| | Perimeter - 95% CI Low | 5.5 | 9.6 | 11.1 | 8.8 | 26.8 | 19.1 | 6.9 | 7.1 | 8.4 | 8.8 | 9.4 | 7.8 |
| | Transition - Geo Mean | 12.2 | 10.2 | 35.7 | 10.3 | 52.0 | 19.1 | 6.5 | 5.8 | 6.7 | 7.2 | 8.1 | 6.6 |
| | Transition - Count | 7 | 5 | 2 | 3 | 1 | 8 | 7 | 6 | 7 | 8 | 9 | 9 |
| | Transition - 95% CI Up | 15.4 | 13.5 | 57.2 | 10.4 | | 21.8 | 7.2 | 6.3 | 7.1 | 7.3 | 8.2 | 6.9 |
| | Transition - 95% CI Low | 9.7 | 7.7 | 22.3 | 10.1 | | 16.8 | 5.9 | 5.2 | 6.3 | 7.2 | 8.0 | 6.4 |
| | Interior - Geo Mean | 9.6 | 9.3 | 16.3 | 9.5 | 102.0 | 31.4 | 8.2 | 6.6 | 6.5 | 6.5 | 7.2 | 7.2 |
| | Interior - Count | 7 | 5 | 4 | 4 | 1 | 2 | 9 | 7 | 5 | 8 | 9 | 9 |
| | Interior - 95% CI Up | 9.9 | 9.5 | 19.0 | 9.5 | | 31.6 | 9.0 | 6.8 | 6.7 | 6.7 | 7.4 | 8.4 |
| | Interior - 95% CI Low | 9.3 | 9.0 | 13.9 | 9.5 | | 31.2 | 7.5 | 6.4 | 6.4 | 6.3 | 7.1 | 6.1 |
| Total Nitrogen (mg/L) | Canal -Geo Mean | 2.04 | 2.60 | 1.96 | 2.07 | 2.21 | 4.57 | 2.27 | 1.68 | 2.15 | 2.21 | 4.18 | 2.48 |
| | Canal - Count | 5 | 5 | 3 | 3 | 3 | 5 | 2 | 3 | 3 | 3 | 5 | 5 |
| | Canal - 95% CI Up | 2.11 | 3.04 | 1.97 | 2.10 | 2.24 | 4.86 | 2.27 | 1.85 | 2.16 | 2.29 | 4.20 | 2.56 |
| | Canal - 95% CI Low | 1.98 | 2.22 | 1.95 | 2.05 | 2.18 | 4.29 | 2.27 | 1.52 | 2.14 | 2.13 | 4.15 | 2.40 |
| | Perimeter - Geo Mean | 1.37 | 1.59 | 1.39 | 1.64 | 1.97 | 2.01 | 1.02 | 1.13 | 1.07 | 1.01 | 1.26 | 1.22 |
| | Perimeter - Count | 20 | 15 | 5 | 11 | 3 | 8 | 1 | 6 | 14 | 12 | 23 | 24 |
| | Perimieter - 95%CI Up | 1.47 | 1.95 | 1.47 | 1.79 | 2.00 | 2.11 | | 1.17 | 1.12 | 1.03 | 1.37 | 1.31 |
| | Perimeter - 95% CI Low | 1.27 | 1.30 | 1.31 | 1.50 | 1.93 | 1.92 | | 1.10 | 1.03 | 0.98 | 1.16 | 1.13 |
| | Transition - Geo Mean | 1.26 | 1.24 | 1.57 | 1.29 | 8.69 | 1.81 | | 0.91 | 0.97 | 0.80 | 0.90 | 0.94 |
| | Transition - Count | 4 | 2 | 1 | 2 | 1 | 2 | 0 | 1 | 1 | 4 | 6 | 6 |
| | Transition - 95% CI Up | 1.35 | 1.31 | | 1.36 | | 1.88 | | | | 0.82 | 0.92 | 0.96 |
| | Transition - 95% CI Low | 1.17 | 1.17 | | 1.22 | | 1.74 | | | | 0.79 | 0.89 | 0.91 |
| | Interior - Geo Mean | 1.63 | 1.49 | 2.19 | 1.58 | 8.40 | 3.17 | 1.10 | 1.02 | 1.14 | 1.20 | 1.11 | 1.14 |
| | Interior - Count | 5 | 3 | 3 | 4 | 1 | 1 | 2 | 4 | 4 | 4 | 7 | 6 |
| | Interior - 95% CI Up | 1.64 | 1.52 | 2.23 | 1.61 | | | 1.10 | 1.04 | 1.15 | 1.22 | 1.12 | 1.15 |
| | Interior - 95% CI Low | 1.62 | 1.47 | 2.15 | 1.55 | | | 1.10 | 1.01 | 1.12 | 1.19 | 1.10 | 1.13 |
| Specific Conductivity (uS/cm) | Canal -Geo Mean | 748 | 999 | 722 | 933 | 879 | 1058 | 668 | 527 | 760 | 811 | 1060 | 1036 |
| | Canal - Count | 5 | 5 | 3 | 3 | 5 | 5 | 4 | 5 | 5 | 5 | 5 | 5 |
| | Canal - 95% CI Up | 754 | 1148 | 722 | 941 | 881 | 1064 | 752 | 599 | 829 | 853 | 1068 | 1090 |
| | Canal - 95% CI Low | 741 | 870 | 722 | 924 | 878 | 1052 | 594 | 464 | 697 | 771 | 1051 | 985 |
| | Perimeter - Geo Mean | 350 | 367 | 390 | 327 | 389 | 533 | 202 | 179 | 210 | 192 | 361 | 406 |
| | Perimeter - Count | 27 | 28 | 12 | 19 | 14 | 23 | 11 | 19 | 29 | 25 | 26 | 30 |
| | Perimieter - 95%CI Up | 415 | 446 | 441 | 369 | 435 | 691 | 222 | 198 | 284 | 235 | 497 | 564 |
| | Perimeter - 95% CI Low | 296 | 301 | 345 | 289 | 348 | 412 | 185 | 162 | 155 | 157 | 262 | 292 |
| | Transition - Geo Mean | 167 | 190 | 219 | 200 | 220 | 149 | 117 | 107 | 125 | 108 | 129 | 145 |
| | Transition - Count | 7 | 3 | 2 | 4 | 2 | 8 | 3 | 6 | 7 | 8 | 9 | 9 |
| | Transition - 95% CI Up | 168 | 191 | 220 | 209 | 221 | 160 | 118 | 110 | 129 | 112 | 136 | 155 |
| | Transition - 95% CI Low | 166 | 190 | 219 | 190 | 219 | 139 | 117 | 104 | 121 | 105 | 122 | 136 |
| | Interior - Geo Mean | 144 | 137 | 220 | 152 | 201 | 112 | 88 | 87 | 105 | 108 | 109 | 120 |
| | Interior - Count | 2 | 4 | 2 | 2 | 1 | 2 | 6 | 7 | 6 | 8 | 9 | 9 |
| | Interior - 95% CI Up | 144 | 142 | 220 | 154 | | 112 | 89 | 92 | 109 | 110 | 110 | 120 |
| | Interior - 95% CI Low | 143 | 133 | 220 | 150 | | 111 | 87 | 83 | 101 | 107 | 109 | 120 |
| Chloride (mg/L) | Canal -Geo Mean | 97.2 | 127.5 | 92.0 | 126.5 | 116.1 | 118.1 | 84.4 | 58.5 | 97.6 | 120.0 | 129.6 | 128.4 |
| | Canal - Count | 5 | 5 | 3 | 3 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| | Canal - 95% CI Up | 98.4 | 149.2 | 92.0 | 128.8 | 116.7 | 119.4 | 93.2 | 74.7 | 110.5 | 123.2 | 130.8 | 140.6 |
| | Canal - 95% CI Low | 96.1 | 108.8 | 92.0 | 124.2 | 115.6 | 116.7 | 76.4 | 45.8 | 86.2 | 116.8 | 128.3 | 117.3 |
| | Perimeter - Geo Mean | 51.3 | 62.1 | 52.6 | 49.7 | 60.1 | 73.4 | 20.3 | 20.6 | 25.8 | 24.3 | 50.4 | 58.9 |
| | Perimeter - Count | 29 | 26 | 14 | 19 | 14 | 23 | 17 | 19 | 29 | 25 | 26 | 30 |
| | Perimieter - 95%CI Up | 59.0 | 78.7 | 59.9 | 55.0 | 65.5 | 93.8 | 21.2 | 22.4 | 36.6 | 30.0 | 70.3 | 81.9 |
| | Perimeter - 95% CI Low | 44.6 | 49.0 | 46.2 | 44.9 | 55.2 | 57.5 | 19.4 | 18.9 | 18.2 | 19.6 | 36.2 | 42.4 |
| | Transition - Geo Mean | 27.7 | 38.6 | 33.8 | 31.2 | 39.3 | 23.3 | 17.3 | 13.9 | 16.6 | 15.2 | 19.3 | 22.4 |
| | Transition - Count | 7 | 5 | 2 | 3 | 2 | 8 | 7 | 6 | 7 | 8 | 9 | 9 |
| | Transition - 95% CI Up | 28.2 | 46.9 | 33.8 | 31.6 | 41.0 | 26.1 | 18.2 | 14.2 | 17.5 | 15.5 | 20.3 | 23.5 |
| | Transition - 95% CI Low | 27.2 | 31.8 | 33.7 | 30.8 | 37.7 | 20.9 | 16.5 | 13.6 | 15.8 | 14.9 | 18.4 | 21.3 |
| | Interior - Geo Mean | 27.1 | 29.5 | 33.1 | 27.2 | 37.6 | 18.9 | 16.6 | 16.1 | 19.6 | 20.2 | 21.0 | 23.0 |
| | Interior - Count | 7 | 5 | 5 | 4 | 1 | 2 | 8 | 7 | 6 | 8 | 9 | 9 |
| | Interior - 95% CI Up | 27.7 | 30.7 | 34.8 | 27.8 | | 19.0 | 16.8 | 16.9 | 20.3 | 20.7 | 21.2 | 23.2 |
| | Interior - 95% CI Low | 26.5 | 28.3 | 31.4 | 26.5 | | 18.9 | 16.4 | 15.4 | 18.9 | 19.8 | 20.8 | 22.9 |
| Sulfate (mg/L) | Canal -Geo Mean | 32.95 | 50.11 | 38.49 | 31.18 | 55.86 | 88.25 | 14.86 | 10.12 | 23.64 | 24.59 | 76.59 | 54.94 |
| | Canal - Count | 5 | 5 | 3 | 3 | 5 | 5 | 5 | 4 | 5 | 5 | 5 | 5 |
| | Canal - 95% CI Up | 35.55 | 55.11 | 38.51 | 32.25 | 56.58 | 89.16 | 46.71 | 15.52 | 46.07 | 44.97 | 78.63 | 72.34 |
| | Canal - 95% CI Low | 30.54 | 45.57 | 38.47 | 30.15 | 55.15 | 87.35 | 4.73 | 6.60 | 12.13 | 13.45 | 74.61 | 41.72 |
| | Perimeter - Geo Mean | 4.38 | 4.54 | 3.55 | 2.62 | 2.73 | 20.15 | 1.26 | 1.61 | 2.43 | 2.17 | 3.66 | 4.15 |
| | Perimeter - Count | 28 | 26 | 14 | 19 | 14 | 23 | 17 | 17 | 29 | 25 | 26 | 30 |
| | Perimieter - 95%CI Up | 12.29 | 12.42 | 8.91 | 4.61 | 7.46 | 49.46 | 1.79 | 3.83 | 8.07 | 3.80 | 31.03 | 32.06 |
| | Perimeter - 95% CI Low | 1.56 | 1.66 | 1.41 | 1.48 | 1.00 | 8.21 | 0.89 | 0.68 | 0.73 | 1.24 | 0.43 | 0.54 |
| | Transition - Geo Mean | 0.49 | 0.75 | 1.10 | 0.44 | 0.37 | 0.95 | 0.25 | 0.26 | 0.41 | 0.63 | 0.79 | 0.64 |
| | Transition - Count | 7 | 5 | 2 | 3 | 2 | 8 | 7 | 4 | 7 | 8 | 9 | 9 |
| | Transition - 95% CI Up | 0.76 | 1.03 | 1.10 | 2.20 | 0.55 | 1.99 | 0.62 | 0.75 | 1.08 | 1.18 | 1.25 | 1.12 |
| | Transition - 95% CI Low | 0.32 | 0.54 | 1.09 | 0.09 | 0.25 | 0.45 | 0.10 | 0.09 | 0.15 | 0.33 | 0.50 | 0.36 |
| | Interior - Geo Mean | 0.06 | 0.09 | 0.16 | 0.18 | 0.20 | 0.40 | 0.15 | 0.14 | 0.08 | 0.11 | 0.10 | 0.11 |
| | Interior - Count | 7 | 5 | 5 | 4 | 1 | 2 | 8 | 7 | 6 | 8 | 9 | 9 |
| | Interior - 95% CI Up | 0.10 | 0.17 | 0.33 | 0.44 | | 0.40 | 0.25 | 0.23 | 0.13 | 0.21 | 0.21 | 0.20 |
| | Interior - 95% CI Low | 0.04 | 0.05 | 0.08 | 0.07 | | 0.40 | 0.09 | 0.08 | 0.06 | 0.05 | 0.05 | 0.06 |
| Tdepth (in.) | Perimeter - Geo Mean | 10.1 | 8.3 | 0.8 | 9.2 | 3.7 | 16.0 | 5.3 | 2.9 | 8.8 | 10.1 | 11.4 | 12.9 |
| | Perimeter - Count | 30 | 29 | 25 | 19 | 19 | 23 | 26 | 30 | 30 | 26 | 29 | 29 |
| | Perimieter - 95%CI Up | 13.4 | 15.7 | * | 13.7 | 7.9 | 17.0 | 8.1 | * | 11.4 | 12.3 | 16.1 | 16.2 |
| | Perimeter - 95% CI Low | 7.6 | 4.4 | 0.0 | 6.2 | 1.7 | 15.0 | 3.5 | * | 6.8 | 8.4 | 8.1 | 10.3 |
| | Transition - Geo Mean | 9.5 | 4.7 | 0.5 | 7.0 | 2.2 | 11.3 | 5.2 | 4.1 | 6.0 | 9.8 | 11.7 | 11.16 |
| | Transition - Count | 7 | 9 | 8 | 4 | 7 | 8 | 9 | 9 | 9 | 8 | 9 | 9 |
| | Transition - 95% CI Up | 12.8 | 11.3 | * | 14.6 | 3.9 | 11.9 | 7.2 | 7.4 | 8.0 | 11.6 | 15.1 | 15.3 |
| | Transition - 95% CI Low | 7.1 | 2.0 | 0.0 | 3.3 | 1.3 | 10.8 | 3.7 | 2.3 | 4.5 | 8.3 | 9.1 | 8.1 |
| | Interior - Geo Mean | 7.0 | 3.9 | 4.1 | 5.6 | 3.2 | 12.2 | 1.8 | 7.2 | 6.7 | 7.4 | 13.1 | 11.6 |
| | Interior - Count | 9 | 9 | 8 | 7 | 5 | 2 | 9 | 9 | 6 | 9 | 9 | 9 |
| | Interior - 95% CI Up | 11.5 | 13.6 | 7.8 | 10.8 | 5.3 | 13.8 | * | 9.7 | 9.3 | 9.6 | 17.2 | 15.6 |
| | Interior - 95% CI Low | 4.3 | 1.1 | 2.2 | 2.9 | 1.9 | 10.9 | * | 5.3 | 4.9 | 5.7 | 10.1 | 8.6 |

* Indicates that geometric mean confidence intervals could not be calculated because there were values close to zero.

**Summary Arithmetic Mean Data By Zone**

(Mean = arithmetic mean, Count = # of sites, 95% CI Up = 95% upper arithmetic mean confidence interval,
95% CI Low = 95% lower arithmetic mean confidence interval)

| | | Jan-04 | Feb-04 | Mar-04 | Apr-04 | May-04 | Jun-04 | Jul-04 | Aug-04 | Sep-04 | Oct-04 | Nov-04 | Dec-04 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Total Phosphorus (ppb)** | Canal - Mean | | | | | | 68.8 | 60.2 | 48.8 | 230.0 | 432.6 | 81.8 | 69.6 |
| | Canal - Count | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| | Canal - 95% CI Up | | | | | | 108.5 | 125.5 | 93.7 | 295.5 | 831.1 | 109.9 | 104.3 |
| | Canal - 95% CI Low | | | | | | 29.1 | -5.1 | 3.9 | 164.5 | 34.1 | 53.7 | 34.9 |
| | Perimeter - Mean | 8.5 | 8.2 | 8.8 | 9.3 | 10.7 | 26.0 | | 27.0 | 28.6 | 69.1 | 16.7 | 23.1 |
| | Perimeter - Count | 6 | 6 | 6 | 4 | 3 | 2 | 0 | 16 | 29 | 30 | 30 | 30 |
| | Perimieter - 95%CI Up | 20.9 | 14.7 | 16.9 | 16.3 | 18.8 | 48.2 | | 71.0 | 97.7 | 252.7 | 46.7 | 92.2 |
| | Perimeter - 95% CI Low | -3.9 | 1.7 | 0.8 | 2.2 | 2.5 | 3.8 | | -17.0 | -40.4 | -114.5 | -13.2 | -46.0 |
| | Transition - Mean | 5.0 | 5.0 | 7.0 | 6.0 | 19.0 | 28.3 | 16.3 | 16.4 | 9.6 | 8.2 | 8.3 | 10.8 |
| | Transition - Count | 1 | 1 | 1 | 1 | 1 | 4 | 3 | 8 | 9 | 9 | 9 | 9 |
| | Transition - 95% CI Up | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | 57.4 | 27.5 | 34.3 | 15.1 | 11.9 | 12.9 | 18.0 |
| | Transition - 95% CI Low | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | -0.9 | 5.2 | -1.5 | 4.0 | 4.6 | 3.7 | 3.6 |
| | Interior - Mean | 8.3 | 10.9 | 11.4 | 13.3 | 13.0 | 16.0 | | 14.9 | 8.7 | 8.4 | 10.1 | 16.3 |
| | Interior - Count | 7 | 7 | 7 | 4 | 5 | 1 | 0 | 7 | 9 | 8 | 9 | 8 |
| | Interior - 95% CI Up | 13.3 | 25.6 | 26.2 | 26.3 | 17.4 | | | 26.2 | 13.3 | 12.1 | 20.5 | 35.5 |
| | Interior - 95% CI Low | 3.3 | -3.9 | -3.4 | 0.2 | 8.6 | | | 3.5 | 4.1 | 4.6 | -0.3 | -3.0 |
| **Total Nitrogen (mg/L)** | Canal - Mean | | | | | | 2.34 | 1.84 | 2.00 | 2.73 | 2.32 | 1.67 | 1.65 |
| | Canal - Count | 0 | 0 | 0 | 0 | 0 | 5 | 3 | 5 | 5 | 4 | 5 | 3 |
| | Canal - 95% CI Up | | | | | | 2.83 | 2.32 | 2.31 | 3.12 | 2.75 | 2.37 | 1.83 |
| | Canal - 95% CI Low | | | | | | 1.85 | 1.36 | 1.70 | 2.33 | 1.88 | 0.96 | 1.47 |
| | Perimeter - Mean | 1.25 | 1.29 | 1.19 | 1.00 | 1.43 | | | 2.32 | 1.92 | 1.37 | 1.31 | 1.49 |
| | Perimeter - Count | 6 | 2 | 6 | 3 | 2 | 0 | 0 | 6 | 29 | 23 | 26 | 19 |
| | Perimieter - 95%CI Up | 2.51 | 1.59 | 1.82 | 1.33 | 1.53 | | | 4.66 | 2.98 | 2.38 | 2.04 | 2.53 |
| | Perimeter - 95% CI Low | -0.01 | 0.98 | 0.56 | 0.67 | 1.34 | | | -0.01 | 0.86 | 0.36 | 0.59 | 0.45 |
| | Transition - Mean | 0.90 | | 0.98 | 1.12 | 2.06 | 3.02 | 2.19 | 1.65 | 1.34 | 0.76 | 1.16 | 1.18 |
| | Transition - Count | 1 | 0 | 1 | 1 | 1 | 2 | 1 | 2 | 9 | 7 | 5 | 7 |
| | Transition - 95% CI Up | | | | | | 6.27 | | 3.91 | | 0.97 | 1.75 | 1.56 |
| | Transition - 95% CI Low | | | | | | -0.23 | | -0.61 | | 0.54 | 0.58 | 0.80 |
| | Interior - Mean | 1.16 | 1.37 | 1.61 | 1.54 | | | | 2.60 | 1.24 | 1.16 | 1.21 | 1.58 |
| | Interior - Count | 5 | 6 | 6 | 2 | 0 | 0 | 0 | 3 | 9 | 8 | 6 | 6 |
| | Interior - 95% CI Up | 1.39 | 2.09 | 2.39 | 2.22 | | | | 5.22 | 1.63 | 1.55 | 1.36 | 2.25 |
| | Interior - 95% CI Low | 0.92 | 0.65 | 0.82 | 0.86 | | | | -0.01 | 0.85 | 0.77 | 1.06 | 0.92 |
| **Specific Conductivity (uS/cm)** | Canal -Mean | | | | | | 911 | 671 | 852 | 804 | 631 | 602 | 659 |
| | Canal - Count | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| | Canal - 95% CI Up | | | | | | 1059 | 998 | 948 | 942 | 827 | 811 | 925 |
| | Canal - 95% CI Low | | | | | | 763 | 344 | 755 | 667 | 435 | 392 | 393 |
| | Perimeter - Mean | 337 | 303 | 255 | 208 | 222 | 463 | | 486 | 633 | 463 | 350 | 355 |
| | Perimeter - Count | 6 | 6 | 6 | 4 | 3 | 2 | 0 | 15 | 29 | 30 | 30 | 30 |
| | Perimieter - 95%CI Up | 715 | 607 | 567 | 417 | 406 | 727 | | 901 | 1068 | 895 | 720 | 689 |
| | Perimeter - 95% CI Low | -42 | -2 | -57 | -1 | 37 | 199 | | 71 | 198 | 31 | -20 | 21 |
| | Transition - Mean | 313 | 313 | 263 | 268 | 332 | 285 | 302 | 217 | 219 | 116 | 115 | 151 |
| | Transition - Count | 1 | 1 | 1 | 1 | 1 | 3 | 3 | 8 | 8 | 9 | 8 | 9 |
| | Transition - 95% CI Up | | | | | | 325 | 416 | 320 | 363 | 169 | 151 | 193 |
| | Transition - 95% CI Low | | | | | | 246 | 187 | 114 | 75 | 63 | 78 | 109 |
| | Interior - Mean | 119 | 119 | 129 | 156 | 215 | 430 | | 151 | 96 | 81 | 96 | 120 |
| | Interior - Count | 7 | 7 | 7 | 4 | 5 | 1 | 0 | 7 | 9 | 9 | 9 | 8 |
| | Interior - 95% CI Up | 154 | 154 | 167 | 206 | 315 | | | 224 | 132 | 121 | 122 | 148 |
| | Interior - 95% CI Low | 84 | 83 | 90 | 106 | 115 | | | 79 | 61 | 42 | 70 | 91 |
| **Chloride (mg/L)** | Canal -Mean | | | | | | 139.8 | 91.3 | 120.8 | 90.5 | 71.0 | 66.3 | 83.2 |
| | Canal - Count | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| | Canal - 95% CI Up | | | | | | 183.3 | 151.1 | 129.8 | 115.2 | 84.5 | 98.7 | 125.3 |
| | Canal - 95% CI Low | | | | | | 96.3 | 31.4 | 111.8 | 65.9 | 57.6 | 34.0 | 41.0 |
| | Perimeter - Mean | 52.3 | 46.5 | 38.2 | 27.7 | 39.2 | | | 78.9 | 81.1 | 52.3 | 46.8 | 49.9 |
| | Perimeter - Count | 6 | 6 | 6 | 3 | 2 | 0 | 0 | 6 | 29 | 30 | 29 | 29 |
| | Perimieter - 95%CI Up | 106.7 | 88.1 | 81.4 | 59.0 | 63.4 | | | 125.3 | 134.5 | 97.9 | 90.6 | 88.6 |
| | Perimeter - 95% CI Low | -2.1 | 4.8 | -5.1 | -3.6 | 14.9 | | | 32.5 | 27.6 | 6.7 | 3.1 | 11.2 |
| | Transition - Mean | 47.4 | 47.6 | 41.6 | 42.7 | 54.9 | 39.3 | 50.0 | 28.7 | 32.9 | 17.3 | 18.7 | 24.9 |
| | Transition - Count | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 9 | 9 | 9 | 9 |
| | Transition - 95% CI Up | | | | | | 63.4 | | 50.0 | 54.7 | 27.4 | 27.2 | 35.8 |
| | Transition - 95% CI Low | | | | | | 15.2 | | 7.4 | 11.1 | 7.3 | 10.3 | 14.0 |
| | Interior - Mean | 22.8 | 24.2 | 26.3 | 30.2 | | | | 26.9 | 17.6 | 15.1 | 18.0 | 22.6 |
| | Interior - Count | 5 | 6 | 6 | 2 | 0 | 0 | 0 | 3 | 9 | 9 | 6 | 6 |
| | Interior - 95% CI Up | 30.9 | 33.2 | 34.3 | 47.5 | | | | 39.4 | 23.3 | 24.3 | 26.5 | 30.8 |
| | Interior - 95% CI Low | 14.6 | 15.1 | 18.4 | 12.8 | | | | 14.4 | 11.9 | 5.8 | 9.5 | 14.3 |
| **Sulfate (mg/L)** | Canal -Mean | | | | | | 49.22 | 46.78 | 60.74 | 54.02 | 32.72 | 22.00 | 21.72 |
| | Canal - Count | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| | Canal - 95% CI Up | | | | | | 60.87 | 76.45 | 70.72 | 73.13 | 61.37 | 51.51 | 59.59 |
| | Canal - 95% CI Low | | | | | | 37.57 | 17.11 | 50.76 | 34.91 | 4.07 | -7.51 | -16.15 |
| | Perimeter - Mean | 7.38 | 5.28 | 3.35 | 1.73 | 1.40 | | | 44.12 | 33.79 | 25.28 | 10.22 | 7.35 |
| | Perimeter - Count | 6 | 6 | 6 | 3 | 2 | 0 | 0 | 6 | 29 | 30 | 29 | 29 |
| | Perimieter - 95%CI Up | 33.13 | 21.95 | 15.07 | 5.81 | 3.34 | | | 90.01 | 75.15 | 64.25 | 34.22 | 24.95 |
| | Perimeter - 95% CI Low | -18.36 | -11.38 | -8.37 | -2.34 | -0.54 | | | -1.78 | -7.58 | -13.69 | -13.77 | -10.25 |
| | Transition - Mean | 2.10 | 2.30 | 1.20 | 1.20 | 1.40 | 3.15 | 1.40 | 2.30 | 4.64 | 1.37 | 0.48 | 0.45 |
| | Transition - Count | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 9 | 9 | 9 | 9 |
| | Transition - 95% CI Up | | | | | | 8.00 | | 5.07 | 16.30 | 4.51 | 1.37 | 1.15 |
| | Transition - 95% CI Low | | | | | | -1.70 | | -0.47 | -7.01 | -1.77 | -0.42 | -0.25 |
| | Interior - Mean | 0.05 | 0.05 | 0.06 | 0.05 | | | | 0.20 | 0.14 | 0.14 | 0.13 | 0.09 |
| | Interior - Count | 5 | 6 | 6 | 2 | 0 | 0 | 0 | 3 | 9 | 9 | 6 | 6 |
| | Interior - 95% CI Up | 0.05 | 0.05 | 0.10 | 0.05 | | | | 0.40 | 0.29 | 0.56 | 0.39 | 0.29 |
| | Interior - 95% CI Low | 0.05 | 0.05 | 0.02 | 0.05 | | | | 0.00 | 0.00 | -0.28 | -0.14 | -0.11 |
| **Tdepth (in.)** | Perimeter - Mean | 26.7 | 29.7 | 24.5 | 10.7 | 5.0 | 1.8 | 0.2 | 5.0 | 14.1 | 17.9 | 18.6 | 15.5 |
| | Perimeter - Count | 6 | 6 | 6 | 6 | 6 | 27 | 30 | 30 | 29 | 30 | 30 | 29 |
| | Perimieter - 95%CI Up | 45.5 | 51.1 | 36.8 | 25.4 | 10.9 | 4.5 | 1.6 | 17.8 | 24.2 | 28.8 | 33.2 | 29.3 |
| | Perimeter - 95% CI Low | 8.0 | 8.3 | 12.3 | -4.1 | -1.0 | -0.9 | -1.1 | -7.8 | 4.1 | 7.0 | 4.1 | 1.8 |
| | Transition - Mean | 37.4 | 39.4 | 27.6 | 23.6 | 11.8 | 3.7 | 2.0 | 4.6 | 12.2 | 17.0 | 13.4 | 11.4 |
| | Transition - Count | 1 | 1 | 1 | 1 | 1 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |
| | Transition - 95% CI Up | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10.8 | 4.9 | 9.9 | 18.0 | 23.1 | 21.3 | 17.2 |
| | Transition - 95% CI Low | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -3.4 | -0.9 | -0.6 | 6.4 | 10.9 | 5.5 | 5.7 |
| | Interior - Mean | 14.0 | 16.3 | 11.2 | 4.7 | 3.8 | 2.6 | 0.7 | 5.1 | 13.0 | 15.7 | 11.4 | 8.9 |
| | Interior - Count | 7 | 7 | 7 | 6 | 7 | 8 | 9 | 9 | 9 | 8 | 9 | 9 |
| | Interior - 95% CI Up | 25.8 | 30.2 | 18.6 | 14.5 | 6.4 | 4.8 | 2.3 | 9.8 | 18.7 | 24.5 | 21.7 | 18.2 |
| | Interior - 95% CI Low | 2.1 | 2.4 | 3.8 | -5.1 | 1.2 | 0.4 | -0.9 | 0.4 | 7.3 | 7.0 | 1.2 | -0.5 |

**Summary Arithmetic Mean Data By Zone**

(Mean = arithmetic mean, Count = # of sites, 95% CI Up = 95% upper arithmetic mean confidence interval,
95% CI Low = 95% lower arithmetic mean confidence interval)

| | | Jan-05 | Feb-05 | Mar-05 | Apr-05 | May-05 | Jun-05 | Jul-05 | Aug-05 | Sep-05 | Oct-05 | Nov-05 | Dec-05 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Total Phosphorus (ppb)** | Canal - Mean | 66.2 | 124.8 | 100.3 | 70.3 | 69.3 | 216.8 | 76.0 | 57.0 | 61.0 | 67.6 | 148.8 | 92.2 |
| | Canal - Count | 5 | 5 | 3 | 3 | 3 | 5 | 5 | 4 | 5 | 5 | 5 | 5 |
| | Canal - 95% CI Up | 97.4 | 213.2 | 125.3 | 78.3 | 121.8 | 335.5 | 100.2 | 72.4 | 79.5 | 110.3 | 223.0 | 146.2 |
| | Canal - 95% CI Low | 35.0 | 36.4 | 75.4 | 62.4 | 16.9 | 98.1 | 51.8 | 41.6 | 42.5 | 24.9 | 74.6 | 38.2 |
| | Perimeter - Mean | 28.3 | 24.7 | 15.7 | 21.5 | 31.1 | 38.5 | 9.2 | 12.6 | 13.5 | 10.8 | 12.0 | 11.1 |
| | Perimeter - Count | 29 | 27 | 14 | 19 | 9 | 23 | 17 | 19 | 29 | 25 | 26 | 30 |
| | Perimieter - 95%CI Up | 136.2 | 72.9 | 39.3 | 66.9 | 52.9 | 101.6 | 18.2 | 34.0 | 33.8 | 18.8 | 22.9 | 28.8 |
| | Perimeter - 95% CI Low | -79.5 | -23.4 | -7.9 | -24.0 | 9.3 | -24.7 | 0.3 | -8.9 | -6.8 | 2.8 | 1.0 | -6.5 |
| | Transition - Mean | 13.7 | 11.6 | 44.5 | 10.3 | 52.0 | 20.4 | 6.9 | 6.0 | 6.9 | 7.3 | 8.1 | 6.8 |
| | Transition - Count | 7 | 5 | 2 | 3 | 1 | 8 | 7 | 6 | 7 | 8 | 9 | 9 |
| | Transition - 95% CI Up | 27.4 | 23.4 | 118.0 | 13.3 | | 35.0 | 12.1 | 9.3 | 10.5 | 8.2 | 9.9 | 9.5 |
| | Transition - 95% CI Low | 0.0 | -0.2 | -29.0 | 7.3 | | 5.7 | 1.6 | 2.7 | 3.2 | 6.3 | 6.3 | 4.0 |
| | Interior - Mean | 9.7 | 9.4 | 17.5 | 9.5 | 102.0 | 31.5 | 8.6 | 6.7 | 6.6 | 6.6 | 7.3 | 7.9 |
| | Interior - Count | 7 | 5 | 4 | 4 | 1 | 2 | 9 | 7 | 5 | 8 | 9 | 9 |
| | Interior - 95% CI Up | 13.2 | 13.0 | 31.7 | 10.6 | | 38.4 | 13.2 | 9.2 | 8.8 | 9.2 | 9.7 | 16.5 |
| | Interior - 95% CI Low | 6.2 | 5.8 | 3.3 | 8.4 | | 24.6 | 3.9 | 4.3 | 4.4 | 4.1 | 4.9 | -0.7 |
| **Total Nitrogen (mg/L)** | Canal - Mean | 2.08 | 2.81 | 1.96 | 2.09 | 2.23 | 4.70 | 2.27 | 1.77 | 2.16 | 2.25 | 4.19 | 2.52 |
| | Canal - Count | 5 | 5 | 3 | 3 | 3 | 5 | 2 | 3 | 3 | 3 | 5 | 5 |
| | Canal - 95% CI Up | 2.99 | 5.32 | 2.26 | 2.60 | 2.86 | 7.03 | 2.35 | 3.09 | 2.54 | 3.27 | 4.94 | 3.51 |
| | Canal - 95% CI Low | 1.17 | 0.31 | 1.66 | 1.57 | 1.59 | 2.37 | 2.19 | 0.44 | 1.78 | 1.24 | 3.44 | 1.53 |
| | Perimeter - Mean | 1.42 | 1.78 | 1.43 | 1.71 | 1.98 | 2.06 | 1.02 | 1.15 | 1.10 | 1.02 | 1.32 | 1.27 |
| | Perimeter - Count | 20 | 15 | 5 | 11 | 3 | 8 | 1 | 6 | 14 | 12 | 23 | 24 |
| | Perimieter - 95%CI Up | 2.28 | 3.66 | 2.25 | 2.75 | 2.64 | 2.94 | | 1.61 | 1.60 | 1.36 | 2.11 | 1.99 |
| | Perimeter - 95% CI Low | 0.57 | -0.10 | 0.61 | 0.68 | 1.33 | 1.19 | | 0.70 | 0.60 | 0.68 | 0.52 | 0.54 |
| | Transition - Mean | 1.30 | 1.28 | 1.57 | 1.33 | 8.69 | 1.84 | | 0.91 | 0.97 | 0.81 | 0.91 | 0.95 |
| | Transition - Count | 4 | 2 | 1 | 2 | 1 | 2 | 0 | 1 | 1 | 4 | 6 | 6 |
| | Transition - 95% CI Up | 2.10 | 2.10 | | 2.17 | | 2.85 | | | | 1.04 | 1.16 | 1.25 |
| | Transition - 95% CI Low | 0.50 | 0.46 | | 0.49 | | 0.84 | | | | 0.57 | 0.65 | 0.64 |
| | Interior - Mean | 1.64 | 1.50 | 2.21 | 1.60 | 8.40 | 3.17 | 1.10 | 1.03 | 1.14 | 1.21 | 1.11 | 1.14 |
| | Interior - Count | 5 | 3 | 3 | 4 | 1 | 1 | 2 | 4 | 4 | 4 | 7 | 6 |
| | Interior - 95% CI Up | 1.94 | 1.95 | 2.98 | 2.12 | | | 1.13 | 1.30 | 1.42 | 1.50 | 1.32 | 1.37 |
| | Interior - 95% CI Low | 1.33 | 1.06 | 1.44 | 1.07 | | | 1.08 | 0.76 | 0.86 | 0.92 | 0.91 | 0.92 |
| **Specific Conductivity (uS/cm)** | Canal -Mean | 751 | 1073 | 722 | 937 | 880 | 1061 | 709 | 563 | 795 | 832 | 1064 | 1063 |
| | Canal - Count | 5 | 5 | 3 | 3 | 5 | 5 | 4 | 5 | 5 | 5 | 5 | 5 |
| | Canal - 95% CI Up | 908 | 1976 | 757 | 1159 | 964 | 1232 | 1257 | 1029 | 1320 | 1254 | 1274 | 1587 |
| | Canal - 95% CI Low | 593 | 171 | 688 | 715 | 797 | 890 | 160 | 97 | 270 | 410 | 854 | 538 |
| | Perimeter - Mean | 381 | 404 | 416 | 347 | 411 | 593 | 211 | 188 | 253 | 215 | 427 | 480 |
| | Perimeter - Count | 27 | 28 | 12 | 19 | 14 | 23 | 11 | 19 | 29 | 25 | 26 | 30 |
| | Perimieter - 95%CI Up | 704 | 760 | 737 | 594 | 687 | 1049 | 332 | 314 | 649 | 435 | 955 | 1064 |
| | Perimeter - 95% CI Low | 59 | 48 | 95 | 101 | 135 | 138 | 91 | 63 | -142 | -5 | -101 | -103 |
| | Transition - Mean | 168 | 191 | 220 | 204 | 221 | 154 | 118 | 108 | 127 | 110 | 132 | 150 |
| | Transition - Count | 7 | 3 | 2 | 4 | 2 | 8 | 3 | 6 | 7 | 8 | 9 | 9 |
| | Transition - 95% CI Up | 198 | 208 | 235 | 303 | 269 | 232 | 135 | 146 | 177 | 157 | 206 | 237 |
| | Transition - 95% CI Low | 137 | 173 | 204 | 106 | 172 | 76 | 100 | 70 | 77 | 64 | 59 | 64 |
| | Interior - Mean | 144 | 140 | 220 | 153 | 201 | 112 | 89 | 90 | 107 | 109 | 110 | 120 |
| | Interior - Count | 2 | 4 | 2 | 2 | 1 | 2 | 6 | 7 | 6 | 8 | 9 | 9 |
| | Interior - 95% CI Up | 156 | 199 | 228 | 204 | | 134 | 112 | 135 | 154 | 137 | 124 | 133 |
| | Interior - 95% CI Low | 131 | 81 | 212 | 102 | | 90 | 65 | 44 | 60 | 81 | 95 | 107 |
| **Chloride (mg/L)** | Canal -Mean | 97.8 | 138.2 | 92.0 | 127.7 | 116.4 | 118.7 | 88.7 | 66.9 | 103.9 | 121.6 | 130.2 | 134.4 |
| | Canal - Count | 5.0 | 5.0 | 3.0 | 3.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| | Canal - 95% CI Up | 121.9 | 261.9 | 93.8 | 170.4 | 134.6 | 145.4 | 149.7 | 150.6 | 183.9 | 166.2 | 158.7 | 223.2 |
| | Canal - 95% CI Low | 73.7 | 14.5 | 90.1 | 85.0 | 98.2 | 92.0 | 27.7 | -16.8 | 23.9 | 77.0 | 101.7 | 45.6 |
| | Perimeter - Mean | 55.0 | 70.4 | 56.2 | 52.2 | 62.7 | 81.0 | 20.8 | 21.4 | 32.0 | 27.4 | 59.7 | 69.4 |
| | Perimeter - Count | 29 | 26 | 14 | 19 | 14 | 23 | 17 | 19 | 29 | 25 | 26 | 30 |
| | Perimieter - 95%CI Up | 95.9 | 145.9 | 99.7 | 85.4 | 99.6 | 139.6 | 29.7 | 33.2 | 86.7 | 58.2 | 132.0 | 150.7 |
| | Perimeter - 95% CI Low | 14.0 | -5.1 | 12.7 | 19.1 | 25.8 | 22.4 | 11.8 | 9.7 | -22.6 | -3.5 | -12.6 | -11.9 |
| | Transition - Mean | 27.9 | 43.3 | 33.8 | 31.4 | 40.2 | 24.6 | 17.8 | 14.0 | 17.1 | 15.3 | 19.8 | 22.9 |
| | Transition - Count | 7 | 5 | 2 | 3 | 2 | 8 | 7 | 6 | 7 | 8 | 9 | 9 |
| | Transition - 95% CI Up | 35.9 | 96.0 | 37.7 | 39.5 | 62.7 | 41.2 | 27.0 | 18.3 | 25.8 | 19.9 | 29.7 | 34.4 |
| | Transition - 95% CI Low | 20.0 | -9.4 | 29.9 | 23.3 | 17.6 | 8.1 | 8.5 | 9.7 | 8.4 | 10.7 | 9.9 | 11.4 |
| | Interior - Mean | 27.4 | 30.1 | 33.9 | 27.5 | 37.6 | 19.0 | 16.7 | 16.5 | 20.0 | 20.5 | 21.1 | 23.1 |
| | Interior - Count | 7 | 5 | 5 | 4 | 1 | 2 | 8 | 7 | 6 | 8 | 9 | 9 |
| | Interior - 95% CI Up | 35.8 | 43.5 | 50.1 | 36.7 | | 20.2 | 20.6 | 24.7 | 28.6 | 26.8 | 25.7 | 27.1 |
| | Interior - 95% CI Low | 19.0 | 16.8 | 17.7 | 18.3 | | 17.7 | 12.8 | 8.4 | 11.3 | 14.1 | 16.5 | 19.1 |
| **Sulfate (mg/L)** | Canal -Mean | 34.20 | 52.60 | 38.50 | 31.73 | 56.20 | 88.70 | 25.64 | 12.05 | 32.76 | 33.28 | 77.60 | 63.16 |
| | Canal - Count | 5 | 5 | 3 | 3 | 5 | 5 | 5 | 4 | 5 | 5 | 5 | 5 |
| | Canal - 95% CI Up | 54.32 | 88.90 | 40.54 | 46.47 | 69.27 | 108.15 | 77.52 | 25.33 | 87.19 | 87.87 | 104.99 | 135.84 |
| | Canal - 95% CI Low | 14.08 | 16.30 | 36.46 | 17.00 | 43.13 | 69.25 | -26.24 | -1.23 | -21.67 | -21.31 | 50.21 | -9.52 |
| | Perimeter - Mean | 7.51 | 7.54 | 5.44 | 3.88 | 4.33 | 27.57 | 1.54 | 2.45 | 5.34 | 2.98 | 11.20 | 12.87 |
| | Perimeter - Count | 28 | 26 | 14 | 19 | 14 | 23 | 17 | 17 | 29 | 25 | 26 | 30 |
| | Perimieter - 95%CI Up | 26.43 | 26.15 | 15.00 | 14.70 | 12.58 | 61.88 | 3.85 | 7.20 | 24.57 | 8.63 | 48.85 | 57.95 |
| | Perimeter - 95% CI Low | -11.42 | -11.07 | -4.12 | -6.93 | -3.93 | -6.73 | -0.76 | -2.29 | -13.89 | -2.68 | -26.45 | -32.20 |
| | Transition - Mean | 0.60 | 0.86 | 1.10 | 0.90 | 0.45 | 1.33 | 0.36 | 0.39 | 0.56 | 0.79 | 0.97 | 0.81 |
| | Transition - Count | 7 | 5 | 2 | 3 | 2 | 8 | 7 | 4 | 7 | 8 | 9 | 9 |
| | Transition - 95% CI Up | 1.31 | 1.72 | 1.38 | 3.13 | 1.14 | 3.59 | 0.94 | 1.00 | 1.24 | 1.66 | 2.08 | 1.83 |
| | Transition - 95% CI Low | -0.11 | 0.00 | 0.82 | -1.33 | -0.24 | -0.94 | -0.21 | -0.22 | -0.12 | -0.09 | -0.15 | -0.20 |
| | Interior - Mean | 0.09 | 0.13 | 0.23 | 0.26 | 0.20 | 0.40 | 0.19 | 0.17 | 0.11 | 0.15 | 0.15 | 0.14 |
| | Interior - Count | 7 | 5 | 5 | 4 | 1 | 2 | 8 | 7 | 6 | 8 | 9 | 9 |
| | Interior - 95% CI Up | 0.27 | 0.43 | 0.65 | 0.70 | | 0.40 | 0.43 | 0.38 | 0.30 | 0.42 | 0.41 | 0.35 |
| | Interior - 95% CI Low | -0.10 | -0.17 | -0.19 | -0.17 | | 0.40 | -0.05 | -0.04 | -0.08 | -0.12 | -0.11 | -0.07 |
| **Tdepth (in.)** | Perimeter - Mean | 11.6 | 11.0 | 5.4 | 11.6 | 5.8 | 16.5 | 6.5 | 6.1 | 10.3 | 11.4 | 13.5 | 14.5 |
| | Perimeter - Count | 30 | 29 | 25 | 19 | 19 | 24 | 26 | 30 | 30 | 26 | 29 | 29 |
| | Perimieter - 95%CI Up | 21.6 | 24.8 | 15.6 | 26.0 | 18.1 | 25.7 | 14.1 | 14.9 | 22.0 | 23.2 | 28.0 | 28.3 |
| | Perimeter - 95% CI Low | 1.6 | -2.8 | -4.7 | -2.7 | -6.5 | 7.3 | -1.2 | -2.8 | -1.4 | -0.5 | -1.0 | 0.7 |
| | Transition - Mean | 9.0 | 5.6 | 2.2 | 7.3 | 3.2 | 11.6 | 4.9 | 4.1 | 5.6 | 8.9 | 11.0 | 10.7 |
| | Transition - Count | 7 | 9 | 8 | 4 | 8 | 9 | 9 | 9 | 9 | 8 | 9 | 9 |
| | Transition - 95% CI Up | 15.9 | 16.4 | 6.4 | 17.0 | 10.1 | 16.8 | 8.3 | 7.6 | 8.5 | 12.5 | 17.8 | 18.7 |
| | Transition - 95% CI Low | 2.1 | -5.1 | -2.1 | -2.5 | -3.7 | 6.4 | 1.6 | 0.7 | 2.6 | 5.4 | 4.3 | 2.7 |
| | Interior - Mean | 8.2 | 5.9 | 4.9 | 7.4 | 4.3 | 13.0 | 8.9 | 7.7 | 7.3 | 8.5 | 14.0 | 12.0 |
| | Interior - Count | 9 | 9 | 8 | 7 | 6 | 3 | 9 | 9 | 6 | 9 | 9 | 9 |
| | Interior - 95% CI Up | 17.8 | 17.1 | 11.6 | 18.2 | 12.1 | 21.5 | 19.4 | 15.0 | 14.1 | 16.6 | 25.5 | 22.5 |
| | Interior - 95% CI Low | -1.5 | -5.3 | -1.9 | -3.4 | -3.5 | 4.5 | -1.6 | 0.4 | 0.5 | 0.4 | 2.4 | 1.6 |

# Appendix 1-3

Time series of structure discharges with corresponding water quality conditions of total phosphorus (top panel) and specific conductivity (bottom panel) for canal stations located as part of the following transects:

**Figure A1-3-1**: STA-1W

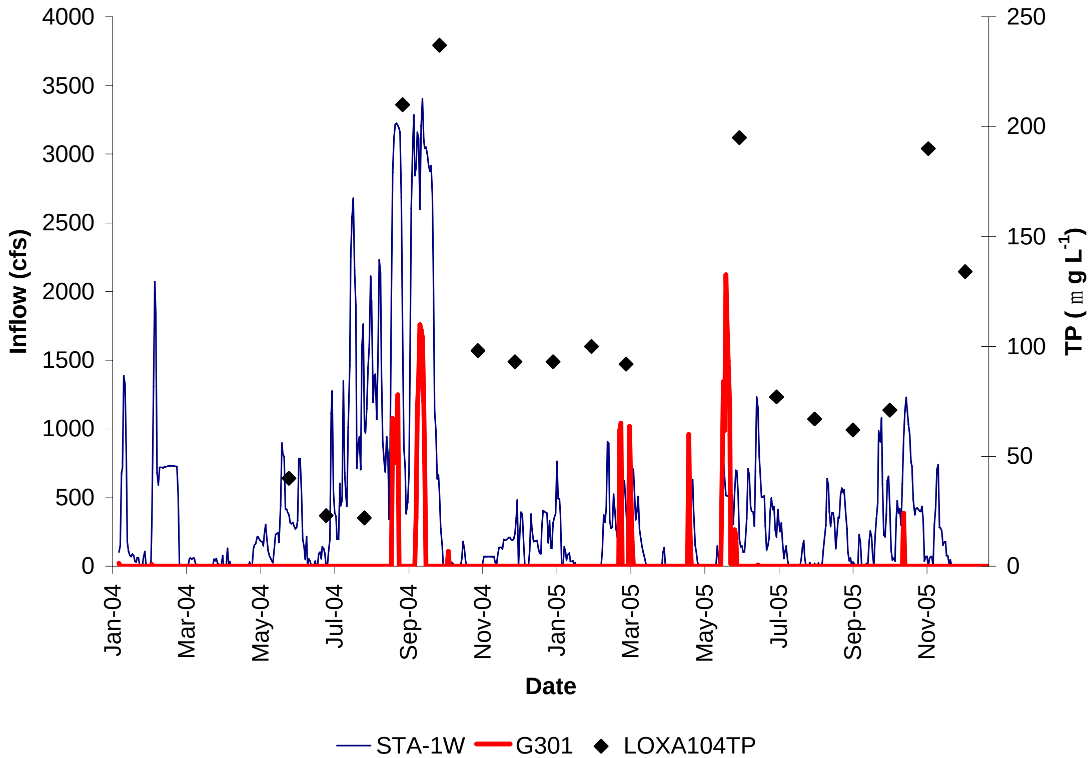
**Figure A1-3-2**: S-6

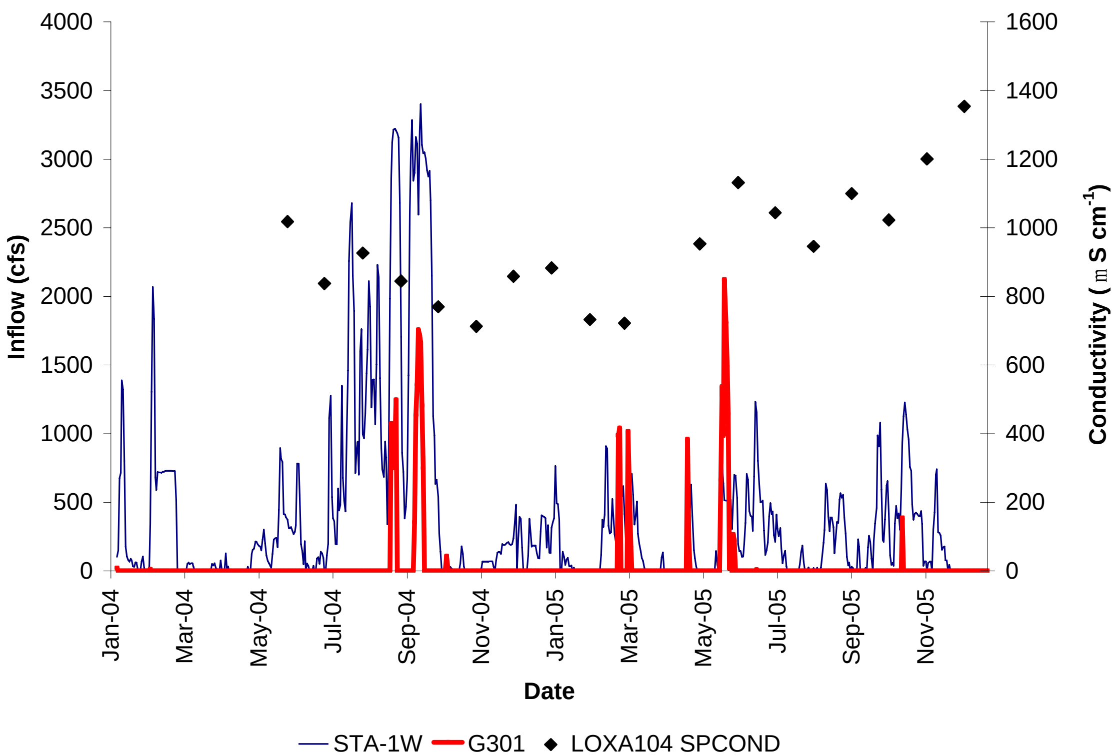
**Figure A1-3-3**: STA-1E

**Figure A1-3-4**: Acme-1

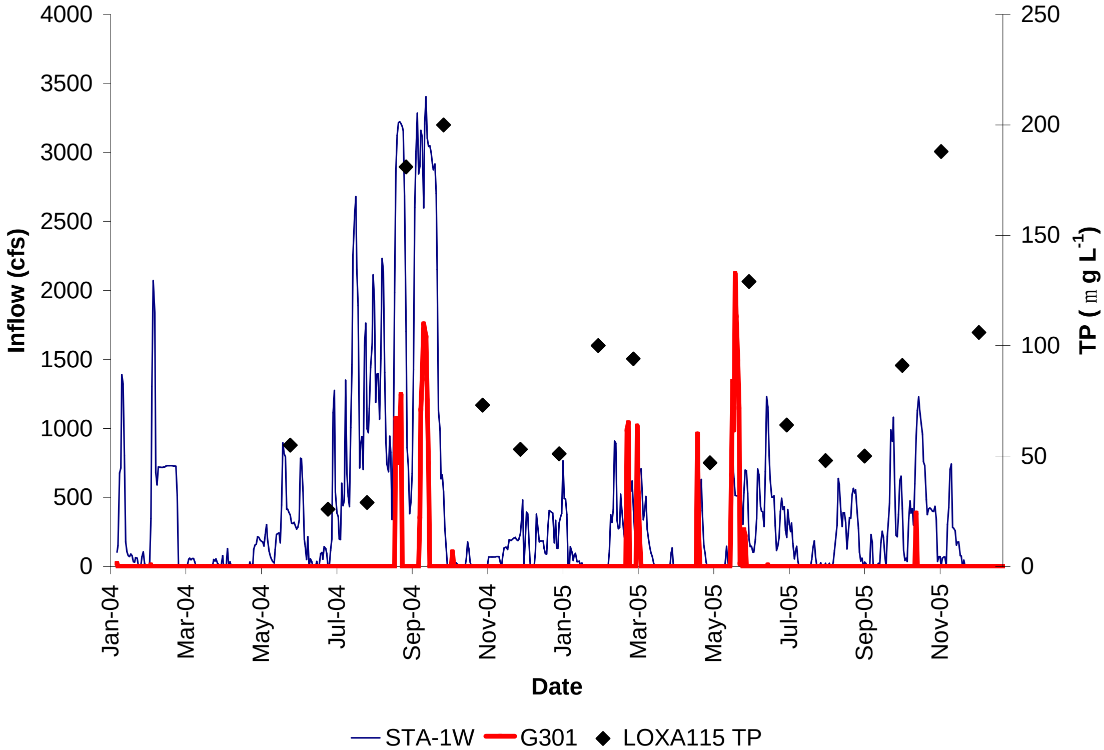
**Figure A1-3-5**: Acme-2

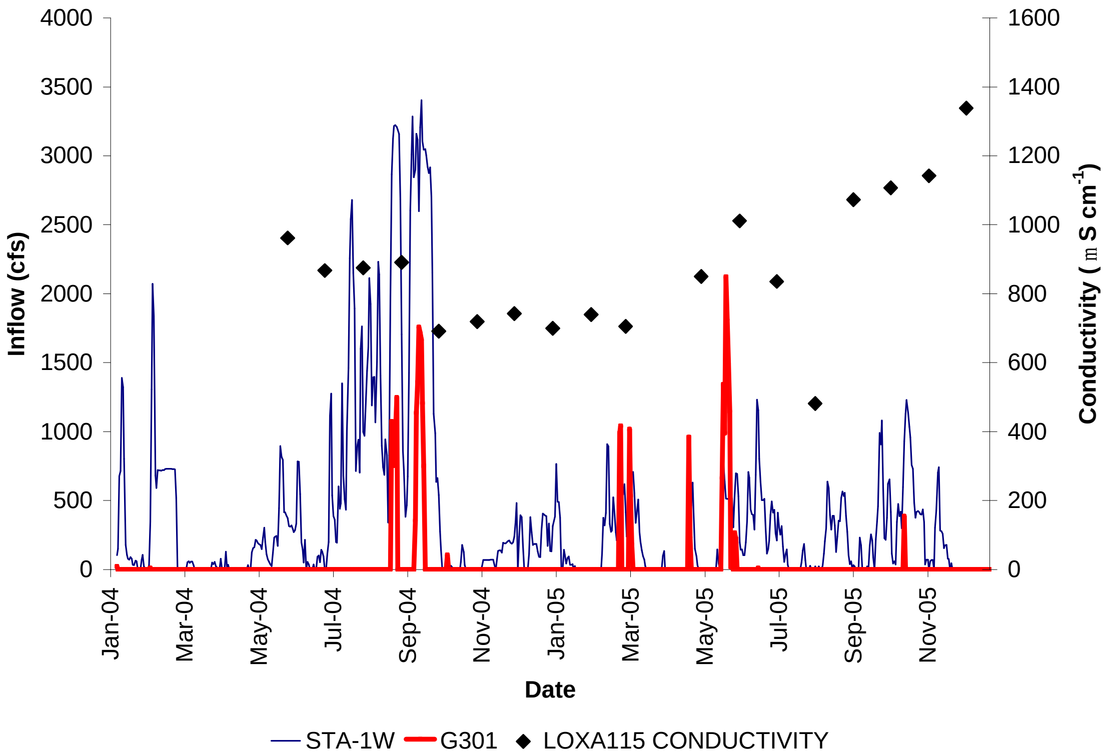
## Figure A1-3-1: STA-1W transect



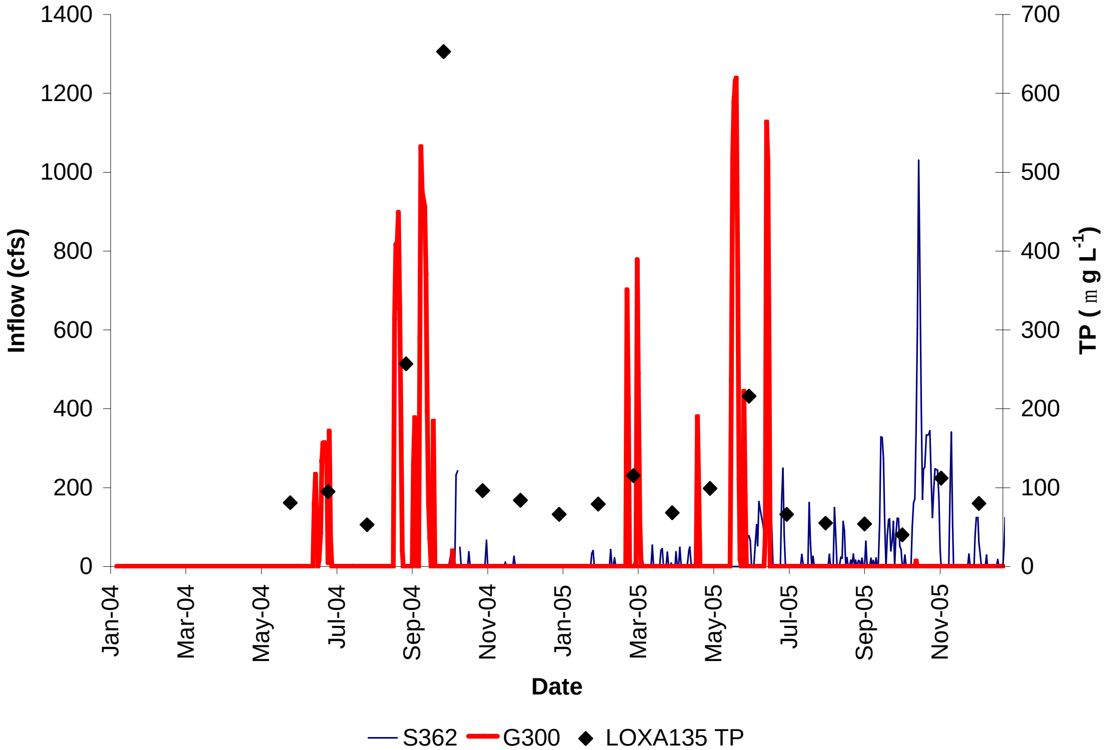



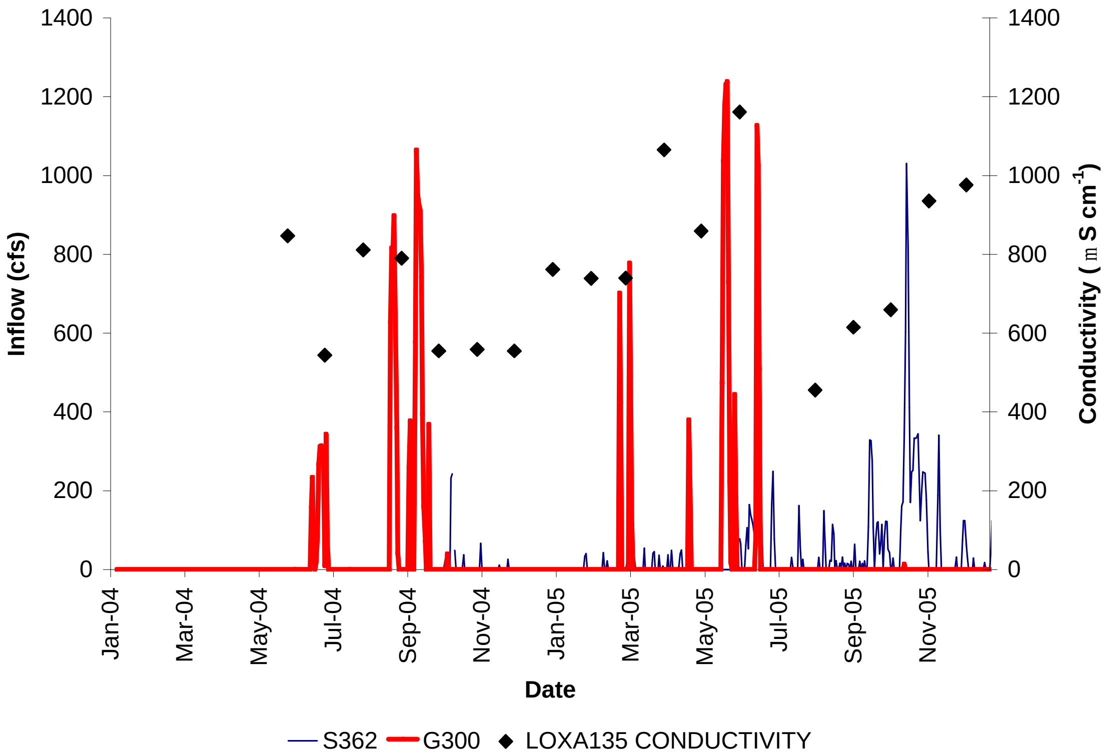
## Figure A1-3-2: S-6 transect



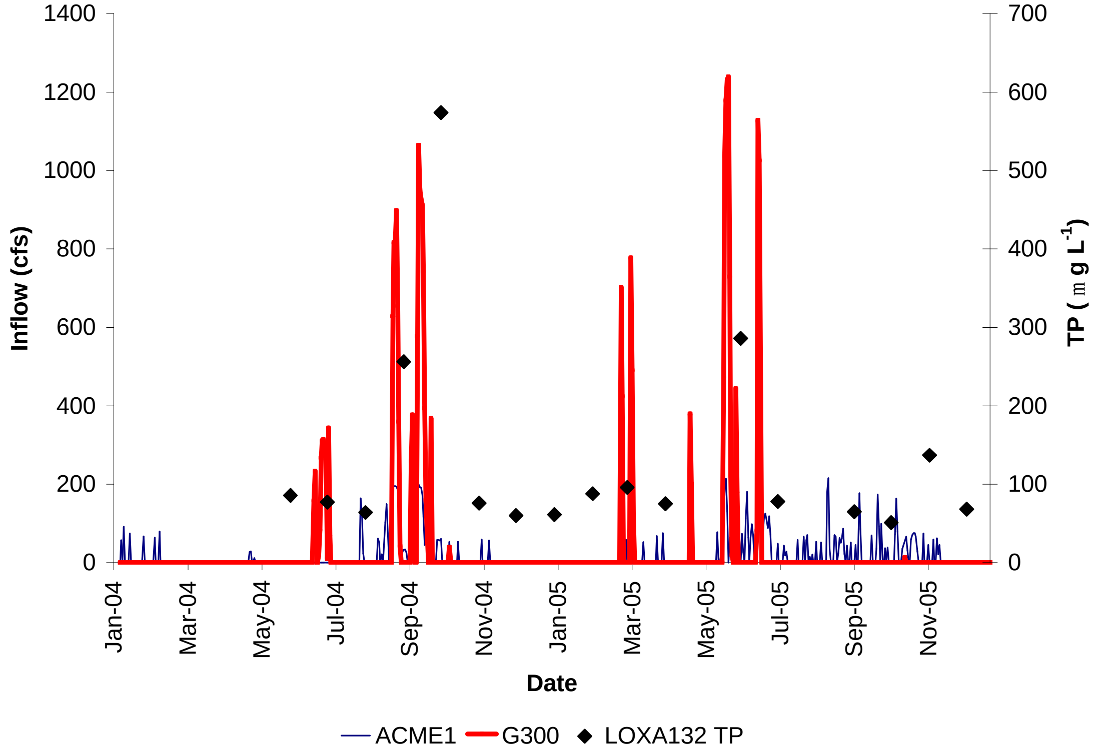



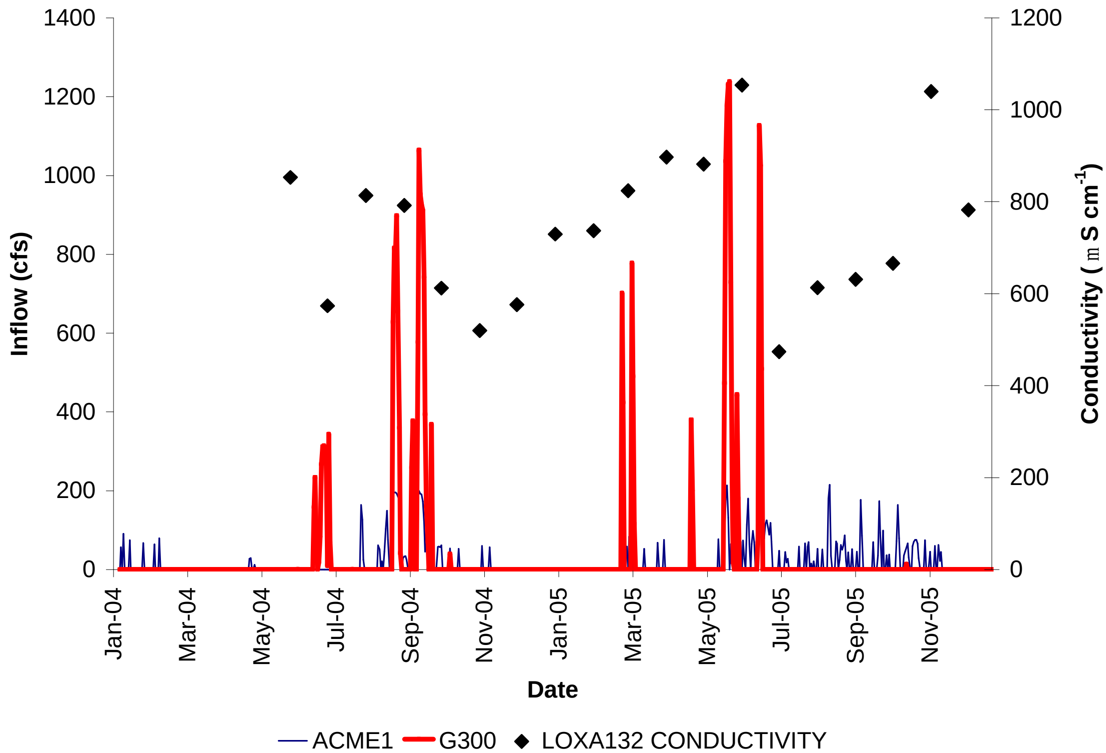
# Figure A1-3-3: STA-1E transect



## Figure A1-3-4: Acme-1 transect



## Figure A1-3-5: Acme-2 transect