Technical Report

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BOARD OF COUNTY COMMISSIONERS

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North Fork New River Operational Flow (OPFLOW) 2002 Study

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Technical Report 03-07

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Conducted by
The Environmental Monitoring Division
Department of Planning and Environmental Protection

Submitted to
The South Florida Water Management District
as part of deliverable for Task 4.3 of C-9899

Broward County
Board of County Commissioners

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EXECUTIVE SUMMARY

This technical document is being submitted to the South Florida Water Management District (SFWMD) by the Broward County Department of Planning and Environmental Protection (BCDPEP) as a portion of the deliverable outlined in the scope of work under the North Fork New River operational flow study (OPFLOW, Task 4.3, Scope of Services). The primary objective of this investigation was to determine the effect of enhancing freshwater flows on the estuarine river's water quality over a longer period than a pilot study performed in 2001 (BCDPEP 2002). Additional objectives included gathering data and information to determine the volume and rate of water delivered to the North Fork New River, as well as measuring potential hydrological effects on the freshwater source waterway (C-13 Canal).

The North Fork New River is a tidal water body in the northwest portion of the City of Ft. Lauderdale with sections of the river existing within unincorporated Broward County, Florida. The BCDPEP (formerly known as Broward County Department of Natural Resource Protection, BCDNRP) has performed numerous North Fork New River water quality assessments and the water body has exhibited chronically poor water quality. In particular, nutrients, bacteria, and dissolved oxygen levels have been water column parameters of concern. Modified historical hydrology, contaminated sediment resuspension, and stormwater inputs are considered the major reasons for the river's water quality problems.

The New River Restoration Plans (BCDNRP 1994, BCDPEP 2001a) proposed that enhancing freshwater flows to the North Fork by re-directing freshwater normally sent to tidal waters thru other Broward County drainage systems would improve the river's poor water quality. The initial OPFLOW 2001 pilot study was performed from October thru December 2001 using freshwater originally from the C-13 Canal (known as OPFLOW Alternative 2) to test the concept's feasibility (BCDPEP 2002). The first study generally showed a North Fork New River with improved water quality in terms of total phosphorus (TP) and chlorophyll a (Chl a) concentrations and to a lesser extent dissolved oxygen (DO) content during the period of enhanced flows. Meteorological and hydrological patterns during this study likely contributed to the improvements as well. Fecal coliform (FC) levels were not greatly reduced by the enhanced flows and/or other conditions. In addition, total organic carbon (TOC) and total nitrogen (TN) content both increased to levels more typically seen in the C-13 Canal.

Recommendations from the pilot study (OPFLOW 2001) included releasing water from the C-13 Canal to the North Fork New River for an extended period (i.e., 4 to 5 months). Thus, the OPFLOW 2002 study was developed and performed from 10/22/02 through 4/4/03. Hourly hydrological and meteorological data were obtained from the SFWMD's water control structures S-36 (C-13 Canal) and S-33 (C-12 Canal) and included rainfall, water elevations, and estimated flow. Stage elevations were measured with a ruler typically two times a week at the Broward County Office of Environmental Services' (BCOES) control structure (CS) 55 that has a known elevation. Elevation data from S-36 and CS 55 were used to gain an estimation of flow rates from the C-13 Canal thru the secondary canal system to the North Fork New River.

Water quality data collection included fine time scale (every 15 minutes) sampling at four sites with YSI 6600® datasonde water quality sensors. Three sites were located at bridges crossing the North Fork (Sites 16 [Broward Blvd.], 64 [Sistrunk Blvd., NW 6th St.], and 101 [Martin Luther King Blvd., NW 31st Ave.]) and one site was in the freshwater secondary canal (Site 113). Parameters measured and reported here included DO, pH, specific conductance, water temperature, turbidity, and chlorophyll via fluorescence. Bi-weekly surface water quality grab samples included TOC, TP, nitrogen species (including ammonia-nitrogen, nitrite + nitrate-nitrogen, total Kjeldahl nitrogen, TN), FC, Chl a, pheophytin, as well as turbidity and were collected at the same sites as the YSI data.

Freshwater flow thru OPFLOW Alternative 2 (Figure 4) to North Fork New River was maintained for almost five consecutive months including three traditionally dry months (December thru February). The flow period could have been longer but was halted in March 2003 because of aquatic plant maintenance requirements within the City of Lauderdale. The aquatic weed problems initially caused by the flow were resolved with the installation of a weed retention structure by the BCOES.

OPFLOW 2002 generally had much higher estimated flow rates over a longer period of time than observed in OPFLOW 2001. The increase in flow rates and volumes may be explained, in part, by dredging activities performed by the City of Lauderdale Lakes in the secondary canal system north of the CS 55 prior to OPFLOW 2002. Flooding was not observed or reported during the operations of the study despite the extra volume of water moved to the North Fork New River.

The implementation of OPFLOW Alternative 2 over a long period of time did not appear to directly affect C-13 Canal levels, although flow discharges to the estuarine C-13 Canal/Middle River were infrequent. For example, the SFWMD S-36 structure was able to maintain the C-13 Canal above the recommended minimum level of 4.0 feet throughout the study even during periods of low rainfall. Regional water management practices, rainfall, and/or groundwater elevations may mask the relatively low volume of water being obtained from the C-13 Canal on short time scales. Potentially, annual volumes of water diverted to the North Fork New River from the C-13 Canal would be more significant if the flow operations are continuously performed based on theoretical calculations. However, the estimated annual flow of OPFLOW Alternative 2 is small in relation to the other estimated freshwater sources to the overall New River system.

With flows from the C-13 Canal diverted to the North Fork New River, total phosphorus levels were substantially lower than historical ambient levels. The occurrence of enhanced freshwater flows also brought the North Fork New River median TP concentrations into compliance with the Broward County standard. Conversely, TN levels increased substantially when compared to historical ambient levels. The implementation of OPFLOW Alternative 2 caused North Fork New River median TN concentrations to approach compliance levels with the Broward County standard at two sites and become out of compliance at the other. Nitrite + nitrate-nitrogen (NOx) concentrations were also higher than previous ambient observations throughout the waterway.

Despite the increase in TN and NOx, North Fork New River Chl a concentrations were observed at levels within compliance of the Florida Department of Environmental Protection's Impaired Water Rule threshold for nutrient impairment (11 ug/l) when OPFLOW Alternative 2 was operating. Conversely, historical ambient Chl a concentrations have been above this threshold indicating nutrient impairment for North Fork New River. When the flow was halted from the C-13 Canal to the North Fork New River in early March, Chl a values reverted back to historical ambient concentrations at two North Fork New River samplings sites furthest downstream from the freshwater inflow point. The physical attributes of flow (reduced stagnation), low water temperatures, and salinity regime changes were other likely factors (beyond nutrients) that influenced Chl a concentrations throughout the study.

Total organic carbon and to a lesser extent pH appear to be good temporal and spatial tracers of C-13 Canal water in the North Fork New River. In particular, TOC appeared to track nutrient response to flow regime as well. As observed in OPFLOW 2001, FC concentrations were not improved by the implementation of OPFLOW Alternative 2 and continued to be out of compliance with most applicable standards. Dissolved oxygen concentrations during flow were generally within compliance of Broward County standards. At two of three North Fork sampling sites, DO content fell out of compliance when flow was halted. Water temperatures were likely a contributing factor to the observed DO concentrations throughout the study.

Grab samples for turbidity levels were always well within compliance of the Broward County standard with or without flow from the C-13 Canal entering the North Fork New River. Following primarily storm events, unattended YSI data sampling revealed turbidity concentrations exceeding water quality standards. The YSI turbidity observations also documented between site variability in terms of event concentrations and amplitude. The area traditionally seen as an area of transition between freshwater and brackish appeared to stay fairly fresh with the implementation of OPFLOW Alternative 2. This benefits local Pond Apple Trees and potentially, a desirable submerged aquatic plant species *Vallisineria* sp.

Eleven recommendations are put forth to continue the efforts to improve and sustain the North Fork New River's water quality beyond the current study and include:

1. Water flows through the secondary canal system should be allowed to continue to be implemented to maintain chlorophyll a, total phosphorus, and dissolved oxygen levels observed in OPFLOW 2 unless C-13 water levels are impacted and/or other management needs arise (e.g., aquatic plant management).

2. Discussions should be held with the SFWMD operations to update them on the OPFLOW studies and discuss future long term viability of continuing flow. In particular, does the project continue to be significant at a local water management level only or does it become larger in scale if performed over longer time periods?

3. A North Fork New River ecological conceptual model could be developed to better determine the effect of different flow scenarios. The model should consider water column, benthic, and shoreline components. This will also help identify missing data gaps. If funding is available, numeric modeling would enhance this effort.

4. BCDPEP should continue monitoring quarterly at the recently added Site 64. Along with the pre-existing North Fork New River quarterly Site 16, the two river sites will monitor long term changes in water quality from improvements in flow, stormwater treatment, and dredging activities.

5. Additional means to monitor the salinity regime at Site 64 on a more frequent basis should be investigated. The main purpose of the monitoring would be to evaluate the aquatic habitat for Pond Apple Trees (*Annona glabra*) and *Vallisineria* sp in this important transition area between freshwater and brackish water. Past examples include monitoring partnerships with local schools, non-profit groups (Broward Urban River Trails) and the Broward County Parks and Recreation Division.

6. Funding for North Fork New River genetic fingerprinting should continued to be pursued by BCDPEP and the SFWMD to determine the origin of elevated FC.

7. An update should be performed of the stormwater GIS coverage map with additional information gathered on the retrofit status of specific outfalls. Both the Broward County and Ft. Lauderdale National Pollutant Discharge Elimination System Multiple Separate Stormwater System permit programs will be a valuable source for this information.

8. A map of *Vallisineria* sp. as well as Pond Apple (*Annona glabra*) tree health would assist in the tracking of the ecological benefits of a surface water quality oriented project.

9. Broward County's Integrated Water Resources Plan (http://www.broward.org/wti01201.pdf and http://www.broward.org/wti01218.pdf) and the Comprehensive Everglades Restoration Plan's (http://www.evergladesplan.org/pm/projects/proj_24.cfm) Broward County Secondary Canal System component should keep the North Fork New River issues as part of their larger water resources discussion.

10. The results of the last two years of OPFLOW studies should be communicated to the local communities (e.g., neighborhood associations) as well the Cities of Ft. Lauderdale, Lauderdale Lakes, Lauderhill, Plantation, and Sunrise and the Old Plantation Water Control District. Other stakeholders may also be identified and should receive information on the OPFLOW initiative.

11. It will also be important to communicate with FDEP personnel on the restoration activities that have taken place when the waterway is evaluated under the IWR for potential placement on a TMDL planning list.

I. Introduction

In July 1998, the South Florida Water Management District (SFWMD) with the Florida Department of Environmental Protection (FDEP) entered into an agreement number C-9899 with the Broward County Board of County Commissioners (Department of Planning and Environmental Protection [BCDPEP], formerly Broward County Department of Natural Resource Protection, BCDNRP) to provide funding for North Fork New River restoration projects. Amendments to the contract occurred in the years 2000 and 2003. This technical document is being submitted to SFWMD by BCDPEP as a portion of the deliverable as outlined in the scope of work under the operational flow study (OPFLOW, Task 4.3, Scope of Services).

The North Fork New River is a tidal water body in the northwest portion of the City of Ft. Lauderdale with sections of the river existing within unincorporated Broward County (Figure 1). The river lies in the same drainage basin as the freshwater C-12 Canal upstream of the S-33 control structure (Figure 1). Within Broward County, the C-12 Canal is the only major freshwater canal without a direct hydrological connection to the Everglades (Water Conservation Areas, Figure 2).

Due primarily to altered hydrology and land use over the last fifty years (Figure 3), the North Fork New River has exhibited some of the poorest water quality within Broward County (BCDNRP 1993, BCDPEP1999, 2001b). Water column parameters of particular concern have included elevated bacteria levels (> 800 colonies per 100 milliliters), high total phosphorus content (> 0.1 milligrams per liter, mg/l), eutrophic chlorophyll a concentrations (> 40 microgram per liter, ug/l), and depressed dissolved oxygen content (< 4.0 mg/l). An original and updated New River Restoration Plan (BCDNRP 1994, http://www.broward.org/wti01300.pdf, and BCDPEP 2001, http://www.broward.org/wti01600.pdf) proposed enhancing freshwater flows to improve water quality in conjunction with additional measures such as stormwater infrastructure improvements and dredging of contaminated sediments. This effort to combat stagnation by returning a consistent freshwater flow to the upper estuarine water body became known as OPFLOW.

Two main water management alternatives were developed from 1995 thru 2000 to perform OPFLOW. These are briefly described here and in detail in BCDPEP 2002. The initial OPFLOW 2001 was performed from October thru December 2001 using freshwater originally from the C-13 Canal (known as Alternative 2, Figure 4) to test the concept's feasibility (BCDPEP 2002). The first study generally showed a North Fork New River with improved water quality in terms of total phosphorus and chlorophyll a concentrations and to a lesser extent dissolved oxygen content during the period of enhanced flows. Meteorological and hydrological patterns during the study likely contributed to the improvements as well. Fecal coliform levels were not greatly reduced by the enhanced flows and/or other conditions. In addition, total organic carbon and total nitrogen content both increased to levels more typically seen in the C-13 Canal.

Figure 1. Location Map of the North Fork of the New River Study Area and Surrounding Municipalities. Additional water bodies and major roadways are also shown. The major South Florida Water Management District water control structures are indicated by the fire hydrant symbol (from BCDPEP 2002).

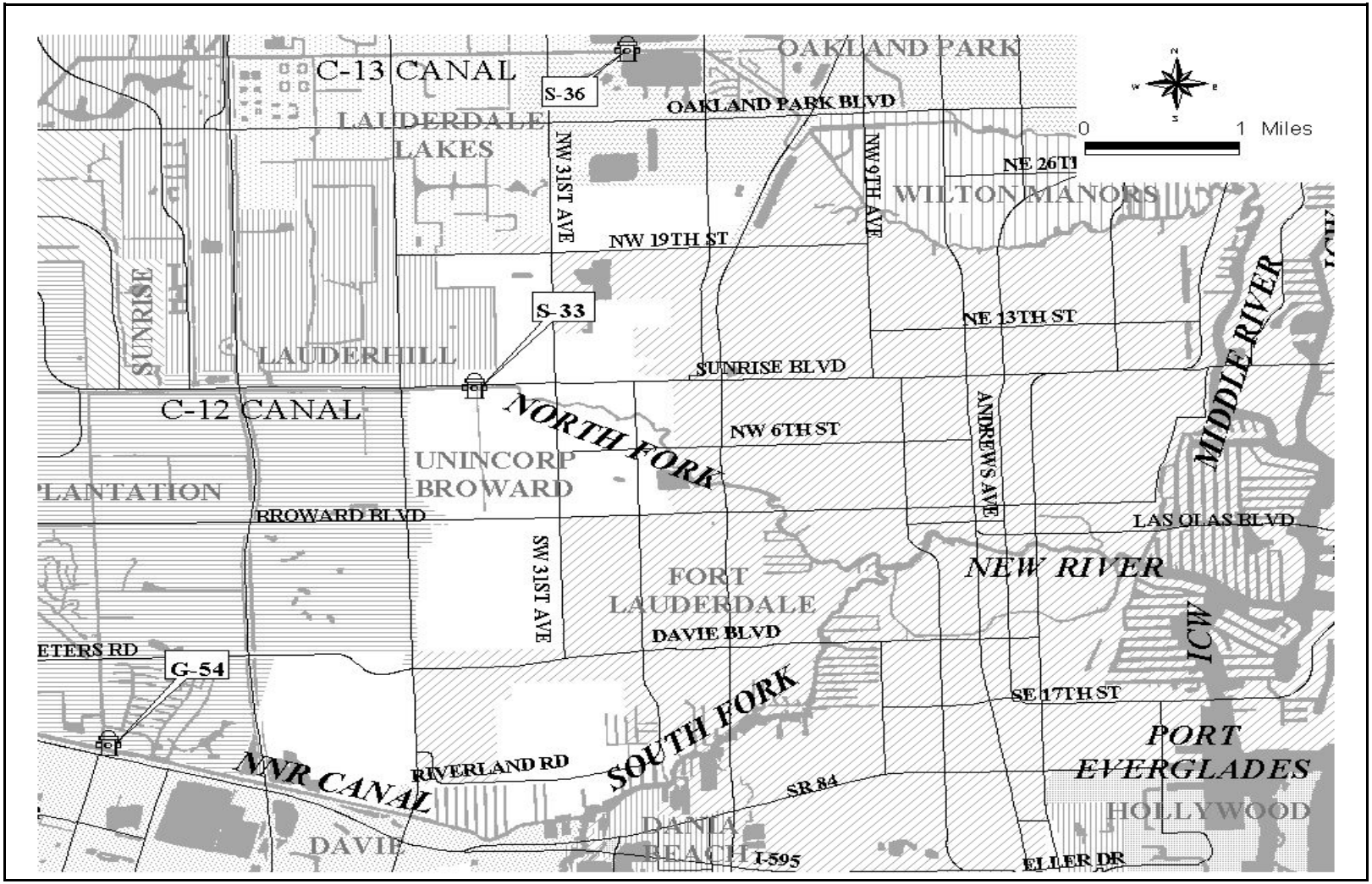


Figure 2. Major Waterways of Eastern Broward County (adapted from Cooper and Lane 1987). With the exception of the Intracoastal Waterway and the C-10 Canal (both tidal water bodies), the South Florida Water Management District operates and maintains the canals shown below. The C-12 Canal (headwaters of North Fork New River; grey circled area) is the only major east-west waterway without a direct connection to the Water Conservation Areas. Please note numerous water control structures (not shown on figure) exist throughout this extensive drainage system (from BCDPEP 2002).

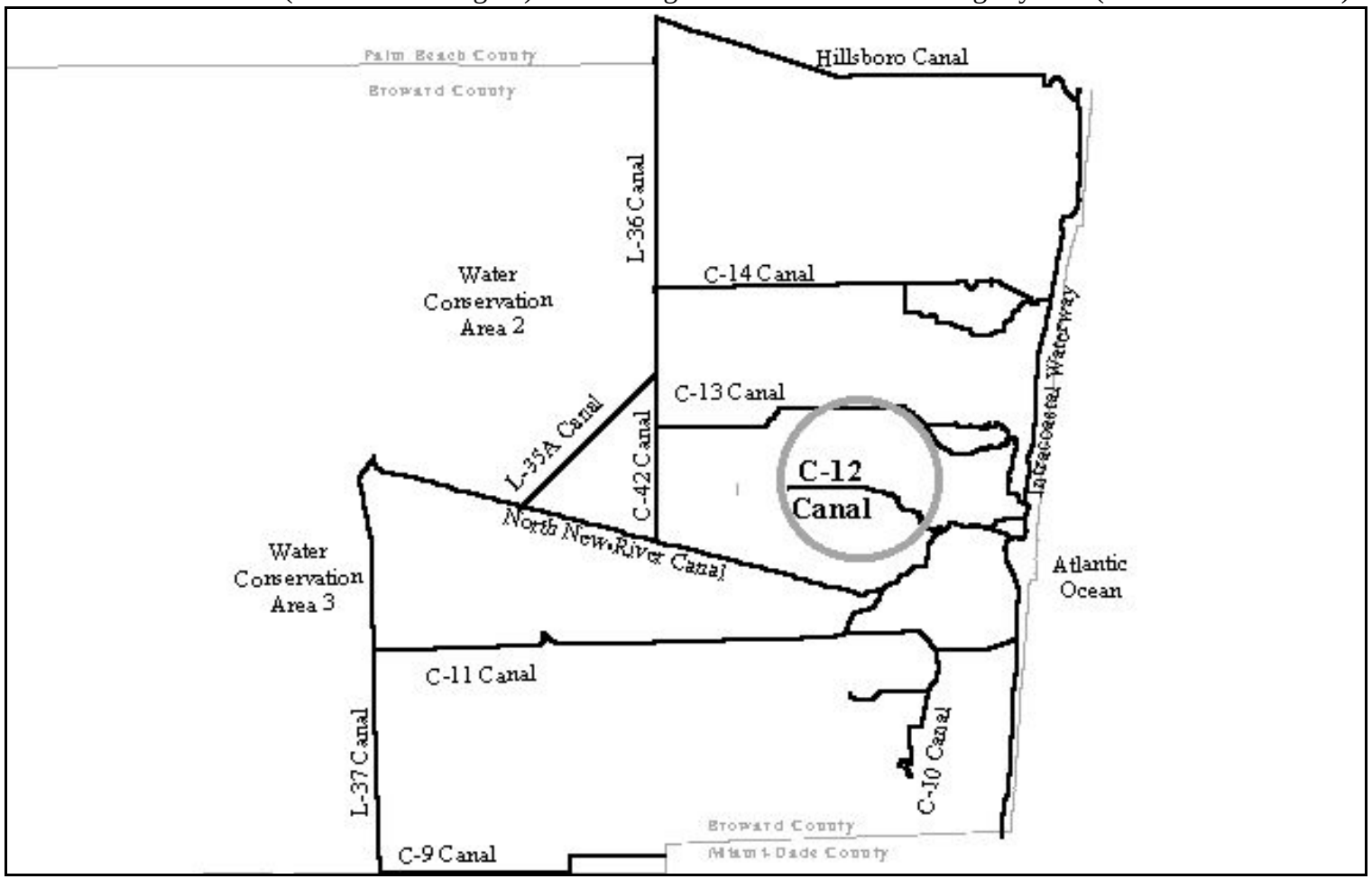
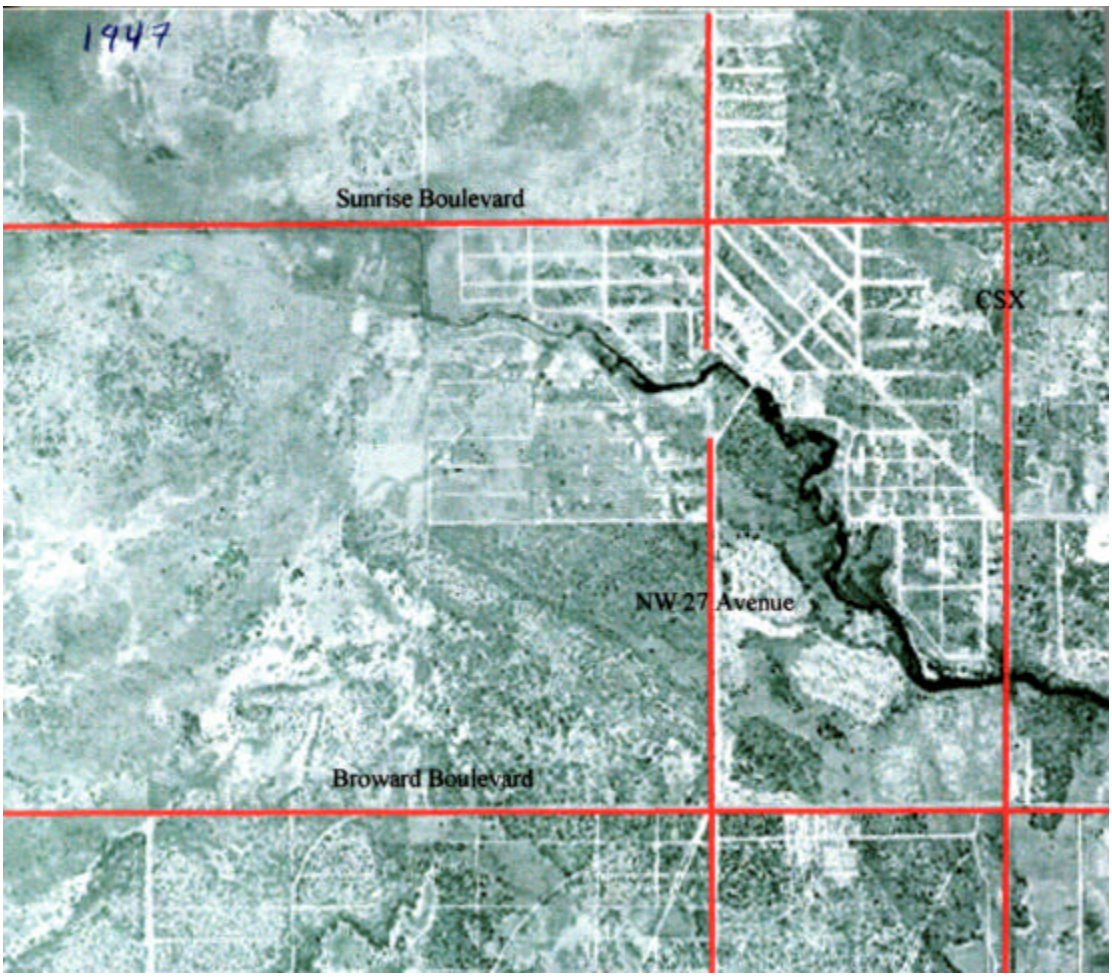


Figure 3. Aerial Photographs of North Fork New River from a) 1947 and b) 2000. The street names and CSX (railroad) lines in 1947 (a) refer to their present location.

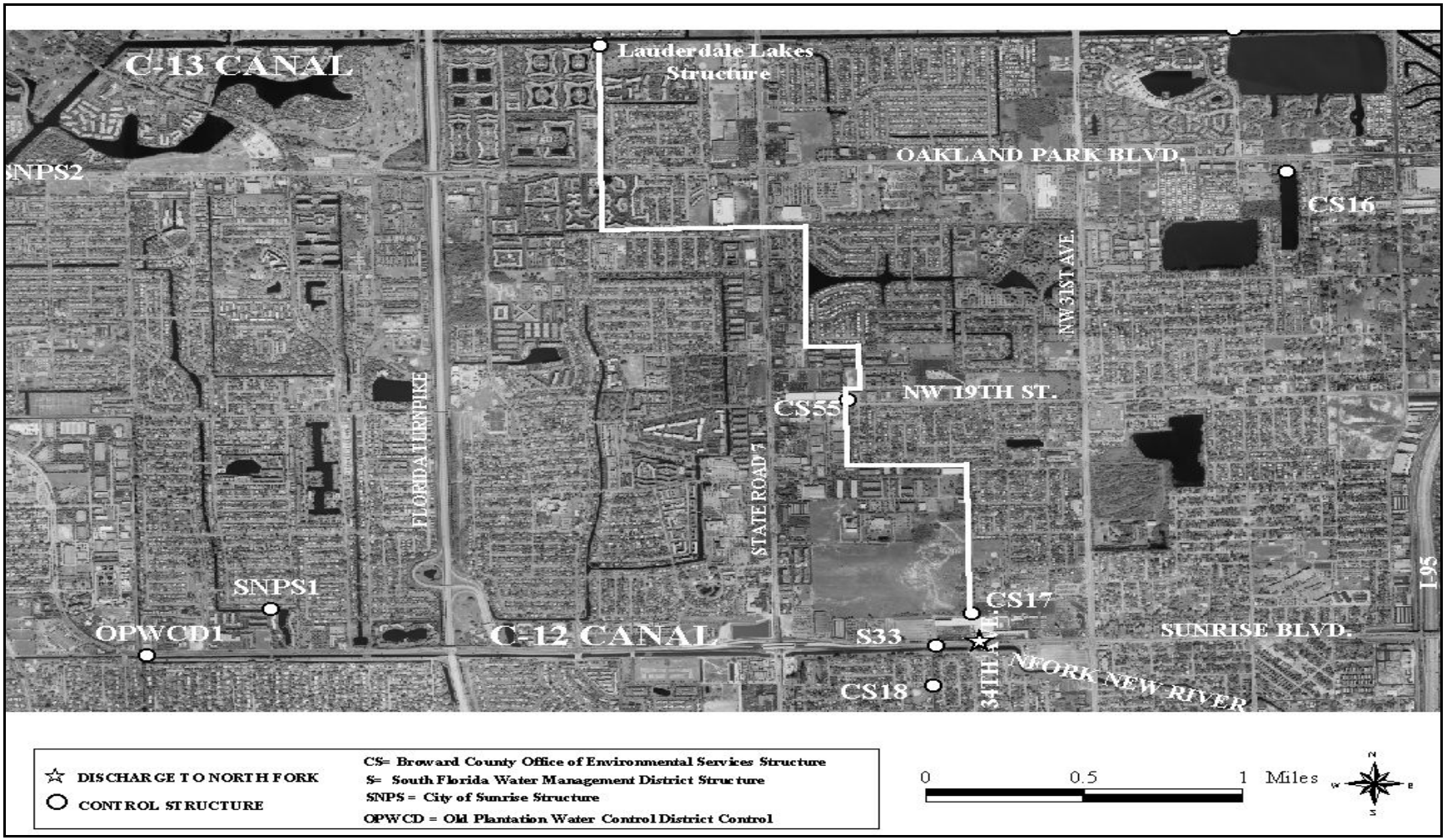
a) 1947



b) 2000

Note: scale bar for b) 2000 only

Figure 4. Aerial Photography of Alternative 2 (C-13 Canal) for North Fork New River Operational Flow Study (OPFLOW). The white line represents main channel of a secondary canal system that connects C-13 Canal to the North Fork via a Lauderdale Lakes structure and two Broward County Office of Environmental Services control structures (CS 55 and CS 17). A culvert exists south of CS 17, under a local business (Swap Shop), that discharges into the North Fork New River (From BCDPEP 2002).



Thus, two major North Fork New River water quality challenges – high total phosphorus and chlorophyll a levels- had been improved with the enhanced flow in a short term pilot study with no apparent impacts to the C-13 Canal. This finding led to a major recommendation from OPFLOW 2001 to re-direct water from the C-13 Canal for a longer period than one month to further understand the viability of this restoration method. In addition to solving eutrophic conditions, freshwater plants and trees such as Pond Apple (*Annona glabra*) benefit from a sustained freshwater release and the overall ecological benefits of long term flow changes needed documentation.

The recommendation for prolonged flows was implemented from 10/22/02 until 3/7/03 with the primary water quality monitoring continuing until 4/04/03. This report will describe the observations over that period. Future management and monitoring initiatives will be recommended to ensure a sustained freshwater source for the North Fork's water quality and habitat functionality.

A. Objectives

The primary objective of this investigation was to monitor the effects of enhancing freshwater flows on the North Fork New River's water quality with Alternative 2 (C-13 Canal) over a longer period than OPFLOW 2001 (i.e., one month). While similar in some aspects (e.g., sample sites) to the previous year's study (BCDPEP 2002), OPFLOW 2002 also featured some design characteristics (e.g., bi-weekly sampling) of the original ambient study in 1998 (BCDPEP 1999). The combined sampling strategies were used to address the following three questions:

* What volume of water can be delivered to the North Fork New River over a long period?

* Will the volume and rate of water in the study influence the C-13 Canal water elevations?

* What effect will extended flow periods from the C-13 Canal have on the North Fork New River's water quality?

II. Methodology

The OPFLOW 2002 study began on 10/22/02 with the opening of Broward County Office of Environmental Services (BCOES) Control Structure (CS) 55 and continued until 4/04/03 (approximately one month after the gate was closed). Most of the OPFLOW 2002 methodology is very similar to OPFLOW 2001 and the following contains similar text as written for the pilot study report (BCDPEP 2002).

Some major changes in methodology occurred in OPFLOW 2002 due to its longer period of study than OPFLOW 2001 (i.e., five months versus one month). Ambient grab sampling was performed on a bi-weekly basis instead of the more labor intensive weekly sampling effort of OPFLOW 2001. Bi-weekly sampling was also performed in a 1998 North Fork New River ambient water quality study (BCDPEP 1999) and those results are used extensively in this report for comparative purposes. Another methodology change was the reduction of ambient grab sampling from five to four sampling sites (Figure 5). Site 100 at NW 27th Avenue was dropped from the sampling plan due, in part, to it exhibiting relatively similar results as Site 101 in OPFLOW 2001. Please note the sampling sites are numbered based on their chronological order within BCDPEP's countywide network and are not sequenced independently for the purpose of this study.

At the completion of major OPFLOW 2002 monitoring (4/4/03), a reduced fine-time scale sampling strategy was performed from 4/17/03 thru 9/12/03. This included one YSI datasonde moored initially at Site 16 (4/17/03 thru 8/29/03) and then at Site 64 (8/29/03 thru 9/12/03, Figure 5). This monitoring aimed to document the river's condition as flow continued and a dredging construction project began (mid-May 2003). Some important wet season (May thru September 2003) observations, in particular chlorophyll a and specific conductance, will be discussed from this sampling period.

A. Hydrological and Meteorological Monitoring

1. SFWMD Data

Water elevation, rainfall, and estimated hourly flow rates measured at the S-36 and S-33 coastal salinity control structures were obtained from the SFWMD (S. Peterkin, personal communication) covering 10/1/02 thru 4/4/03. The S-36 and the S-33 (See Figure 1) are major factors in determining water elevations (head waters) in the C-13 and C-12 Canals, respectively. Hourly water elevations from the S-33 tail waters (North Fork New River) and S-36 tail waters (C-13/Middle River) were also obtained from SFWMD (S. Peterkin, personal communication) to observe the influence of tidal action in the estuarine reaches. Flow data is estimated by the SFWMD from the water elevations of the head and tail waters. The data was obtained to determine other potential freshwater sources to the North Fork New River (i.e., C-12 Canal) and how the C-13 Canal was being managed during the dry season. Hourly rainfall levels from both structures allowed for two spatially distinct rain gauges within the study area.

Figure 5. North Fork of the New River OPFLOW 2002 Water Quality Sampling Site Locations. The C-12 Canal (upstream) is divided from the North Fork of the New River (Sites 16, 64, and 101) by the S-33 Control Structure. Site 113 is located in an upstream, secondary canal separated from the North Fork by the CS 17 control structure.

2. BCOES CS 55

Approximately two times per week, the BCDPEP water quality consultant, Genesis Environmental Services, manually measured the stage (with a ruler) at the north and south sides of the BCOES CS 55 water control structure at NW 19th Street. Flow rates were calculated by the BCOES based on the elevations of the C-13 Canal and at CS 55 combined with the gate height and weir opening area at CS 17.

B. Water Quality Sampling

Water quality sampling was conducted at three tidal sites (Sites 16, 64, and 101) on the North Fork of the New River and at one site (Site 113) upstream of the BCOES CS-17 in a secondary canal near the Swap Shop (Figure 5). The CS-17 controls water levels and flows in this secondary canal that was utilized to deliver freshwater from the northern C-13 canal, southward to the North Fork of the New River. The North Fork New River sites were located at the Broward Boulevard (Site 16), Sistrunk Boulevard (NW 6th Street, Site 64), and Martin Luther King Boulevard (NW 31st Avenue, Site 101) bridges. The two main water quality sampling strategies included 1.) Fine time scale (every 15 minutes) sampling and 2.) Bi-weekly surface grab sampling.

1. Fine Time Scale Sampling

The YSI 6600 Datasonde ® water quality sensors were deployed in the North Fork (Sites 16, 64, and 101) and a fourth (Site 113) in the secondary canal. The first day of deployment at Sites 64 and 101 was on 11/27/02. Site 16 YSI sampling began on 12/4/02 and Site 113 on 12/7/02. The purpose of the YSI unattended deployments was to obtain *in situ* measurements of dissolved oxygen, pH, specific conductance, water temperature, depth, turbidity, and chlorophyll via fluorescence. Perforated PVC casings were attached to the bridge pilings for Sites 16, 64, and 101 to house the unattended YSI units in the field (Figure 6). The PVC casing at Site 113 was setup midstream approximately 35 meters north of the CS 17 water control structure. Each site was accessed by boat.

Before deployment, datasondes were calibrated and prepped at the BCDPEP laboratory. The YSI manual was our source for calibration and maintenance protocols and is the basis for our in-house Standard Operating Procedures. Data readings were recorded by the sondes at fifteen minute intervals for twenty-four hours per day. An individual datasonde spent one to two weeks deployed at a specific site after which it was rotated out with another calibrated datasonde and brought back to the laboratory for downloading of data. Post-calibration and maintenance (primarily sensor cleaning) were performed on the instruments for quality control purposes. Overall, the YSI datasondes were used in a rotating system that allowed for continuous monitoring throughout the study.

Figure 6. YSI Datasondes Housed and Locked in Perforated PVC Casings Attached to the Bridge Pilings at Martin Luther King Boulevard (Site 101), Sistrunk Boulevard (Site 64), and Broward Boulevard (Site 16). The PVC casing at Site 113 was setup midstream approximately 35 meters north of the CS 17 water control structure (from BCDPEP 2002).

During the YSI 'swap-out', chlorophyll a grab samples were collected and brought to the laboratory for analysis in order to provide a reference value for the fluorometric measurements made by the datasonde. These samples will be displayed with the bi-weekly sampling data as this provided weekly chlorophyll a analyses. In addition, the data was collected to be used at a later date for a ground truth investigation with the fluorometic chlorophyll observations.

2. Bi-weekly Surface Grab Sampling

Ambient bi-weekly sampling began two days (10/24/02) after CS 55 was opened on 10/22/02 and proceeded until 3/27/03 for a total of twelve sampling events. North Fork New River (Sites 16, 64, and 101) samples were normally collected near or at the mid-point of an outgoing tide. Site 113 was sampled the same day as the North Fork New River with the exception of the first week of November when river samples were collected on 11/7/02 and Site 113 was collected on 11/8/02. Fecal coliform was not collected at Site 113 on 11/8/02.

Water quality samples included total organic carbon, total phosphorus, nitrogen species (including ammonia-nitrogen, nitrite + nitrate-nitrogen, total Kjeldahl nitrogen, total nitrogen), fecal coliform, chlorophyll a and pheophytin, and turbidity. Sub-surface water samples were collected with a Kemmerer bottle and placed in separate whirlpak® bags for each specific laboratory analysis. Chlorophyll a and pheophytin samples were filtered in the field onto 47 millimeter (0.45 micron) nitrocellulose filters and placed in capped test tubes.

The BCDPEP laboratory (Environmental Monitoring Division) is certified under the National Environmental Laboratory Accreditation Conference through the Florida Department of Health (#E46053) and follows a comprehensive quality assurance plan. All samples were preserved and analyzed according to U.S. Environmental Protection Agency (EPA) and Standard Method protocols (Table 1) and were transported on ice to the BCDPEP laboratory within three to four hours where they were stored in a walk-in cooler, except chlorophyll a and pheophytin samples that were placed in a freezer. Fecal coliform samples were filtered and plated immediately upon receipt by the laboratory and prepared for their incubation within the six hour holding time.

Three grab sampling events (10/24/02, 11/07/02, and 11/14/02) occurred before the deployment of fine-time scale sampling YSI datasondes. A single YSI datasonde was used on those dates to record single observations of sub-surface dissolved oxygen, pH, specific conductance, water temperature, depth, turbidity and chlorophyll via fluorescence at all four sites.

C. Data Analysis and Reporting

Bi-weekly grab sampling data analyses were performed in SigmaPlot® 8.0 and SigmaStat® 2.03. Database storage and manipulations were primarily performed with Corel® Quattro Pro (version 9.0) and Microsoft® Excel 2002. References to Broward County's water quality standards refer to concentrations listed in Chapter 27, Article V, Section 27-195 of the Municipal Code (Broward County 2003, http://www.broward.org/dni01100.htm). The fine-time scale observations were computed into hourly averages of the four fifteen minute readings. The YSI data were processed in EcoWatch® for Windows and Microsoft® Excel 2002.

Table 1. Broward County DPEP's Laboratory Methodologies for Water Quality Parameters. Total nitrogen was calculated by adding nitrite+nitrate-nitrogen and total Kjeldahl nitrogen concentrations.

Parameter	Technique	Method
Temperature	Thermometric, mercury/mechanical/thermister	EPA 170.1
Specific Conductance	Wheatstone bridge or equivalent	EPA 120.1
pH	Electrometric, glass electrode	EPA 150.1
Salinity	Electrical conductivity	SM 2520D
Turbidity	Nephelometric	EPA 180.1
Dissolved Oxygen	Membrane electrode	EPA 360.1
Total Organic Carbon	Persulfate oxidation, NDIR	EPA 415.1 EPA 415.2
Total Phosphorus	Acid, block digestion, automated, ascorbic acid	EPA 365.4
Nitrite+Nitrate-Nitrogen	Cadmium reduction, automated	EPA 353.2
Ammonia-Nitrogen	Automated phenate	EPA 350.2 EPA 350.1
Total Kjeldahl Nitrogen	Acid, block digestion, automated phenate	EPA 351.2
Chlorophyll a / Pheophytin	Acetone (95%) extraction of seston collected on 47 millimeter (0.45 micron) nitrocellulose filters.	SM 10200H NC
Fecal Coliform	Membrane filter	SM 909C

EPA = United State Environmental Protection Agency Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020, March 1983

SM = Standard Methods for the Examination of Water and Waste Water, 18th ed., American Public Health Association, 1992

III. Results

A. Hydrological and Meteorological Monitoring

1. Rainfall

Rainfall patterns were generally similar between S-33 on the C-12 Canal and S-36 on the C-13 Canal (Figures 7 and 8) which are approximately 2.7 miles (4.4 kilometers) apart (Figure 3). Although during the same storm events, some variability in rainfall levels existed between sites. For example, on 11/12/02 (1800, military time) S-36 recorded 0.80 inches of rain while 0.23 inches were recorded at S-33 (Figures 7a and 8a). The period with the most precipitation was between 11/01/02 and12/15/02 and the highest hourly amount occurred on 12/10/02 (0300) at each site. Both sites were relatively dry between 1/1/03 and the date (3/7/03) the CS 55 structure was closed (Figures 7b and 8b). After 3/7/03, hourly rain event frequency and level increased from the previous two months at S-33 and S-36.

2. S-36 Water Elevation and Flow

Water elevations were generally stable at S-36 with the exceptions of rapid decreases in mid-November (Figure 9a) and late February (Figure 9b). These water level fluctuations were associated with the only two major flow occurrences during the water quality monitoring (10/24/02 thru 4/4/03, Figure 10). The November flow period was continuous for three days and flow rates ranged between 100 to 155 cubic feet per second (cfs) of freshwater discharges to the estuarine C-13 Canal/Middle River system (Figure 10b). The February flow event was slightly shorter (2.25 days) but was characterized by similar flow rates as observed in November 2002 (Figure 10). Interestingly, water elevations in the C-13 Canal (Figure 9) were the lowest (near 4.0 feet, NGVD) after S-36 released water (Figure 10) but increased quickly after the structure was closed despite no major local rain events (Figure 8).

3. S-33 Water Elevation and Flow

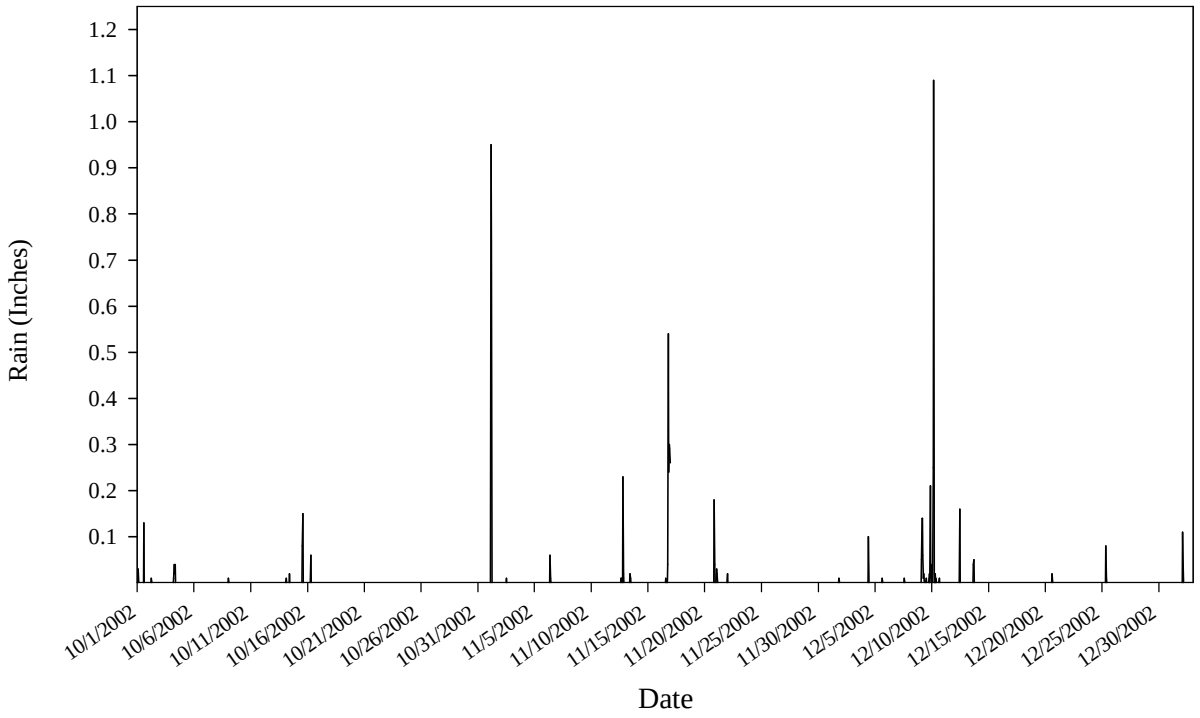
The C-12 Canal's water elevations at S-33 (headwaters, Figure 11) were normally between 2.9 and 3.3 feet and tended to drift downward slowly after periods of rain (see Figure 7). Rainfall appeared to dictate the highest water elevations which were normally near 3.6 feet (Figure 11). The lowest elevations were typically around 2.80 feet with one outlier (2.54 feet, Figure 11b) existing during a flow event (3/10/03, 0900, Figure 12B). Only three flow data points (hourly) existed during the study (Figure 12). This equates to the S-33 providing freshwater to the North Fork New River during 0.09 percent of the study (in hours) compared to the S-36 which discharged freshwater to the estuarine C-13 Canal/Middle River 3.5 percent of the time (Figure 10).

4. Tidal Elevation and Amplitude

Tidal elevation patterns were very similar between the tail waters of the S-33 (North Fork New River, Figure 13) and the S-36 (C-13 Canal/Middle River, Figure 14). However, tidal amplitude and elevation were slightly lower at S-33 (Figure 13a) than S-36 (Figure 14a) from October until

Figure 7. Hourly Rainfall Data Collected by the South Florida Water Management District at Coastal Salinity Structure S-33 on C-12 Canal. Data is divided between 10/1/02 thru 12/31/02 (a) and 1/1/03 thru 4/4/03 (b) to allow for better visual resolution. Grey line represents when flow from the C-13 Canal to the North Fork New River was halted on 3/7/03 at the Broward County Control Structure (CS) 55.

a) S-33 Rain: 10/01/02 thru 12/31/02



b) S-33 Rain: 01/01/03 thru 4/4/03

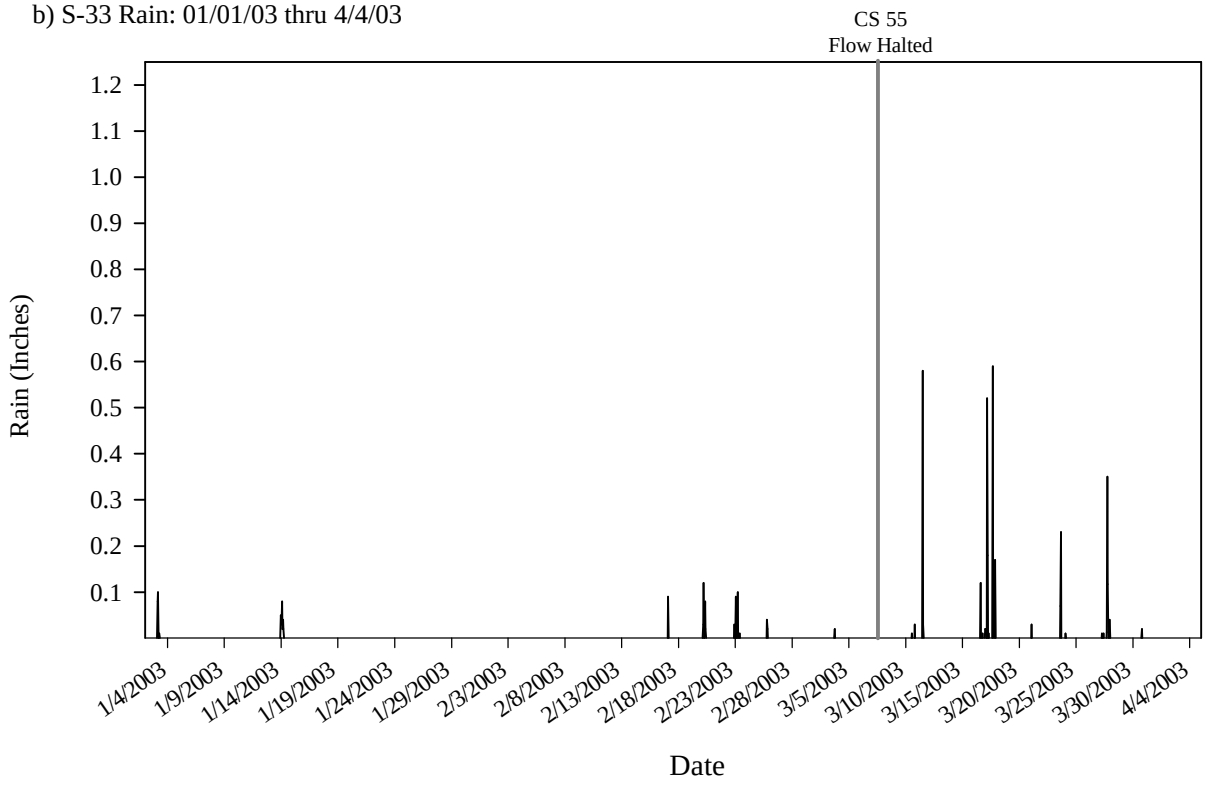
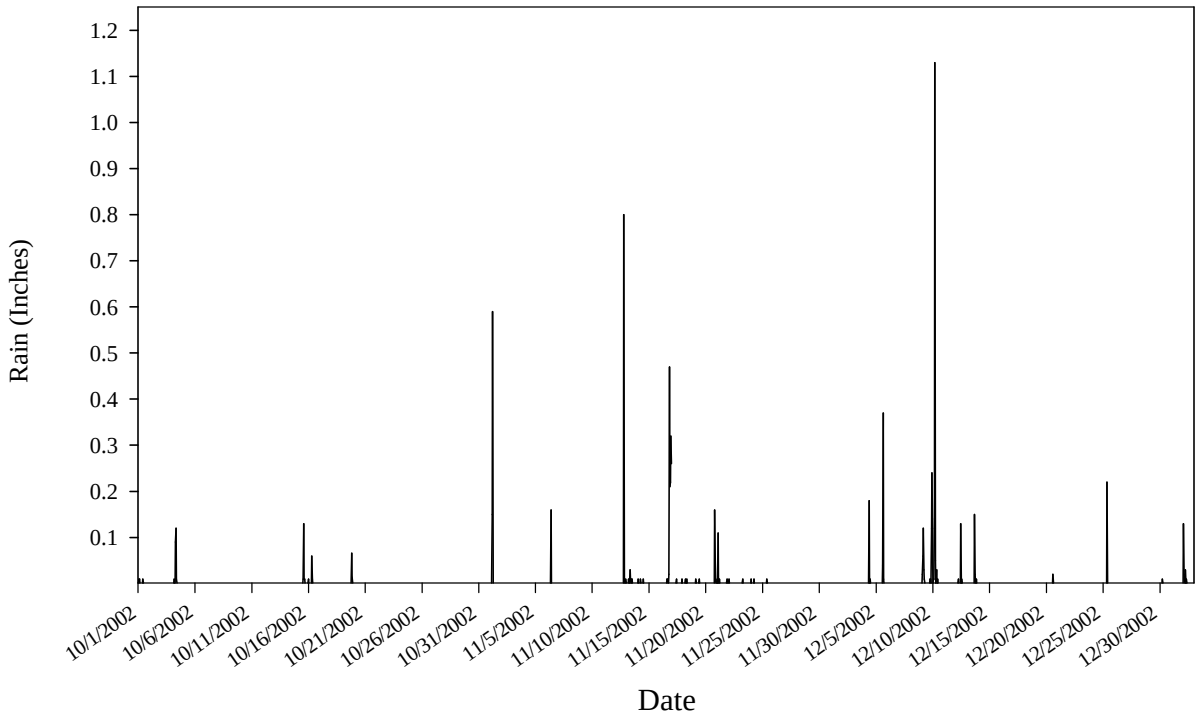


Figure 8. Hourly Rainfall Data Collected by the South Florida Water Management District at Coastal Salinity Structure S-36 on C-13 Canal. Data is divided between 10/1/02 thru 12/31/02 (a) and 1/1/03 thru 4/4/03 (b) to allow for better visual resolution. Grey line represents when flow from the C-13 Canal to the North Fork New River was halted on 3/7/03 at the Broward County Control Structure (CS) 55.

a) S-36 Rain: 10/01/02 thru 12/31/02



b) S-36 Rain: 01/01/03 thru 4/4/03

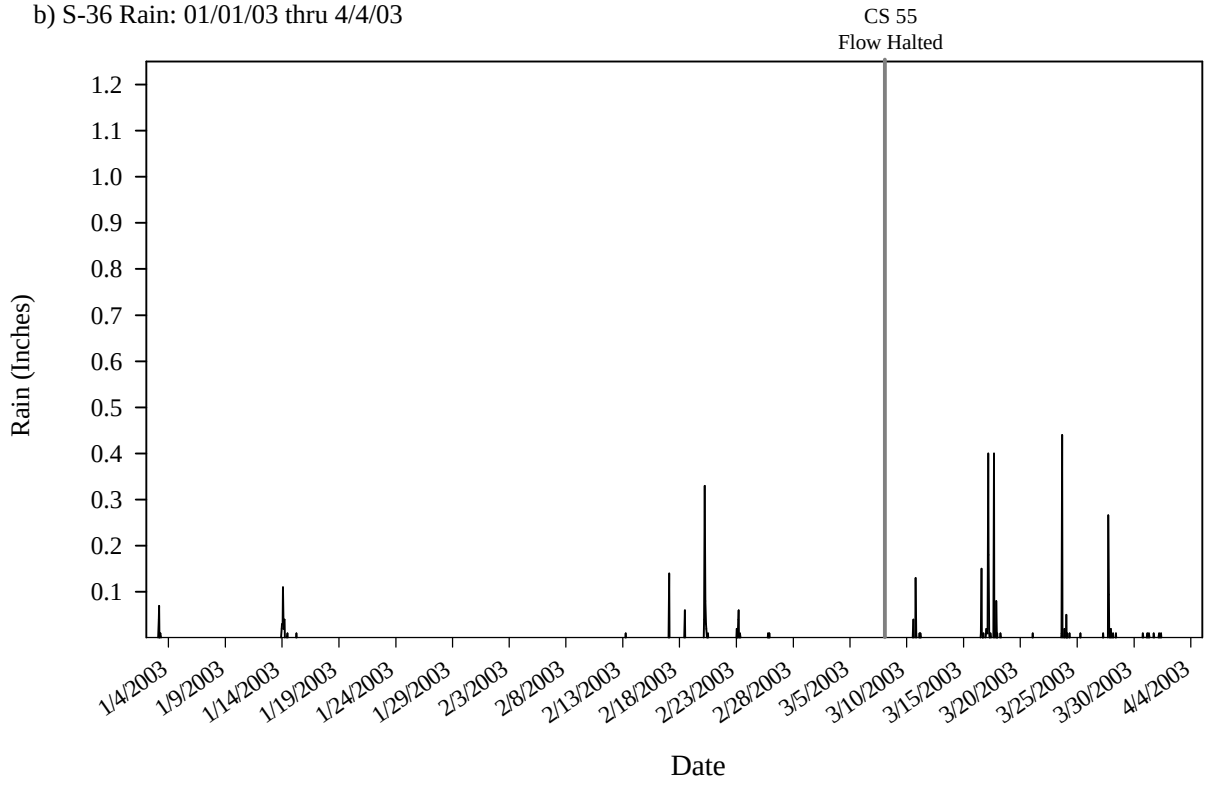
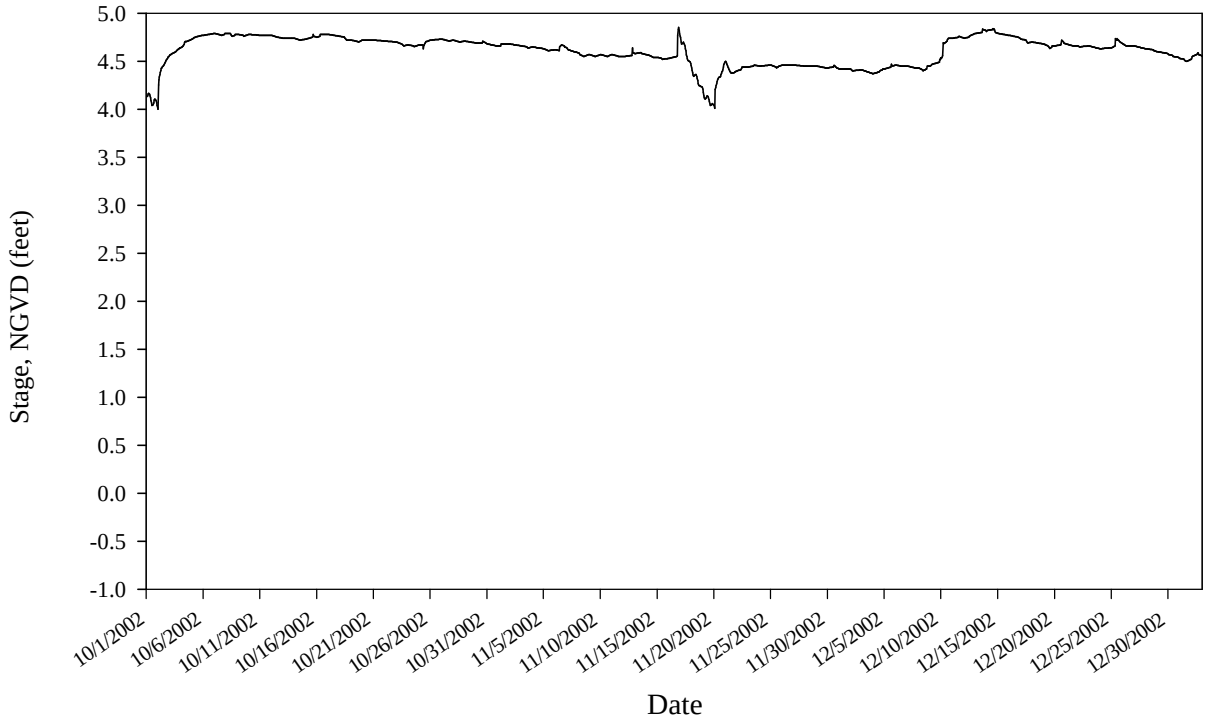


Figure 9. Hourly Stage Data (Feet, National Geodetic Vertical Datum, NGVD) Collected by the South Florida Water Management District Upstream of the Coastal Salinity Structure S-36 on the C-13 Canal. Data is divided between 10/1/02 thru 12/31/02 (a) and 1/1/03 thru 4/4/03 (b) to allow for better visual resolution. Grey line represents when flow from the C-13 Canal to the North Fork New River was halted on 3/7/03 at the Broward County Control Structure (CS) 55.

a) S-36 Upstream Stage: 10/01/02 thru 12/31/02



b) S-36 Upstream Stage: 01/01/03 thru 4/4/03

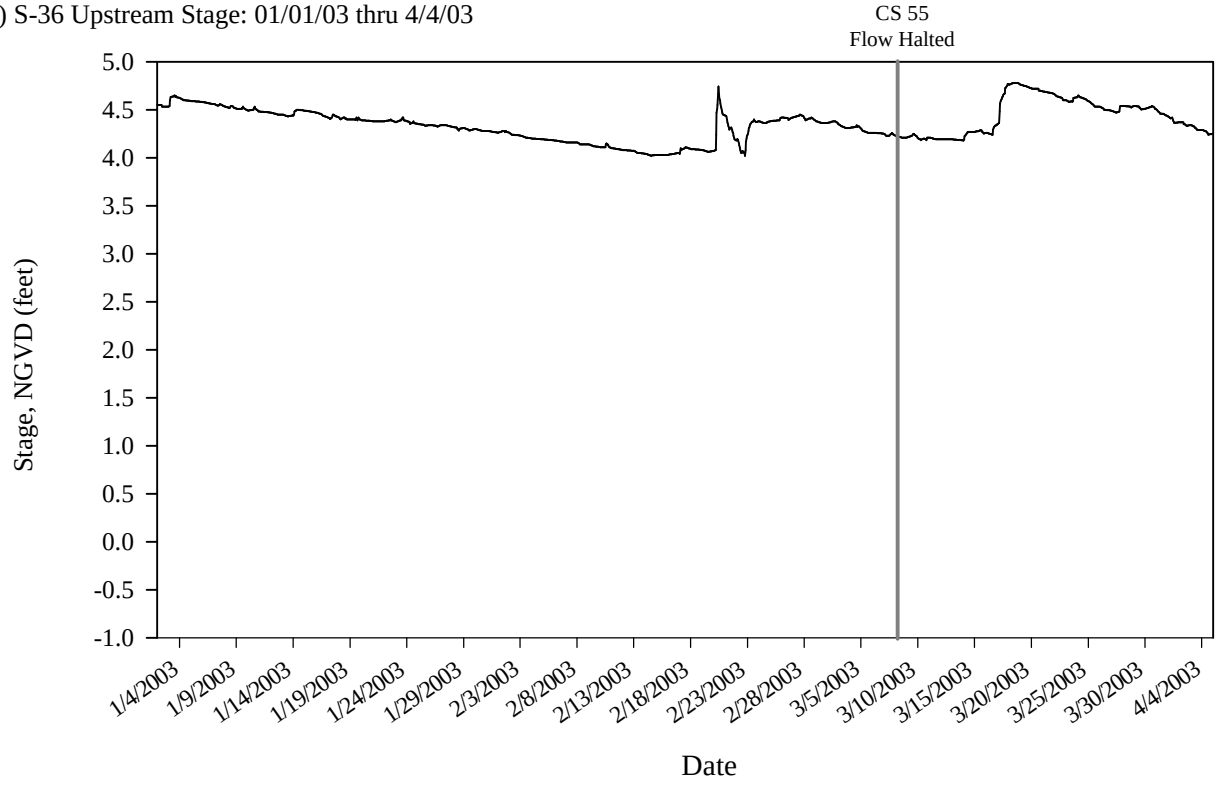
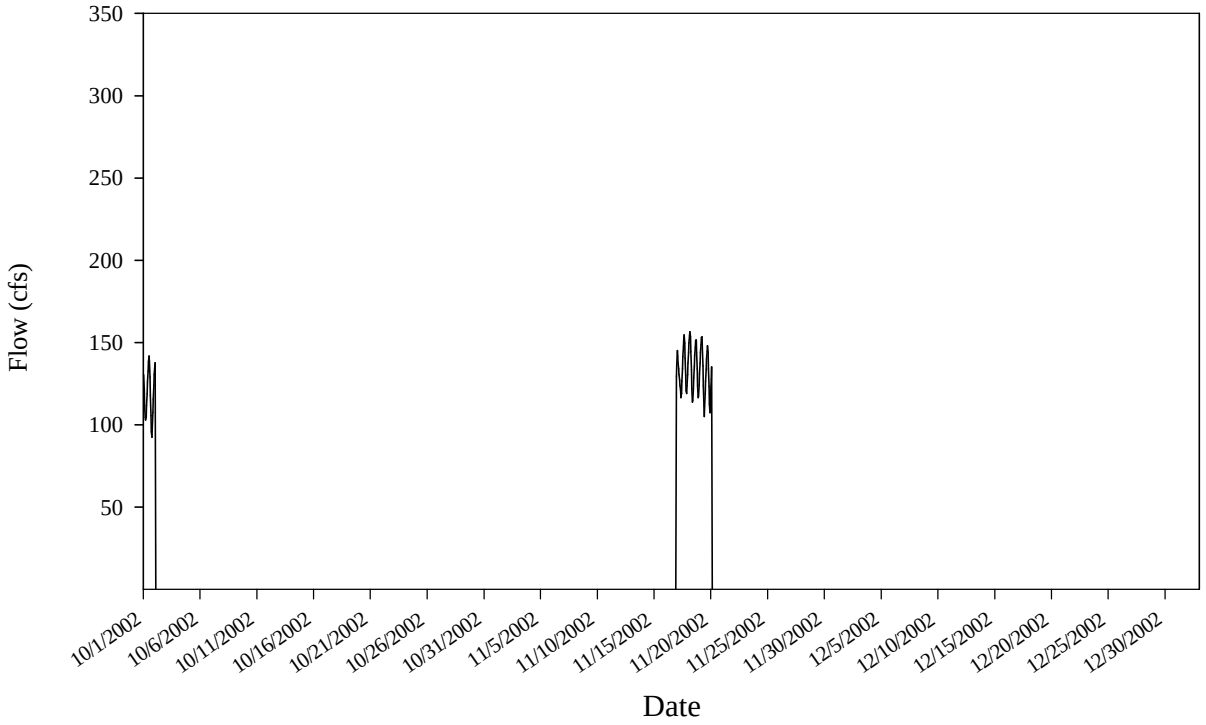


Figure 10. Hourly Flow Data (Cubic Feet Per Second) Collected by the South Florida Water Management District at Coastal Salinity Structure S-36 on the C-13 Canal. Data is divided between 10/1/02 thru 12/31/02 (a) and 1/1/03 thru 4/4/03 (b) to allow for better visual resolution. Grey line represents when flow from the C-13 Canal to the North Fork New River was halted on 3/7/03 at the Broward County Control Structure (CS) 55.

a) S-36 Flow: 10/01/02 thru 12/31/02



b) S-36 Flow: 01/01/03 thru 4/4/03

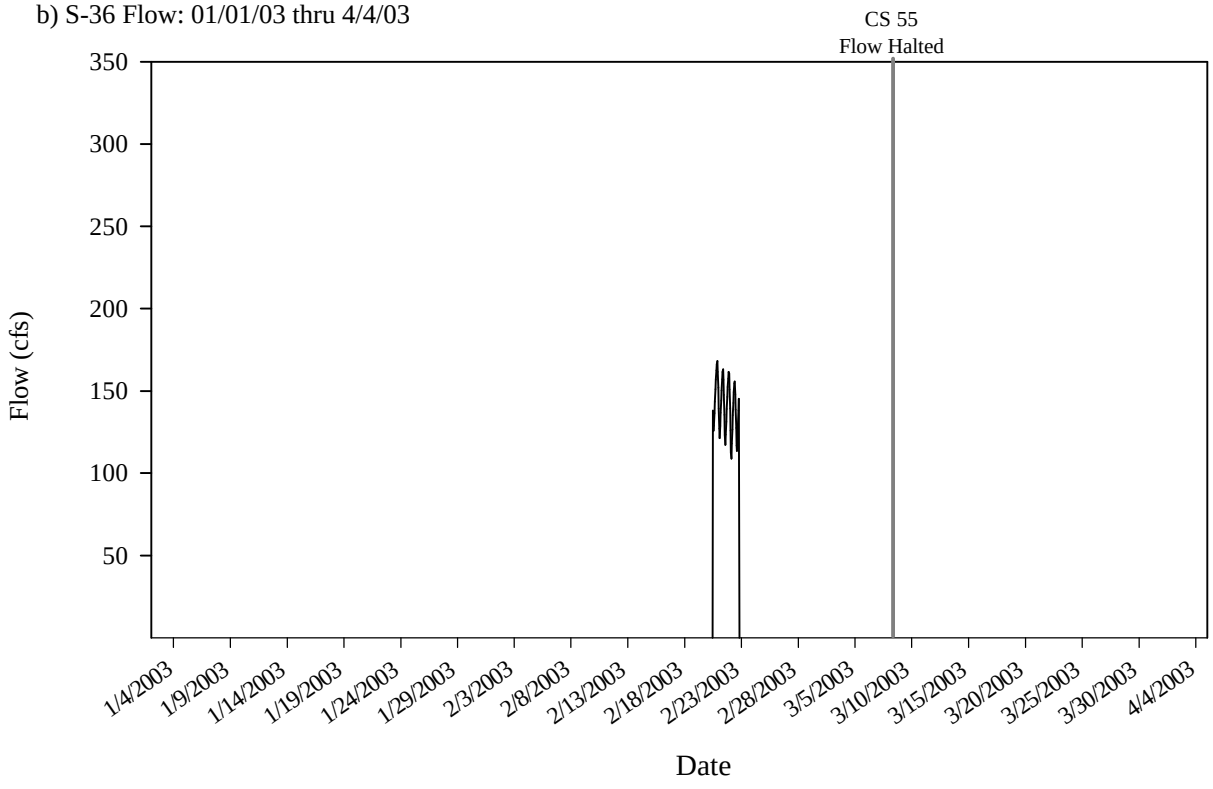
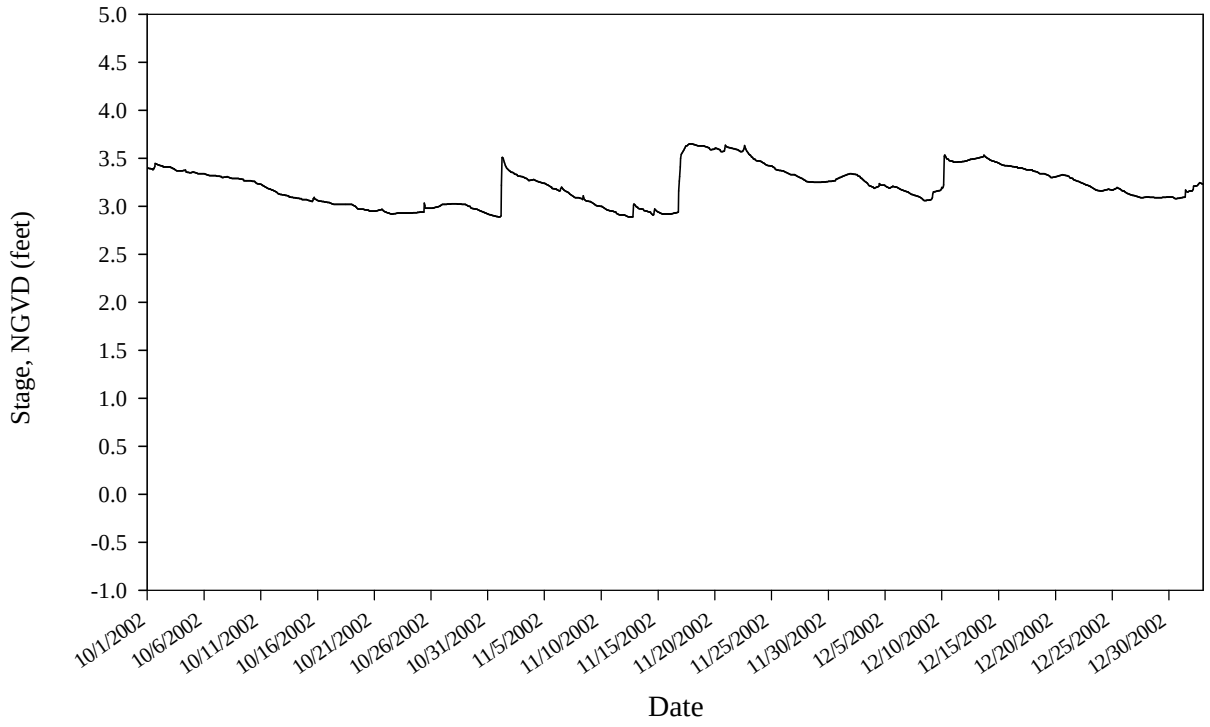


Figure 11. Hourly Stage Data (Feet, National Geodetic Vertical Datum, NGVD) Collected by the South Florida Water Management District Upstream of the Coastal Salinity Structure S-33 on C-12 Canal. Data is divided between 10/1/02 thru 12/31/02 (a) and 1/1/03 thru 4/4/03 (b) to allow for better visual resolution. Grey line represents when flow from the C-13 Canal to the North Fork New River was halted on 3/7/03 at the Broward County Control Structure (CS) 55.

a) S-33 Upstream Stage: 10/01/02 thru 12/31/02



b) S-33 Upstream Stage: 01/01/03 thru 4/4/03

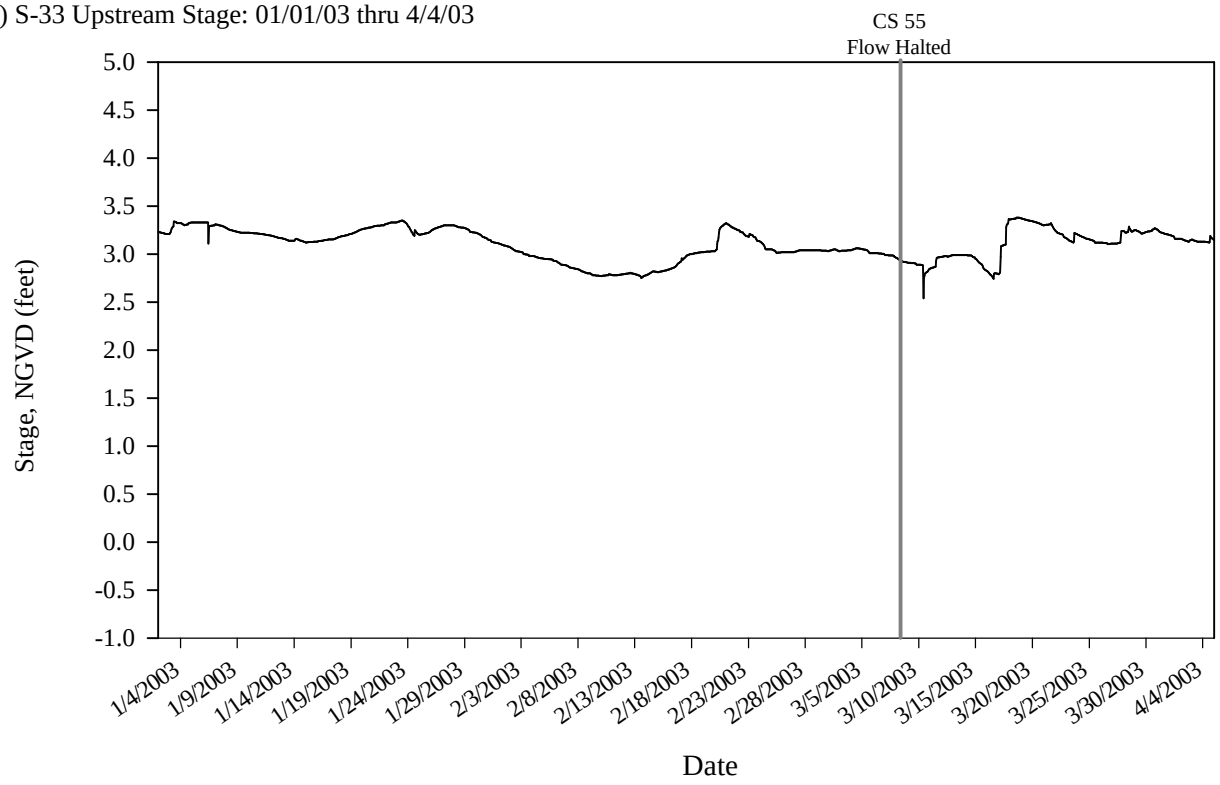
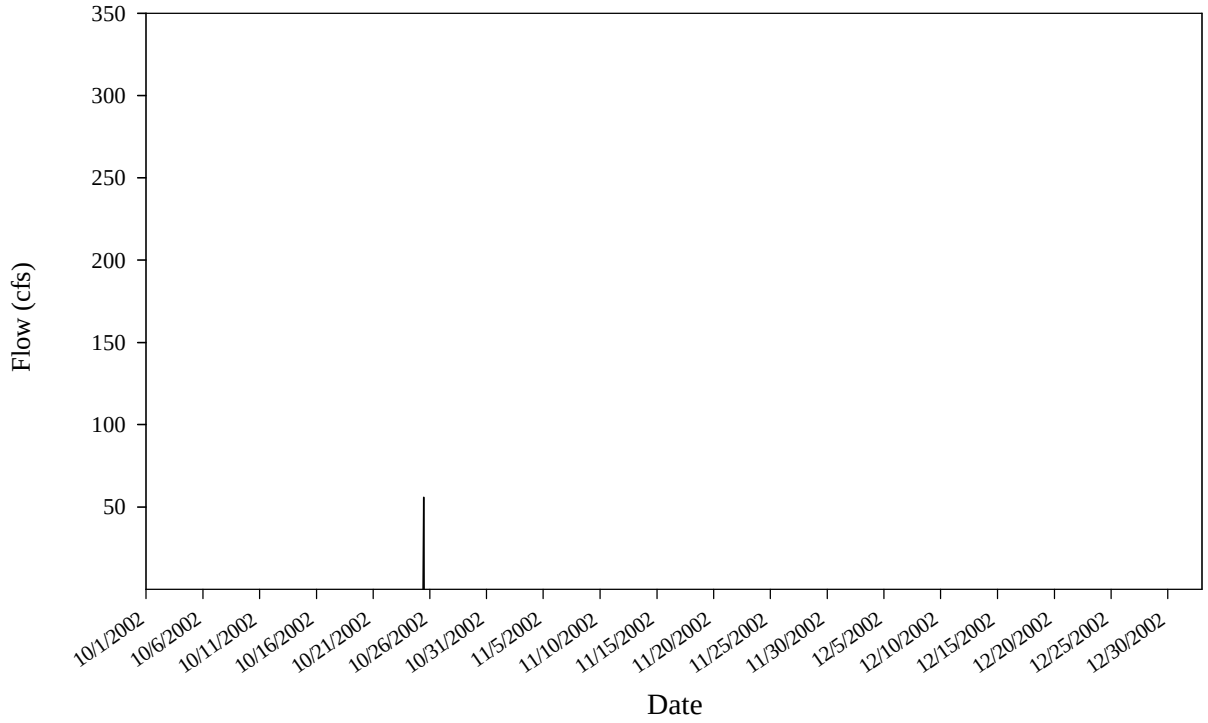


Figure 12. Hourly Flow Data (Cubic Feet Per Second) Collected by the South Florida Water Management District at Coastal Salinity Structure S-33 on C-12 Canal. Data is divided between 10/1/02 thru 12/31/02 (a) and 1/1/03 thru 4/4/03 (b) to allow for better visual resolution. Grey line represents when flow from the C-13 Canal to the North Fork New River was halted on 3/7/03 at the Broward County Control Structure (CS) 55.

a) S-33 Flow: 10/01/02 thru 12/31/02



b) S-33 Flow: 01/01/03 thru 4/4/03

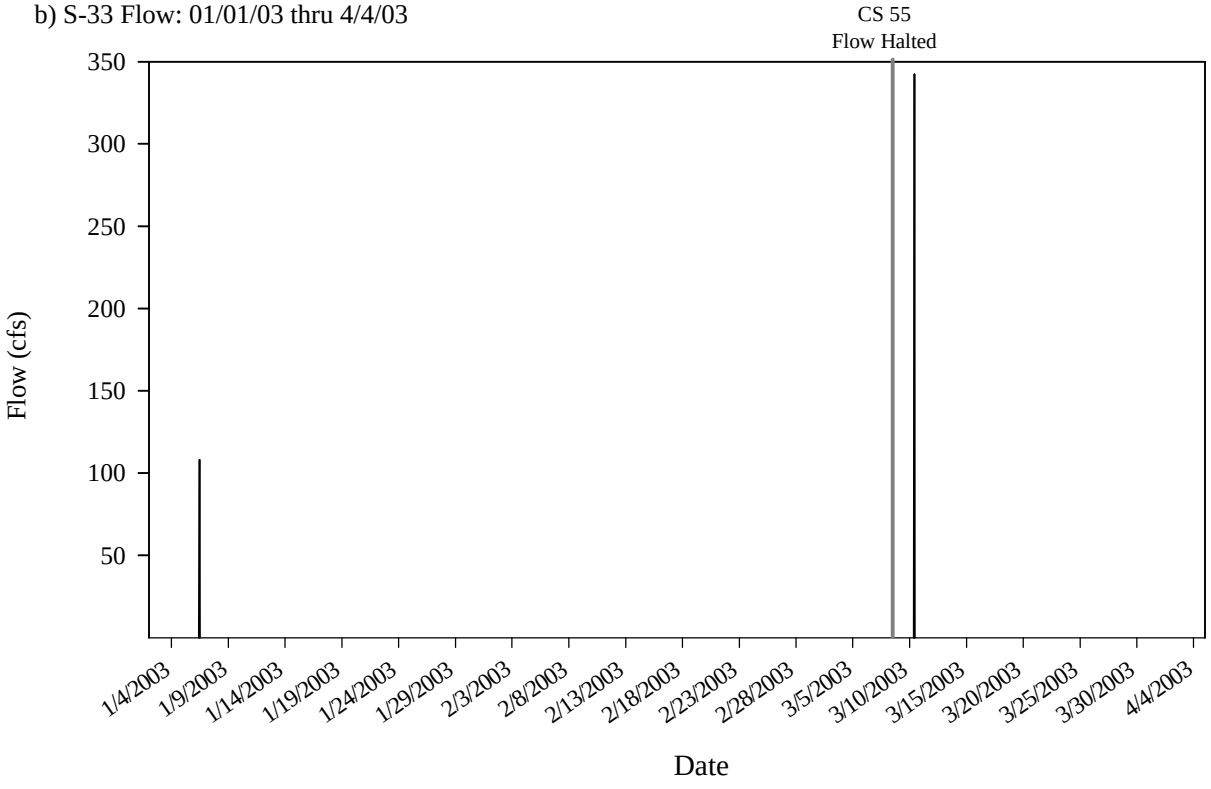
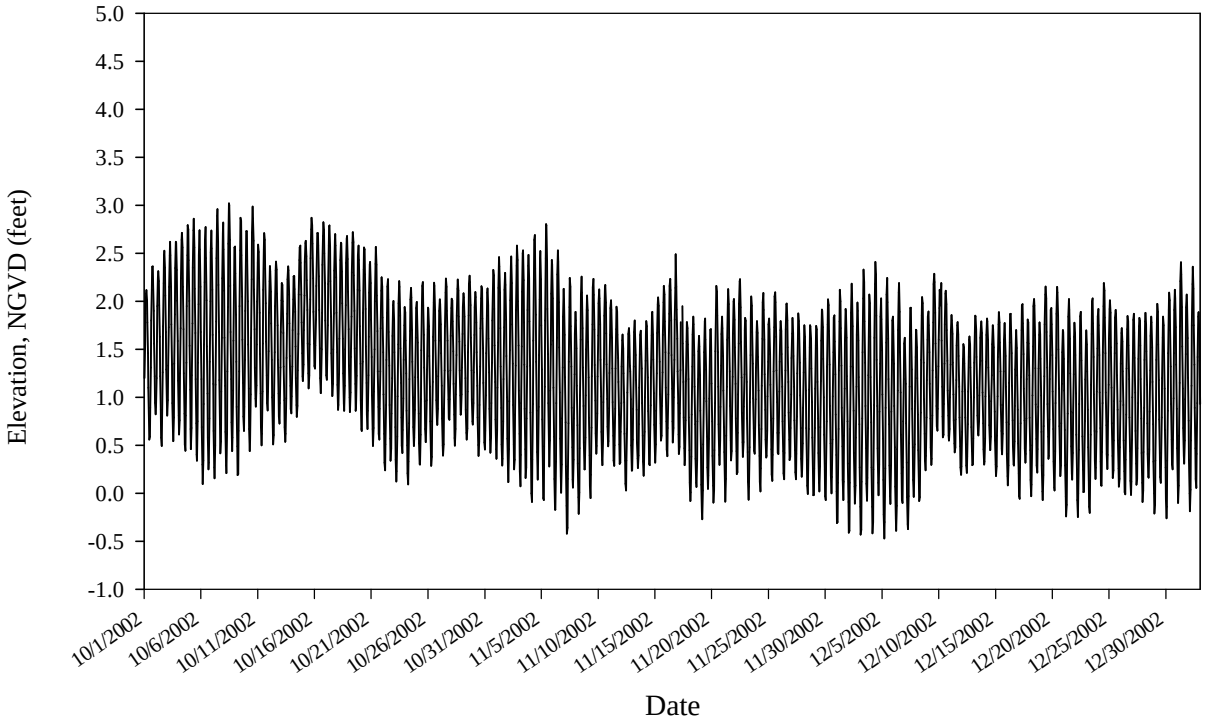


Figure 13. Hourly Stage Data (Feet, National Geodectic Vertical Datum, NGVD) Collected by the South Florida Water Management District Downstream of the Coastal Salinity Structure S-33 on tidal North Fork New River. Data is divided between 10/1/02 thru 12/31/02 (a) and 1/1/03 thru 4/4/03 (b) to allow for better visual resolution. Grey line represents when flow from C-13 Canal to North Fork New River was halted on 3/7/03 at the Broward County Control Structure (CS) 55. Note Broward County's tidal waters are characterized by a six hour period between the low and high tides (i.e., twice a day).

a) S-33 Downstream Stage: 10/01/02 thru 12/31/02



b) S-33 Downstream Stage: 01/01/03 thru 4/4/03

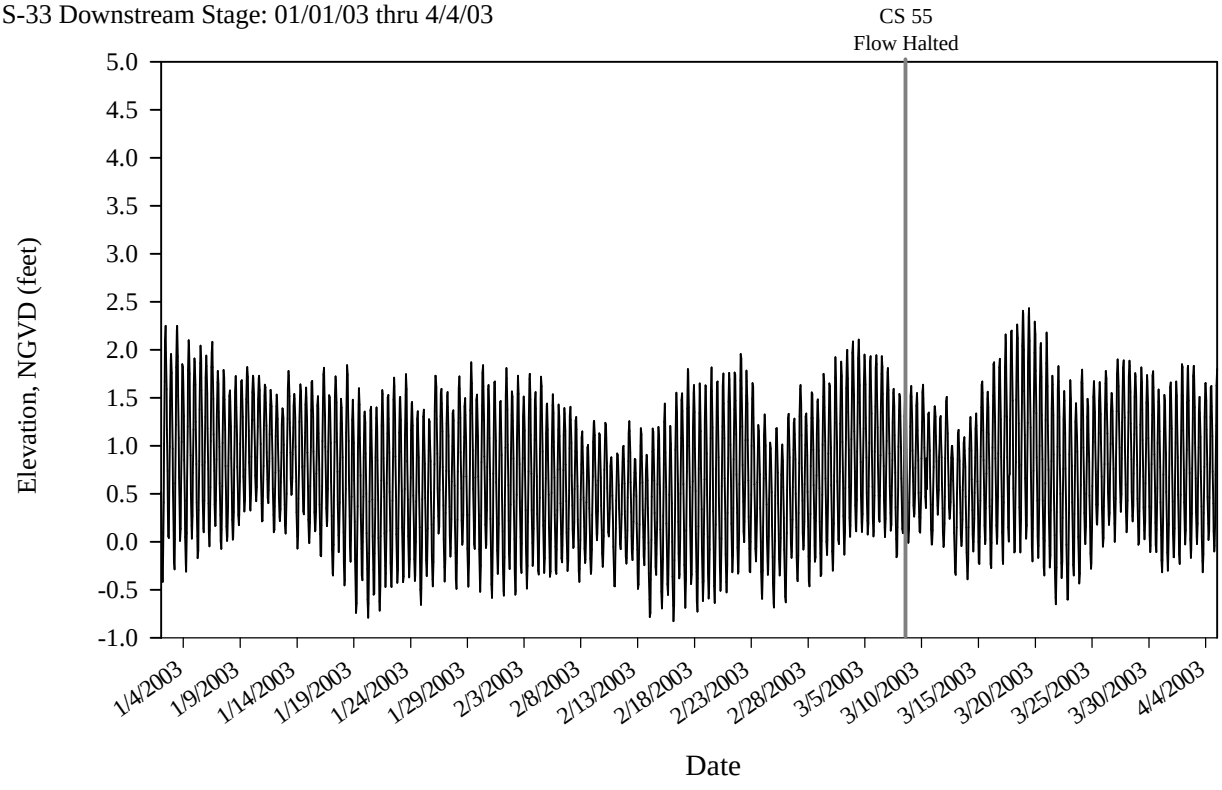
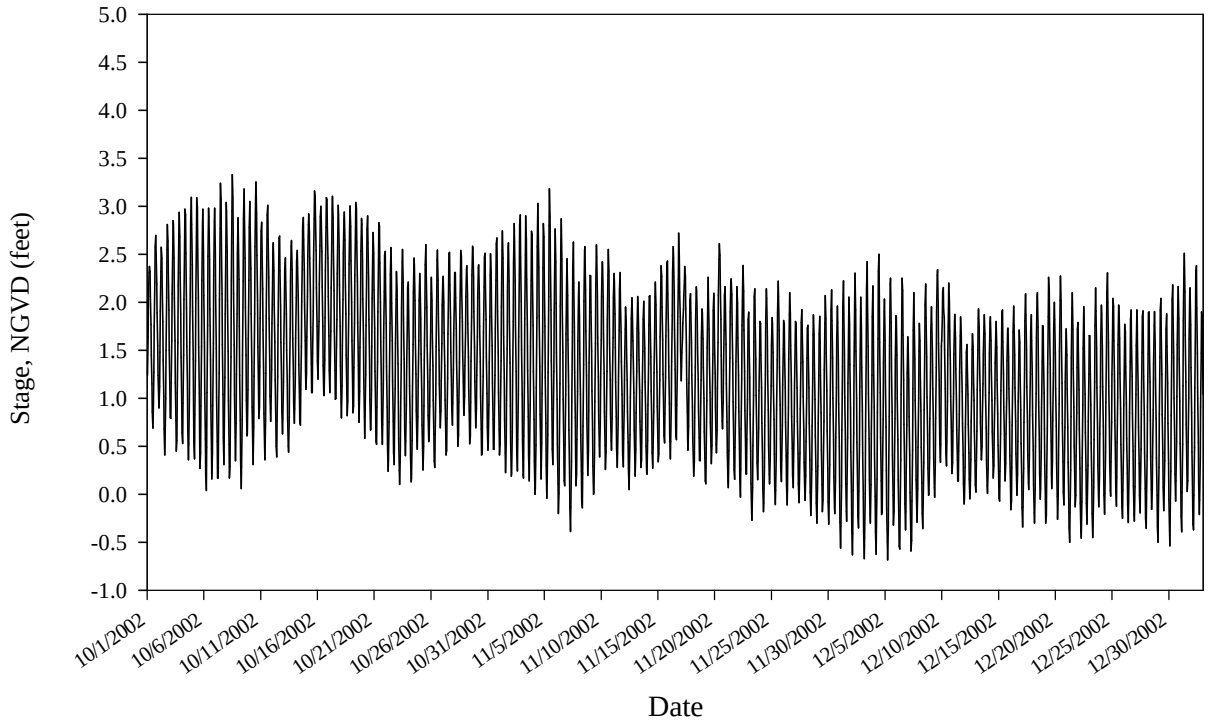
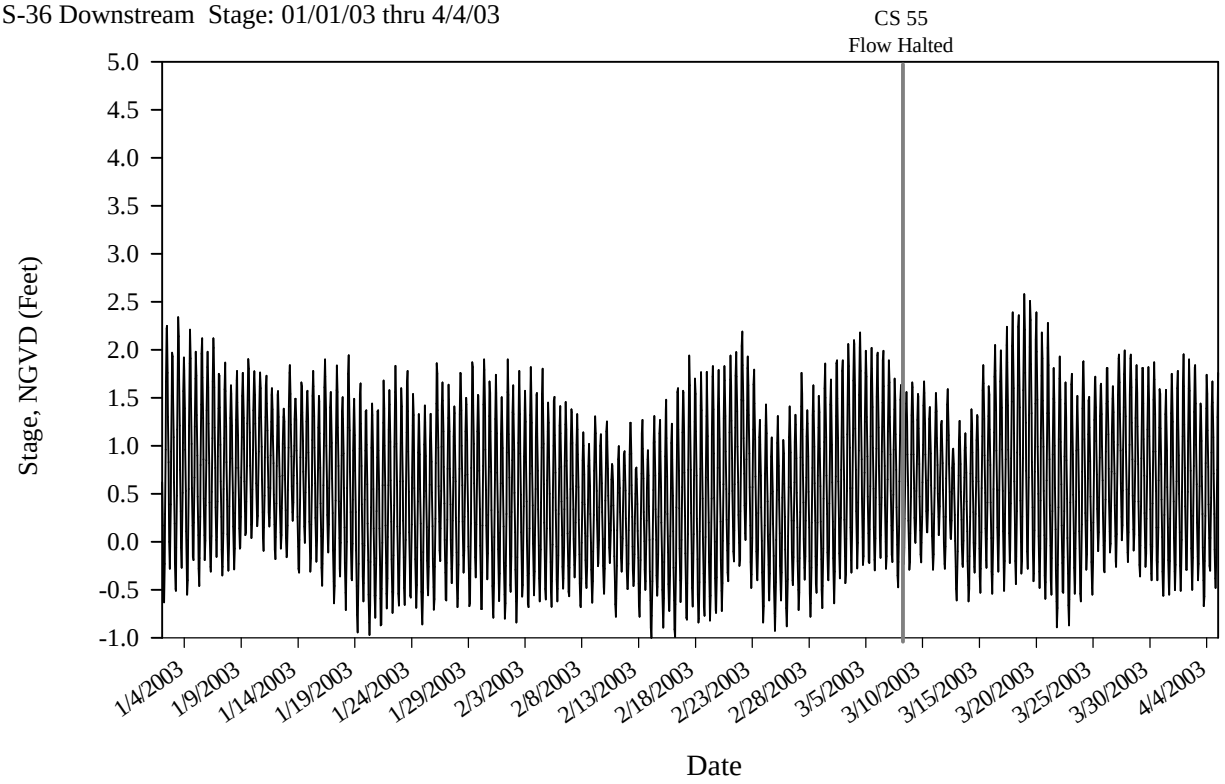


Figure 14. Hourly Stage Data (Feet, National Geodetic Vertical Datum, NGVD) Collected by the South Florida Water Management District Downstream of the Coastal Salinity Structure S-36 on Tidal C-13 Canal. Data is divided between 10/1/02 thru 12/31/02 (a) and 1/1/03 thru 4/4/03 (b) to allow for better visual resolution. Grey line represents when flow from the C-13 Canal to the North Fork New River was halted on 3/7/03 at the Broward County Control Structure (CS) 55. Note Broward County's tidal waters are characterized by a six hour period between the low and high tides (i.e., twice a day).

a) S-36 Downstream Stage: 10/01/02 thru 12/31/02



b) S-36 Downstream Stage: 01/01/03 thru 4/4/03



December. For both sites, the first three months of the study were characterized by higher tidal amplitude and elevation than the last three months.

5. CS 55 elevations

The opening of CS 55 at 19th Street allows flow from the C-13 Canal south into the North Fork New River (Figure 4) and is the critical water management tool for the OPFLOW Alternative 2. On 10/22/02 the CS 55 was opened (i.e., raised) and two risers were removed from CS 17 to establish flow into the North Fork (see Figure 4). The CS 55 was lowered on 12/11/02 to reduce flows for water management purposes upstream of the structure. Overall, CS 55 was open throughout the study until 3/7/03 when it was closed by the City of Lauderdale Lakes to perform aquatic plant maintenance. The enhanced flow thru the secondary canal system was bringing a nuisance macroalgae, *Hygrophila* sp., into the City of Lauderdale Lakes at a much more rapid and constant rate than previously had occurred. The BCOES placed a fence north of the Lauderdale Lakes structure (Figure 4) to block the path of the invasive exotic plant *Hygrophila* sp. from entering the secondary canal system in the City of Lauderdale Lakes and flow occurred again after 4/2/03.

Figure 15 shows the elevations measured on the north and south sides of CS 55 as well as the S-36 (C-13 Canal). Elevation on the north side of CS 55 and the C-13 Canal remained relatively stable after the opening and then showed a noticeable decline in late November which was due primarily to the S-36's flow event (Figure 10a). The large (> one inch) rain event on 12/10/02 (Figures 7a and 8a) likely contributed to the increase in elevation throughout the system around the date the CS 55 was lowered (12/11/02). After the CS 55 was lowered, elevations steadily declined during the period of low rainfall (Figures 7b and 8b) until the late February flow event at S-36 (Figure 10b). After the CS 55 was closed on 3/7/03, water elevations south of CS 55 substantially decreased due to no flow from the north side (Figure 15). Overall, flooding was not observed or reported during the study either upstream or downstream of the CS 55.

Using the S-36 and CS 55 (south) elevations shown in Figure 15, flow rates were roughly estimated by BCOES based on the width of CS 17 (Figure 16). These calculations have not been groundtruthed and thus should be used cautiously. The calculation was made complex when water elevations were above 3.5 feet south of CS 55 (see Figure 15) because two factors had to be used: 1) the notch of the weir and 2) the area extended above the notch. In general, flow rates were between 20 to 30 cubic feet per second (cfs, Figure 16a) during most of the study which equates to around 15 to 20 million gallons per day (mgd, Figure 16b). Lowering CS 55 on 12/11/02 was supposed to decrease flow rates but instead they rose substantially on this day. This occurrence is likely due to the large rain event on 12/11/02 discussed above. As expected, flow dropped dramatically after CS 55 was closed and then increased after it was re-opened on 4/2/03.

Figure 15. Water Elevations (Feet, National Geodetic Vertical Datum, NGVD) Observed During OPFLOW 2002. Data for the S-36 control structure (headwaters, C-13 Canal) was obtained from the South Florida Water Management District. Ruler measurements were made by Genesis Environmental Services at the CS 55 (north and south; secondary canal system). Vertical lines indicate significant CS 55 management activities.

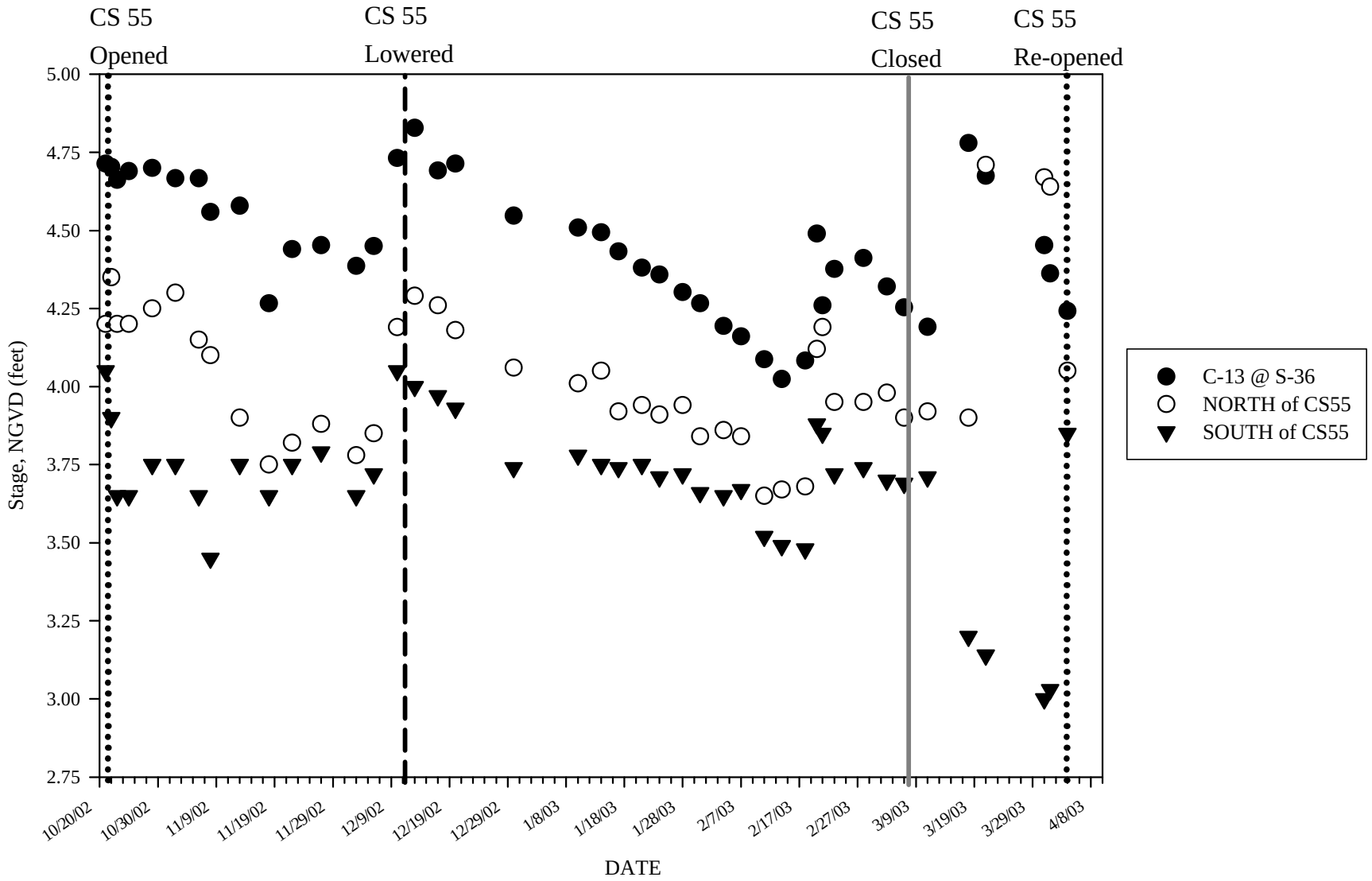
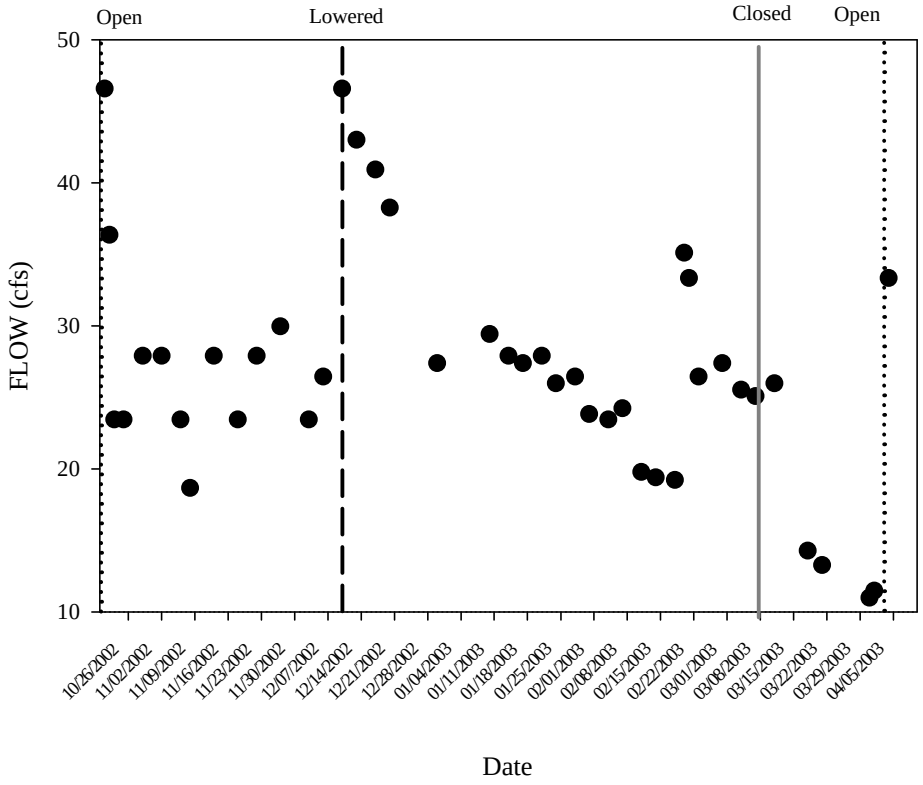
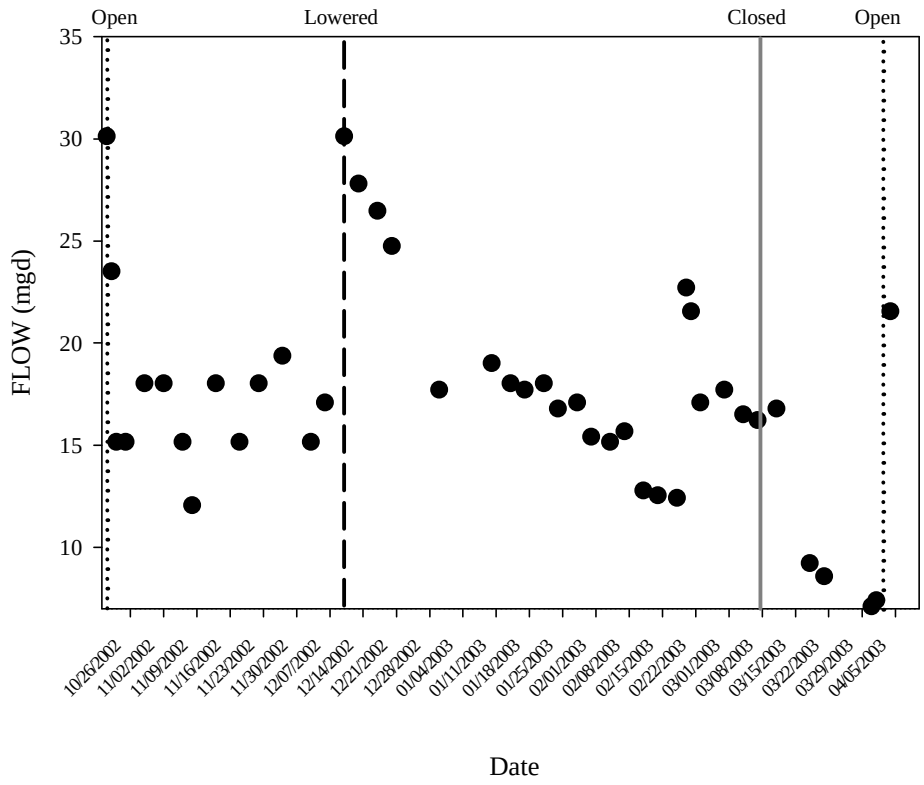


Figure 16. Estimated Flow Rates at CS 17 During the OPFLOW 2002. Please note these are 'rough' estimations of flow based on the different control structure (CS) sizes (see text) and elevation data from the S-36 (headwaters, Figure 9a) and CS-55 (tailwaters; see Figure 15). The data are the same but shown as both cubic feet per second (cfs, a) and million gallons per day (mgd, b). The status of the CS 55 is shown on the upper x-axis.

a) cubic feet per second (cfs)



b) million gallons per day (mgd)



B. YSI Datasonde Measurements

Four YSI datasondes were monitored during this study. Site 113 represents the secondary canal water entering the North Fork New River (i.e. upstream). Sites 101, 64, and 16 represent the downstream components, respectively, for the North Fork New River (Figure 5)

1. Specific Conductance

Freshwater typically has a specific conductance value of less than 1,000 umhos/cm. Specific conductance at Site 113, located in the secondary canal leading to the North Fork of the New River, remained relatively constant, ranging from ~200 umhos/cm to 700 umhos/cm with a mean specific conductivity of ~620 $\pm$ 80 umhos/cm (mean $\pm$ SD, Figure 17a). Site 101 also had a similar, strong and relatively constant freshwater signal ranging from 225 to 675 umhos/cm and mean of ~600 $\pm$ 70 umhos/cm (Figure 17b). Site 64 was more variable with periods of elevated conductivity reaching upwards of 3000 umhos/cm (Figure 17c). Site 64 had an average value of ~750 $\pm$ 310 umhos/cm. Elevated specific conductance values were more apparent after flow through CS 55 was stopped on 3/7/03. Site 16 is the most downstream site and not unexpectedly is the most brackish of the three river sites. The average value for specific conductance at this site was approximately 3550 $\pm$ 2100 umhos/cm (mean $\pm$ SD). Site 16 also exhibited much larger oscillations in specific conductance over time suggesting a strong tidal influence (Figure 17d).

On 3/7/03, Control Structure 55 was closed and flow between Site 113 and the North Fork of the New River ceased. There was no large change in overall conductivity values at either Sites 113 or 101, though a slight trend towards decreasing conductivity was noted. Eliminating the enhanced freshwater input to the North Fork of the New River did not appear to have any effect on Site 16 waters (Figure 17d). However, at Site 64, closing CS 55 resulted in an increase in specific conductivity values as well as an increase in the overall amplitude of this signal. Mixing with the more brackish downstream waters as well as loss of the freshwater input are probably responsible for the observed trends (Figure 17c). Short term decreases in specific conductance were observed at all four sites in December 2002 and March 2003 and likely reflect the influence of rain events on this system (Figures 17 and 7). Specific conductance returned to previously observed values within a few days following rain events.

2. Temperature and pH

Overall, temperature values ranged from 16 to 31 degrees Celsius (Figure 18). All four sites followed a similar trend with temperature generally decreasing until the end of January. Temperatures values steadily increased during the latter half of the study until late March – early April when water temperature at all sites showed a rapid decline in temperature followed by a slight increase. Halting flow through CS 55 did not seem to result in major differences between sites (Figure 18).

Figure 17. Specific Conductance Values Observed During the OPFLOW 2002 Study. Values are hourly averages of data collected every 15 minutes. Site 113 (a) is located in a freshwater canal north of Broward County Office of Environmental Services Control Structure (BCOES CS) 17. Site 101 (b) is the most upstream site of the North Fork New River sites followed by Sites 64 (c, note scale difference) and 16 (d). The solid grey line indicates flow was halted from the C-13 Canal to the North Fork New River on 3/7/03 at the BCOES CS 55.

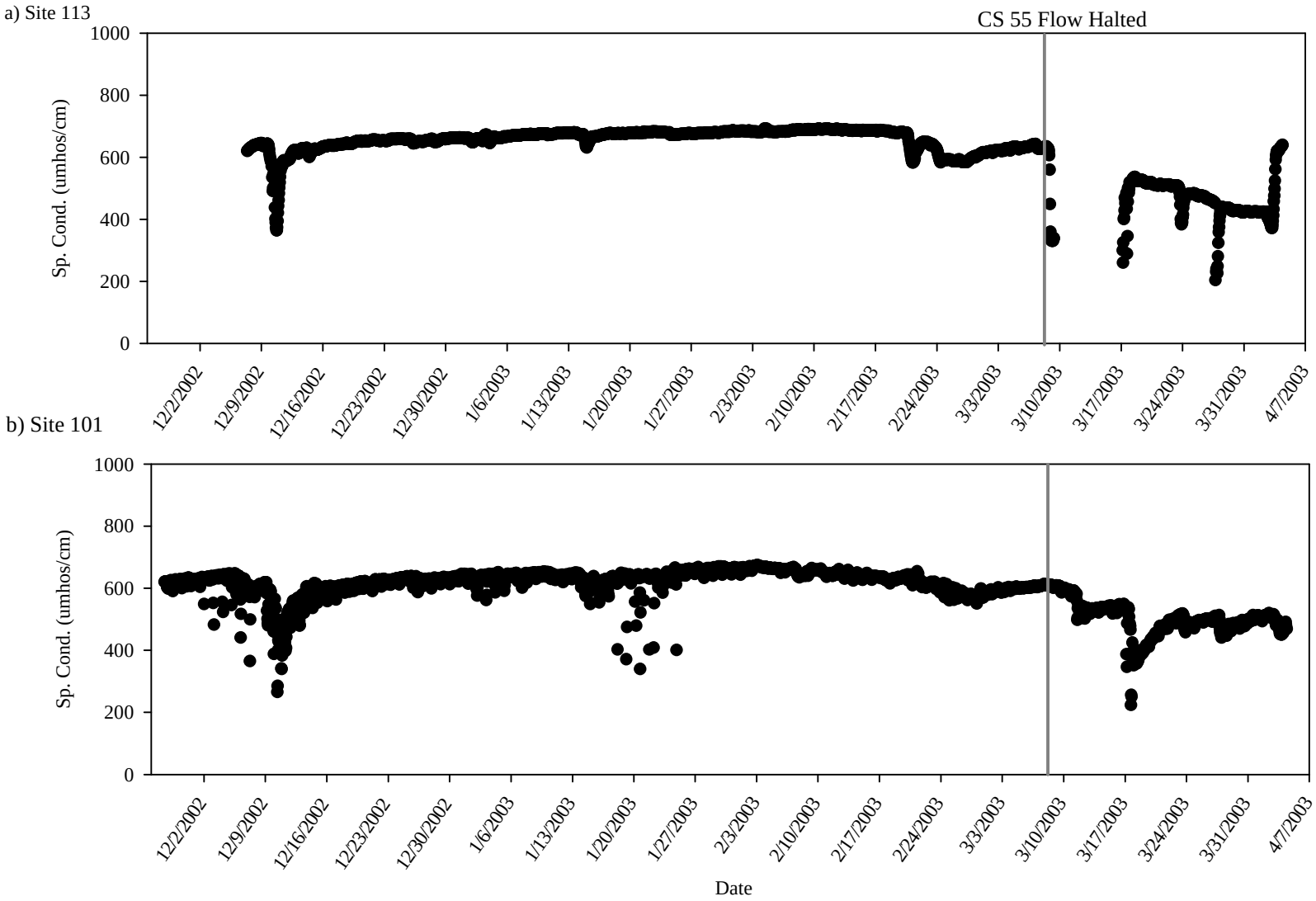


Figure 17 (cont). Specific Conductance Values Observed During the OPFLOW 2002 Study. Values are hourly averages of data collected every 15 minutes. Site 113 (a) is located in a freshwater canal north of Broward County Office of Environmental Services Control Structure (BCOES CS) 17. Site 101 (b) is the most upstream site of the North Fork New River sites followed by Sites 64 (c, note scale difference) and 16 (d). The solid grey line indicates flow was halted from the C-13 Canal to the North Fork New River on 3/7/03 at the BCOES CS 55.

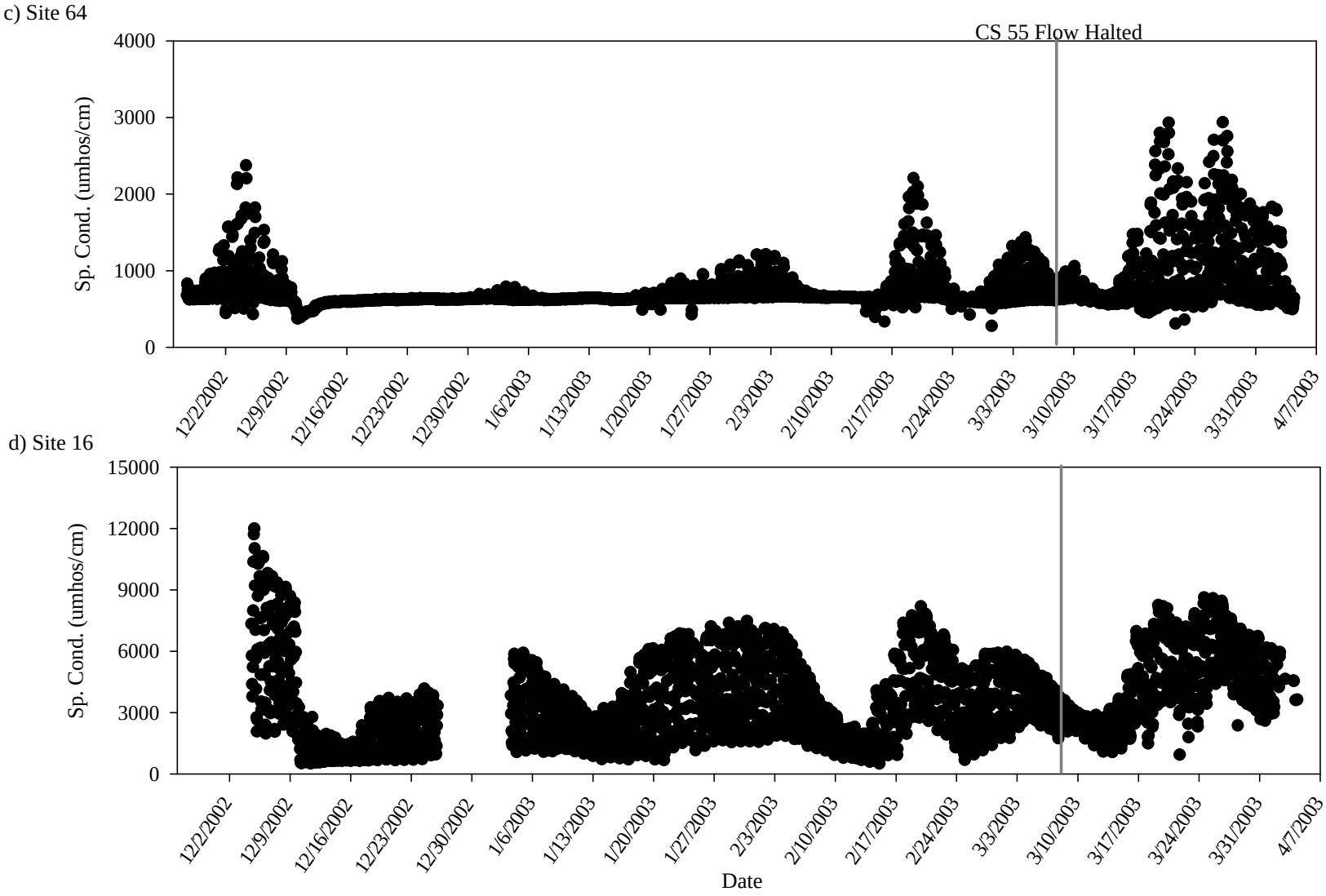


Figure 18. Temperature Values Observed During the OPFLOW 2002 Study. Values are hourly averages of data collected every 15 minutes. Site 113 (a) is located in a freshwater canal north of Broward County Office of Environmental Services Control Structure (BCOES CS) 17. Site 101 (b) is the most upstream site of the North Fork New River sites followed by Sites 64 (c) and 16 (d). The solid grey line indicates flow was halted from C-13 Canal to North Fork New River on 3/7/03 at the BCOES CS 55.

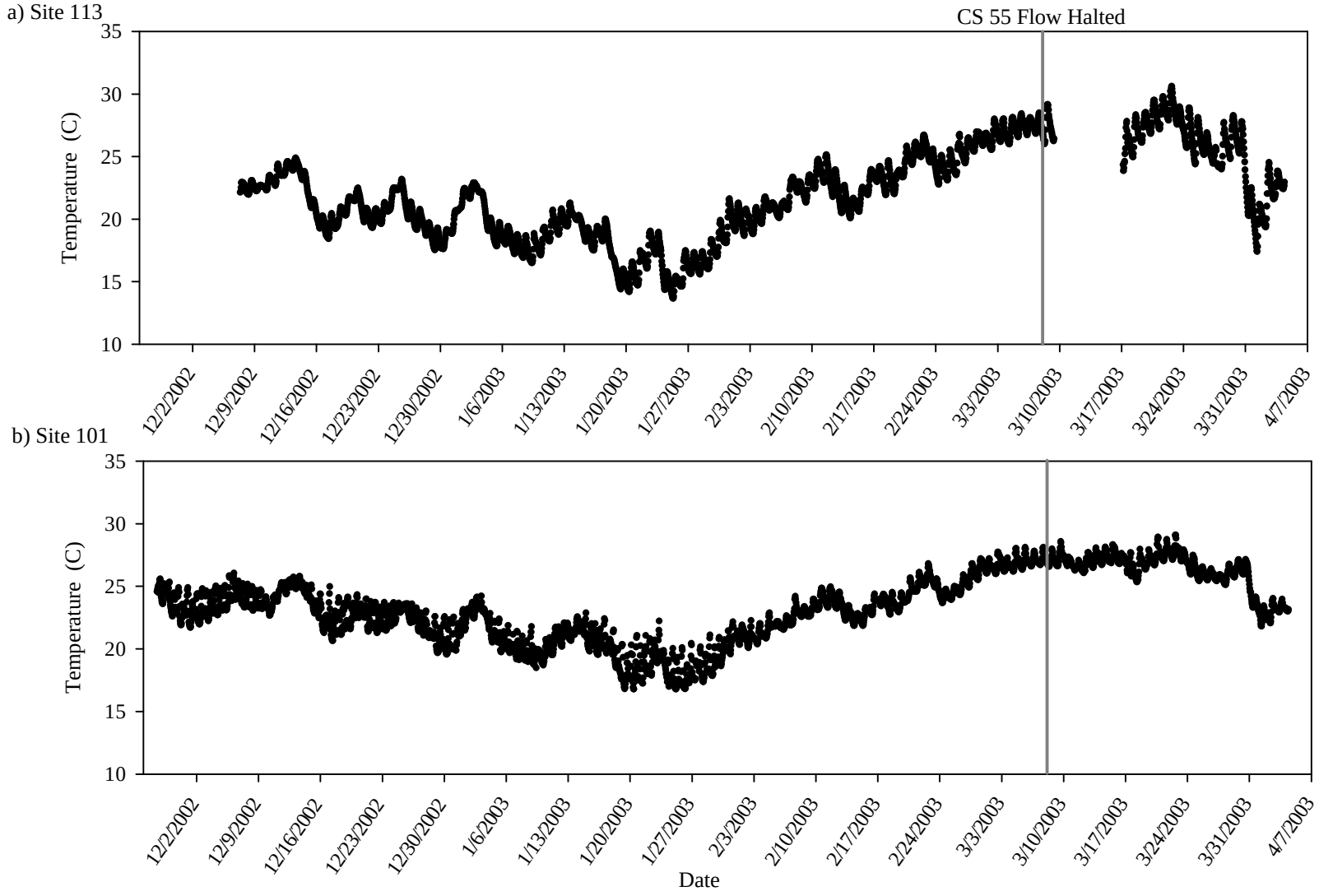
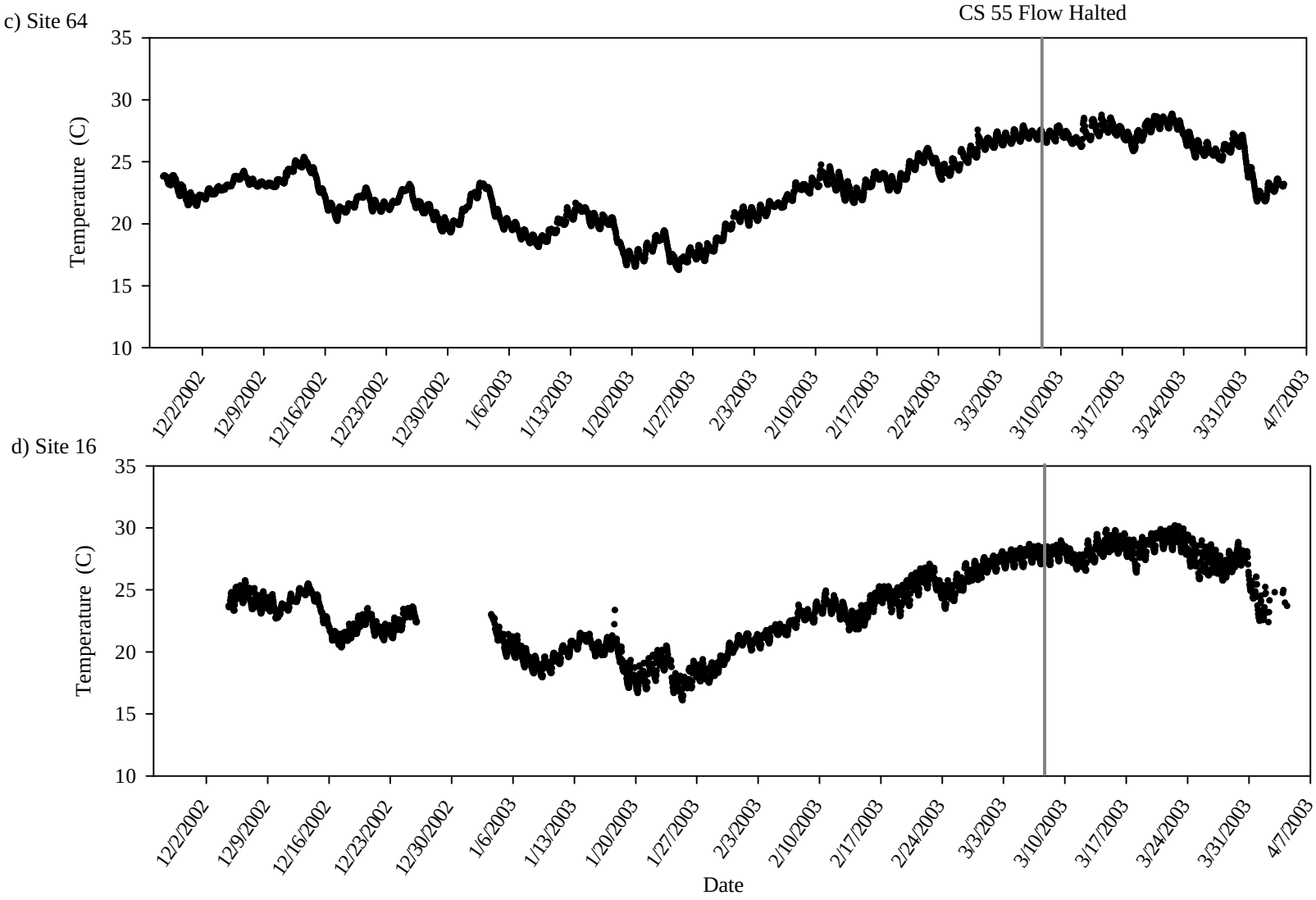


Figure 18 (cont.). Temperature Values Observed During the OPFLOW 2002 Study. Values are hourly averages of data collected every 15 minutes. Site 113 (a) is located in a freshwater canal north of Broward County Office of Environmental Services Control Structure (BCOES CS) 17. Site 101 (b) is the most upstream site of the North Fork New River sites followed by Sites 64 (c) and 16 (d). The solid grey line indicates flow was halted from C-13 Canal to North Fork New River on 3/7/03 at the BCOES CS 55.



The pH of waters at Site 113 in the secondary canal, ranged from 7.5 to 8.5 with an average pH of 7.9 ± 0.2 (mean ± SD, Figure 19a). All the North Fork New River sites had a lower pH, varying between 7 to 8 with Site 101 exhibiting the greatest variability over time (Figures 19b, 19c, and 19d). The average pH at Sites 101 and 64 was 7.5 ± 0.1. Site 16 had an average pH of 7.6 ± 0.1. Elevated pH values were associated with rain events (December 2002 and March 2003) at Sites 101, 64 and 16. Eliminating the freshwater inputs to the North Fork of the New River in March 2003 did not have any effect on pH values at Sites 64 and 16 other than a slight trend towards increased variability in the amplitude of the pH signal compared to early in the study. Preventing the exchange of water between the secondary canal and the North Fork of the New River caused pH to increase at Site 113 but decrease at Site 101 (Figures 19a and 19b).

3. Dissolved Oxygen

Site 113 had the highest oxygen values of all four sites. Dissolved oxygen (DO) concentration ranged from 4.6 to 11 mg/l with an average concentration of 7.2 ± 0.9 mg/l (mean ± SD, Figure 20a). Oxygen concentrations were generally lower and more variable at the three North Fork New River sites (Figures 20b, 20c, and 20d). Site 101 had the highest average oxygen concentration of the river sites with a mean of 5.4 ± 1.5 mg/l and range of 1.3 to 9.9 mg/l (Figure 20b). The higher oxygen concentrations indicate mixing of freshwater inputs from Site 113. Site 64 and 16 had similar oxygen concentrations of approximately 4.8 ± 1.4 mg/l, and 4.8 ± 1.2 mg/l respectively. Dissolved oxygen concentrations at site 64 ranged from 0.4 to 8.4 mg/l. Site 16 oxygen concentrations were slightly more variable and ranged from ~1 mg/l to 10.1 mg/l (Figures 20c and 20d). Chapter 27 of Broward County's Municipal Code states that water bodies are expected to exceed an average daily oxygen concentration of 5.0 mg/l daily average concentration and have a greater than 4.0 mg/l oxygen concentration for any single sample (Broward County 2003, http://www.broward.org/dni01100.htm). The waters of the North Fork New River fall somewhere between those two criteria.

Closing CS 55 and eliminating freshwater inputs in the North Fork New River had a mixed effect on dissolved oxygen concentrations. In general, dissolved oxygen concentrations were more variable at all sites after flow through CS 55 was stopped (Figure 20). Dissolved oxygen levels also appeared to increase at the two end member sites (113 and 16) but decreasing at the two center ones (Sites 101 and 64) compared to DO prior to 3/7/03 (Figure 20). On average, oxygen levels increased in the two end member sites (113 and 16) following the closure of CS 55.

4. Chlorophyll

The optical fluorescence data presented here is from the YSI datasonde and has not yet been post calibrated to fluorescence values obtained by laboratory analysis for chlorophyll from grab samples collected each time the YSI datasondes were "swapped out". However, the grab sample data is presented with the YSI data to compare general trends over time in chlorophyll. Chlorophyll (Chl) concentrations were similar and relatively constant between sites when water was flowing through CS 55 into the North Fork New River (Figure 21).

Figure 19. The pH Values Observed During the OPFLOW 2002 Study. Values are hourly averages of data collected every 15 minutes. Site 113 (a) is located in a freshwater canal north of Broward County Office of Environmental Services Control Structure (BCOES CS) 17. Site 101 (b) is the most upstream site of the North Fork New River sites followed by Sites 64 (c) and 16 (d). The solid grey line indicates flow was halted from C-13 Canal to North Fork New River on 3/7/03 at the BCOES CS 55.

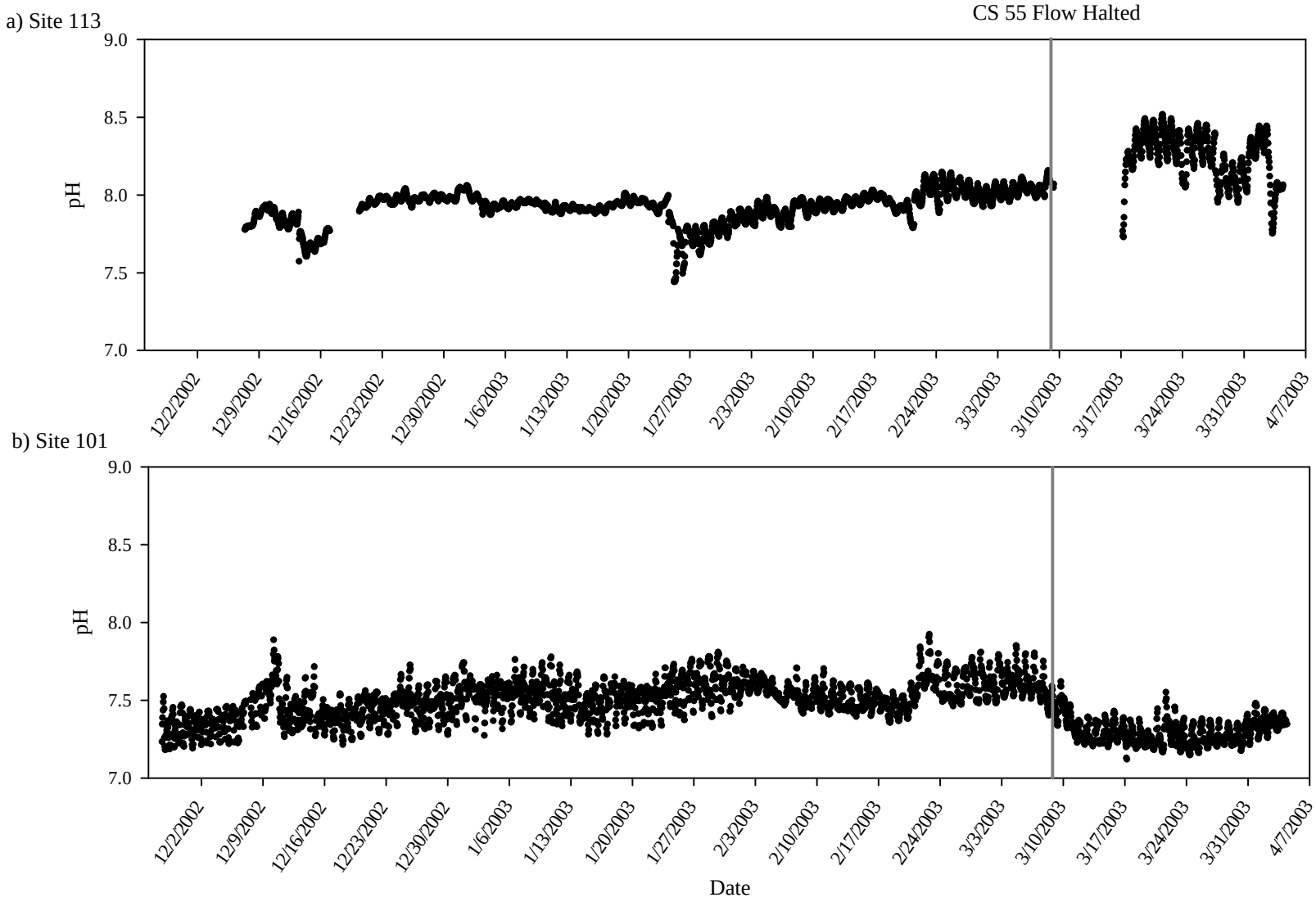


Figure 19 (cont.). The pH Values Observed During the OPFLOW 2002 Study. Values are hourly averages of data collected every 15 minutes. Site 113 (a) is located in a freshwater canal north of Broward County Office of Environmental Services Control Structure (BCOES CS) 17. Site 101 (b) is the most upstream site of the North Fork New River sites followed by Sites 64 (c) and 16 (d). The solid grey line indicates flow was halted from C-13 Canal to North Fork New River on 3/7/03 at the BCOES CS 55.

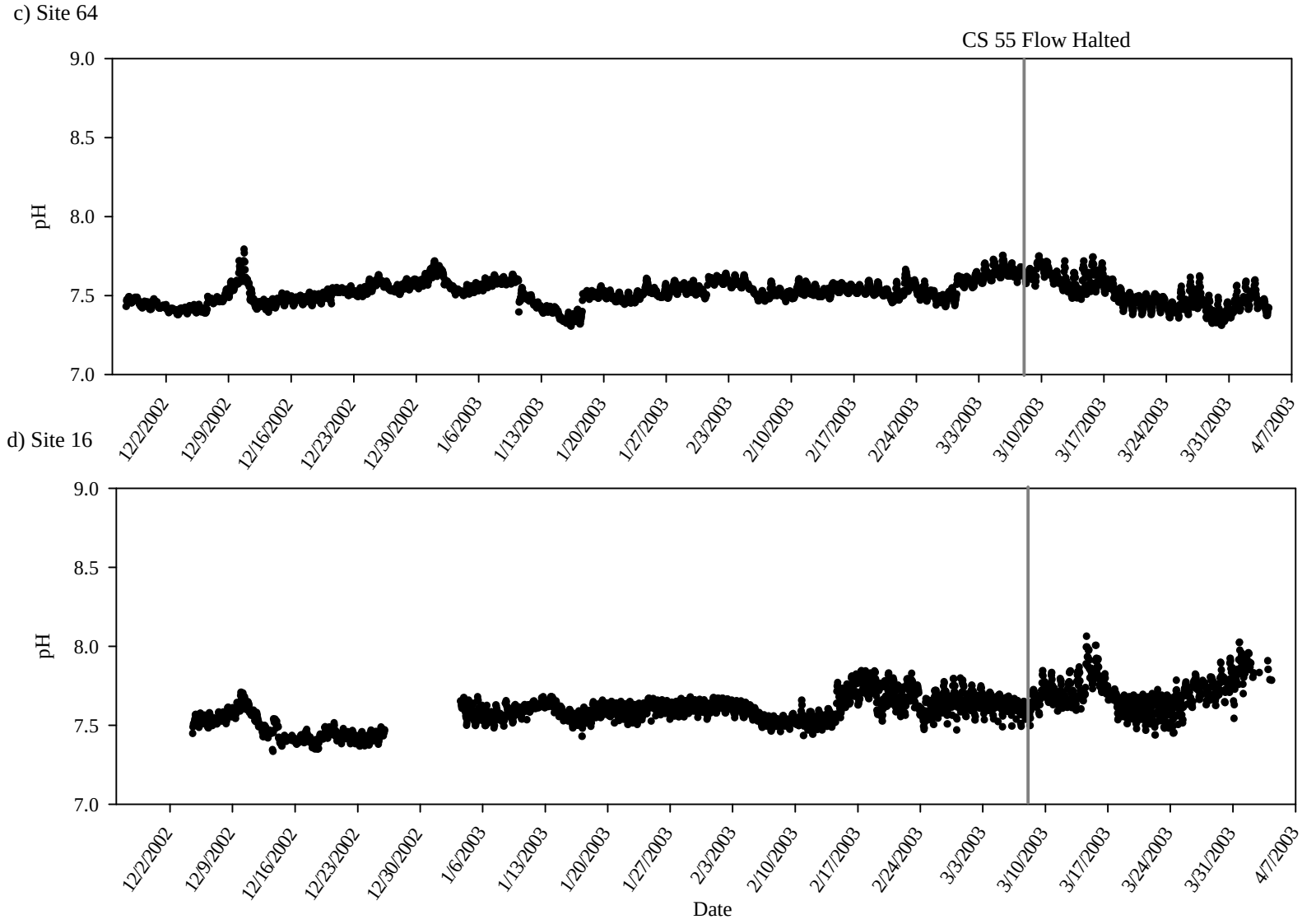


Figure 20. Dissolved Oxygen Concentrations Observed During the OPFLOW 2002 Study. Values are hourly averages of data collected every 15 minutes. Site 113 (a) is located in a freshwater canal north of Broward County Office of Environmental Services Control Structure (BCOES CS) 17. Site 101 (b) is the most upstream site of the North Fork New River sites followed by Sites 64 (c) and 16 (d). The solid grey line indicates flow was halted from the C-13 Canal to North Fork New River on 3/7/03 at the BCOES CS 55. Chapter 27 of the of Broward County's Municipal Code (Broward County 2003) states that water bodies are expected to exceed 5.0 mg/l for a daily average concentration and 4.0 mg/l for any single sample.

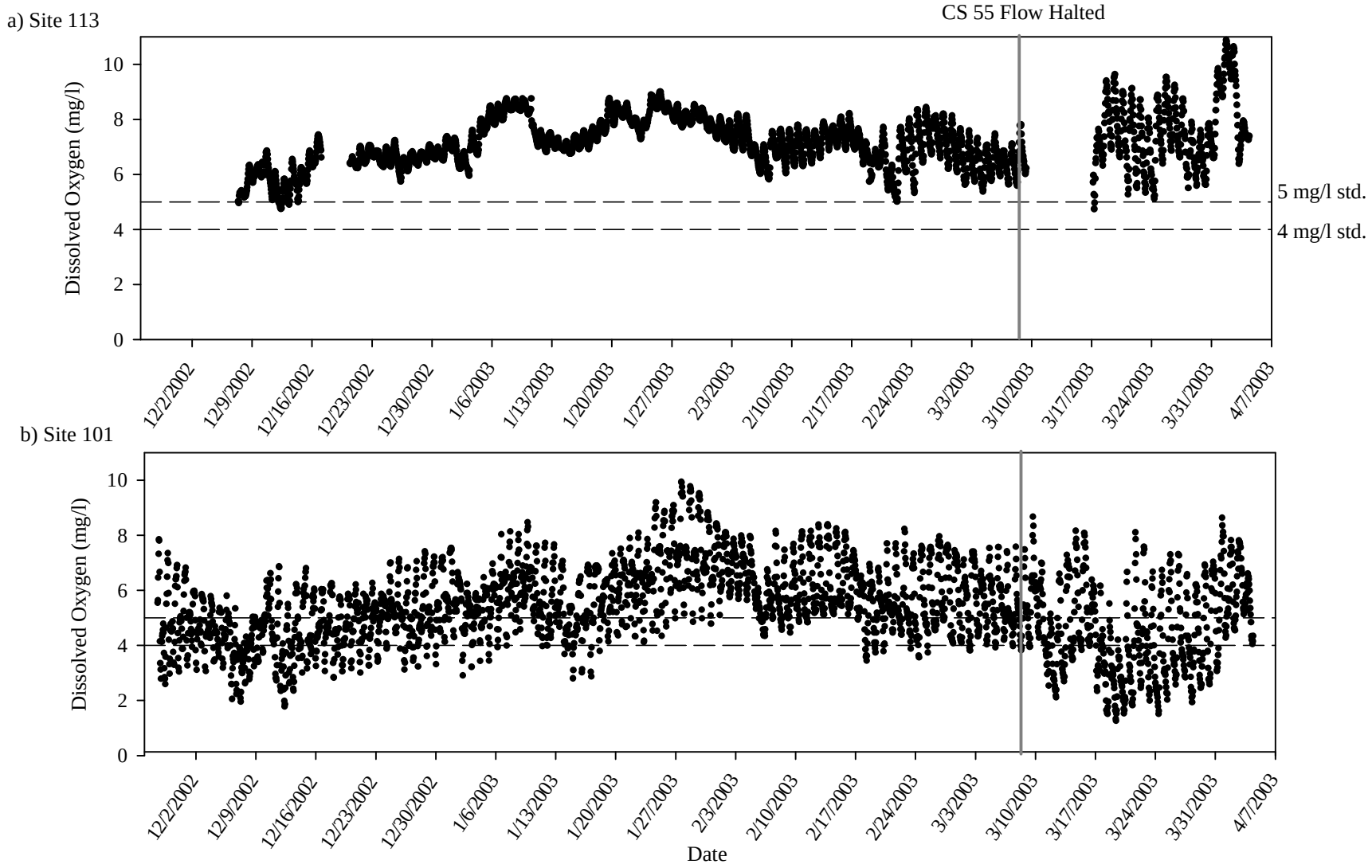


Figure 20 (cont.). Dissolved Oxygen Concentrations Observed During the OPFLOW 2002 Study. Values are hourly averages of data collected every 15 minutes. Site 113 (a) is located in a freshwater canal north of Broward County Office of Environmental Services Control Structure (BCOES CS) 17. Site 101 (b) is the most upstream site of the North Fork New River sites followed by Sites 64 (c) and 16 (d). The solid grey line indicates flow was halted from the C-13 Canal to North Fork New River on 3/7/03 at the BCOES CS 55. Chapter 27 of the of Broward County's Municipal Code (Broward County 2003) states that water bodies are expected to exceed 5.0 mg/l for a daily average concentration and 4.0 mg/l for any single sample.

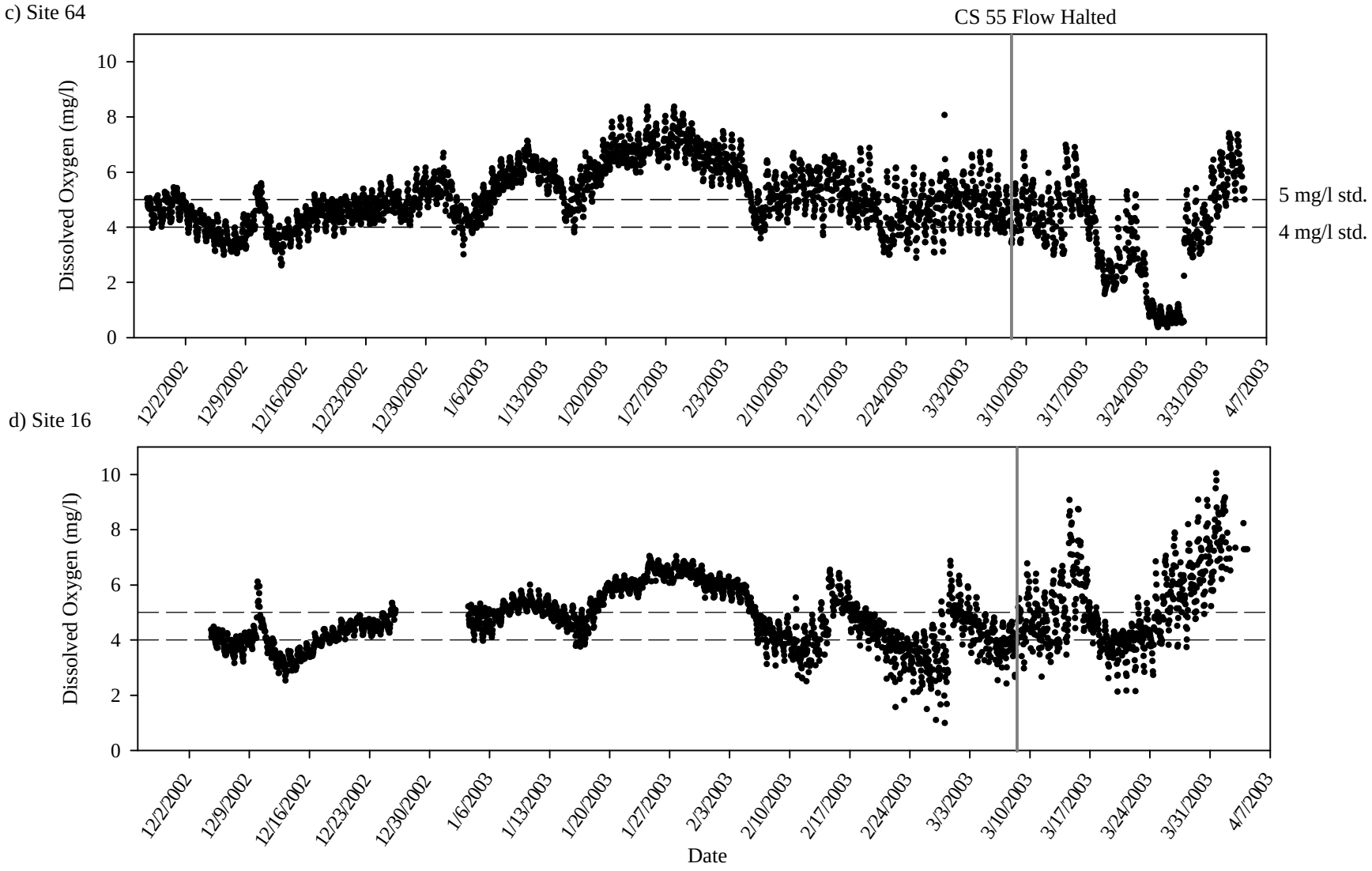


Figure 21. Chlorophyll (Chl) Values Observed During the OPFLOW 2002 Study. Values are based on fluorescence and are hourly averages of data collected every 15 minutes. Site 113 (a) is located in a freshwater canal north of Broward County Office of Environmental Services Control Structure (BCOES CS) 17. Site 101 (b) is the most upstream site of the North Fork New River sites followed by Sites 64 (c) and 16 (d). The solid grey line indicates flow was halted from C-13 Canal to North Fork New River on 3/7/03 at the BCOES CS 55. The solid grey circles are Chl a grab samples collected when the YSI data sondes were "swapped out" and analyzed in the laboratory.

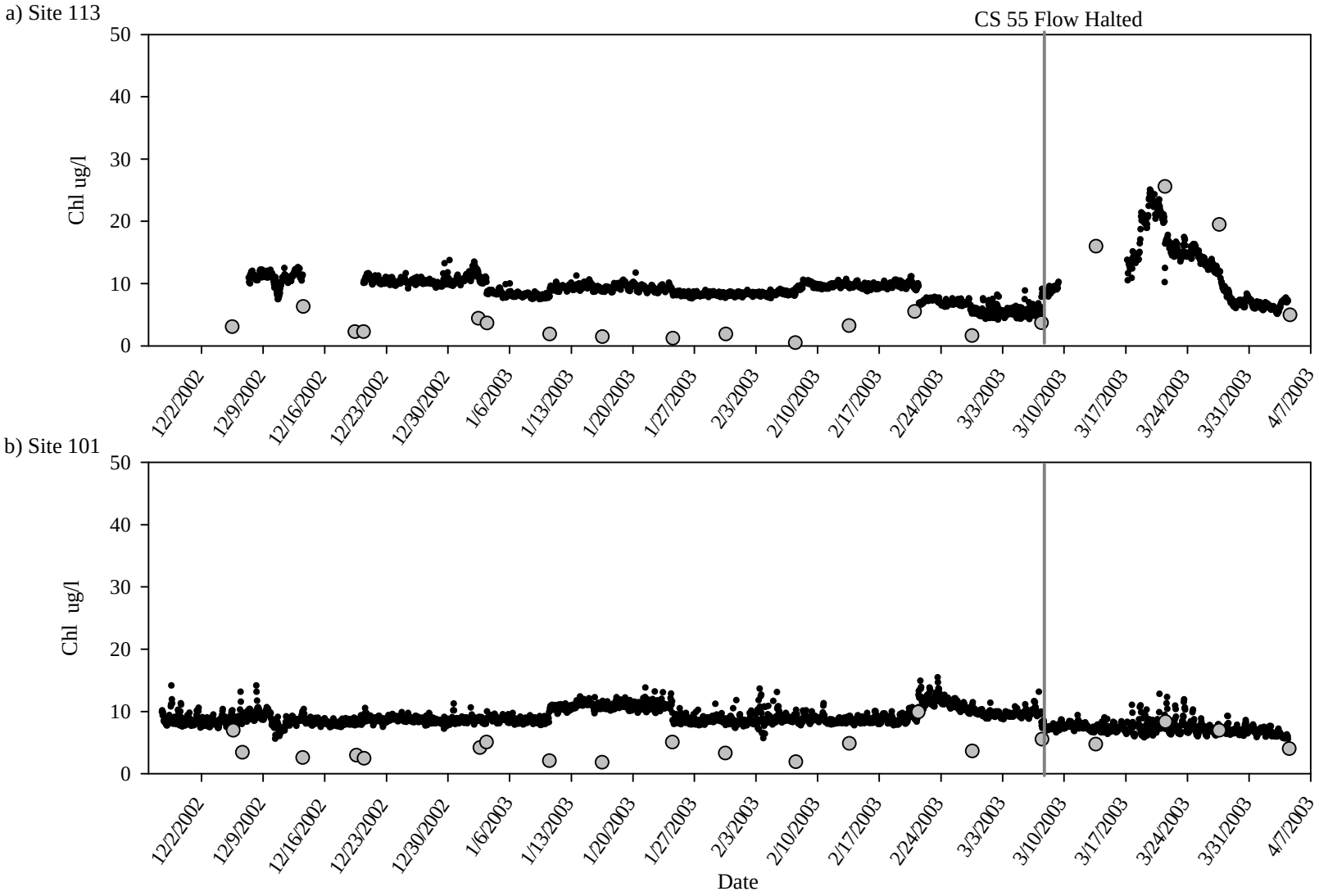
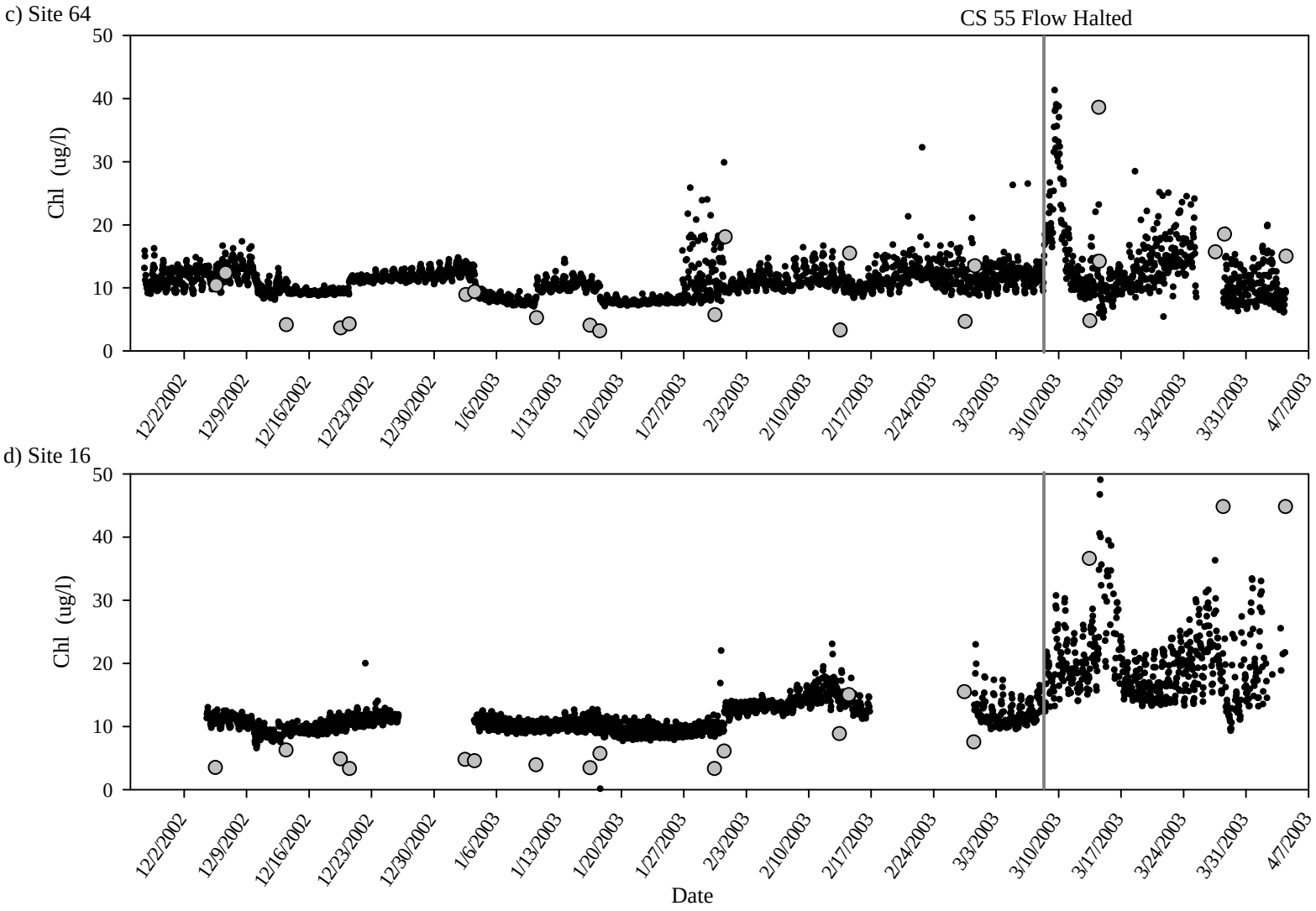


Figure 21 (cont.). Chlorophyll (Chl) Values Observed During the OPFLOW 2002 Study. Values are based on fluorescence and are hourly averages of data collected every 15 minutes. Site 113 (a) is located in a freshwater canal north of Broward County Office of Environmental Services Control Structure (BCOES CS) 17. Site 101 (b) is the most upstream site of the North Fork New River sites followed by Sites 64 (c) and 16 (d). The solid grey line indicates flow was halted from C-13 Canal to North Fork New River on 3/7/03 at the BCOES CS 55. The solid grey circles are Chl a grab samples collected when the YSI data sondes were "swapped out" and analyzed in the laboratory.



The data does suggest a slight trend towards increasing Chl concentrations from upstream to downstream during the flow period (Figure 21). Sites 113 and 101 had chlorophyll concentrations averaging 8.3 $\pm$ 1.6 (mean $\pm$ SD) mg/l and 9.2 $\pm$ 1.2 mg/l respectively while Sites 64 and 16 averaged ~11.2 $\pm$ 3.3 mg/l and 11.2 $\pm$ 2.3 mg/l respectively.

After CS 55 was closed and flow ceased, Chl concentrations increased at all sites (Figure 21) with the exception Site 101 (Figure 21b) where it declined slightly. Site 113 averaged 12.3 $\pm$ 5 mg/l. Chl concentrations at Site 101 were approximately 7.3 $\pm$ 1 mg/l, Site 64 had concentrations of 14.4 $\pm$ 4 mg/l and Site 16 levels were 20.9 $\pm$ 6 mg/l. The trend of increasing chlorophyll concentration at the further downstream stations is much more pronounced during the no-flow period.

5. Turbidity

Turbidity levels were similar at all four stations and generally less than 5 nephelometric turbidity units (NTUs) over the course of this study (Figure 22) and were normally well within the Broward County standard of 10 NTUs (Broward County 2003). There were no clear differences in turbidity trends during flow and no flow periods. Increases in turbidity levels (Figure 22) appeared to be associated with rain events (Figure 7). An exception was observed at Site 64 (Figure 22c) where the highest turbidity level (532 NTUs) was not associated with rain. Potentially, illegal dumping of turbid water either directly or indirectly (e.g., storm drains) led to this observation. The gaps in the data are the result of equipment failure. Grab samples analyzed in the laboratory during the bi-weekly monitoring were very similar to values observed by the YSI (not shown).

C. Bi-weekly Water Quality Monitoring

1. Total Organic Carbon

With values typically between 16 and 17 milligrams per liter (mg/l), Site 113 exhibited the highest total organic carbon (TOC) concentrations of the study (Figure 23a). Site 113 TOC content was at the low end (25th percentile) of historic C-13 Canal values. Sites 101 and 64 TOC concentrations were lower than observed at Site 113 with a typical range of 12 to 14 mg/l during the flow period (Figures 23b and 23c). Total organic carbon values were relatively consistent at Sites 101 and 64 until flow was halted (3/7/03) after which they decreased to historic levels. Site 16 showed an apparent lag response to flow based on TOC concentrations increasing on 12/5/02 substantially from previous values that were near the historic median (Figure 23d). The TOC content at Site 16 was slightly higher than Sites 101 and 64 which suggest other factors (e.g., tidal input of South Fork New River water) may have been contributing to the observed concentrations (Figures 23b, 23c, and 23d). Historically, Site 16 has slightly higher ambient values than the other North Fork sites.

2. Fecal Coliform

All four sites exhibited fecal coliform (FC) values above (i.e., out of compliance) the single sample water quality standard of 800 colonies/ 100 ml (Broward County 2003, Figure 24). The existence of flow did not appear to influence the occurrence of peak FC values. With

Figure 22. Turbidity Values Observed During the OPFLOW 2002 Study. Values are hourly averages of data collected every 15 minutes. Site 113 (a) is located in a freshwater canal north of Broward County Office of Environmental Services Control Structure (BCOES CS) 17. Site 101 (b) is the most upstream site of the North Fork New River sites followed by Sites 64 (c) and 16 (d). The solid grey line indicates flow was halted from C-13 Canal to North Fork New River on 3/7/03 at the BCOES CS 55.

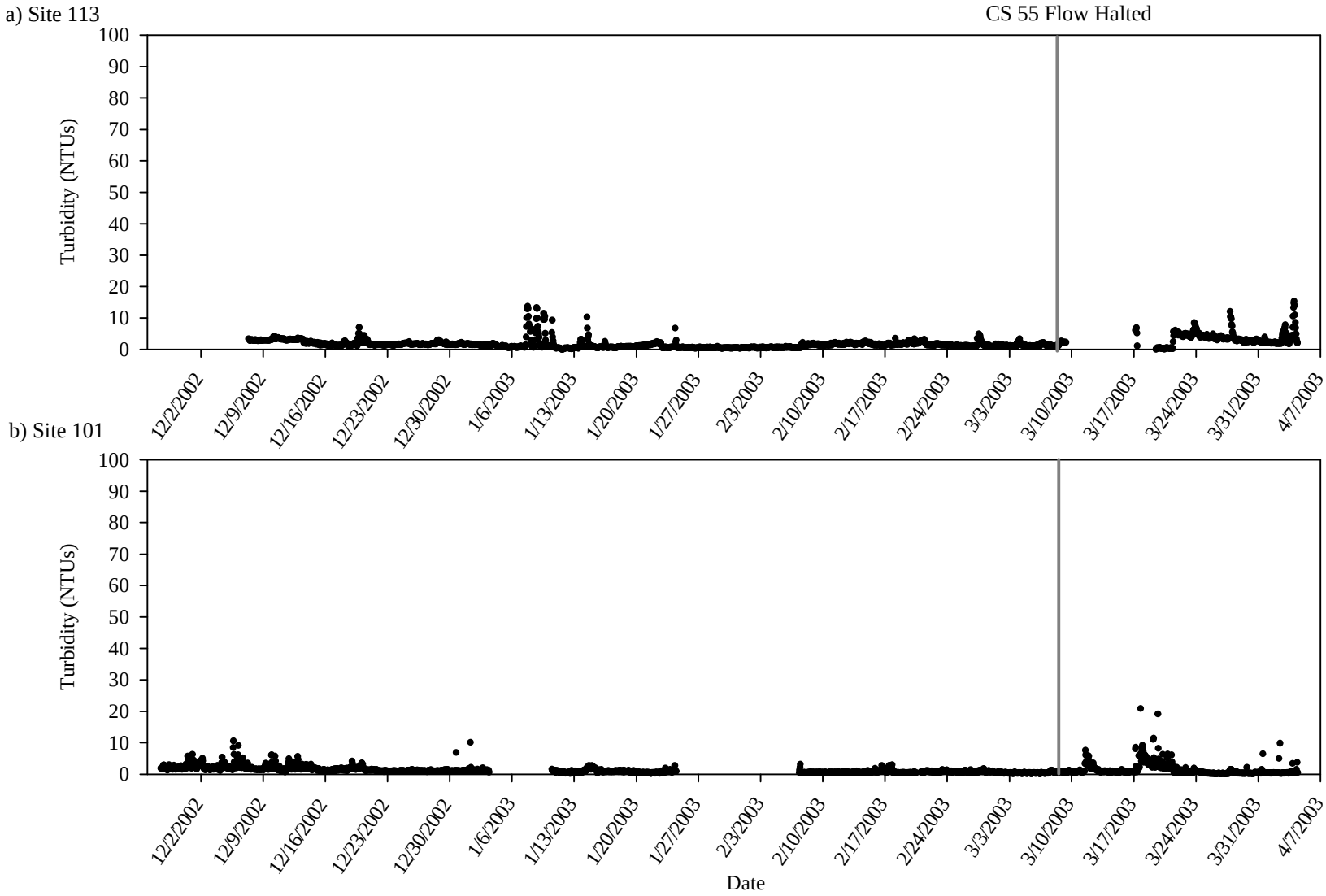


Figure 22 (cont.). Turbidity Values Observed During the OPFLOW 2002 Study. Values are hourly averages of data collected every 15 minutes. Site 113 (a) is located in a freshwater canal north of Broward County Office of Environmental Services Control Structure (BCOES CS) 17. Site 101 (b) is the most upstream site of the North Fork New River sites followed by Sites 64 (c) and 16 (d). The solid grey line indicates flow was halted from C-13 Canal to North Fork New River on 3/7/03 at the BCOES CS 55.

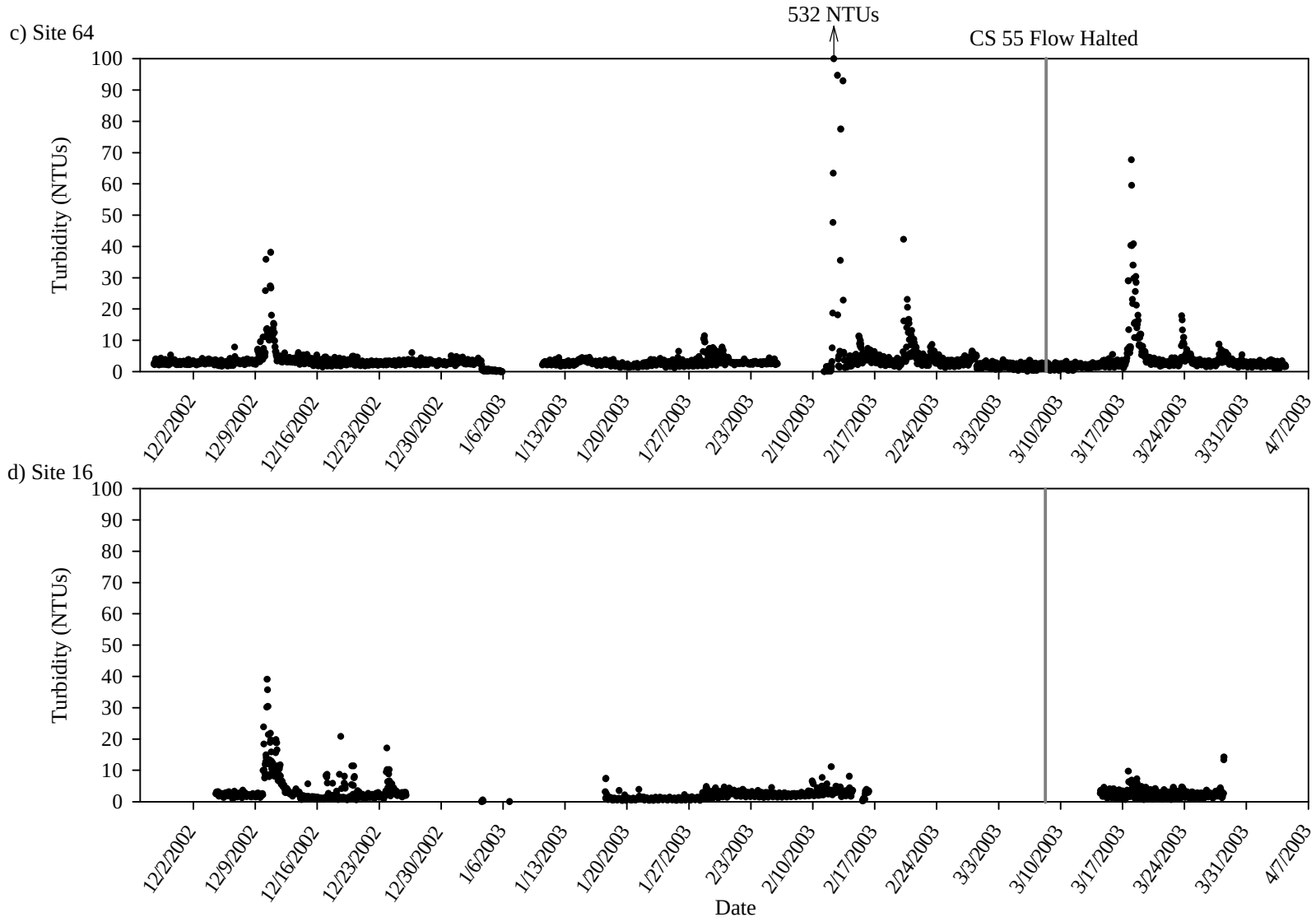
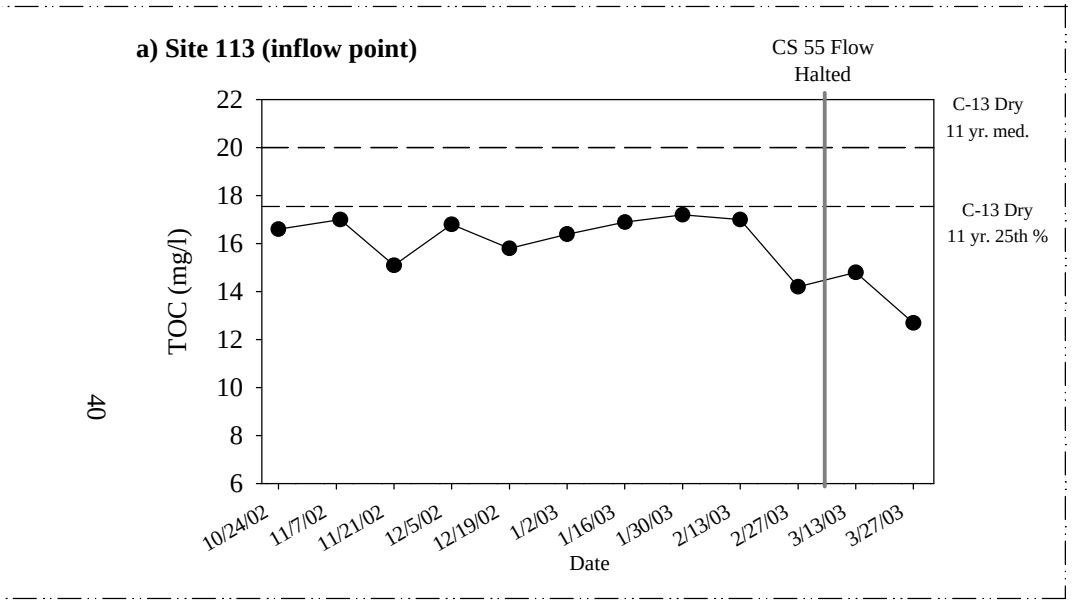
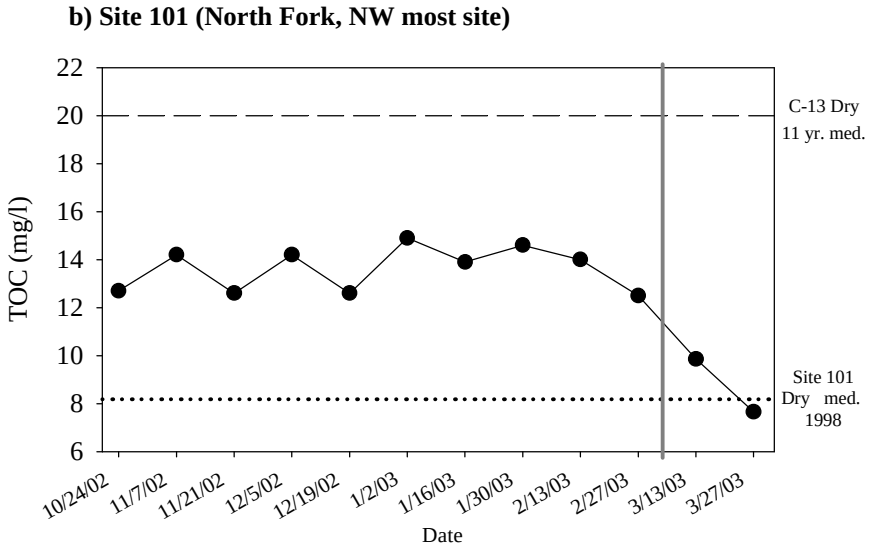
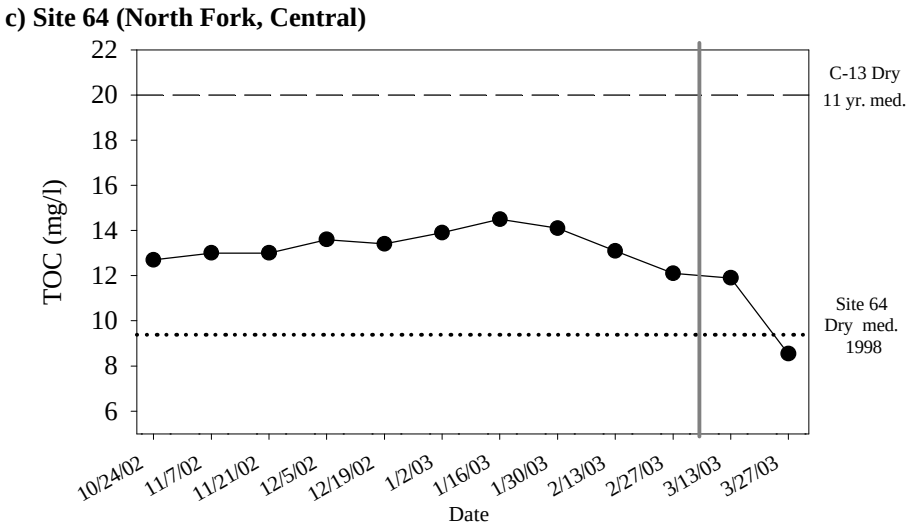


Figure 23. Total Organic Carbon (TOC) Values Observed Over Time. Site 113 (a) data are compared to median and 25th percentile TOC concentrations in the C-13 Canal (BCDEP Site 13) obtained from 1992 thru 2002 quarterly monitoring (dry season values only). The North Fork New River sites 101 (b), 64 (c), and 16 (d) are compared to the C-13 median value, as well as any historical data for the specific site. Sites 101 and 64 historical TOC values are from a 1998 bi-weekly monitoring program (dry season) Quarterly monitoring data (dry season) from 1992 thru 2002 were used for Site 16. The grey vertical bar represents when flow was halted from C-13 Canal to North Fork New River on 3/7/03 at the BCOES CS 55.







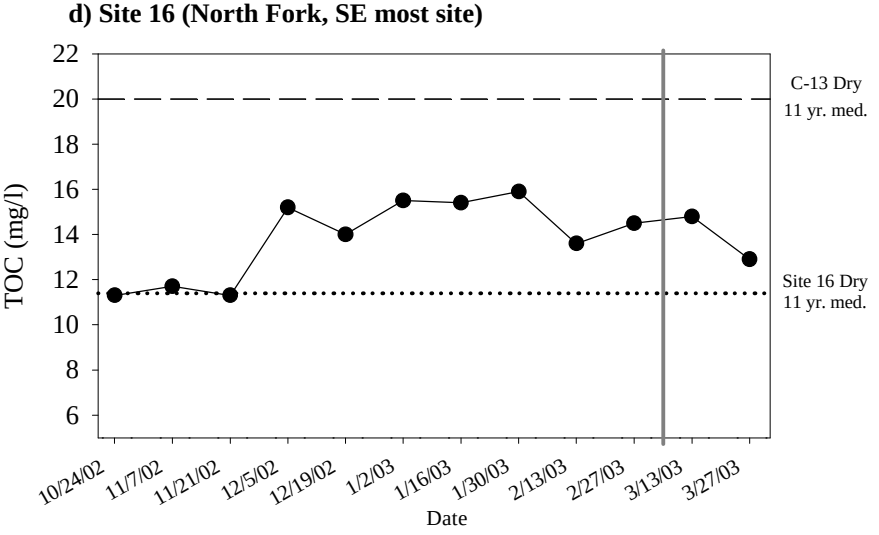
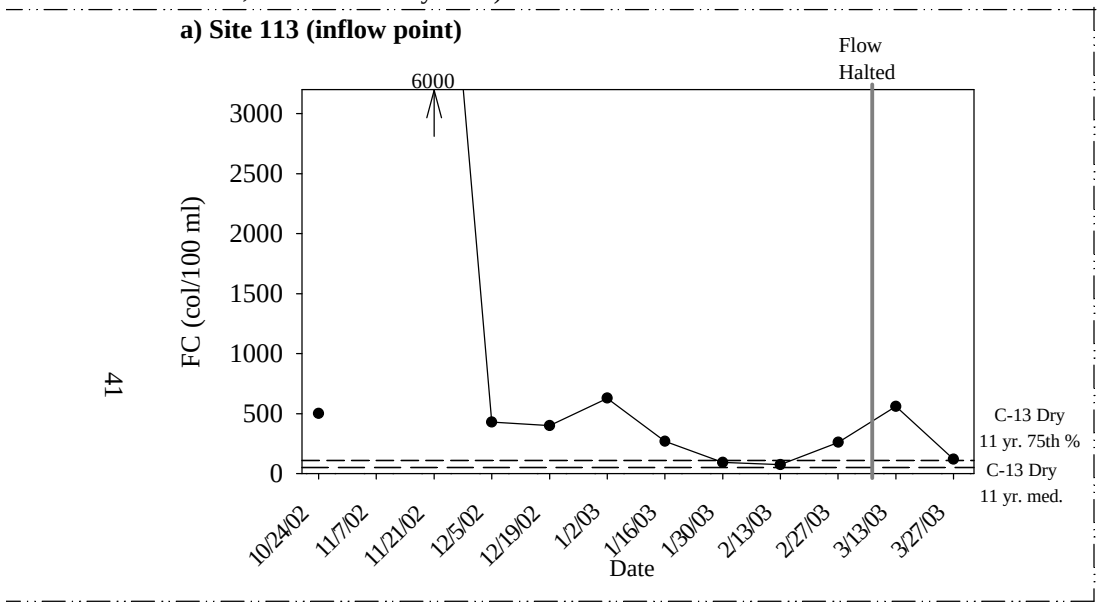
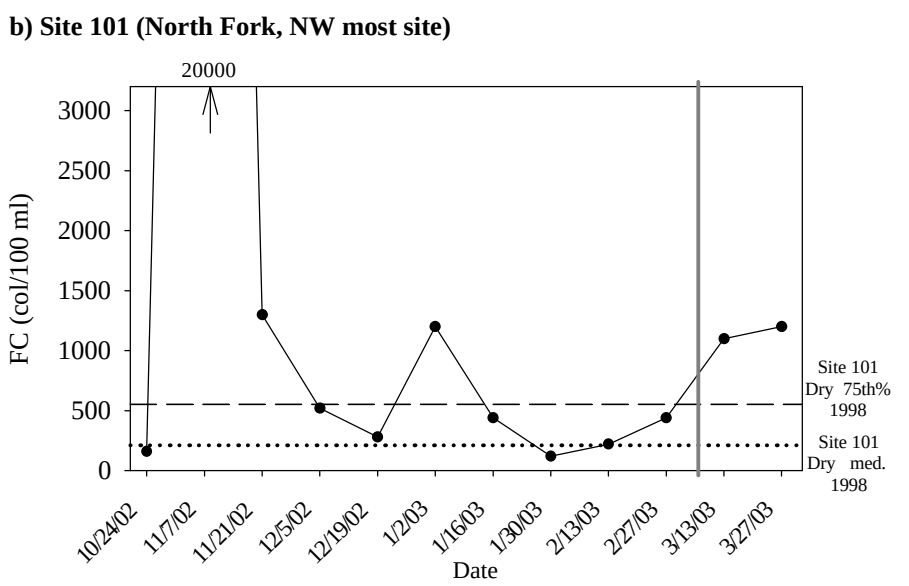
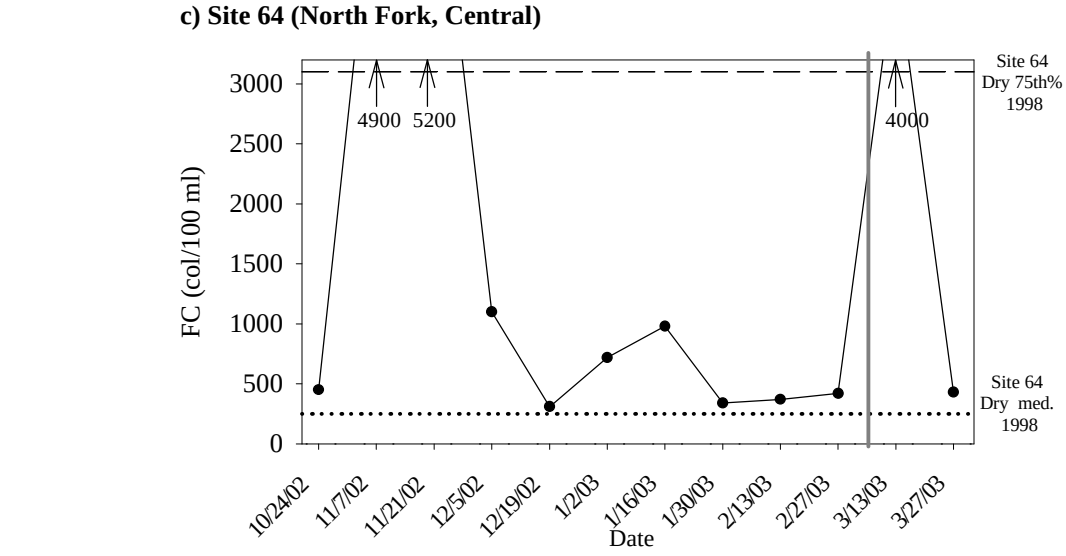
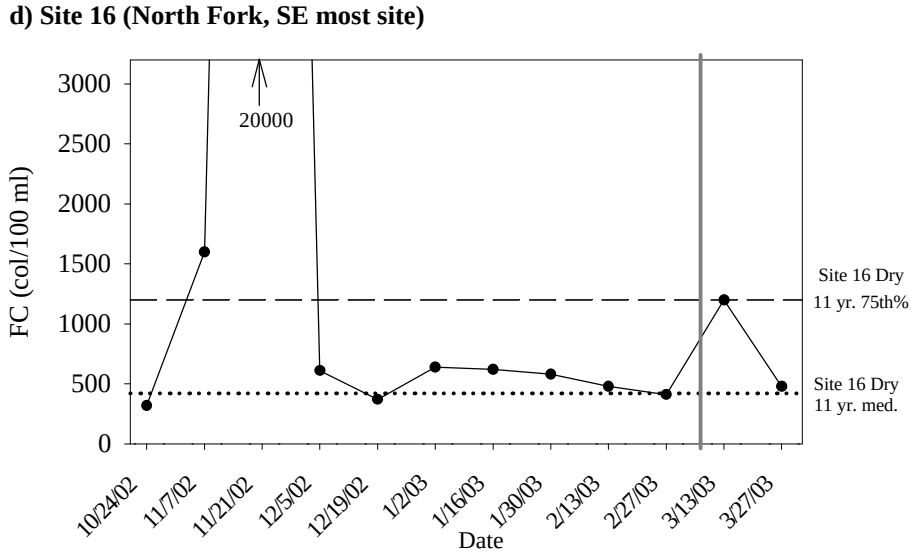


Figure 24. Fecal Coliform (FC) Values Observed Over Time. Site 113 (a) data are compared to median and 75th percentile FC concentrations in the C-13 Canal (BCDEP Site 13) obtained from 1992 thru 2002 quarterly monitoring (dry season values only). The North Fork New River sites 101 (b), 64 (c), and 16 (d) are compared to historical median and 75th percentile %) data for the specific site. Sites 101 and 64 historical FC values are from a bi-weekly monitoring (dry season) program in 1998. Quarterly monitoring data (dry season only) from 1992 thru 2002 were used for Site 16. The grey vertical bar represents when flow was halted from C-13 Canal to North Fork New River on 3/7/03 at the BCOES CS 55. Note the single sample water quality standard is 'shall not exceed 800 colonies per 100 ml' (col/ 100 ml, Broward County 2003).









few exceptions, most FC counts were also above the monthly standard of 200 colonies/100 ml, as well as the C-13 Canal historic dry season median value. However, many of the samples at the three North Fork sites (101, 64, and 16) were below their specific historical median (Figures 24a, 24b, and 24c).

3. Nitrogen

Total nitrogen (Figure 25) is the sum of total Kjeldhal nitrogen (TKN, Figure 26) and nitrite and nitrate-nitrogen (NO_x, Figure 27). Ammonia-nitrogen (NH_3, Figure 28) and organic nitrogen constitute TKN. Both NH_3 and NO_x are the forms of nitrogen most readily available to phytoplankton.

At Site 113, total nitrogen (TN) concentrations appeared consistent with historic C-13 Canal values until flow was halted and the final sample revealed much lower TN content than previously observed (Figure 25a). Water flow from the C-13 Canal appeared to increase total nitrogen values in the North Fork New River (Figures 25b, 25c, and 25d). Sites 101 and 64 consistently had values at or near the historic C-13 median until the CS 55 was closed and a decreasing trend was observed. Site 16 had the highest TN values (Figure 25d) despite being the furthest downstream of the inflow point (Site 113) and may have other significant contributions of nitrogen.

The TKN values (Figure 26) generally tracked the pattern of TN concentrations (Figure 25). However, Sites 113, 101, and 64 had TKN values typically below the C-13 Canal historic median (Figures 26a, 26b, and 26c). Sites 101 and 64 even had TKN values more closely associated with their previous ambient values despite having more overall TN. Conversely, NO_x values (Figure 27) were much greater during the flow period. Thus, the elevated TN (Figure 25) consisted of a larger pool of NO_x than previously observed. The NO_x levels decreased after the CS 55 was closed at all sites. Ammonia-nitrogen values did not exhibit a consistent pattern with the exception of a steady decline at Site 16 after January 30th (Figure 28). Site 101 (Figure 28b) was characterized by much lower NH_3 values than observed previously while Site 16 showed the converse (Figure 28d).

4. Total Phosphorus

Total phosphorus (TP) concentrations decreased rapidly over the first eight weeks throughout the study area (Figure 29). After the first four observations, TP levels remained relatively stable with occasional exceptions until the CS 55 flow was halted. The TP concentrations at Site 113 were very similar to C-13 Canal values after the initial decrease. All three North Fork New River sites exhibited decreases in TP content when compared to their historic medians (Figures 29b, 29c, and 29d). Site 101 and 64 TP levels were actually more reflective of the historic C-13 Canal median than their respective ambient values until CS 55 was closed (Figures 29b and 29c). The effect of closing CS 55 did not initially seem as pronounced at Site 16 (Figure 29d) and Site 16 typically had the highest TP values of the study, though improvements were seen.

Figure 25. Total Nitrogen (TN) Values Observed Over Time. Site 113 (a) data are compared to median and 25th percentile TN concentrations in the C-13 Canal (BCDEP Site 13) obtained from 1992 thru 2002 quarterly monitoring (dry season values only). The North Fork New River sites 101 (b), 64 (c), and 16 (d) are compared to the C-13 median value, as well as any historical data for the specific site. Sites 101 and 64 historical TN values are from a 1998 bi-weekly monitoring program (dry season). Quarterly monitoring data (dry season) from 1992 thru 2002 were used for Site 16. The grey vertical bar represents when flow was halted from C-13 Canal to North Fork New River on 3/7/03 at the BCOES CS 55.

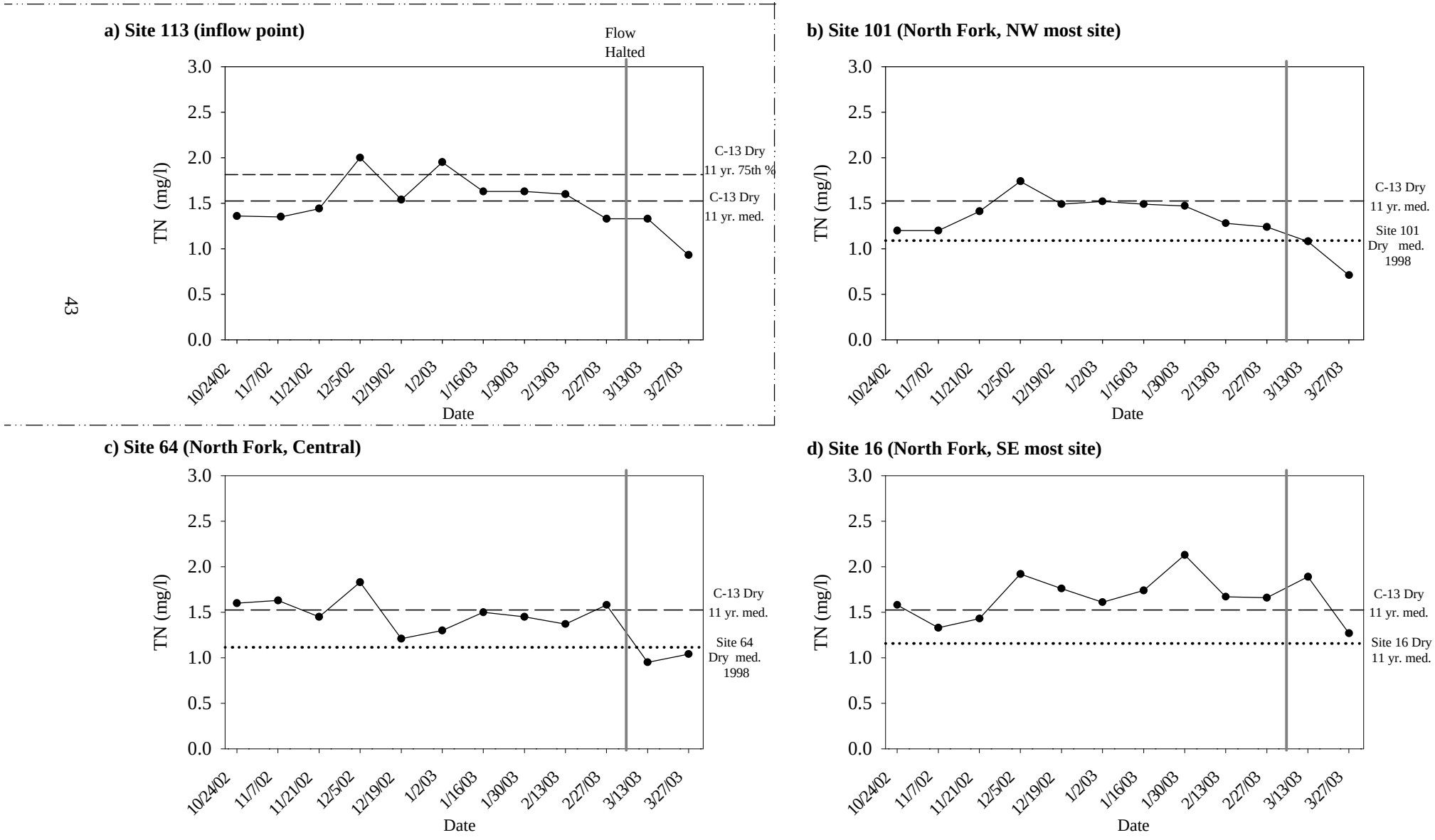
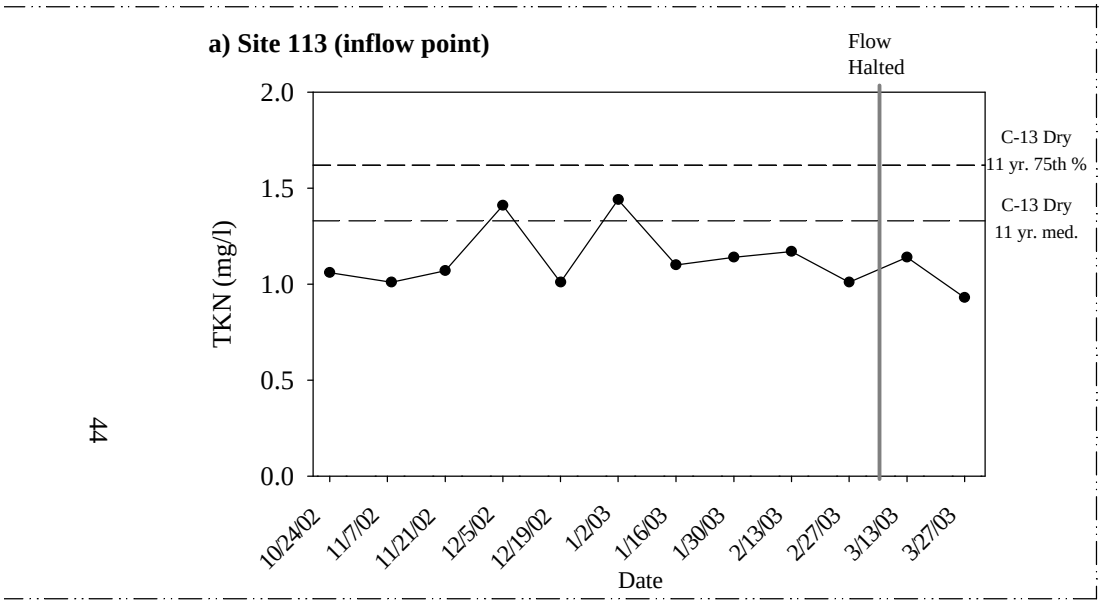
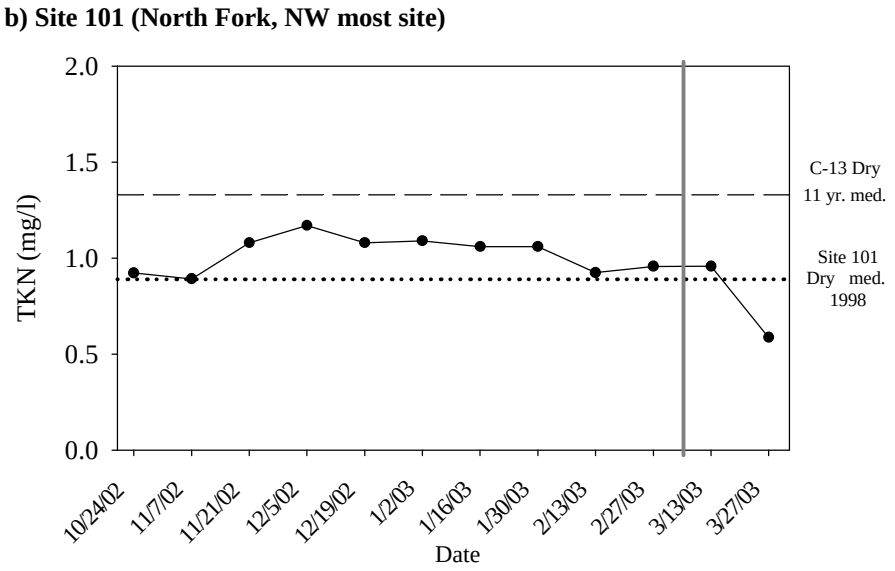
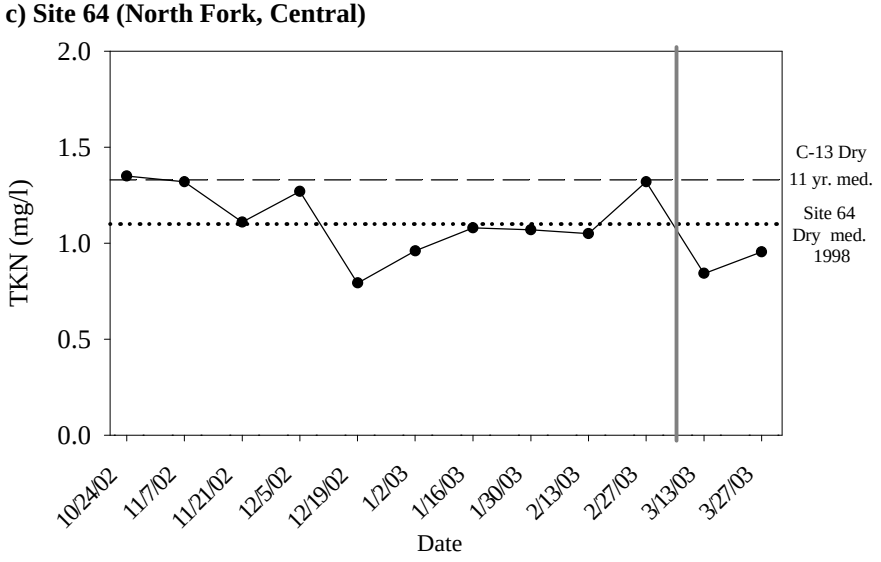


Figure 26. Total Kjeldhal Nitrogen (TKN) Values Observed Over Time. Site 113 (a) data are compared to median and 75th percentile TKN concentrations in the C-13 Canal (BCDEP Site 13) obtained from 1992 thru 2002 quarterly monitoring (dry season values only). The North Fork New River sites 101 (b), 64 (c), and 16 (d) are compared to the C-13 median value, as well as any historical data for the specific site. Sites 101and 64 historical TKN values are from a 1998 bi-weekly monitoring program. Quarterly monitoring data (dry season) from 1992 thru 2002 were used for Site 16. The grey vertical bar represents when flow was halted from C-13 Canal to North Fork New River on 3/7/03 at the BCOES CS 55.







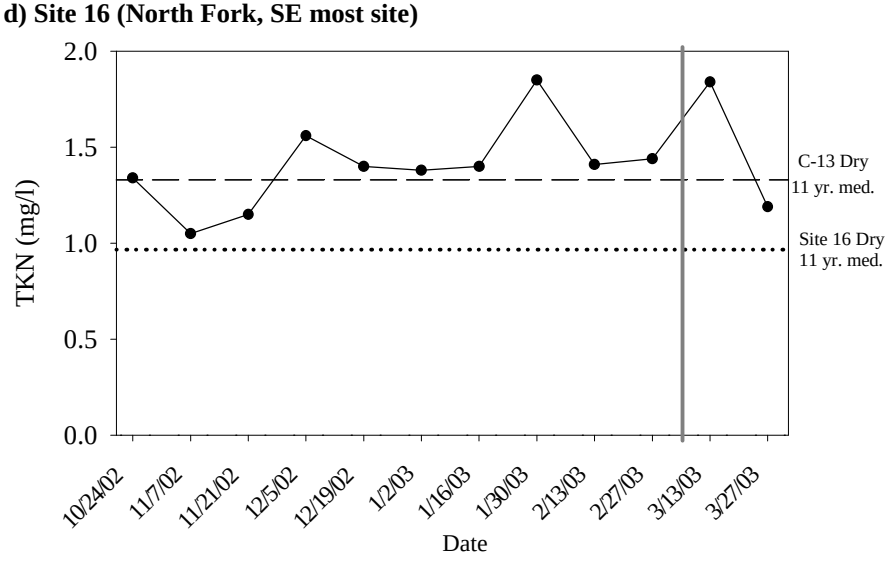


Figure 27. Nitrite and Nitrate-Nitrogen (NOx) Values Observed Over Time. Site 113 (a) data are compared to median and 75th percentile NOx concentrations in the C-13 Canal (BCDEP Site 13) obtained from 1992 thru 2002 quarterly monitoring (dry season values only). The North Fork New River sites 101 (b), 64 (c), and 16 (d) are compared to the C-13 median value, as well as any historical data for the specific site. Sites 101and 64 historical NOx values are from a 1998 bi-weekly monitoring program. Quarterly monitoring data (dry season) from 1992 thru 2002 were used for Site 16. The grey vertical bar represents when flow was halted from C-13 Canal to North Fork New River on 3/7/03 at the BCOES CS 55.

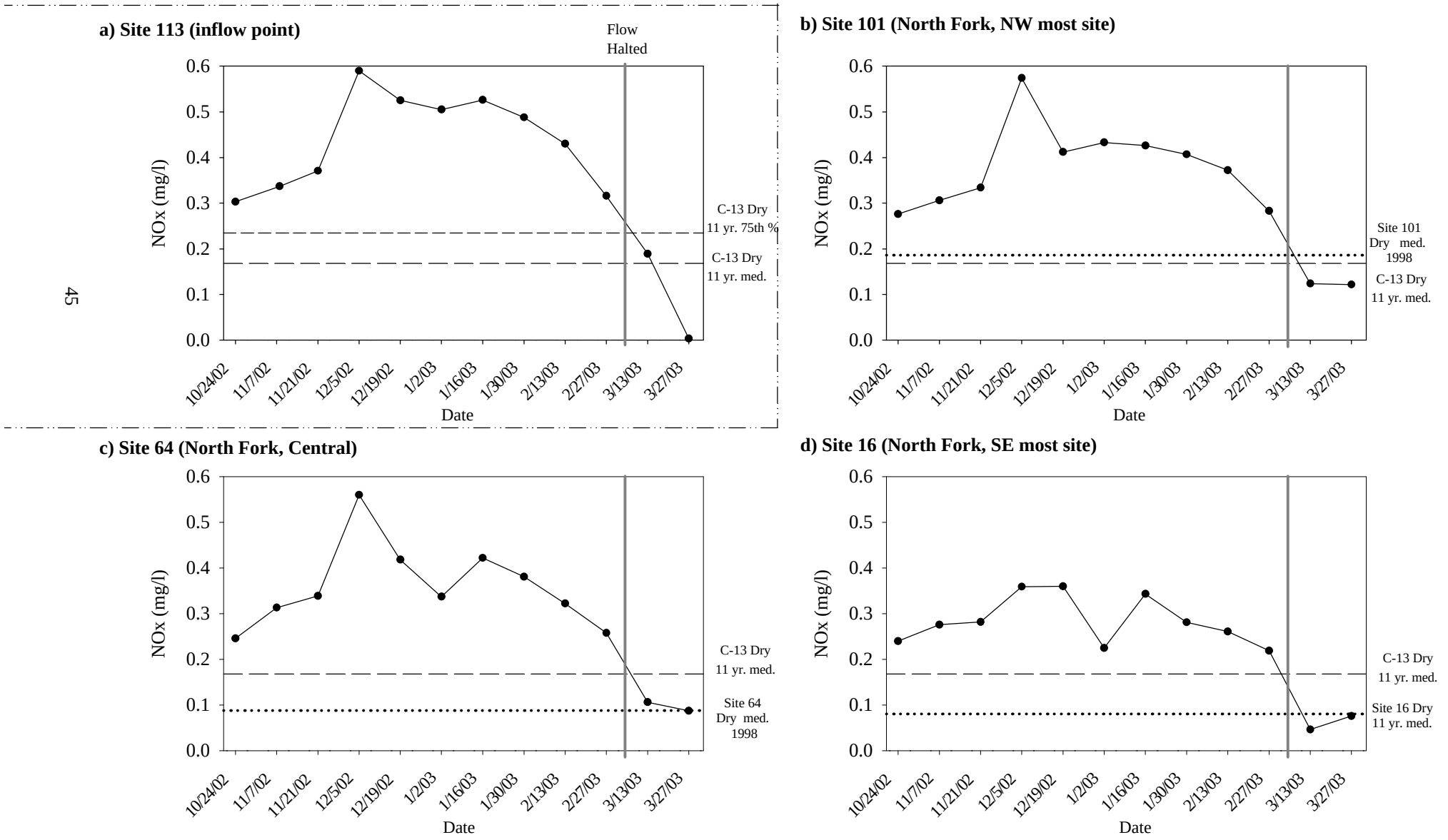


Figure 28. Ammonia-Nitrogen (NH3) Values Observed Over Time. Site 113 (a) data are compared to median and 75th percentile NH3 concentrations in the C-13 Canal (BCDEP Site 13) obtained from 1992 thru 2002 quarterly monitoring (dry season values only). The North Fork New River sites 101 (b), 64 (c), and 16 (d) are compared to the C-13 median value, as well as any historical data for the specific site. Sites 101and 64 historical NH3 values are from a 1998 bi-weekly monitoring program Quarterly monitoring data (dry season) from 1992 thru 2002 were used for Site 16. The grey vertical bar represents when flow was halted from C-13 Canal to North Fork New River on 3/7/03 at the BCOES CS 55.

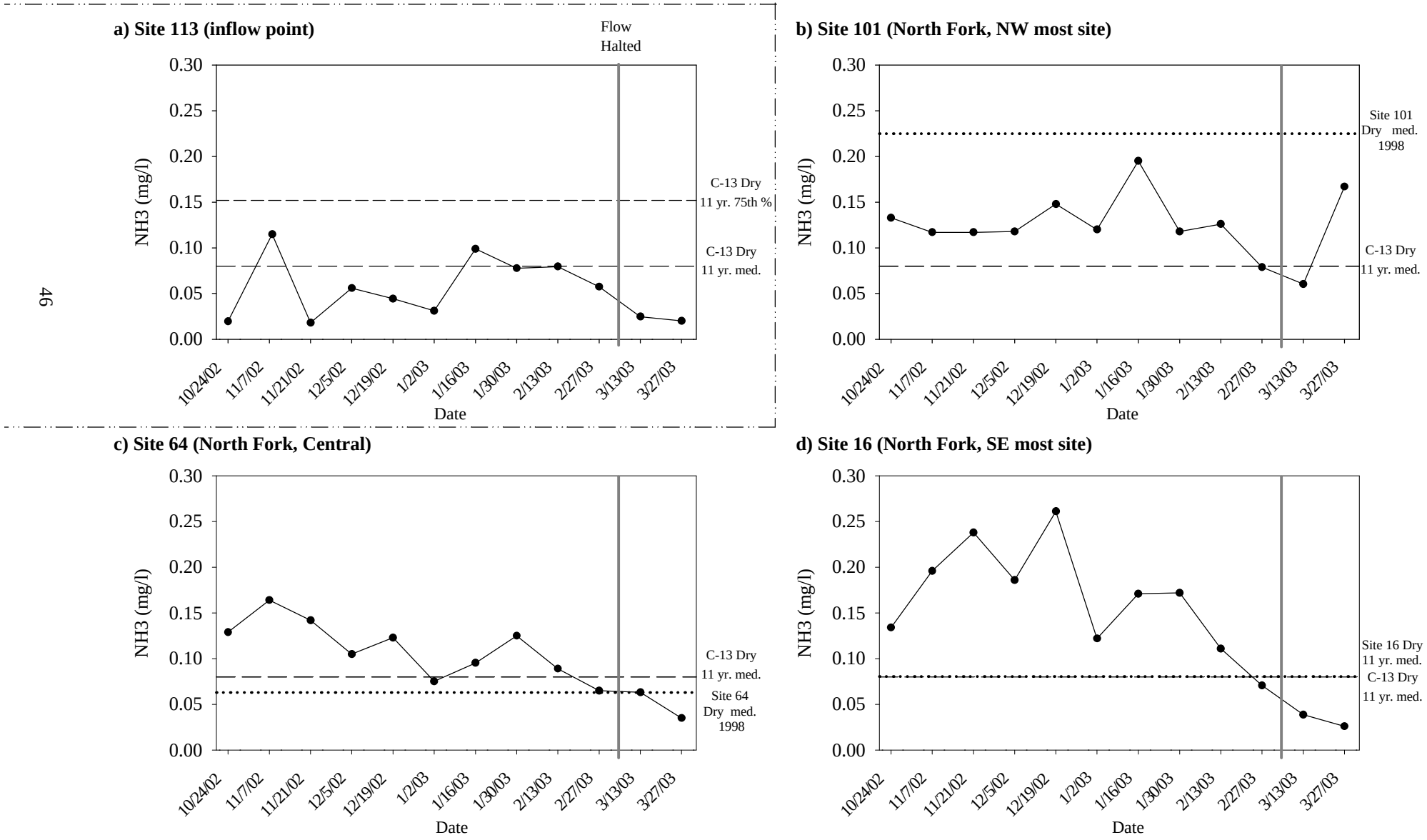
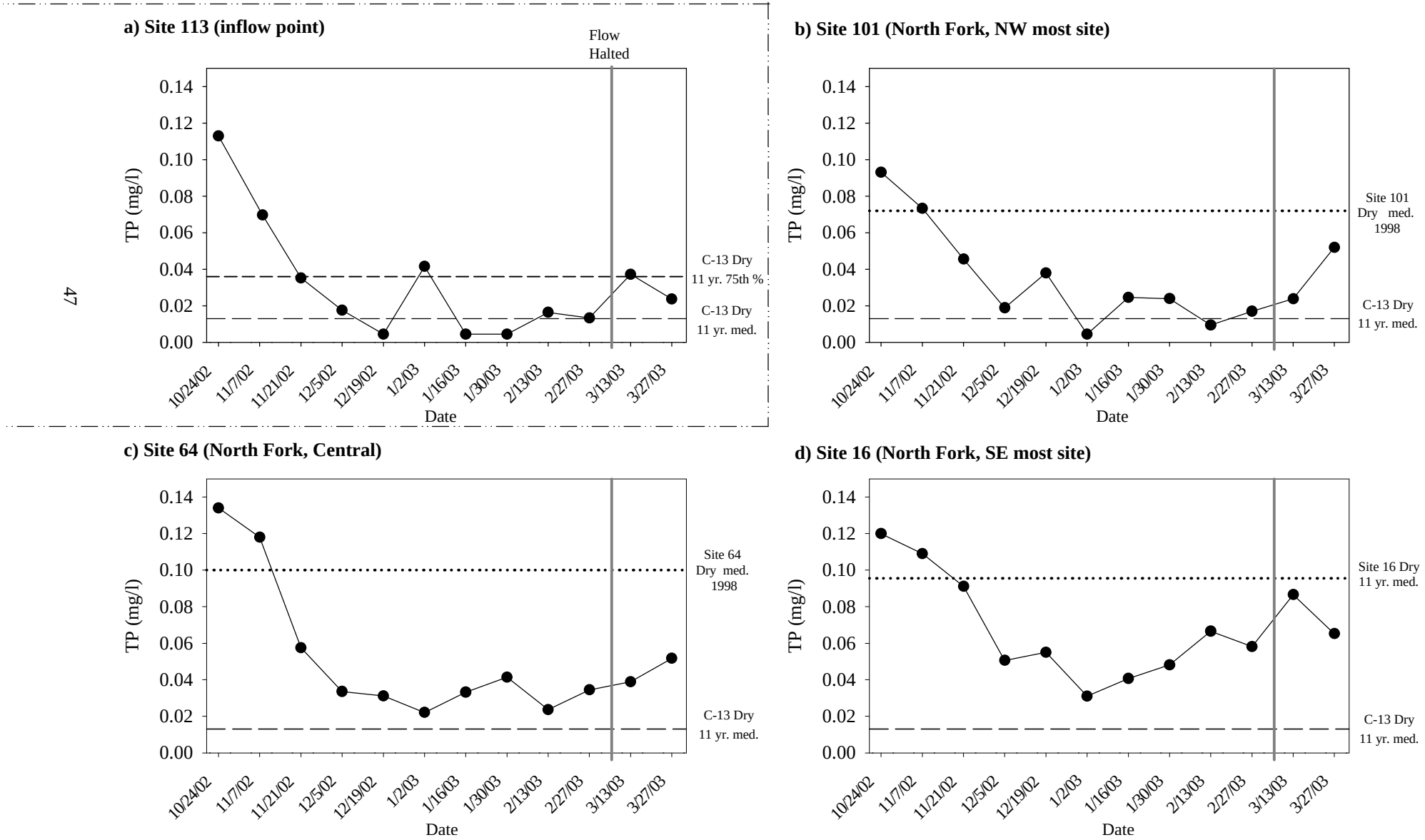


Figure 29. Total Phosphorus (TP) Values Observed Over Time. Site 113 (a) data are compared to median and 75th percentile TP concentrations in the C-13 Canal (BCDEP Site 13) obtained from 1992 thru 2002 quarterly monitoring (dry season values only). The North Fork New River sites 101 (b), 64 (c), and 16 (d) are compared to the C-13 median value, as well as any historical data for the specific site. Sites 101and 64 historical TP values are from a 1998 bi-weekly monitoring program. Quarterly monitoring data (dry season) from 1992 thru 2002 were used for Site 16. The grey vertical bar represents when flow was halted from C-13 Canal to North Fork New River on 3/7/03 at the BCOES CS 55.



5. Chlorophyll a

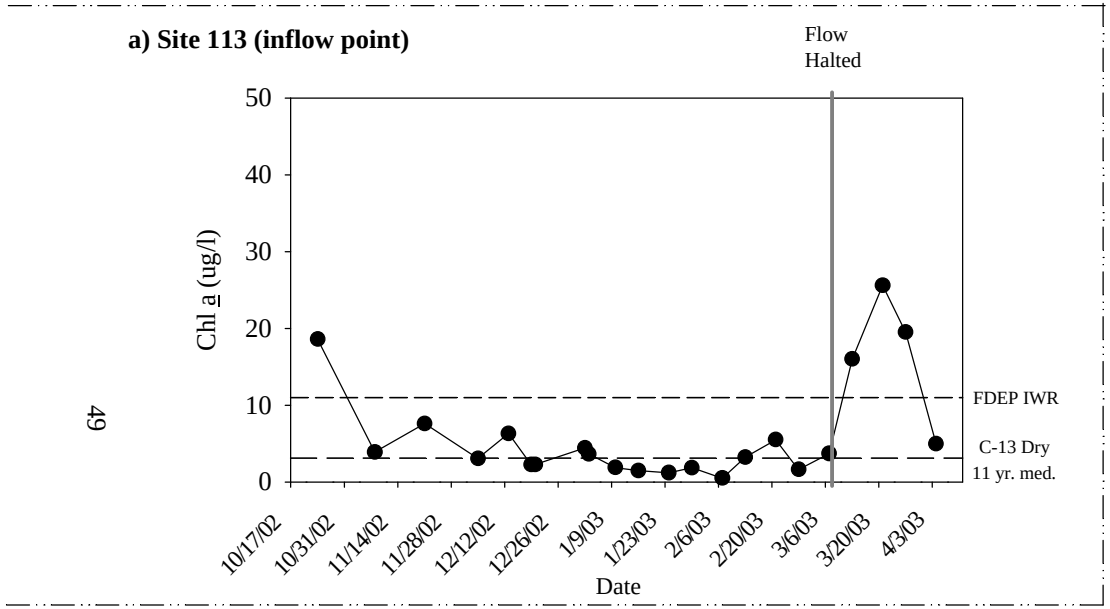
Chlorophyll a (Chl a) grab measurements were taken more frequently than other bi-weekly parameters because of the YSI fluorometric chlorophyll monitoring (see Figure 21). The Chl a grab samples are normally a more accurate measurement than fluorometric chlorophyll. Thus, the Chl a grab samples and were obtained during the 'swap out' to ground truth the YSI datasonde analyses, as well as during bi-weekly sampling.

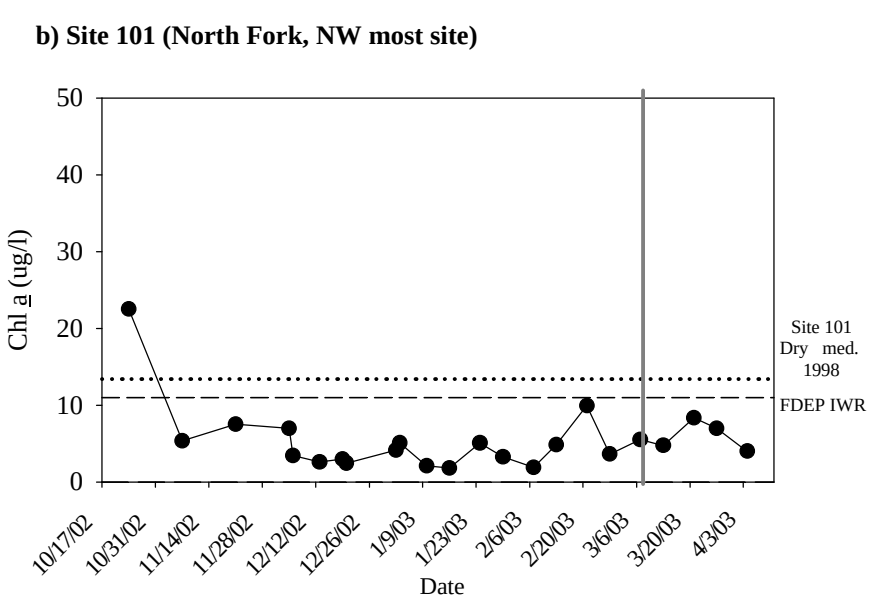
Sampling was done on some occasions twice a week with a two week period between sampling days. Weekly sampling occurred at other times. All data are shown in Figure 30 and compared to both historic ambient concentrations and a Florida Department of Environmental Protection (FDEP) Chl a threshold value (11 ug/l). This annual mean value is being used in the development of total maximum daily loads for nutrients in estuaries as listed in the FDEP's Impaired Water Rule (IWR, Florida Administrative Code 2002, 62-303) http://www.dep.state.fl.us/water/tmdl/index.htm.

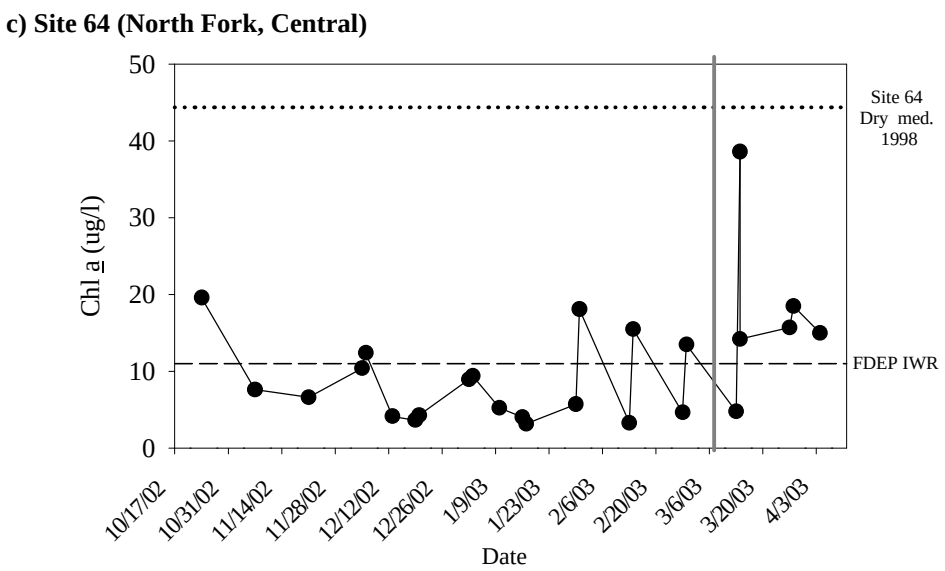
An estuarine water body (e.g., North Fork New River) exhibiting a Chl a annual mean over 11 ug/l will likely be designated a candidate for a TMDL based on nutrient impairment. The FDEP IWR value for estuaries is being used at Site 113 (a freshwater canal, Figure 30a) in order to evaluate it as a discharge point into an estuary. The historic dry season Chl a median at all North Fork sites was greater than the IWR nutrient impairment (Figure 30). Conversely, the C-13 Canal median Chl a at the inflow point was well below the IWR threshold.

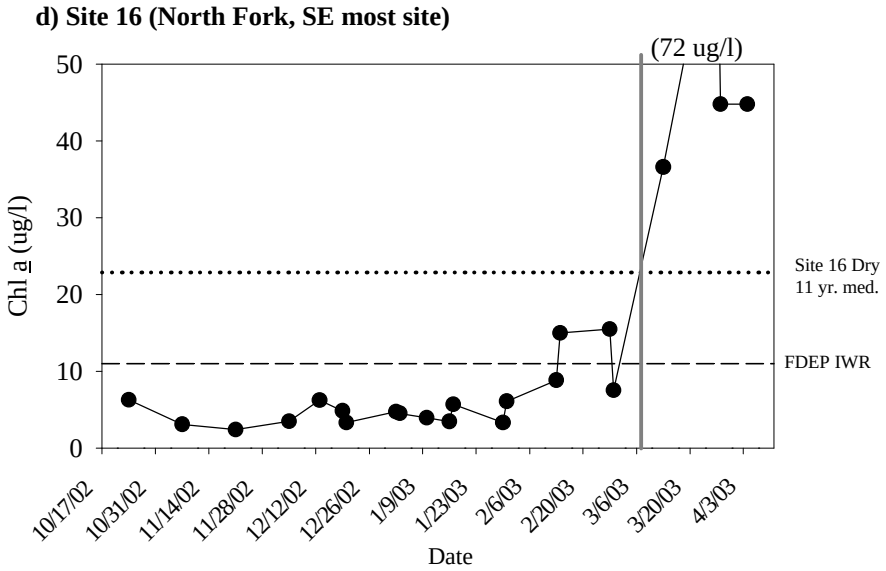
With some exceptions, the North Fork New River and the secondary canal had Chl a values below 11 ug/l throughout much of the period of flow (10/22/02 thru 3/7/03, Figures 30b, c, and d). The first sampling day (10/24/02) was one notable exception at Sites 113, 101 and 64 but not Site 16. Site 64 was characterized by the most occurrences above 11 ug/l and displayed the most between sample variability of all sites. The samples at Site 64 frequently varied by 11 ug/l (Figure 30c) even though they were collected at similar tidal stages one day apart. Sites 113, 64 and 16 showed substantial increases above the IWR threshold after the CS 55 was closed while Site 101 remained relatively stable (Figure 30c and d).

Figure 30. Chlorophyll a (Chl a) Values Observed Over Time. Site 113 (a) data are compared to median Chl a concentrations in the C-13 Canal (BCDEP Site 13) obtained from 1996 thru 2002 quarterly monitoring (dry season values only). The North Fork New River sites 101 (b), 64 (c), and 16 (d) are compared to historical data for the specific site. Sites 101and 64 historical Chl a values are from a 1998 bi-weekly monitoring program (dry season). Quarterly monitoring data (dry season) from 1996 thru 2002 were used for Site 16. All sites are compared to the Florida Department of Environmental Protection's Impaired Water Rule (FDEP IWR) annual mean value (11 ug/l) for determining whether an estuary is impaired by nutrients (see text). The grey vertical bar represents when flow was halted from C-13 Canal to North Fork New River on 3/7/03 at the BCOES CS 55.









IV. Discussion

In many respects, this report is the culmination of over ten years of planning, monitoring, and analysis by numerous individuals and agencies in both the private and public sectors. The main purpose of the entire effort has been to improve water quality and ecological condition in the North Fork New River without causing hydrological (e.g., flooding) and/or environmental challenges in other areas. Over time, consideration has also been given towards water management decisions that will affect the long term viability of improving flows to the waterway. In particular, the implementation of the Comprehensive Everglades Restoration Plan (CERP, http://www.evergladesplan.org/index.cfm) will change the regime of freshwater flow to Broward County's estuarine waters such as the North Fork New River. The following text will discuss the OPFLOW 2002 study results in terms of water quality and habitat improvements by focusing on the study's objectives, as well as future directions for management of the North Fork New River. The initial questions were:

* What volume of water can be delivered to the North Fork New River over a long period?

* Will the volume and flow rate of water in the study influence the C-13 Canal water elevations?

* What effect will extended flow periods from the C-13 Canal have on the North Fork New River's water quality?

A. What volume of water can be delivered to the North Fork New River over a long period?

Freshwater flow thru OPFLOW Alternative 2 (Figure 4) to North Fork New River was maintained for almost five consecutive months including three traditionally dry months (December thru February). This demonstrates a significant capability of delivering water at relatively low volumes to the North Fork during periods of low rainfall. It also implies that freshwater deliveries during the wet season should not be a significant issue, at least in terms of regional water management.

The flow period could have been longer but was halted in March 2003 because of aquatic plant maintenance requirements. A fence was placed north of the Lauderdale Lakes structure by BCOES (Figure 4) to block the path of the invasive exotic plant *Hygrophila* from entering the secondary canal system in the City of Lauderdale Lakes. Flow was re-established again after 4/2/03. *Hygrophila* already existed in the waterway but not at the levels observed after flow from the C-13 Canal was initiated in October 2002 (City of Lauderdale Lakes, personal communication). The species already exists in the North Fork New River, so the threat of introducing *Hygrophila* to the area was not a concern. To facilitate future aquatic plant management needs, the BCOES has given the city permission to close the CS 55 when

necessary as long as the opening and closings are communicated. In addition, the City of Lauderdale Lakes will be included in future long term water management decisions concerning the secondary canal system.

OPFLOW 2002 generally had much higher flow rates over a longer period of time than observed in OPFLOW 2001. The average value for OPFLOW 2002 was 18.4 million gallons per day (see Figure 16b) compared to the approximately 10.1 million gallons a day estimated for OPFLOW 2001 (BCDPEP 2002). The estimated values have some degree of error because they are made by calculation and not by direct flow measurements.

The increase in flow rates and volumes may be explained, in part, by dredging activities performed by the City of Lauderdale Lakes in the secondary canal system north of the CS 55 prior to OPFLOW 2002. The dredging likely improved the secondary canal's ability to move water (i.e., conveyance) south from the C-13 Canal. This allowed more water over time to flow south of CS 55 establishing water elevations typically above an important threshold of 3.5 feet (National Geodetic Vertical Datum, Figure 15). When water elevations south of CS 55 are over 3.5 feet and the wood risers are removed at CS 17 (Figure 31a), flow occurs both thru the notched weir (Figure 31b) and over the sides of the entire structure (Figure 31c). This only occurred on the initial day of the OPFLOW 2001 pilot study and the remaining month of flow was characterized by an elevation below 3.5 feet south of CS 55. Thus, a combination of flow thru and over the CS 17 created more flow into the North Fork New River in OPFLOW 2002 than in OPFLOW 2001.

The ability to increase flows to the North Fork is important for future water management decisions in the basin. Broward County developed an Integrated Water Resources Plan (http://www.broward.org/wti01201.pdf and http://www.broward.org/wti01218.pdf) that focuses on integrating water resource needs for natural areas (e.g., North Fork New River) as well as public water supply (i.e., drinking water) by integrating secondary canals with regional water bodies more efficiently. Thru the IWRP process, the diversion of flows from the secondary canal system north of CS 17 west to the C-12 Canal is being considered for public water supply needs (well field recharge). It now appears more water is available for both the IWRP component and North Fork New River than originally observed last year (OPFLOW 2001). The field observations and flow estimations from OPFLOW 2002 could also be important data for 'groundtruthing' for future runs of the IWRP's Central Broward County Model (CDM and DHI 2002) which has a secondary canal system component.

Future water management decisions in this basin will be influenced by the Broward County Secondary Canal component of the Comprehensive Everglades Restoration Plan (http://www.evergladesplan.org/pm/projects/proj_24.cfm). Similar to the IWRP, the project's goals are the reduction of water shortages in the local wellfields and stabilization of saltwater intrusion through efficient management of canal systems. As the C-12 and C-13 constitute two of the three major canals in the project, the North Fork New River OPFLOW efforts should be considered when Broward County Secondary Canal components are being planned and implemented by the specific Project Delivery Team.

Figure 31. Different Water Elevation (Stage) Conditions at Broward County Office of Environmental Services Control Structure (CS) 17. The structure is shown closed (a) and opened (b). When water levels are greater than 3.5 feet water flows over the sides of CS 17 (c). Water stages during OPFLOW 2002 were typically a combination of b and c.

a) CS 17 closed and water elevations less than 3.5 feet

b) CS 17 with two wood risers removed and water elevations less than 3.5 feet

c) CS 17 closed with water elevations greater than 3.5 feet

B. Will the volume and flow rate of water in the study influence the C-13 Canal water elevations?

Two major S-36 discharge events occurred during OPFLOW 2002 with one in the middle of the dry season (February, Figure 32). During this event, the C-13 water elevations increased almost one half foot in less than a day after the S36 discharge. The stage increase from 2/22/03 to 2/23/03 occurred with relatively low rainfall locally (less than one tenth of an inch). In addition, flows were occurring over CS 55 and CS 17 into the North Fork New River. Perhaps low rain, groundwater and/or regional surface water elevations (e.g., in the western Water Conservation Area) were sufficient to increase the C-13 Canal stage while OPFLOW 2002 continued.

The recommended minimum stage level for the C-13 Canal at S-36 is 4.0 feet (SFWMD 2000, http://www.sfwmd.gov/org/wsd/wsp/lec/lecfinalpdfs/appvol1/lecappd.pdf). After the Februrary flow event (Figure 32), C-13 Canal elevations were sustained above 4.2 feet until the CS 55 flows were halted (see Figure 9b). This would also suggest regional water management practices, rainfall perturbations, and/or groundwater seepage generally mask the water volumes being diverted to the North Fork New River from the C-13 Canal via the secondary canal system. Future discussions with the SFWMD on maintaining flow to the North Fork New River should consider the hydrological and meteorological events leading to S-36 flow periods while OPFLOW 2002 occurred.

To better understand the influence of OPFLOW Alternative 2 on the C-13 Canal in a more long-term and regional context, a hypothetical annual flow volume was calculated based on the average OPFLOW 2002 flow rate of 18.4 million gallons per day (see Figure 16b). The estimated annual water flow from the C-13 Canal thru the secondary canal system to the North Fork New River was 6.205 billion gallons a year based on the elevations obtained at CS 55. Figure 33 illustrates how this annual flow volume compares to estimated average discharge volumes from four SFWMD coastal control structures: S-36 (C-13 Canal), S-33 (C-12 Canal), G-54 (North New River Canal, NNRC), and S13 (C-11 East Canal). Ten years of (1993 thru 2002) average daily flow data were obtained from the SFWMD DBHYDRO Internet database (http://www.sfwmd.gov/org/ema/dbhydro/index.html) for each structure. Some interannual variability was present (note standard deviation at G-54, Figure 32), but OPFLOW's theoretical annual volume was well below three of the four structures. Only the S-33, which is typically closed (see BCDPEP 1999), had a lower estimated volume of water than the CS 17 discharge to the North Fork New River. In fact, the S-33 estimated annual discharge is less than half of the theoretical OPFLOW annual discharge. The low flow volume from S-33 was identified as one of the major freshwater flow issues to the North Fork New River (see BCDPEP 2002).

These estimates are not actual flow measurements (e.g., Acoustic Doppler Current Profiler, see Tillis and Swain 1998, http://fl.water.usgs.gov/PDF_files/wri98_4007_tillis.pdf). They do represent general estimations of freshwater flows to estuarine systems and allow for a general comparison of how much water is theoretically being sent to North Fork New River. For example, OPFLOW 2002's estimated annual volume of water, when CS 55 is left continuously open, would be approximately 33% of the estimated C-13 flow thru the S-36 on

Figure 32. Hourly Stage Data (Feet, National Geodetic Vertical Datum, NGVD) and Rain Data Collected by the South Florida Water Management District Upstream of the Coastal Salinity Structure S-36 on C-13 Canal. Data is shown for 2/15/03 thru 3/1/3. Complete data sets are shown in Figures 8 and 9. Dotted line represents the a period of flow at the S-36 (Figure 10).

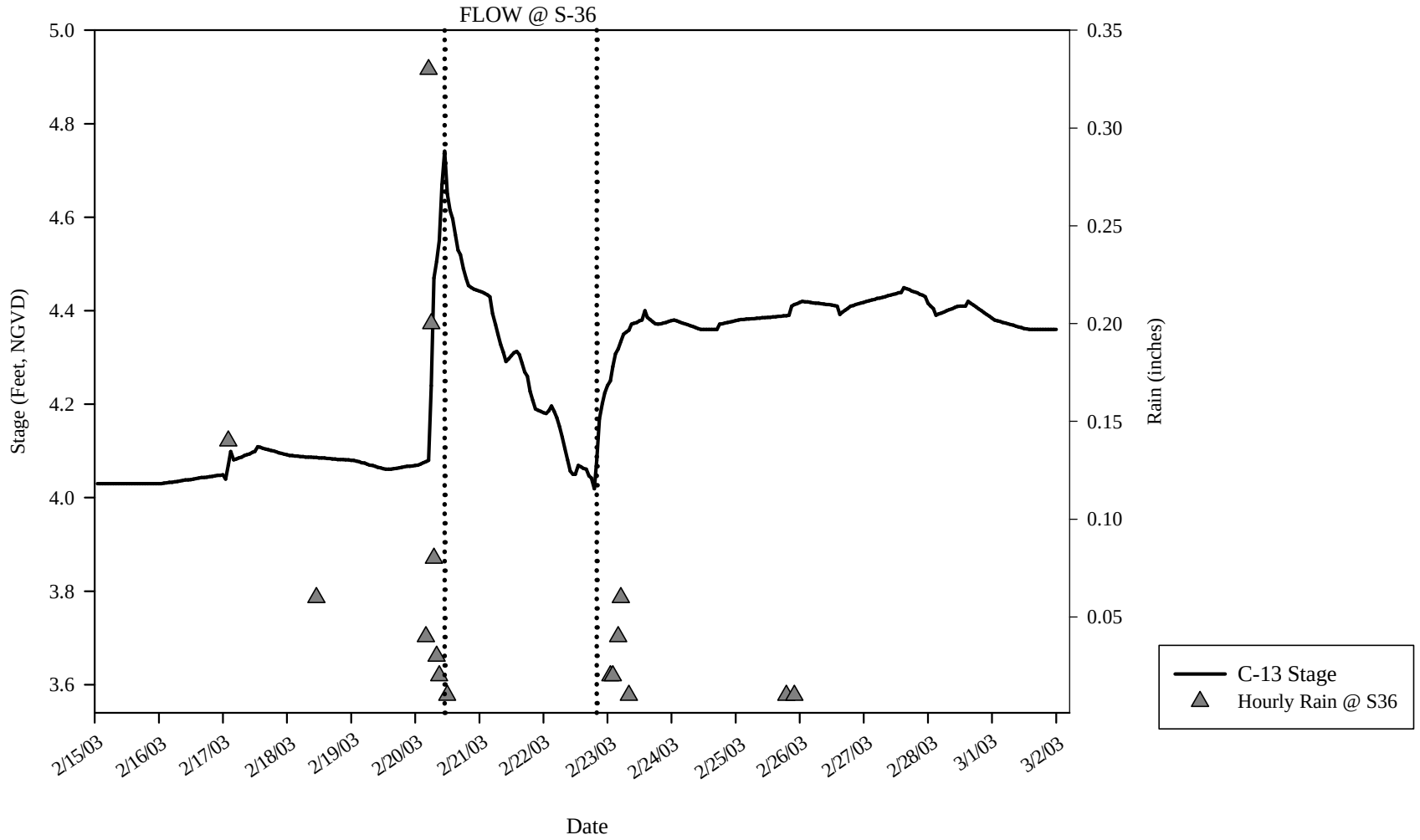
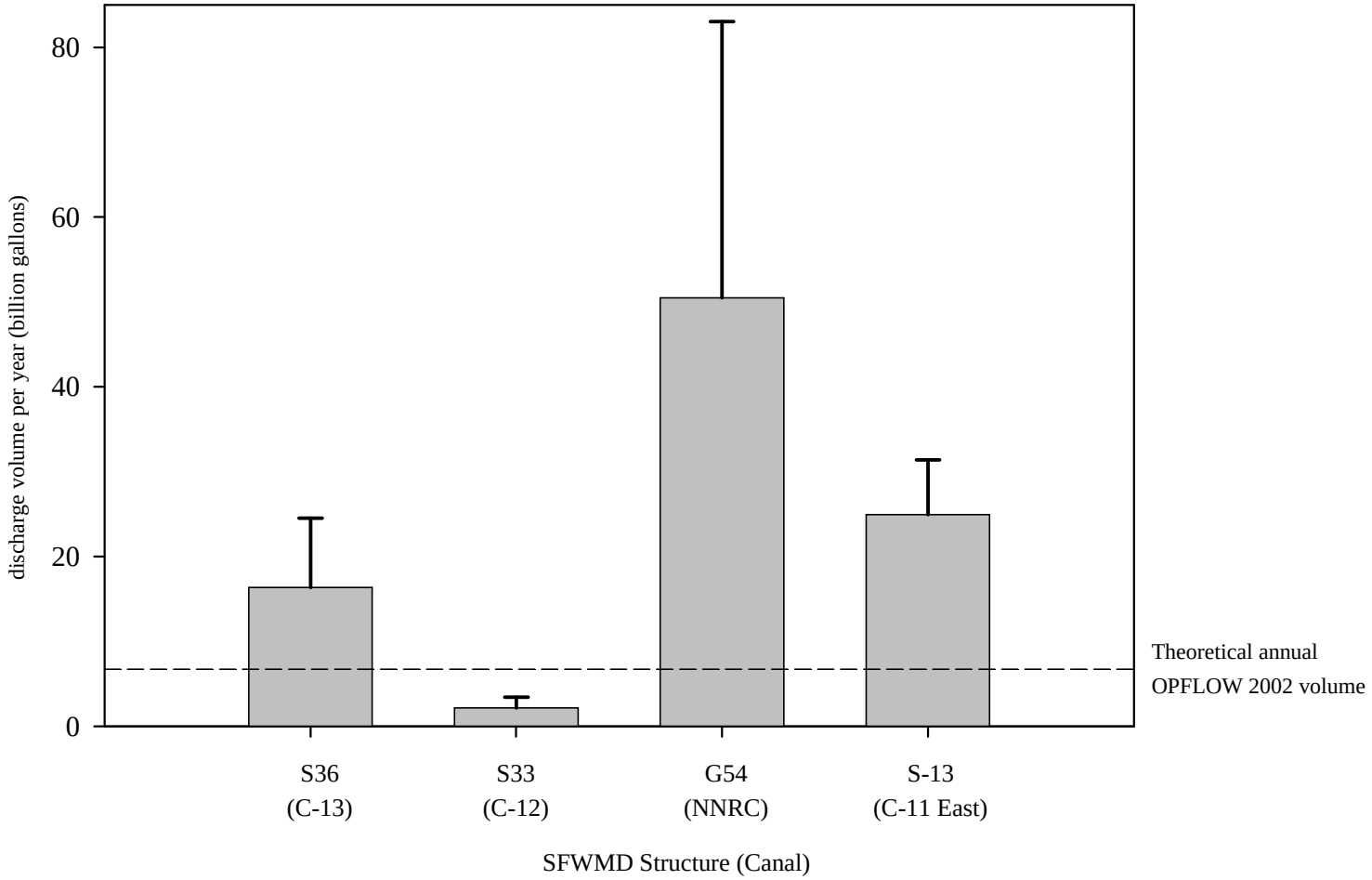


Figure 33. Estimated Annual Mean Discharge Volumes at Four South Florida Water Management District Coastal Salinity Structures from 1993 thru 2002. The S-36 is on the C-13 Canal while the S-33 controls the C-12 Canal. Water discharged intoThe North New River Canal (NNRC) by G-54 reaches the estuarine NNRC and South Fork of the New River. The S-13 discharge reaches both the South Fork New River and the Dania Cut-off Canal. Bars represent the average (with standard deviation) of annual total volume discharged based on the summation of avergae daily flow data obtained from http://www.sfwmd.gov/org/ema/dbhydro/index.html for each structure. The dashed line represents the theoretical annual discharge of C-13 Canal water into North Fork New River based on OPFLOW 2002's estimated mean flow rate of 18.4 million gallons per day multiplied by 365 days. All values should be viewed as estimates as flows were calculated based on water elevations.



continuously open, would be approximately 33% of the estimated C-13 flow thru the S-36 on an average yearly basis. The OPFLOW 2002 estimated annual flow is approximately 9% of other structures discharging to the main New River as a whole (all G-54 and S-33, 50% of S13 = approximately 65 billion gallons a year). An important future management need is an understanding of how significant these estimations are in terms of freshwater allocation for North Fork New River water quality and habitat improvements. In addition, the timing of the freshwater flow could be an important consideration in long term plans as the CS 55 will not likely be opened all year long (e.g., aquatic plant management closings).

C. What effect will extended flow periods from the C-13 Canal have on the North Fork New River's water quality?

1. Nutrients and Chlorophyll a

Local (Broward County 2003, Chapter 27) water quality standards exist for Broward County waters. In addition, the state of Florida has water quality standards (Florida Administrative Code, FAC 62-302) and the FDEP is implementing its total maximum daily load program (TMDL) through the Impaired Waters Rule (IWR, FAC 62-303). The following discussion begins with how the OPFLOW 2002 and historical North Fork New River ambient values (dry season) complied with standards and/or IWR criteria.

Total phosphorus (TP) and total nitrogen (TN) exhibited opposite trends in their relationships to historic dry season values and standard compliance (Table 2). OPFLOW 2002 median TP content at all three North Fork New River sites became substantially lower (range 44 to 71%) than historical median values. This led to compliance of the TP marine standard of 0.050 mg/l at Sites 101 and 64 and borderline compliance for Site 16 where the median was 0.053 mg/l. Conversely, OPFLOW 2002 TN values were considerably higher than observed previously (Table 2). This caused Sites 101 and 64 to be minimally within compliance of the 1.5 mg/l TN standard and Site 16 was out of compliance. All three historical values were well within the Broward County standard of 1.5 mg/l. Thus, OPFLOW brought one nutrient (TP) into compliance when it had been well out of compliance while having the opposite influence on the other nutrient (TN).

Table 2. Broward County (BC) Chapter 27 Compliance Status of OPFLOW 2002 and Historical Ambient Median Total Phosphorus (TP) and Total Nitrogen (TN) Concentrations. The OPFLOW 2002 median values are a subset of the entire study and were obtained from 11/21/02 until 2/27/03 at the North Fork New River (Sites 101, 64, and 16; see Figures 25 and 29). This period is one month after the beginning of freshwater flows from the C-13 Canal south to the North Fork New River through a secondary canal system (see Figure 4) until the end date (3/7/03). The time frame was chosen to reduce potential transitory features of data collected two and sixteen days after flow began. Sites 101 and 64 historical TOC values are from a 1998 bi-weekly monitoring program (dry season) Quarterly monitoring data (dry season) 1992 thru 2002 were used for Site 16.

Site/ Parameter	OPFLOW 2002 median mg/l	BC Std mg/l	OPFLOW 2002 compliant with std. ?		Historic Ambient Median mg/l	Historic Ambient compliant with std. ?	% Change OPFLOW 2002 from Historic Ambient
Site 101 TP	0.021	0.050	Yes		0.072	No	71% Lower
Site 64 TP	0.033	0.050	Yes		0.1	No	67% Lower
Site 16 TP	0.053	0.050	Border*		0.095	No	44% Lower
Site 101 TN	1.48	1.50	Yes		1.09	Yes	36% Higher
Site 64 TN	1.45	1.50	Yes		1.12	Yes	29% Higher
Site 16 TN	1.71	1.50	No		1.16	Yes	47% Higher

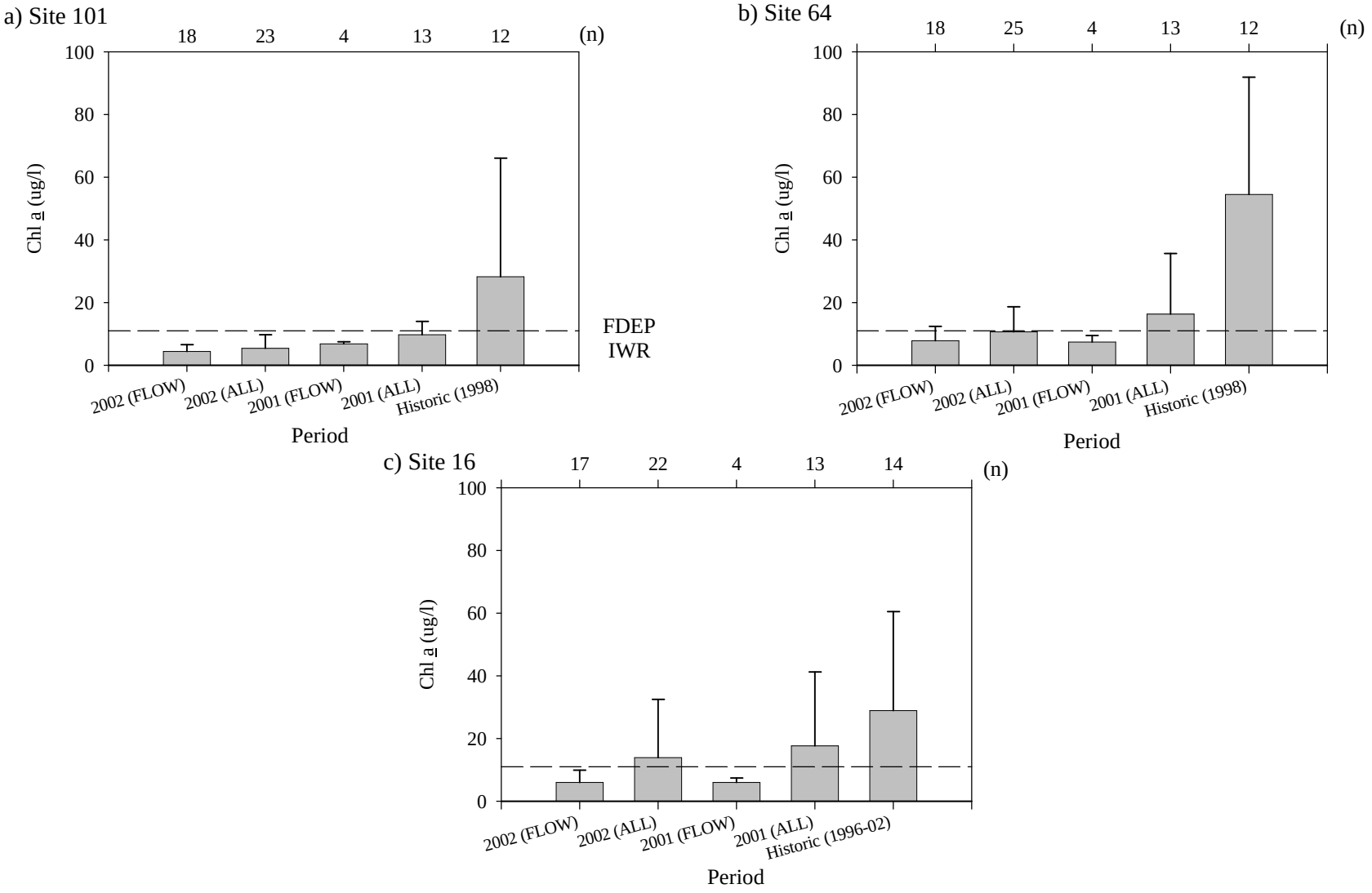
* The relative significance of a parameter being 0.003 mg/l over the std. led to a borderline (Border) designation.

The state of Florida does not currently have a numerical standard for nutrients but instead has narrative language that in effect states 'no ecological imbalance' may occur because of nutrients (FAC 62-302). The FDEP is working with the United States Environmental Protection Agency (USEPA) in the development of numeric criteria (http://www.dep.state.fl.us/water/surfacewater/nutr_ann.htm). Until those values are developed, a pertinent reference for nutrient levels is the FDEP IWR (62-303.353) that states an estuarine water body (e.g., North Fork New River) "shall be included on the planning list (for TMDL) for nutrients if their annual mean chlorophyll a for any year is greater than 11 ug/l or if data indicate annual mean chlorophyll a have increased by more than 50% over historical values for at least two consecutive years."

Figure 34 illustrates how North Fork New River values compare to the 11 ug/l threshold over five different sampling periods. This includes two OPFLOW studies (shown with and without flow) and the historical dry season observations. Both OPLFOW (2001 and 2002) studies had mean chlorophyll a (Chl a) values well below the IWR indicating no impairment when flow from the secondary canal to the North Fork (i.e., thru CS 17) occurred. If all data from the two OPFLOW studies are compared to the IWR, Site 16 and 64 are at or slightly over the threshold while Site 101 remains in compliance. Conversely, the historical ambient dry season averages greatly exceed the 11 ug/l at all three North Fork sampling sites and would likely place the waterway on a TMDL planning list.

Thus, the OPFLOW Chl a data suggest no nutrient impairment when flow is occurring during the transition to and during the dry season (November until February). The large decrease in

Figure 34. Chlorophyll a Concentrations From Three North Fork New River Sampling Periods (OPFLOW 2002, OPFLOW 2001, and Historical Ambient). OPFLOW 2002 observations are divided between when samples coincided with flow (FLOW) and the entire data set (ALL). Note the first sampling day of OPFLOW 2002 is not included in the flow portion (2002 FLOW) because it came only 48 hours after flow commenced. OPFLOW 2001 included four weeks of flow measurements (FLOW) out of thirteen total samples (ALL). Sites 101and 64 historical Chl a values are from a 1998 bi-weekly monitoring program (dry season). Quarterly monitoring data (dry season) from 1996 thru 2002 were used for Site 16. All sites are compared to the Florida Department of Environmental Protection's Impaired Water Rule (FDEP IWR) annual mean value (11 ug/l) for determining whether an estuary is impaired by nutrients (see text).



TP from ambient condition (i.e., no flow) and compliance with the Broward County standard offer further evidence the OPFLOW Alternative 2 provides beneficial changes to the North Fork New River's nutrient regime. However, TN levels increased dramatically throughout OPFLOW 2002 and 2001 (see BCDPEP 2002). Although two sites were technically within standard compliance, the waterway's TN concentrations (see Table 1) and nitrite and nitrate-nitrogen (NOx) content (see Figure 27), were well above historical ambient background levels.

The 'high TN/low TP' water is characteristic of the source water for OPFLOW, the C-13 Canal, based on its historical values (see Figures 25 and 29 and see BCDPEP 2001b). The overall increase of TOC in the secondary canal and North Fork (Figure 23) further indicates C-13 water is moving south through the secondary canal system. To some extent pH levels also support the idea of C-13 Canal water maintaining many of its characteristics before flowing into the North Fork, particularly at Site 101 (see Figure 19b). The TOC concentrations also appear to be a good tracer of the temporal and spatial effects of OPFLOW discharges. For example, TOC values were not seen above ambient levels at Site 16 (furthest downstream from freshwater input) until the fourth sampling event (12/5/02) (Figure 23d). This is also the same date TN values increased to nearly 2.0 mg/l (Figure 25d) and TP content decreased by nearly fifty percent (Figure 29d) at the same site.

From a management perspective, the large TP reduction may be more important than increases in TN because the tidal North Fork New River is dominated by fresh to low saline water (Figure 17). Freshwater systems are traditionally more influenced by phosphorus levels, although exceptions exist. An indicator of ecological response to nutrients, Chl a, decreased while TP levels were lowered. This combined response suggests phosphorus is the most important nutrient in this upper estuarine system. From this perspective, the OPFLOW Alternative 2 is beneficial to the North Fork New River because TP levels decreased during its implementation in both 2001 (BCPEP 2002) and this study.

Other benefits of the flow period on Chl a concentrations are the physical characteristics of flow that decrease stagnant conditions thereby preventing phytoplankton populations from developing blooms. In addition, the low water temperatures during the middle of the OPFLOW 2002 study (Figure 18) likely contributed to less Chl a content although historical ambient data showed high Chl a levels when cold water temperatures would be expected (i.e., dry season). These factors need to be considered in the overall success of OPFLOW Alternative 2 lowering Chl a concentrations.

The overall downstream transport of the TN into the main New River system would not seem to be a major issue based on the flow volume comparison of the OPFLOW to the G-54 and S-13 (Figure 31). Both of these structures contribute substantially more water on an estimated annual basis to the South Fork New River and main New River system than the North Fork. In addition, the source water from these systems has historically (BCDPEP 2001b) had TN content similar to (G-54, North New River Canal) or above (S-13, C-11 east) the values observed in OPFLOW 2002. The South Fork New River also receives a daily input of millions of gallons of cooling water from the Florida Power and Light plant which make it an exceptionally more dynamic system than the North Fork New River. Thus, the

estimated new 9% contribution of overall freshwater flows into the North Fork New River (Figure 31) would not appear to have a major influence on water bodies further downstream.

However, the long term fate of increased TN within the North Fork New River itself may be most important when flow from CS 55 is halted at a time optimal for salinity levels to increase. For example, Site 64 and 16 experienced bloom like conditions (> 40 ug/l Chl a, SFWMD 1999) when flows stopped in March 2003. The flow stoppage likely led to a more stagnant condition allowing a more stabilized water column for primary production and subsequent high Chl a (Figure 30) and fluorometric Chl concentrations (Figures 21c and d). Furthermore, the highest peak in Chl a values was at the most brackish site in the study, Site 16 (see Figure 17d). Site 64 also showed an increase in specific conductance during this period (Figure 17c). The shift in salinity coupled with lower flow and higher temperatures than observed previously may have led to the bloom. The rapid decline of NOx when flow stopped on 3/7/03 (see Figure 27) may further indicate it was used up by the phytoplankton populations although those types of relationships can only be inferred from this data set. The overall relationship is made even more complex by the increase in water temperatures (Figure 18) and rainfall with associated runoff (Figure 7) after flow was halted on 3/7/03.

The impacts of nutrient and salinity regime shifts on the water column ecology remain a management question for the North Fork New River. An analysis of phytoplankton species composition coupled with the data similar to OPFLOW 2002 would enhance our knowledge of the river. Benthic nutrient inputs also need to be quantified, particularly since major portions of the river have just been dredged in the summers of 2001 and 2003. As these components are pieced together, a future planning need is a conceptual model that diagrams the river's main nutrient pathways, sinks, and their response with and without OPFLOW Alternative 2. The influence of temperature and physical benefits of flow also need to be used in building a conceptual model for North Fork nutrient dynamics. Potentially this conceptual model can be quantified with computer simulations as budget constraints allow. The models (conceptual and/or numerical) could provide information on the ecological and water quality significance of diverting a freshwater resource to an estuarine water body. This may be particularly relevant to any IWRP of CERP Broward County Secondary Canal components which may share a need for freshwater currently going to the North Fork New River.

2. Fecal Coliform

As observed in OPFLOW 2001, fecal coliform levels were not improved by the implementation of OPFLOW Alternative 2 and generally reflected a range of historical values (see Figure 24). Overall, the North Fork New River FC levels are normally out of Broward County regulatory compliance (Table 3). The median values are only compliant with values in categories that technically would not be applicable (i.e., the 400 colonies per 100 ml standard requires 10% of samples and/or the 800 colonies per 100 ml standard is for single samples only). Significantly, the waterway's OPFLOW and historical values shown on Table 3 are never in the Florida Department of Health's good category and typically rated poor (http://apps3.doh.state.fl.us/env/beach/beachresults.cfm?county=Broward). It is very probable the North Fork New River with or without OPFLOW is a candidate for a TMDL

Table 3. Broward County Chapter 27 Compliance Status of OPFLOW 2002 and Historical Ambient Median, 75th percentile (%), and Maximum Fecal Coliform (FC) Concentrations. The OPFLOW 2002 median values are a subset of the entire study and were obtained from 11/21/02 until 2/27/03 at the North Fork New River (Sites 101, 64, and 16; see Figure 40). This period started one month after the beginning of freshwater flows from the C-13 Canal south to the North Fork New River through a secondary canal system (see Figure 4) until the end date (3/7/03). The time frame was chosen to reduce potential transitory features of the first two data points collected two and sixteen days after flow began. Sites 101 and 64 historical TOC values are from a 1998 bi-weekly monitoring program (dry season) Quarterly monitoring data (dry season) 1992 thru 2002 were used for Site 16. Broward County (BC) has three classifications of FC standards including, 200 colonies per 100 milliters (col/ 100 ml) for a monthly average, 400 col/ 100 ml for 10% of samples, and 800 col/ 100 ml in any sample. Note the state of Florida criteria is the similar but includes the language that the 'monthly average shall be expressed as geometric means based on a minimum of ten samples taken over 30 days' (Florida Administrative Code 62-302-530). The Florida Department of Health (FDOH) classifies a waterway good based on FC counts less than 200 col/ 100 ml. Surface waters are considered to be in a moderate condition with FC concentrations between 200 and 399 col/ 100 ml. Poor water quality is designated with FC of 400 col/ 100 ml and can lead to a health advisory or warning (http://apps3.doh.state.fl.us/env/beach/beachresults.cfm?county=Broward).

Site/ FC Value Description	OPFLOW 2002 col/ 100 ml	BC Std. 200 col/100 ml Compliant ?	BC Std. 400 col/100 ml Compliant ?	BC Std. 800 col/100 ml Compliant ?	FDOH Criteria		Historic Ambient Values col/ 100 ml	BC Std. 200 col/100 ml Compliant ?	BC Std. 400 col/100 ml Compliant ?	BC Std. 800 col/100 ml Compliant ?	FDOH Criteria
Site 101 FC median	250	No	Yes	Yes	Moderate		210	No	Yes	Yes	Moderate
Site 101 FC 75th %	860	No	No	No	Poor		552	No	No	Yes	Poor
Site 101 FC Maximum	1300	No	No	No	Poor		6400	No	No	No	Poor
Site 64 FC median	570	No	No	Yes	Poor		250	No	Yes	Yes	Moderate
Site 64 FC 75th %	1040	No	No	No	Poor		3400	No	No	No	Poor
Site 64 FC Maximum	5200	No	No	No	Poor		28000	No	No	No	Poor
Site 16 FC median	595	No	No	Yes	Poor		420	No	No	Yes	Poor
Site 16 FC 75th %	630	No	No	Yes	Poor		1200	No	No	No	Poor
Site 16 FC maximum	20000	No	No	No	Poor		5000	No	No	No	Poor

based on the FDEP's IWR which uses standard exceedances as its criteria for FC impairment (FAC 62-303).

The bacteria problem in this waterway has been well documented over the last ten years (BCDNRP 1993, BCDNRP unpublished data 1995 thru 1998, BCDPEP 1999, 2001b, 2002) and the City of Ft. Lauderdale convened a Blue Ribbon Task Force to address the problem. The causal mechanisms for bacteria's fate and subsistence in the river's soils has been well described (Solo-Gabriele et al. 2000). In addition, some potential sources are now considered less important (e.g., septic tanks south of Broward Blvd., Solo-Gabriele et al. 2000) than others (e.g., stormwater, BCDPEP 1999, Solo-Gabriel et al. 2000).

The management 'bottom line' at this time is the need to determine, quantitatively, whether this bacteria source is human or non-human. While health risks may still be associated with non-human bacteria, any attempts to remediate the problem are made very complex without a clear understanding of what the main source(s) of the bacteria to the river is. In the fall of 2002, the Broward County DPEP and the SFWMD began to cooperatively seek funds through granting agencies to perform genetic fingerprinting of the North Fork New River's waters and potential bacteria sources (e.g., stormwater). This combined effort is scheduled to continue and when it succeeds should lead to improvements in the solving this long standing water quality problem.

3. Other Water Quality Parameters

Dissolved oxygen concentrations were normally (see Figure 20) between the single sample standard of 4.0 mg/l and daily average of 5.0 mg/l (Broward County 2003, Chapter 27) at all sites when flow was occurring. Low temperatures (Figure 18) also occurred during most of the flow period which can contribute to high DO levels. When flow was halted, Sites 101 and 64 DO levels tended to drop below compliance levels. Water temperatures also increased in March primarily because of an unusual abrupt period of warm air temperatures (> 90 degrees Fahrenheit). The increase in water temperatures may have also contributed to DO levels decreasing at two of three North Fork sites. Maximum DO values and daily variability rose at Site 16 and were likely associated with the algal bloom (Figure 30d) yet were within standard compliance more frequently than the other North Fork sampling sites.

Thus, DO levels during the implementation of OPFLOW 2002 Alternative 2 generally met compliance levels in the dry season but cold temperatures likely contributed to this pattern. Future work should investigate the influence of wet season conditions which normally has increased temperature readings and stormwater inputs. Historic wet season DO values were lower at Site 16 than dry season observations (BCDPEP 2001b). As with most of Broward County's waterways, the relationship between groundwater and surface water interaction still needs to be improved for a better overall understanding of dissolved oxygen concentrations (BCDPEP 2001b).

Turbidity levels in the grab sampling were always below 3.5 nephelometric turbidity units (NTUs) (data not shown) and well within compliance of the 10 NTUs Broward County turbidity standard. The influence of the flow period on turbidity was basically insignificant

because of the relatively low levels seen throughout the study, as well as historical ambient investigations (see BCDPEP 1999 and 2001b). However, the physical attributes of flow reducing stagnation may benefit the waterway when turbidity levels increase after storm events (see Figure 22). The YSI turbidity data suggests the immediate drainage areas surrounding Sites 64 and 16 are contributing more turbidity to the waterway during storm events. In addition, the shoreline in the stretch of waterway between Sites 64 and 16 could also be characterized by more erosion than upstream (i.e., Site 101).

The contribution of solids (based on turbidity readings) may be significant in terms of pollutant loads to the water column (e.g., nutrients) or to the sediments (e.g., metals). The retrofitting of stormwater outfalls has begun in the North Fork New River's surrounding basin (see http://www.broward.org/oes/pdi00600.htm) but is not complete. An initial inventory of stormwater outfalls and catch basins (BCDPEP 1999) should be updated with an analysis of which areas are now providing some levels of stormwater treatment and which areas are not. This information would be important in continuing the stormwater retrofitting in this basin. Both the Broward County and Ft. Lauderdale National Pollutant Discharge Elimination System Multiple Separate Stormwater System permit programs will be a valuable source for this information.

4. Submerged Aquatic Plants and Trees

Freshwater plants such as the Pond Apple (*Annona glabra*) tree thrive throughout much of the North Fork New River. However, the change of the river's hydrology has led to brackish water intrusion and the colonization of a marine wood boring isopod (crustacean) which impacts Pond Apple tree root systems causing them to fall. The general area of freshwater/saltwater transition and 'healthy' Pond Apple trees based on their root stabilization characteristics has been near Site 64. Specific conductance readings at Site 64 were always below 2,500 umhos/cm (approximately 1.3 part per thousand salinity) and often below 1,000. Values began to increase when flow was halted suggesting that OPFLOW 2002 flows were beneficial to Pond Apples from a freshwater perspective. However, the area should be considered for long term monitoring of salinity changes, particularly with dredging having occurred in the summers of 2001 and 2003. Site 64 has recently been added to DPEP's quarterly monitoring network which should assist in detecting shifts in salinity regime.

The desirable submerged aquatic plant *Vallisineria* sp. has spread remarkably over the last two years (personal observation). Initially the plant was only observed around and west of Martin Luther King Boulevard (31st Ave). It now is found thriving throughout the North Fork shorelines downstream until approximately Samuel L Delevoe Park, near site 64. Although turbidity levels were not different over the study, our environmental consultant, (Genesis Environmental Services) who grew up along the river, said the river anecdotally appeared 'clearer' than they previously remembered. The mapping of this important species would be beneficial in understanding if its spread and future range is due to changes in water quality and/or change in freshwater conditions in the upper portions of the North Fork.

5. Wet Season ‘Epilogue’

Unattended YSI datasonde and chlorophyll a collection was performed at one site after the end of the major portion of the study (4/4/03). This included the deployment of the YSI datasonde at Site 16 (4/17/03 thru 8/29/03) and later Site 64 (8/29/03 thru 9/12/03). No other parameters were obtained during this period. The dredging activity from May thru July undoubtedly made our observations aberrant. In addition, the CS 55 was closed on at least two occasions for several weeks by the City of Lauderdale Lakes. Currently, we are trying to determine when the North Fork could be considered ‘settled’ from the dredging and shoreline vegetation projects (August and September 2003) before performing major data analysis. However, the data set will be particularly useful for comparing wet season specific conductance values in the upcoming years. In addition, chlorophyll a values may provide information once the influence of atypical projects is determined. It is apparent a wet season investigation would add to the understanding of OPFLOW Alternative 2 benefits.

V. Conclusions

1. Freshwater flow was provided to the North Fork New River from the C-13 Canal via a secondary canal system (OPFLOW Alternative 2) for nearly five months, including three months in the dry season.

2. Water elevations and estimated flow rates were higher in OPLFOW 2002 than OPFLOW 2001. The dredging of portions of the secondary canal system by the City of Lauderdale Lakes likely contributed to the increased volume of water.

3. The implementation of OPFLOW Alternative 2 did not appear to directly affect C-13 Canal levels; however, regional water management practices, rainfall, and/or groundwater elevations may mask the relatively low volume of water being obtained from the C-13 Canal on short time scales.

4. A theoretical annual OPFLOW discharge volume was much lower than estimated for three of four South Florida Water Management District coastal salinity structures but could constitute a third of C-13 Canal coastal discharges if OPFLOW is run continuously over an entire year.

5. A theoretical annual OPFLOW discharge volume was over twice the estimated volume of the North Fork New River's current freshwater source (C-12 Canal thru S-33).

6. The implementation of OPFLOW Alternative 2 lowered TP levels substantially when compared to historical ambient levels. The occurrence of enhanced freshwater flows also brought the North Fork New River median TP concentrations into compliance with the Broward County standard.

7. The implementation of OPFLOW Alternative 2 increased TN levels substantially when compared to historical ambient levels. The occurrence of enhanced freshwater flows caused North Fork New River median TN concentrations to approach compliance levels with the Broward County standard at two sites and become out of compliance at the other.

8. The amount of nitrite+nitrate-nitrogen also increased substantially above historical ambient levels with the implementation of OPFLOW Alternative 2.

9. North Fork New River chlorophyll a concentrations were observed at levels within compliance of the Florida Department of Environmental Protection's Impaired Water Rule threshold for nutrient impairment (11 ug/l) when OPFLOW Alternative 2 was implemented. Conversely, historical ambient chlorophyll a concentrations have been above this threshold indicating nutrient impairment for North Fork New River.

10. The physical attributes of flow (reduced stagnation), low water temperatures, and salinity regime changes were likely factors (beyond nutrients) that influenced chlorophyll a concentrations.

11. Total organic carbon and to a lesser extent pH appear to be good temporal and spatial tracers of C-13 Canal water in the North Fork New River.

12. Fecal coliform concentrations were not improved by the implementation of OPLFOW Alternative 2 and continued to be out of compliance of most applicable standards and public health indicators.

13. Dissolved oxygen concentrations were generally within compliance of Broward County standards with the implementation OPLFOW Alternative 2. At two of three North Fork sampling sites, DO content fell out of compliance when flow was halted. Water temperatures were likely a contributing factor to the observed DO concentrations throughout the study.

14. Grab samples for turbidity levels were always well within compliance of the Broward County standard. Following primarily storm events, unattended YSI data sampling revealed turbidity concentrations exceeding water quality standards. The YSI turbidity observations also documented between site variability in terms of event concentrations and amplitude.

15. The area traditionally seen as an area of transition between freshwater and brackish appeared to stay fairly fresh with the implementation of OPFLOW Alternative 2. This benefits local Pond Apple Trees and potentially, a desirable submerged aquatic plant species *Vallisineria* sp.

16. Flooding was not observed or reported during this study.

17. Aquatic weed problems initially caused by the flow were resolved with a weed retention structure.

VI. Recommendations

1. Water flows through the secondary canal system should be allowed to continue to be implemented to maintain chlorophyll a, total phosphorus, and dissolved oxygen levels observed in OPFLOW 2 unless C-13 water levels are impacted and/or other management needs arise (e.g., aquatic plant management).

2. Discussions should be held with the SFWMD operations to update them on the OPFLOW studies and discuss future long term viability of continuing flow. In particular, does the project continue to be significant at a local water management level only or does it become larger in scale if performed over longer time periods?

3. A North Fork New River ecological conceptual model could be developed to better determine the effect of different flow scenarios. The model should consider water column, benthic, and shoreline components. This will also help identify missing data gaps. If funding is available, numeric modeling would enhance this effort.

4. BCDPEP should continue monitoring quarterly at the recently added Site 64. Along with the pre-existing North Fork New River quarterly Site 16, the two river sites will monitor long term changes in water quality from improvements in flow, stormwater treatment, and dredging activities.

5. Additional means to monitor the salinity regime at Site 64 on a more frequent basis should be investigated. The main purpose of the monitoring would be to evaluate the aquatic habitat for Pond Apple Trees (*Annona glabra*) and *Vallisineria* sp in this important transition area between freshwater and brackish water. Past examples include monitoring partnerships with local schools, non-profit groups (Broward Urban River Trails) and the Broward County Parks and Recreation Division.

6. Funding for North Fork New River genetic fingerprinting should continued to be pursued by BCDPEP and the SFWMD to determine the origin of elevated FC.

7. An update should be performed of the stormwater GIS coverage map with additional information gathered on the retrofit status of specific outfalls. Both the Broward County and Ft. Lauderdale National Pollutant Discharge Elimination System Multiple Separate Stormwater System permit programs will be a valuable source for this information.

8. A map of *Vallisineria* sp. as well as Pond Apple (*Annona glabra*) tree health would assist in the tracking of the ecological benefits of a surface water quality oriented project.

9. Broward County's Integrated Water Resources Plan (http://www.broward.org/wti01201.pdf and http://www.broward.org/wti01218.pdf) and the Comprehensive Everglades Restoration Plan's Broward County Secondary Canal System component (http://www.evergladesplan.org/pm/projects/proj_24.cfm) should keep the North Fork New River issues as part of their larger water resources discussion.

10. The results of the last two years of OPFLOW studies should be communicated to the local communities (e.g., neighborhood associations) as well the Cities of Ft. Lauderdale, Lauderdale Lakes, Lauderhill, Plantation, and Sunrise and the Old Plantation Water Control District. Other stakeholders may also be identified and should receive information on the OPFLOW initiative.

11. It will also be important to communicate with FDEP personnel on the restoration activities that have taken place when the waterway is evaluated under the IWR for potential placement on a TMDL planning list.

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11. ABSTRACT

The primary objective of this investigation was to determine the effect of enhancing freshwater flows (known as OPFLOW Alternative 2) on the estuarine North Fork New River's water quality over a longer period than a pilot study performed in 2001. In OPFLOW 2002, water quality data collection included fine time scale (every 15 minutes) sampling at four sites with YSI 6600® datasonde water quality sensors (DO, pH, specific conductance, water temperature, turbidity, and chlorophyll via fluorescence). Bi-weekly surface water quality grab samples included total organic carbon (TOC), total phosphorus (TP), nitrogen species (including ammonia-nitrogen, nitrite + nitrate-nitrogen, total Kjeldahl nitrogen, total nitrogen [TN]), fecal coliform (FC), chlorophyll a (Chl a), pheophytin, as well as turbidity. Freshwater flow thru the OPFLOW Alternative 2 to North Fork New River was maintained for almost five consecutive months including three traditionally dry months (December thru February). OPFLOW 2002 generally had much higher estimated flow rates over a longer period of time than observed in OPFLOW 2001. Flooding was not observed or reported during the operations of the study despite the extra volume of water moved to the North Fork New River. The implementation of OPFLOW Alternative 2 over a long period of time did not appear to directly affect the main freshwater source (C-13 Canal) water levels, although flow discharges to the estuarine C-13 Canal/Middle River were infrequent. With flows from the C-13 Canal diverted to the North Fork New River, TP levels were substantially lower than historical ambient levels and were brought into compliance with the Broward County standard. Conversely, TN levels increased substantially when compared to historical ambient levels. Nitrite + nitrate-nitrogen (NOx) concentrations were also higher than previous ambient observations throughout the waterway. Despite the increase in TN and NOx, North Fork New River Chl a concentrations were observed at levels within compliance of the Florida Department of Environmental Protection's Impaired Water Rule threshold for nutrient impairment (11 ug/l) when OPFLOW Alternative 2 was operating. Conversely, historical ambient Chl a concentrations have been above this threshold indicating past nutrient impairment for North Fork New River. The physical attributes of flow (reduced stagnation), low water temperatures, and salinity regime changes were other likely factors (beyond nutrients) that influenced Chl a concentrations throughout the study. Total organic carbon and to a lesser extent pH appear to be good temporal and spatial tracers of C-13 Canal water in the North Fork New River. FC concentrations were not improved by the implementation of OPFLOW Alternative 2 and continued to be out of compliance with most applicable standards. Dissolved oxygen concentrations during flow were generally within compliance of Broward County standards. Management recommendations are put forth based on the results of the study as well as current and future water resource planning in South Florida. We believe flow should continue based on the improvements observed in the North Fork New River's TP and Chl a concentrations, as well as salinity regime.

12. KEY WORDS

water quality, nutrients, chlorophyll a, fecal coliform, dissolved oxygen, total organic carbon, pH, temperature, salinity, specific conductance, hydrologic flow, rainfall

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