# Indian River Lagoon

**Optimization Leader: David Wade, Janicki Environmental**
**Statistician: David Wade, Janicki Environmental**

**Project Code:** IRL

**Type:** Type II

**Mandate or Permit:**
- Surface Water Improvement and Management Plan (SWIM) Chapter 373.451-373.4595 F.S.
- WRDA 2000 Public Law 106-541, Title VI, Section 601. Comprehensive Everglades Restoration Plan – Indian River Lagoon South project (CERP-IRL)
- REstoration COordination and VERification (RECOVER) Monitoring and Assessment Plan
- FL Watershed Restoration Act Chapter 403.067 F.S. (TMDLs/MFLs/PLRGs)

**Project Start Date:** 1988

**Division Manager:** Coastal Ecosystems Division: Sean Sculley (Acting)
RECOVER: John Ogden

**Program Manager:** Dan Crean

**Points of Contact:** Dan Crean, Nenad Iricanin, Monique Laham-Pass, Patti Sime

**Field Point of Contact:** Monique Laham-Pass

**Spatial Description:**
The Indian River Lagoon is located on the east coast of Florida and runs along the coast from northern Palm Beach County near Jupiter north to the Titusville area in Orange County. The northern portion of the lagoon is under the jurisdiction of the St. Johns Water Management District while the more southern portion is under the jurisdiction of the South Florida Water Management District. The IRL Water Quality monitoring project focuses on the southern portion of the Indian River Lagoon that is within the South Florida Water Management District boundaries. This area is essentially defines as extending from the northern St. Lucie county line south to the Jupiter inlet. This portion of the IRL is flushed by three inlets to the ocean. These inlets include Ft. Pierce inlet to the north, St. Lucie inlet in the center and Jupiter inlet in the south. Freshwater inflows into the IRL are from the C-25 canal in northern St. Lucie County and the St. Lucie canal which serves as a navigation channel to Lake Okeechobee.

There are twenty-one stations sampled as part of the IRL project. These stations were selected because they are associated with seagrass beds in the lagoon.

**Project Purpose, Goals and Objectives:**
The purpose of the IRL monitoring project is to address the mandates listed above. Like the St. Lucie Estuary, the IRL supports a variety of commercial and recreational activities, and it provides critical habitat for many aquatic organisms. Therefore, water quality monitoring is needed to document short and long term trends relative to the Florida Department of Environmental Protection's (FDEP) Classification and Use of the Waters (Class II or III) Act. Additional goals for the IRL monitoring are to document point sources of pollution and impacts on biological resources, such as seagrasses and oyster beds. Restoration and protection of seagrasses is a major goal of the Indian River Lagoon (IRL) Surface Water Improvement and Management (SWIM) Plan (Steward et al. 1994). Monitoring conducted for this project will be necessary to establish a correlative link between water quality and the health of seagrass in the southern IRL. Long-term monitoring in the IRL will also help determine the chemical and biological parameters that will best evaluate the water quality of the lagoon and the estuary.

**Sampling Frequency and Parameters Sampled:**
Sampling at all stations for Project IRL occurs seven times per year, generally in January, February, April, May/June, July, August and October. Grab samples are collected at ½ the total water column depth and analyzed for color, turbidity, total suspended solids, volatile suspended solids, total Kjeldahl nitrogen, total phosphorus, orthophosphate, ammonia, nitrite, and nitrite+nitrate. In situ measurements are also collected at all sites and include pH, dissolved oxygen, temperature, salinity, specific conductance and photosynthetically active radiation. Total depth and sechhi depth at each location is also recorded. Samples are also collected and analyzed for chlorophyll a, chlorophyll b, chlorophyll c, carotenoids, and pheophytin from ½ the total photic (secchi) depth. The in situ measurements are collected at the top, middle and bottom of the water column if the station is greater than 2 meters, and only at mid depth if the station is less than 2 meters in depth.

In discussions with District staff familiar with Project IRL, it was suggested that several parameters could be removed from the Project. It is believed that the data for these parameters is not used and the costs incurred in analysis, QA/QC, database maintenance and storage could be reduced. The parameters suggested for removal include: Chlorophyll b, chlorophyll c, and carotenoids. These parameters are not included in the parameter summary tables below.

In 1999-2000 an analysis was conducted to determine if a change in sampling frequency would result in the ability to detect changes in seagrass due to water quality. District staff reported that the analysis results suggested that with quarterly sampling, it would take approximately 10 years to see changes. With sampling approximately seven times per year, it would take approximately 6 years to see changes. To enable the increased frequency of sampling, monitoring at several of the original sampling stations was discontinued.

**Current and Future Data Uses**
The South Florida Water Management District has an agreement with the St. Johns Water Management District to monitor the entire Indian River Lagoon. Currently, the South Florida water Management District is the only agency conducting monitoring of the St. Lucie Estuary – Indian River Lagoon system. The data gathered from this monitoring is critical to a number of District operations and reports. District operations use this information to monitor water in the lagoon and estuary and how it changes with releases. The data are incorporated (or will be incorporated in the near future) in the South Florida Environmental Report and the Water Quality Targets Report and are critical for the Indian River Lagoon Feasibility Study. The data will also be used to develop Minimum Flows and Levels (MFLs) and will be used by the District and DEP to develop TMDLs and PLRGs.

Data collected from SE, IRL and WQM also are used in several modeling activities being developed by the District. The St. Lucie Estuary FDC model is being developed to evaluate the estuarine portion of the waterbody whereas the WASH model is being developed to evaluate the surrounding watershed.

The St. Lucie Estuary – Indian River Lagoon system is also included in CERP and RECOVER. The data from the SE, IRL and WQM monitoring projects will be necessary for the North Palm Beach County CERP projects (Pal-Mar and J.W. Corbett Wildlife Management Area Hydropattern Restoration, L-8 Basin Modification, C-51 and L-8 Reservoir, Lake Worth Lagoon Restoration, C-17 Backpumping and Treatment and C-51 Backpumping and Treatment), as well as the Indian River Lagoon – South CERP project (C-44 Reservoir, C-44 East STA, C-44 West STA, C23/24 Basins and the C-25 and Northfork and Southfork Basins). The C-44 Reservoir and the STAs in the EAA have also been designated as ACCELER8 Projects. Many of the monitoring stations from SE, IRL, and WQM will also be monitored as part of the RECOVER Monitoring and Assessment Plan, Northern Estuaries module.

**Identified Optimization Opportunities:**
Discussions with District staff identified some potential opportunities for optimization. Additionally, questions were generated that will provide useful for guiding the optimization.

- Are there spatial and temporal redundancies at the stations?

- Are there redundancies in the parameters sampled? Which parameters can adequately address water quality in the lagoon?
- Is the sampling frequency sufficient to detect trends and determine potential problems?
- Is the frequency sufficient to detect changes to seagrass communities at a level that is effective for management?

**Parameters Measured for Project IRL**

| Station | DO | PH | TEMP | SALIN | SCOND | PAR | SECCI | CHLA | CHLA2 | PHAEO | COLOR | TKN | NH4 | NO2 | NOX | OPO4 | TPO4 | TSS | TURBI | VSS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IRL02 | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr |
| IRL04 | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr |
| IRL06 | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr |
| IRL08B | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr |
| IRL11B | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr |
| IRL12B | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr |
| IRL15B | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr |
| IRL17 | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr |
| IRL18B | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr |
| IRL21 | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr |
| IRL22 | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr |
| IRL24 | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr |
| IRL25 | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr |
| IRL27 | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr |
| IRL28 | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr |
| IRL29 | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr |
| IRL31B | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr |
| IRL34B | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr |
| IRL36 | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr |
| IRL39 | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr |
| IRL40 | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr | 7/yr |

7/yr = 7 times per year; gray shading indicates a Type 2 station

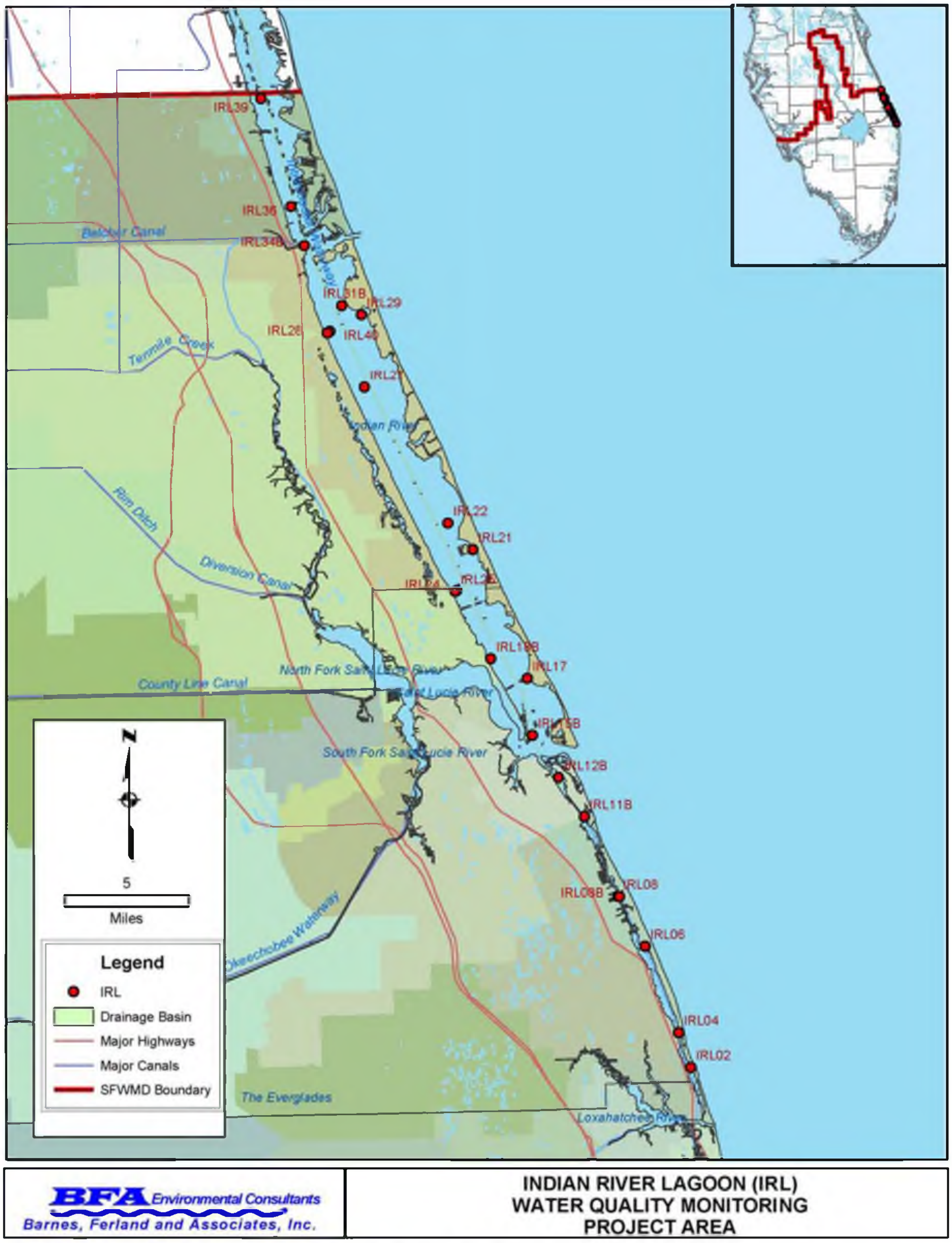



**Figure 1. IRL Sampling Locations.**

**Optimization analysis:**

Optimization of the IRL water quality monitoring project was undertaken with respect to the specific tasks outlined above and detailed in the optimization plan modified and approved in September 20005. Briefly, the spatial and temporal adequacy of the IRL project was evaluated with respect to being able to detect changes between time periods and being able to detect trends in water quality parameters by station within the project The parameters identified for optimization in this project were: Color, TSS, TPO4, DO, PAR (K) and Turbidity. Units and DBHydro codes are:

| Parameter | Units | DBHydro Code |
|---|---|---|
| Color | PCU | 13 |
| Dissolved Oxygen | mg/L | 8 |
| PAR | 1/m | 197 (data provided separately from DBHydro) |
| TPO4 | mg/L | 25 |
| TSS | mg/L | 16 |
| Turbidity | NTU | 12 |

- To estimate power and detectable effect size of the current monitoring program, Monte Carlo simulation using the nonparametric sign test was used to estimate the detectable change in median value for each parameter of interest across stations corresponding to a significant shift in the distribution from current levels given the current sampling effort. Further, the test was constructed to establish whether or not a given magnitude of change would result in an observable exceedance of a water quality target.

- To estimate the power to detect a trend for a given water quality parameter, Monte Carlo simulations were performed using the Seasonal Kendall Tau Test for Trend. This procedure is being documented as a statistical evaluation tool for the SFWMD and the procedure will be outlined in detail in separate documentation. Briefly, the simulations result in an estimate of the slope (time series trend) that can be detected for a given monitoring routine using the current annual effort and under alternative sampling strategies. Again, target criteria were used to assess the power for trend detection.

The IRL project has specified targets for each parameter of interest that would qualify a measurement as an exceedance. These targets values are:

- Color > 8.0 (pcu)
- TSS > 20.0 (mg/L)
- TPO4 > 0.053 (mg/L)
- DO < 6.09 (mg/L)
- PAR < -1.2 (1/m)
- Turb > 2.84 (ntu)

Therefore, these targets were used as criteria for assessing the power to detect changes in median concentrations and in detecting if trends that would result in an exceedance of a specific water quality target can be detected with statistical significance. The focus of this optimization was on optimizing the sampling frequency necessary to detect changes in water quality parameter medians with respect to the specific targets listed above and estimating the ability to detect time series trends (i.e., changes in slope).

The first component of the optimization was to examine the project-wide distribution for each parameter of interest, calculate the long term median value for each parameter of interest and generate a simulation dataset that could be used to test the effectiveness of the current monitoring sampling design to estimate changes in water quality parameters of interest to the district. Details of the sign test methods are conveyed in the master document. Briefly, the sign test simulation exercise is meant to demonstrate the ability of a sampling program to detect changes from a baseline value under a given sampling frequency. The long term median value was used to represent a baseline value and the test was constructed as a one-sample test to estimate the power to detect a change in the median value for each water quality variable of interest. Since there is only variability associated with one group of data for the comparison, the test is more powerful than a two- sample test where uncertainty is expressed in the distribution of each comparison group. Further, the sign test simulations do not account for serial auto-correlation which can be present in monitoring data. The presence of significant auto correlation, if not accounted for, can yield unrealistically optimistic assessments of the sample size necessary to detect changes. However, from a regulatory perspective, auto-correlation is usually not considered when assessing whether or not a water body is meeting or exceeding a given water quality target (e.g., Impaired Waters Rule F.A.C. 62-303.320). Auto-correlation is not considered in the sign test simulations but is considered in the test for trend analysis presented later in this document.

Table 1. provides a summary of the simulation results using the Sign Test to estimate the effect size detectable under the current monitoring strategy and identify the sample size required to detect a specified magnitude of change from current conditions. Since water quality targets are established for the IRL the inference from the sign test was with respect to assessing the number of samples required to detect a shift to the water quality target value.

**Table 1. Results of Monte Carlo simulation using the Sign Test to determine the effect size and number of samples to detect a 20% change in long term median value (Target) with 80% power.**

| Parameter | Nobs/Year | Long Term Median Value | Target Value | Annual Percent Change Detected | Number of Samples to Detect Shift to Target |
|---|---|---|---|---|---|
| Color | 91 | 6.00 | 8.00 | 13.93 | 50 |
| DO | 91 | 6.03 | 6.09 | 7.65 | >500 |
| PAR | 91 | -0.949 | -1.20 | 18.75 | 91 |
| TPO4 | 91 | 0.043 | 0.053 | 19.10 | 91 |
| TSS | 91 | 9.4 | 20 | 9.03 | 20 |
| Turbidity | 91 | 4.08 | 2.84 | 33.91 | 150 |

Results suggest that the basin-wide sampling frequency was sufficient to detect a target exceedance on an annual basis for Color, PAR and TSS. For turbidity, a shift in median to the target would take two years worth of sampling. For DO the long term median value was very close to the target such that detecting such a small shift in median would require an extremely large sample size.

The second component of the optimization was to assess the power to detect time series trends for the water quality parameters of interest. For the IRL project, data from 2000 to 2004 were used to estimate the seasonal variability and autocorrelation for each station/parameter set. A simulation dataset was generated from which samples could be pulled representing a 5 year time series. For each replicate trial, the Seasonal Kendall Tau Test for Trend was used to estimate the annual percent change in slope that could be detected under the current sampling design and under alternative sampling frequencies.

The ability to detect trends that would lead to a target exceedance for individual stations within the IRL project was parameter dependent. For the parameter PAR, several stations including IRL24, IRL29, IRL31B, IRL36 and IRL39 had sufficient sampling frequencies to detect a trend in PAR towards an exceedance in 5 years (Table 2). For stations IRL40 and IRL15B increasing sampling frequencies to 24samples/year would allow for trend detection for PAR. For the remaining stations, it appears that the PAR values in 2000 were close enough to the target values or that variability in the time series was large enough not to allow for trend detection to the target. This was also the case for several other parameters of interest, especially DO which was generally very close to or in exceedance (a value lower than the target) of the target value. There also appeared to be a spatial component to the trend detection with stations in southern IRL better able to detect trends in Turbidity while several stations in northern IRL were capable of detecting trends for PAR. Only in two cases was there a detectable trend in Color even with bi-weekly sampling while in no case was there a detectable trend in TSS.

**Table 2. Results of Monte Carlo simulation using the Seasonal Kendall Tau Test for Trend on a 5 year time series of grab samples to determine the effect size for change in slope parameter.**

| Station | Parameter | Number of samples per year | Slope Estimate | Annual Percent Change Detectable | Can You Detect an Exceedance in 5 Years? |
|---|---|---|---|---|---|
| IRL02 | Color | 7 | 0 | 24.6 | Y |
| | DO | 7 | 0 | 46.3 | N |
| | PAR | 7 | 0 | NC | |
| | TPO4 | 7 | 0 | 0.91 | Y |
| | TSS | 7 | 0 | 24.9 | N |
| | Turbidity | 7 | 0.0900 | 14.2 | Y |
| | | | | | |
| IRL04 | Color | 7 | 0 | 23.2 | Y |
| | DO | 7 | 0 | 57.5 | N * |
| | PAR | 7 | 0 | 19.3 | N |
| | TPO4 | 7 | 0 | 0.91 | Y |
| | TSS | 7 | 0 | 21.9 | N |
| | Turbidity | 7 | 0 | 14.6 | Y |
| | | | | | |
| IRL06 | Color | 7 | 0 | 28.4 | N |
| | DO | 7 | 0 | 36.2 | N * |
| | PAR | 7 | 0 | 15.4 | N |
| | TPO4 | 7 | 0 | 1.7 | Y |
| | TSS | 7 | 0 | 24.8 | N |
| | Turbidity | 7 | 0 | 17.6 | Y |
| | | | | | |
| IRL08B | Color | 7 | 0 | 28.6 | N * |
| | DO | 7 | 0 | 34.4 | N * |
| | PAR | 7 | 0 | 17.3 | N * |
| | TPO4 | 7 | 0 | 2.4 | Y |
| | TSS | 7 | 0 | 29.8 | N |
| | Turbidity | 7 | 0.088 | 10.9 | Y |
| | | | | | |
| IRL11B | Color | 7 | 0 | 36.7 | N * |
| | DO | 7 | 0 | 26.1 | N * |
| | PAR | 7 | -0.1138 | 12.6 | N |
| | TPO4 | 7 | 0 | 1.4 | Y |
| | TSS | 7 | 0 | 22.2 | N |
| | Turbidity | 7 | 0.0840 | 10.7 | Y |
| | | | | | |
| IRL12B | Color | 7 | 0 | 39.2 | N * |
| | DO | 7 | 0 | 28.7 | N |
| | PAR | 7 | 0 | 16.1 | N * |
| | TPO4 | 7 | 0 | 2.0 | Y |
| | TSS | 7 | 0 | NC | |
| | Turbidity | 7 | 0 | NC | |
| | | | | | |
| IRL15B | Color | 7 | 0 | NC | |
| | DO | 7 | 0 | 38.6 | N |
| | PAR | 7 | 0 | 16.8 | N + |
| | TPO4 | 7 | 0 | 3.0 | Y |
| | TSS | 7 | 0 | NC | |
| | Turbidity | 7 | 0 | 29.1 | N |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | |
| IRL17 | Color | 7 | 0 | 39.8 | N |
| | DO | 7 | 0 | 30.0 | N * |
| | PAR | 7 | 0 | 17.6 | N * |
| | TPO4 | 7 | 0 | 1.7 | Y |
| | TSS | 7 | -0.1799 | 23.9 | N * |
| | Turbidity | 7 | 0 | 39.8 | N |
| | | | | | |
| IRL18B | Color | 7 | 0 | 47.4 | N |
| | DO | 7 | 0 | NC | |
| | PAR | 7 | 0 | 16.3 | N |
| | TPO4 | 7 | 0 | 2.0 | Y |
| | TSS | 7 | -0.2039 | 23.9 | N * |
| | Turbidity | 7 | 0 | 23.2 | N |
| | | | | | |
| IRL21 | Color | 7 | 0 | 30.0 | N |
| | DO | 7 | 0 | NC | |
| | PAR | 7 | 0 | 10.5 | N * |
| | TPO4 | 7 | 0 | 1.4 | Y |
| | TSS | 7 | -0.1582 | 22.7 | N * |
| | Turbidity | 7 | 0 | 22.6 | N |
| | | | | | |
| IRL22 | Color | 7 | 0 | 36.7 | N |
| | DO | 7 | 0 | 98.2 | N |
| | PAR | 7 | 0 | 13.9 | N |
| | TPO4 | 7 | 0 | 0.8 | Y |
| | TSS | 7 | 0 | 25.9 | N |
| | Turbidity | 7 | 0 | 18.2 | N |
| | | | | | |
| IRL24 | Color | 7 | 0 | 55.8 | N |
| | DO | 7 | 0 | 42.6 | N |
| | PAR | 7 | 0 | 12.4 | Y |
| | TPO4 | 7 | 0 | 1.2 | Y |
| | TSS | 7 | 0 | 21.6 | N * |
| | Turbidity | 7 | 0 | 22.5 | N * |
| | | | | | |
| IRL25 | Color | 7 | 0 | 32.2 | N |
| | DO | 7 | 0 | 67.8 | N |
| | PAR | 7 | -0.1721 | 14.0 | N |
| | TPO4 | 7 | 0 | 3.3 | Y |
| | TSS | 7 | 0 | 20.4 | N * |
| | Turbidity | 7 | 0 | 19.1 | N |
| | | | | | |
| IRL27 | Color | 7 | 0 | 28.2 | N |
| | DO | 7 | 0 | 34.7 | N |
| | PAR | 7 | 0 | 11.2 | N + |
| | TPO4 | 7 | 0 | 0.8 | Y |
| | TSS | 7 | 0 | 31.2 | N |
| | Turbidity | 7 | 0 | 40.4 | N |
| | | | | | |
| IRL28 | Color | 7 | 0 | 23.2 | N |
| | DO | 7 | 0 | 82.7 | N * |

| | | | | | |
|---|---|---|---|---|---|
| | PAR | 7 | 0 | 95.9 | N |
| | TPO4 | 7 | 0 | 0.8 | Y |
| | TSS | 7 | -0.2620 | 33.0 | N * |
| | Turbidity | 7 | -0.1780 | 25.3 | N * |
| | | | | | |
| IRL29 | Color | 7 | 0 | 23.8 | N |
| | DO | 7 | 0 | 154.9 | N * |
| | PAR | 7 | 0 | 8.3 | Y |
| | TPO4 | 7 | 0 | 0.7 | Y |
| | TSS | 7 | 0 | 29.2 | N |
| | Turbidity | 7 | 0 | 15.1 | Y |
| | | | | | |
| IRL31B | Color | 7 | 0 | 43.5 | N |
| | DO | 7 | 0 | 62.6 | N * |
| | PAR | 7 | 0 | 17.2 | Y |
| | TPO4 | 7 | 0 | 0.9 | Y |
| | TSS | 7 | 0 | 24.4 | N |
| | Turbidity | 7 | 0 | 21.3 | N |
| | | | | | |
| IRL34B | Color | 7 | 0 | 144.8 | N |
| | DO | 7 | 0 | 54.6 | N |
| | PAR | 7 | 0 | 16.1 | N * |
| | TPO4 | 7 | 0 | 3.2 | Y |
| | TSS | 7 | 0 | 26.5 | N * |
| | Turbidity | 7 | 0 | 25.6 | N * |
| | | | | | |
| IRL36 | Color | 7 | 0 | 58.7 | N |
| | DO | 7 | 0 | 50.6 | N |
| | PAR | 7 | 0 | 7.5 | Y |
| | TPO4 | 7 | 0 | 1.5 | Y |
| | TSS | 7 | 0 | 24.3 | N |
| | Turbidity | 7 | 0 | 20.4 | N |
| | | | | | |
| IRL39 | Color | 7 | 0 | 41.6 | N * |
| | DO | 7 | 0 | 86.6 | N |
| | PAR | 7 | 0 | 6.7 | Y |
| | TPO4 | 7 | 0 | 1.9 | Y |
| | TSS | 7 | 0 | 24.3 | N |
| | Turbidity | 7 | 0 | 27.4 | N |
| | | | | | |
| IRL40 | Color | 7 | 0 | 32.1 | N |
| | DO | 7 | 0 | 50.2 | N * |
| | PAR | 7 | 0 | 6.1 | N + |
| | TPO4 | 7 | 0 | 0.7 | Y |
| | TSS | 7 | 0 | 38.7 | N |
| | Turbidity | 7 | 0 | 24.8 | N |

NC = non-convergence of covariance pattern model
* = mean parameter value was above the target value in year 2000
\+ = increasing sampling frequency to bi weekly would result in detection of slope to target exceedance in 5 years

The time series trend power analysis was also performed on the median monthly values of 13 stations specifically designated to represent basin-wide trends over areas with Submerged Aquatic Vegetation (SAV). The trend detection procedure was performed identically to the methods described above with the exception that the median value for the 13 stations each year/month was computed and used as the time series metric for trend detection (see Appendix IRL-1).

**Table 3. Results of Monte Carlo simulation using the Seasonal Kendall Tau Test for Trend on a 5 year time series for the 13 stations used by the IRL program to identify basin-wide trends.**

| Parameter | Number of samples per year | Slope Estimate | Annual Percent Change Detectable | Can You Detect an Exceedance in 5 Years? |
|---|---|---|---|---|
| Color | 7 | 0 | 17.9 | N |
| DO | 7 | 0 | 57.1 | N |
| Turbidity | 7 | 0 | 87.8 | N |
| TPO4 | 7 | 0 | 0.91 | Y |
| TSS | 7 | 0 | 30.5 | N |
| PAR | 7 | -0.1185 | 12.3 | N + |

\+ = increasing sampling frequency to monthly would result in detection of slope to target exceedance in 5 years

Results using the median values suggested that only TPO4 and, with additional sampling, PAR had sufficient power to detect a trend that would result in a target exceedance over 5 years. It appears that taking median values from the thirteen stations of interest does not result in an increase in power for most parameters. Turbidity and DO were close to or above the target through much of the timeseries, decreasing the power to detect changes to the target. Parameters such as TPO4 often recorded values below the detection limit which influenced the power analysis.

**Recommendations:**

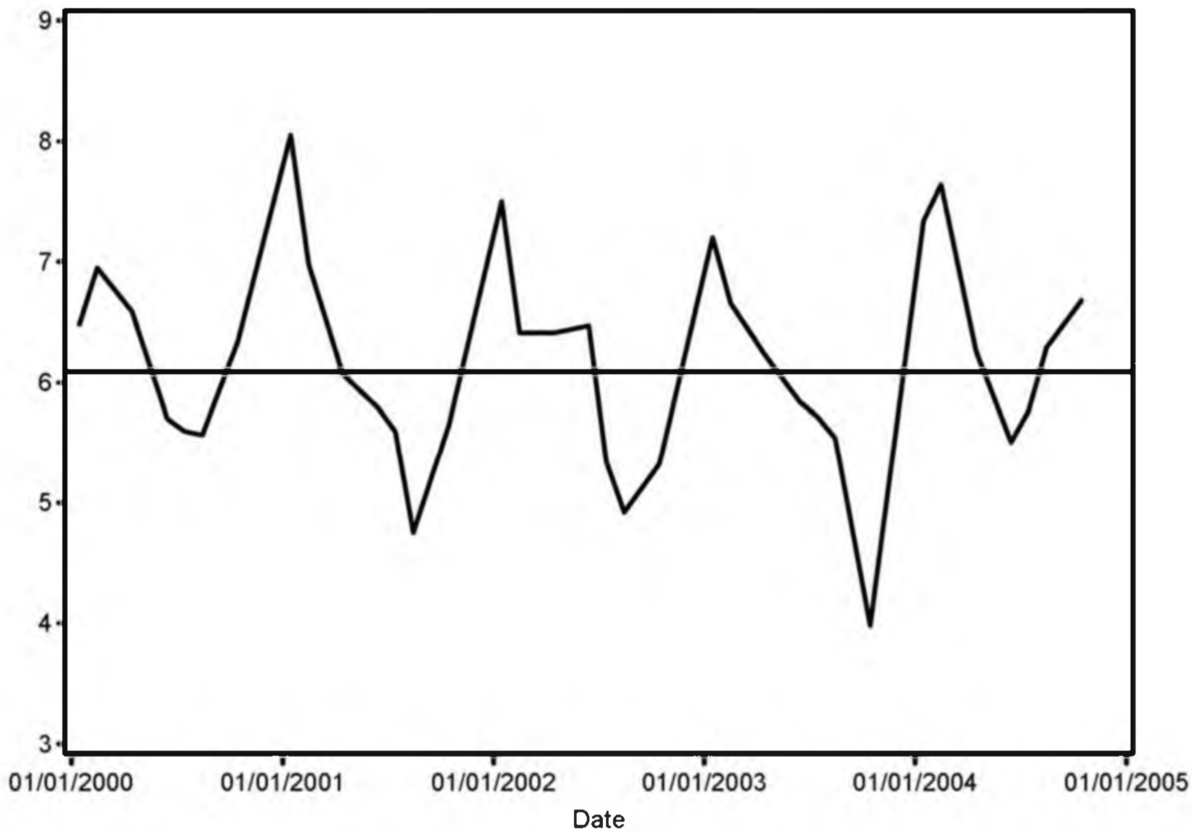
The IRL project is an important part of the South Florida's Water Quality Monitoring Network. The IRL is a highly productive estuarine system and is a receiving body from the St Lucie River as well as several major drainage basins from Lake Okeechobee and associated agricultural areas. A primary goal of the monitoring program is to ensure water quality in the IRL is suitable for the health and productivity of sea grasses. The monitoring program was altered in 2000 to reduce the annual sampling frequency to a more seasonally oriented approach with sampling occurring only 7 months of the year. The Seasonal Kendall Tau Test for Trend is used to evaluate trend in several water quality targets related to sea grass productivity. The program has developed specific targets as water quality criteria to assess these trends. Results of these analyses using the 2000 to 2004 time series suggest that for parameters TPO4 and PAR, the sampling frequencies are adequate in many cases; however, for the other parameters much more frequent sampling would be required without certainty that a trend resulting in a water quality exceedance would be detected. This is due to where the average values for these parameters are in relation to the target. For example, DO is generally very close to the target value such that detecting a very shallow slope that would result in an exceedance is difficult to accomplish. Further, the time series of data used here includes a period of extreme drought in Florida (2000), a period of significantly wetter than average condition (2003) and a period of extreme hurricane activity (2004). This appears to have introduced a large amount of variability into the time series which effectively reduced the power of the trend test.

From an optimization perspective the IRL project appears to be well optimized for detecting long term trends in water quality for TPO4 and to some extent PAR but for other parameters more sampling would be required. There are several considerations regarding alternative ways to evaluate the water quality data for changes over time. One important aspect is evaluating the criterion established for each parameter of interest. For example, the current DO criterion of 6.09 mg/L is a strenuous criterion to use in a lagoon/estuarine system. If the parameter average values are close to the target as with DO then the power necessary to detect changes will be small and the sample size requirements will be large. The high power to detect trends in TPO4 is likely the result of a boundary condition set for detection of TPO4 in the sample which caused reduced variability in the data. A second aspect for consideration is the time series of data applied to the power analysis. Statistically, the power for trend detection is based on the time series of data used in the analysis. The time series from 2000-2004 was used here but water quality data do exist for the IRL prior to 2000 that would be useful in assessing the power to detect trends over a longer time series. Using a longer time series has several advantages including better estimates of the long-term medians used to de-seasonalize the data prior to assessing trends using the Seasonal Kendall Tau program. Longer time series also increase the precision of inter-annual differences in water quality related to long term climatic cycles such as el nino/ la nina events. Additionally, consideration should be given to using a meta-analysis approach to assess basin-wide trends in addition to using the median condition from the thirteen stations. The meta–analysis approach is described in the EPA's Seasonal Kendall Tau software methodology book commonly used by the District. This approach pools the results of individual station trend tests to evaluate "collectively" what the trend is for a parameter of interest across all stations in the program. This may be a more effective means of assessing trends across stations than using the median values. This study has led to the development and delivery to the District of an important simulation based trend test power tool to facilitate future optimizations for the IRL project. Currently, the IRL project is sampling at a minimum frequency necessary to detect trends in water quality at most stations. Given the large variability in climatic events during the 2000-2004 dataset, a longer time series of data would be beneficial to better represent the long term condition of this system.

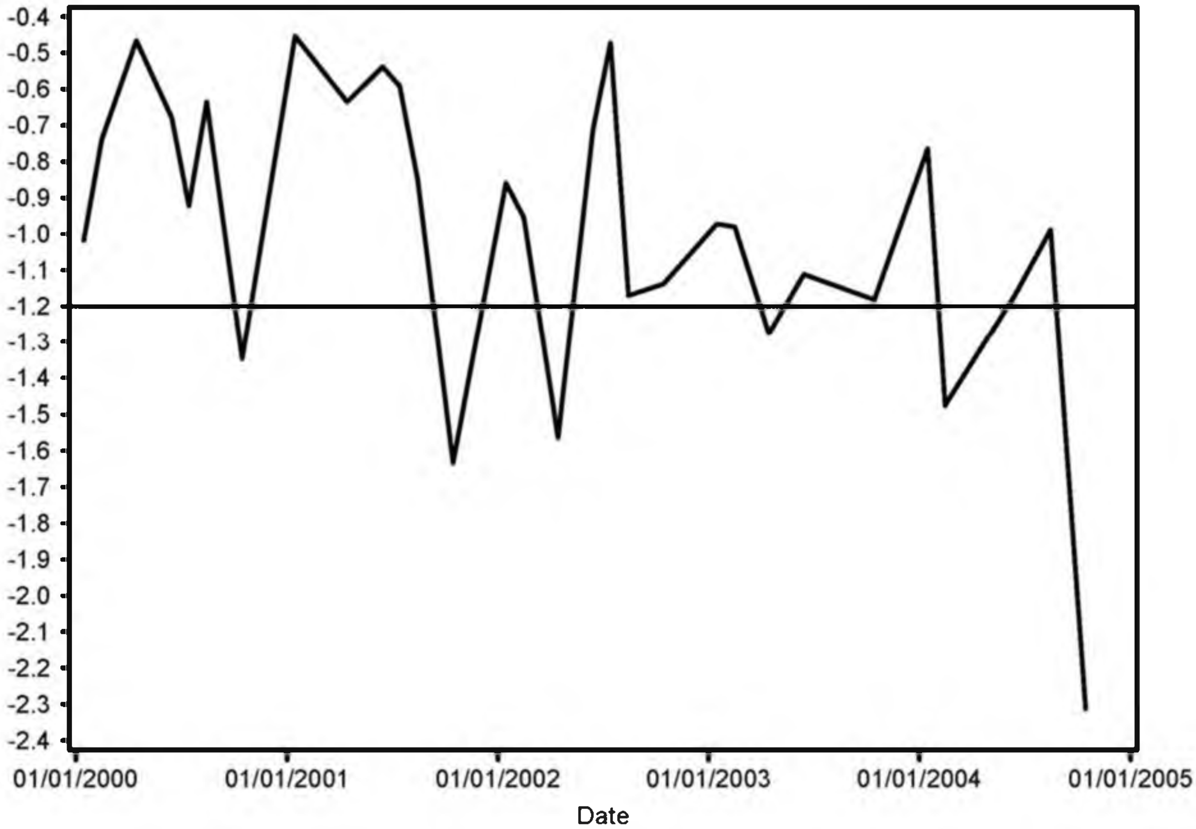
# Appendix IRL-1

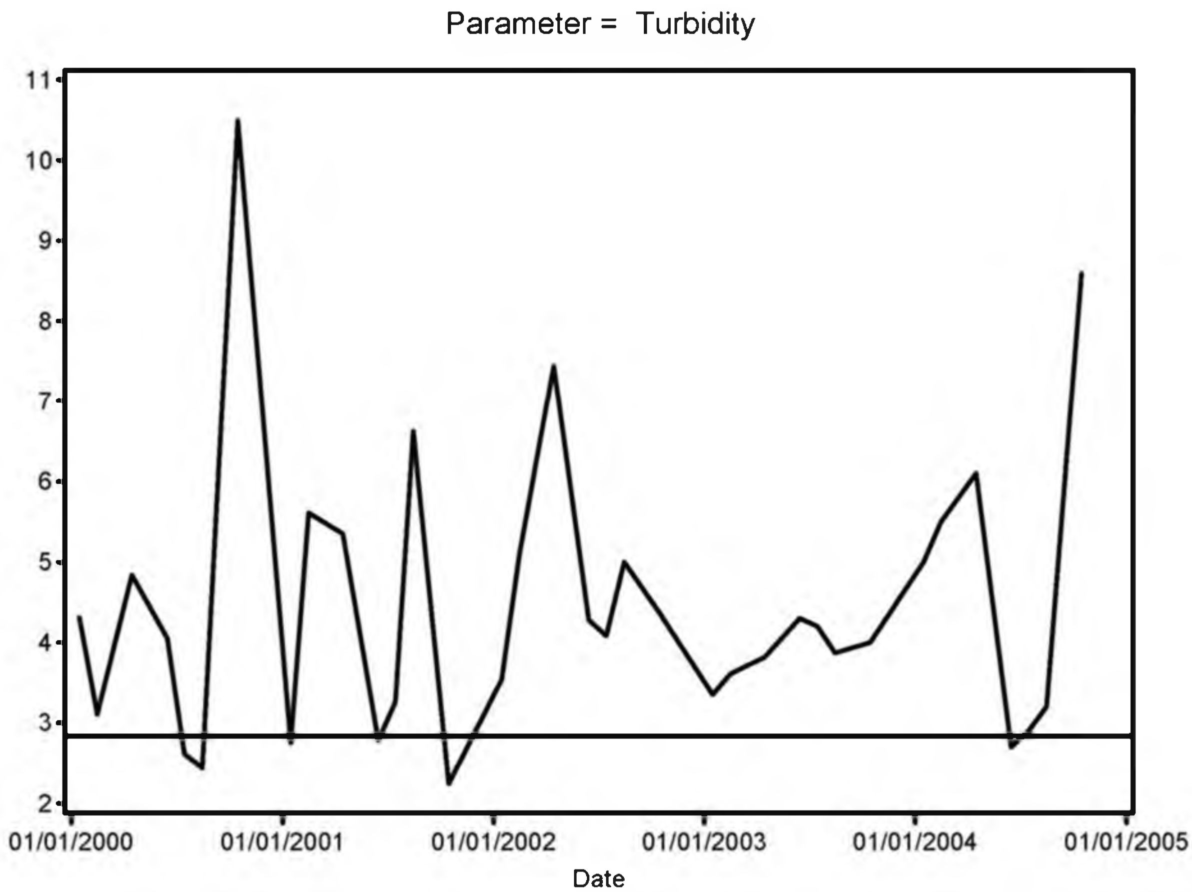
Time series plots for median of 13 stations

Parameter = DO

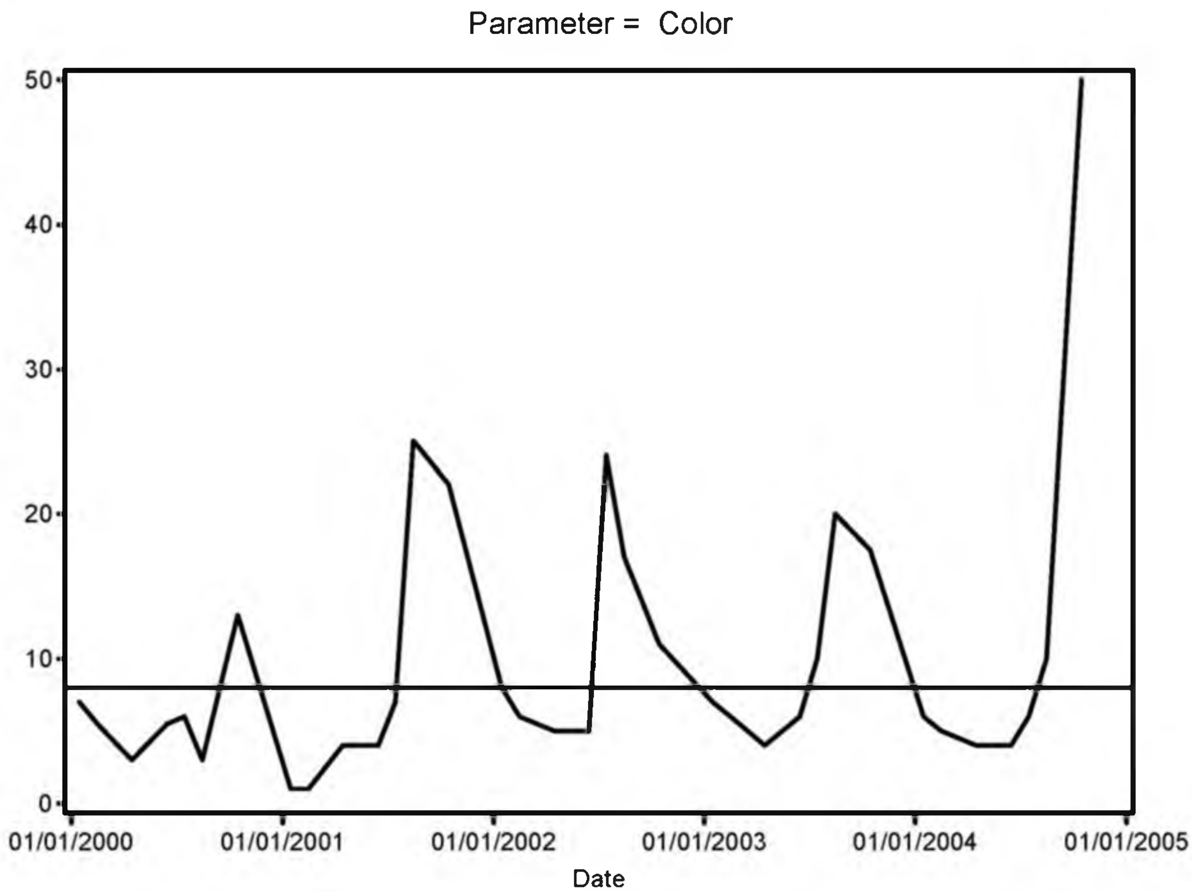


Parameter = PAR

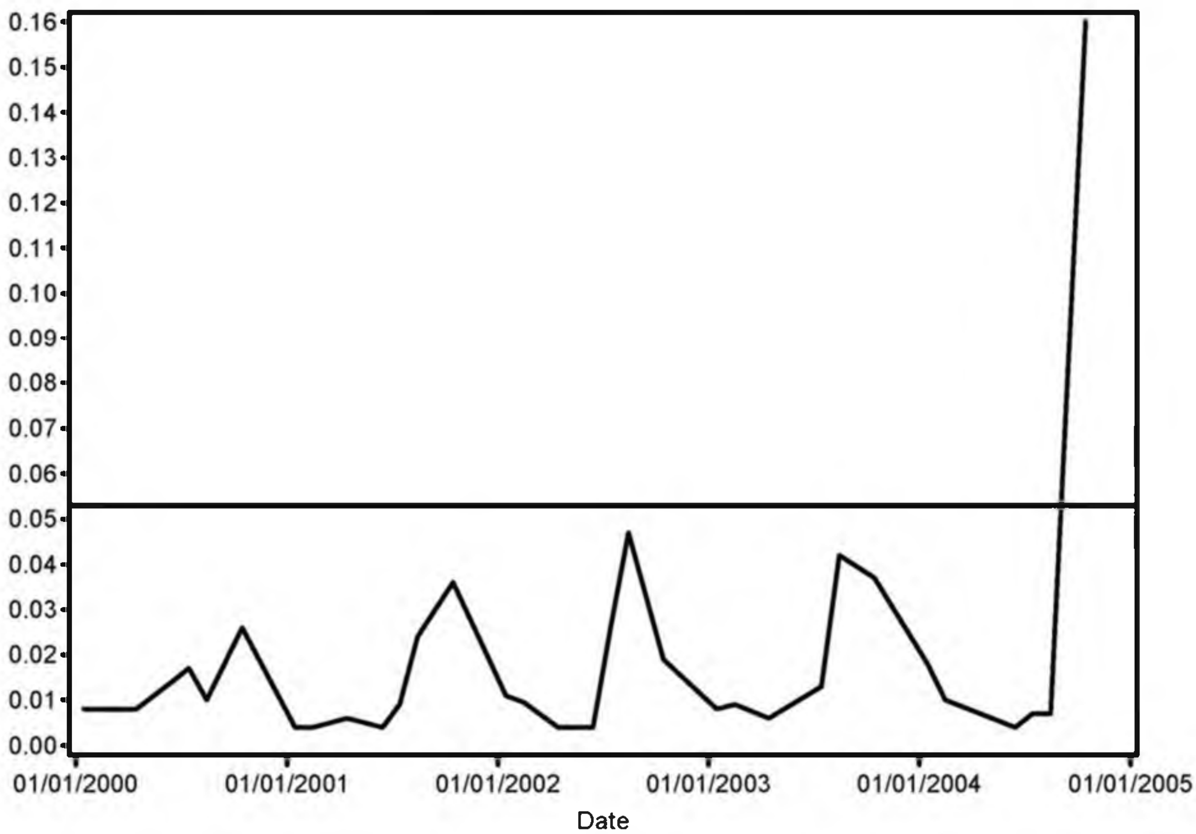


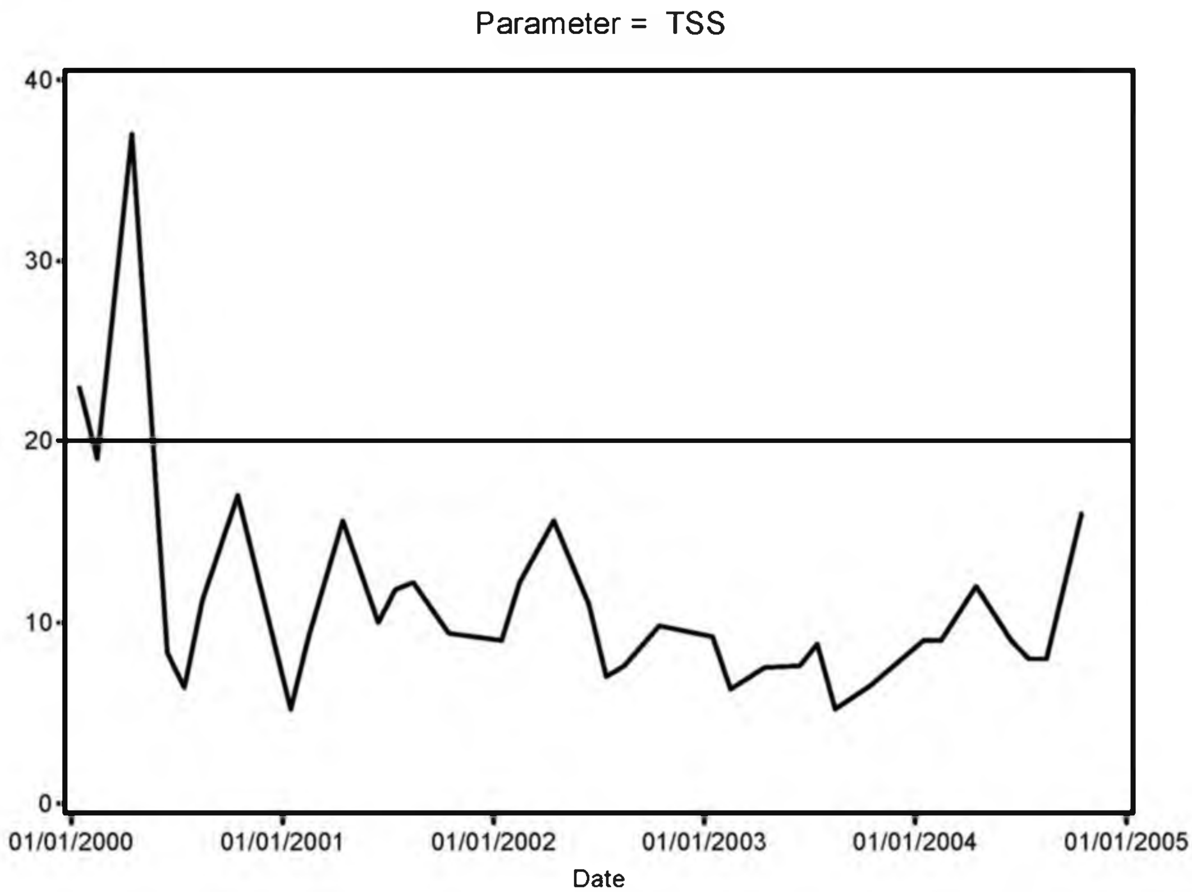


Parameter = Turbidity
11
10
9
8
7
6
5
4
3
2
01/01/2000
01/01/2001
01/01/2002
01/01/2003
01/01/2004
01/01/2005
Date


Parameter = Color
50
40
30
20
10
0
01/01/2000
01/01/2001
01/01/2002
01/01/2003
01/01/2004
01/01/2005
Date

Parameter = TPO4




Parameter = TSS
40
30
20
10
0
01/01/2000
01/01/2001
01/01/2002
01/01/2003
01/01/2004
01/01/2005
Date

*The MEANS Procedure*

**Parameter=Color**

| Analysis Variable : avg_date_value VALUE | |
|---|---|
| **N** | **Median** |
| 458 | 7.0000000 |

**Parameter=DO**

| Analysis Variable : avg_date_value VALUE | |
|---|---|
| **N** | **Median** |
| 900 | 6.0500000 |

**Parameter=PAR**

| Analysis Variable : avg_date_value VALUE | |
|---|---|
| **N** | **Median** |
| 305 | -0.9800950 |

**Parameter=TPO4**

| Analysis Variable : avg_date_value VALUE | |
|---|---|
| **N** | **Median** |
| 418 | 0.0440000 |

**Parameter=TSS**

| Analysis Variable : avg_date_value VALUE | |
|---|---|
| **N** | **Median** |
| 454 | 9.6000000 |

## *The MEANS Procedure*

### Parameter=Turbidity

| Analysis Variable : avg_date_value VALUE | |
|---|---|
| **N** | **Median** |
| 458 | 4.1000000 |

# St. Lucie Estuary

**Optimization Leader: David Wade, Janicki Environmental**
**Statistician: David Wade, Janicki Environmental**

**Project Code:** SE

**Type:** Type II

**Mandate or Permit:**

- Surface Water Improvement and Management Plan (SWIM) Chapter 373.451-373.4595 F.S.
- WRDA 2000 Public Law 106-541, Title VI, Section 601. Comprehensive Everglades Restoration Plan – Indian River Lagoon South project (CERP-IRL)
- REstoration COoordination and VERification (RECOVER) Monitoring and Assessment Plan
- FL Watershed Restoration Act Chapter 403.067 F.S. (TMDLs/MFLs/PLRGs)

**Project Start Date:** October 1989

**Division Manager:** Coastal Ecosystems Division: Sean Sculley (acting)

**Program Manager:** Dan Crean

**Points of Contact:** Dan Crean, Nenad Iricanin, Monique Laham-Pass

**Field Point of Contact:** Monique Laham-Pass

**Spatial Description:**
The St. Lucie Estuary is located on the east coast of southern central Florida in Martin and St. Lucie counties. Water from the eastern portion of Lake Okeechobee flows through the S-308 structure and into the C-44 Canal (e.g., St. Lucie Canal), which eventually drains into the southern portion of the St. Lucie Estuary. This canal provides a navigational channel from the lake to the east coast of Florida. The St. Lucie Estuary has both a north fork and south fork branching from the main inlet. The SE monitoring project contains sampling locations in the inlet (SE11, SE01, SE02, and SE03), the north fork (SE04, HR1, SE06, SE07, SE12 and SE13) and the south fork (SE08, SE09, SE10). Based on the canals draining into these two forks of the estuary, the south fork will receive water from the C-44 drainage basin and the north fork will receive water from the C-23 and C-24 drainage basins.

The Indian River Lagoon is divided into north and south portions by the St. Lucie Estuary inlet. Several of the IRL water quality monitoring project stations are located in close proximity to the St. Lucie inlet sampling locations. These station include IRL12B and IRL 15B and may need to be considered when evaluating data for project SE.

**Project Purpose, Goals and Objectives:**
The purpose of the SE project is to address the mandates listed above. The St. Lucie estuary supports a variety of commercial and recreational activities, and it provides critical habitat for many aquatic organisms. Therefore, a main focus of the SE water quality monitoring is to provide baseline water quality data to better evaluate problem areas within the estuary, especially those related to point source discharges. These data can be used to determine short and long term water quality trends within the estuary; determine the effects of fresh water releases upon sea grasses, oyster beds, and macroinvertatbrates; and determine the movement and duration of salinity gradients. The monitoring data can also indicate changes in water quality which allows for better management of the estuary for environmental enhancement, and prevention of further degradation.

**Sampling Frequency and Parameters Sampled:**
Sampling at all stations for Project SE occurs on a monthly basis. Grab samples are collected at ½ the total water column depth and analyzed for color, turbidity, total suspended solids, volatile suspended solids, total Kjeldahl nitrogen, total phosphorus, orthophosphate, ammonia, nitrite, and nitrite+nitrate. In situ measurements are also

collected at all sites and include pH, dissolved oxygen, temperature, salinity, specific conductance and photosynthetically active radiation. Total depth and sechhi depth at each location is also recorded. Samples are also collected and analyzed for chlorophyll a, chlorophyll b, chlorophyll c, carotenoids, and pheophytin from ½ the total photic (secchi) depth. In situ measurements are collected every ½ meter in the water column at each station.

In discussions with District staff familiar with Project SE, it was suggested that several parameters could be removed from Project SE. It is believed that the data for these parameters is not used and the costs incurred in analysis, QA/QC, database maintenance and storage could be reduced. The parameters suggested for removal include: Chlorophyll b, chlorophyll c, and carotenoids. These parameters are not included in the parameter summary tables below.

**Current and Future Data Uses:**
Currently, the District is the only agency conducting monitoring of the St. Lucie Estuary – Indian River Lagoon system. The data gathered from this monitoring is critical to a number of District operations and reports. District operations use this information to monitor water in the estuary and how it changes with releases. The data is incorporated (or will be incorporated in the near future) in the South Florida Environmental Report and the Water Quality Targets Report. The data will also be used to develop Minimum Flows and Levels (MFLs) and will be used by the District and DEP to develop TMDLs and PLRGs.

Data collected from SE, IRL and WQM also are used in several modeling activities being developed by the District. The St. Lucie Estuary FDC model is being developed to evaluate the estuarine portion of the waterbody whereas the WASH model is being developed to evaluate the surrounding watershed.

The St. Lucie Estuary – Indian River Lagoon system is also included in CERP and RECOVER. The data from the SE, IRL and WQM monitoring projects will be necessary for the North Palm Beach County CERP projects (Pal-Mar and J.W. Corbett Wildlife Management Area Hydropattern Restoration, L-8 Basin Modification, C-51 and L-8 Reservoir, Lake Worth Lagoon Restoration, C-17 Backpumping and Treatment and C-51 Backpumping and Treatment), as well as the Indian River Lagoon – South CERP project (C-44 Reservoir, C-44 East STA, C-44 West STA, C23/24 Basins and the C-25 and Northfork and Southfork Basins). The C-44 Reservoir and the STAs in the EAA have also been designated as ACCELER8 Projects. Many of the monitoring stations from SE, IRL, and WQM will also be monitored as part of the RECOVER Monitoring and Assessment Plan, Northern Estuaries module.

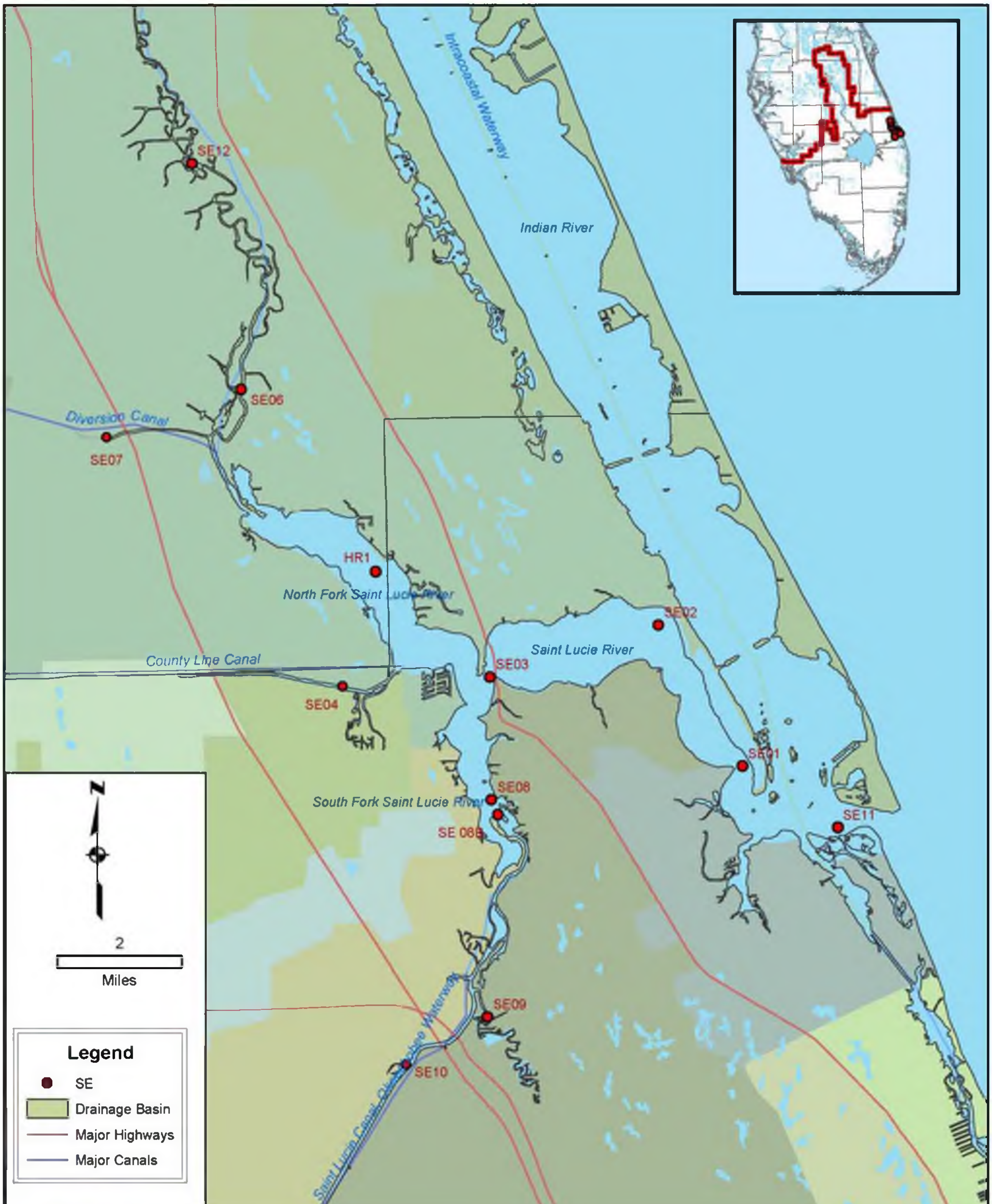
**Identified Optimization Opportunities:**
Discussions with District staff identified some potential opportunities for optimization. Additionally, questions were generated that will provide useful for guiding the optimization.

- Are there spatial and temporal redundancies at the estuarine stations? Freshwater stations?
- Are there redundancies in the parameters sampled? Which parameters can adequately address water quality in the estuary?
- Is the sampling frequency sufficient to detect trends and determine potential problems?

**Parameters Measured for Project SE**

| Station | DO | PH | TEMP | SALIN | SCOND | PAR | SECCI | CHLA | CHLA2 | PHAEO | COLOR | TKN | NH4 | NO2 | NOX | OPO4 | TPO4 | TSS | TURBI | VSS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HR1 | m | m | m | m | m | m | m | m | M | m | m | m | m | m | m | m | m | m | m | m |
| SE01 | m | m | m | m | m | m | m | m | M | m | m | m | m | m | m | m | m | m | m | m |
| SE02 | m | m | m | m | m | m | m | m | M | m | m | m | m | m | m | m | m | m | m | m |
| SE03 | m | m | m | m | m | m | m | m | M | m | m | m | m | m | m | m | m | m | m | m |
| SE04 | m | m | m | m | m | m | m | m | M | m | m | m | m | m | m | m | m | m | m | m |
| SE06 | m | m | m | m | m | m | m | m | M | m | m | m | m | m | m | m | m | m | m | m |
| SE07 | m | m | m | m | m | m | m | m | M | m | m | m | m | m | m | m | m | m | m | m |
| SE08B | m | m | m | m | m | m | m | m | M | m | m | m | m | m | m | m | m | m | m | m |
| SE09 | m | m | m | m | m | m | m | m | M | m | m | m | m | m | m | m | m | m | m | m |
| SE10 | m | m | m | m | m | m | m | m | M | m | m | m | m | m | m | m | m | m | m | m |
| SE11 | m | m | m | m | m | m | m | m | M | m | m | m | m | m | m | m | m | m | m | m |
| SE12 | m | m | m | m | m | m | m | m | M | m | m | m | m | m | m | m | m | m | m | m |
| SE13 | m | m | m | m | m | m | m | m | M | m | m | m | m | m | m | m | m | m | m | m |

m = monthly; gray shading indicates a Type 2 station




BFA Environmental Consultants
Barnes, Ferland and Associates, Inc.

St. LUCIE ESTUARY (SE)
WATER QUALITY MONITORING
PROJECT AREA

**Figure 1. SE Sampling Locations**

**Optimization analysis:**
Optimization of the SE water quality monitoring project was undertaken with respect to the specific tasks outlined above and detailed in the optimization plan modified and approved in September 20005. Briefly, the spatial and temporal adequacy of the SE project was evaluated with respect to being able to detect changes between time periods, being able to detect trends in water quality parameters by station within the project, assessing information redundancies among stations and identifying stations located in proximity to potential point source discharges. The parameters identified for optimization in this project were:

| Parameter | Units | DBHydro Code |
|---|---|---|
| Chla corrected | mg/M3 | 112 |
| Color | PCU | 13 |
| Salinity | ppt | 98 |
| TPO4 | mg/L | 25 |
| TSS | mg/L | 16 |

- To estimate power and detectable effect size of the current monitoring program, Monte Carlo simulation using the nonparametric sign test was used to estimate the detectable change in median value for each parameter of interest across stations corresponding to a significant shift in the distribution from current levels (i.e. long-term median condition) given the current sampling effort. Further, the test was constructed to establish whether or not a given magnitude of change would result in an observable change in median identified *a priori* as a 20% change in long term median value.

- To estimate the power to detect a trend for a given water quality parameter, Monte Carlo simulations were performed using the Seasonal Kendall Tau test . This procedure is being documented as a statistical evaluation tool for the SFWMD and the procedure will be outlined in detail in separate documentation. Briefly, the simulations result in an estimate of the slope (time series trend) that can be detected for a given monitoring routine using the current annual effort and under alternative sampling strategies. Again a 20% change in parameter value over a 5 year time period was used as a target change for detection.

- Time series plots and Spearmans rank correlation test were used to identify station/parameter sets that tended to covary over time. The station groupings described above were used to examine the covariance of stations for each parameter of interest.

The SE project represents a long term data collection effort dating back to 1992. Stations SE 00 and SE 05 have been discontinued in 1994 and 1996 respectively. Station HR1 was highly correlated with SE 05 for the parameters of interest over the same period of record. Stations SE 12 and SE 13 are relatively new station beginning in 2003. Otherwise, sampling frequencies are fairly consistent through time. The SE project area is a receiving body for freshwater releases from structures on the East side of Lake Okeechobee. Incorporating flow data into the analysis was beyond the scope of this study. Therefore, the focus of this optimization was on optimizing the sampling frequency necessary to detect changes in water quality parameters with respect to a 20% change from long term median and estimating the ability to detect changes in time series trend (slope). Spatial redundancies were assessed using time series plots and station correlations.

The first component of the optimization was to examine the project-wide distribution for each parameter of interest, calculate the long term median value for each parameter of interest and generate a simulation dataset that could be used to test the effectiveness of the current monitoring sampling design to estimate changes in water quality parameters of interest to the district. Details of the sign test methods are conveyed in the master document. Briefly, the sign test simulation exercise is meant to demonstrate the ability of a sampling program to detect changes from a baseline value under a given sampling frequency. The long term median value was used to represent a baseline value and the test was constructed as a one-sample test to estimate the power to detect a change in the median value for each water quality variable of interest. Since there is only variability associated with one group of data for the comparison, the test is more powerful than a two- sample test where uncertainty is expressed in the distribution of each comparison group. Further, the sign test simulations do not account for serial auto-correlation which can be present in monitoring data. The presence of significant auto correlation, if not accounted for, can yield unrealistically optimistic assessments of the sample size necessary to detect changes. However, from a regulatory perspective, auto-correlation is often not considered when assessing whether or not a water body is meeting or exceeding a given water quality target (e.g., Impaired Waters Rule F.A.C. 62-303.320). Auto-correlation is not considered in the sign test simulations but is considered in the test for trend analysis presented later in this document.

Table 1 provides a summary of the simulation results using the Sign Test to estimate the effect size detectable under the current monitoring strategy and identify the number of years of data required to detect a twenty percent change in magnitude from the baseline condition. Data included all samples collected as part of the SE project from 1992 through 2004. When present, vertical profile data were averaged for each station/collection date combination prior to creating the simulation pool for analysis. The sample size (Nobs) was then calculated as the average annual number of samples for collections from 2000-2004. Stations SE 00 and SE 05 were not considered since sampling was discontinued in 1994 and 1996, respectively.

**Table 1. Results of Monte Carlo simulation using the Sign test to determine the effect size and number of samples to detect a 20% change in long term median value (Target) with 80% power.**

| Parameter | Average Nobs/Year | Long Term Median Value | Annual Percent Change Detected | Number of Samples to Detect Shift to Target |
|---|---|---|---|---|
| Chla corrected | 141 | 7.7 | 28.8 | 560 |
| Color | 144 | 47.0 | 26.5 | 430 |
| TPO4 | 139 | 0.17 | 21.5 | 170 |
| TSS | 144 | 8.0 | 23.9 | 200 |

The Annual Percent Change (APC) in median detectable with the current sampling effort was in the vicinity of 20% for all parameters tested though Color and Chla corrected would require 3 and 4 years of sampling, respectively, at the current effort to detect the established 20% change detection criteria. The sign test results estimate the sampling efficiency on a basin-wide inference scale. More refined analysis are detailed below that examine the ability to detect trends at individual stations within the SE project as well as capture the time series aspect of modeling water quality parameters such as the effects of auto-correlation on the uncertainty of trend detection estimates.

To assess the variability among stations within the project, box plots (Appendix SE-1), Spearmans rank correlation (Appendix SE-2) and time series plots (Appendix SE-3) were used to examine the distributional similarities and degree of covariance among stations for each parameter of interest. Generally, stations located in the inlet stations were highly correlated, especially stations SE01 SE02 and SE03. For the parameter Color and TPO4, most stations were highly correlated regardless of where in the project area they were located. Total Suspended Solids appeared to be less correlated across stations than the other parameters of interest.

The second component of the optimization was to assess the power to detect time series trends for the water quality parameters of interest. The entire time series for each parameter was modeled to estimate the seasonal variability and autocorrelation in the data. A simulation dataset was generated from which samples could be pulled representing a 5 year time series. For each replicate trial, the Seasonal Kendall Tau test was used to estimate the annual percent change in slope that could be detected under the current sampling design and under alternative sampling frequencies. A significant change in median was operationally defined a priori as a 20% increase in the median over a 5 year time frame. The collection method for all parameters was from grab samplings expect salinity where in situ field measurements (i.e., collect_method =FP) were used. Salinity measures from field collections were vertically averaged for each collection.

For the parameter TPO4, a 20% change in slope was detectable under a five year scenario for all stations (Table 2). For all other parameters of interest, the detection of a significant trend would require additional sampling. However, in all these cases doubling the sample size would not result in power to detect a 20% change in slope.

**Table 2. Results of Monte Carlo simulation using the Seasonal Kendall Tau test on a 5 year time series to determine the effect size for change in slope parameter.**

| Station | Parameter | Number of samples per year | Slope Estimate | Annual Percent Change Detectable | Can You Detect an Trend in 5 Years? |
|---|---|---|---|---|---|
| SE01 | CHLa | 12 | 0 | 35.3 | N |
| SE01 | Color | 12 | 0 | 50.9 | N |
| SE01 | Salinity | 12 | 0 | 19.8 | N |
| SE01 | TPO4 | 12 | 0 | 2.3 | Y |
| SE01 | TSS | 12 | -0.068 | 41.5 | N |
| | | | | | |
| SE02 | CHLa | 12 | 0 | 24.3 | N |
| SE02 | Color | 12 | 0 | 38.6 | N |
| SE02 | Salinity | 12 | 0 | 35.3 | N |
| SE02 | TPO4 | 12 | 0 | 2.5 | Y |
| SE02 | TSS | 12 | -0.068 | 39.0 | N |
| | | | | | |
| SE03 | CHLa | 12 | 0 | 21.8 | N |
| SE03 | Color | 12 | 0 | 31.2 | N |
| SE03 | Salinity | 12 | 0 | 45.6 | N |
| SE03 | TPO4 | 12 | 0 | 2.4 | Y |
| SE03 | TSS | 12 | 0 | 34.0 | N |
| | | | | | |
| SE04 | CHLa | 12 | 0.040 | 27.9 | N |
| SE04 | Color | 12 | 0 | 40.6 | N |
| SE04 | Salinity | 12 | 0 | 59.9 | N |
| SE04 | TPO4 | 12 | 0 | 4.0 | Y |
| SE04 | TSS | 12 | 0 | 28.8 | N |
| | | | | | |
| SE05 | CHLa | | | | |
| SE05 | Color | No longer sampled | | | |
| SE05 | Salinity | | | | |
| SE05 | TPO4 | | | | |
| SE05 | TSS | | | | |
| | | | | | |
| SE06 | CHLa | 12 | 0 | 29.2 | N |
| SE06 | Color | 12 | 0 | 21.1 | N |
| SE06 | Salinity | 12 | 0.078 | 46.1 | N |
| SE06 | TPO4 | 12 | 0.003 | 2.5 | Y |
| SE06 | TSS | 12 | 0 | 17.9 | N |
| | | | | | |
| SE07 | CHLa | 12 | 0 | 27.9 | N |
| SE07 | Color | 12 | 0 | 33.4 | N |
| SE07 | Salinity | 12 | 0.075 | 59.3 | N |
| SE07 | TPO4 | 12 | 0 | 2.9 | Y |
| SE07 | TSS | 12 | 0 | 24.2 | N |
| | | | | | |
| SE08 | CHLa | 12 | 0.050 | 24.1 | N |
| SE08 | Color | 12 | 0 | 28.8 | N |
| SE08 | Salinity | 12 | 0 | 64.6 | N |

| | | | | | |
|---|---|---|---|---|---|
| SE08 | TPO4 | 12 | 0 | 1.4 | Y |
| SE08 | TSS | 12 | 0 | 24.0 | N |
| | | | | | |
| SE09 | CHLa | 12 | 0 | 24.8 | N |
| SE09 | Color | 12 | 0 | 23.7 | N |
| SE09 | Salinity | 12 | 0 | 60.3 | N |
| SE09 | TPO4 | 12 | 0 | 1.9 | Y |
| SE09 | TSS | 12 | 0 | 20.2 | N |
| | | | | | |
| SE010 | CHLa | 12 | 0 | 25.6 | N |
| SE010 | Color | 12 | 0 | 22.2 | N |
| SE010 | Salinity | 12 | 0 | 65.1 | N |
| SE010 | TPO4 | 12 | 0 | 2.4 | Y |
| SE010 | TSS | 12 | 0 | 43.1 | N |
| | | | | | |
| SE011 | CHLa | 12 | 0 | NC** | NC** |
| SE011 | Color | 12 | 0 | 48.8 | N |
| SE011 | Salinity | 12 | 0 | 19.8 | N |
| SE011 | TPO4 | 12 | 0 | 2.0 | Y |
| SE011 | TSS | 12 | -0.184 | 29.5 | N |
| | | | | | |
| HR1 | CHLa | 12 | 0 | 31.9 | N |
| HR1 | Color | 12 | 0 | 27.1 | N |
| HR1 | Salinity | 12 | 0 | 57.4 | N |
| HR1 | TPO4 | 12 | 0 | 2.6 | Y |
| HR1 | TSS | 12 | 0 | 29.5 | N |

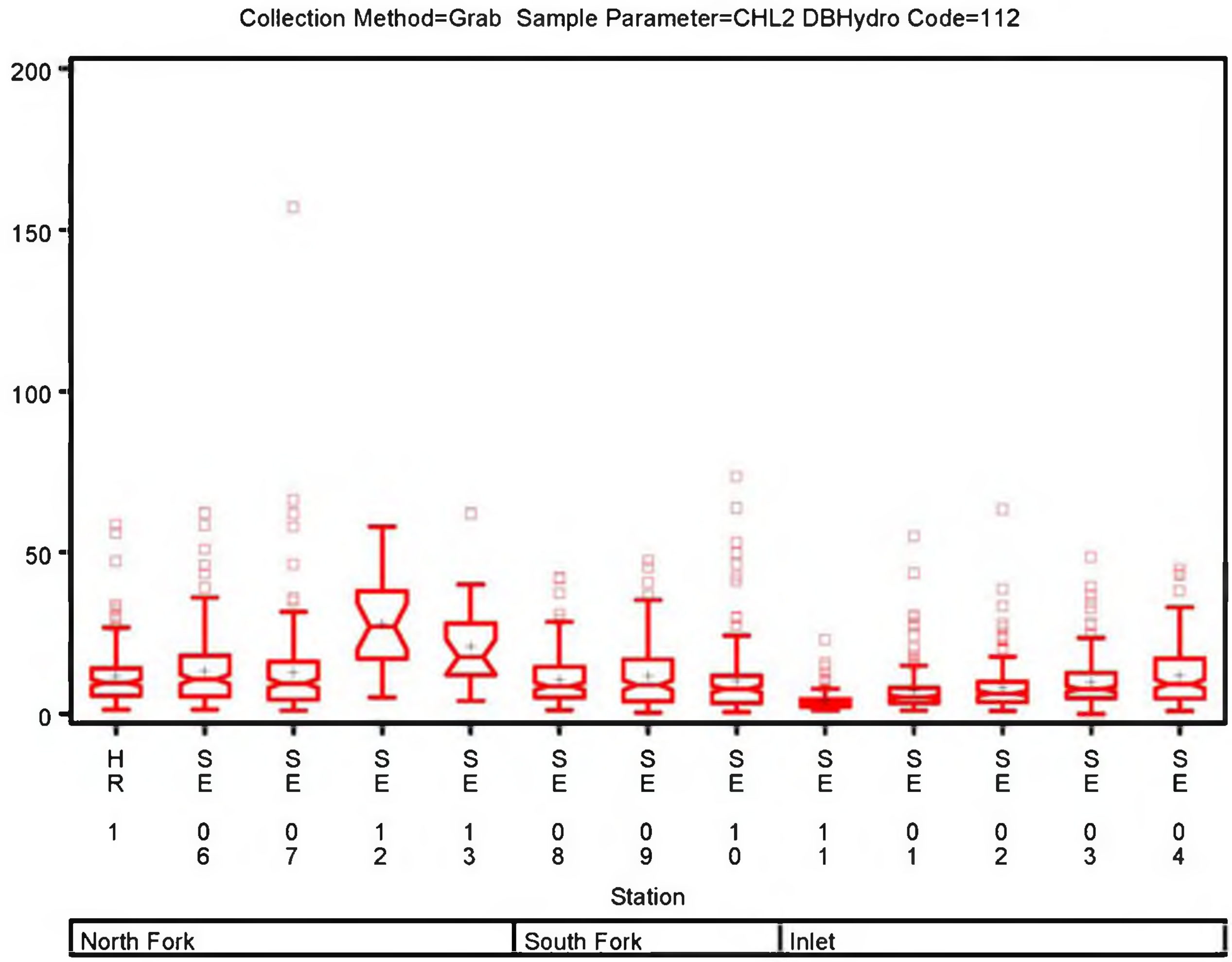
** non convergence of mixed model

**Recommendations:**

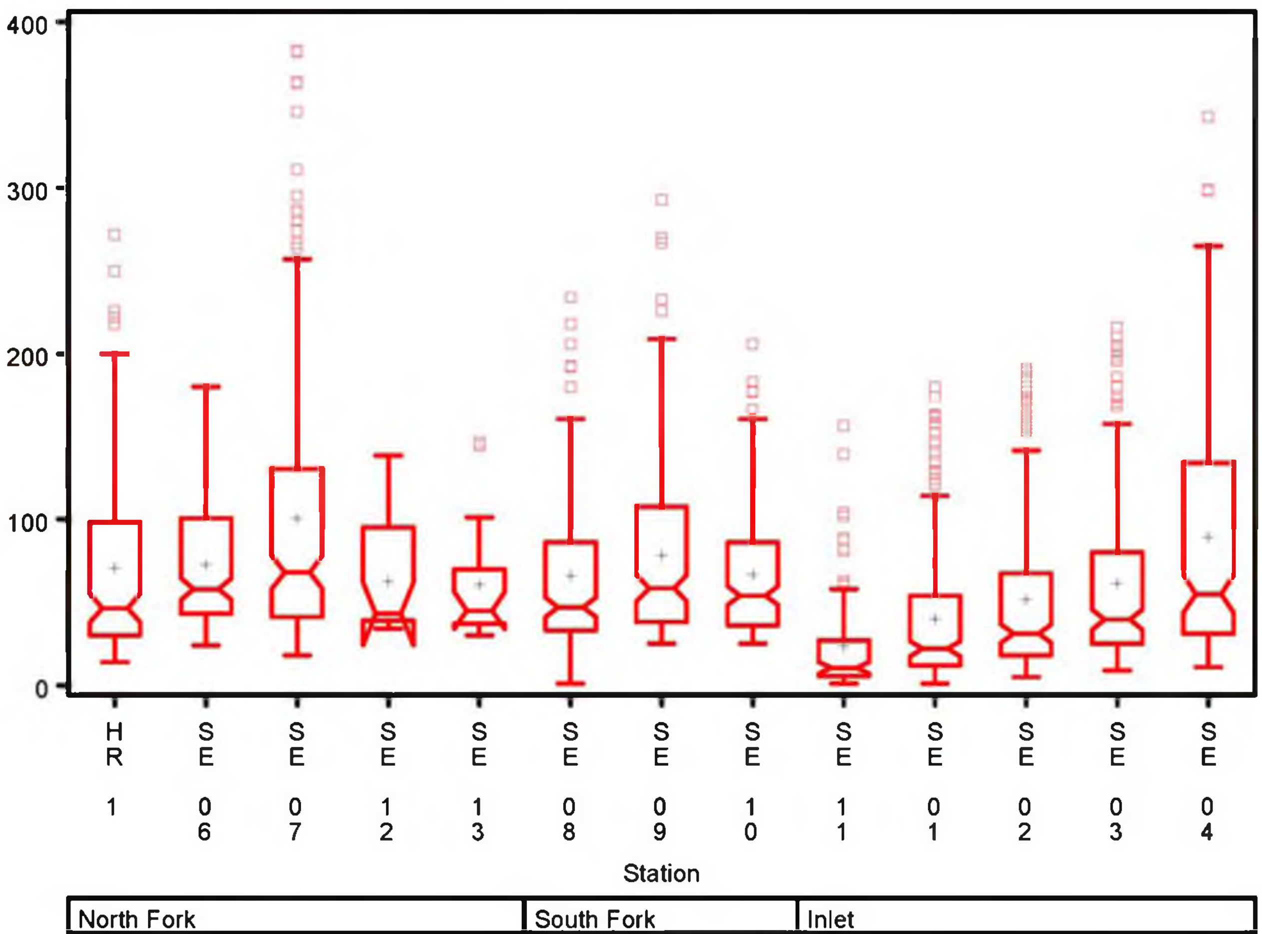
The St Lucie Estuary water quality monitoring project has provided an excellent baseline characterization for many important water quality parameters that influence estuarine ecosystem health through a consistent routine monitoring program. The estuarine portion of the St. Lucie is a highly productive system known to be sensitive to nutrient loading corresponding to large freshwater pulses. Incorporating flow data was beyond the scope of this study, so the monitoring program was evaluated with respect to nutrient concentrations. The main goals of the SE project are to establish baseline water quality conditions, identify trends in water quality parameters and identify potential point source discharges. The program appears to be achieving these aims. When evaluating the project area as a unit there seems to be adequate power to detect changes in median concentrations within a 5 year time window given the current sampling regime. For TPO4, there was sufficient power to detect a 5 year trend in water quality that would result in a 20% change in slope over five years. However, for all other parameters of interest, the ability for detecting trends at individual stations within the project appears to be limited. Identification of point source discharges may reveal themselves as a more frequent exceedances of water quality targets and not necessarily result in a time series trend.

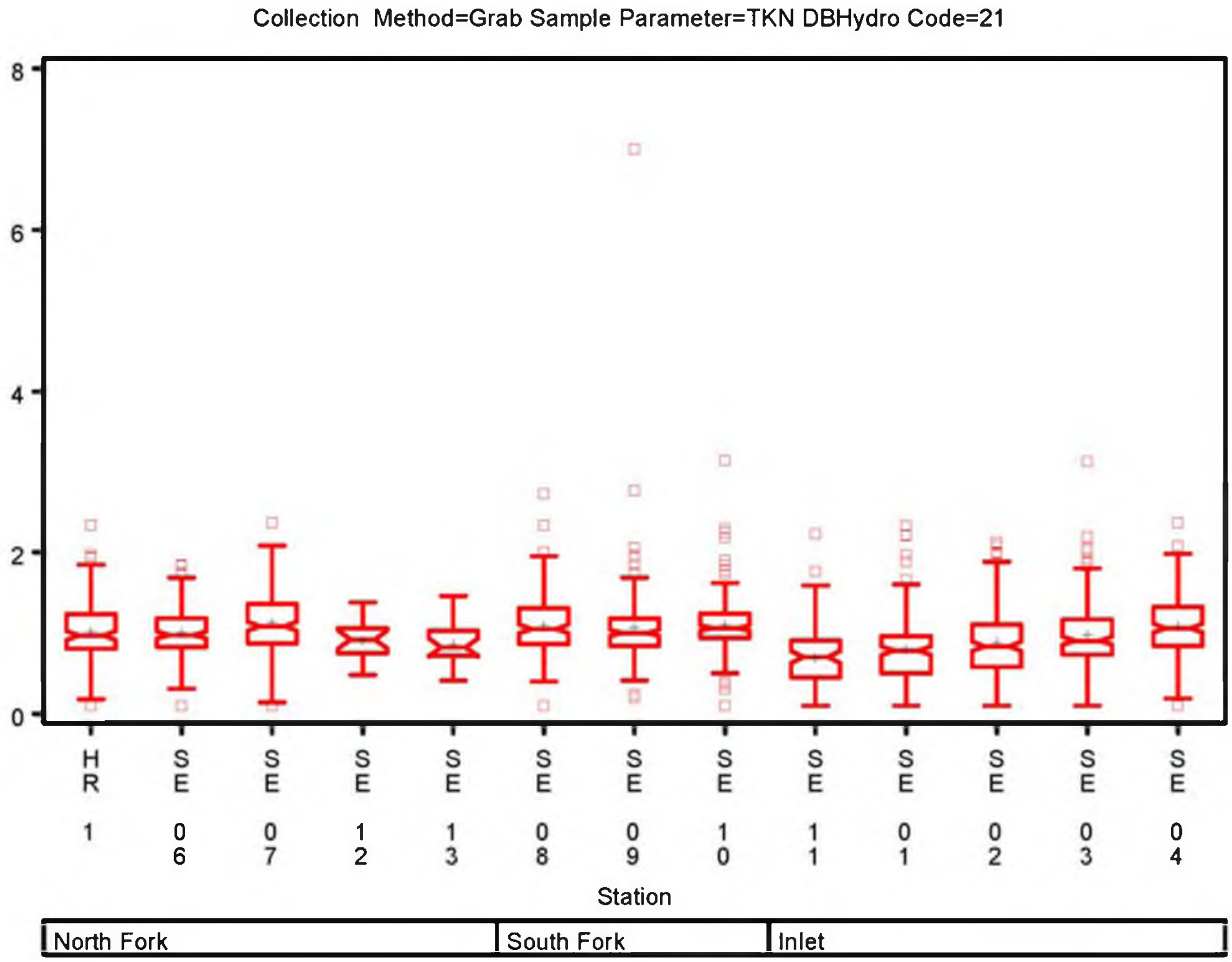
From an optimization perspective, the spatial delineations described for the SE project (i.e., south fork, north fork and inlet) might serve as strata about which to making inferences regarding water quality. If the program directive were to report on water quality within stratum rather on a station specific estimate, it is possible that sampling effort could be reduced. One alternative would be to randomly assign one or two of the fixed stations from each of the stratum on a monthly basis. This would serve to reduce sampling effort while maintaining the ability to make inferences on water quality within strata. This scheme would also maintain sampling effort at individual fixed station albeit on a lower sampling frequency. Indications from this analysis are that assessing water quality trends at individual stations within the SE project would only be achieved if large trends were observed in the data or if sampling intensity were weekly. Since individual stations within strata appear to be highly correlated for most parameters of interest, a reduced sampling frequency within each stratum should allow for an efficient assessment of the more general strata-wide trends in the estuary over a 5 year time scale. This alternative sampling strategy could be investigated further using simulation to see, for each strata within the project, how many samples would be required and over what time scale inference is possible if the program manager should decide this is the best course of action. If basin-wide inferences are required bi-annually then the sampling frequency is appropriate for all parameters except Chla and Color and should remain at current levels.

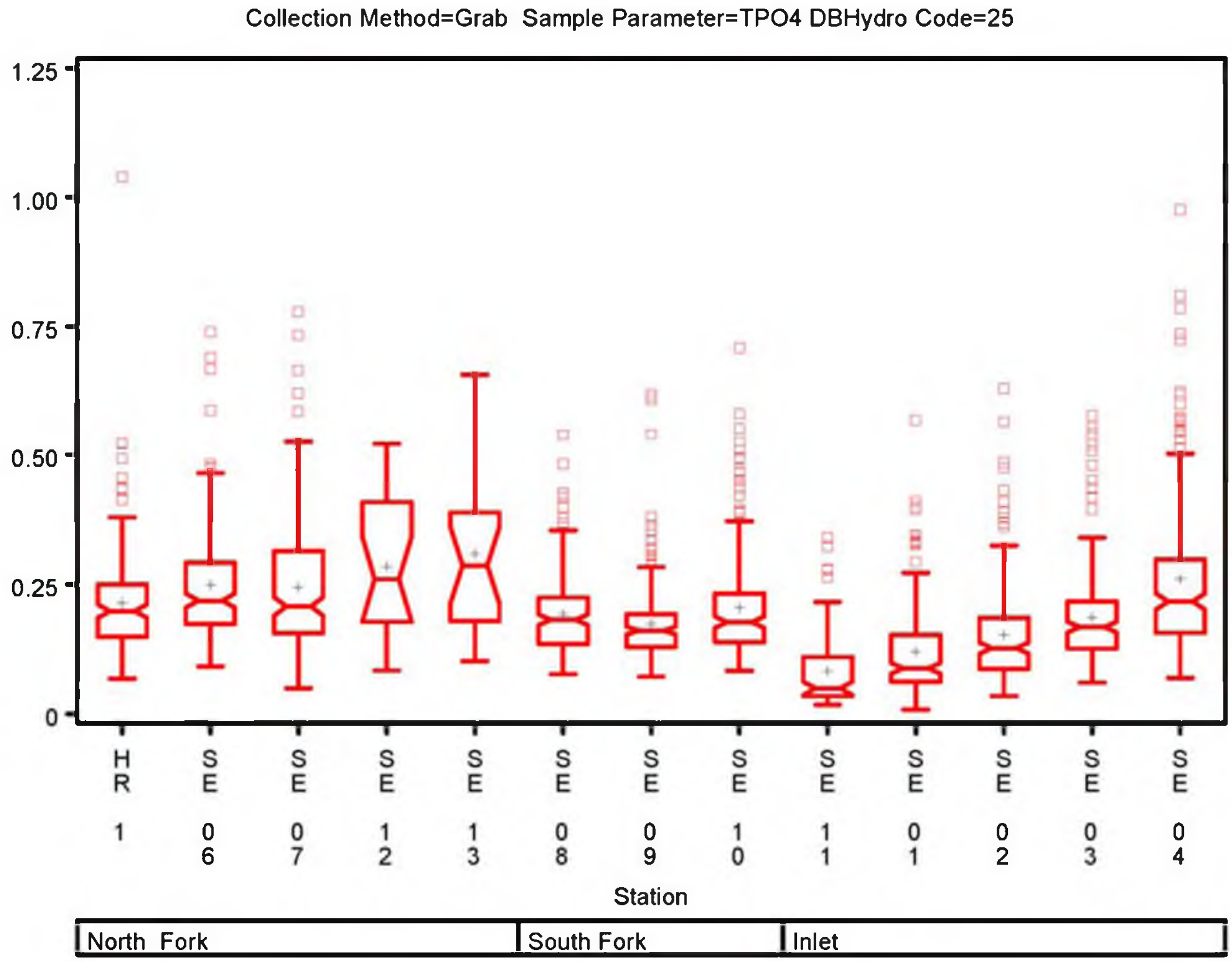
# Appendix SE-1

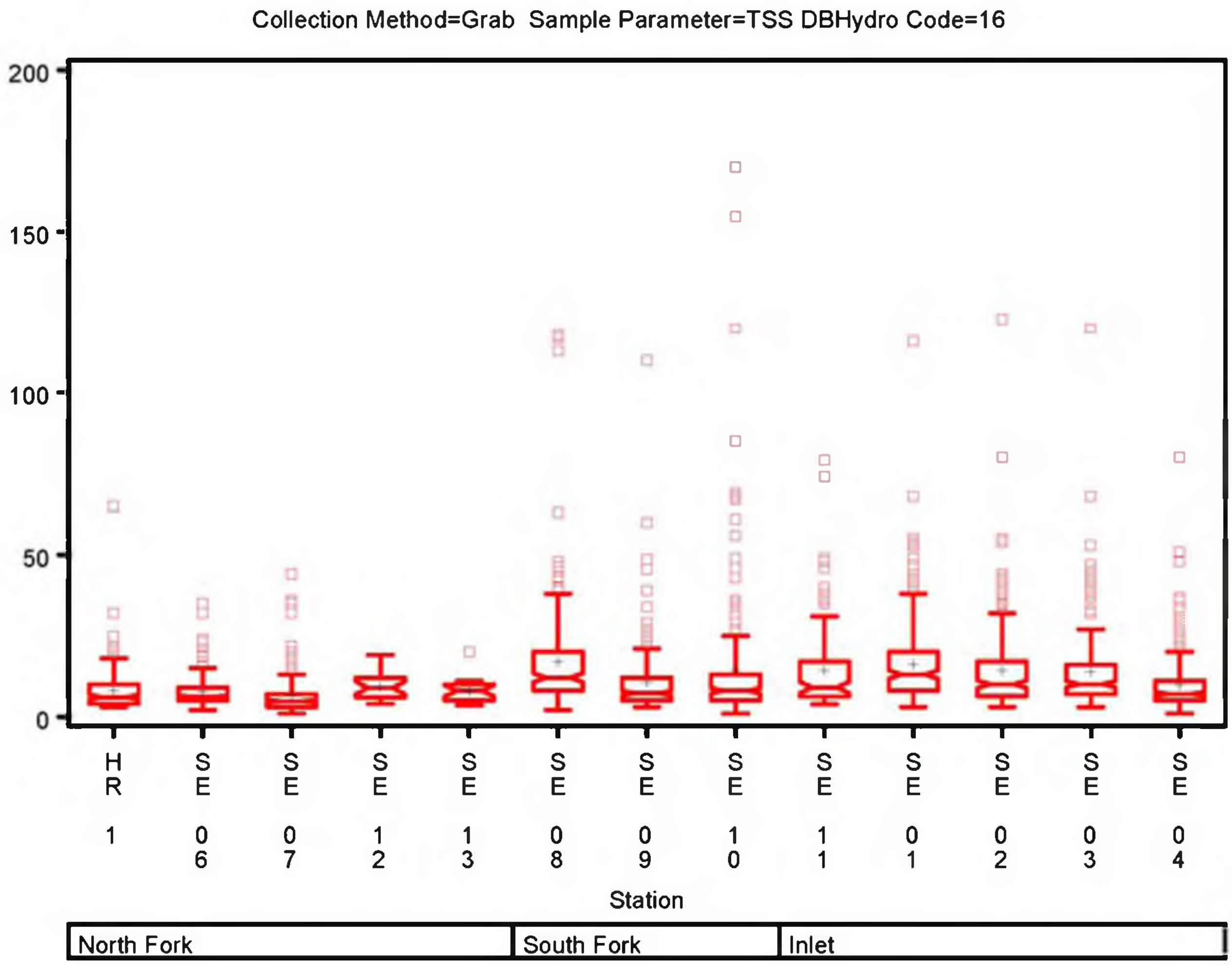

Collection Method=Grab Sample Parameter=CHL2 DBHydro Code=112
200
150
100
50
0
HR 1
SE 06
SE 07
SE 12
SE 13
SE 08
SE 09
SE 10
SE 11
SE 01
SE 02
SE 03
SE 04
Station
North Fork
South Fork
Inlet

Collection Method=Grab Sample Parameter=Color DBHydro Code=13




Collection Method=Grab Sample Parameter=TKN DBHydro Code=21
8
6
4
2
0
HR 1
SE 06
SE 07
SE 12
SE 13
SE 08
SE 09
SE 10
SE 11
SE 01
SE 02
SE 03
SE 04
Station
North Fork
South Fork
Inlet


Collection Method=Grab Sample Parameter=TPO4 DBHydro Code=25
1.25
1.00
0.75
0.50
0.25
0
HR 1
SE 06
SE 07
SE 12
SE 13
SE 08
SE 09
SE 10
SE 11
SE 01
SE 02
SE 03
SE 04
Station
North Fork
South Fork
Inlet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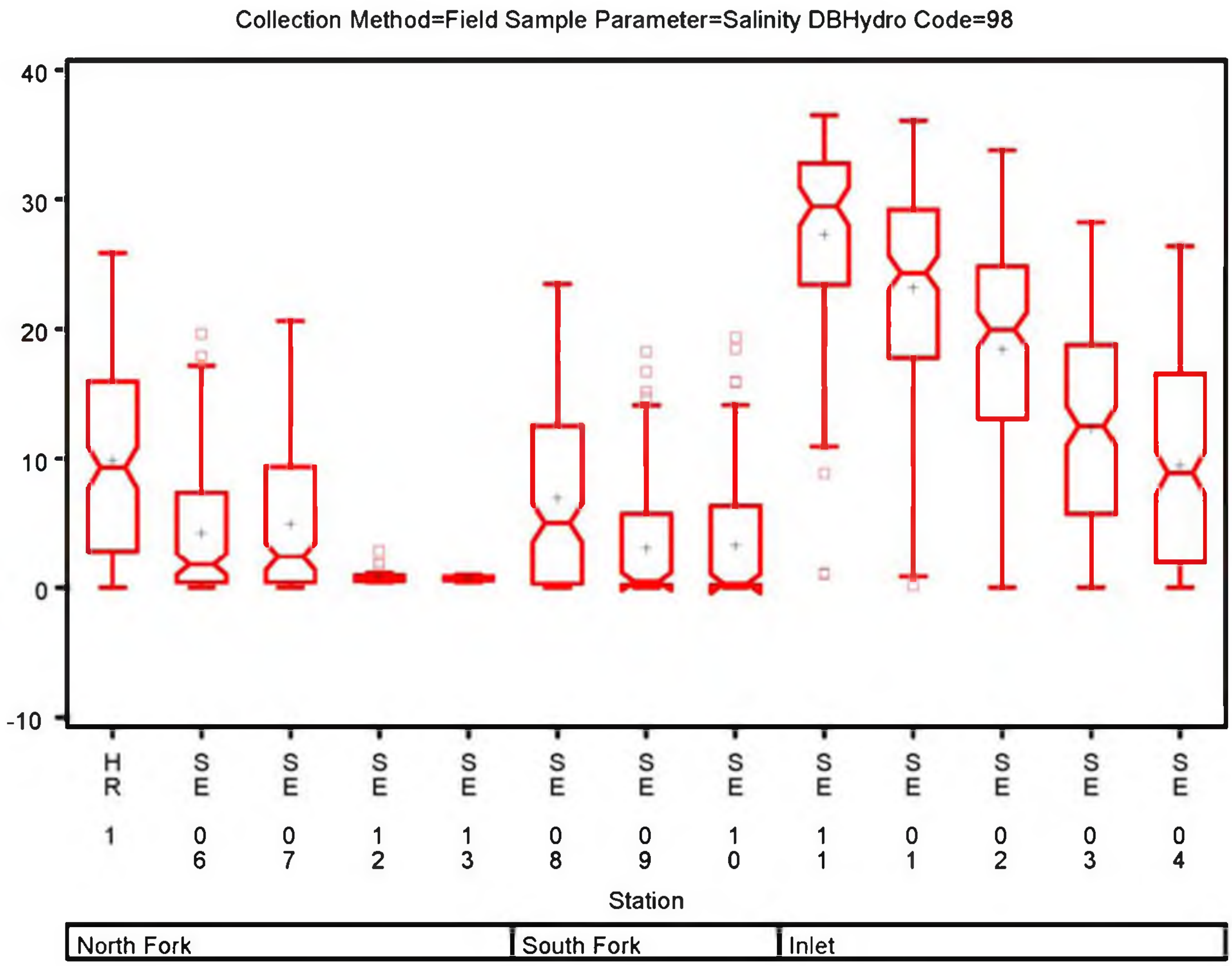
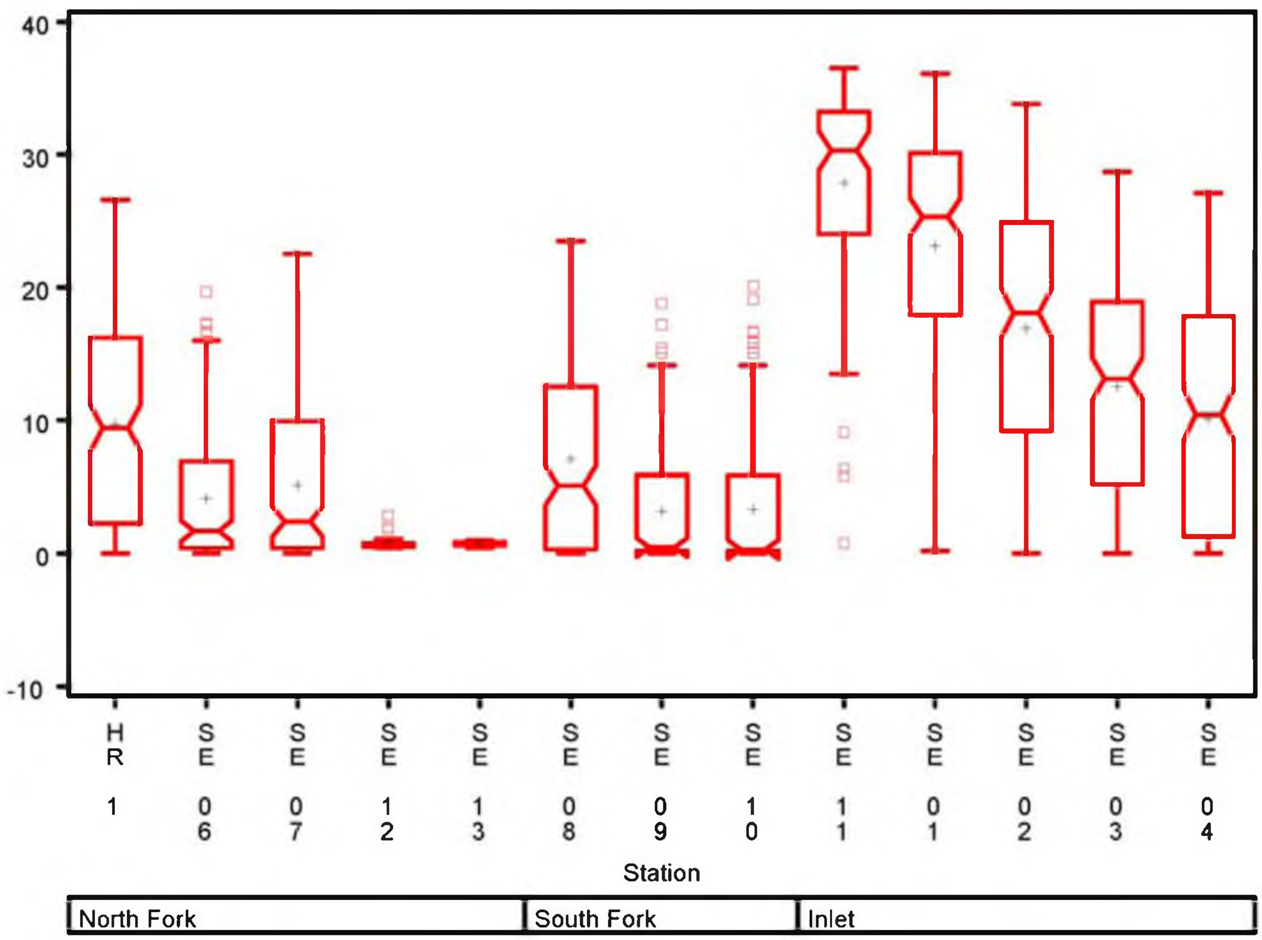
200
150
100
50
0
HR 1
SE 06
SE 07
SE 12
SE 13
SE 08
SE 09
SE 10
SE 11
SE 01
SE 02
SE 03
SE 04
Station
North Fork
South Fork
Inlet



Collection Method=Field Sample Parameter=Salinity DBHydro Code=98
40
30
20
10
0
-10
HR1
SE06
SE07
SE12
SE13
SE08
SE09
SE10
SE11
SE01
SE02
SE03
SE04
Station
North Fork
South Fork
Inlet

Collection Method=Grab Sample Parameter=Salinity DBHydro Code=98



# Appendix SE-2

# Correlation

## Parameter=Chlorophyll-a Corrected

| Station | Corr HR1 | Corr IRL12B | Corr IRL15B | Corr SE01 | Corr SE02 | Corr SE03 | Corr SE04 | Corr SE06 | Corr SE07 | Corr SE08 | Corr SE09 | Corr SE10 | Corr SE11 | Corr SE12 | Corr SE13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HR1 | 1.00** | -0.50 | | 0.57 ** | 0.62 ** | 0.69 ** | 0.51** | 0.38** | 0.24 * | 0.38** | 0.29 * | 0.29** | 0.35** | 0.43 | -0.10 |
| IRL12B | -0.50 | 1.00 ** | 0.68 ** | 0.80 | 0.80 | 0.50 | -0.50 | | 0.80 | | | 1.00** | 1.00** | | |
| IRL15B | | 0.68 ** | 1.00 ** | -1.00** | -1.00** | -1.00** | | | -0.50 | | | -0.80 | -0.50 | | |
| SE01 | 0.57** | 0.80 | -1.00 ** | 1.00 ** | 0.78 ** | 0.54 ** | 0.36** | 0.26** | 0.22 * | 0.33** | 0.18 | 0.27** | 0.62** | 0.42 | 0.29 |
| SE02 | 0.62** | 0.80 | -1.00 ** | 0.78 ** | 1.00 ** | 0.61 ** | 0.35** | 0.26** | 0.25 * | 0.38** | 0.25 * | 0.35** | 0.53** | 0.50 | 0.33 |
| SE03 | 0.69** | 0.50 | -1.00 ** | 0.54 ** | 0.61 ** | 1.00 ** | 0.42** | 0.38** | 0.31** | 0.40** | 0.30** | 0.36** | 0.33 * | 0.58 * | 0.28 |
| SE04 | 0.51** | -0.50 | | 0.36 ** | 0.35 ** | 0.42 ** | 1.00** | 0.45** | 0.45** | 0.47** | 0.45** | 0.25 * | 0.11 | 0.60 * | 0.46 |
| SE06 | 0.38** | | | 0.26 ** | 0.26 ** | 0.38 ** | 0.45** | 1.00** | 0.38** | 0.37** | 0.53** | 0.36** | -0.13 | 0.63 * | 0.49 |
| SE07 | 0.24 * | 0.80 | -0.50 | 0.22 * | 0.25 * | 0.31 ** | 0.45** | 0.38** | 1.00** | 0.40** | 0.51** | 0.29** | 0.06 | 0.31 | 0.47 |
| SE08 | 0.38** | | | 0.33 ** | 0.38 ** | 0.40 ** | 0.47** | 0.37** | 0.40** | 1.00** | 0.54** | 0.41** | 0.04 | 0.54 | 0.59 |
| SE09 | 0.29 * | | | 0.18 | 0.25 * | 0.30 ** | 0.45** | 0.53** | 0.51** | 0.54** | 1.00** | 0.61** | -0.20 | 0.69 * | 0.54 |
| SE10 | 0.29** | 1.00 ** | -0.80 | 0.27 ** | 0.35 ** | 0.36 ** | 0.25 * | 0.36** | 0.29** | 0.41** | 0.61** | 1.00** | -0.03 | 0.71 * | 0.50 |
| SE11 | 0.35** | 1.00 ** | -0.50 | 0.62 ** | 0.53 ** | 0.33 * | 0.11 | -0.13 | 0.06 | 0.04 | -0.20 | -0.03 | 1.00** | 0.04 | -0.06 |
| SE12 | 0.43 | | | 0.42 | 0.50 | 0.58 * | 0.60 * | 0.63 * | 0.31 | 0.54 | 0.69 * | 0.71 * | 0.04 | 1.00** | 0.72** |
| SE13 | -0.10 | | | 0.29 | 0.33 | 0.28 | 0.46 | 0.49 | 0.47 | 0.59 | 0.54 | 0.50 | -0.06 | 0.72** | 1.00** |

* Prob > |r| Under HC: RHO=0 < 0.01
** Prob > |r| Under HC: RHO=0 < 0.001

**Parameter=Color**

| Station | Corr HR1 | Corr IRL12B | Corr IRL15B | Corr SE01 | Corr SE02 | Corr SE03 | Corr SE04 | Corr SE06 | Corr SE07 | Corr SE08 | Corr SE09 | Corr SE10 | Corr SE11 | Corr SE12 | Corr SE13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HR1 | 1.00** | 1.00 ** | -0.50 | 0.86** | 0.95** | 0.95** | 0.93** | 0.93** | 0.94** | 0.89** | 0.85** | 0.83** | 0.86** | 0.84** | 0.75** |
| IRL12B | 1.00** | 1.00 ** | 0.62 ** | 0.50 | 0.80 | 1.00** | 1.00** | | -0.40 | | | 0.50 | 0.80 | | |
| IRL15B | -0.50 | 0.62 ** | 1.00 ** | | -0.50 | -0.50 | -0.50 | | 0.50 | | | -0.80 | -0.50 | | |
| SE01 | 0.86** | 0.50 | | 1.00** | 0.92** | 0.90** | 0.87** | 0.86** | 0.84** | 0.88** | 0.85** | 0.83** | 0.93** | 0.87** | 0.81** |
| SE02 | 0.95** | 0.80 | -0.50 | 0.92** | 1.00** | 0.97** | 0.93** | 0.91** | 0.90** | 0.93** | 0.90** | 0.85** | 0.91** | 0.87** | 0.78** |
| SE03 | 0.95** | 1.00 ** | -0.50 | 0.90** | 0.97** | 1.00** | 0.94** | 0.91** | 0.91** | 0.94** | 0.92** | 0.88** | 0.89** | 0.79** | 0.73** |
| SE04 | 0.93** | 1.00 ** | -0.50 | 0.87** | 0.93** | 0.94** | 1.00** | 0.90** | 0.90** | 0.90** | 0.89** | 0.85** | 0.82** | 0.84** | 0.76** |
| SE06 | 0.93** | | | 0.86** | 0.91** | 0.91** | 0.90** | 1.00** | 0.90** | 0.87** | 0.85** | 0.82** | 0.81** | 0.90** | 0.82** |
| SE07 | 0.94** | -0.40 | 0.50 | 0.84** | 0.90** | 0.91** | 0.90** | 0.90** | 1.00** | 0.85** | 0.83** | 0.80** | 0.80** | 0.84** | 0.83** |
| SE08 | 0.89** | | | 0.88** | 0.93** | 0.94** | 0.90** | 0.87** | 0.85** | 1.00** | 0.95** | 0.93** | 0.85** | 0.86** | 0.76** |
| SE09 | 0.85** | | | 0.85** | 0.90** | 0.92** | 0.89** | 0.85** | 0.83** | 0.95** | 1.00** | 0.94** | 0.76** | 0.89** | 0.83** |
| SE10 | 0.83** | 0.50 | -0.80 | 0.83** | 0.85** | 0.88** | 0.85** | 0.82** | 0.80** | 0.93** | 0.94** | 1.00** | 0.74** | 0.90** | 0.80** |
| SE11 | 0.86** | 0.80 | -0.50 | 0.93** | 0.91** | 0.89** | 0.82** | 0.81** | 0.80** | 0.85** | 0.76** | 0.74** | 1.00** | 0.82** | 0.77** |
| SE12 | 0.84** | | | 0.87** | 0.87** | 0.79** | 0.84** | 0.90** | 0.84** | 0.86** | 0.89** | 0.90** | 0.82** | 1.00** | 0.96** |
| SE13 | 0.75** | | | 0.81** | 0.78** | 0.73** | 0.76** | 0.82** | 0.83** | 0.76** | 0.83** | 0.80** | 0.77** | 0.96** | 1.00** |

* Prob > |r| Under HC: RHO=0 < 0.01
** Prob > |r| Under HC: RHO=0 < 0.001

## Parameter=Salinity

| Station | Corr HR1 | Corr IRL12B | Corr IRL15B | Corr SE01 | Corr SE02 | Corr SE03 | Corr SE04 | Corr SE06 | Corr SE07 | Corr SE08 | Corr SE09 | Corr SE10 | Corr SE11 | Corr SE12 | Corr SE13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HR1 | 1.00** | 0.80 | -0.50 | 0.89** | 0.94** | 0.96** | 0.97** | 0.92** | 0.93** | 0.89** | 0.89** | 0.82** | 0.90** | 0.66** | 0.77** |
| IRL12B | 0.80 | 1.00 ** | 0.52 ** | 0.80 | 1.00** | 1.00 ** | 0.80 | | 0.20 | | | 1.00** | 0.80 | | |
| IRL15B | -0.50 | 0.52 ** | 1.00 ** | -0.50 | -0.50 | -0.50 | -0.50 | | 0.50 | | | 0.00 | -0.50 | | |
| SE01 | 0.89** | 0.80 | -0.50 | 1.00** | 0.94** | 0.91** | 0.88** | 0.83** | 0.78** | 0.88** | 0.85** | 0.79** | 0.96** | 0.45 | 0.50 |
| SE02 | 0.94** | 1.00 ** | -0.50 | 0.94** | 1.00** | 0.96** | 0.92** | 0.85** | 0.81** | 0.90** | 0.86** | 0.80** | 0.95** | 0.63 * | 0.73** |
| SE03 | 0.96** | 1.00 ** | -0.50 | 0.91** | 0.96** | 1.00** | 0.95** | 0.86** | 0.84** | 0.92** | 0.88** | 0.83** | 0.91** | 0.69** | 0.78** |
| SE04 | 0.97** | 0.80 | -0.50 | 0.88** | 0.92** | 0.95** | 1.00** | 0.90** | 0.89** | 0.87** | 0.87** | 0.82** | 0.88** | 0.66** | 0.76** |
| SE06 | 0.92** | | | 0.83** | 0.85** | 0.86** | 0.90** | 1.00** | 0.93** | 0.80** | 0.84** | 0.76** | 0.86** | 0.74** | 0.81** |
| SE07 | 0.93** | 0.20 | 0.50 | 0.78** | 0.81** | 0.84** | 0.89** | 0.93** | 1.00** | 0.76** | 0.80** | 0.72** | 0.86** | 0.65** | 0.72** |
| SE08 | 0.89** | | | 0.88** | 0.90** | 0.92** | 0.87** | 0.80** | 0.76** | 1.00** | 0.92** | 0.89** | 0.87** | 0.64 * | 0.69 * |
| SE09 | 0.89** | | | 0.85 ** | 0.86** | 0.88** | 0.87** | 0.84** | 0.80** | 0.92** | 1.00** | 0.94** | 0.87** | 0.65 * | 0.76** |
| SE10 | 0.82** | 1.00 ** | 0.00 | 0.79** | 0.80** | 0.83** | 0.82** | 0.76** | 0.72** | 0.89** | 0.94** | 1.00** | 0.78** | 0.63 * | 0.70 * |
| SE11 | 0.90** | 0.80 | -0.50 | 0.96** | 0.95** | 0.91** | 0.88** | 0.86** | 0.86** | 0.87** | 0.87** | 0.78** | 1.00** | 0.69** | 0.77** |
| SE12 | 0.66** | | | 0.45 | 0.63 * | 0.69** | 0.66** | 0.74** | 0.65** | 0.64 * | 0.65 * | 0.63* | 0.69** | 1.00** | 0.76** |
| SE13 | 0.77** | | | 0.50 | 0.73 * | 0.78** | 0.76** | 0.81** | 0.72** | 0.69 * | 0.76** | 0.70* | 0.77** | 0.76** | 1.00** |

* Prob > |r| Under HC: RHO=0 < 0.01
** Prob > |r| Under HC: RHO=0 < 0.001

## Parameter=Total Phosphate as P

| Station | Corr HR1 | Corr IRL12B | Corr IRL15B | Corr SE01 | Corr SE02 | Corr SE03 | Corr SE04 | Corr SE06 | Corr SE07 | Corr SE08 | Corr SE09 | Corr SE10 | Corr SE11 | Corr SE12 | Corr SE13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HR1 | 1.00** | 0.40 | 0.50 | 0.75** | 0.88** | 0.91** | 0.85** | 0.83** | 0.70** | 0.70** | 0.54** | 0.59 * | 0.76** | 0.72** | 0.76** |
| IRL12B | 0.40 | 1.00 ** | 0.67 ** | -0.20 | 0.40 | 0.50 | 0.00 | | -0.40 | | | 1.00** | 0.00 | | |
| IRL15B | 0.50 | 0.67 ** | 1.00 ** | -0.50 | -0.50 | 0.50 | 1.00** | | 0.50 | | | -0.40 | -1.00** | | |
| SE01 | 0.75** | -0.20 | -0.50 | 1.00** | 0.91** | 0.85** | 0.84** | 0.67** | 0.57** | 0.70** | 0.60** | 0.62** | 0.88 ** | 0.57 * | 0.59 * |
| SE02 | 0.88** | 0.40 | -0.50 | 0.91** | 1.00** | 0.94** | 0.90** | 0.75** | 0.67** | 0.76** | 0.63** | 0.65** | 0.82 ** | 0.65 * | 0.69** |
| SE03 | 0.91** | 0.50 | 0.50 | 0.85** | 0.94** | 1.00** | 0.91** | 0.79** | 0.72** | 0.79** | 0.67** | 0.68** | 0.81 ** | 0.72** | 0.76** |
| SE04 | 0.85** | 0.00 | 1.00 ** | 0.84** | 0.90** | 0.91** | 1.00** | 0.75** | 0.63** | 0.71** | 0.60** | 0.62** | 0.78 ** | 0.68 * | 0.72** |
| SE06 | 0.83** | | | 0.67** | 0.75** | 0.79** | 0.75** | 1.00** | 0.81** | 0.69** | 0.67** | 0.68** | 0.61 ** | 0.95** | 0.92** |
| SE07 | 0.70** | -0.40 | 0.50 | 0.57** | 0.67** | 0.72** | 0.63** | 0.81** | 1.00** | 0.64** | 0.65** | 0.62** | 0.41 ** | 0.77** | 0.72** |
| SE08 | 0.70** | | | 0.70** | 0.76** | 0.79** | 0.71** | 0.69** | 0.64** | 1.00** | 0.81** | 0.82** | 0.76 ** | 0.46 | 0.45 |
| SE09 | 0.54** | | | 0.60** | 0.63** | 0.67** | 0.60** | 0.67** | 0.65** | 0.81** | 1.00** | 0.82** | 0.47 ** | 0.31 | 0.28 |
| SE10 | 0.59** | 1.00 ** | -0.40 | 0.62** | 0.65** | 0.68** | 0.62** | 0.68** | 0.62** | 0.82** | 0.82** | 1.00** | 0.52 ** | 0.40 | 0.40 |
| SE11 | 0.76** | 0.00 | -1.00 ** | 0.88** | 0.82** | 0.81** | 0.78** | 0.61** | 0.41** | 0.76** | 0.47** | 0.52** | 1.00** | 0.43 | 0.48 |
| SE12 | 0.72** | | | 0.57 * | 0.65 * | 0.72** | 0.68 * | 0.95** | 0.77** | 0.46 | 0.31 | 0.40 | 0.43 | 1.00** | 0.94** |
| SE13 | 0.76** | | | 0.59 * | 0.69** | 0.76** | 0.72** | 0.92** | 0.72** | 0.45 | 0.28 | 0.40 | 0.48 | 0.94** | 1.00** |

* Prob > |r| Under HC: RHO=0 < 0.01
** Prob > |r| Under HC: RHO=0 < 0.001

**Parameter=Total Suspended Solids**

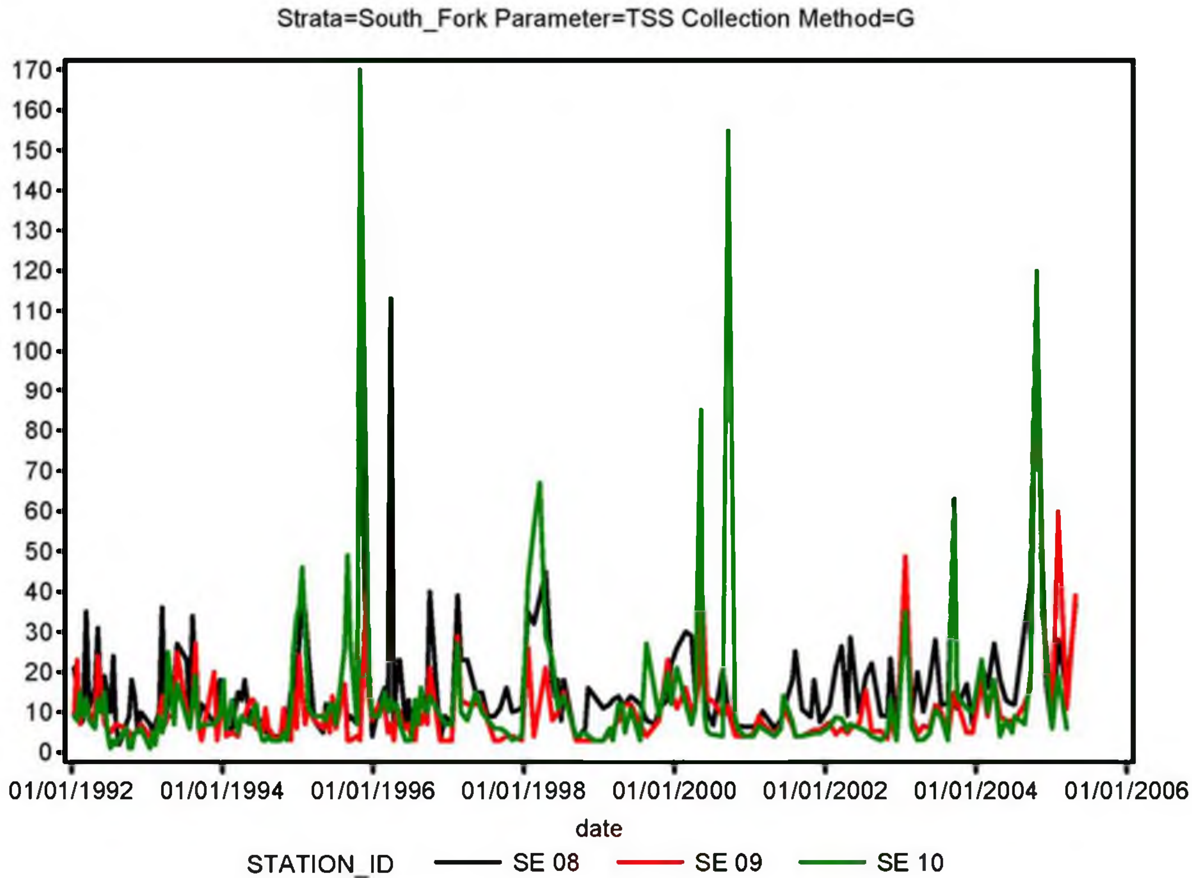
| Station | Corr HR1 | Corr IRL12B | Corr IRL15B | Corr SE01 | Corr SE02 | Corr SE03 | Corr SE04 | Corr SE06 | Corr SE07 | Corr SE08 | Corr SE09 | Corr SE10 | Corr SE11 | Corr SE12 | Corr SE13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HR1 | 1.00** | 0.80 | 0.50 | 0.61** | 0.62** | 0.63** | 0.55** | 0.53** | 0.42** | 0.31** | 0.44** | 0.29** | 0.47** | 0.49 | 0.12 |
| IRL12B | 0.80 | 1.00 ** | 0.70 ** | 0.80 | 1.00** | 1.00** | 0.80 | | 0.40 | | | 0.50 | 0.40 | | |
| IRL15B | 0.50 | 0.70 ** | 1.00 ** | 1.00** | 1.00** | 1.00** | 0.50 | | 0.50 | | | 0.80 | 1.00** | | |
| SE01 | 0.61** | 0.80 | 1.00 ** | 1.00** | 0.72** | 0.57** | 0.48** | 0.29** | 0.28** | 0.23 * | 0.19 | 0.19 | 0.80** | -0.03 | -0.02 |
| SE02 | 0.62** | 1.00 ** | 1.00 ** | 0.72** | 1.00** | 0.71** | 0.53** | 0.38** | 0.36** | 0.30** | 0.30** | 0.25** | 0.60** | 0.09 | -0.26 |
| SE03 | 0.63** | 1.00 ** | 1.00 ** | 0.57** | 0.71** | 1.00** | 0.44** | 0.34** | 0.30** | 0.45** | 0.41** | 0.30** | 0.57** | 0.07 | -0.11 |
| SE04 | 0.55** | 0.80 | 0.50 | 0.48** | 0.53** | 0.44** | 1.00** | 0.49** | 0.51** | 0.21 * | 0.22 * | 0.20 * | 0.28 * | 0.14 | 0.05 |
| SE06 | 0.53** | | | 0.29** | 0.38** | 0.34** | 0.49** | 1.00** | 0.46** | 0.24** | 0.33** | 0.04 | 0.14 | 0.63* | 0.27 |
| SE07 | 0.42** | 0.40 | 0.50 | 0.28** | 0.36** | 0.30** | 0.51 * | 0.46** | 1.00** | 0.24** | 0.24 * | 0.25** | 0.35** | 0.52 | 0.16 |
| SE08 | 0.31** | | | 0.23 * | 0.30** | 0.45 * | 0.21 * | 0.24 * | 0.24** | 1.00** | 0.57** | 0.50** | 0.23 | -0.16 | -0.10 |
| SE09 | 0.44** | | | 0.19 | 0.30** | 0.41** | 0.22 * | 0.33** | 0.24 * | 0.57** | 1.00** | 0.54** | 0.10 | 0.07 | 0.27 |
| SE10 | 0.29** | 0.50 | 0.80 | 0.19 | 0.25** | 0.30** | 0.20 * | 0.04 | 0.25** | 0.50** | 0.54** | 1.00** | 0.23 | -0.16 | -0.09 |
| SE11 | 0.47** | 0.40 | 1.00 ** | 0.80 * | 0.60** | 0.57** | 0.28* | 0.14 | 0.35** | 0.23 | 0.10 | 0.23 | 1.00** | -0.28 | -0.04 |
| SE12 | 0.49 | | | -0.03 | 0.09 | 0.07 | 0.14 | 0.63 * | 0.52 | -0.16 | 0.07 | -0.16 | -0.28 | 1.00** | 0.44 |
| SE13 | 0.12 | | | -0.02 | -0.26 | -0.11 | 0.05 | 0.27 | 0.16 | -0.10 | 0.27 | -0.09 | -0.04 | 0.44 | 1.00** |

* Prob > |r| Under HC: RHO=0 < 0.01

** Prob > |r| Under HC: RHO=0 < 0.001

# Appendix SE -3

# Time series plots



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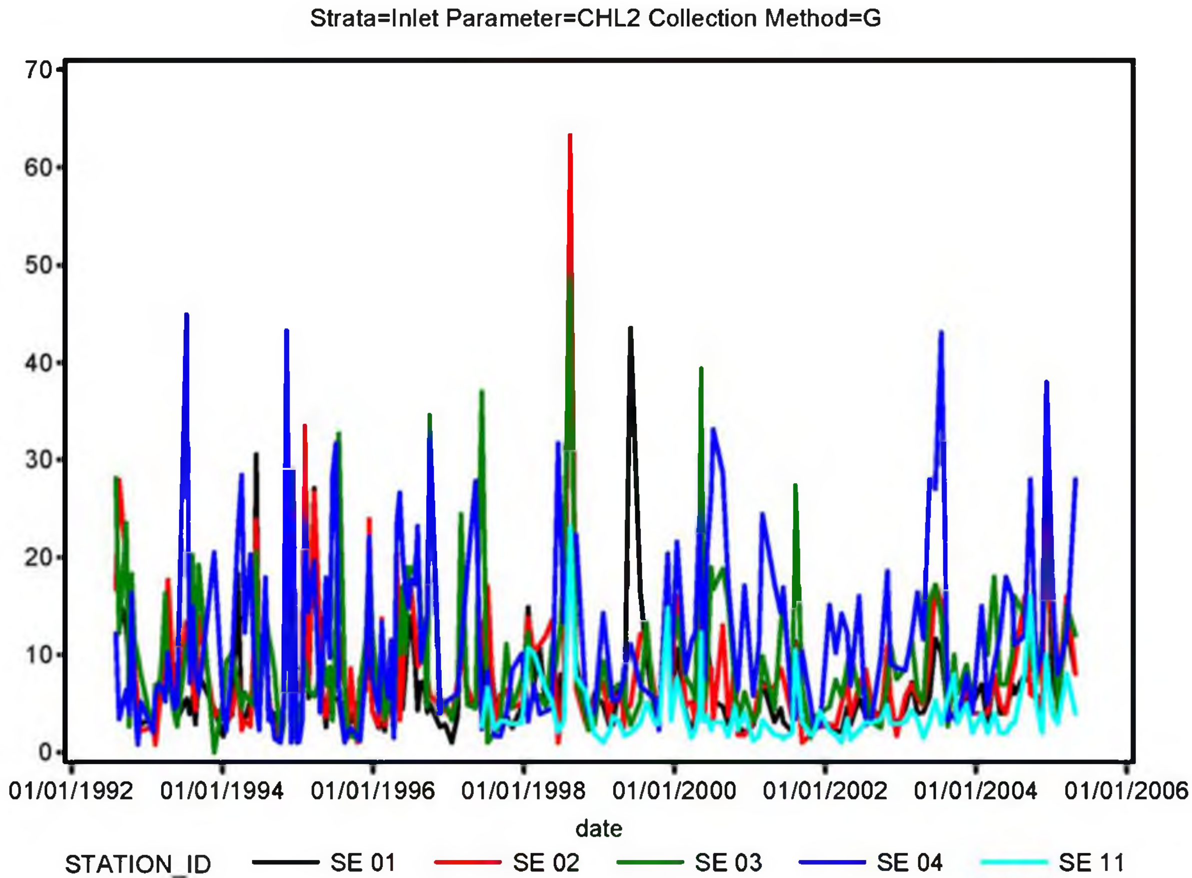
SE 09
SE 10



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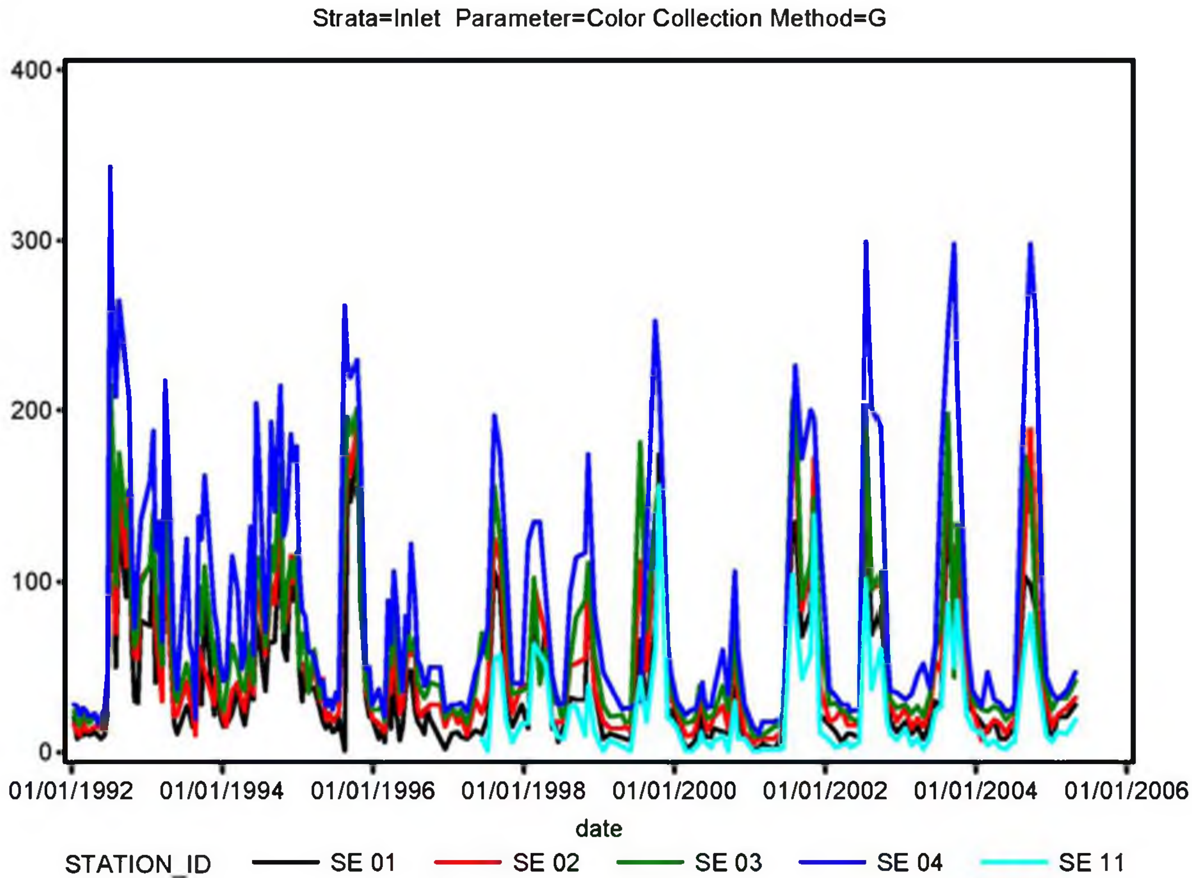
SE 03
SE 04
SE 11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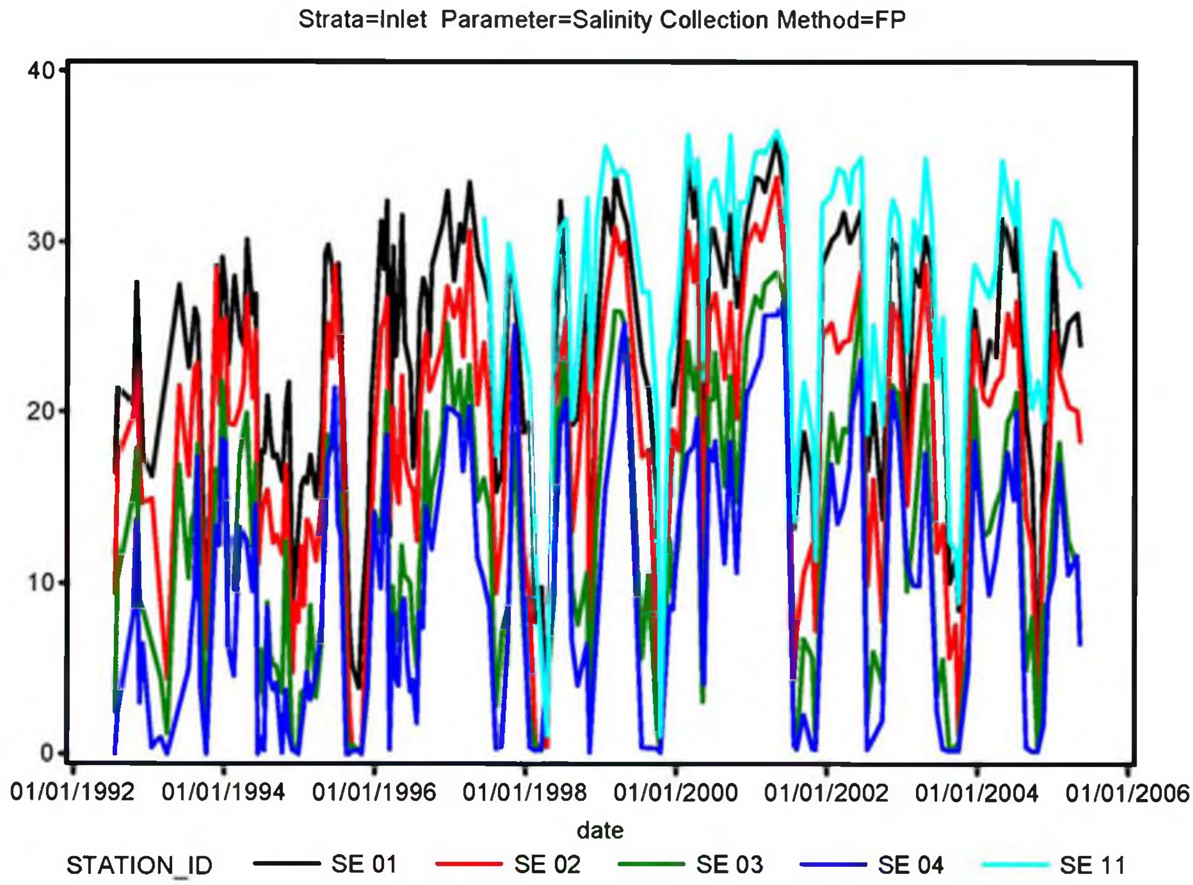
SE 11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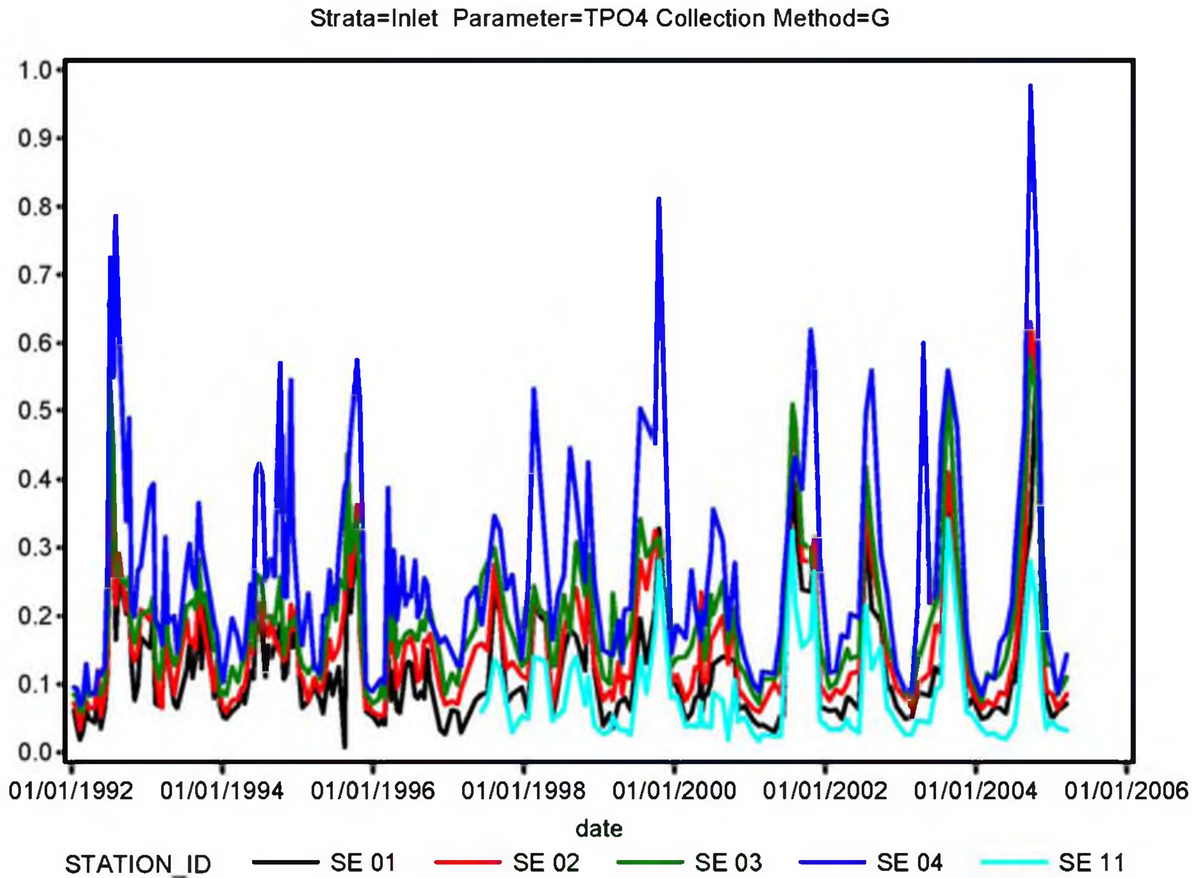
SE 03
SE 04
SE 11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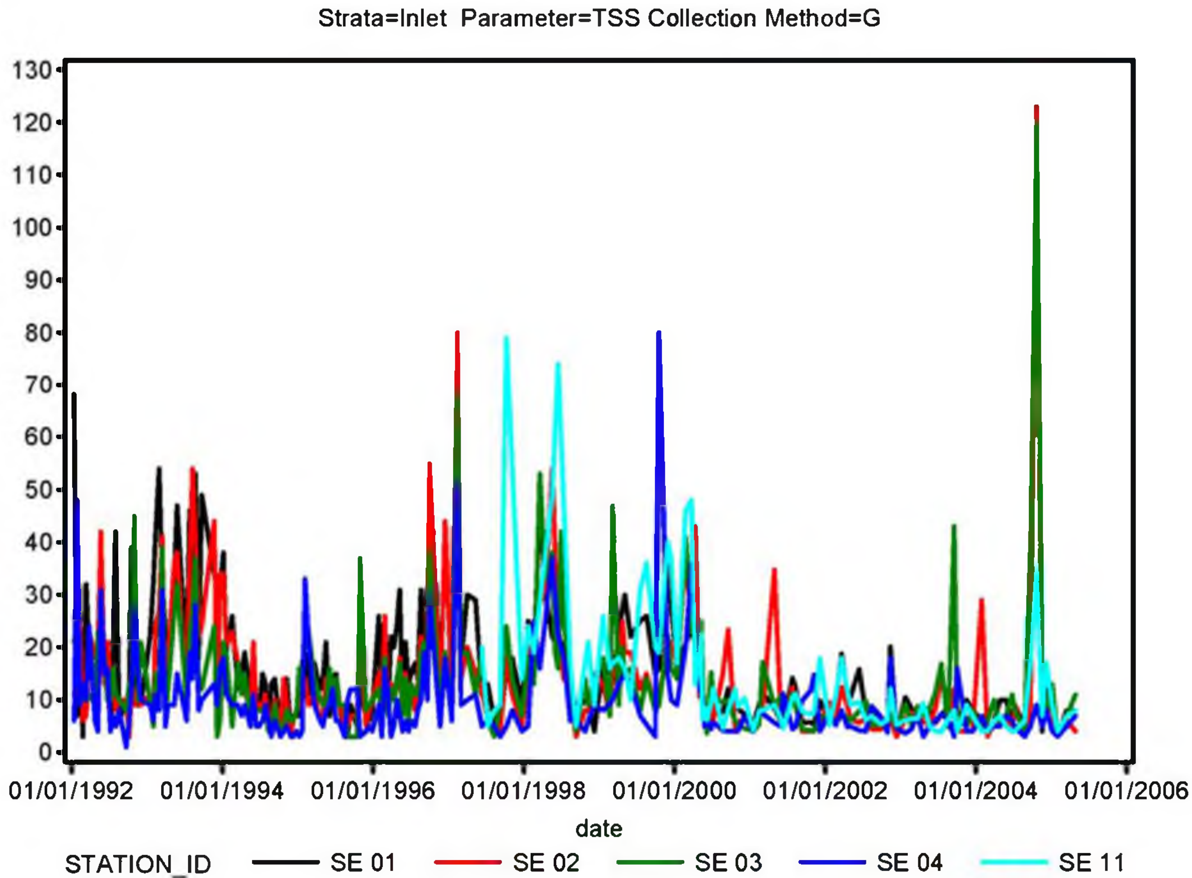
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01/01/1998
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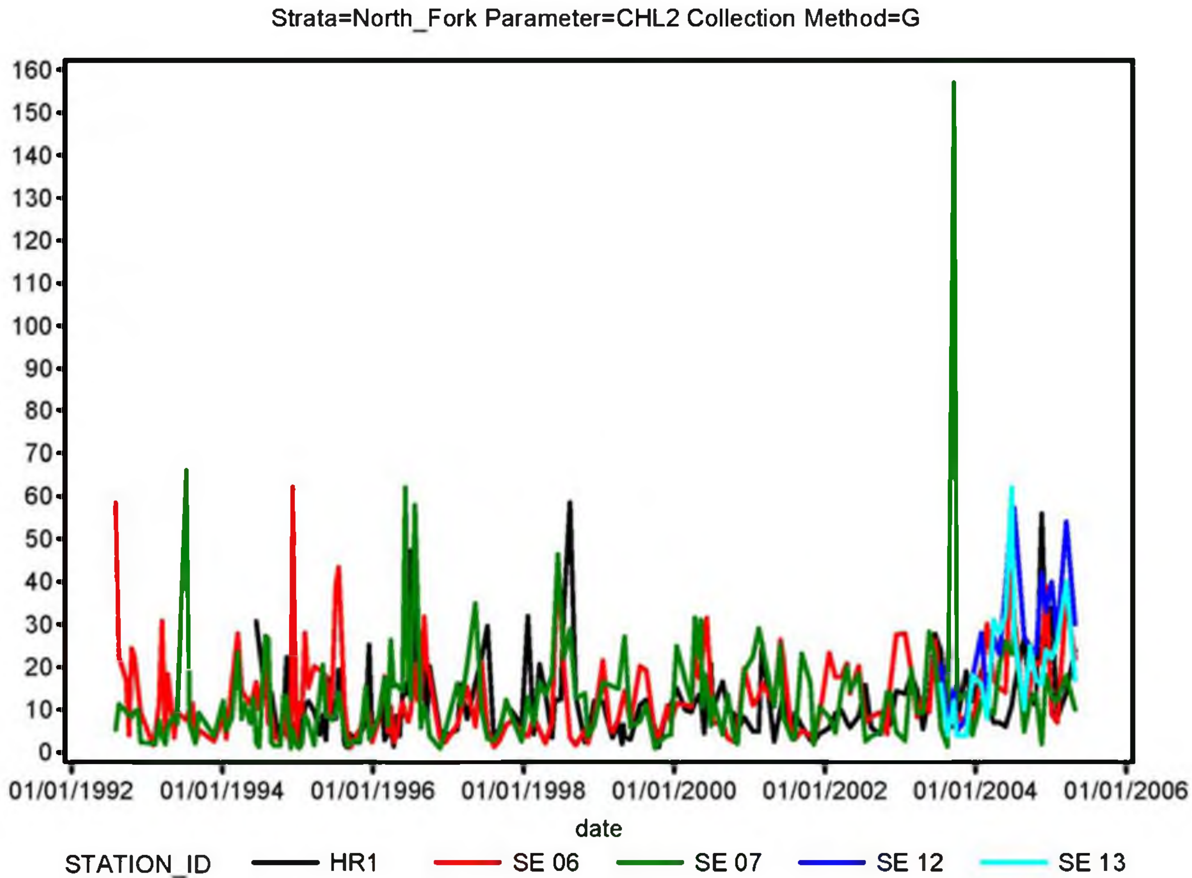
SE 11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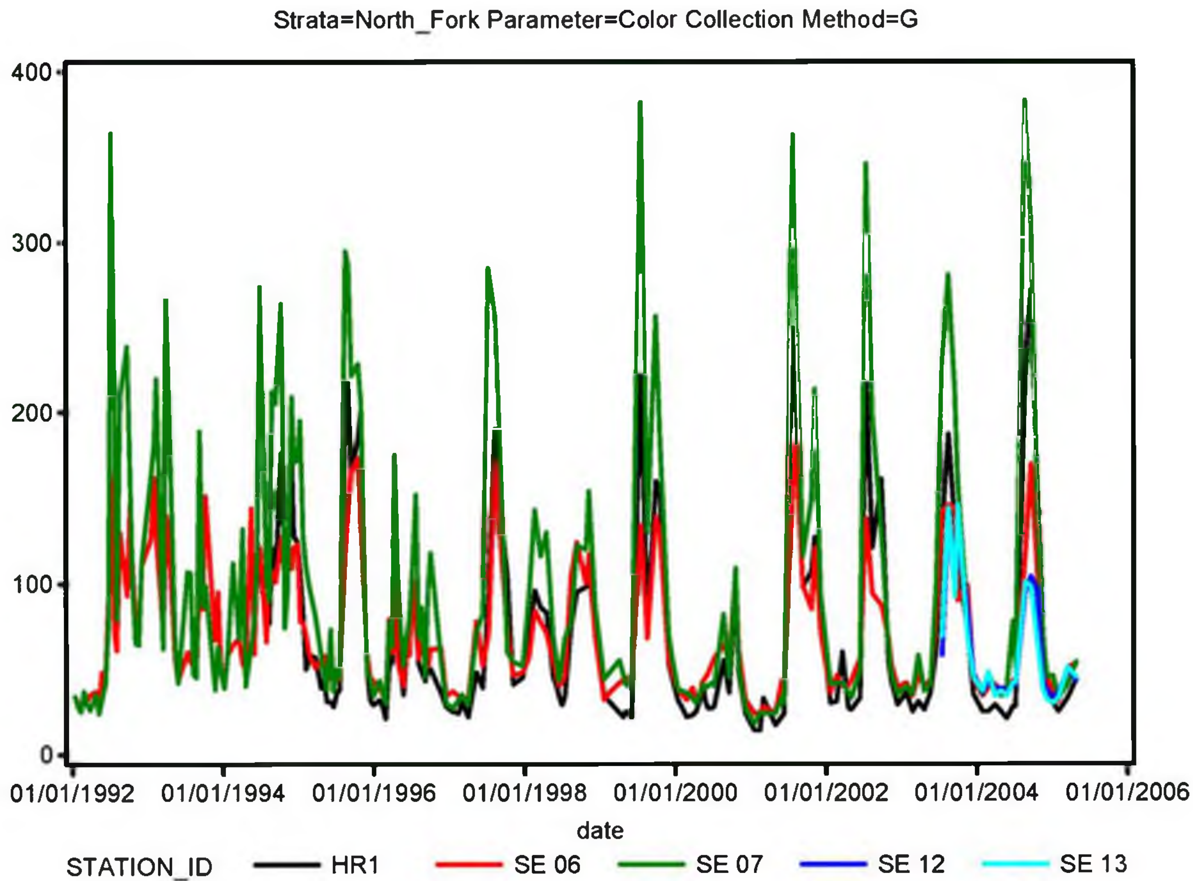
SE 06
SE 07
SE 12
SE 13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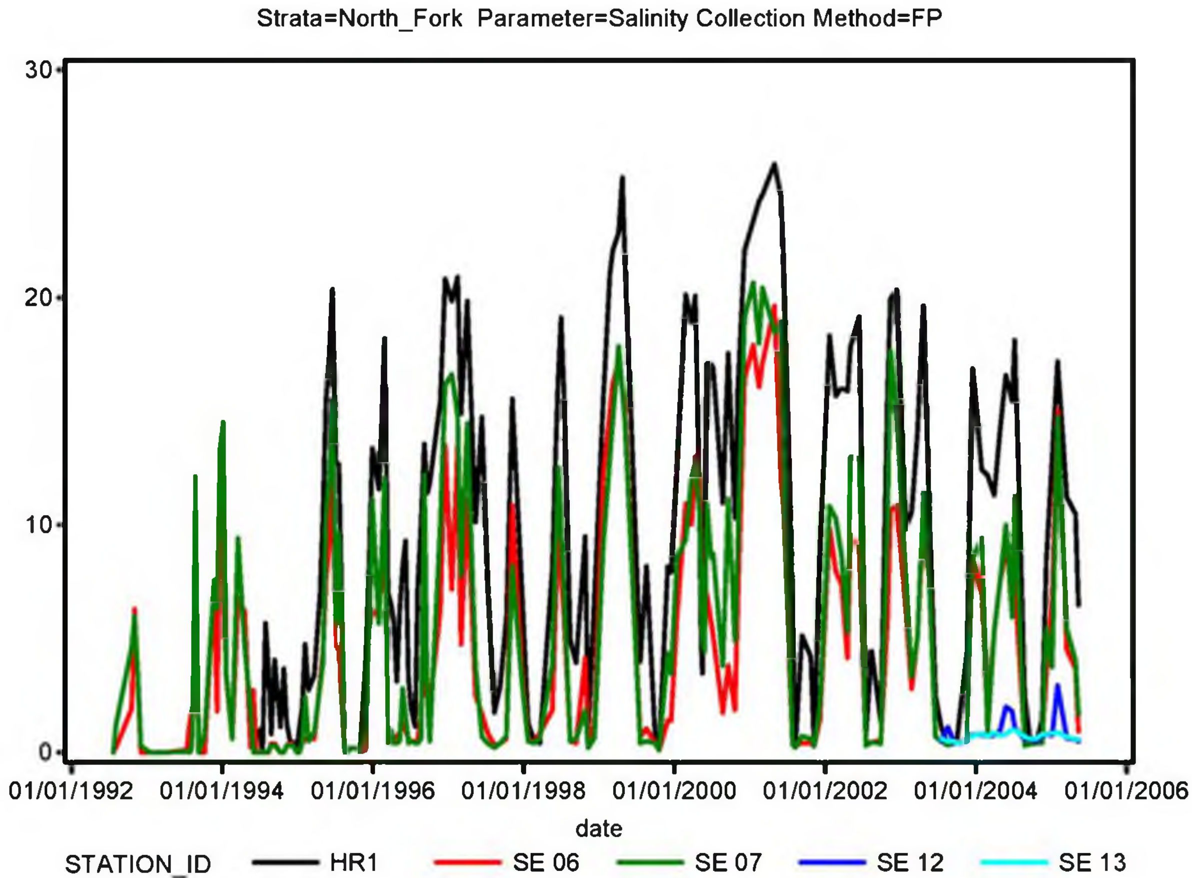
SE 06
SE 07
SE 12
SE 13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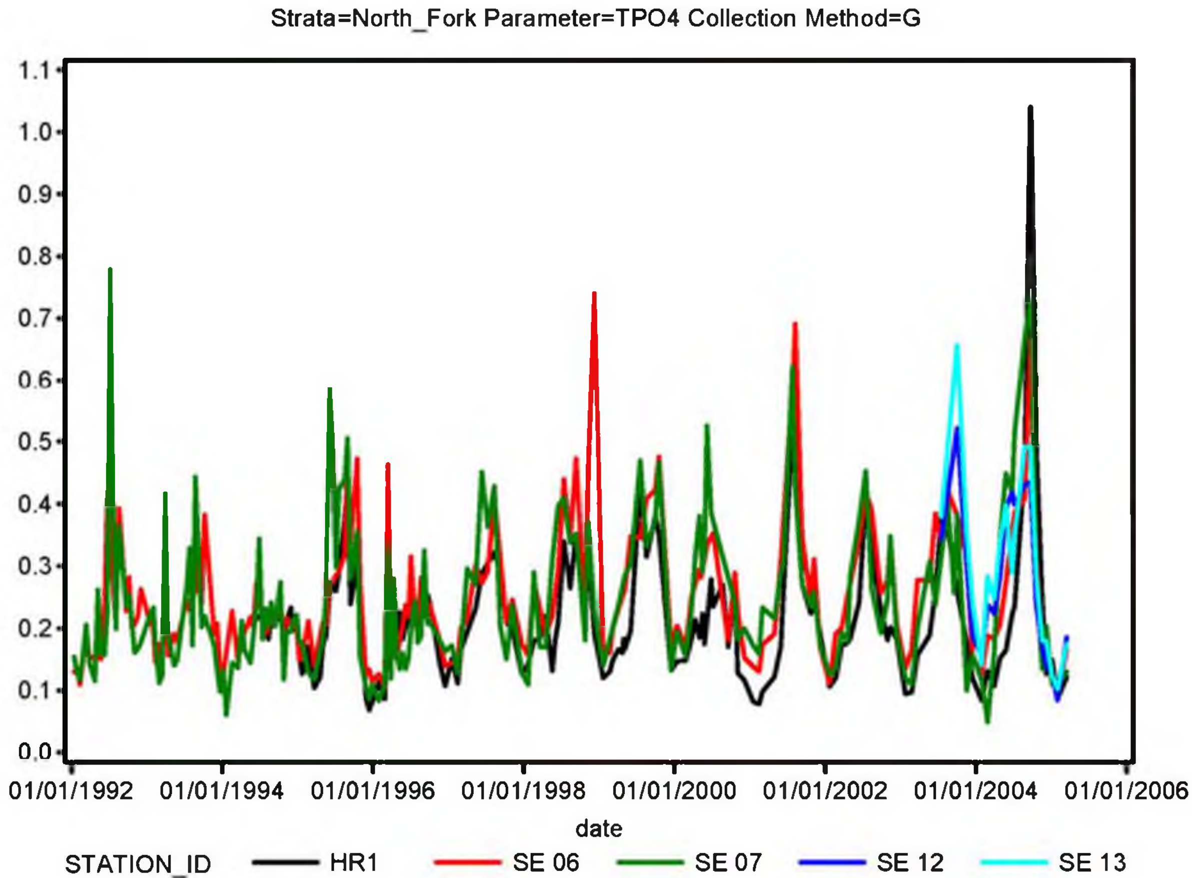
SE 07
SE 12
SE 13



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0.1
0.0
01/01/1992
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01/01/1996
01/01/1998
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date
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SE 06
SE 07
SE 12
SE 13

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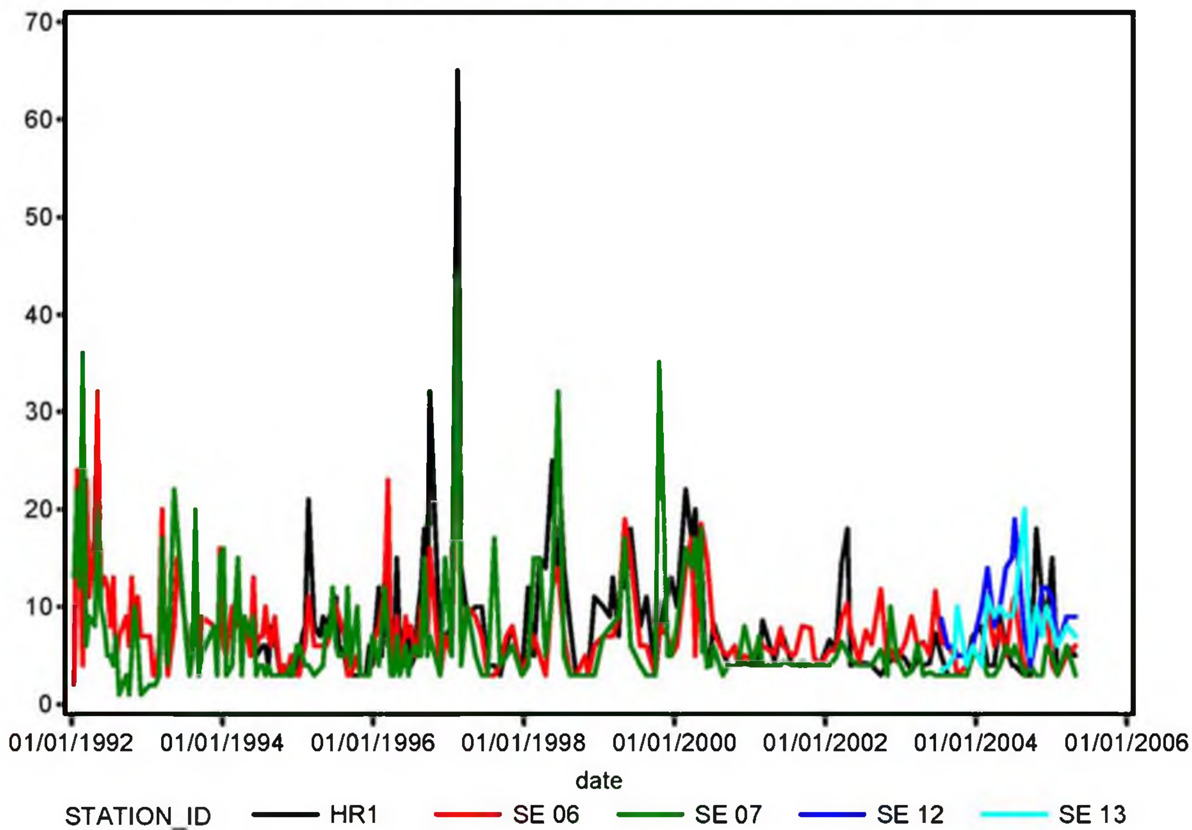

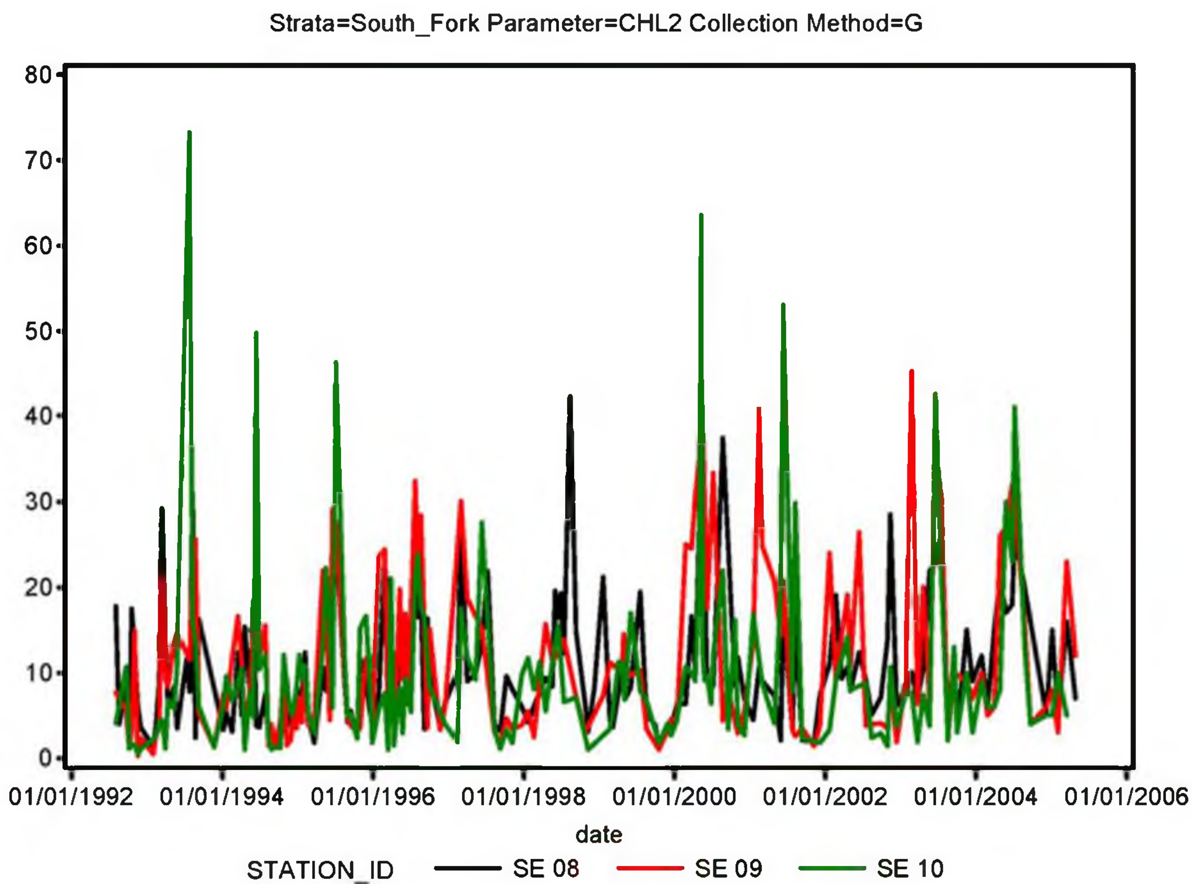

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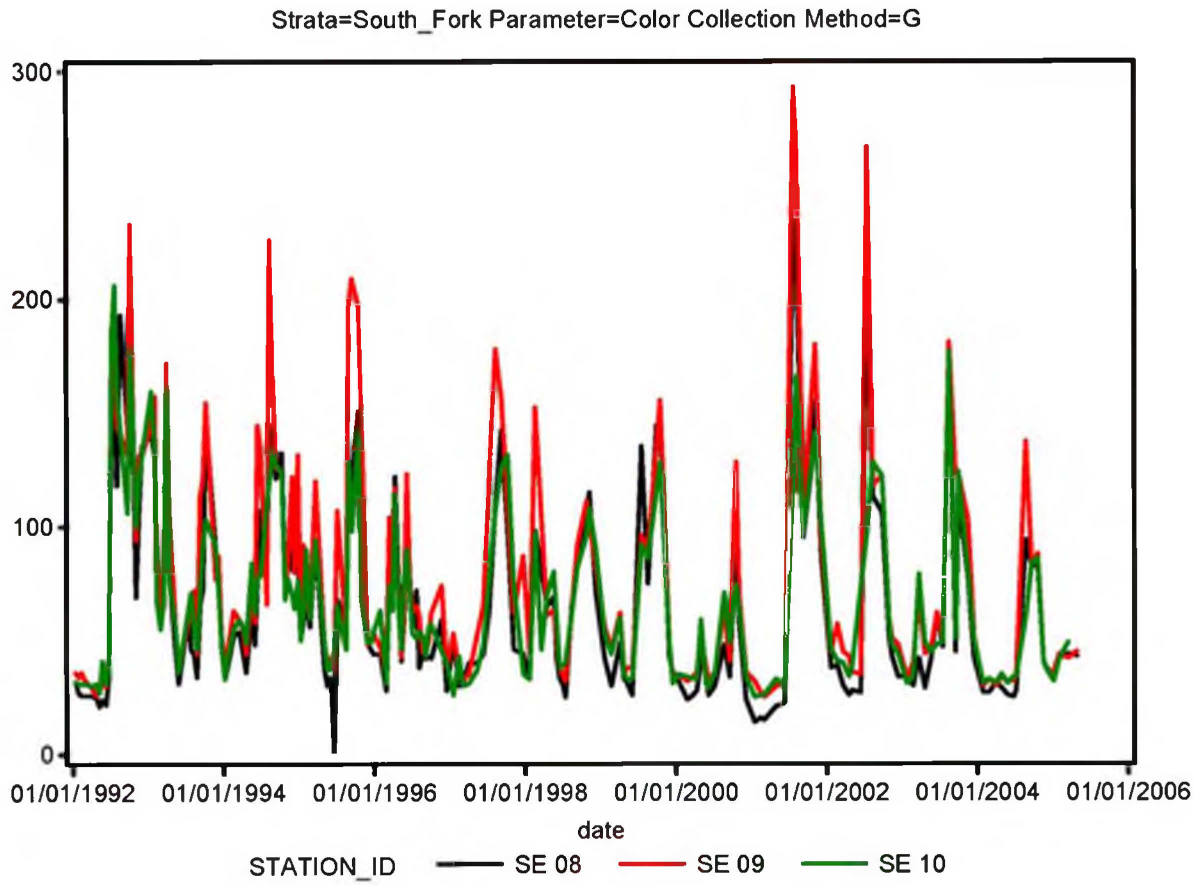
SE 10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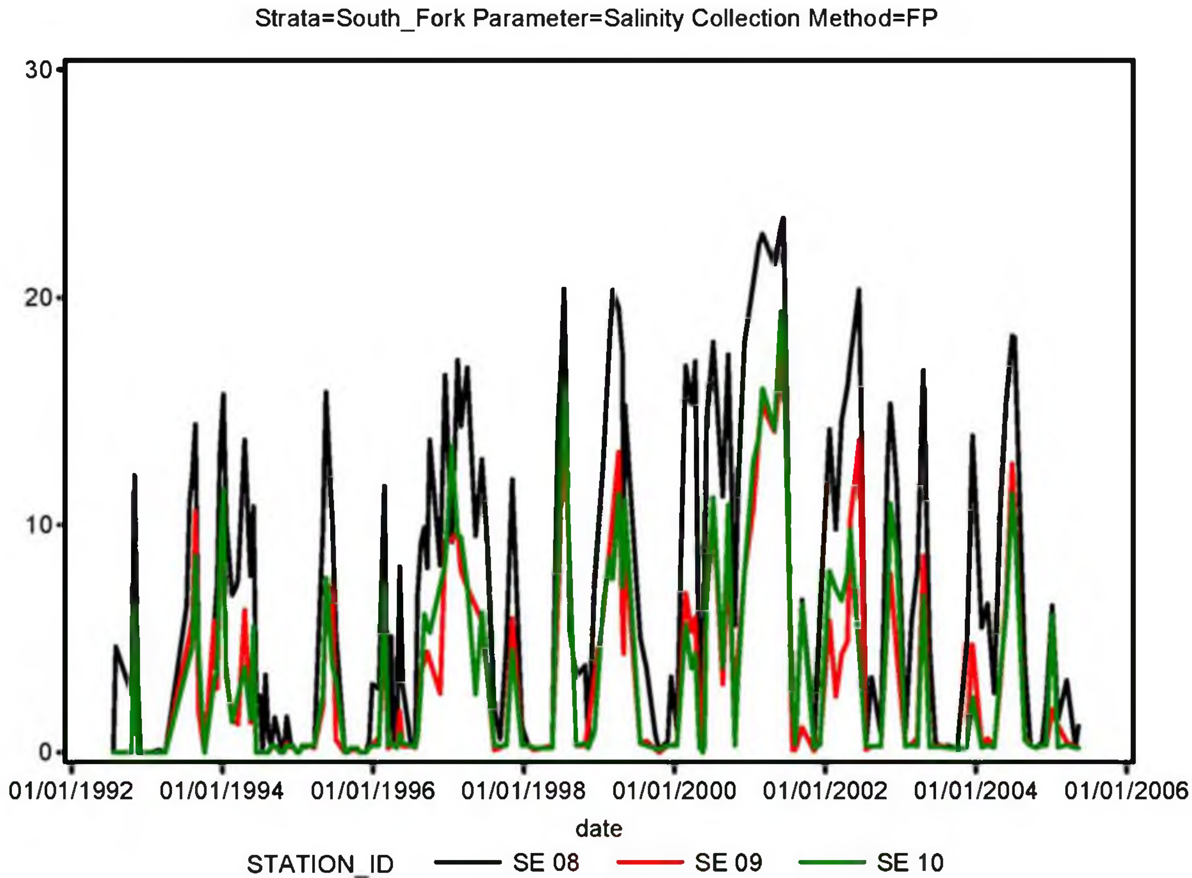
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01/01/1992
01/01/1994
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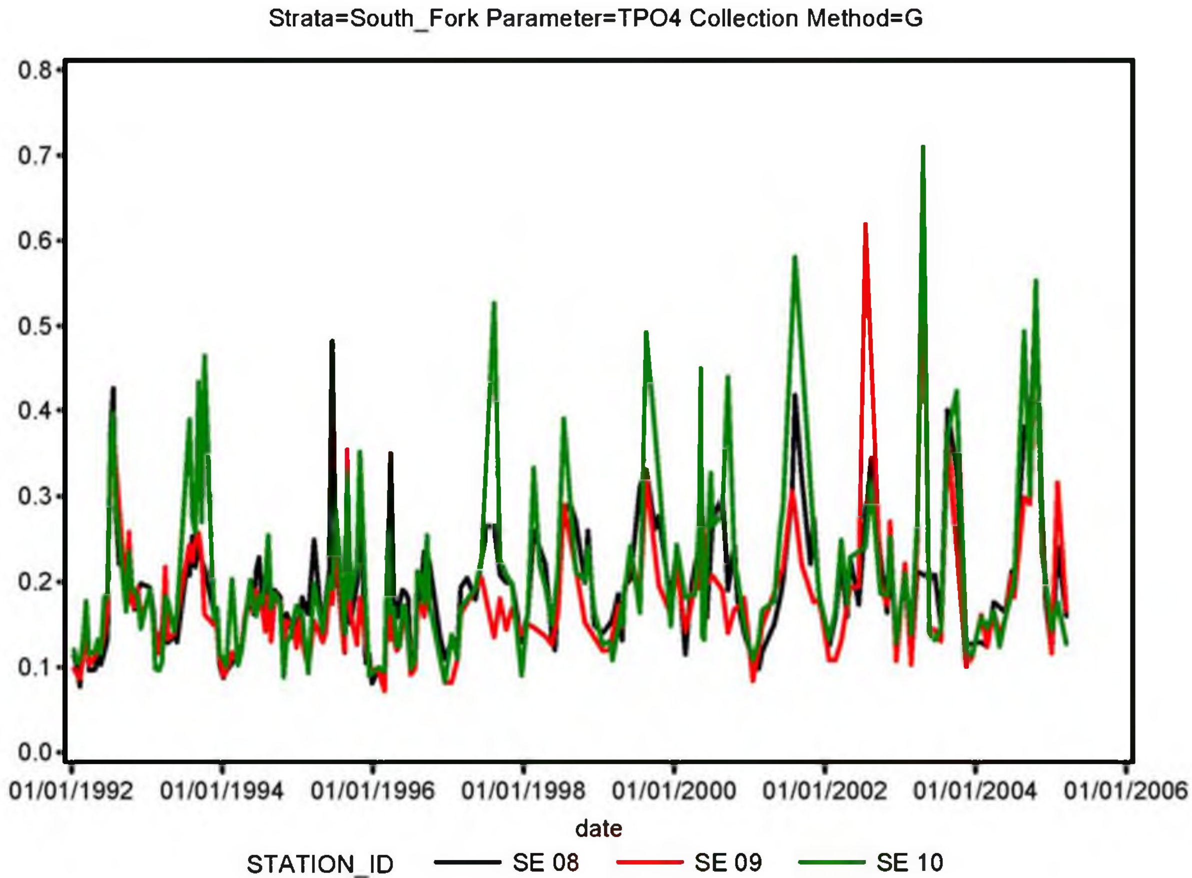

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01/01/2000
01/01/2002
01/01/2004
01/01/2006
date
STATION_ID
SE 08
SE 09
SE 10

# Northeast Coastal Structures

**Optimization Leader: Mike Wessel, Janicki Environmental**
**Statistician: Mike Wessel, Janicki Environmental**

**Project Code:** WQM

**Type:** Type II

**Mandate or Permit:**

- Surface Water Improvement and Management Plan (SWIM) Chapter 373.451-373.4595 F.S.
- WRDA 2000 Public Law 106-541, Title VI, Section 601. Comprehensive Everglades Restoration Plan – Indian River Lagoon South project (CERP-IRL)
- REstoration COordination and VERification (RECOVER) Monitoring and Assessment Plan
- FL Watershed Restoration Act Chapter 403.067 F.S. (TMDLs/MFLs/PLRGs)
    - Pollution Load Reduction Goals (PLRG's) for the Indian River Lagoon

**Project Start Date:** October 2002

**Division Manager:** Coastal Assessment Division: Sean Sculley (Acting)
RECOVER: John Ogden

**Program Manager:** Yongshan Wan

**Points of Contact:** Yongshan Wan, Dan Crean, Nenad Iricanin, Monique Laham-Pass

**Field Point of Contact:** Monique Laham-Pass

**Spatial Description:**
The Water Quality Monitoring Project includes sampling stations in St. Lucie County (Stations C25S50, Gordy Road, and C24S49), Martin County (C23S48 and C44S80) and Palm Beach County (C18S46, C18G92 and C17S44 in northern Palm beach County; C51S155 in more central Palm Beach County; and C16S41 and C15S40 in southern Palm Beach County). Many of the sampling locations for this monitoring project are located at structures on canals that discharge directly into the St. Lucie Estuary and Indian River Lagoon. In the northern portion of this project area, several of these canals drain agricultural areas (i.e., C24, C-25 and C-44 Basins), while the more southern portion of the project area drains basins where there is substantial urban development. In St. Lucie County, structures located on the C-25 and C-24 canals are monitored. In Martin County, structures located on the C-23 and C-44 canals are monitored. The C-18, C-17, C-51, C-16 and C-15 canals are monitored in Palm Beach County for the Northeast Coastal Structures project.

Because the Northeast Coastal Structures project is closely related to the SE and IRL projects, there may be some sampling stations located in close proximity. Station C44S80, on the C-44 canal (i.e., St. Lucie River) is in close proximity to Station SE10 from Project SE. Station C23S48, on the C-23 canal is located in close proximity to Station SE04 from Project SE.

Discussions with District staff suggested that station C18S46 and C18G92 may be very similar and should be looked at in detail. Staff mentioned that the G92 structure controls water going to Leinhart Dam. Several staff feel monthly data at Leinhart dam would be more useful. There is a question as to whether the data from the G92 structure and S46 structure are redundant (i.e., providing the same information). If the data at these two structures are similar, staff felt that the sampling at Leinhart Dam may replace that being conducted at G92.

**Project Purpose, Goals and Objectives:**
The purpose of the Northeast Coastal Structures monitoring project is to address the mandates listed above. Additionally, this project serves as one of several projects to implement a comprehensive research and monitoring program called for by the Lake Okeechobee Technical Advisory Committee. The monitoring sites were established to identify seasonal and discharge related water quality trends and determine loadings to the Indian River Lagoon, St. Lucie Estuary, Loxahatchee River and Lake Worth Lagoon. Therefore, the specific objectives of this project are

to: determine short and long term trends in water quality; and calculate material loads, basin-wide area export rates, and flow weighted concentrations to these receiving waterbodies.

### Sampling Frequency and Parameters Sampled:

Sampling is collected via autosamplers at the St. Lucie County and Martin County stations only (i.e., 5 of the 11 stations) for the Northeast Coastal Structures project. These stations include: C25S50, Gordy Road, C24S49, C23S48, and C44S80. Samples are collected weekly for Total Kjeldahl Nitrogen, Total phosphorus and nitrite+nitrate. These stations are also sampled monthly via grab samples for alkalinity, calcium, chloride, magnesium, total arsenic, total chromium, total copper, ammonia, total Kjeldahl nitrogen, nitrite, nitrite+nitrate, total phosphorus, orthophosphorus, color, turbidity and TSS. In additional to these parameters, total organic carbon (TOC) is sampled monthly at Gordy Road. At all five stations, these same parameters, along with iron, sulfate, silica, sodium and potassium are sampled quarterly at these stations. Currently, Environmental Quality Inc. samples these five stations.

The remaining six stations located in Palm Beach County are sampled by Palm Beach County Environmental Resource Management. These stations include C18S46, C18G92, C17S44, C51S155, C16S41 and the C15S40. These stations are sampled monthly via grab samples for alkalinity, chloride, ammonia, total Kjeldahl nitrogen, nitrite, nitrite+nitrate, total phosphorus, orthophosphorus, color, turbidity and TSS. In addition to these parameters, several additional parameters are sampled quarterly including calcium, potassium, magnesium, sodium, sulfate, silicate, and iron.

For all Northeast Coastal Structures stations, grab samples are collected ½ meter from the surface. In situ measurements are also collected at all sites, both monthly and quarterly and include pH, dissolved oxygen, temperature, and specific conductance.

### Current and Future Data Uses:

The data gathered from the Northeast Coastal Structures monitoring is critical to a number of District operations and reports. District operations use this information to monitor water that is flowing into the St. Lucie Estuary and Indian River Lagoon and to evaluate the impact of releases. The data are incorporated (or will be incorporated in the near future) in the South Florida Environmental Report and the Water Quality Targets Report and are critical for the Indian River Lagoon Feasibility Study. The data will also be used to develop Minimum Flows and Levels (MFLs) and will be used by the District and DEP to develop TMDLs and PLRGs. The data from the more northern sampling locations (St. Lucie and Martin Counties) are instrumental in the BMP program.

Data collected from SE, IRL and Northeast Coastal Structures also are used in several modeling activities being developed by the District. The St. Lucie Estuary FDC model is being developed to evaluate the estuarine portion of the waterbodies whereas the WASH model is being developed to evaluate the surrounding watershed.

The areas sampled for the Northeast Coastal Structures project are also included in CERP and RECOVER. The data from the SE, IRL and Northeast Coastal Structures monitoring projects will be necessary for the North Palm Beach County CERP projects (Pal-Mar and J.W. Corbett Wildlife Management Area Hydropattern Restoration, L-8 Basin Modification, C-51 and L-8 Reservoir, Lake Worth Lagoon Restoration, C-17 Backpumping and Treatment and C-51 Backpumping and Treatment), as well as the Indian River Lagoon – South CERP project (C-44 Reservoir, C-44 East STA, C-44 West STA, C23/24 Basins and the C-25 and Northfork and Southfork Basins). Many of the monitoring stations from SE, IRL, and Northeast Coastal Structures will also be monitored as part of the RECOVER Monitoring and Assessment Plan, Northern Estuaries module.

### Identified Optimization Opportunities:

Discussions with District staff identified some potential opportunities for optimization. Additionally, questions were generated that will provide useful for guiding the optimization.

- Are there spatial and temporal redundancies at the stations?
- Are data at G92 and S46 redundant? Can a station be added at Leinhart Dam?
- Are there redundancies in the parameters sampled? Which parameters can adequately address water quality?
- Is the sampling frequency sufficient to detect trends and determine potential problems?

**Parameters Measured (via autosampler) for the St. Lucie County/Martin County Sampling Stations for Project Northeast Coastal Structures**

| Station | NOX | TKN | TPO4 |
|---|---|---|---|
| C25S50 | w | w | w |
| GORDYRD | w | w | w |
| C24S49 | w | w | w |
| C23S48 | w | w | w |
| C44S80 | w | w | w |

w = weekly; gray shading indicates a Type 2 station

**Parameters Measured (via grab or in situ) for the St. Lucie County/Martin County Sampling Stations for Project Northeast Coastal Structures**

| Station | DO | TEMP | PH | SCOND | ALKA | CA | CL | K | NA | MG | TOT AS | TOT CR | TOT CU | TOT FE | NH4 | TKN | NO2 | NOX | TPO4 | OPO4 | SIO2 | SO4 | TORGC | COLOR | TSS | TURBI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C25S50 | m | m | m | m | m | m | m | qrt | qrt | m | m | m | m | qrt | m | m | m | m | m | m | qrt | qrt | | m | m | m |
| GORDYRD | m | m | m | m | m | m | m | qrt | qrt | m | m | m | m | qrt | m | m | m | m | m | m | qrt | qrt | m | m | m | m |
| C24S49 | m | m | m | m | m | m | m | qrt | qrt | m | m | m | m | qrt | m | m | m | m | m | m | qrt | qrt | | m | m | m |
| C23S48 | m | m | m | m | m | m | m | qrt | qrt | m | m | m | m | qrt | m | m | m | m | m | m | qrt | qrt | | m | m | m |
| C44S80 | m | m | m | m | m | m | m | qrt | qrt | m | m | m | m | qrt | m | m | m | m | m | m | qrt | qrt | | m | m | m |

m = monthly; qtr = quarterly; gray shading indicates a Type 2 station

**Parameters Measured (via grab or in situ) for the Palm Beach County Sampling Stations for Project Northeast Coastal Structures**

| Station | DO | TEMP | PH | SCOND | ALKA | CA | CL | K | NA | MG | TOT FE | NH4 | TKN | NO2 | NOX | TPO4 | OPO4 | SIO2 | SO4 | COLOR | TSS | TURBI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C18S46 | m | m | m | m | m | qrt | m | qrt | qrt | qrt | qrt | m | m | m | m | m | m | qrt | qrt | m | m | m |
| C18G92 | m | m | m | m | m | qrt | m | qrt | qrt | qrt | qrt | m | m | m | m | m | m | qrt | qrt | qrt | m | m |
| C17S44 | m | m | m | m | m | qrt | m | qrt | qrt | qrt | qrt | m | m | m | m | m | m | qrt | qrt | qrt | m | m |
| C51S155 | m | qrt | m | m | m | qrt | m | qrt | qrt | qrt | qrt | m | m | m | m | m | m | qrt | qrt | m | m | m |
| C16S41 | m | m | m | qrt | m | qrt | m | qrt | qrt | qrt | qrt | m | m | m | m | qrt | m | qrt | qrt | m | qrt | qrt |
| C15S40 | m | m | m | m | m | qrt | m | qrt | qrt | qrt | qrt | m | m | m | m | m | m | qrt | qrt | m | m | m |

m = monthly; qtr = quarterly; gray shading indicates a Type 2 station

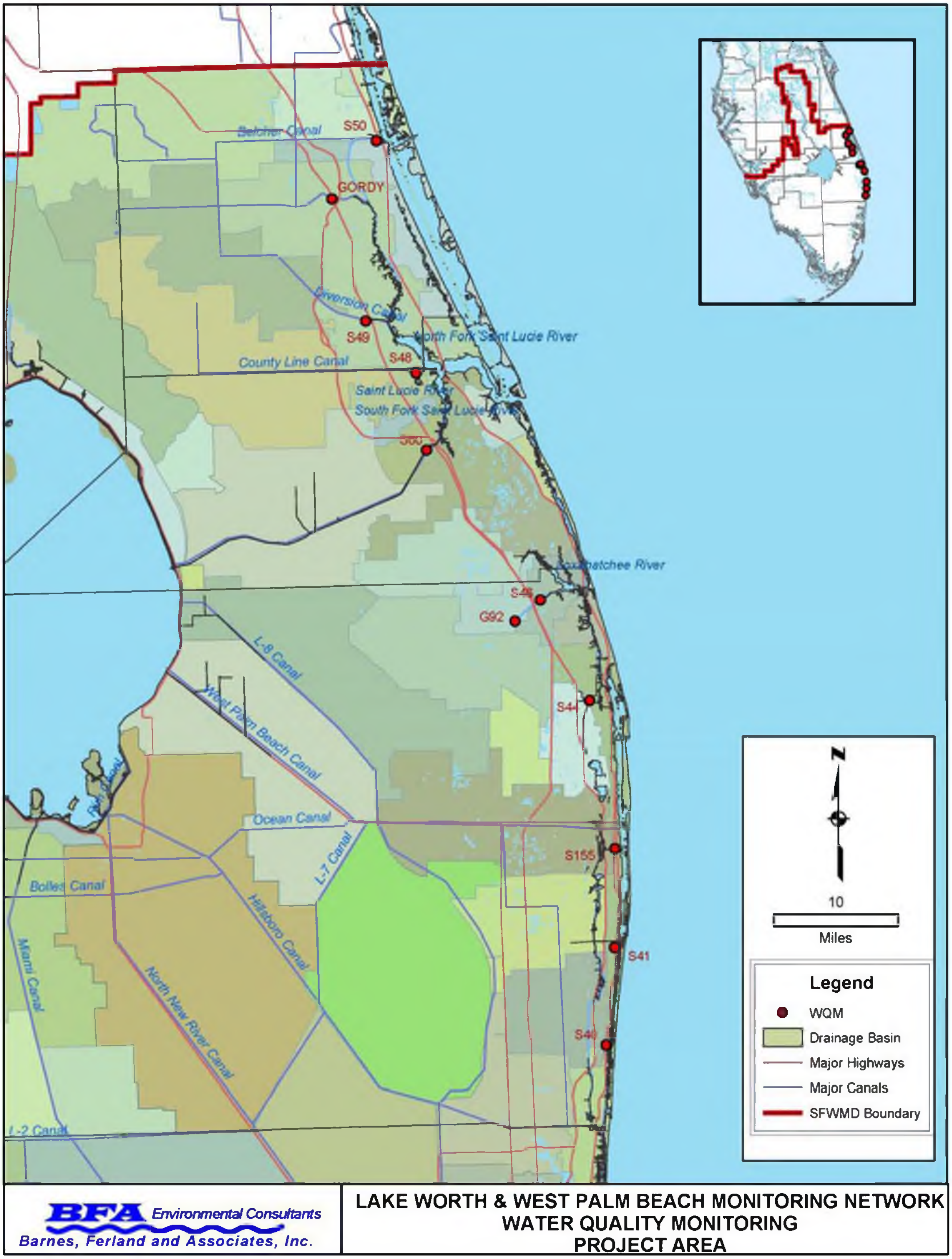



**Figure 1. WQM Sampling Locations in the Lake Worth and West Palm Beach study area.**

**Optimization analysis:**
Optimization of the Northeast Coastal Structures water quality monitoring project was undertaken with respect to the specific tasks outlined above and detailed in the optimization plan modified and approved in September 20005. Briefly, the spatial and temporal adequacy of the Northeast Coastal Structures project was evaluated with respect to being able to detect changes between time periods, being able to detect trends in water quality parameters by station within the project, assessing information redundancies among stations and identifying stations located in proximity to potential point source discharges. The parameters identified for optimization in this project were:

| Parameter | Units | DBHydro Code |
|---|---|---|
| Color | PCU | 13 |
| NOx | mg/L | 18 |
| TKN | mg/L | 21 |
| TPO4 | mg/L | 25 |
| TSS | mg/L | 16 |

- To estimate power and detectable effect size of the current monitoring program, Monte Carlo simulation using a nonparametric Sign Test was used to estimate the detectable change in median value for each parameter of interest across stations corresponding to a significant shift in the distribution from current levels (i.e. long-term median condition) given the current sampling effort. Further, the test was constructed to establish whether or not a given magnitude of change would result in an observable shift to a target value (e.g. DO standard of 5.0 mg/L) or when a target was unavailable a 20% change in long term median was used as the target value.

- To estimate the power to detect a trend for a given water quality parameter, Monte Carlo simulations were performed using the Seasonal Kendall Tau Test for Trend. This procedure is being documented as a statistical evaluation tool for the SFWMD and the procedure is outlined in detail in separate documentation (Rust 2005). Briefly, the simulations result in an estimate of the slope (time series trend) that can be detected for a given monitoring routine using the current annual effort and under alternative sampling strategies. Again a 20% change in slope was used as a target change for detection.

- To examine similarities between C18S46 and C18G92, two stations identified for potential optimization, time series plots, Spearmans Rank correlation and the Wilcoxon Rank Sum test was used to examine the similarities and degree of covariance between stations.

The Northeast Coastal Structures project is primarily directed towards calculating export loads and identifying areas of point sources of nutrient inputs. Both grab samples and automated sampling schemes are used to collect water quality information. Incorporating flow data into the analysis was beyond the scope of this study; however, flow proportional auto-samplers are used at five of the eleven stations monitored within the Northeast Coastal Structures network. The focus of this optimization was on optimizing the sampling frequency necessary to detect changes in water quality parameters with respect to a 20% change from long term median and estimating the ability to detect time series trends (i.e., changes in slope).

The first component of the optimization was to examine the project-wide distribution for each parameter of interest, calculate the long term median value for each parameter of interest and generate a simulation dataset that could be used to test the effectiveness of the current monitoring sampling design to estimate changes in water quality parameters of interest to the District. Details of the sign test methods are conveyed in the comprehenisive report for the project (Hunt et al. 2006). Briefly, the Sign Test simulation exercise is meant to demonstrate the ability of a sampling program to detect changes from a baseline value under a given sampling frequency. The long term median value was used to represent a baseline value and the test was constructed as a one-sample test to estimate the power to detect a change in the median value for each water quality variable of interest. Since there is only variability associated with one group of data for the comparison, the test is more powerful than a two- sample test where uncertainty is expressed in the distribution of each comparison group. Further, the sign test simulations do not account for serial auto-correlation which can be present in monitoring data. The presence of significant auto correlation, if not accounted for, can yield unrealistically optimistic assessments of the sample size necessary to detect changes. However, from a regulatory perspective, auto-correlation is usually not considered when assessing whether or not a water body is meeting or exceeding a given water quality target (e.g., Impaired Waters Rule F.A.C. 62-303.320). Auto-correlation is not considered in the Sign Test simulations but is considered in the test for trend analysis presented later in this document.

Table 1 provides a summary of the simulation results using the Sign Test on all data pooled to estimate the effect size detectable under the current monitoring strategy and identify the number of years of data required to detect a specified magnitude of change from current conditions.

**Table 1. Results of Monte Carlo simulation using the Sign Test to determine the effect size and number of samples to detect a 20% change in long term median value (Target) with 80% power.**

| Parameter | Nobs/Year | Long Term Median Value | Annual Percent Change Detected | Number of Samples to Detect Shift to Target |
|---|---|---|---|---|
| Color | 130 | 55.00 | 9.59 | 65 |
| NOx | 250 | 0.075 | 27.20 | 500 |
| TKN | 130 | 1.060 | 9.23 | 65 |
| TPO4 | 250 | 0.135 | 17.04 | 220 |
| TSS | 130 | 3.00 | 5.00 | 60 |

The results suggest that the basin-wide sampling frequency for all data pooled was sufficient to detect annual changes of 20 % in the basin-wide median value for Color, TSS, TKN, and TPO4. Inference regarding a 20 % change in median for NOx required approximately two years at the current sampling frequency. While basin wide sampling frequency appears to be adequate for most parameters, there was considerable variability among stations within the project (see Appendix 1 box plots). Power estimation for individual stations incorporated more sophisticated analytical techniques to estimate the ability to detect trends at individual stations within the Northeast Coastal Structures project.

The second component of the optimization was to assess the power to detect time series trends for the water quality parameters of interest at individual stations within the project. For the Northeast Coastal Structures project, grab sample and flow proportional autosampler (ACF) data from 2000 to 2004 were used to estimate the seasonal variability and autocorrelation for each station/parameter set. A simulation dataset was generated from which samples could be pulled representing a five year time series. For each replicate trial, the Seasonal Kendall Tau Test for Trend was used to estimate the annual percent change in slope that could be detected under the current sampling design and under alternative sampling frequencies.

For the majority of grab sampling stations in the Northeast Coastal Structures project, the sampling frequency was adequate to detect a 20% change in slope over five years for NOx and TPO4 (Table 2). For TKN, two groups of stations, C18S46 & C18G92 and C25S50 & GORDYRD had sufficient sampling frequency while the remainder of stations required additional sampling. However, only for station C44S80 would sample frequency increases to 36 samples per year result in a detectable 20% change in trend. The statistical analysis resulted in non convergence in the covariance pattern model in several cases for TSS and TKN. This likely was the result of inability to estimate the covariance pattern in the time series using the spatial power function. Further investigation would be required to elucidate the specific mechanisms causing failure of convergence for these station/parameter frequency sets. However, the power was generally very low to detect a 20% change in TSS such that increasing sampling frequency would not result in the desired increase in precision for this parameter. Time series trends were detected at four stations (i.e., C17S44, C18G92, C18S46, and C25S50). Interestingly, the slope estimates for C18G92 and C18S46 were very similar for the parameters NOx and TKN. These two stations were identified as stations of interest for examining spatial sampling redundancy.

**Table 2. Results of Monte Carlo simulation using the Seasonal Kendall Tau Test for Trend on a five year time series of grab samples to determine the effect size for change in slope parameter.**

| Station | Parameter | Number of samples per year | Slope Estimate | Annual Percent Change Detectable | Can You Detect an Trend in 5 Years? |
|---|---|---|---|---|---|
| C25S50 | Color | 12 | 0 | 25.97 | N |
| | NOx | 12 | 0 | 2.46 | Y |

| Station | Parameter | Number of samples per year | Slope Estimate | Annual Percent Change Detectable | Can You Detect an Trend in 5 Years? |
|---|---|---|---|---|---|
| | TKN | 12 | 0 | 3.49 | Y |
| | TPO4 | 12 | 0 | 2.86 | Y |
| | TSS | 12 | 0 | 13.99 | N |
| | | | | | |
| GORDYRD | Color | 12 | 0 | 10.45 | N |
| | NOx | 12 | 0 | 5.06 | N |
| | TKN | 12 | 0 | 3.95 | Y |
| | TPO4 | 12 | 0 | 3.20 | Y |
| | TSS | 12 | 0 | NC | NC |
| | | | | | |
| C24S49 | Color | 12 | 0 | 13.32 | N |
| | NOx | 12 | 0 | 1.85 | Y |
| | TKN | 12 | 0 | NC | NC |
| | TPO4 | 12 | 0 | 3.38 | Y |
| | TSS | 12 | 0 | 33.24 | N |
| C23S48 | Color | 12 | 0 | 29.54 | N |
| | NOx | 12 | 0 | 2.05 | Y |
| | TKN | 12 | 0 | 4.85 | N |
| | TPO4 | 12 | 0.0323 | 3.86 | Y |
| | TSS | 12 | 0 | NC | NC |
| | | | | | |
| C44S80 | Color | 12 | 0 | 15.01 | N |
| | NOx | 12 | 0 | 5.87 | N |
| | TKN | 12 | 0 | 4.22 | N |
| | TPO4 | 12 | 0 | 1.99 | Y |
| | TSS | 12 | 0 | 50.81 | N |
| | | | | | |
| C18S46 | Color | 12 | 0 | 24.16 | N |
| | NOx | 12 | 0,008 | 0.80 | Y |
| | TKN | 12 | 0.036 | 1.83 | Y |
| | TPO4 | 12 | 0 | 0.53 | Y |
| | TSS | 12 | 0 | 81.78 | N |
| | | | | | |
| C18G92 | Color | 12 | 0 | 19.04 | N |
| | NOx | 12 | 0.008 | 0.91 | Y |
| | TKN | 12 | 0.038 | 2.45 | Y |
| | TPO4 | 12 | 0 | 0.49 | Y |
| | TSS | 12 | 0 | 37.63 | N |
| | | | | | |
| C17S44 | Color | 12 | 0 | 10.34 | N |
| | NOx | 12 | 0 | NC | NC |
| | TKN | 12 | 0.030 | 2.28 | Y |
| | TPO4 | 12 | 0 | 0.53 | Y |
| | TSS | 12 | 0 | NC | NC |
| | | | | | |
| C51S155 | Color | 12 | 0 | 7.98 | N |
| | NOx | 12 | 0 | NC | NC |
| | TKN | 12 | 0 | 5.01 | N |
| | TPO4 | 12 | 0 | 2.50 | Y |

| Station | Parameter | Number of samples per year | Slope Estimate | Annual Percent Change Detectable | Can You Detect an Trend in 5 Years? |
|---|---|---|---|---|---|
| | TSS | 12 | 0 | NC | NC |
| | | | | | |
| C16S41 | Color | 12 | 0 | 6.45 | N |
| | NOx | 12 | 0 | 3.37 | Y |
| | TKN | 12 | 0 | 11.68 | N |
| | TPO4 | 12 | 0 | 2.85 | Y |
| | TSS | 12 | 0 | 44.04 | N |
| | | | | | |
| C15S40 | Color | 12 | 0 | 5.98 | N |
| | NOx | 12 | 0 | 3.68 | Y |
| | TKN | 12 | 0 | 14.03 | N |
| | TPO4 | 12 | 0 | 2.63 | Y |
| | TSS | 12 | 0 | 119.54 | N |

** NC = non-convergence of covariance pattern model

The time series trend power analysis was also performed on the four stations where ACF auto samplers were used to collect data on water quality. Again, data from 2000 through 2004 were used to estimate power for detecting a 20% change in the time series trend.

**Table 3. Results of Monte Carlo simulation using the Seasonal Kendall Tau Test for Trend on a five year time series of flow-proportional autosamplers to determine the effect size for change in slope parameter.**

| Station | Parameter | Number of samples per year | Slope Estimate | Annual Percent Change Detectable | Can You Detect an Trend in 5 Years? |
|---|---|---|---|---|---|
| C25S50 | NOx | 24 | 0 | 2.08 | Y |
| C25S50 | TKN | 24 | 0 | 4.04 | N |
| C25S50 | TPO4 | 24 | 0 | 2.58 | Y |
| | | | | | |
| GORDYRD | NOx | 48 | 0 | 3.03 | Y |
| GORDYRD | TKN | 48 | 0 | 4.41 | N |
| GORDYRD | TPO4 | 48 | 0 | 3.07 | Y |
| | | | | | |
| C24S49 | NOx | 24 | 0 | 1.33 | Y |
| C24S49 | TKN | 24 | 0 | 3.83 | Y |
| C24S49 | TPO4 | 24 | 0 | 2.73 | Y |
| | | | | | |
| C23S48 | NOx | 24 | 0 | 1.92 | Y |
| C23S48 | TKN | 24 | 0 | 2.29 | Y |
| C23S48 | TPO4 | 24 | 0 | 4.19 | N |

For all stations, the current sampling frequency was sufficient to detect a trend for NOx. In two cases (C25S50 and GORDYRD) TKN was very near the detection level under the current sample size (Table 3) and for C23S48, the sampling frequency was marginal to detect a 20% change in slope for TPO4. Otherwise, the sampling frequency was more than adequate to detect trends using the 20% criterion.

A final objective of optimization was to compare two stations (i.e., C18S46 and C18G92) to examine if they are providing the same information with respect to the parameters of interest. To do this, data from 2000 through 2004 were used and time series plots, box plots, the non parametric Wilcoxon Rank Sum test and Spearman correlation were used to estimate the distributional characteristics, compare medians and test for similarities in covariance for each parameter of interest.

Results suggest that for each parameter the medians were not statistically different and the stations were significantly correlated (Appendix Northeast Coastal Structures -2). The two stations were 90% correlated for Color although only 65% correlated for NOx. Time series plots suggested that higher values of NOx tended to occur at C18G92 while higher TPO4 tended to be recorded at C18S46. Further, results of trend analysis at these stations suggested that the slope estimates for NOx and TKN were very similar. However, note that care should be exercised in interpreting these results since these two stations were not sampled in the Spring and Summer of 2004 which may have an affect on the slope estimate.

**Recommendations:**

The Northeast Coastal Structures project is an important part of the South Florida's Water Quality Monitoring Network. The network monitors several drainage basins that empty into the St. Lucie Estuary and the Indian River Lagoon. Monitoring nutrient loads into these receiving bodies are a critical component of maintaining the health of these important ecosystems. Power analysis estimates for basin-wide changes in median condition suggested ample sampling frequency for detecting annual changes of 20% in the median for all parameters of interest except NOx. Further, for NOx, and TPO4 there appeared to be sufficient power to detect a 20% change in a five year time series trend under the current monthly grab sampling effort at many individual stations. When power was insufficient for a particular station/parameter set, increasing the sampling frequency to 36 samples per year would not in most cases result in the necessary increase in power to detect the criterion change in trend. However, increasing sampling frequency would yield a significant detection for trend at stations C44S80 and C51S155 for the parameter TKN. Incorporating flow data was beyond the scope of this study; however, data from composite flow proportional auto-sampler were available and used as part of the optimization process. These data were assessed using the time series power analysis techniques which found sampling frequencies to be sufficient to detect the target 20 percent change for NOx at all stations, TKN at C24S49 and C23S48, and TPO4 at all stations except C23S48. If the target criterion for trend detection were relaxed to a 25% change over five years, all stations would yield sufficient power.

From an optimization perspective, comparison of sampling methods at the same location suggests the auto sampler data is only slightly more powerful than grab sampling for trend detection i.e., differences were not substantial (i.e., within 10% over the five year time series) although the auto sampler effort was at least double that of the grab sampling. While the analysis suggests that sampling variability outweighs the benefits of additional sampling given the criterion established for trend detection, in the absence of flow information the auto-samplers provide more information on loading estimates than grab sample collections, thus may need to remain a component of the sampling scheme since a major objective is to estimate loads into the receiving bodies.

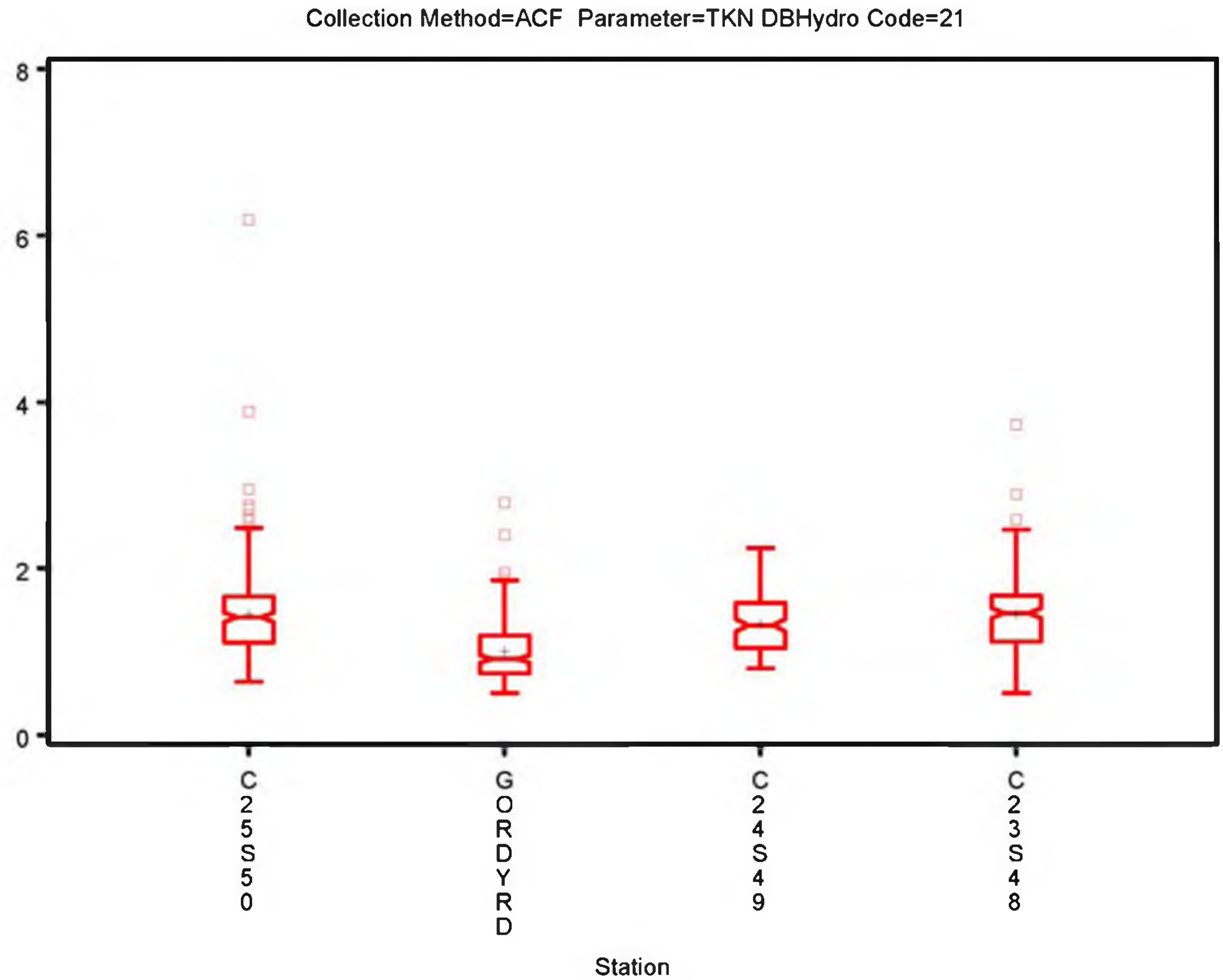
The specific comparison between stations at C18S92 and C18S46 with respect to the potential of relocating C18G92 to Leinhart Dam suggests that the overall medians for each parameter are not significantly different and that the stations are significantly correlated such that similar information is recorded for each parameter at each station. Only the timeseries plots found evidence that the stations differed to some degree through capturing spikes in NOx which tended to occur at C18G92 and spikes in TPO4 which tended to be recorded at C18S46. If these spikes were to cause a target an exceedance, then the difference may be enough to keep both stations, otherwise it appears that one station may adequately serve to capture the information currently provided by both of these grab sample stations and relocations of C18G92 to Leinhart Dam further evaluated.

**References**

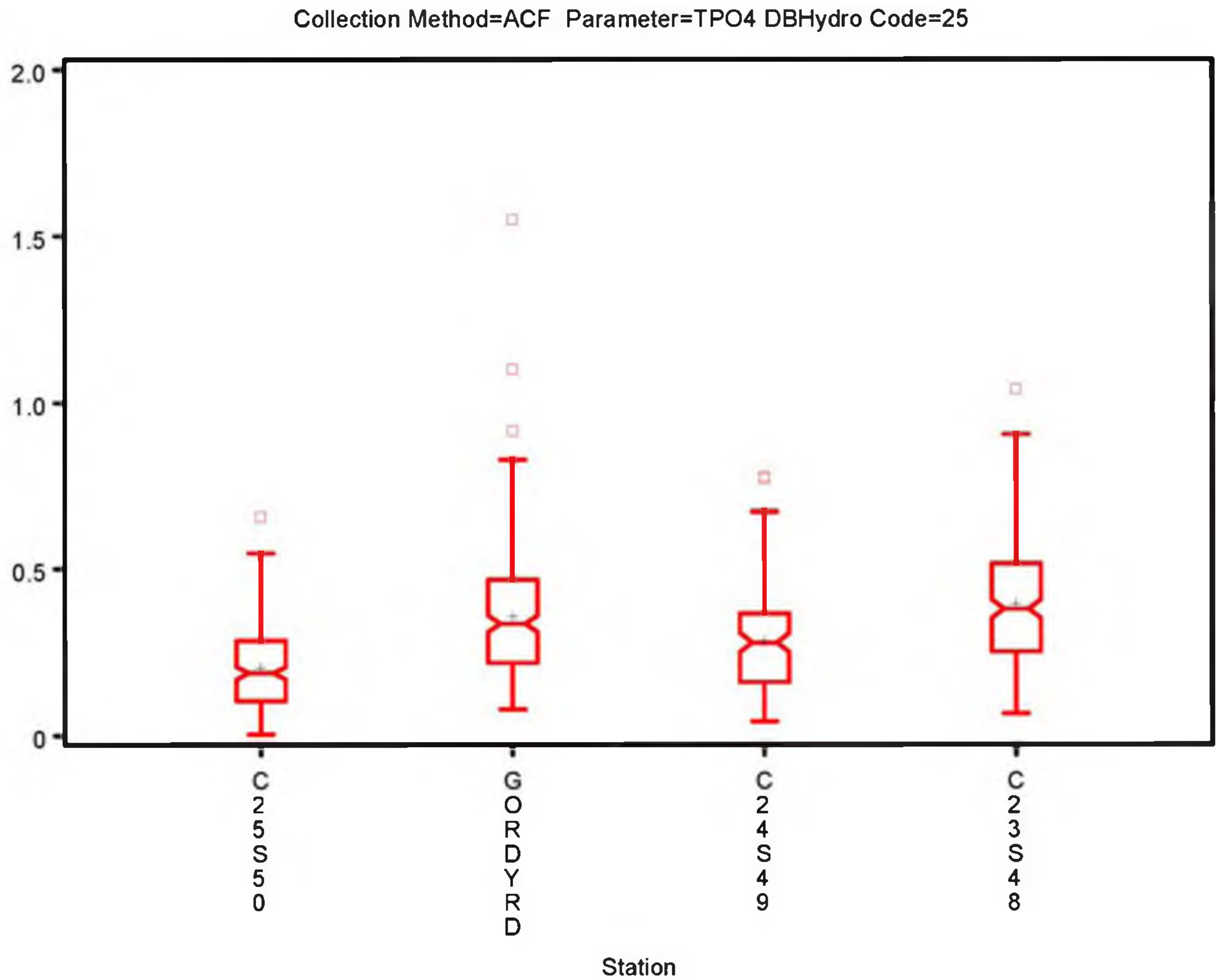
Hunt, CD. Field, J, Rust, S. 2006. Surface Water Quality Monitoring Network Optimization Comprehensive Report. Final report to the South Florida Water Management District. February 2006.

Rust SW. 2005. Power Analysis Procedure for Trend Detection with Accompanying SAS Software. Battelle Report to South Florida Water Management District, November 2005.

# Appendix Northeast Coastal Structures -1
# Boxplots



Collection Method=ACF Parameter=TKN DBHydro Code=21
8
6
4
2
0
C25S50
GORDYRD
C24S49
C23S48
Station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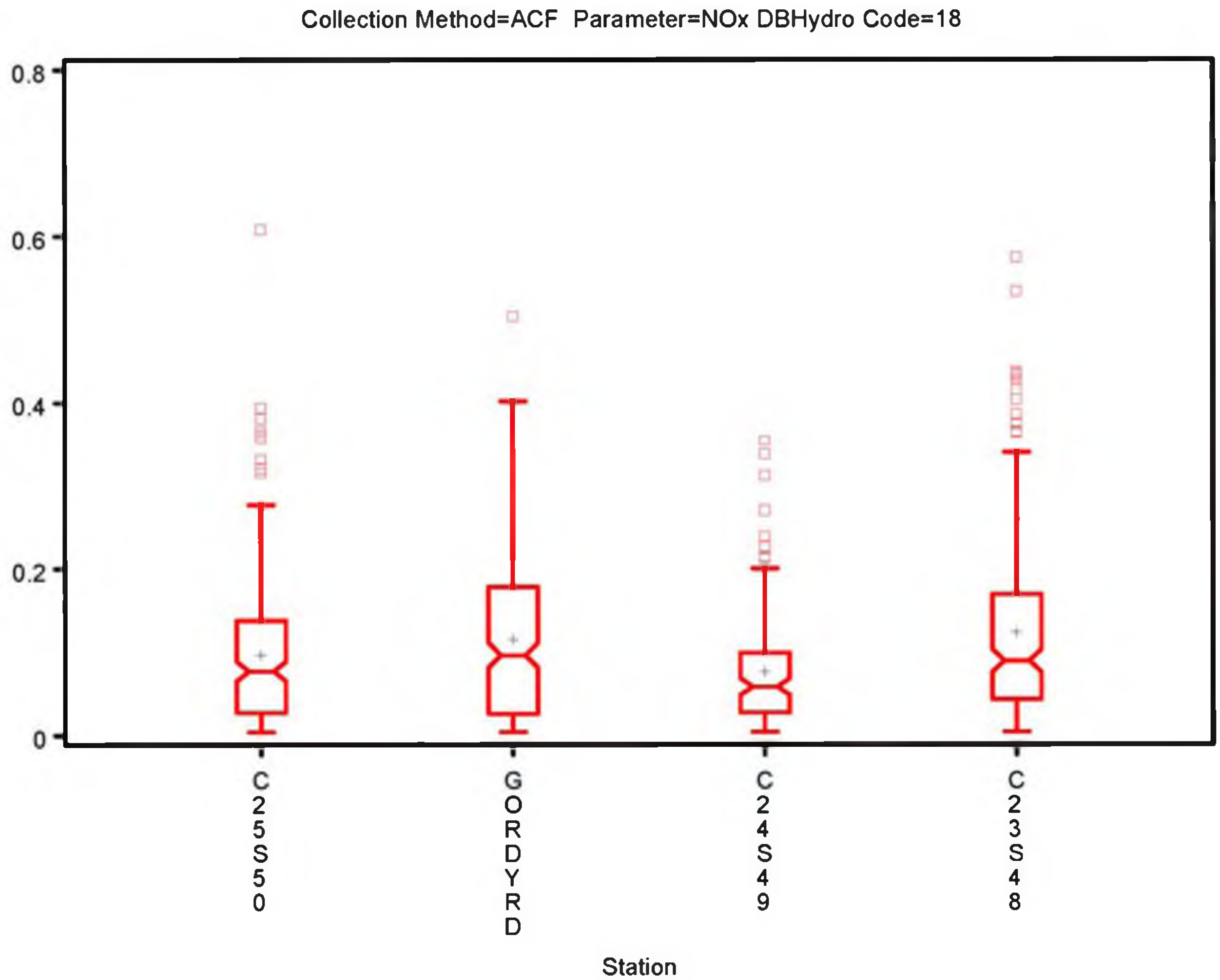
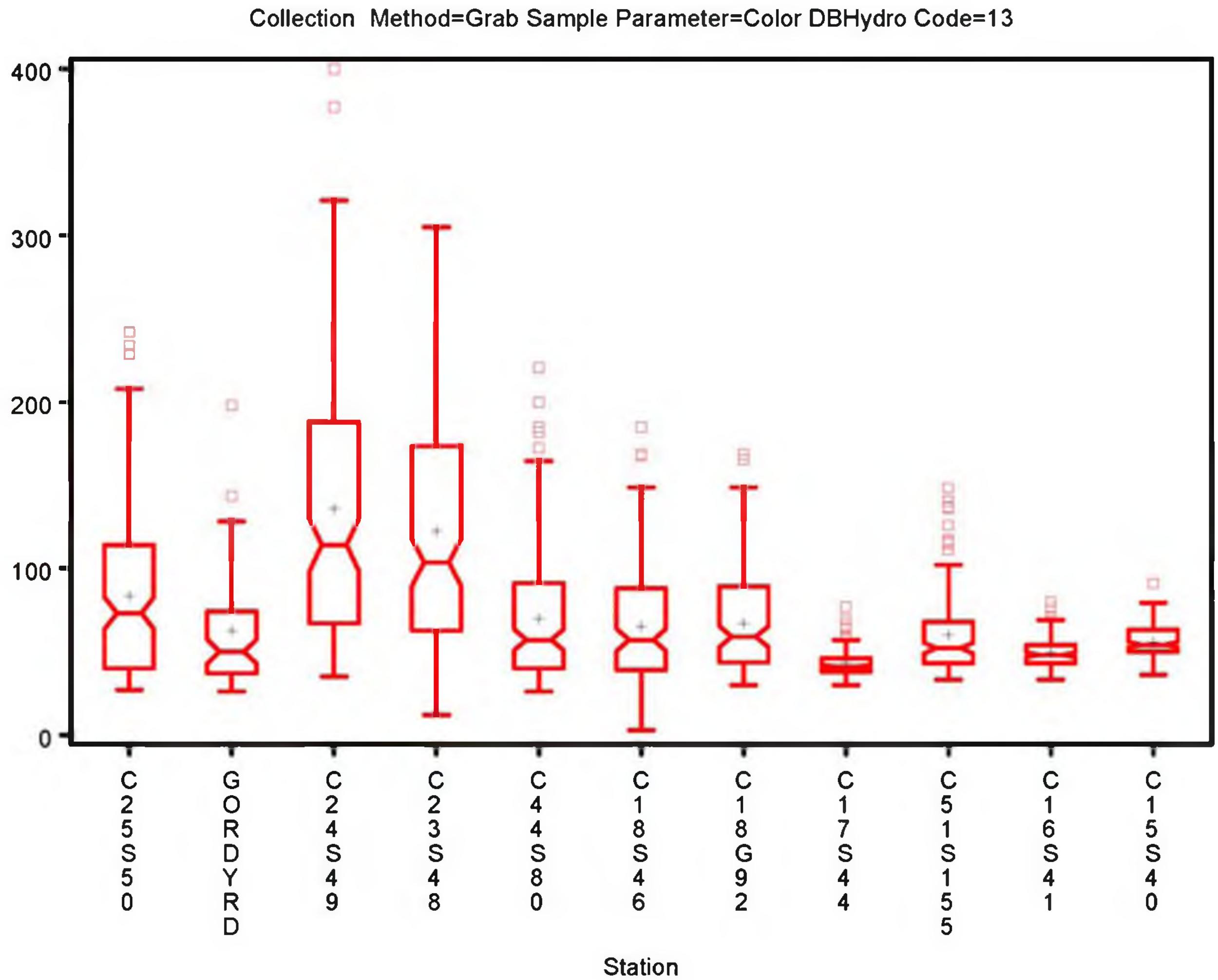
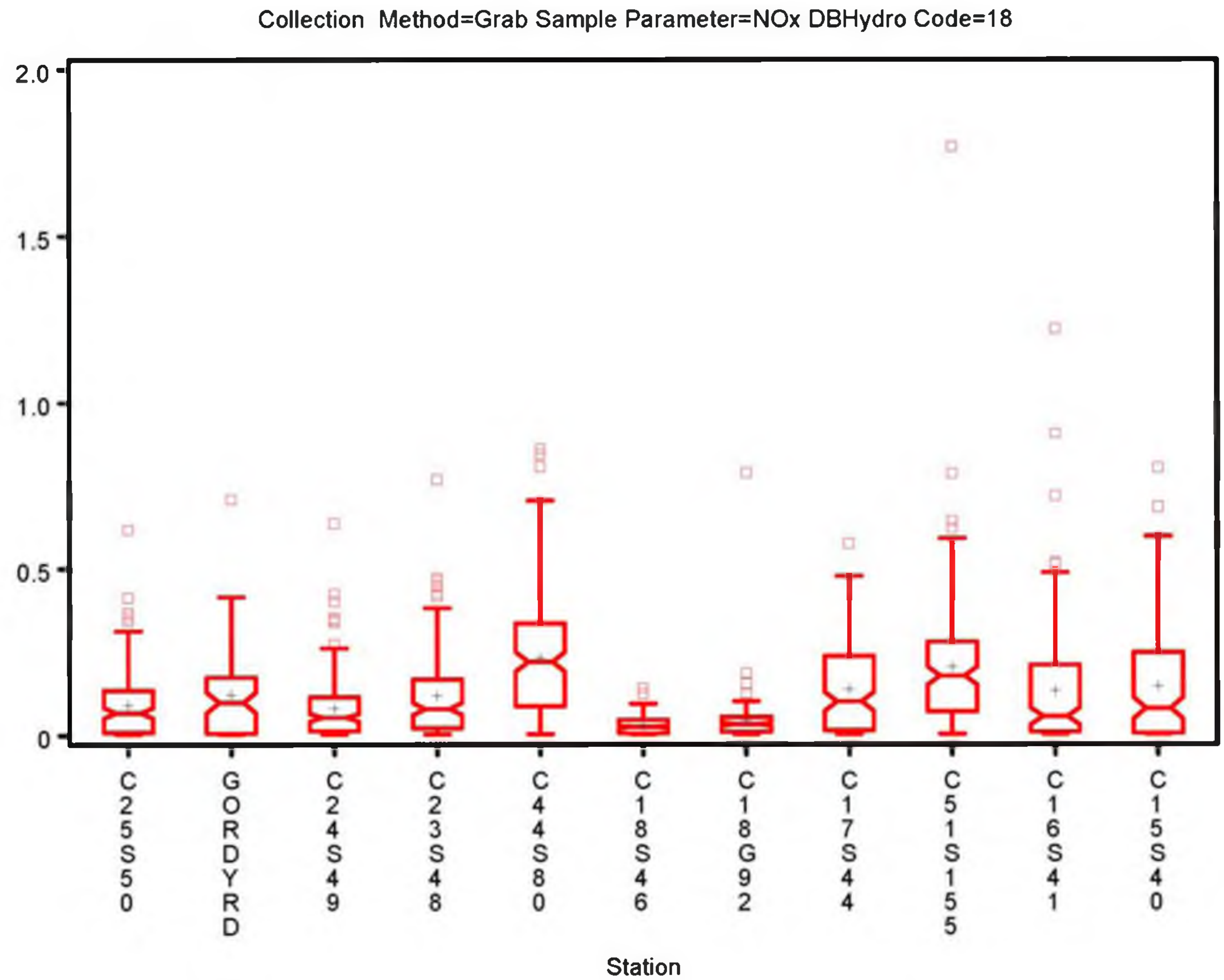
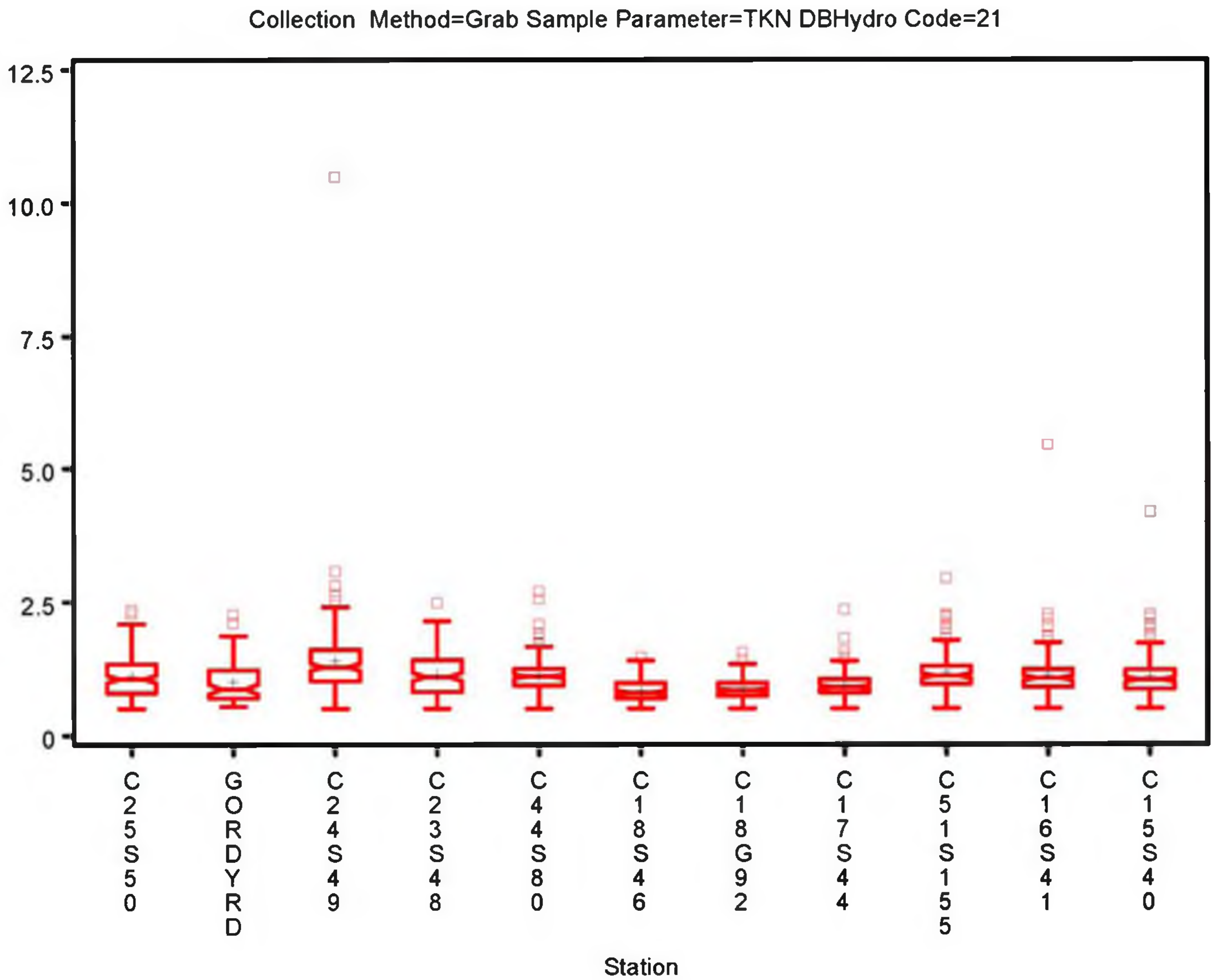
1.5
1.0
0.5
0
C25S50
GORDYRD
C24S49
C23S48
Station

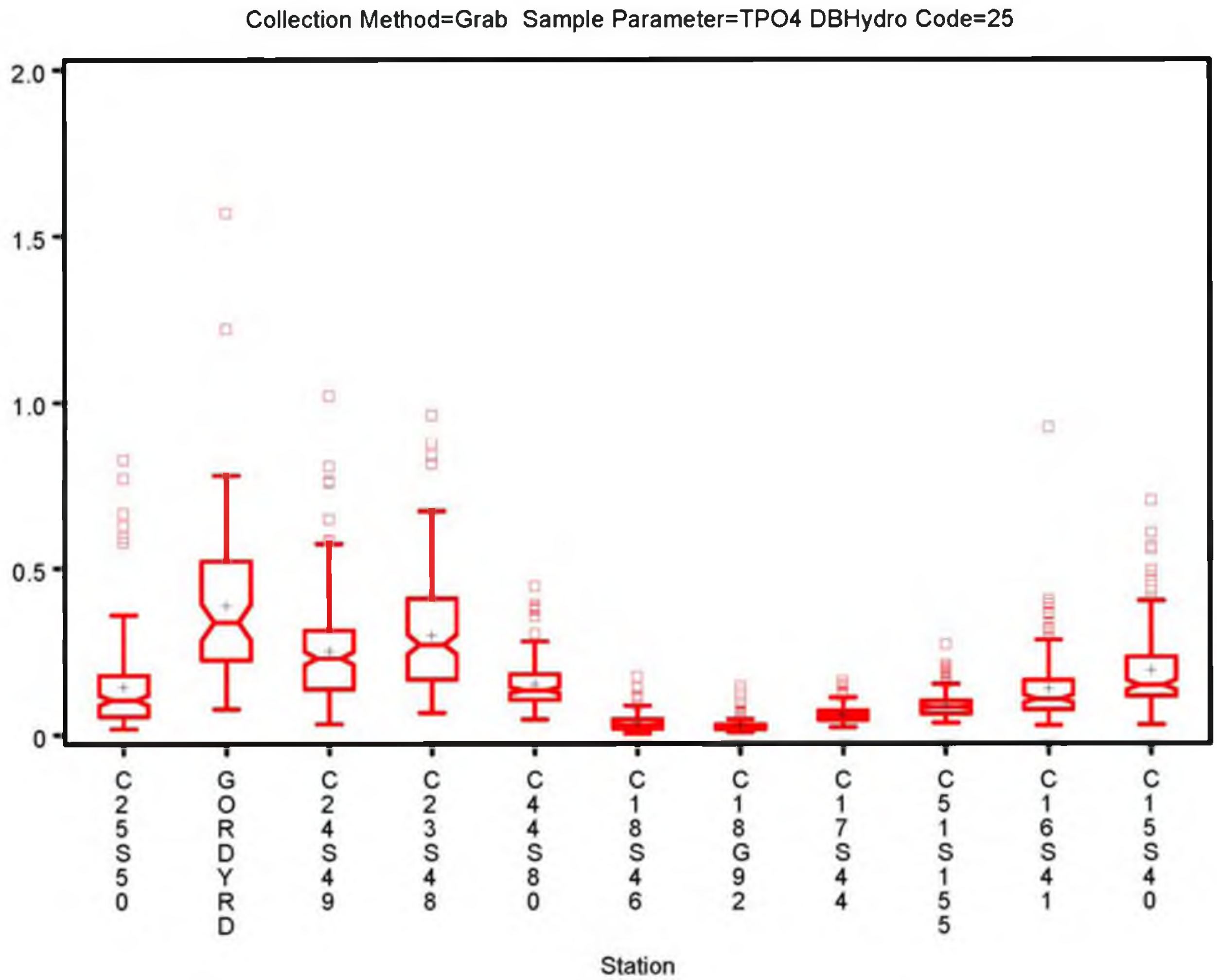

Collection Method=ACF Parameter=NOx DBHydro Code=18
0.8
0.6
0.4
0.2
0
C25S50
GORDYRD
C24S49
C23S48
Station

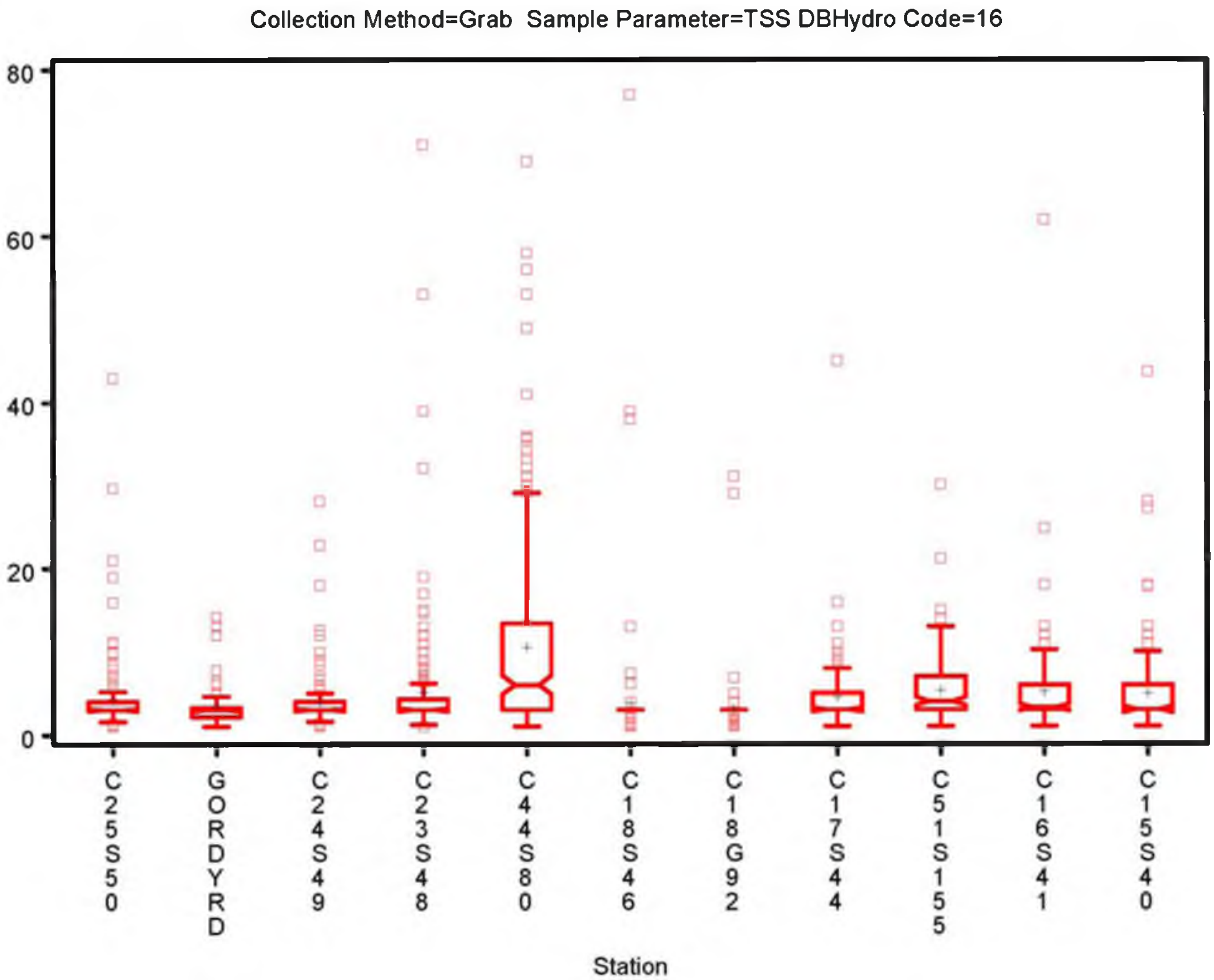

Collection Method=Grab Sample Parameter=Color DBHydro Code=13
400
300
200
100
0
C25S50
GORDYRD
C24S49
C23S48
C44S80
C18S46
C18G92
C17S44
C51S155
C16S41
C15S40
Station


Collection Method=Grab Sample Parameter=NOx DBHydro Code=18
2.0
1.5
1.0
0.5
0
C25S50
GORDYRD
C24S49
C23S48
C44S80
C18S46
C18G92
C17S44
C51S155
C16S41
C15S40
Station



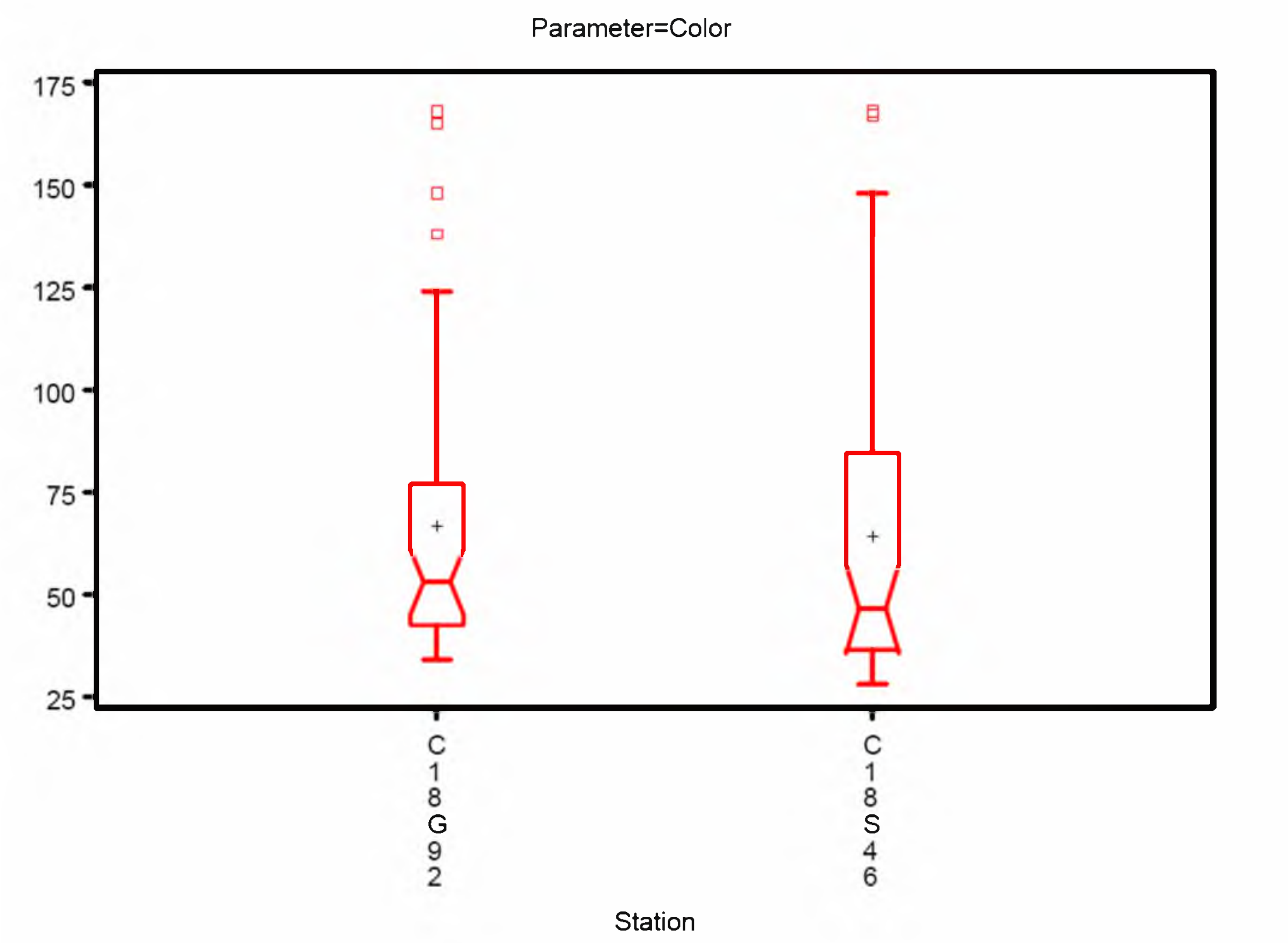
Collection Method=Grab Sample Parameter=TKN DBHydro Code=21
12.5
10.0
7.5
5.0
2.5
0
C25S50
GORDYRD
C24S49
C23S48
C44S80
C18S46
C18G92
C17S44
C51S155
C16S41
C15S40
Station


Collection Method=Grab Sample Parameter=TPO4 DBHydro Code=25
2.0
1.5
1.0
0.5
0
C25S50
GORDYRD
C24S49
C23S48
C44S80
C18S46
C18G92
C17S44
C51S155
C16S41
C15S40
Station

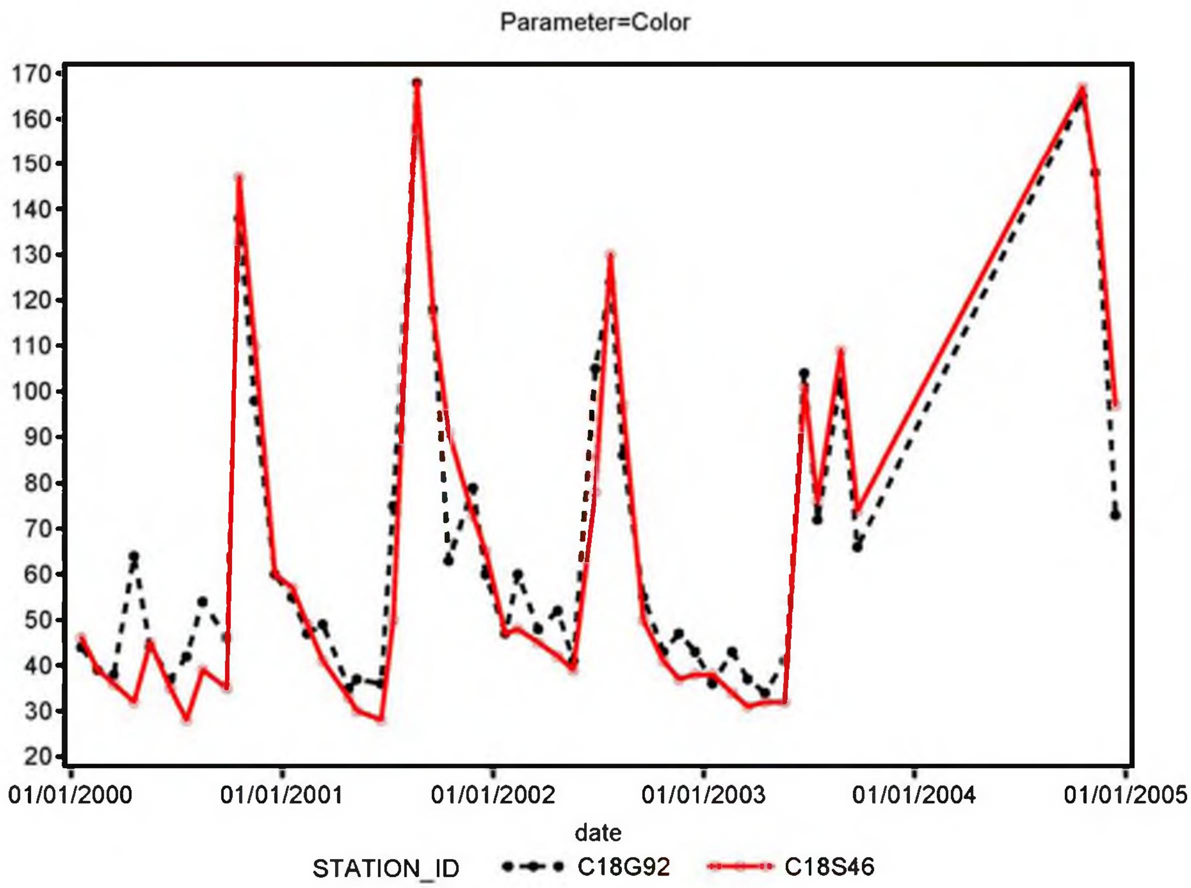

Collection Method=Grab Sample Parameter=TSS DBHydro Code=16
80
60
40
20
0
C25S50
GORDYRD
C24S49
C23S48
C44S80
C18S46
C18G92
C17S44
C51S155
C16S41
C15S40
Station

# Appendix Northeast Coastal Structures - 2

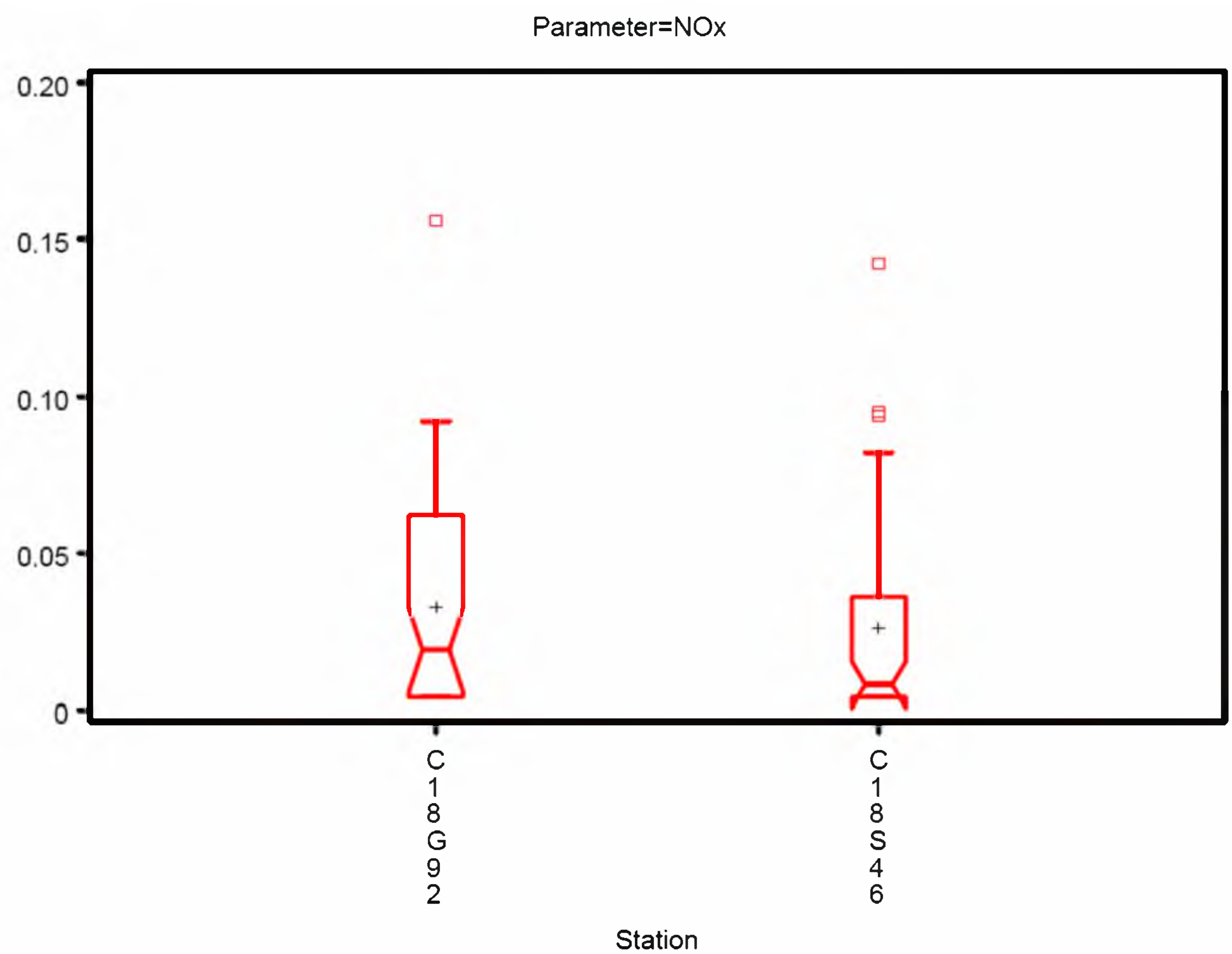
Comparing stations C18S46 and C18S92



Parameter=Color
175
150
125
100
75
50
25
C18G92
C18S46
Station



Parameter=Color
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
01/01/2000
01/01/2001
01/01/2002
01/01/2003
01/01/2004
01/01/2005
date
STATION_ID
C18G92
C18S46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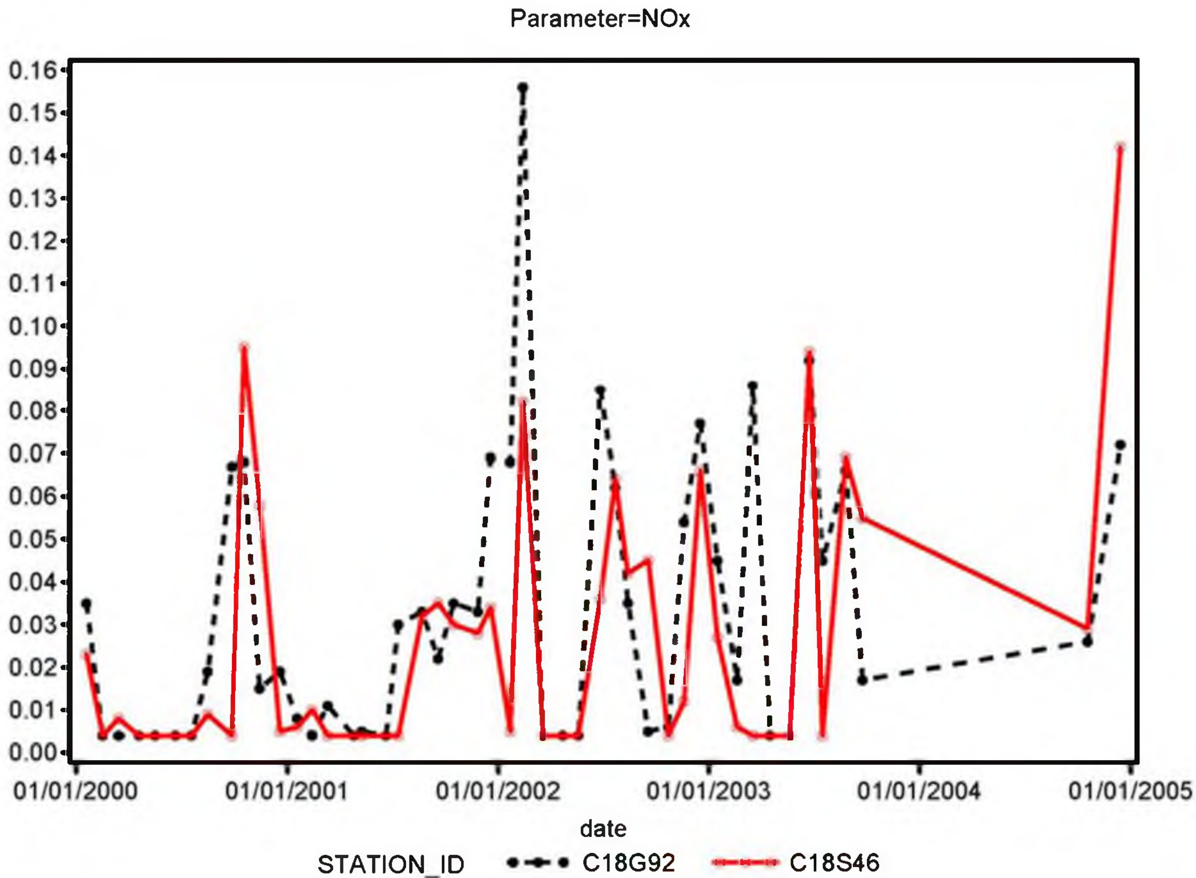
0.15
0.10
0.05
0
C18G92
C18S46
Station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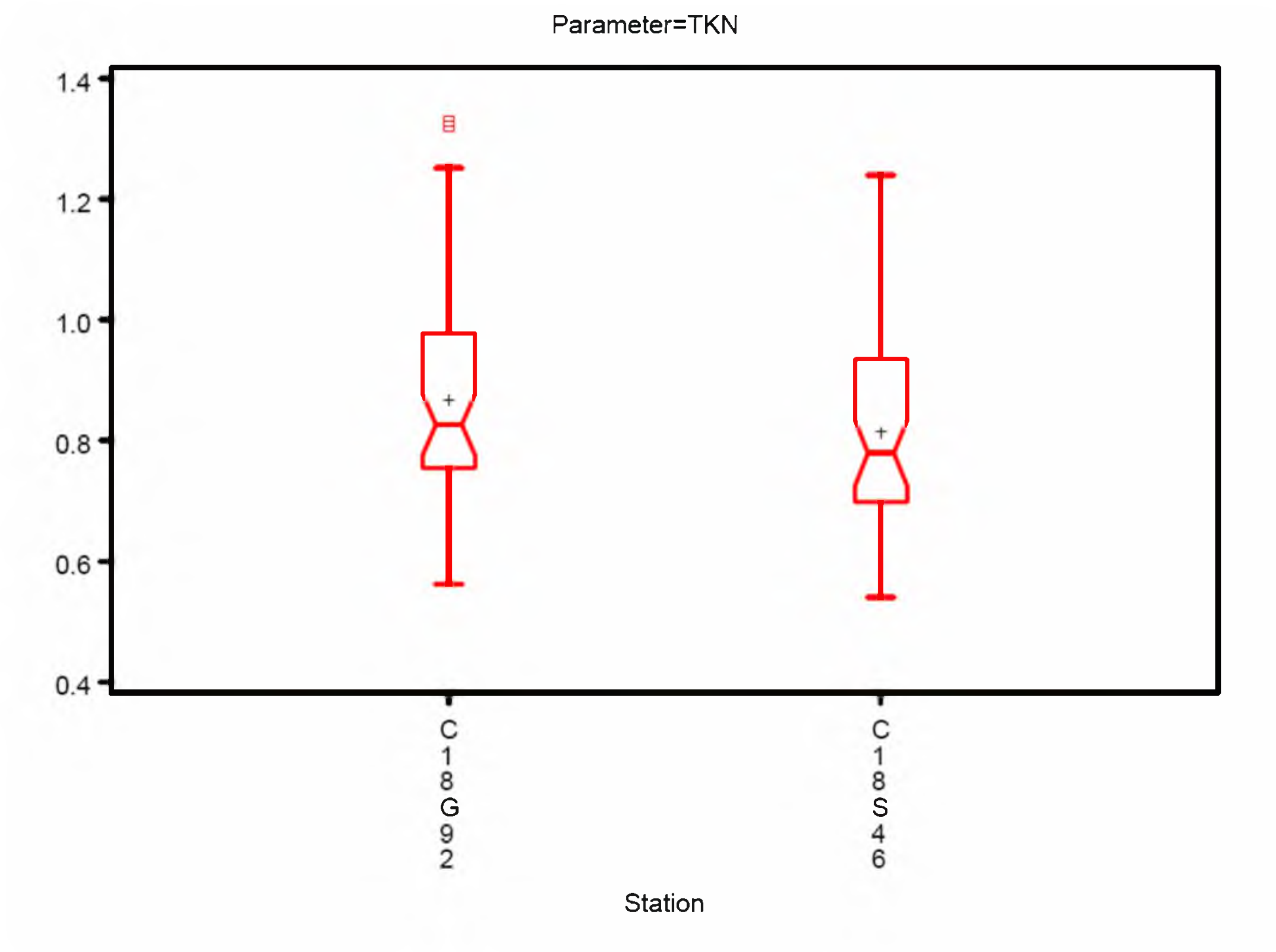
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
01/01/2000
01/01/2001
01/01/2002
01/01/2003
01/01/2004
01/01/2005
date
STATION_ID
C18G92
C18S46



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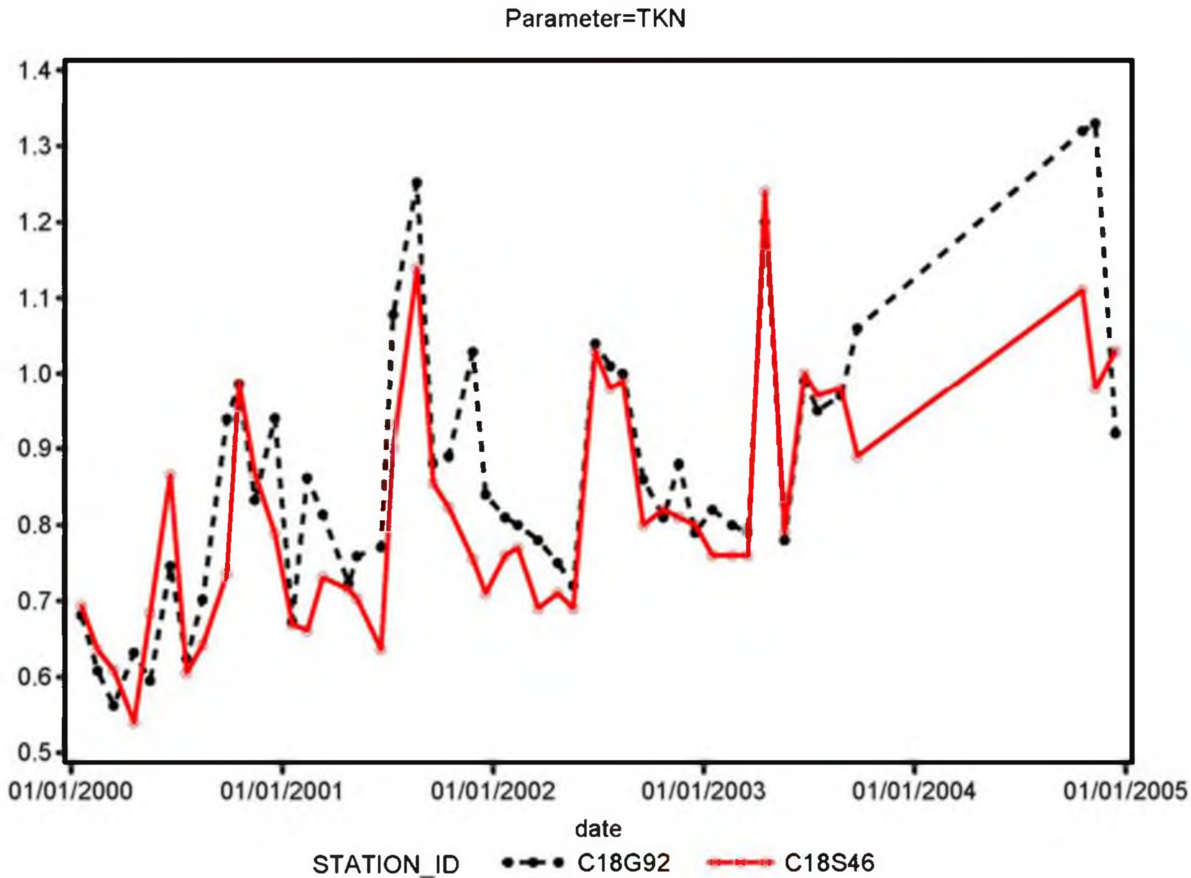
1.2
1.0
0.8
0.6
0.4
C18G92
C18S46
Station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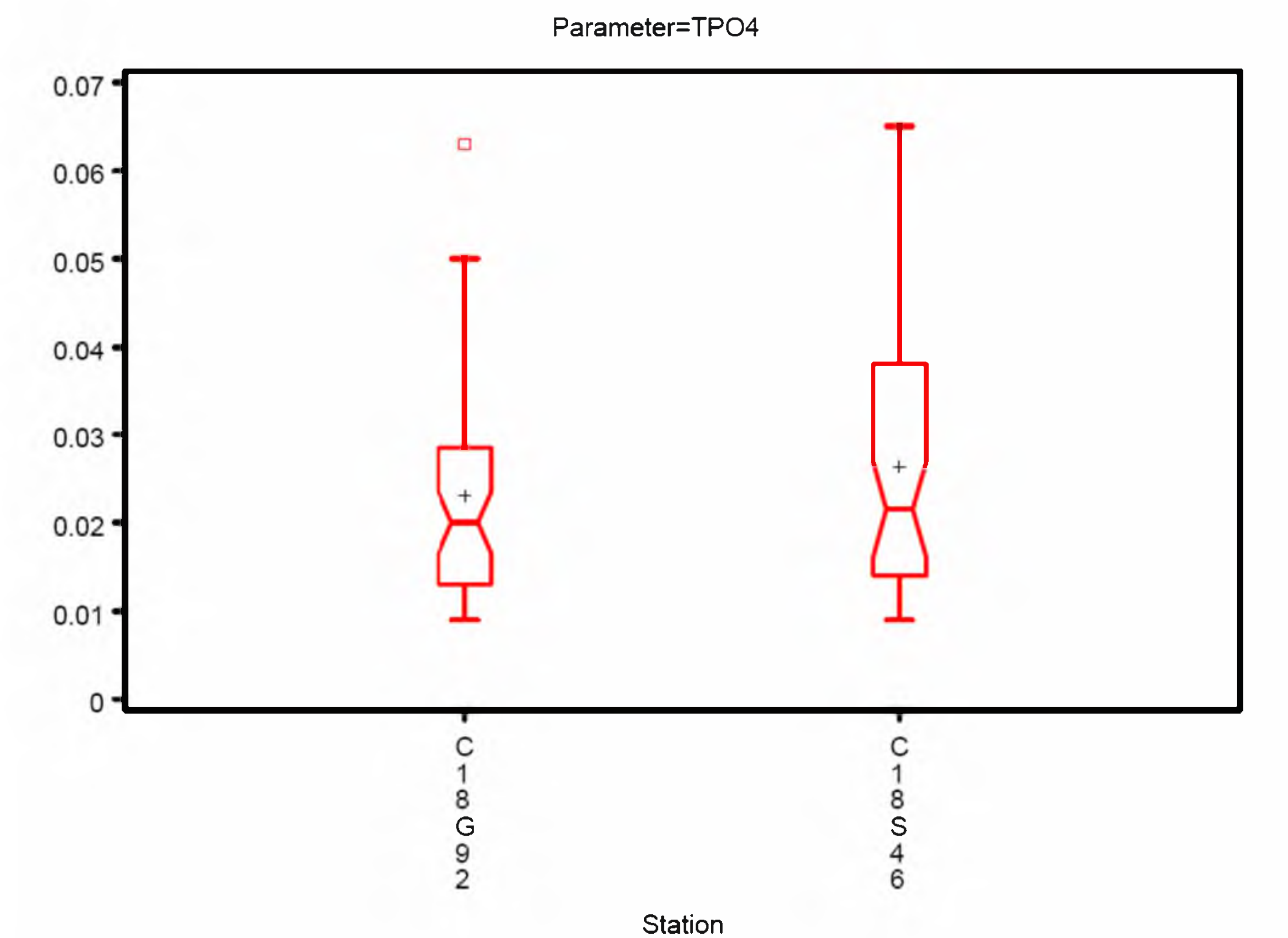
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
01/01/2000
01/01/2001
01/01/2002
01/01/2003
01/01/2004
01/01/2005
date
STATION_ID
C18G92
C18S46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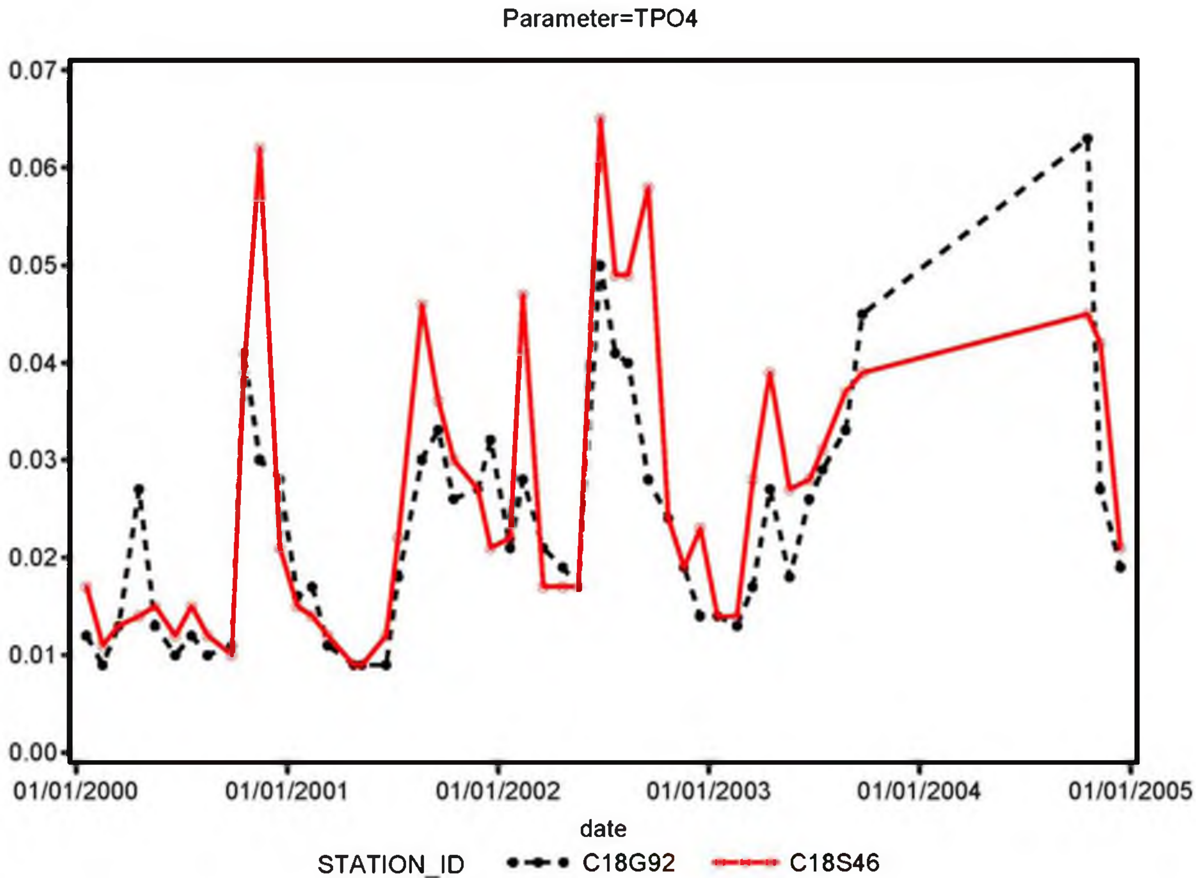
0.06
0.05
0.04
0.03
0.02
0.01
0
C18G92
C18S46
Station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0.06
0.05
0.04
0.03
0.02
0.01
0.00
01/01/2000
01/01/2001
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01/01/2004
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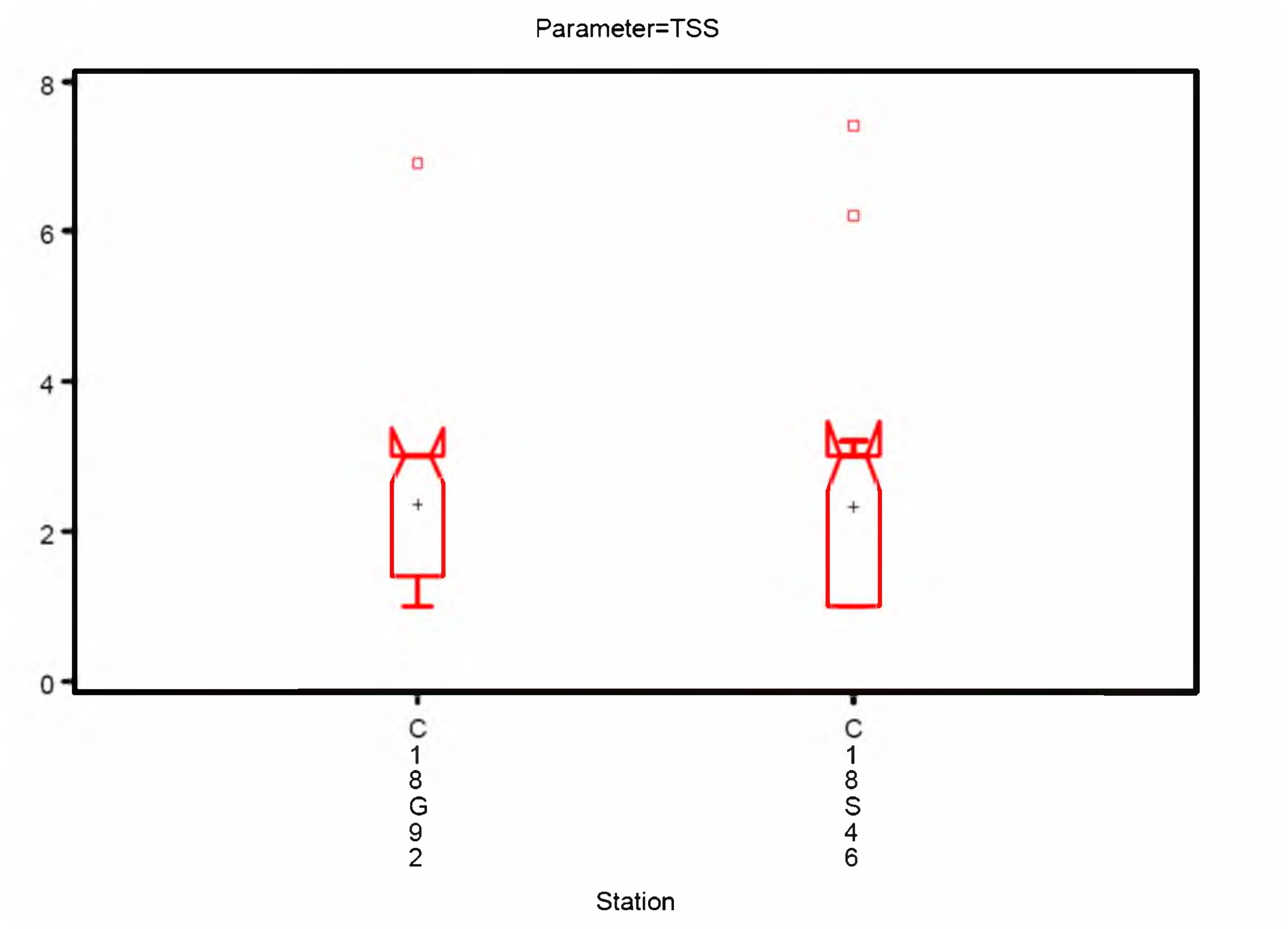
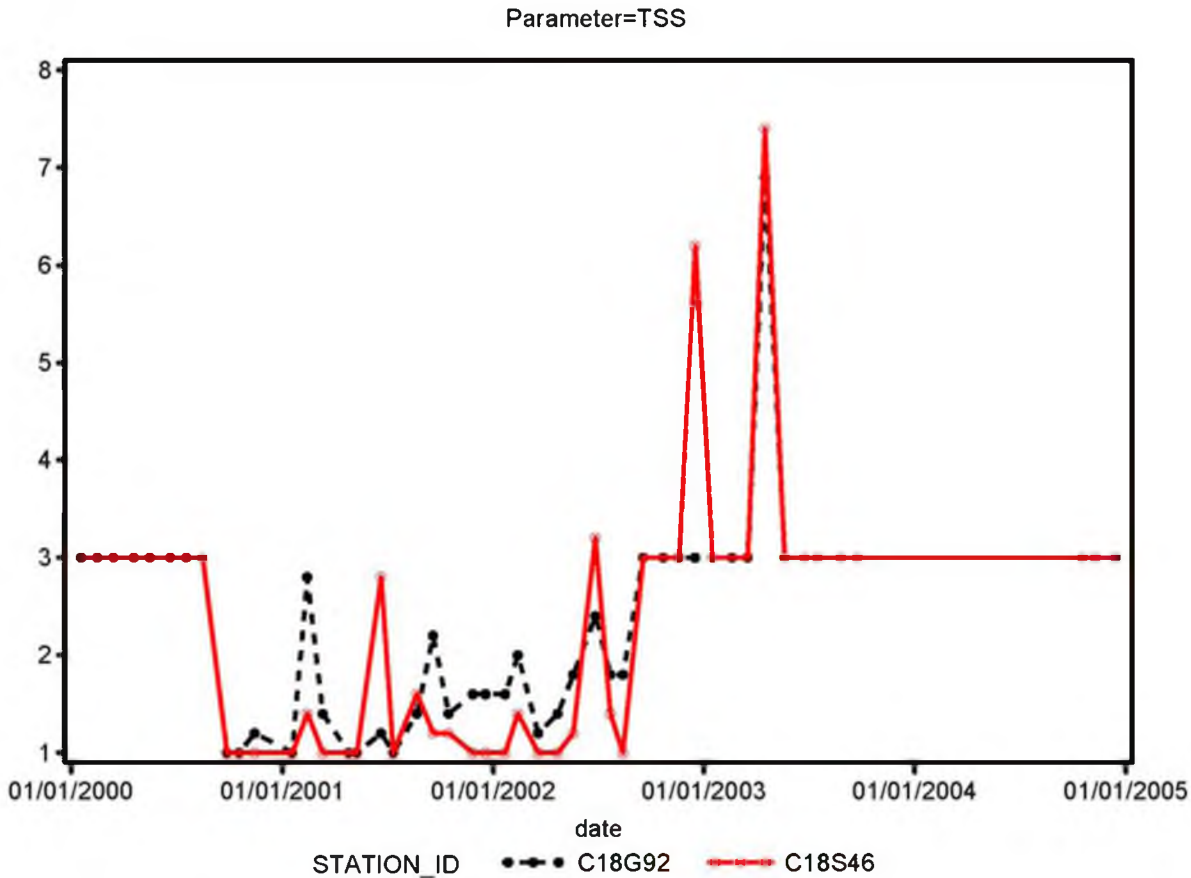
date
STATION_ID
C18G92
C18S46


Parameter=TSS
8
6
4
2
0
C18G92
C18S46
Station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8
7
6
5
4
3
2
1
01/01/2000
01/01/2001
01/01/2002
01/01/2003
01/01/2004
01/01/2005
date
STATION_ID
C18G92
C18S46