Conservation Area Inflows and Outflows

Optimization Leader: Skip Newton, Battelle
Statistician: Skip Newton, Battelle

Project Code: CAMB

Mandate/Permit:

- Non-Everglades Construction Project Permit
- 1991 Settlement Agreement
- Everglades Forever Act
- EAA Rule Ch40E-63
- Seminole Agreement
- Clean Water Act

Type: Type I and Type II

Project Start Date: December, 1977

Division Manager: Everglades Division: Jamie Serino

Program Manager: Garth Redfield

Points of Contact: Garth Redfield, Stuart Van Horn, Barb Powell, Cheol Mo, Nenan Iricanin, Linda Crean, Patrick Martin

Field Point of Contact: Patrick Martin

Spatial Description:
Project CAMB focuses on the inflows and outflows of the Water Conservation Areas (WCAs). The WCAs are located southeast of Lake Okeechobee in Palm Beach, Broward, and Miami-Dade counties. The WCAs are marsh areas that receive waters from a variety of land uses including agricultural, native and improved pastures, and urban and rural communities.

Thirty-seven stations are sampled for the CAMB project. Several of these stations are sampled under multiple mandates, and therefore may be considered Type I for one mandate and Type 2 for another mandate (Table 1).

Discussions with District staff familiar with CAMB suggested removal of several sites prior to the optimization. These sites include S12A, S12B, S12C, S12D, S333. These sites are being optimized for the Western Miami-Dade Optimization Project. They are outflows from the WCAs at the most southern boundary, but also serve as inflows into Everglades National Park.

Project Purpose, Goals and Objectives:
CAMB is essentially a selection of stations that have various mandates and have all been grouped together into one project based on their locations throughout the WCAs to address those mandates. The CAMB program was created to comply with water quality monitoring requirements of the Everglades National Park Memorandum of agreement between the National Park Service, District and Corps. The data collected under this program are used to determine the effectiveness of basin management plans to reduce nutrient loading to the WCAs and to establish nutrient budgets for the WCAs. The monitoring of nutrients and other water quality parameters are also used to quantify the effects of inflows on the ecology of marshes.

Sampling Frequency and Parameters Sampled:

For Project CAMB, sampling is conducted via autosampler at 11 stations and via grab sample at 38 stations. The parameters and frequency with which those parameters are sampled varies by station due to the stations containing multiple mandates. Please see the Tables below for a comprehensive list of parameters and frequency.

Current and Future Data Uses:
The data from Project CAMB are used in many District reports including the South Florida Environmental Report, the reports to the tribes (via the Seminole Agreement), the NPDS report to the State, the C-139 BMP Annual Compliance Report, the EAA BMP Annual Compliance Report, reports for the Everglades Forever Act and annual workshop. These data may also be useful for CERP projects some stations may be included as long-term monitoring stations for the RECOVER Monitoring and Assessment Plan, Greater Everglades module. These RECOVER MAP sites have yet to be selected.

Identified Optimization Opportunities:
Discussions with District staff identified some potential opportunities for optimization, particularly the removal of the APA parameter, change of sampling frequency for ions to semiannually, and change of sampling protocols for in situ measurements. Additionally, questions were generated that will provide useful for guiding the optimization.

- Can we look at optimizing by mandate?
- Do we need to optimize on the parameters that are not listed in the permit? Settlement Agreement parameters need to be optimized.
- Should the southernmost outflow stations (12A, 12B, 12C, 12D, S333) be eliminated from the analysis since they are being optimized under another effort?
- For internal canals and stations, can the stations on those canals be optimized using a gradient-type analysis? For example:
  - S7, S11A, S11B, S11C, G123
  - S6, S10A through S10D, S39
  - 11B, S145, S38
  - S8, C123R84, S151, S31
  - S9, S151, S112D
- How similar are the CAMB stations94D, ACEMEID to nearby VOW stations? Is there value added from the more frequently sampled sites?
- How closely to autosampler data compare with grab sample data at each site? Do the triggering conditions make a difference on the autosampler data?

Summary Updates:
The CAMB project optimization summary was finalized in June 2005. Fundamental changes affecting the statistical optimization process (e.g., elimination of station or analytes) resulting from ongoing interactions with District staff that took place after June 2005 are a part of the optimization process. The following list documents these changes.

Changes requested by Patrick Martin 02 June 2005.

1. Remove Larry Grosser from contact list
2. Remove S10E from list and tables. Site has been dismantled
3. Table 3
   a. G94D - Alkalinity is BWF/M
   b. S38B - Totfe is QRTLY
   c. L3BRS - TSS, K, MG, CA, NA, SI02, SO4, TOTFE not required. Remove from Table.
   d. S31 - Cl is BWF/M, SO4 is quarterly
   e. S39 - Totfe is QRTLY
   f. S12A - Totfe is QRTLY
   g. S12C - Totfe is QRTLY
   h. S12D - Totfe is QRTLY
   i. S333 - Totfe is QRTLY

Table 1. Mandates by Station for Stations monitored for CAMB

Station	Type	Mandate
ACME1DS	1	Everglades Forever Act
C123SR84	1	1991 Settlement Agreement
	1	Everglades Forever Act
G123	1	1991 Settlement Agreement
		Everglades Forever Act
G136	1	EAA Rule Ch40E-63
G94D	1	Everglades Forever Act
L28I	1	1991 Settlement Agreement
L3BRS	1	1991 Settlement Agreement
	2	Seminole Agreement
S10A	1	1991 Settlement Agreement
S10C	1	1991 Settlement Agreement
S10D	1	1991 Settlement Agreement
S11A	1	1991 Settlement Agreement
	1	Everglades Forever Act
S11B	1	1991 Settlement Agreement
S11C	1	1991 Settlement Agreement
S12A	1	1991 Settlement Agreement
S12B	1	1991 Settlement Agreement
S12C	1	1991 Settlement Agreement
S12D	1	1991 Settlement Agreement
	1	Everglades Forever Act
S140	1	1991 Settlement Agreement
	1	Everglades Forever Act
	2	Everglades Forever Act
S145	1	1991 Settlement Agreement
	1	Everglades Forever Act
S150	1	1991 Settlement Agreement
	1	EAA Rule Ch40E-63
S151	1	1991 Settlement Agreement
	1	Everglades Forever Act
S190	1	1991 Settlement Agreement
	1	Everglades Forever Act
	2	Everglades Forever Act
S31	1	1991 Settlement Agreement
	1	Everglades Forever Act
S333	1	1991 Settlement Agreement
	1	Everglades Forever Act
S34	1	1991 Settlement Agreement
	1	Everglades Forever Act
S38	1	1991 Settlement Agreement
	1	Everglades Forever Act
S38B	1	1991 Settlement Agreement
	1	Everglades Forever Act
S39	1	1991 Settlement Agreement
	1	Everglades Forever Act
S5A	1	1991 Settlement Agreement
	1	Clean Water Act
	1	Everglades Forever Act

	1	EAA Rule Ch40E-63
	2	Everglades Forever Act
S5AE	1	1991 Settlement Agreement
S5AS	1	1991 Settlement Agreement
S5AW	1	1991 Settlement Agreement
S6	1	1991 Settlement Agreement
	1	Clean Water Act
	1	Everglades Forever Act
	1	EAA Rule Ch40E-63
	2	Everglades Forever Act
S7	1	1991 Settlement Agreement
	1	EAA Rule Ch40E-63
S8	1	1991 Settlement Agreement
	1	EAA Rule Ch40E-63
S9	1	1991 Settlement Agreement
	1	Everglades Forever Act
USSO	2	Seminole Agreement

Table 2. Parameters Collected by Autosampler for Project CAMB

Station	NOX	TKN	TPO4
G-123	wf	wf	wf
G-136	wf	wf	wf
S-140	wf	wf	wf
S-150	wf	wf	wf
S-190	wf	wf	wf
S-5A	wf	wf	wf
S-6	wf	wf	wf
S-7	wf	wf	wf
S-8	wf	wf	wf
S-9	wf	wf	wf
USSO	wf	wf	wf

w = weekly when flowing

Table 3. Parameters collected from Grabs for Project CAMB

Station	APA[1]	CHLA	CHLA2	PHAEO	COLOR	TSS	TURBI	ALKA	CL	NH4	NO2	NOX	TKN	TPO4	OPO4	CA[2]	K[2]	MG[2]	NA[2]	SIO2	SO4	TOT CD	TOT CU	TOT FE	TOT ZN
ACME1DS					bwf/m	bwf/m	bwf/m	qrt	qrt	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	qrt	qrt	qrt	qrt	qrt	qrt	semi	semi	qrt	semi
G-123					bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	w	bwf/m	qrt	qrt	qrt	qrt	qrt	qrt	semi	semi	qrt	semi
G94D					bwf/m	bwf/m	bwf/m	bwf/m	qrt	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	qrt	qrt	qrt	qrt	qrt	qrt	semi	semi	qrt	semi
S-140					bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	w	bwf/m	qrt	qrt	qrt	qrt	qrt	qrt	semi	semi	qrt	semi
S190					bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	qrt	qrt	qrt	qrt	qrt	qrt	semi	semi	qrt	semi
S-34					bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m		qrt		qrt	qrt	qrt	semi	semi		semi
S-38B					bwf	bwf	bwf	bwf	bwf	bwf	bwf	bwf	bwf	bwf	bwf	qrt	qrt	qrt	qrt	qrt	qrt	semi	semi	qrt	semi
S5A	bwf/m	bwf/m			bwf/m	qrt	bwf/m	bw	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	w	qrt	qrt	qrt	qrt	qrt	bw	semi	semi	qrt	semi
S8					bwf/m	qrt	bwf/m	bwf/m	bwf/m	wf	bwf/m	wf	wf	wf	bwf/m	qrt	qrt	qrt	qrt	qrt	qrt	semi	semi	qrt	semi
S-9					bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	w	bwf/m	qrt	qrt	qrt	qrt	qrt	qrt	semi	semi	qrt	semi
G136					bwf/m	qrt	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	w	bwf/m	qrt	qrt	qrt	qrt	qrt	qrt			qrt	
L28I					bwf/m	qrt	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	qrt	qrt	qrt	qrt	qrt	qrt			qrt	
L3BRS					bwf/m		bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m										
S10A					bwf/m	qrt	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	qrt	qrt	qrt	qrt	qrt	qrt			qrt	
S10C					bwf/m	qrt	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	qrt	qrt	qrt	qrt	qrt	qrt			qrt	
S10D					bwf/m	qrt	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	qrt	qrt	qrt	qrt	qrt	qrt			qrt	
S-11A					bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m		qrt		qrt	qrt	qrt				
S-11B					bwf	qrt	bwf	bwf	bwf	bwf	bwf	bwf	bwf	bwf	bwf	qrt	qrt	qrt	qrt	qrt	qrt			qrt	
S-11C					bwf/m	qrt	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	qrt	qrt	qrt	qrt	qrt	qrt			qrt	
S-145					bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m		qrt		qrt	qrt	qrt				
S-150					bwf/m	qrt	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	w	bwf/m	qrt	qrt	qrt	qrt	qrt	qrt			qrt	
S-151					bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m		qrt		qrt	qrt	qrt				
S31					bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m		qrt		qrt	qrt	qrt				
S-38					bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m		qrt		qrt	qrt	qrt				
S39					bwf/m	qrt	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m		qrt		qrt	qrt	qrt			qrt	
S5AE					bwf/m	qrt	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	qrt	qrt	qrt	qrt	qrt	qrt			qrt	
S5AS					bwf/m	qrt	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	qrt	qrt	qrt	qrt	qrt	qrt			qrt	
S5AW					bwf/m	qrt	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	qrt	qrt	qrt	qrt	qrt	qrt			qrt	
S6					bwf/m	qrt	bwf/m	bwf/m	bwf/m	wf	bwf/m	wf	wf	w	bwf/m	qrt	qrt	qrt	qrt	qrt	bwf/m			qrt	
S-7					bwf/m	qrt	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	w	bwf/m	qrt	qrt	qrt	qrt	qrt	qrt			qrt	
USSO					bwf/m	qrt	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	w	bwf/m	qrt	qrt	qrt	qrt	qrt	qrt			qrt	
C123SR84					bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m		qrt		qrt	qrt	qrt				
S12A	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	qrt	qrt			Qrt	
S12B	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	qrt	qrt			bwf/m	
S12C	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	qrt	qrt			Qrt	
S12D	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	qrt	qrt			Qrt	
S333	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	qrt	qrt			Qrt	
S10E*																									

* Taken out of service as of 2/2005; w = weekly; wf = weekly when flowing; bw = bi-weekly; m = monthly; bm = bimonthly, bwf = bi-weekly when flowing; bwf/m = bi-weekly if flowing else monthly; qtr = quarterly; semi = semianuually; req = storm event or upon request; unk = unknown

[1] APA has been proposed for removal because the data do not appeared to be used

[2] these parameters have been proposed for semiannual collection as opposed to quarterly and/or biweekly when flowing else monthly

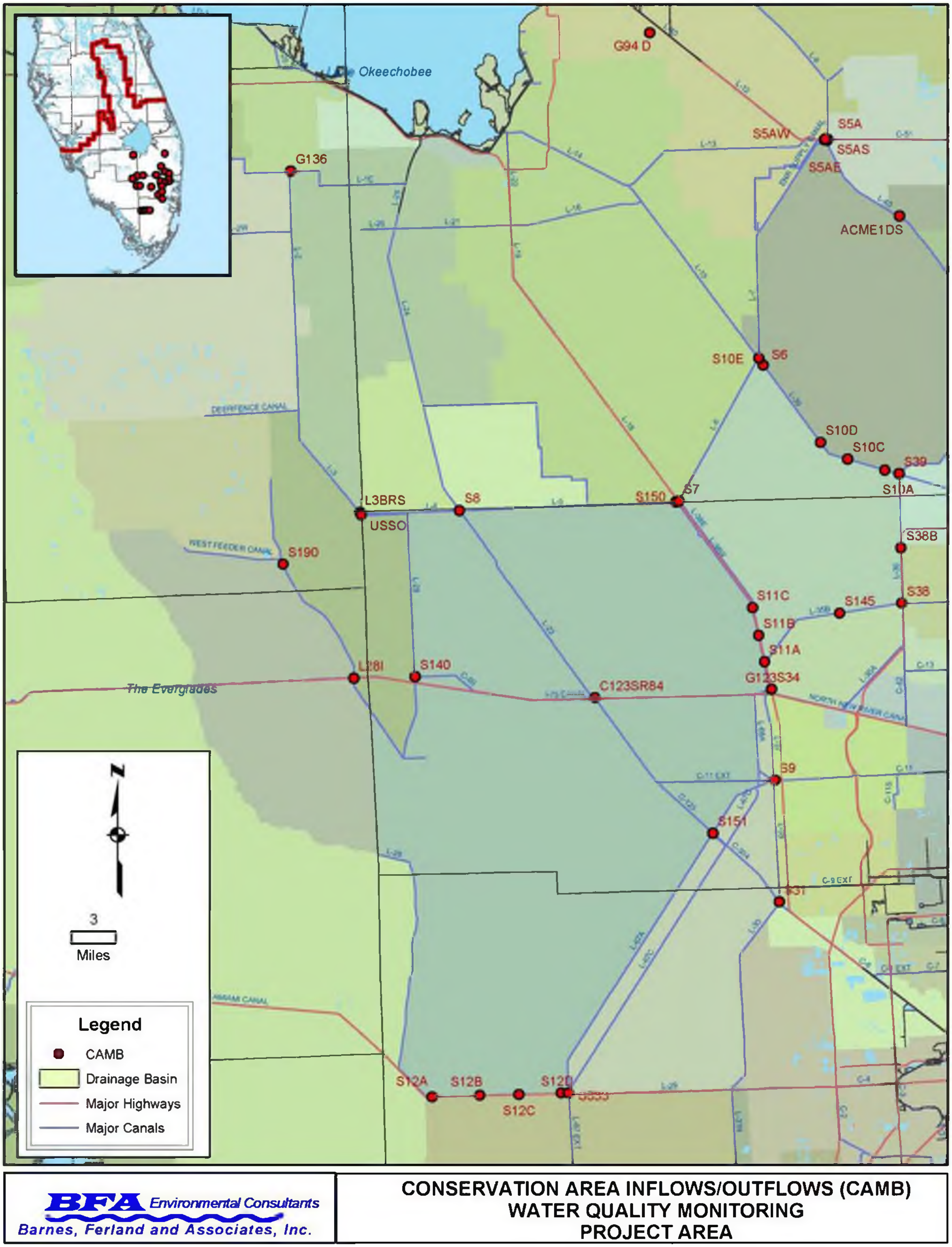


Figure 1. CAMB Sampling Locations

Optimization Analysis:
Optimization of the CAMB water quality monitoring project was undertaken with respect to the tasks outlined above, detailed in the optimization plan modified and approved in September 2005. The spatial and temporal adequacy of the CAMB project was evaluated with respect to detecting changes between time periods (annual), differentiating water quality parameters by station within the project that share a common structure (canal), and comparing grab sampling and autosampler measurements. Data collected under this program are focused upon the effectiveness of basin management plans to reduce nutrient loading to the WCAs and to establish nutrient budgets for the WCAs. The optimization parameters were primarily selected to support nutrient studies and, secondarily, for consistency of the long term database. The five optimization parameters chosen are listed with in Table 4.

Table 4. Optimization parameters, alias names and DBHYDRO codes.

Optimization Parameter	Abbreviation	Test Name	Test Number
Chloride	CL	CHLORIDE	32
Total Kjeldahl Nitrogen	TKN	KJELDAHL NITROGEN, TOTAL	21
NOX	NOX	NITRATE+NITRITE-N	18
Total Phosphate	TPO4 (occasionally TP)	PHOSPHATE, TOTAL AS P	25
Turbidity	TUR	TURBIDITY	12

Six stations possessing type 2 mandates were considered for optimization. All stations were sampled with grabs and autosamplers; however, the actual number of samples collected varies greatly. As stated in the general summary, data collected under this program are used to determine the effectiveness of basin management plans to reduce nutrient loading and to establish nutrient loads. However, incorporating flow data into the optimization was beyond the scope of this study, thus optimizations could not be conducted on flow weighted concentrations. Three optimization categories are addressed:

- Temporal adequacy is evaluated to estimate the annual percentage change (detectable_APC) detectable with 80% power and p= 0.05 for current and alternative monitoring designs. Detectable_APC results are produced by a simple hypothesis testing procedure performed on slope estimate associated with the seasonal Kendal Tau procedure, also referred to as the Mann-Kendall procedure. Details of the statistical process and the SAS program used in the evaluation are presented in Rust 2005. (Rust, SW. 2005. Power Analysis Procedure for Trend Detection with Accompanying SAS Software. Battelle Report to South Florida Water Management District, November 2005).

- Similarities between stations identified for potential optimization are examined using monthly box-whisker plots, simple linear regressions (graphical and fit information), and Spearmans Rank correlation.

- Similarities between sampling techniques are examined using simple linear regressions (graphical and fit information) and Spearmans Rank correlation.

Temporal Adequacy:
The CAMB project is primarily directed towards monitoring the quality of water (nutrients) as inflows and outflows of the WCAs. Both grab and automated sampling (autosamplers) schemes are used to collect water samples. Two types of autosamplers have been used, composite time proportional (ACT) and composite flow proportional (ACF). For temporal optimizations, autosamplers were considered generic and processed as a single sampler type.

Statistical power analyses were used to determine the smallest water quality trends that will be detectable with high probability based on water quality data collected according to current monitoring plans. Power analyses were performed by carrying out the following steps for each station and sampler combination.

- Fit a statistical model to the water quality parameter data in order to have a basis for generating simulated data to support a Monte Carlo based power analysis procedure

- Generate multiple replicate simulated water quality time series data sets; for all power analyses reported here, each time series generated was for a 5-year monitoring period

- Perform a Mann-Kendall trend analysis procedure (Reckhow et al. 1993) for each simulated time series data set; in particular, obtain a point estimate of the slope vs. time for the log-transformed water quality parameter values

- Estimate the annual percent change (APC) in water quality parameter values that is detectable with 80% power using a simple two-sided test based on the Mann-Kendall slope estimate performed at a 5% significance level

Parameter values were natural log-transformed for statistical modeling because the log-transformed data was more nearly normally distributed than were the untransformed data. The fitted statistical model contains the following components:

- Fixed seasonal effects that repeat themselves in an annual cycle

- A long-term linear trend in the log-transformed parameter concentrations; this corresponds to a fixed percentage increase or decrease in the water quality parameter each year

- A random error term representing temporal variability in true water quality parameter values; these error terms are allowed to be correlated from one time point to the next in order to capture any serial autocorrelation that is present in the monitoring data

- A random error term representing sampling and chemical analysis variability; these error terms are assumed to be stochastically independent from one time point to the next

The fitted statistical model is used to perform a Monte Carlo simulation analysis in which multiple time series data sets are simulated and used to determine the anticipated statistical properties of trend detection procedures that will be used by the District. All statistical trend analyses performed on the simulated data were based on the Mann-Kendall trend analysis procedure (Reckhow et al. 1993) preferred by the District.

In the course of performing the power analyses for the District, it was determined that the basic Mann-Kendall trend detection procedures do not necessarily control the true significance level of the hypothesis test for trend when there is serial autocorrelation exhibited in the data. This was found to be true even for procedures that attempt to correct for serial autocorrelation. For this reason, all power analysis results reported here are for a simple hypothesis test procedure based on the median slope estimator that accompanies the Mann-Kendall test procedure. The median slope estimator is assumed to follow a normal distribution and power results are obtained by performing a simple z-test with this estimator.

Temporal optimization assessed the power to detect temporal trends for the five optimization analytes. Data, based on availability for each station and type of sampler, were used to estimate the seasonal variability and autocorrelation for each station. Figures 2 and 3 provide examples of the distribution of TPO4 by season and month across all years, respectively. The simulation model used to generate detectable_APC results was modified to account for unpredictable sampling frequencies associated with stations where sample collection was dependent on water flow (Tables 5 and 6). The modified simulation permits the specification of a proportion of missing data (pmiss) and a data simulation macro sets each observation to missing with probability equal to pmiss. The missing values represent the "non-flowing" cases.

Table 5. By station CAMB sampling conditions and simulations processed for Chloride, TKN and NOX using the unmodified or modified trend simulation procedure.

Station	Optimization Parameter	Sampler Type	Sampled when Flowing	Number of Samples Reported	Modified Simulation Run (Yes/No) and Freq
L3BRS	Chloride	G	Yes	260	Yes - Bi-weekly
S140	Chloride	G	Yes	231	Yes - Bi-weekly
S190	Chloride	G	Yes	210	Yes - Bi-weekly
S5A	Chloride	ACF	Yes	4	Not Processed
S5A	Chloride	G	Yes	265	Yes - Bi-weekly
S6	Chloride	ACF	Yes	1	Not Processed
S6	Chloride	G	Yes	254	Yes - Bi-weekly
USSO	Chloride	ACF	Yes	1	Not Processed
USSO	Chloride	G	Yes	187	Yes - Bi-weekly
L3BRS	TKN	ACF	Yes	1	Not Processed
L3BRS	TKN	G	Yes	258	Yes - Bi-weekly
S140	TKN	ACT	Yes	3	Not Processed
S140	TKN	G	Yes	229	Yes - Bi-weekly
S190	TKN	ACT	Yes	1	Not Processed
S190	TKN	G	Yes	211	Yes - Bi-weekly
S5A	TKN	ACF	Yes	373	Yes - Bi-weekly
S5A	TKN	G	Yes	352	Yes - Bi-weekly
S6	TKN	ACF	Yes	334	Yes - Weekly
S6	TKN	G	Yes	350	Yes - Weekly
USSO	TKN	ACF	Yes	311	Yes - Bi-weekly
USSO	TKN	G	Yes	195	Yes - Bi-weekly
L3BRS	NOX	G	Yes	257	Yes - Bi-weekly
S140	NOX	ACT	Yes	1	Not Processed
S140	NOX	G	Yes	225	Yes - Bi-weekly
S190	NOX	ACT	Yes	1	Not Processed
S190	NOX	G	Yes	206	Yes - Bi-weekly
S5A	NOX	ACF	Yes	359	Yes - Bi-weekly
S5A	NOX	G	Yes	348	Yes - Bi-weekly
S6	NOX	ACF	Yes	328	Yes - Weekly
S6	NOX	G	Yes	342	Yes - Weekly
USSO	NOX	ACF	Yes	305	Yes - Bi-weekly
USSO	NOX	G	Yes	191	Yes - Bi-weekly

Table 6. By station CAMB sampling conditions and simulations processed for TPO4 and Turbidity using the unmodified or modified trend simulation procedure.

Station	Optimization Parameter	Sampler Type	Sampled Only When Flowing	Number of Samples Reported	Modified Simulation Run (Yes/No) and Freq
L3BRS	TPO4	ACF	Yes	1	Not Processed
L3BRS	TPO4	G	Yes	266	Yes - Bi-weekly
S140	TPO4	ACF	Yes	61	Yes - Bi-weekly
S140	TPO4	ACT	Yes	120	Yes - Bi-weekly
S140	TPO4	G	Yes	294	Yes - Bi-weekly
S190	TPO4	ACF	Yes	75	Yes - Bi-weekly
S190	TPO4	ACT	Yes	96	Yes - Bi-weekly
S190	TPO4	G	Yes	220	Yes - Bi-weekly
S5A	TPO4	ACF	Yes	360	Yes - Weekly
S5A	TPO4	G	Yes	547	Yes - Weekly
S6	TPO4	ACF	Yes	328	Yes - Weekly
S6	TPO4	G	Yes	621	No - Weekly
USSO	TPO4	ACF	Yes	382	Yes - Weekly
USSO	TPO4	G	Yes	268	No - Weekly
L3BRS	Turbidity	G	Yes	260	Yes - Bi-weekly
S140	Turbidity	G	No	230	Yes - Bi-weekly
S190	Turbidity	G	Yes	211	Yes - Bi-weekly
S5A	Turbidity	G	Yes	265	Yes - Bi-weekly
S6	Turbidity	G	No	253	Yes - Bi-weekly
USSO	Turbidity	ACF	Yes	1	Not Processed
USSO	Turbidity	G	No	187	Yes - Bi-weekly

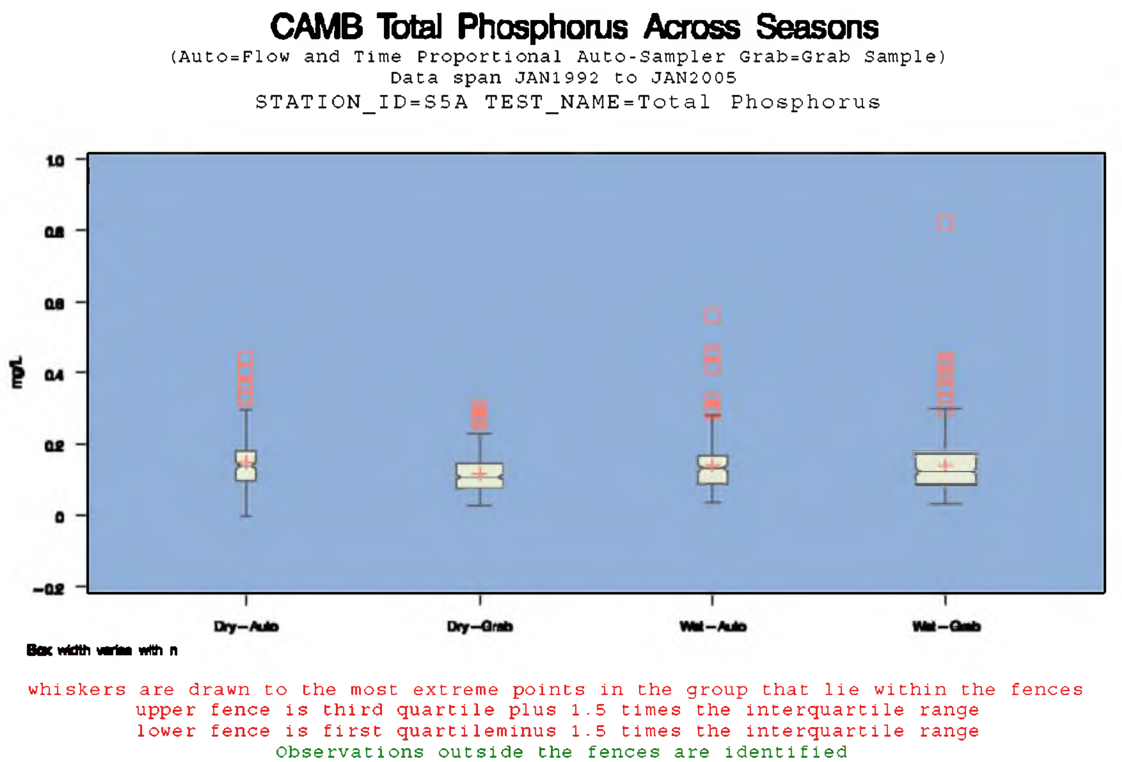


Figure 2. Station S5A TPO4 concentrations reported from autosamplers and grabs across wet and dry seasons.

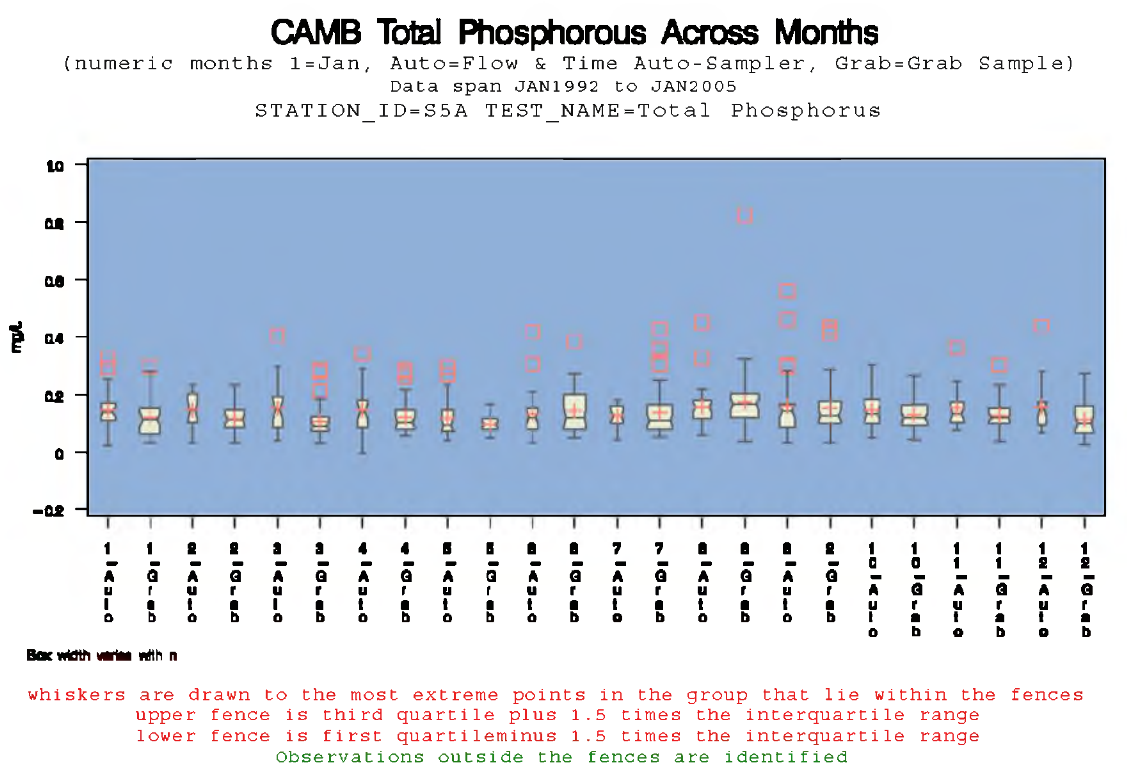


Figure 3. Station S5A TPO4 concentrations reported from autosamplers and grabs across months.

Simulations were run on a station by station basis, with the base condition set to represent the requisite/ideal number of annual sampling periods (e.g., weekly = 52, bi-weekly = 26, monthly = 12). Separate simulation runs were conducted for grab and automated samplers when sufficient data was available. Initial simulation results were visually examined for outliers and, when found, were removed from subsequent analyses. Additionally, for one station (S140 - grab) where the sampling frequency was defined as weekly, the bulk of the reported data was actually collected less frequently. The modified simulation model accounting for missing observations was employed when the number of samples collected was far below the number expected (e.g., S140 – grab).

Figures 4 through 11 graphically present the annual percentage change in optimization analytes detectable with 80% power (p=0.05), for grab samples and autosamples. Representative simulation runs typical of the output for each station and sampler type are presented in Figures 12 and 13 (grab and autosampler, respectively). Most stations were processed using a sampling base interval of bi-weekly (26 samples per year, Tables 5 and 6). Alternative monitoring designs were simulated with sampling frequencies of weekly (52 samples per year), bi-weekly (26 samples per year) and monthly (12 samples per year). Temporal optimization results and recommendations by analyte are presented below. Note that optimization recommendations are based on single analytical parameters only and, as such, no statements are made considering the efficiency of changing sampling frequencies of selected parameters at a given station. Such decisions are under the purview of the District, which must take into consideration all parameters measured, not just the five selected for this analysis.

Chloride:

Temporal Optimization

Table 7 presents specifics for each sampling method. The current sampling frequency was adequate to detect a 20% change in slope over 5 years for chloride (Figure 4) for all grab sampling stations in the CAMB project. When simulations were run reducing the sampling frequency from bi-weekly to monthly, detectable_APCs rose slightly, all stations remained below 20 percent, with the exception of S140. Increasing sampling frequency to weekly provided minimal improvements in the ability to detect annual percentage change.

Temporal Recommendations

Monitoring nutrient loads into WCAs is an important component of monitoring the health of this important ecosystem. Examination of Figures 4 and 5 suggest that all examined grab stations, except S140 can be optimized by reducing sampling frequency from bi-weekly to monthly-weekly, without an unacceptable loss in information.

Table 7. Effect of chloride sampling frequency on detectable_APC for grab samples.

Analyte	Station	Number of Samples Per Year**	Annual Detectable Percentage Change	Can a 20 % Change be Detected?
Chloride	L3BRS	52	10	Yes
		26	11	Yes
		12	13	Yes
	S140	52	17	Yes
		26	18	Yes
		12	20	No
	S190	52	9	Yes
		26	10	Yes
		12	13	Yes
	S5A	52	13	Yes
		26	14	Yes
		12	19	Yes
	S6	52	9	Yes
		26	11	Yes
		12	13	Yes
	USSO	52	4	Yes
		26	5	Yes
		12	6	Yes

Mandated base sampling frequency in **bold

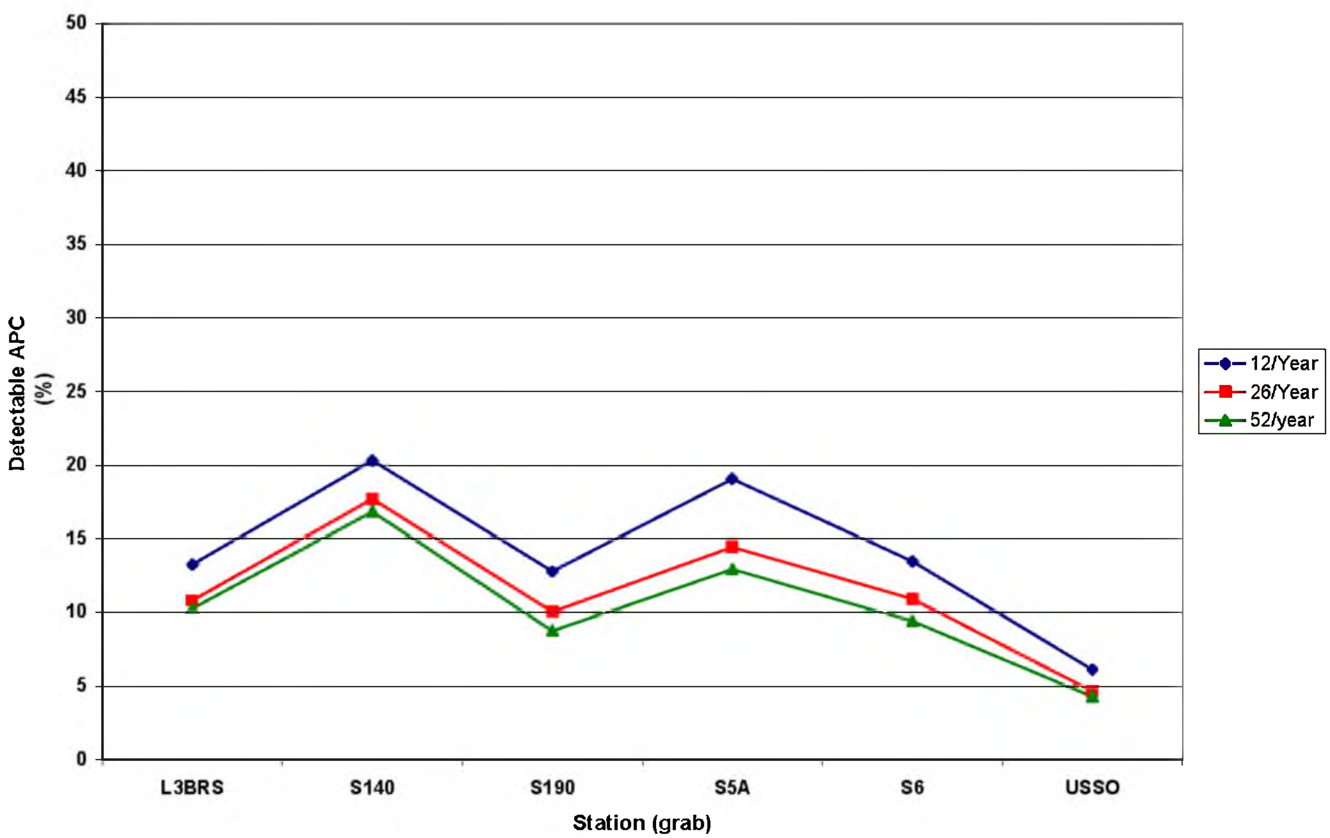


Figure 4. Comparison of annual percentage change (detectable_APC) in chloride with 80% power (p=0.05) from grab samples at CAMB monitoring stations.

NOX:

Temporal Optimization

Tables 8 and 9 present the specifics for each sampling method. Current grab sampling frequencies cannot detect a 20% change in slope over 5 years for NOX (Figure 5) at any station, with the exception of S6. S6 is the only station monitored for NOX on a weekly basis and, when simulated under a bi-weekly sampling regime, a 20% change in slope cannot be detected. When sampling frequencies are doubled for bi-weekly sampled grab stations, all detectable_APC remain greater than 20%.

Three autosampling stations (S5A, S6, USSO) had sufficient information to support temporal optimization (Table 5). Figure 6 shows that the current sampling frequency is capable of detecting a 20% change for only station USSO. Reducing the frequency from weekly to bi-weekly raises the detectable_APC to 17%. The covariance pattern model resulted in non-convergence in the 12-month simulation for station S6 (autosampler) and a detectable_APC could not be calculated.

Temporal Recommendations

Only station USSO sampled with an autosampler retains a detectable_APC below 20 percent when sampled on a reduced frequency (bi-weekly), and is a possible candidate optimization.

Table 8. Effect of NOX sampling frequency on detectable_APC for grab samples.

Analyte	Station	Number of Samples Per Year**	Annual Detectable Percentage Change	Can a 20 % Change be Detected?
NOX	L3BRS	52	41	No
		26	49	No
		12	62	No
	S140	52	27	No
		26	33	No
		12	41	No
	S190	52	36	No
		26	40	No
		12	56	No
	S5A	52	21	No
		26	27	No
		12	35	No
	S6	**52**	14	Yes
		26	20	No
		12	32	No
	USSO	52	23	No
		26	26	No
		12	37	No

Mandated base sampling frequency in **bold

Table 9. Effect of NOX sampling frequency on detectable_APC for autosamplers.

Analyte	Station	Number of Samples Per Year**	Annual Detectable Percentage Change	Can a 20 % Change be Detected?
NOX	S5A	**52**	61	No
		26	72	No
		12	107	No
	S6	**52**	20	No
		26	30	No
		12		Cannot Determine
	USSO	**52**	12	Yes
		26	17	Yes
		12	26	No

Mandated base sampling frequency in **bold

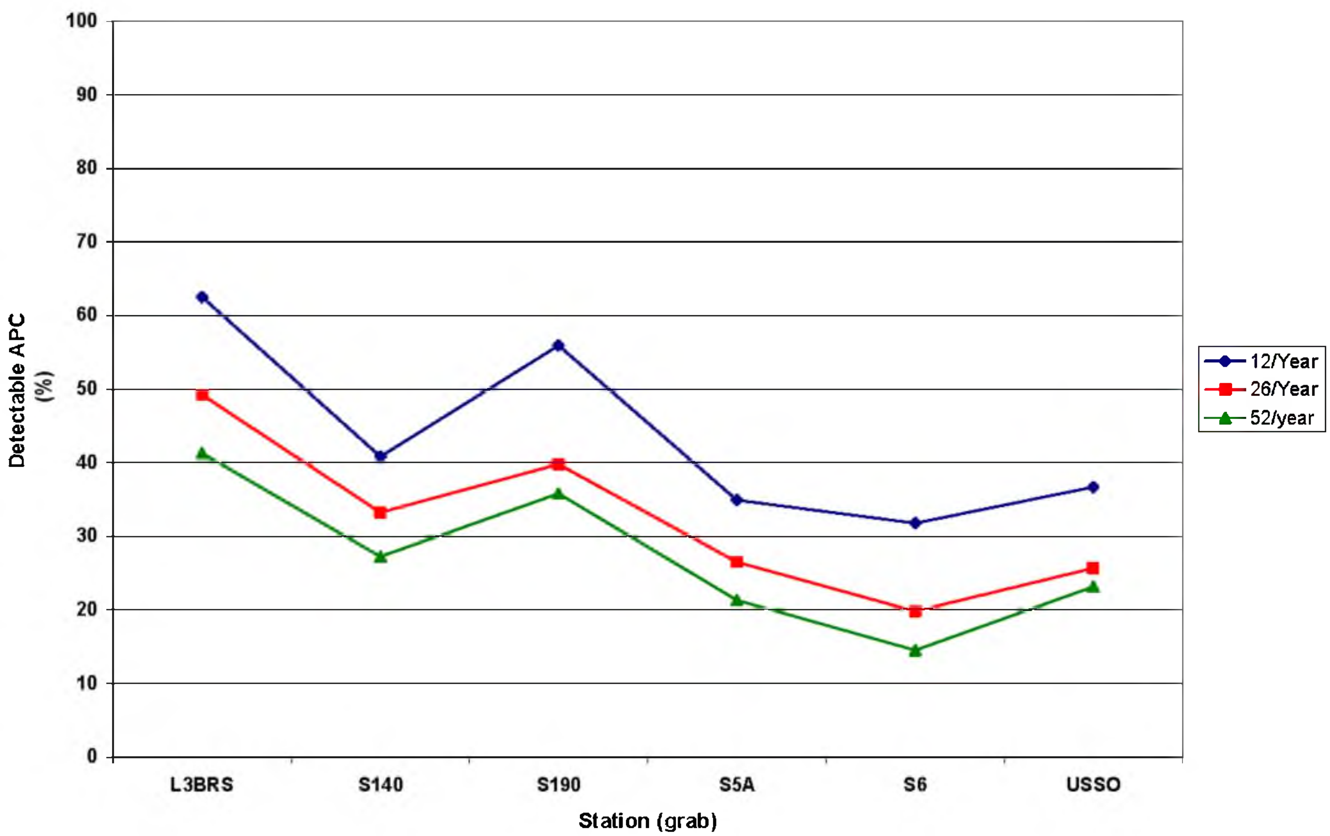


Figure 5. Comparison of annual percentage change (detectable_APC) in NOX with 80% power (p=0.05) from grab samples at CAMB monitoring stations.

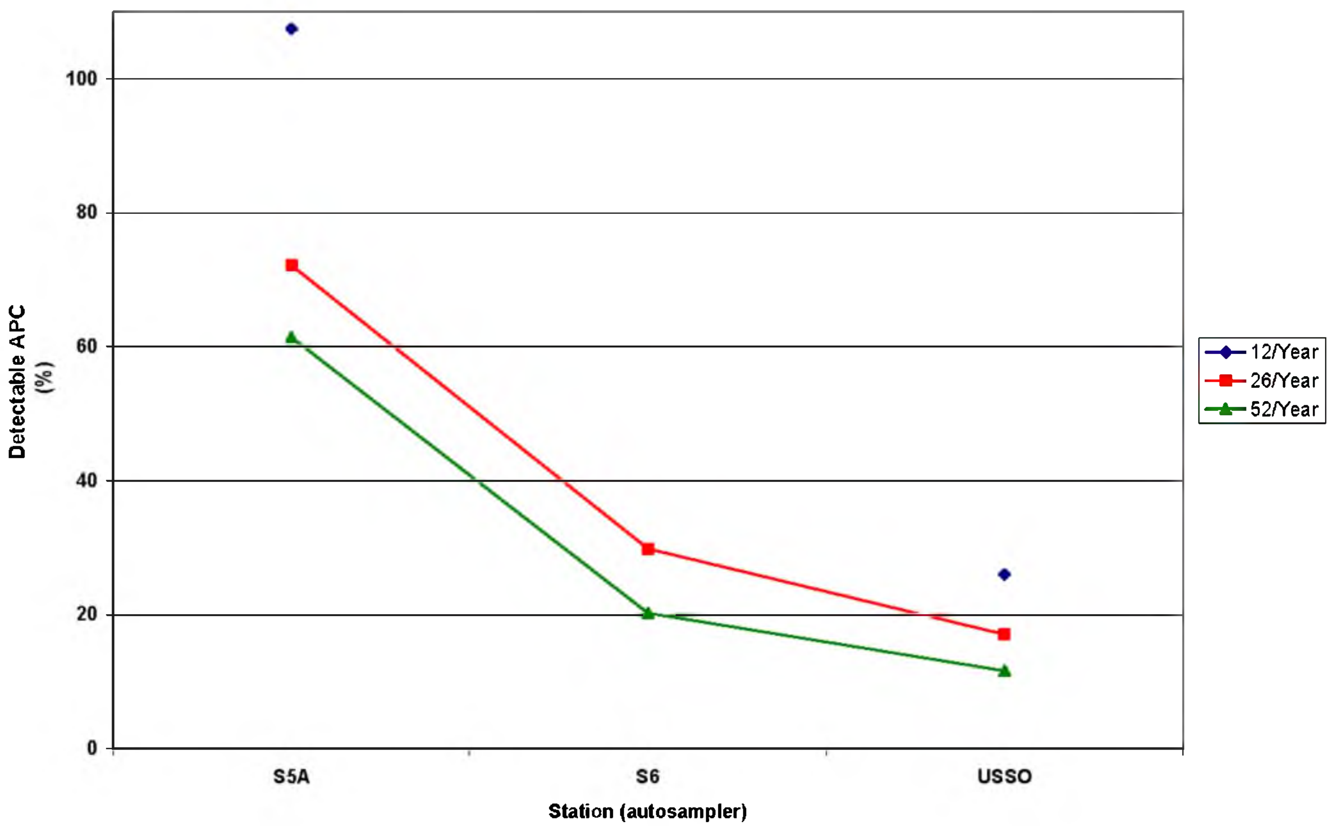


Figure 6. Comparison of annual percentage change (detectable_APC) in NOX with 80% power (p=0.05) from autosamplers at CAMB monitoring stations.

TKN:

Temporal Optimization

Tables 10 and 11 present the specifics for each sampling method. Current grab sampling frequencies are sufficient to detect a 20% change in slope over 5 years for TKN at all stations for grab and autosamplers (Figures 5 and 6). Alternative monitoring design simulations suggest that all bi-weekly frequencies can be reduced to monthly for grab samples. S6 currently sampled on a weekly basis appears to be capable of providing detectable_APCs, even when sampled on a monthly basis using grabs.

Three autosampling stations (S5A, S6, USSO) had sufficient information to support temporal optimization (Table 11). Figure 11 shows that the current sampling frequency is capable of detecting a 20% change for all stations when sampled on a monthly basis, with the exception of S5A.

Temporal Recommendations

Based upon simulations, all stations sampled on a bi-weekly basis can detect at least a 20% annual percentage in TKN and, thus, are optimization candidates. Optimization of Station S6 (currently sampled weekly for grabs) is not recommended to be reduced beyond bi-weekly, even though the monthly detectable_APC was calculated to be 19%. Of stations that are currently sampled on a weekly basis using autosamplers, all can be optimized to monthly, except for S5A which should not be optimized below bi-weekly sampling.

Table 10. Effect of TKN sampling frequency on detectable_APC for grab samples.

Analyte	Station	Number of Samples Per Year**	Annual Detectable Percentage Change	Can a 20 % Change be Detected?
TKN	L3BRS	52	5	Yes
		26	5	Yes
		12	7	Yes
	S140	52	6	Yes
		26	7	Yes
		12	9	Yes
	S190	52	7	Yes
		26	8	Yes
		12	10	Yes
	S5A	52	10	Yes
		26	12	Yes
		12	15	Yes
	S6	**52**	9	Yes
		26	12	Yes
		12	19	Yes
	USSO	52	6	Yes
		26	6	Yes
		12	8	Yes

Mandated base sampling frequency in **bold

Table 11. Effect of TKN sampling frequency on detectable_APC for autosamplers.

Analyte	Station	Number of Samples Per Year**	Annual Detectable Percentage Change	Can a 20 % Change be Detected?
TKN	S5A	**52**	11	Yes
		26	14	Yes
		12	21	No
	S6	**52**	8	Yes
		26	10	Yes
		12	15	Yes
	USSO	**52**	5	Yes
		26	7	Yes
		12	11	Yes

Mandated base sampling frequency in **bold

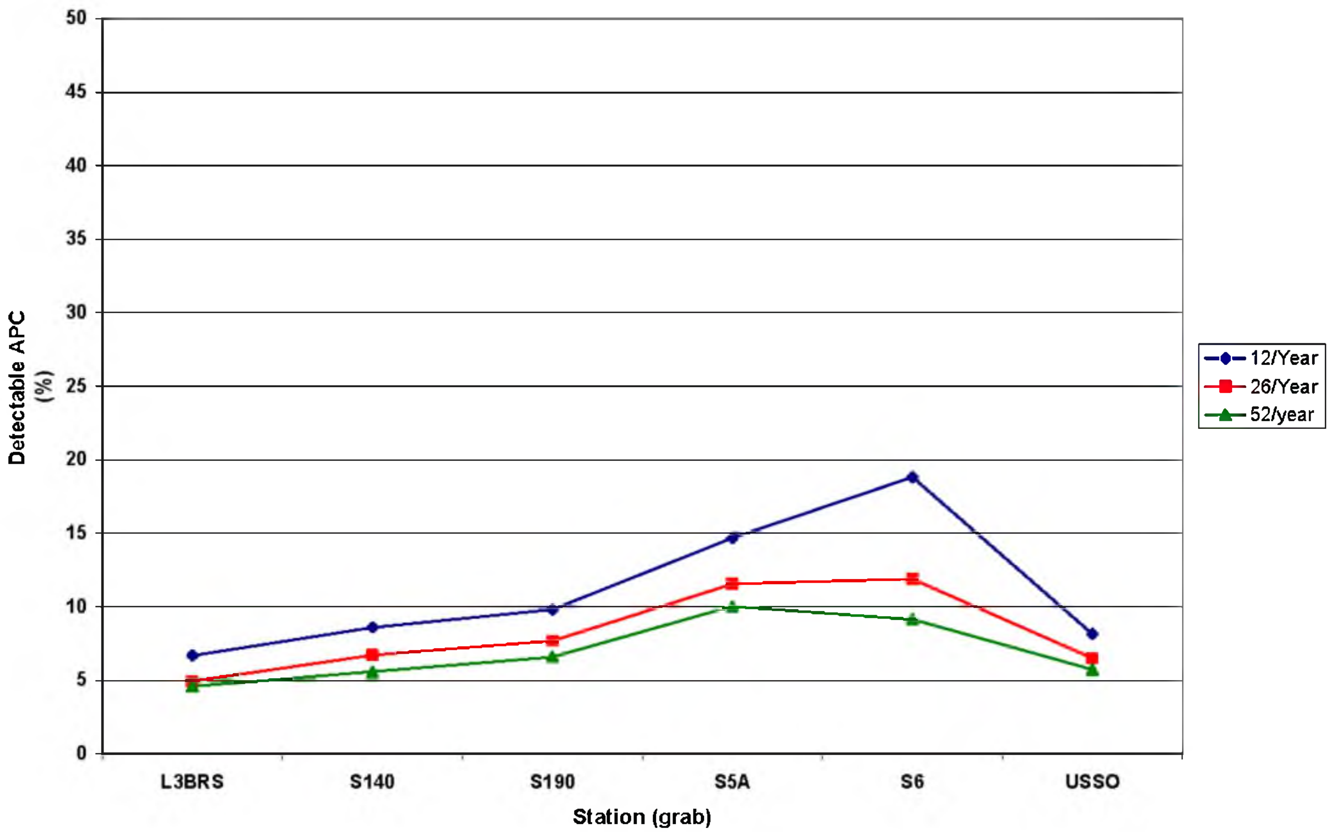


Figure 7. Comparison of annual percentage change (detectable_APC) in TKN with 80% power (p=0.05) from grab samplers at CAMB monitoring stations.

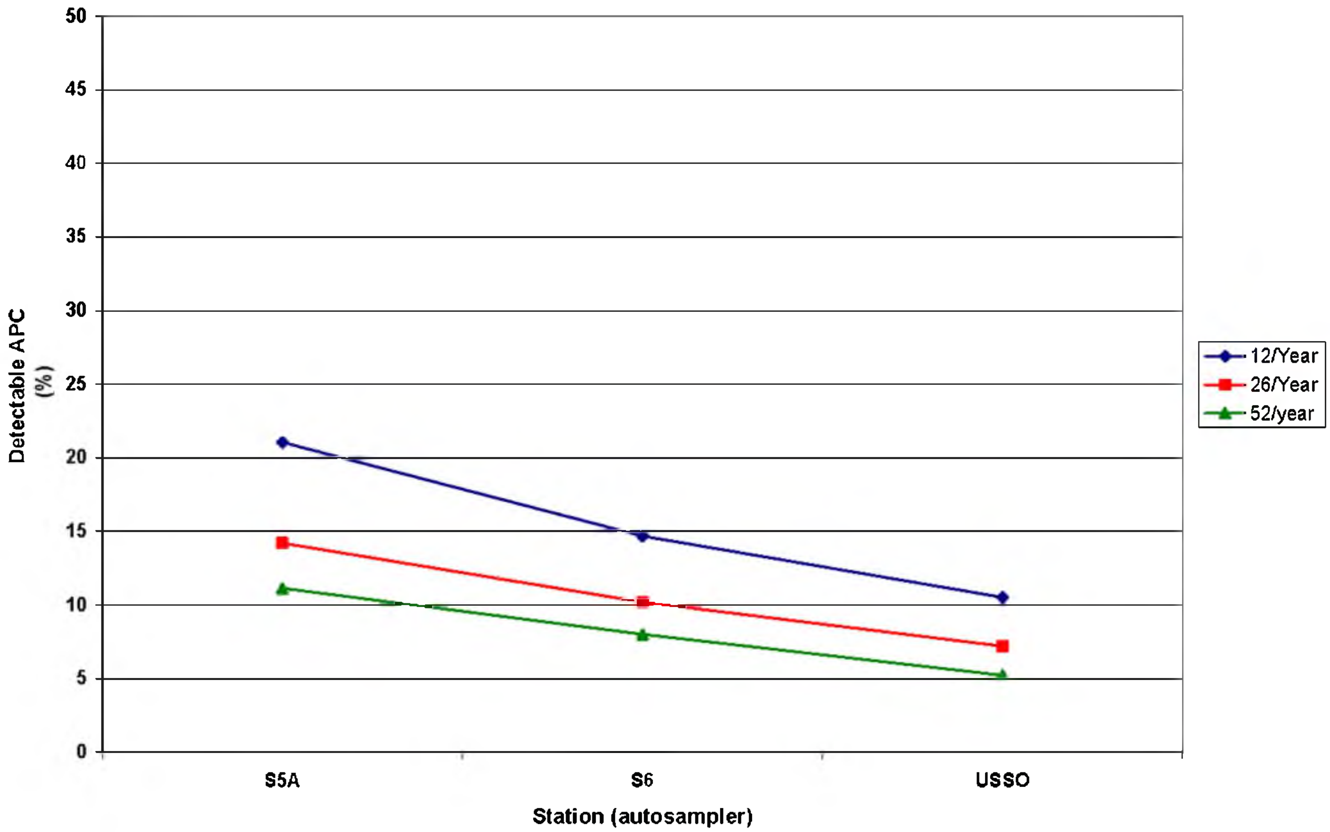


Figure 8. Comparison of annual percentage change (detectable_APC) in TKN with 80% power (p=0.05) from autosamplers at CAMB monitoring stations.

TPO4:

Temporal Optimization

Tables 12 and 13 present the specifics for each sampling method. The current sampling frequency was adequate to detect a 20% change in slope over 5 years for TPO4 collected by grab sampling (Figure 9) for all stations. L3BRS is very close to the 20% detection baseline, with the current bi-weekly sampling frequency capable of detecting 19.96% change. Doubling the sampling frequency to weekly improves the detectable_APC resolution at L3BRS to an acceptable 17%. Simulations run on mandated bi-weekly grab stations (L3BRS, S140, S190) data reducing the sampling frequency to monthly slightly increased detectable_APCs, and only S140 remained below 20%. All three grab stations normally sampled on a weekly basis (S5A, S6, USSO), when simulated for bi-monthly sampling, were below 20% detectable_APC level. Further reductions in the sampling frequency of these stations to monthly left S5A and USS below a 20% detection level (19% and 16%, respectively).

All autosampler stations were typically sampled on a weekly basis and provided detectable_APCs below 20%. Bi-weekly and monthly alternate monitoring frequencies were simulated the results of which are summarized in Table 13 and graphically in Figure 10. S140, S190, S5A, and USSO remained below the 20% benchmark for bi-monthly simulations; however, at 19.8% S5A was very close to the benchmark limit. S140, S190, and USSO remained below the 20% benchmark for monthly simulations, with USSO approaching the 20% benchmark.

Temporal Recommendations

Current TPO4 monitoring frequencies for grab and auto collected water samples are capable of achieving detectable_ACPs of less than 20%. Optimization from biweekly to monthly sampling should be considered for grab station station S140. Grab stations presently sampled on a weekly basis can be optimized to bi-weekly (S5A and S6) and to monthly for station USSO. Changing weekly autosampler collections to bi-weekly should be considered for station USSO. S140 and S190 can be optimized to monthly sampling.

Table 12. Effect of TPO4 sampling frequency on detectable_APC for grab samples.

Analyte	Station	Number of Samples Per Year**	Annual Detectable Percentage Change	Can a 20 % Change be Detected?
TPO4	L3BRS	52	17	Yes
		26	20	No
		12	27	No
	S140	52	9	Yes
		26	10	Yes
		12	14	Yes
	S190	52	13	Yes
		26	16	Yes
		12	22	No
	S5A	**52**	10	Yes
		26	12	Yes
		12	19	Yes
	S6	**52**	10	Yes
		26	14	Yes
		12	21	No
	USSO	**52**	9	Yes
		26	11	Yes
		12	16	Yes

Mandated base sampling frequency in **bold

Table 13. Effect of TPO4 sampling frequency on detectable_APC for autosamplers.

Analyte	Station	Number of Samples Per Year**	Annual Detectable Percentage Change	Can a 20 % Change be Detected?
TPO4	S140	**52**	7	Yes
		26	10	Yes
		12	14	Yes
	S190	**52**	9	Yes
		26	12	Yes
		12	17	Yes
	S5A	**52**	15	Yes
		26	20	No
		12	27	No
	S6	**52**	18	Yes
		26	24	No
		12	33	No
	USSO	**52**	11	Yes
		26	14	Yes
		12	19	Yes

Mandated base sampling frequency in **bold

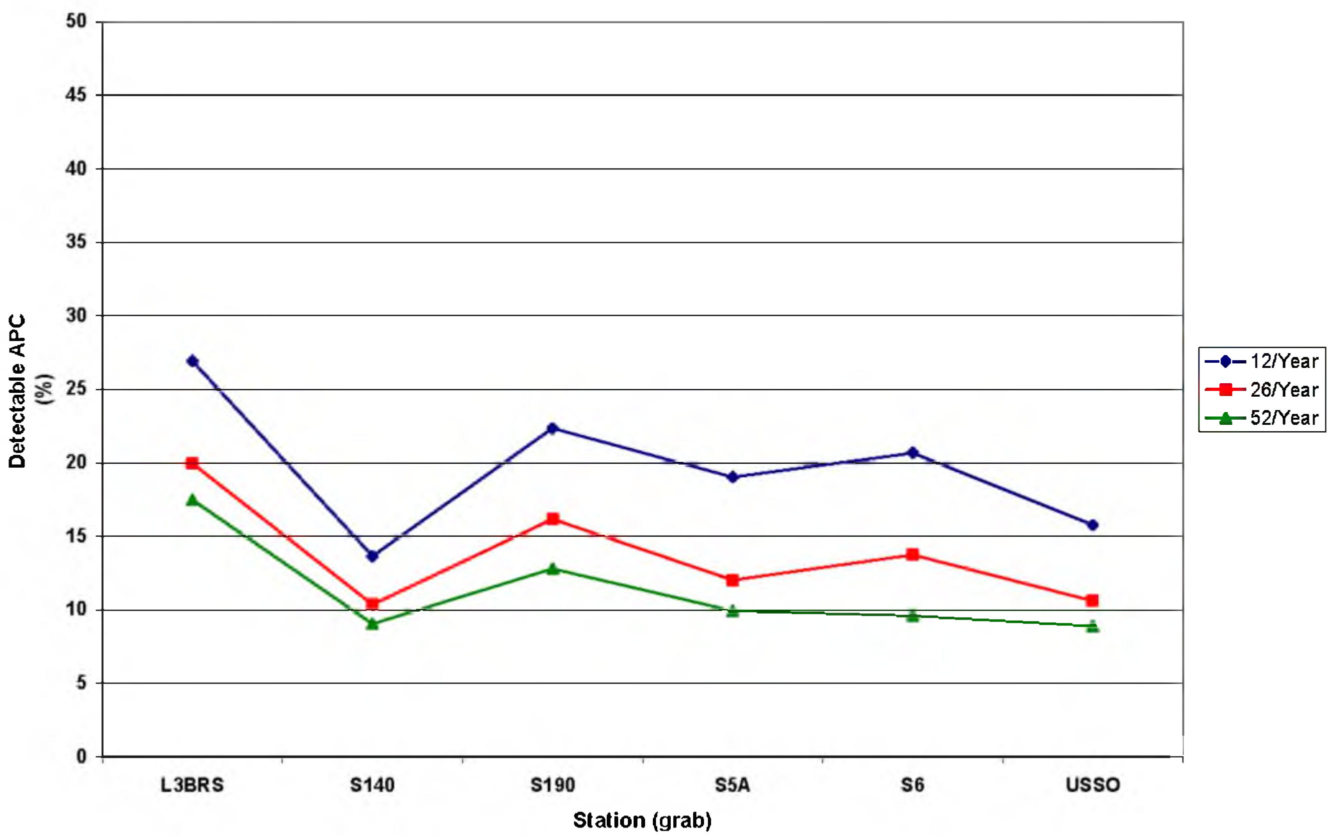


Figure 9. Comparison of annual percentage change (detectable_APC) in TPO4 with 80% power (p=0.05) from grab samplers at CAMB monitoring stations.

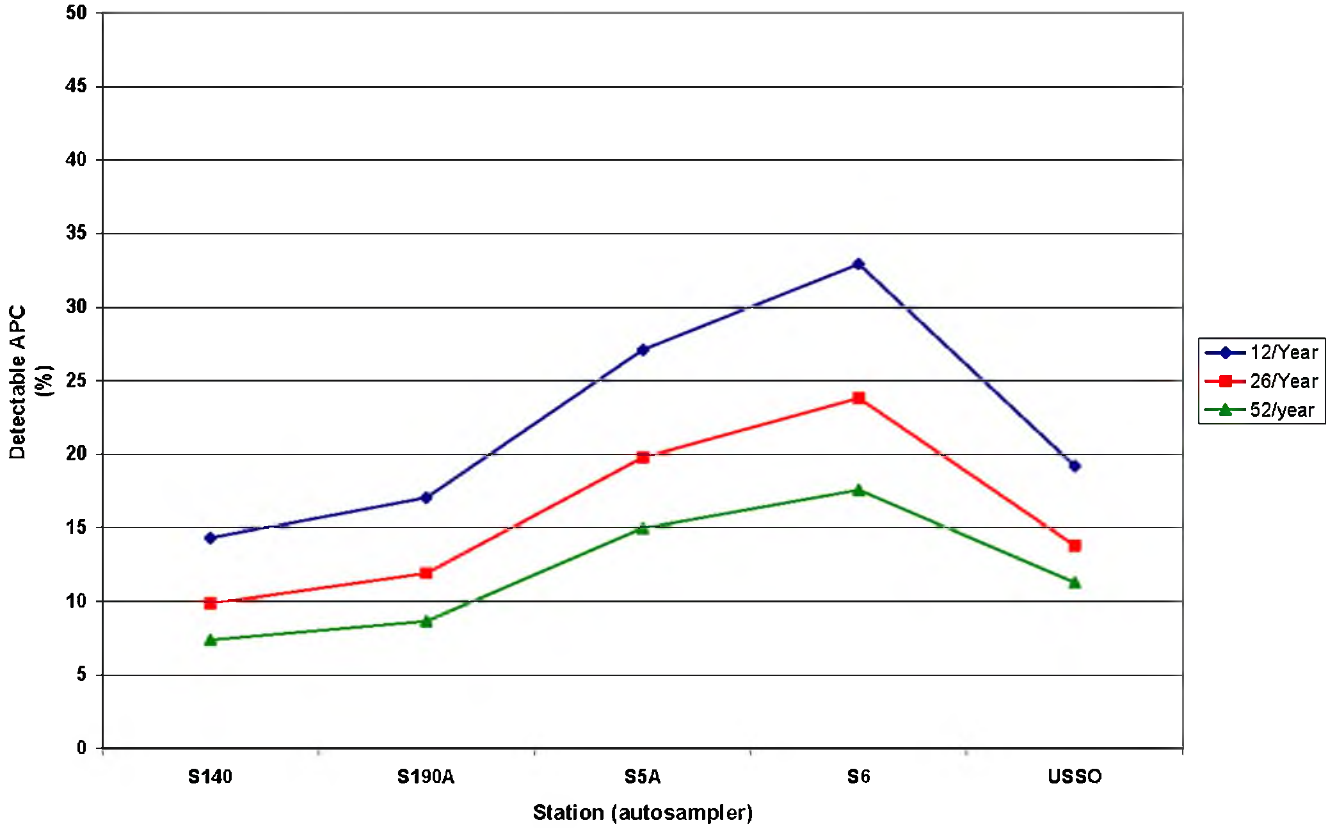


Figure 10. Comparison of annual percentage change (detectable_APC) in TPO4 with 80% power (p=0.05) from autosamplers at CAMB monitoring stations.

Turbidity:
Temporal Optimization

Table 14 presents specifics for each sampling method. Station S190 is the only station examined where the current sampling frequency was adequate to detect a 20% change in slope over 5 years for turbidity (detectable_ACP = 17%). Simulations run at an increased sampling frequency (weekly) resulted in marginal detectable_APCs reductions with only USSO dropping below 20% (Figure 11).

Temporal Recommendations
The ability to predict annual changes in turbidity appears to be tenuous even when current sampling frequencies are doubled to weekly. No optimization is recommended for this parameter.

Table 14. Effect of Turbidity sampling frequency on detectable_APC for grab samples.

Analyte	Station	Number of Samples Per Year**	Annual Detectable Percentage Change	Can a 20 % Change be Detected?
Turbidity	L3BRS	52	19	Yes
		26	21	No
		12	26	No
	S140	52	38	No
		26	38	No
		12	42	No
	S190	52	13	Yes
		26	17	Yes
		12	23	No
	S5A	52	27	No
		26	33	No
		12	39	No
	S6	52	86	No
		26	84	No
		12	93	No
	USSO	52	28	No
		26	31	No
		12	38	No

Mandated base sampling frequency in **bold

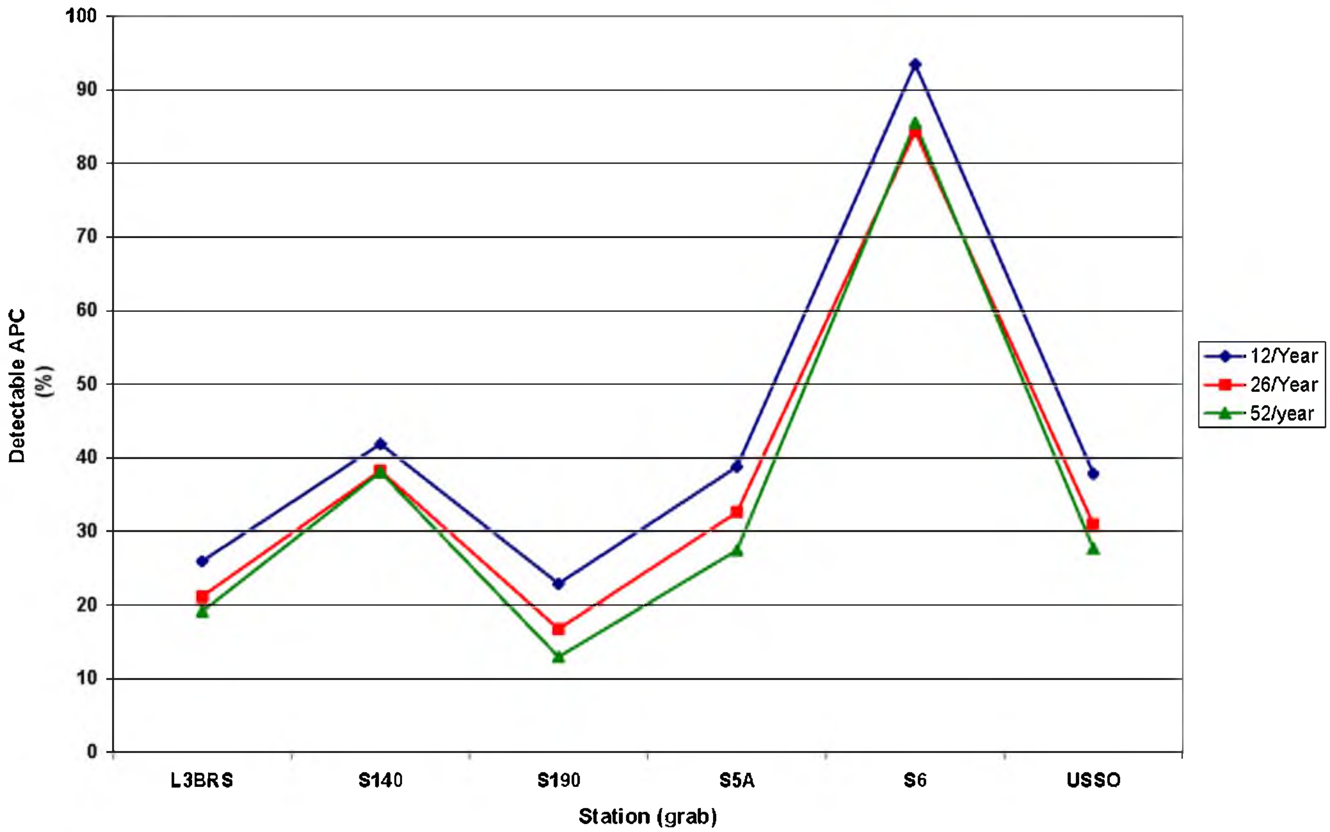


Figure 11. Comparison of annual percentage change (detectable_APC) in turbidity with 80% power (p=0.05) from grab samplers at CAMB monitoring stations.

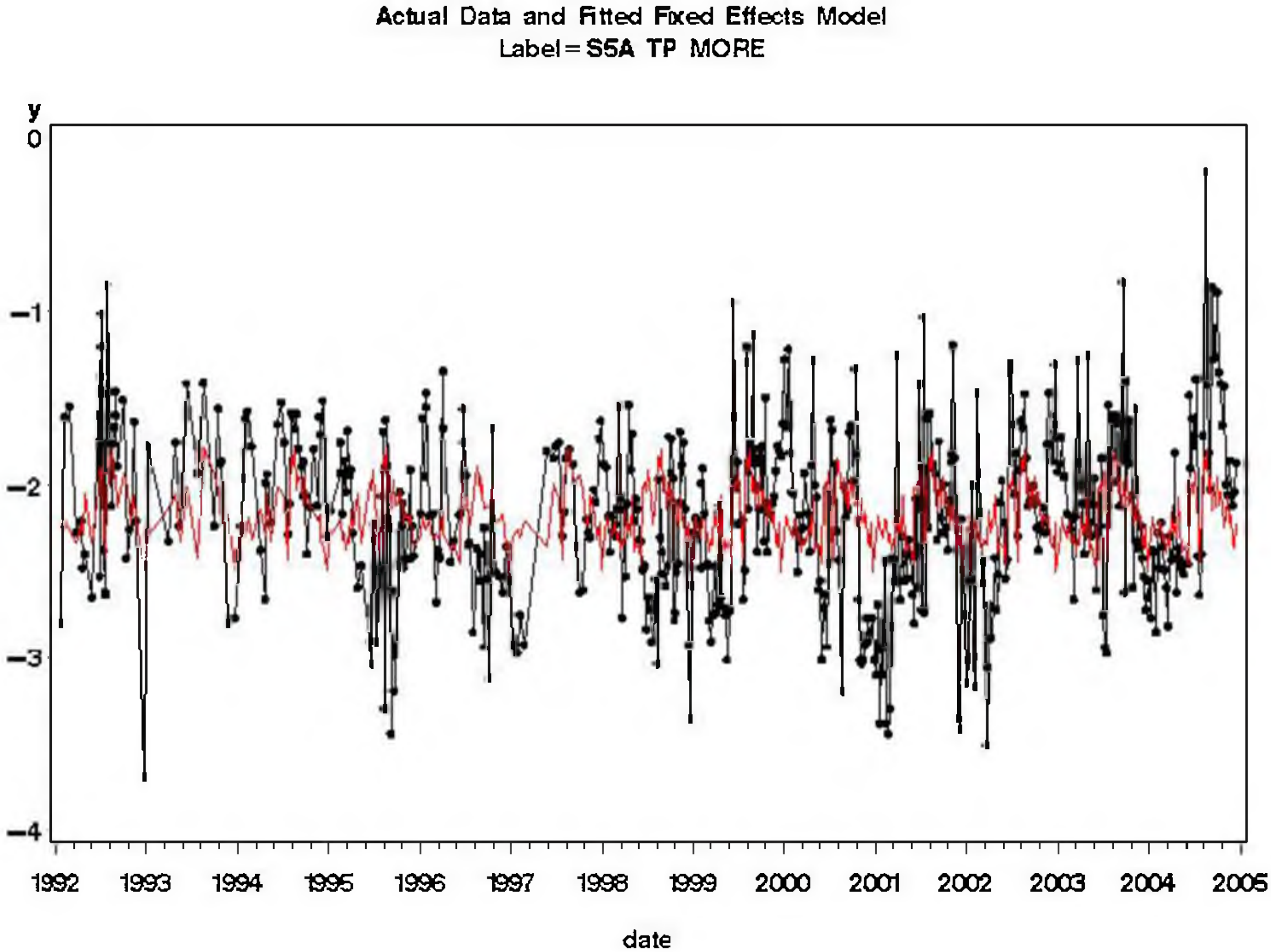


Figure 12. CAMB station S5A grab sampling, actual data (black line) and simulated output for model. Y-axis is log transformed TPO4 and x-axis is year.

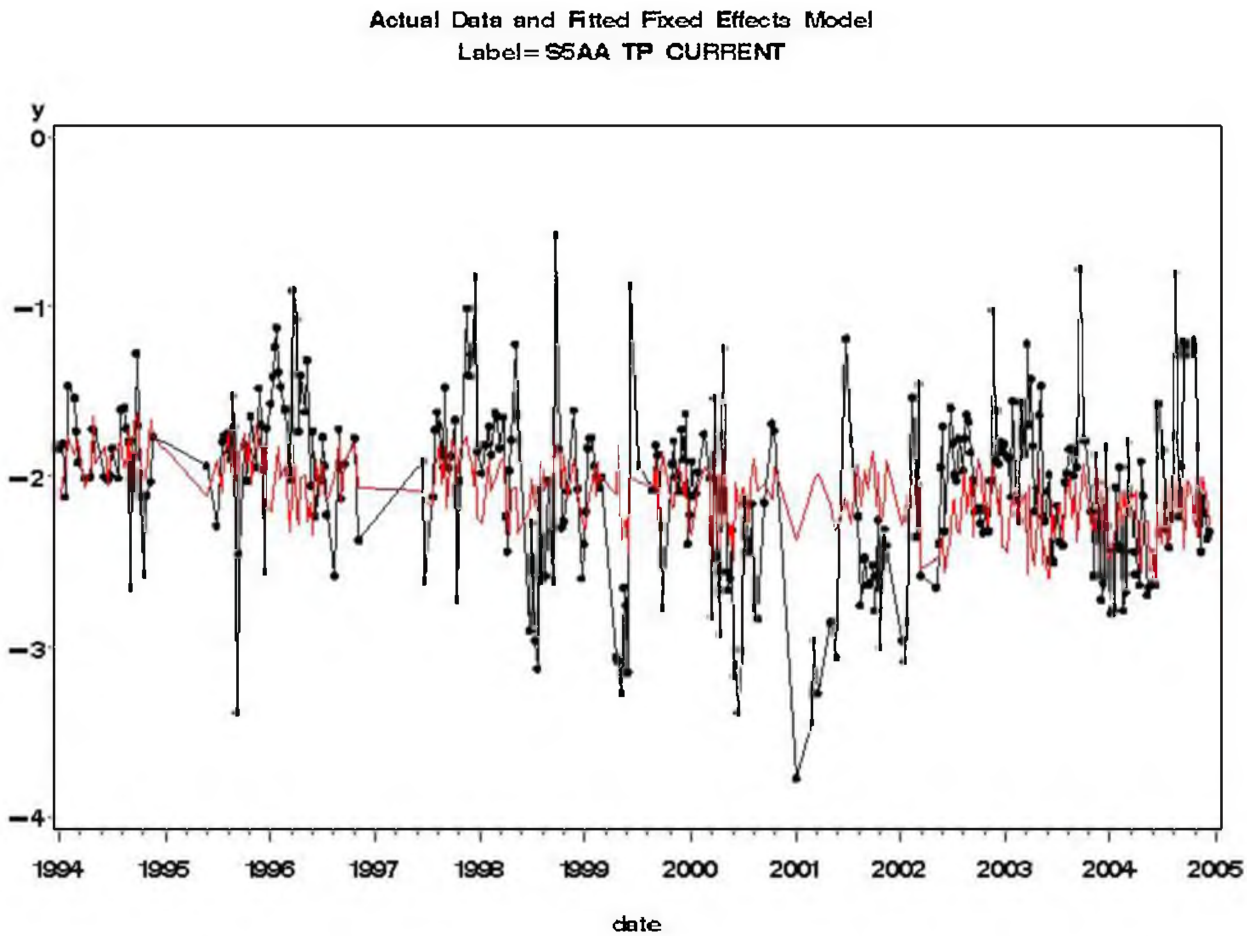


Figure 13. CAMB station S5A autosamplers, actual data (black line) and simulated output for model. Y-axis is log transformed TPO4 and x-axis is year.

Spatial Optimization:
Five combinations of internal canals and stations were on interest by District for potential optimization using a "gradient-type analysis." Station S6 feeds water into stations S10A through S10D and is the only Type 2 station in the five canal groups of interest. Optimization parameters of interest (Table 5) were examined at Station S6 and the closest station, S10D, to see if S6 provides the same information as concurrently sampled station S10D. Stations providing reasonably similar data could be considered redundant and were considered as candidates for optimization.

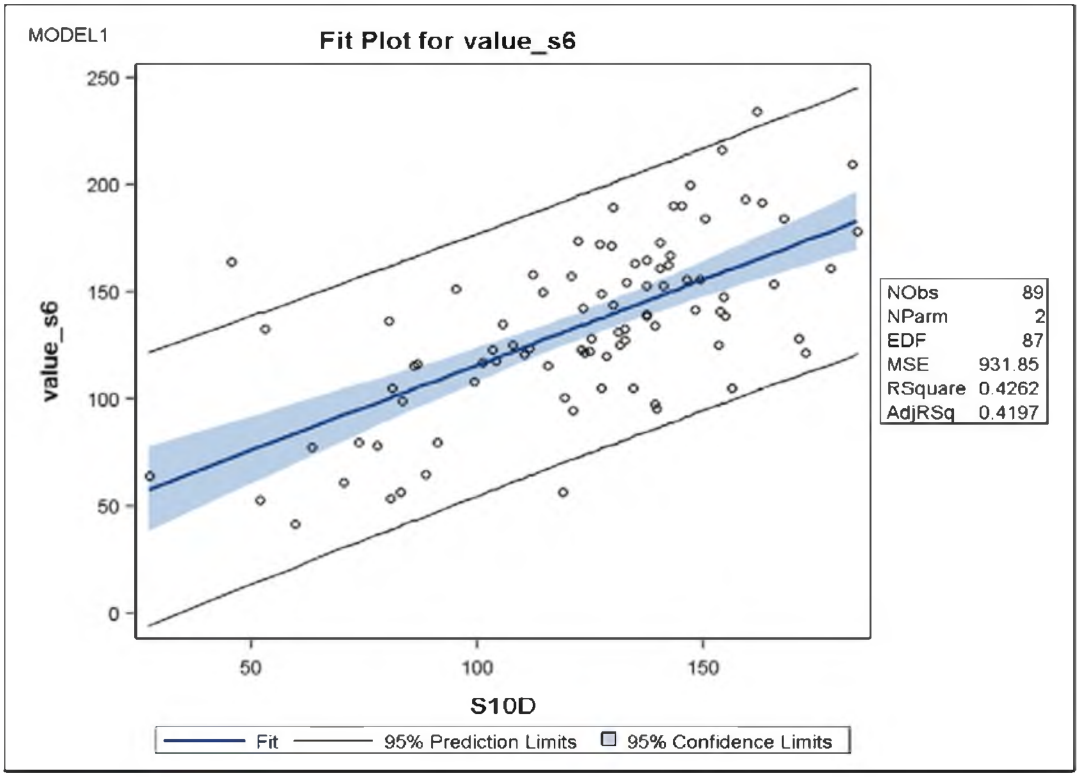
Similarities between stations for untransformed concentrations for the optimization parameters were examined using monthly box-whisker plots, simple linear regressions, and Spearmans Rank correlations. Only grab samples were compared, since autosamplers are not used at S10D. Box-whisker plots for all parameters were initially produced to provide a general perspective on special and temporal variability (examples in Figures 2 and 3). Prior to the processing of regressions and correlations, station data were paired by date and screened for instances where both stations reported non-detected measurements (dual non-detects). A very small number of dual non-detects were found and these were not included in the subsequent analyses.

Table 15 summarizes the results of linear regressions and Spearmans Rank correlations. Analysis of data collected by grabs suggests a reasonable correspondence between stations, with slopes ranging from 0.2096 to 0.7507 and significant Spearmans Rank correlations ranging from 0.426 to 0.745. Figures 14 through 18 graphically present linear regression information.

Spatial Recommendations
Due to reasonably strong, significant correlations and regression equation slopes much greater than zero (one is a correspondence of unity), Station S6 can considered as a spatial optimization candidate for chloride and TKN. NOX and TPO4 are potential parameter optimization candidates, since correlations are greater than 0.5 and trend detection for both stations were below 20% detectable_APC (see temporal optimizations). Turbidity should not be considered as a candidate for optimization, because the Spearmans Rank correlation is less than 0.5 and temporal optimizations indicated high general variability.

Table 15. Summary of station to station comparisons.

Optimization Parameter	n	Sample Dates Spanned		Regression Equation Station S6 vs. S10D	Spearmans Rank Correlation	Significance (p)
		Beginning	Ending			
Chloride (CL)	89	3/24/1992	2/18/2004	S10D = 0.5347 * S6 + 51.4274, n=89	0.635	<0.001
TKN	89	3/24/1992	2/18/2004	S10D = 0.7507 * S6 + 0.5334, n=89	0.745	<0.001
NOX	88	3/24/1992	2/18/2004	S10D = 0.5799 * S6 + 0.0290, n=88	0.573	<0.001
TPO4	91	3/24/1992	2/18/2004	S10D = 0.5985 * S6 + 0.0296, n=91	0.564	<0.001
Turbidity (TUR)	88	3/24/1992	2/18/2004	S10D = 0.2096 * S6 + 4.6782, n=88	0.426	<0.001



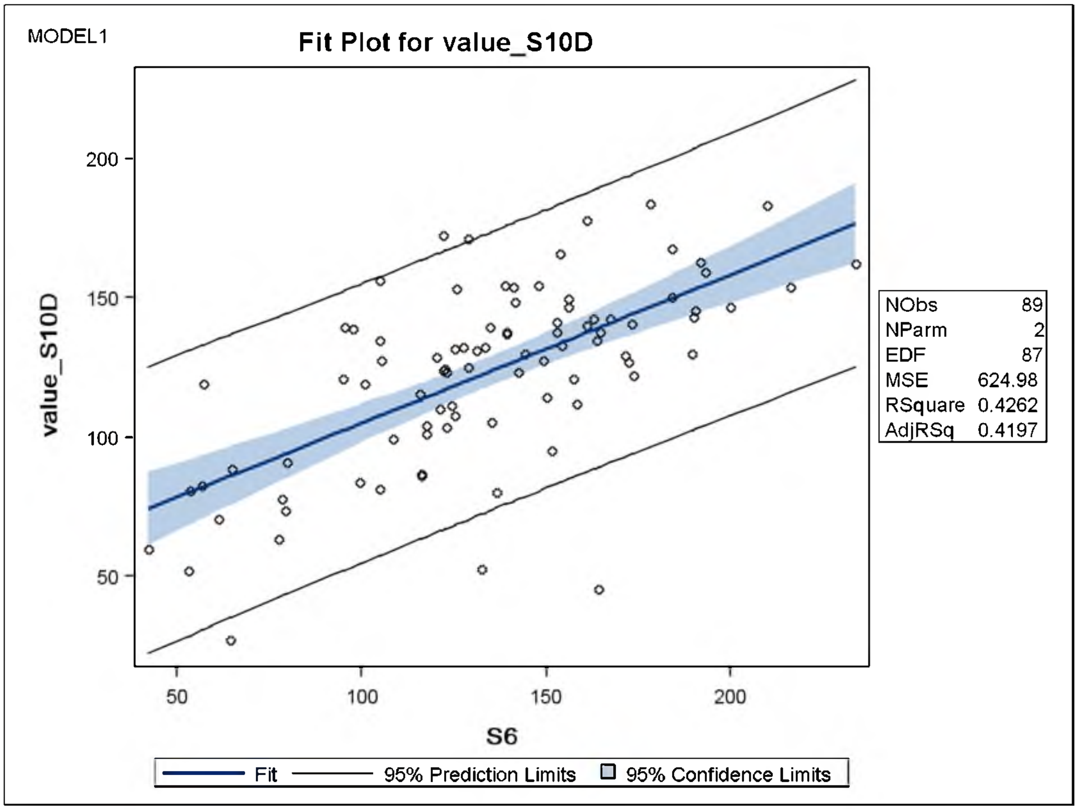
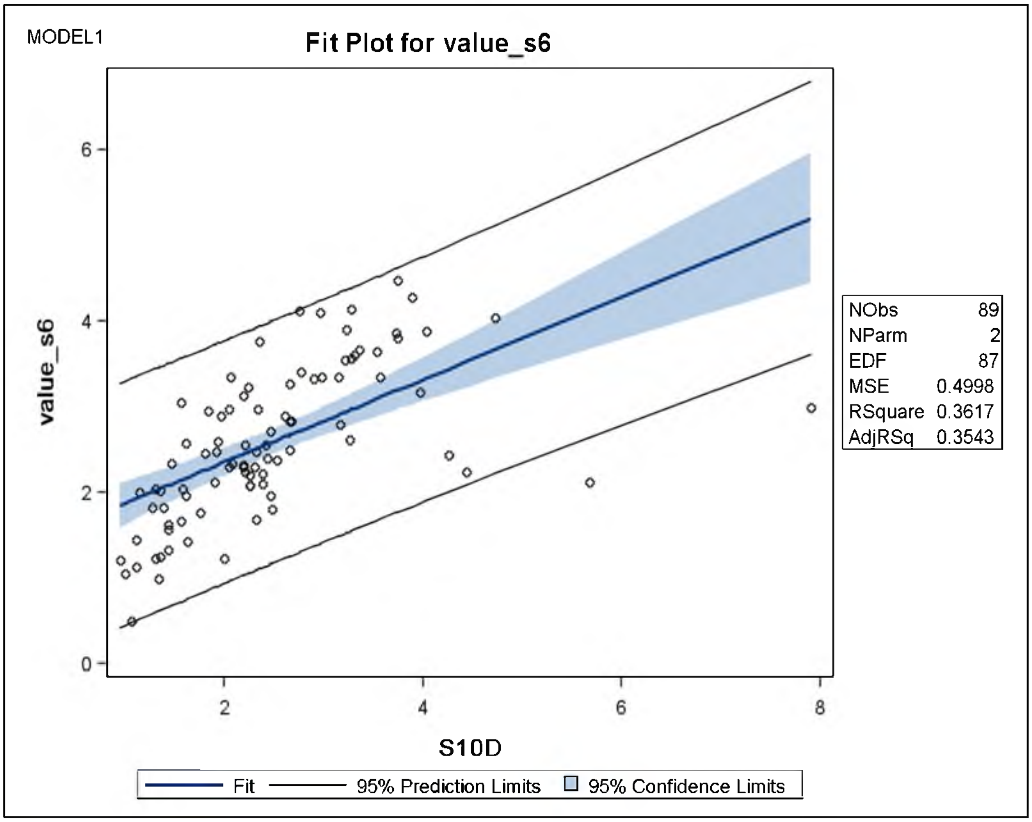


Figure 14. Linear regression of chloride concentrations collected by grab sampling at stations S6 and S10D.



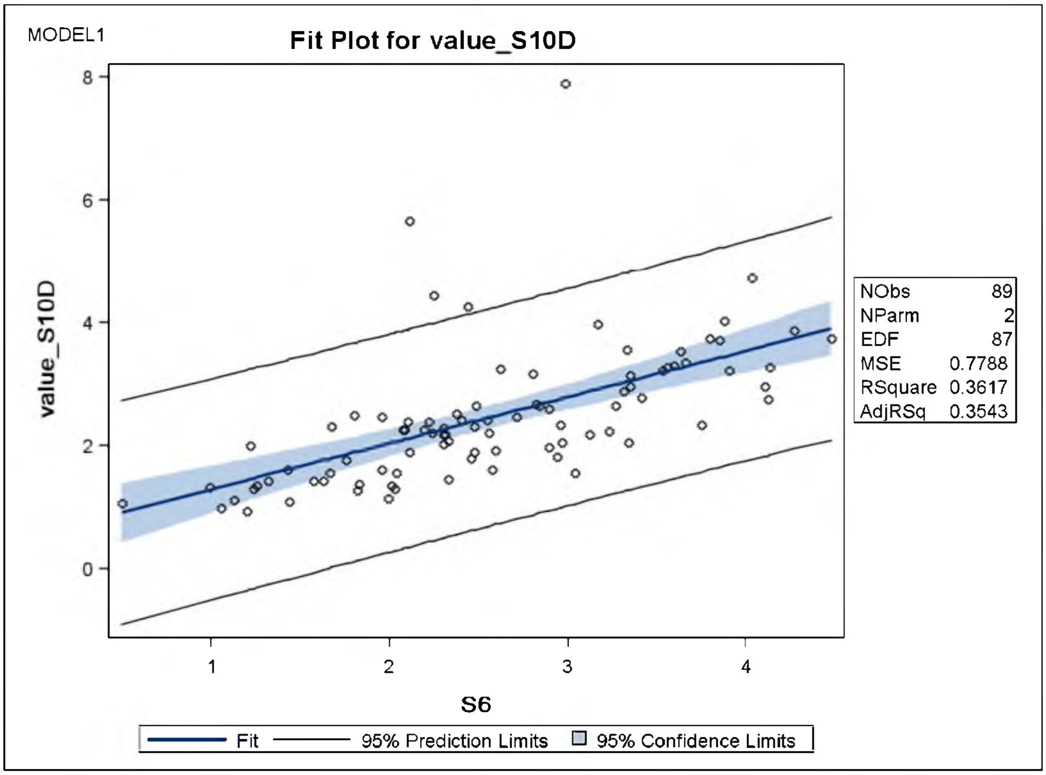
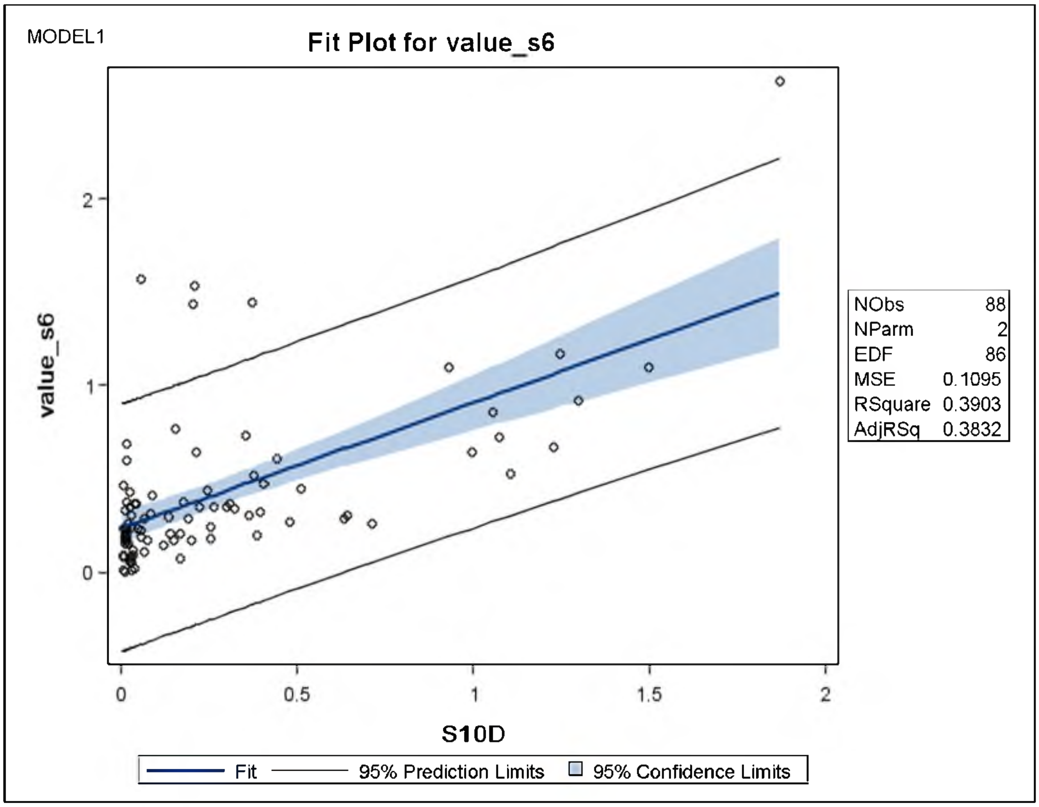


Figure 15. Linear regression of TKN concentrations collected by grab sampling at stations S6 and S10D.



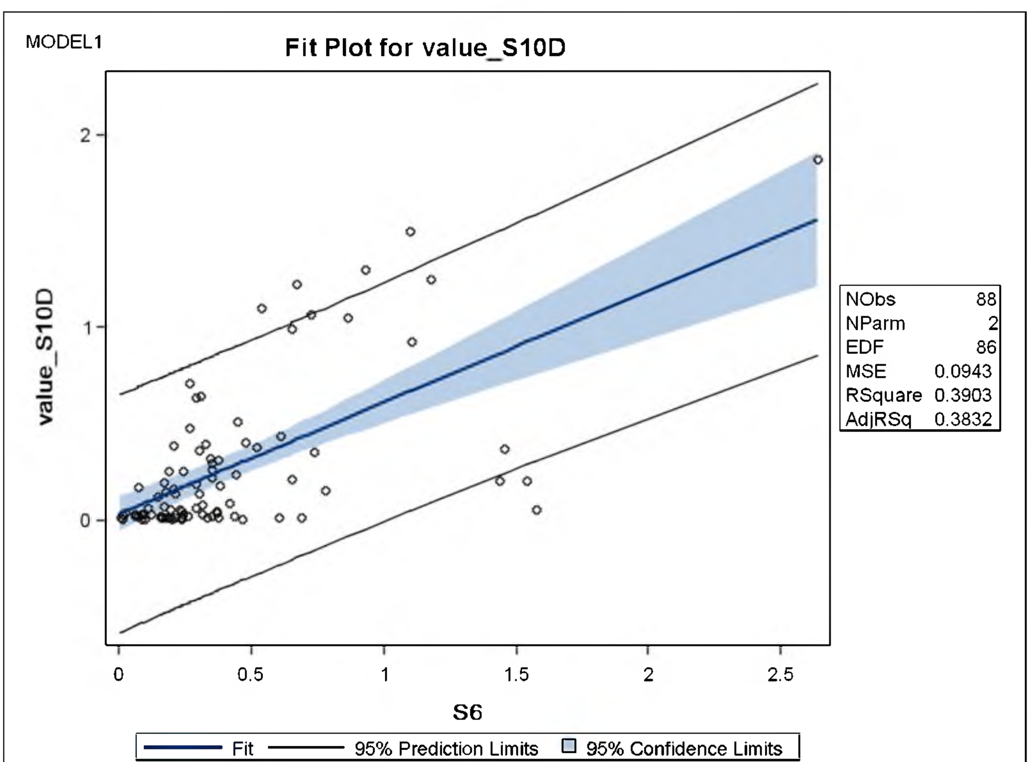
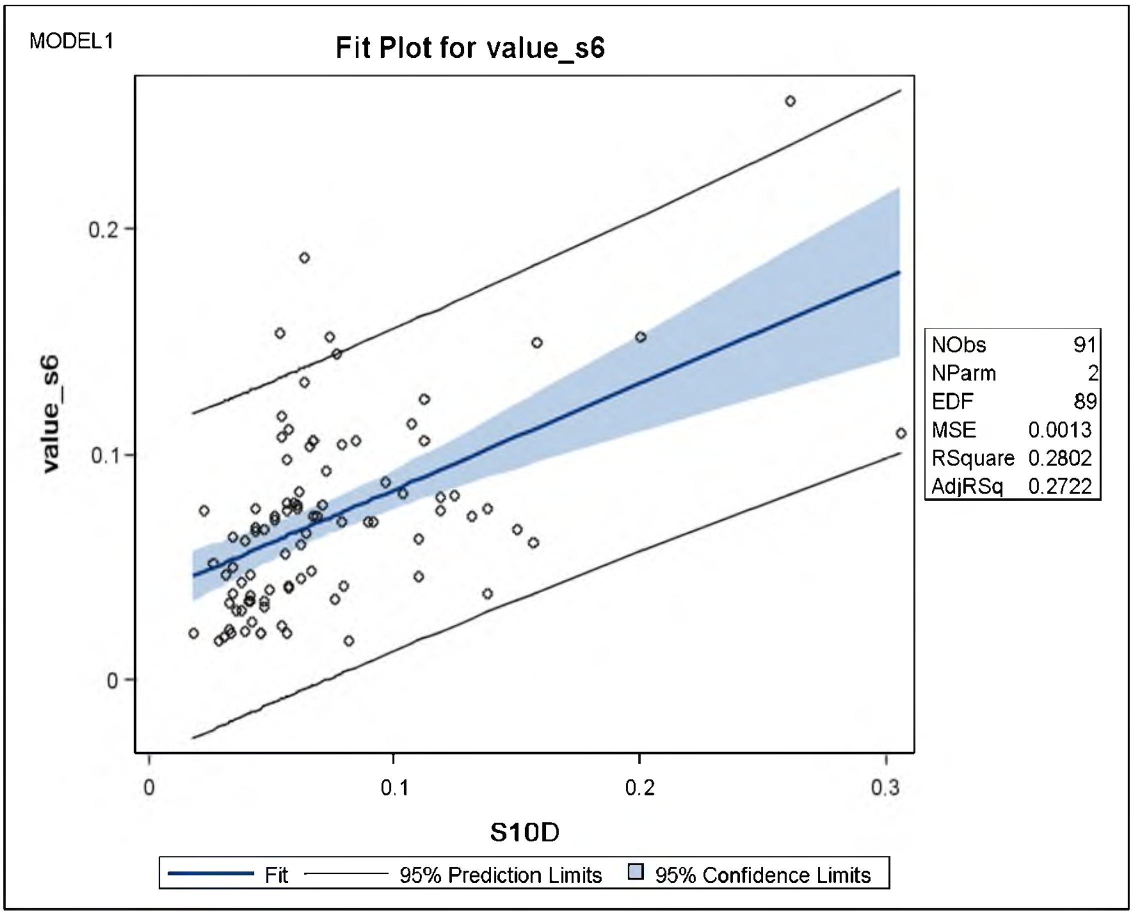


Figure 16. Linear regression of NOX concentrations collected by grab sampling at stations S6 and S10D.



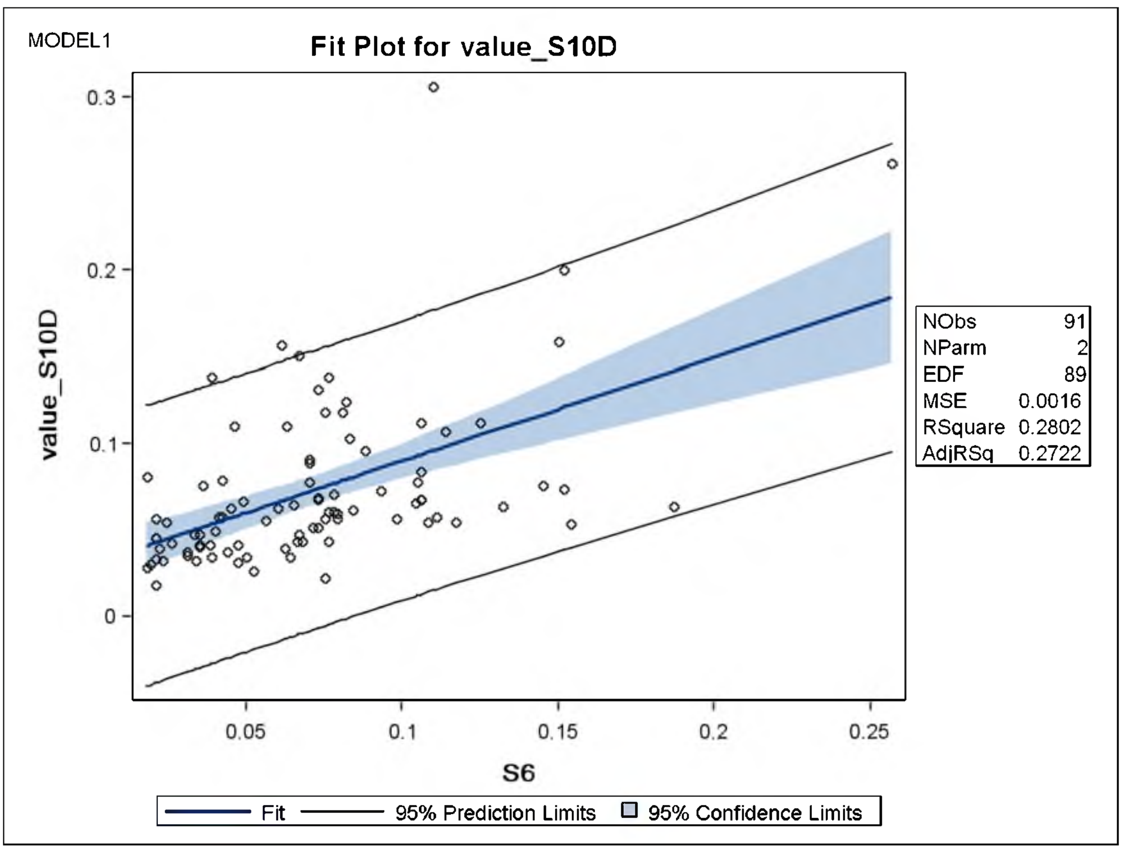
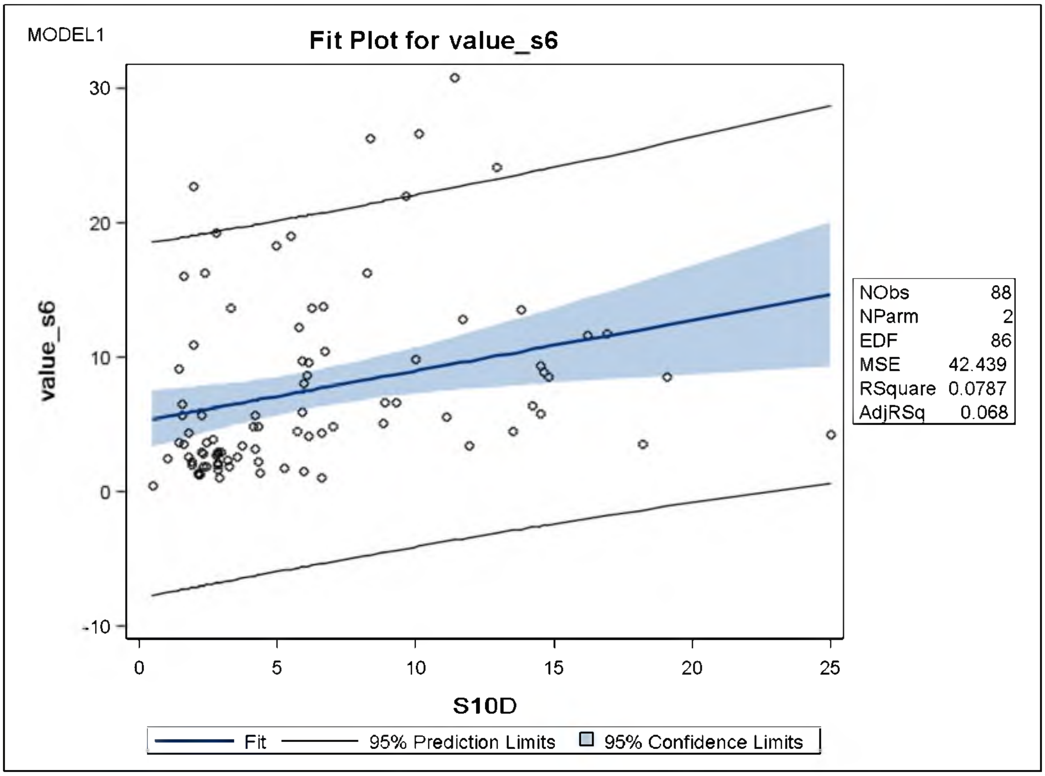


Figure 17. Linear regression of TPO4 concentrations collected by grab sampling at stations S6 and S10D.



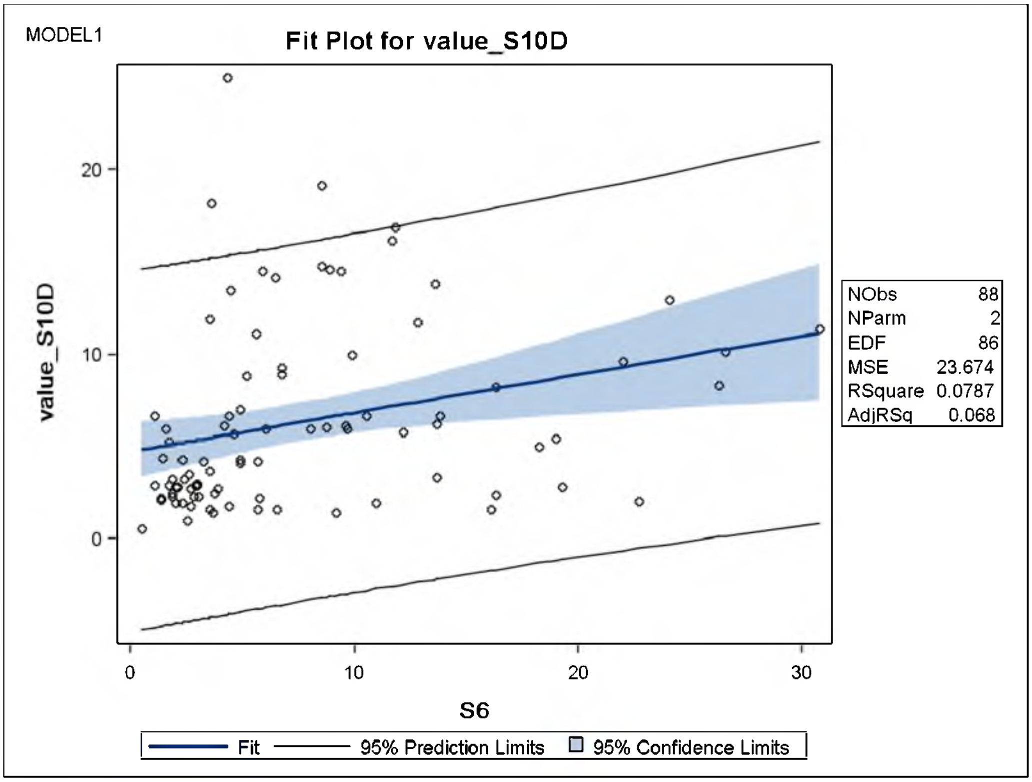


Figure 18. Linear regression of turbidity concentrations collected by grab sampling at stations S6 and S10D.

Sampler Optimization:

Five of the six stations examined in this optimization were sampled with automated collection devices (L3BRS is sampled only with grabs). Similarities between sampling techniques for untransformed TPO4 concentrations were examined using monthly box-whisker plots, simple linear regressions, and Spearmans Rank correlations. Optimization analytes were examined at these stations to see if grab and autosamplers were providing the same information with respect to analyte concentration. Sampling methods providing reasonably similar data can be considered optimizable and, as such, only analysis need be made for one collection method.

Similarities between stations for untransformed analyte concentrations were examined using monthly box-whisker plots, simple linear regressions, and Spearmans Rank correlations. Autosamplers, regardless of type, were considered generic and processed as a single collection type. Box-whisker plots were initially produced to provide a general perspective on the spatial and temporal variability optimization parameters (examples in Figures 2 and 3).

Table 16 summarizes the results of linear regressions and Spearmans Rank correlations. Spearmans Rank correlations for sampling techniques are generally strong ranging from 0.414 to 0.890 and significant ($p<0.001$). Regression equations have positive slopes and range from 0.0471 to 1.9119, indicating predictable associations between sampler types for all stations, with the exception of TKN at station USSO. As a note of clarification for Table 16, station names beginning with "A" in the regression equation represent autosampler data (X-axis in Figure 19). Autosamplers tended to provide greater estimates of optimization analytes, as evidenced by slopes of less than one in the regression equations. For TKN, station USSO appears to be the only station where slope approaches zero and suggests a random association between grab and autosampler results. Figures 19 and 20 are a representative regression graphics for grab and autosamper data.

Sampler Recommendations

Strong significant correlations and regression equation slopes generally greater than 0.5 (1.0 is a perfect correspondence) suggest optimization of sampler type through the elimination of one sampling technique. This recommendation should, however, be viewed with caution and the choice of which technique to eliminate should be carefully considered, especially if grab sampling is to be considered as a "backup," or quality assurance procedure. The data examined in this optimization do not provide insight into which sampling technique better reflects "real" analyte concentrations. Grab sampling has the potential to capture episodic extremes, while autosamplers tend to average out small scale temporal variance and may preclude the identification of spikes. Additionally, optimization analyte relationships between grab samples and autosamplers vary between stations and add additional uncertainty into the practicality of completely eliminating one sampling technique.

Table 16. Summary of grab and autosampler comparisons.

Optimization Parameter	Station	n	Sample Dates Spanned		Regression Equation Grab vs. Autosampler	Spearmans Rank Correlation	Significance (p)
			Beginning	Ending			
NOX	S5A	164	8/17/1992	12/14/2004	S5A = 0.3602 * AS5A + 0.4217, n=164	0.524	<0.001
	S6	108	9/4/1992	12/8/2004	S6 = 0.6820 * AS6 + 0.1851, n=108	0.596	<0.001
	S140	1					
	S190	1					
	USSO	69	3/7/1996	10/1/2002	USSO = 1.9119 * AUSSO + -0.0094, n=69	0.593	<0.001
TKN	S5A	163	8/17/1992	12/7/2004	S5A = 0.7629 * AS5A + 0.5092, n=163	0.750	<0.001
	S6	115	9/4/1992	12/8/2004	S6 = 0.7817 * AS6 + 0.5726, n=115	0.717	<0.001
	S140	3					
	S190	1					
	USSO	70	3/7/1996	10/1/2002	USSO = 0.0471 * AUSSO + 1.2730, n=70	0.584	<0.001
TPO4	S5A	282	8/17/1992	12/7/2004	S5A = 0.6239 * AS5A + 0.0498, n=282	0.540	<0.001
	S6	255	9/4/1992	1/5/2005	S6 = 0.7265 * AS6 + 0.0172, n=255	0.548	<0.001
	S140	61	12/24/2002	12/14/2004	S140 = 0.2829 * AS140 + 0.0264, n=61	0.414	<0.001
	S190	29	7/8/2002	10/13/2004	S190 = 1.0147 * AS190 + -0.0020, n=29	0.89	<0.001
	USSO	164	3/7/1996	12/13/2004	USSO = 0.5669 * AUSSO + 0.0369, n=164	0.718	<0.001

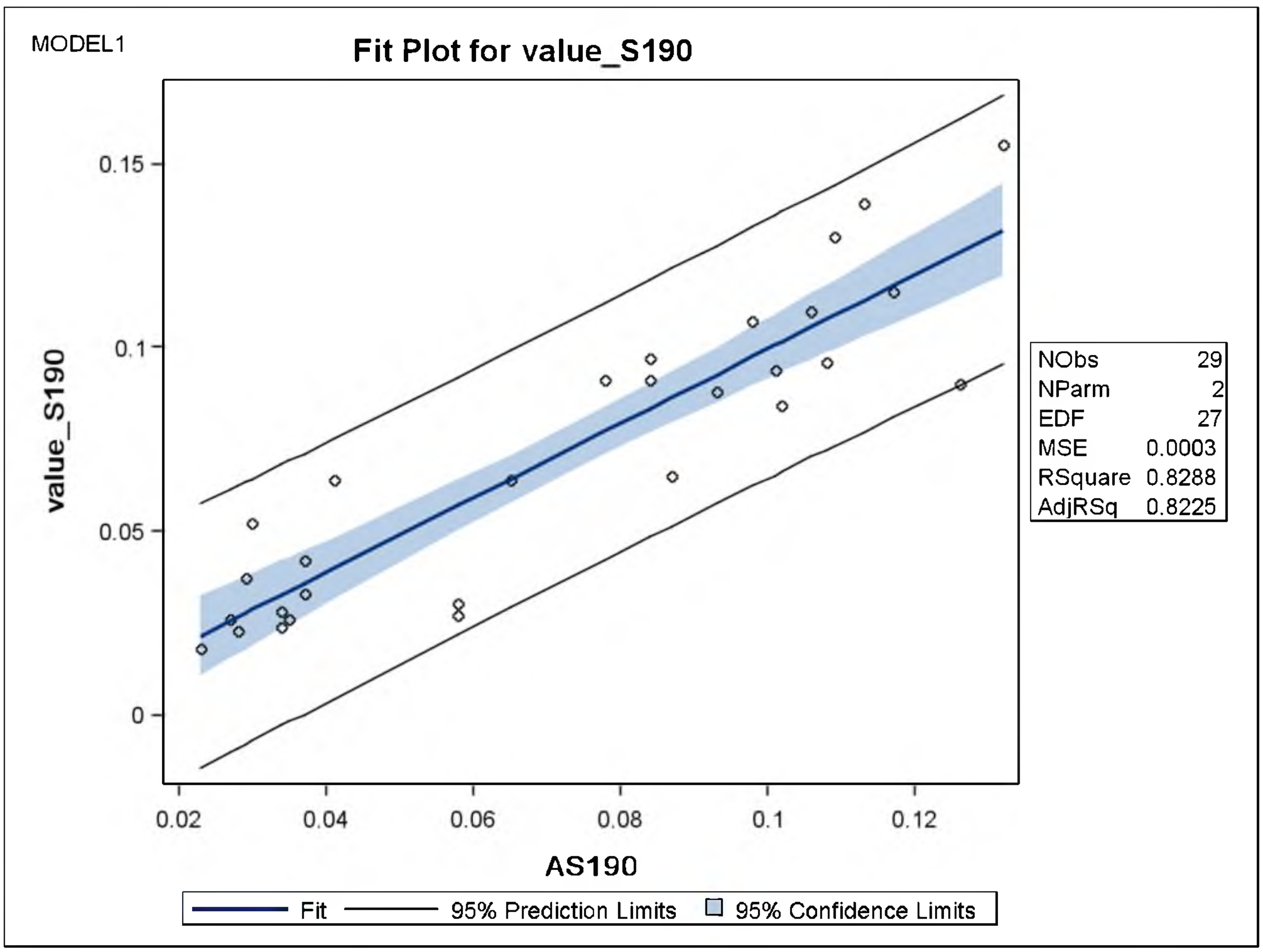


Figure 19. Linear regression of TPO4 concentrations produced from samples collected by grabs and autosamplers at station S190.

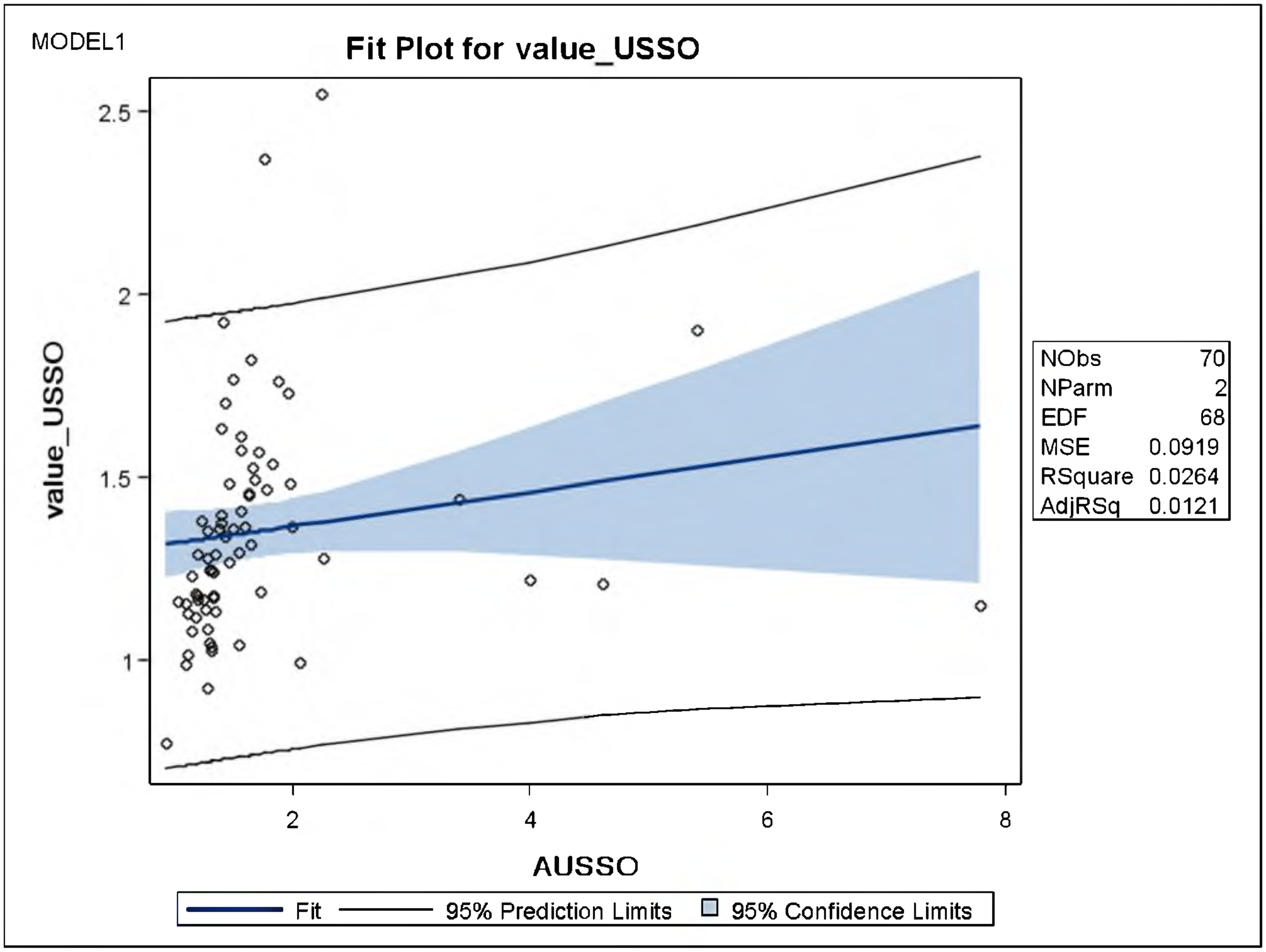


Figure 20. Linear regression of TKN concentrations produced from samples collected by grabs and autosamplers at station USSO.

Seminole Reservation

Optimization Leader: Skip Newton, Battelle
Statistician: Skip Newton, Battelle

Project Code: SEMI

Type: Type II

Mandate or Permit:

- Water Rights Compact, Section C of Part V & Section D of Part VI - Agreement between the Seminole Tribe and SFWMD

Project Start Date: 05/22/1996

Division Manager: Everglades Division: Jamie Serino

Program Manager: Pam Sievers

Points of Contact: Pam Sievers, Stuart Van Horn, Barbara Powell, Danielle Tharin

Field Point of Contact: Danielle Tharin

Spatial Description:
The Big Cypress Seminole Reservation is the location of Project SEMI. This reservation is located north of the Big Cypress National Preserve in Hendry County. The agreement calls for monitoring at the inflows into the reservation. Sampling stations were stipulated in the agreement and sites were selected based on the most direct route for water inflow into the reservation. Some stations were modified slightly based on sampling logistics. The sampling stations include WWEIR, NFEED, G409, USSO, G357, and G404. The NFEED station has been replaced by G108 and PC17A. The G357 and G404 stations must be monitored to test the quality of water flowing into stations G409 and USSO.

The sampling stations in Project SEMI are generally Type 2 mandated; however, G404, G357, G409 and WWEIR are also Type 1 under the EAA rule. Two stations, USSO and L3BRS are sampled for the CAMB project, but data should be evaluated with the Project SEMI data for optimization. USSO is a Type 2 station and L3BRS is both a Type 2 for the Seminole agreement mandate and Type 1 for the 1991 Settlement Agreement mandate.

Project Purpose, Goals and Objectives:
The main purpose of the SEMI Project is to satisfy the requirements of the agreement between the South Florida Water Management District and the Seminole Tribe of Florida. The goal of the project is to determine the quality of water as inflow to the Big Cypress Seminole Indian Reservation through the L28 Borrow canal, the North Feeder and West Feeder canals and the G409 pump station.

Sampling Frequency and Parameters Sampled:
Total phosphorus is the only parameter sampled for Project SEMI. Total phosphorus is sampled from autosamplers weekly at stations G108, PC17A, G357 and G409, and weekly when flowing at stations G404, USSO and WWEIR. Total phosphorus is also sampled via grab samples weekly at all these stations. Additionally a grab sample is collected at L3BRS bi-weekly when flowing; otherwise it is collected monthly at this location.

In situ measurements are collected weekly when grab samples are collected. In situ measurements include dissolved oxygen, pH, water temperature and specific conductivity. District staff familiar with this project suggested that the in situ measurements are never used. Specific conductivity is sometimes used, but it is rare. A suggestion was made to evaluate whether a quarterly deployment of a datasonde for 4 days to measure the in situ parameters would be more beneficial than a single deployment when samples are collected.

Current and Future Data Uses:
The data for Project SEMI are used in various reports including:

- Seminole Agreement Report to the tribe
- South Florida Environmental Repot
- EAA report and annual workshop
- McDaniels Compliance report

The Project SEMI data will also be critical for CERP, particularly the L28 levee system projects. The data may also be used for the RECOVER Monitoring and Assessment Plan; however, monitoring stations for the Greater Everglades module have yet to be selected.

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.

- Would bi-weekly sampling during dry season and weekly during wet season be sufficient to address the water quality questions for the reservation?
- What advantages to the monitoring does autosampler data provide?
- What are the spatial and temporal similarities from a loading perspective? From a concentration perspective?
- Is flow the main driver of the loading term?
- Are the concentration, load, and flow sufficiently different between stations to justify sampling all stations?

Table 1. Parameters measured by flow proportional autosampler for Project SEMI

Station	Mandate	Type	TPO4
G108		2	w
PC17A		2	w
G357	Seminole agreement EAA Rule	2 1	w
G404	Seminole agreement EAA Rule	2 1	wf
G409	Seminole agreement EAA Rule	2 1	w
USSO	Seminole agreement	2	wf
WWEIR	Seminole agreement EAA Rule	2 1	wf

w = weekly; wf = weekly if flowing

Table 2. Parameters measured In Situ and by grab samples for Project SEMI

Station	Mandate	Type	DO	DEPTH	TEMP	PH	SCOND	TPO4
G108			w	w	w	w	w	w
PC17A			w	w	w	w	w	w
G357	Seminole agreement EAA Rule	2 1	w w	w w	w w	w w	w w	w w
G404	Seminole agreement EAA Rule	2 1	w w	w w	w w	w w	w w	w w
G409	Seminole agreement EAA Rule	2 1	w w	w w	w w	w w	w w	w w
L3BRS	Seminole Agreement Settlement Agreement	2 1	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m	bwf/m
USSO	Seminole agreement	2	w	w	w	w	w	w
WWEIR	Seminole agreement EAA Rule	2 1	w w	w w	w w	w w	w w	w w

w = weekly; bwf/m = bi-weekly if flowing else monthly

NOTE: Additional parameters are collected at USSO and L3BRS in accordance with the Settlement Agreement under project code CAMB.

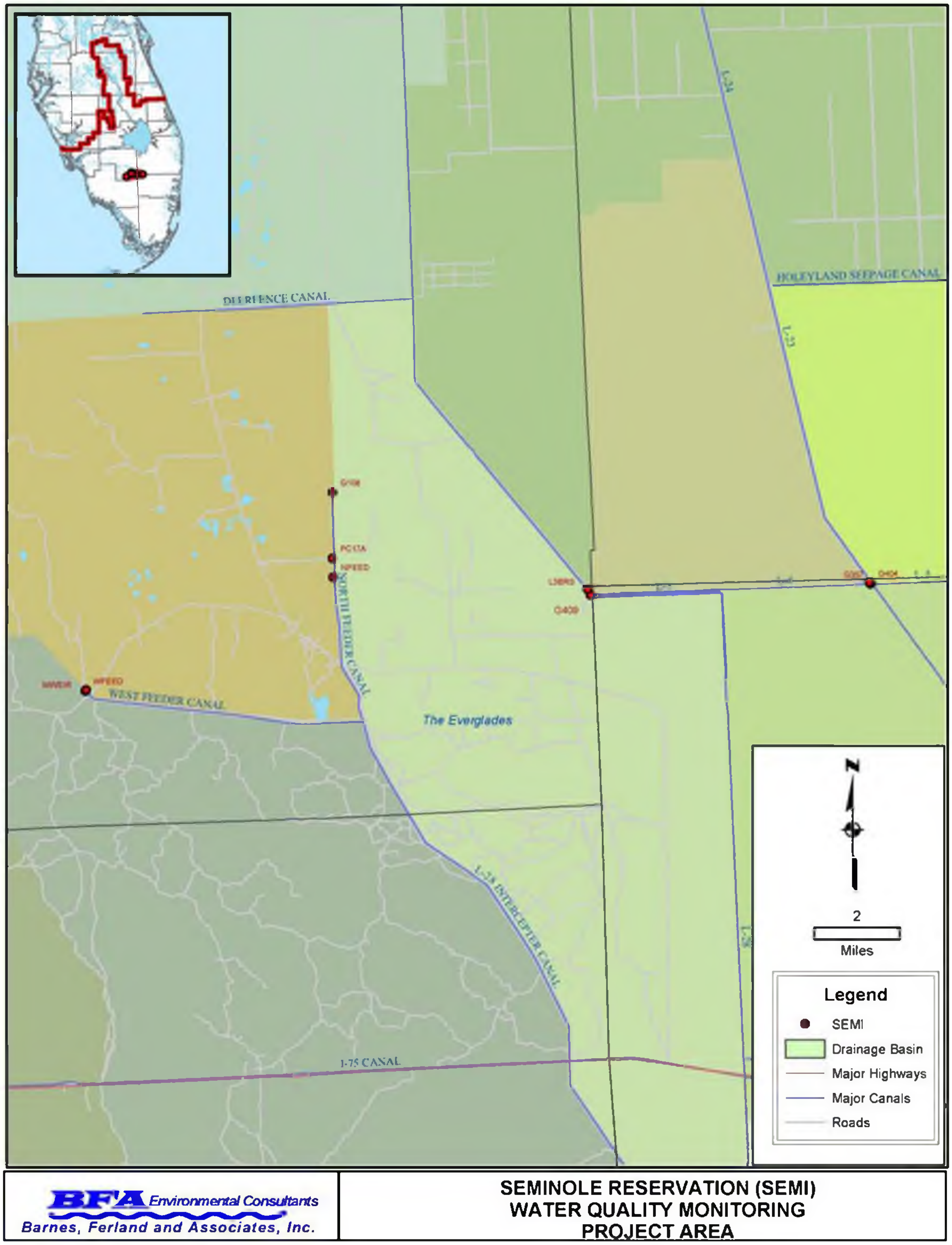


Figure 1. SEMI Sampling Locations

Optimization Analysis:
Optimization of the SEMI water quality monitoring project was undertaken with respect to the tasks outlined above, detailed in the optimization plan modified, and approved in September 2005. The spatial and temporal adequacy of the SEMI project was evaluated with respect to detecting changes between time periods (annual), differentiate water quality parameters by station within the project that share a common structure (canal), and comparing grab sampling and autosampler measurements. The optimization parameter of interest was total phosphorus, often referred to as "TPO4," "PHOSPHATE, TOTAL AS P," and coded as 25 in DBHYDRO. Eight stations possessing Type 2 mandates were considered (Table 1). All stations were sampled with grabs and autosamplers; however, the actual number of samples collected across the stations varies greatly. As indicated in the general summary, the goal of the SEMI project is to determine the quality of water as inflow. However, incorporating flow data into the optimization was beyond the scope of this study, thus optimizations could not be conducted on flow weighted concentrations. Three optimization categories are addressed:

- Temporal adequacy was evaluated to estimate the annual percentage change (Detectable_APC) detectable with 80% power and p= 0.05 for current and alternative monitoring designs. Detectable_APC results are produced by a simple hypothesis testing procedure performed on slope estimate associated with the seasonal Kendal Tau procedure, also referred to as the Mann-Kendall procedure. Details of the statistical process and the SAS program used in the evaluation are presented in Rust (2005). (Rust, SW. 2005. Power Analysis Procedure for Trend Detection with Accompanying SAS Software. Battelle Report to South Florida Water Management District, November 2005).

- Similarities between stations identified for potential optimization are examined using monthly box-whisker plots, simple linear regressions (graphical and fit information), and Spearmans Rank correlation.

- Similarities between sampling techniques are examined using, simple linear regressions (graphical and fit information), and Spearmans Rank correlation.

Temporal Adequacy:
The SEMI project is primarily directed towards monitoring the quality of water (e.g., TPO4) as inflow to the Big Cypress Seminole Indian Reservation through several canals. Both grab samples and automated sampling (autosamplers) schemes are used to collect water samples. Two types of autosamplers have been used, composite time proportional (ACT) and composite flow proportional (ACF).

Statistical power analyses were used to determine the smallest water quality trends that will be detectable with high probability based on water quality data collected according to current monitoring plans. Power analyses were performed by carrying out the following steps for each station and sampler combination.

- Fit a statistical model to the water quality parameter data in order to have a basis for generating simulated data to support a Monte Carlo based power analysis procedure

- Generate multiple replicate simulated water quality time series data sets; for all power analyses reported here, each time series generated was for a 5-year monitoring period

- Perform a Mann-Kendall trend analysis procedure (Reckhow et al. 1993) for each simulated time series data set; in particular, obtain a point estimate of the slope vs. time for the log-transformed water quality parameter values

- Estimate the annual percent change (APC) in water quality parameter values that is detectable with 80% power using a simple two-sided test based on the Mann-Kendall slope estimate performed at a 5% significance level

Parameter values were natural log-transformed for statistical modeling because the log-transformed data was more nearly normally distributed than were the untransformed data. The fitted statistical model contains the following components:

- Fixed seasonal effects that repeat themselves in an annual cycle

- A long-term linear trend in the log-transformed parameter concentrations; this corresponds to a fixed percentage increase or decrease in the water quality parameter each year

- A random error term representing temporal variability in true water quality parameter values; these error terms are allowed to be correlated from one time point to the next in order to capture any serial autocorrelation that is present in the monitoring data

- A random error term representing sampling and chemical analysis variability; these error terms are assumed to be stochastically independent from one time point to the next

The fitted statistical model is used to perform a Monte Carlo simulation analysis in which multiple time series data sets are simulated and used to determine the anticipated statistical properties of trend detection procedures that will be used by the District. All statistical trend analyses performed on the simulated data were based on the Mann-Kendall trend analysis procedure (Reckhow *et al.* 1993) preferred by the District.

In the course of performing the power analyses for the District, it was determined that the basic Mann-Kendall trend detection procedures do not necessarily control the true significance level of the hypothesis test for trend when there is serial autocorrelation exhibited in the data. This was found to be true even for procedures that attempt to correct for serial autocorrelation. For this reason, all power analysis results reported here are for a simple hypothesis test procedure based on the median slope estimator that accompanies the Mann-Kendall test procedure. The median slope estimator is assumed to follow a normal distribution and power results are obtained by performing a simple z-test with this estimator.

Temporal optimization assessed the power to detect time series trends for TPO4. Data, based on availability for each station and type of sampler, were used to estimate the seasonal variability and autocorrelation for each station. Figures 2 and 3 provide an example of the distribution of TPO4 by season and month across all years, respectively. The simulation model used to generate detectable_APC results was modified to account for unpredictable sampling frequencies associated with stations where sample collection was dependent on water flow (G404, L3BRS, USSO, WWEIR). The modified simulation permits the specification of a proportion of missing data (pmiss) and a data simulation macro sets each observation to missing with probability equal to pmiss. The missing values represent the "non-flowing" cases.

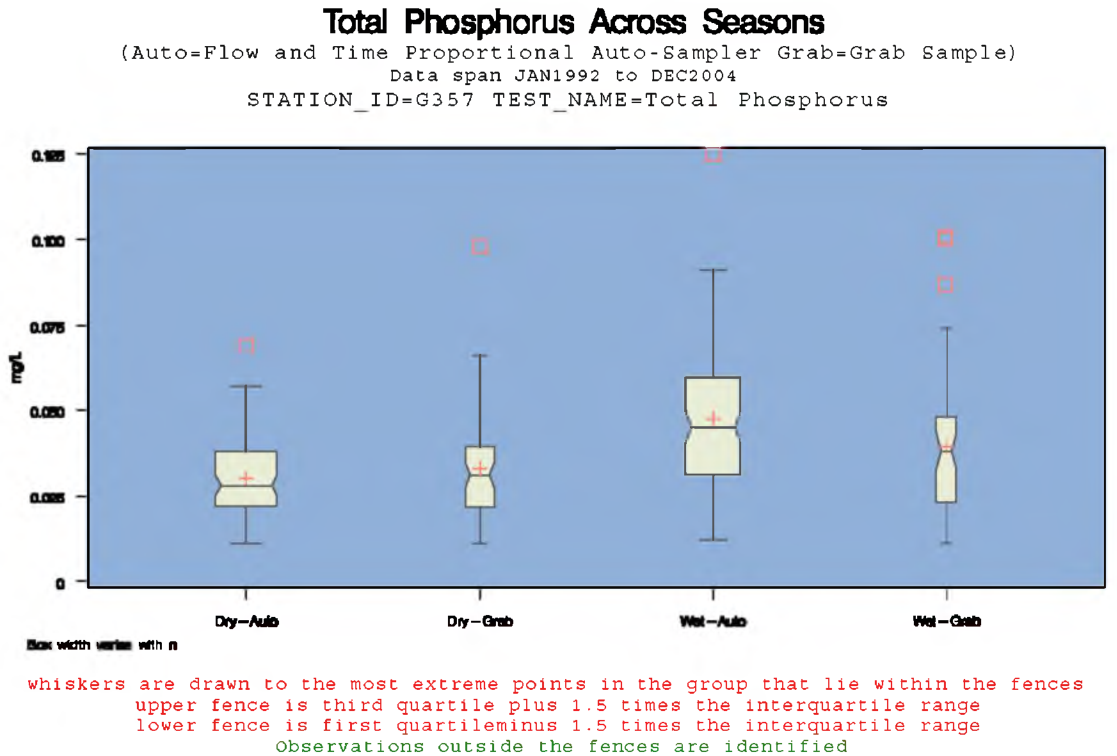


Figure 2. Station G357 TPO4 concentrations reported from autosamplers and grabs across wet and dry seasons.

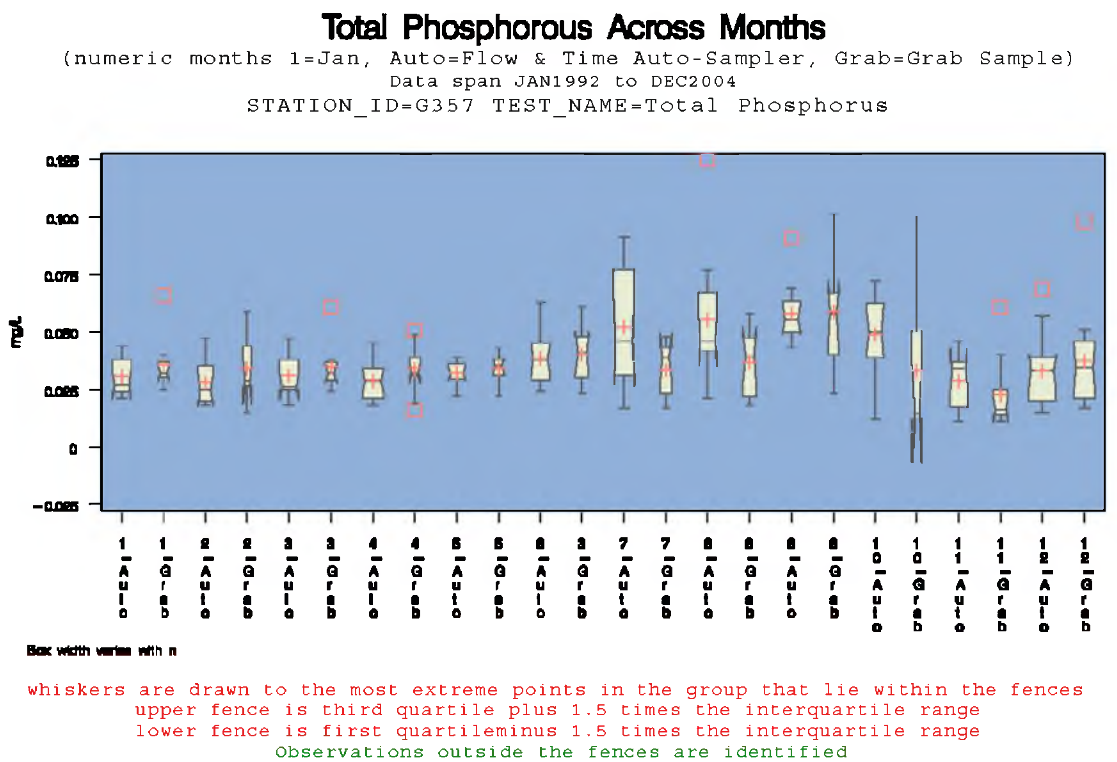


Figure 3. Station G357 TPO4 concentrations reported from autosamplers and grabs across months.

Simulations were run on a station by station basis, with the base condition set to represent the requisite/ideal number of annual sampling periods (weekly = 52, bi-weekly = 26, monthly = 12). Separate simulation runs were conducted for grab and automated samplers. Three stations provided data collected from both flow and time proportional autosamplers (G357, G404, G409). For these stations, autosampler types were combined to provide a long term data set. Initial simulation results were visually examined for outliers and, when found, were removed from subsequent analyses. Additionally, for several stations where the sampling frequency was defined as weekly, the bulk of the reported data was collected less frequently. The modified simulation model that accounts for missing observations was employed when the number of samples collected was far below the number expected (Table 3).

Table 3. By station SEMI simulations processed using the modified trend simulation procedure.

Station	Type Processed	Collection Method	Number of Samples Reported	Modified Simulation Run (Yes/No) and Freq
G108*	Grab	Grab	39	Not Processed
G357	Auto	Composite Flow Proportional	3	Yes - Weekly
G357	Auto	Composite Time Proportional	153	
G357	Grab	Grab	115	No - Weekly
G404	Auto	Composite Flow Proportional	98	Yes - Weekly
G404	Auto	Composite Time Proportional	29	
G404	Grab	Grab	147	Yes - Weekly
G409	Auto	Composite Flow Proportional	7	Yes - Weekly
G409	Auto	Composite Time Proportional	146	
G409	Grab	Grab	133	No - Weekly
L3BRS*	Auto	Composite Flow Proportional	1	Not Processed
L3BRS	Grab	Grab	266	Yes - Bi-weekly
PC17A*	Auto	Composite Flow Proportional	13	Not Processed
PC17A*	Grab	Grab	39	Not Processed
USSO	Auto	Composite Flow Proportional	382	Yes - Weekly
USSO	Grab	Grab	268	Yes - Weekly
WWEIR	Auto	Composite Flow Proportional	246	Yes - Weekly
WWEIR	Grab	Grab	377	Yes - Weekly

*Not processed in annual simulation due to minimal time series data

Figures 4 and 5 graphically present the annual percentage change in TPO4 detectable with 80% power (p=0.05), for grab samples and autosamples respectively. Representative simulation runs typical of the output for each station and sampler type are presented in Figures 6 and 7 (grab and autosampler, respectively). All stations, with the exception of L3BRS, were processed using a sampling base interval of weekly (52 samples per year, Tables 1 and 2). Alternative monitoring designs were simulated with sampling bi-weekly (26 samples per year) and monthly (12 samples per year). L3BSR is sampled on a bi-weekly basis, when flowing, or monthly if not. This station was process with base sampling frequency of bi-weekly and alternate monitoring designs simulated as weekly and monthly.

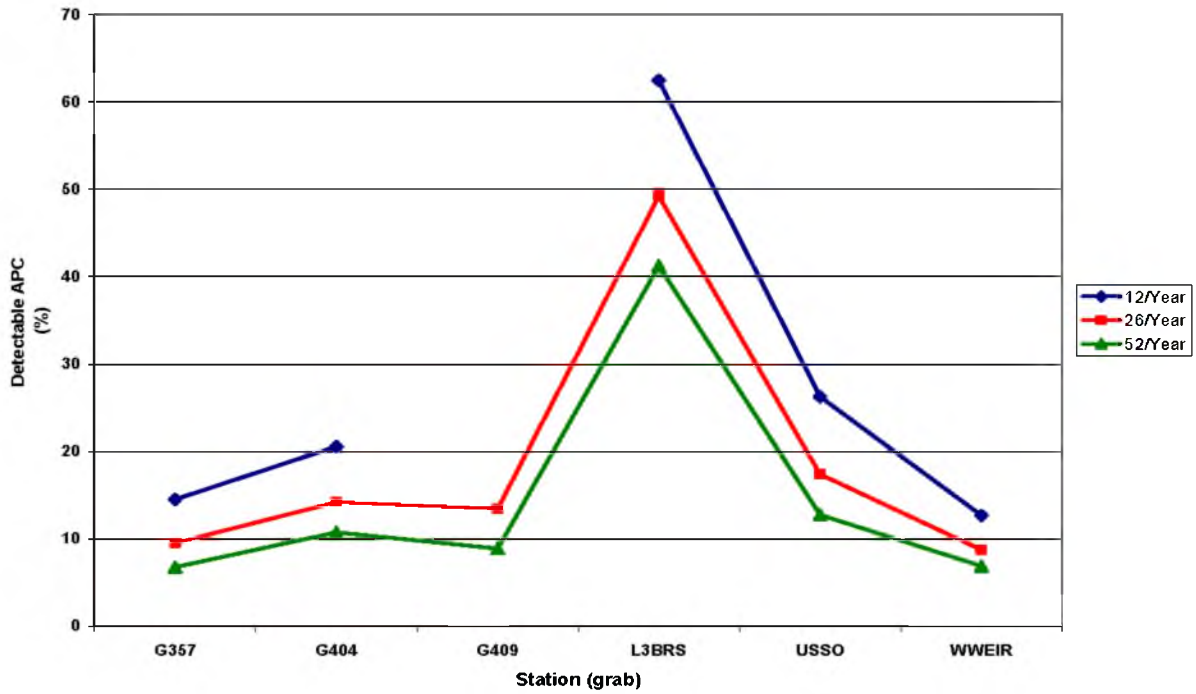


Figure 4. Comparison of annual percentage change (detectable_APC) in TPO4 with 80% power (p=0.05) for grab samples at SEMI monitoring stations.

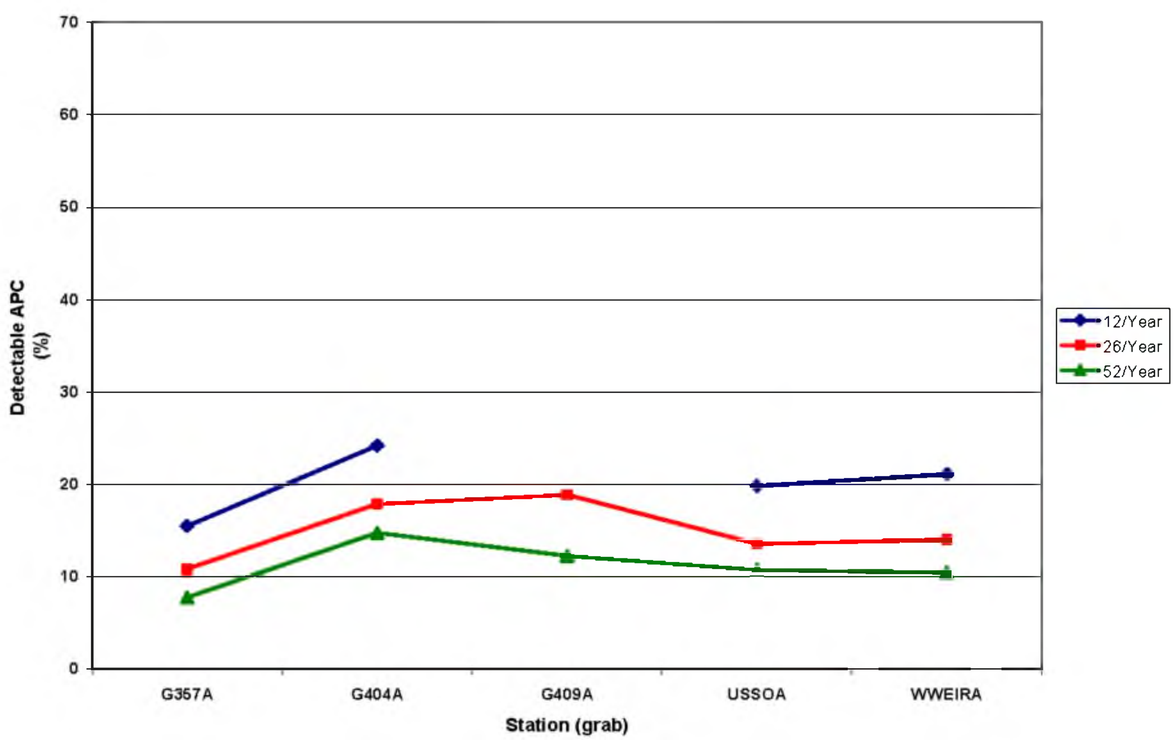


Figure 5. Comparison of annual percentage change (detectable_APC) in TPO4 with 80% power (p=0.05) for autosamples at SEMI monitoring stations.

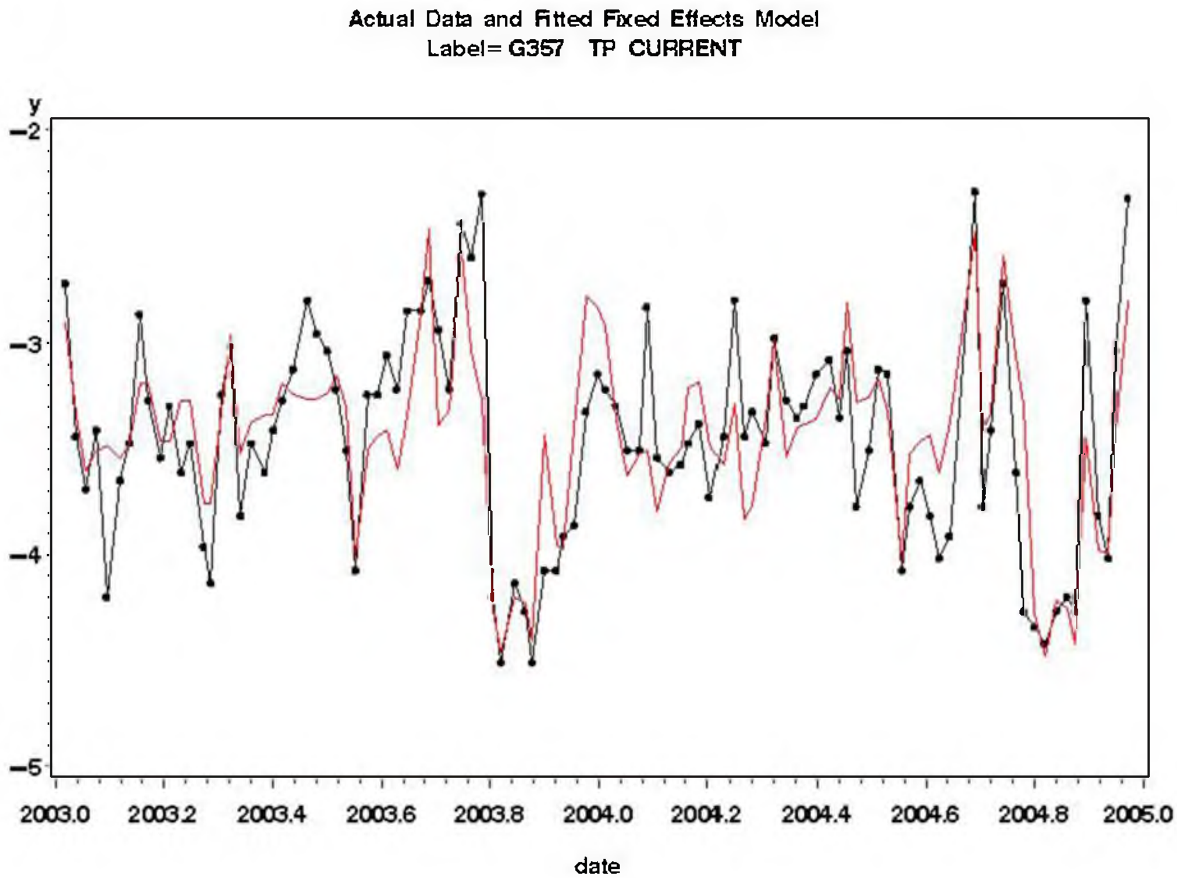


Figure 6. SEMI station G357 grab sampling, actual data (black line) and simulated output for model. Y-axis is log transformed TPO4 and x-axis is fractional year.

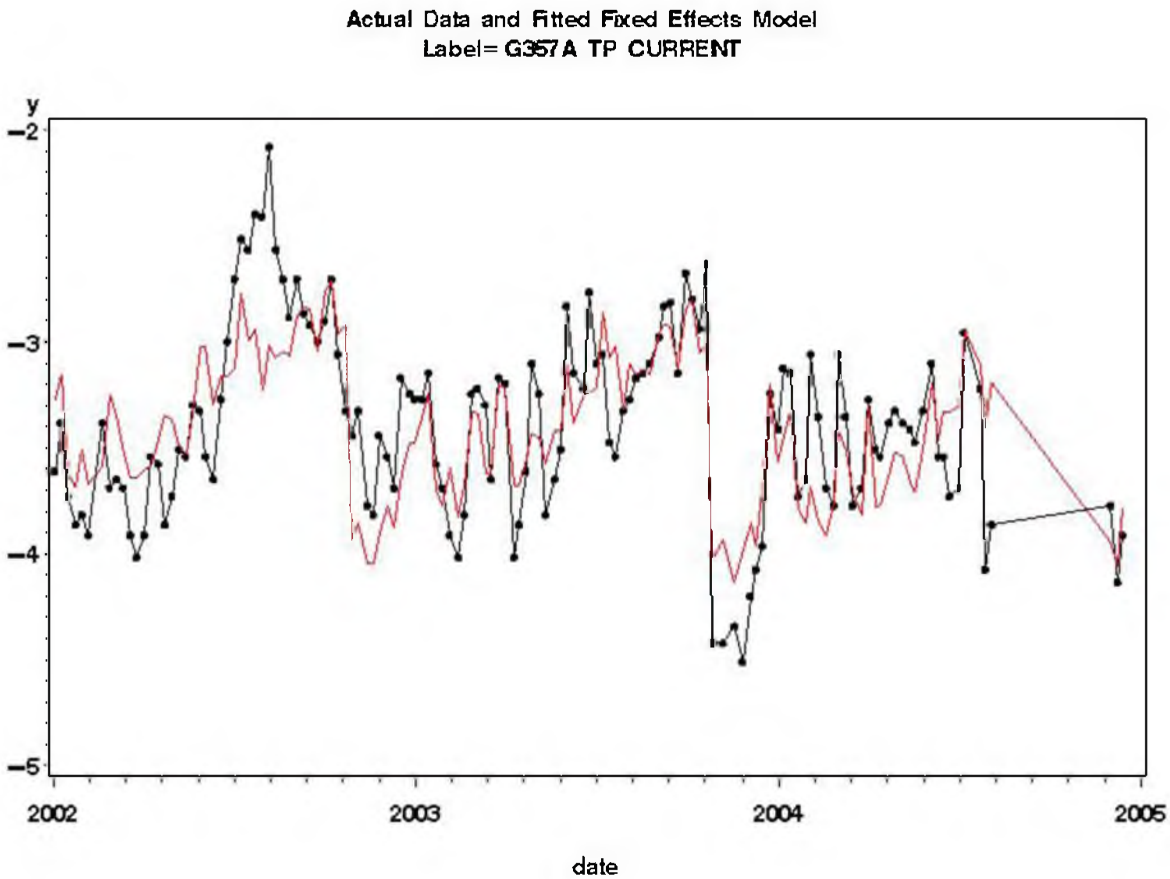


Figure 7. SEMI station G357 autosampler, actual data (black line) and simulated output (red line) for model. Y-axis is log transformed TPO4 and x-axis is fractional year.

Tables 4 and 5 present specifics for each sampling method. For the majority of grab sampling stations in the SEMI project, the current sampling frequency was adequate to detect a 20% change in slope over 5 years for TPO4 (Table 4 and 5). L3BRS is the exception with the current bi-weekly sampling frequency capable of detecting only a 49% change. Doubling the sampling frequency to weekly minimally improves the detectable_APC resolution to 41%. When simulations were run reducing the sampling frequency from weekly to bi-weekly, detectable_APCs rose slightly, all stations/samplers remained below 20% (Tables 4 and 5). Further reductions in sampling frequency to monthly pushed all stations above the 20% detection level, with the exception of G357 (grab and autosampler) and WWEIR (grab). The covariance pattern model resulted in non convergence in the 12 month simulation for station G409 (grab and autosampler) and a detectable_APC could not be calculated.

Temporal Recommendations:
Monitoring nutrient loads into to the Big Cypress Seminole Indian Reservation is an important component of maintaining the health of this important ecosystem. Examination of Figures 4 and 5 suggest that grab stations G357, G404, G409 and WWER can be optimized by reducing sampling frequency from weekly to bi-weekly, without an unacceptable loss in information. Grab stations G357 and WWEIR might also be considered as monthly sampling candidates. Optimization of autosampler stations G357 and USSO to bi-weekly sampling should be considered, as detectable_APC remain well below 20%. Only station G357 retains a detectable_APC below 20% when sampled on a monthly basis and is a possible candidate for monthly optimization.

Table 4. Effect of sampling frequency on detectable_APC for grab samples.

Station	Sampler Type	Number of Samples Per Year**	Annual Detectable Percentage Change	Can a 20 % Change be Detected?
G357	Grab	**52**	7	Yes
		26	10	Yes
		12	15	Yes
G404	Grab	**52**	11	Yes
		26	14	Yes
		12	21	No
G409	Grab	**52**	9	Yes
		26	13	Yes
		12	Cannot Calculate	Cannot Determine
L3BRS*	Grab	52	41	No
		26	49	No
		12	62	No
USSO	Grab	**52**	13	Yes
		26	17	Yes
		12	26	No
WWEIR	Grab	**52**	7	Yes
		26	9	Yes
		12	13	Yes

*Sampling frequency is bi-weekly when flowing, or monthly - 26 samples per year maximum
**Mandated base sampling frequency

Table 5. Effect of sampling frequency on detectable_APC for autosamplers.

Station	Sampler Type	Number of Samples Per Year**	Annual Detectable Percentage Change	Can a 20 % Change be Detected?
G357	Auto	52	8	Yes
		26	11	Yes
		12	15	Yes
G404	Auto	52	15	Yes
		26	18	Yes
		12	24	No
G409	Auto	52	12	Yes
		26	19	Yes
		12	Cannot Calculate	Cannot Determine
USSO	Auto	52	11	Yes
		26	14	Yes
		12	20	No
WWEIR	Auto	52	10	Yes
		26	14	Yes
		12	21	No

**Mandated base sampling frequency

Spatial Optimization:
Stations G357 and G404 feed water into stations G409 and USSO. TPO4 concentrations were examined at these stations to see if either G357, or G404, were providing the same information as concurrently sampled stations G404 and USSO. Stations providing reasonably similar data could be considered redundant and are candidates for optimization.

Similarities between stations for untransformed TPO4 concentrations were examined using monthly box-whisker plots, simple linear regressions, and Spearmans Rank correlations. TOP4 data were organized into four main groupings and compared as follows; G357:G409, G357:USSO, G404:G409, G404:USSO. Additionally, since all four stations under consideration are concurrently sampled by grabs and autosamplers TPO4, concentrations were compared by sampler type. Box-whisker plots were initially produced to provide a general perspective on special and temporal variability in TPO4 (see Figures 2 and 3 for examples).

Table 6 summarizes the results of linear regressions and Spearmans Rank correlations. Spearmans Rank correlations for grab samples are very small and only one comparison (G404:G409) is considered significant ($p \leq 0.05$). Regression equations for grab data have slopes ranging from 0.0154 to 0.0877, indicating a lack of predictable association between TPO4 measured on the same day. Analysis of TPO4 data collected by autosamplers suggest slightly better relationships, with slopes ranging from 0.0821 to 0.1480 and significant Spearmans Rank correlations ranging from 0.349 to 0.454. This is as might be expected, since grab sampling has the potential to capture episodic extremes, while autosamplers tend to average out small scale temporal variance. Figures 8 and 9 are representative regression graphics for G357:G409 grab and autosamper, respectively.

Spatial Recommendations:
Due to the absence of strong significant correlations and regression equation slopes much less than one (a correspondence of unity), stations G357 and G404 are not considered candidates for spatial optimization.

Table 6. Summary of station to station comparisons.

Stations Compared	Samper Type	n	Sample Dates Spanned: Beginning	Ending	Regression Equation TPO4 Grab vs. Autosampler	Spearman Rank Correlation	Significance (p)
G357-G409	Grab	111	8/3/2000	12/21/2004	G357 = 0.0786 * G409 + 0.0308, n=111	0.147	0.123
G357-USSO		108	11/13/2002	12/21/2004	G357 = 0.0154 * USSO + 0.0349, n=108	0.106	0.275
G404-G409		125	6/1/2000	12/21/2004	G404 = 0.0877 * G409 + 0.0292, n=125	0.183	0.041
G404-GSSO		114	9/18/2000	12/21/2004	G404 = 0.0593 * USSO + 0.0336, n=114	0.117	0.217
G357-G409	Auto	148	7/30/2001	12/13/2004	G357 = 0.0999 * G409 + 0.0322, n=148	0.349	<0.001
G357-USSO		134	8/7/2001	12/13/2004	G357 = 0.1480 * USSO + 0.0289, n=134	0.454	<0.001
G404-G409		104	5/30/2001	12/13/2004	G404 = 0.0821 * G409 + 0.0389, n=104	0.342	<0.001
G404-GSSO		107	4/11/2001	12/13/2004	G404 = 0.0881 * USSO + 0.0366, n=107	0.350	<0.001

SEMI Station G357 vs Station G409
(grabs on same day, double NDs excluded)

The REG Procedure
Model: MODEL1
Dependent Variable: value_G357 G357

Analyte=Total Phosphorous (TPO4)

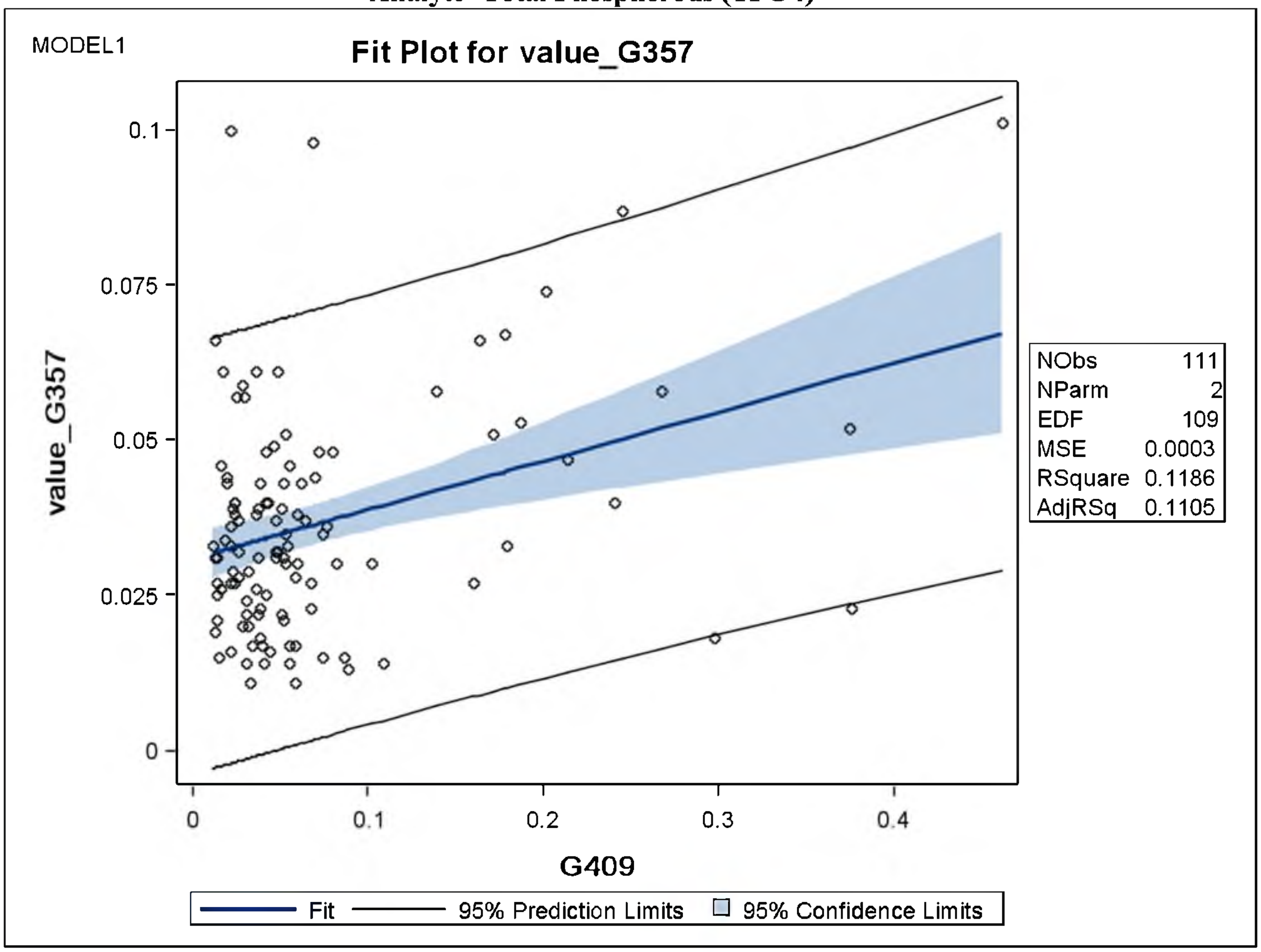


Figure 8. Linear regression of TPO4 concentrations collected by grab sampling at stations G357 and G409.

SEMI Station G357 vs Station G409
(Autosampler on same day, double NDs excluded)

The REG Procedure
Model: MODEL1
Dependent Variable: value_G357 G357

Analyte=Total Phosphorous

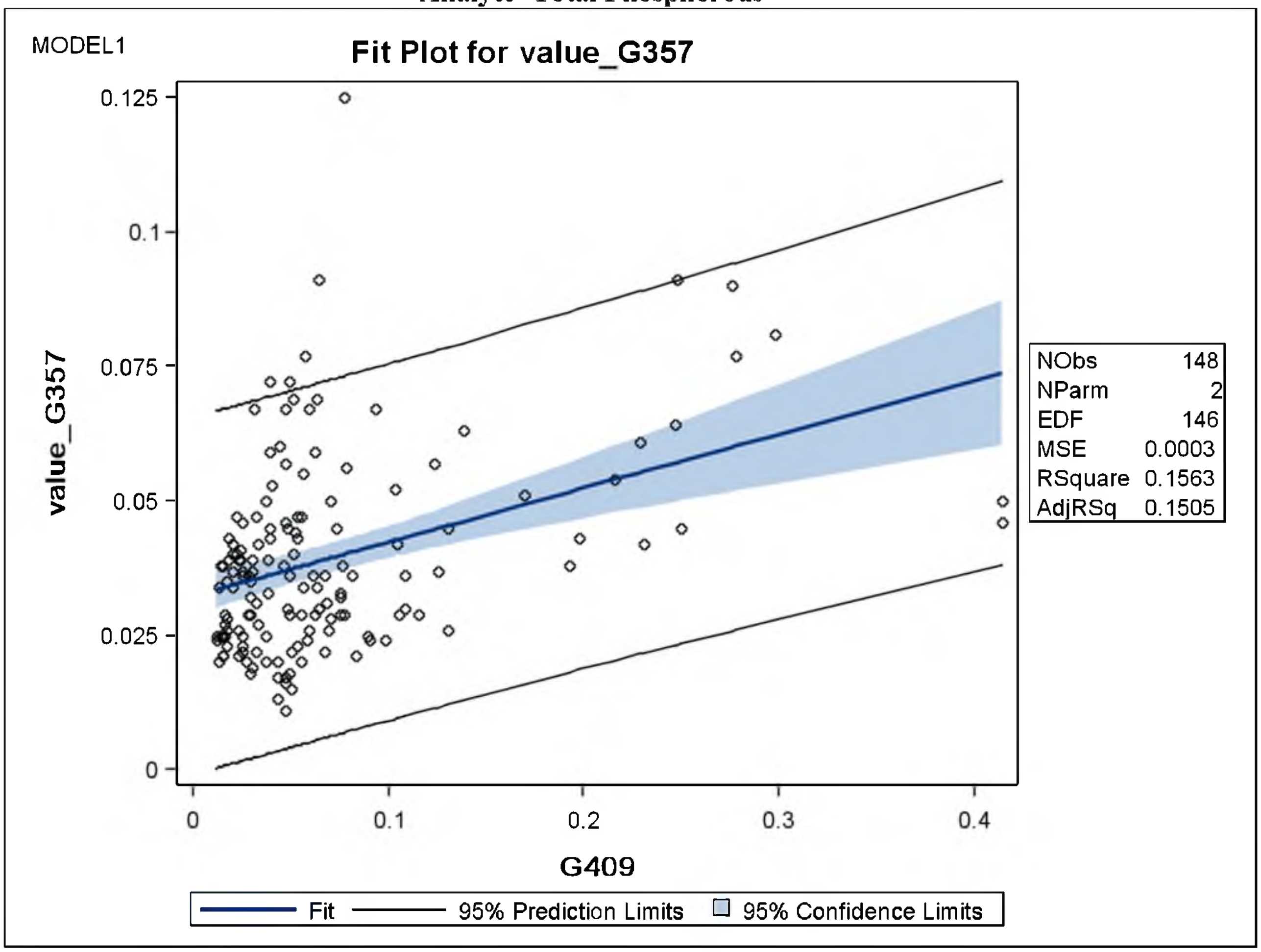


Figure 9. Linear regression of TPO4 concentrations collected by autosampler at stations G357 and G409.

Sampler Optimization:
Seven of the eight stations examined in this optimization are sampled with automated collection devices (L3BRS has only one observation derived from an autosampler). Similarities between sampling techniques for untransformed TPO4 concentrations were examined using monthly box-whisker plots, simple linear regressions, and Spearmans Rank correlations. TPO4 concentrations were examined at these stations to see if grab and autosamplers were providing the same information with respect to TPO4 concentration. Sampling methods providing reasonably similar data can be considered as candidates for optimization. As such, only samples from one collection device need be analyzed.

Similarities between stations for untransformed TPO4 concentrations were examined using monthly box-whisker plots, simple linear regressions, and Spearmans Rank correlations. Autosamplers, regardless of type, were considered generic and processed as a single sampler type. Box-whisker plots were initially produced to provide a general perspective on special and temporal variability in TPO4 (see examples shown in Figures 2 and 3).

Table 7 summarizes the results of linear regressions and Spearmans Rank correlations. Spearmans Rank correlations for sampling techniques are generally strong ranging from .0575 to 0.965 and significant ($p<0.001$). Regression equations have positive slopes and range from 0.4665 to 0.9636, indicating predictable association between sampler types collecting TPO4 samples on the same day. As a note of clarification for Table 7, station names beginning with "A" in the regression equation represent autosampler data (X-axis in Figure 8). Autosamplers tended to provide consistently greater estimates of TPO4, as evidenced by the positive slopes in the regression equations. Figure 10 is a representative regression graphic for grab and autosampler data.

Sampler Recommendations:
Strong significant correlations and regression equation slopes generally greater than 0.5 (1.0 is a perfect correspondence) suggest optimization of sampler type through the elimination of one sampling technique is warranted. This recommendation should; however, be viewed with caution and the choice of the technique to be eliminated carefully considered, especially if grab sampling is to be considered as a "backup," or quality assurance procedure. The data examined in this optimization do not provide insight into which sampling technique better reflects "real" TPO4 concentrations. Grab sampling has the potential to capture episodic extremes, while autosamplers tend to average out small scale temporal variance and may preclude the identification of high concentration TPO4 spikes. Additionally, the TPO4 relationship between grab samples and autosamplers vary between stations and add additional uncertainty into the practicality of completely eliminating one sampling technique.

Table 7. Summary of grab and autosampler comparisons.

Station	n	Sample Dates Spanned		Regression Equation	Spearman	Significance
		Beginning	Ending	TPO4 Grab vs. Autosampler	Rank	(p)
G357	91	5/21/2002	8/3/2004	G357 = 0.8290 * AG357 + 0.0079, n=91	0.727	<0.001
G404	80	2/19/2002	12/13/2004	G404 = 0.5172 * AG404 + 0.0166, n=80	0.575	<0.001
G409	84	11/13/2002	8/3/2004	G409 = 0.9636 * AG409 + 0.0047, n=84	0.877	<0.001
NFEED	219	6/19/1997	5/7/2002	NFEED = 0.9424 * ANFEED + 0.0019, n=219	0.904	<0.001
PC17A	12	8/10/2004	11/9/2004	PC17A = 0.5383 *APC17A + 0.0539, n=12	0.965	<0.001
USS0	161	3/7/1996	12/13/2004	USSO = 0.4665 * AUSSO + 0.0402, n=161	0.711	<0.001
WWEIR	246	12/24/1997	12/13/2004	WWEIR = 0.5161 * AWWEIR + 0.0169, n=246	0.823	<0.001

SEMI Station G357 Grab vs Autosampler

(sampled on same day, double NDs excluded)

The REG Procedure

Model: MODEL1

Dependent Variable: value_G357 G357

Analyte=Total Phosphorous

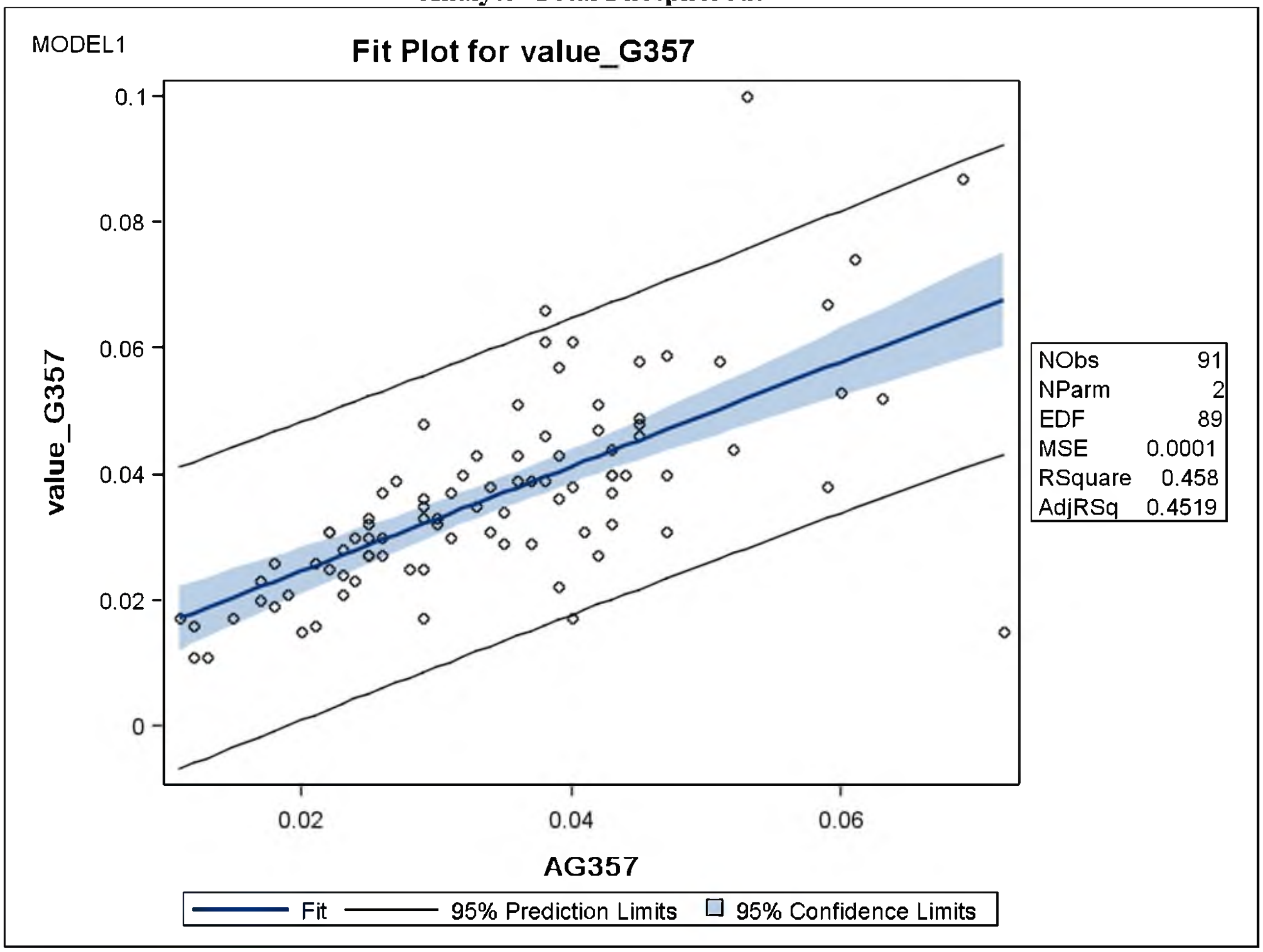


Figure 10. Linear regression of TPO4 concentrations produced from samples collected by grabs and autosamplers.

Stormwater Treatment Area 1 West

Optimization Leader: Probas Adack, Barnes, Ferland and Associates
Statistician: Probas Adack, Barnes, Ferland and Associates

Project Title: ST1W

Type: Type II

Mandate or Permit:

- Everglades Forever Act Chapter 373.4592 F.S.
- Clean Water Act
- EAA Rule Ch40E-63

Project Start Date: June 1994 for the first 4 cells;
1998 - Optimization to reduce sites and frequency;
2000 - Cell 5 came online

Division Manager: Everglades Division: Jamie Serino

Program Manager: Program Manager: Dean Powell

Project Manager: Jana Newman

Points of Contact: Jana Newman and Kristin Larson

Field Point of Contact: Kristin Larson

Spatial Description:
Stormwater Treatment Areas (STAs) are large treatment wetlands that are being constructed in many locations throughout South Florida to remove nutrients from stormwater prior to discharge into the Everglades Protection Area. The initial short-term nutrient removal occurs via uptake by emergent and submergent vegetation (along with associated periphytic algae), while long-term phosphorus removal from the surface water is effected through the accretion of peat over time. Stormwater Treatment Area 1 West (STA-1W) was constructed in two phases, with the first phase of construction, Cell 1- 4, completed in 1994. The first phase, often referred to as the Everglades Nutrient Removal Project (ENR and ENRP) was constructed to begin to evaluate the effectiveness of phosphorus removal within in a large constructed wetland in south Florida. STA-1W was subsequently expanded with the construction of Cell 5, which became operational in 2000.

STA-1W is located in western Palm Beach County, bordered by the Everglades Agricultural Area (EAA) to the north and west and by Water Conservation Area 1 (WCA 1) to the south and east. It is currently comprised of five cells that are separated by a series of canals and levees and provides 6,670 acres of effective treatment area (Figure 1).

All STAs are required to have NPDES permits, which, at a minimum, require flow-proportional water sampling be conducted at the major inflows and outflows of the STA. However, the Long Term Plan for Achieving Water Quality Goals, which was accepted into the revised Everglades Forever Act, mandates that phosphorus mass into and out of each treatment cell be reported annually. This mandate requires additional sampling sites be located along the internal levees of the STAs. The database and monitoring plans for STA-1W list 22 internal locations that have been sampled via grab, by autosampler, or both over the course of time. All of these locations are Type 2 mandated sites, although three of these locations (G300, G301, G302) were identified in early 2005 as likely to become Type 1 permit mandated sites for the Loxahatchee National Refuge permit. Early discussions with District staff identified two additional locations to consider along with the information from ST1W for this optimization. These stations include ENR012 (G251) and G310. These stations are sampled under ST1W.

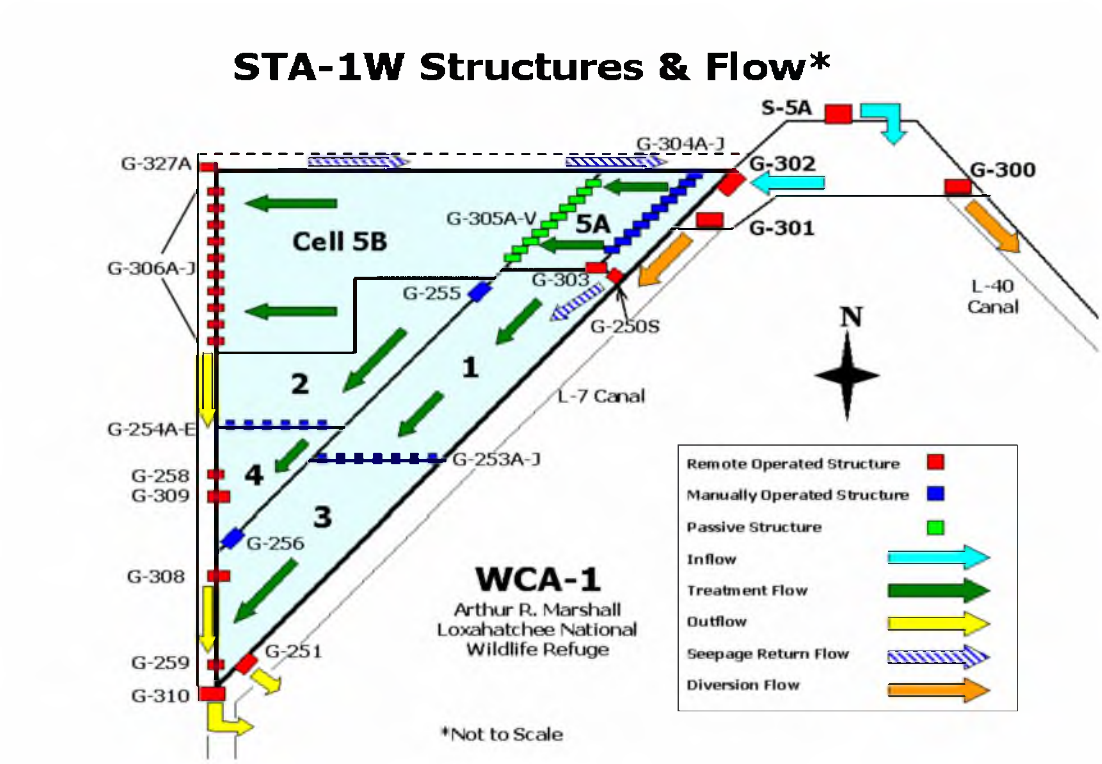


Figure 1. Configuration of sampling stations and flows in STA-1W as of October 2005.

Project Purpose, Goals and Objectives:
Due to the long project history, the ST1W project was formerly also coded as ENRR and ENRU projects. The primary purpose of Project ST1W is to respond to the Everglades Forever Act mandate that requires the annual reporting of phosphorus mass into and out of each cell within STA-1W. The main focus of the monitoring is to determine the long-term phosphorus removal performance of each cell, both independently as well as within a flow-path. The objective being that this data will be used to further calibrate a dynamic operational model and provide direction to further optimize the STA to reach the phosphorous criterion of 10 ug-P/L. Secondarily, the monitoring data is used to try to determine any effects management or operational decisions may have on treatment performance.

Project ST1W is unique in that some of the monitoring stations comprising this project were used to support the research conducted as part of projects ENRR and ENRU. Therefore, some of the nomenclature referring to these sites as research sites still exists within the current sampling documents. However, sampling at many of the original research sites that tested parameters associated with projects ENRR and ENRU has been discontinued. Additionally, the list of test parameters at each site has been drastically reduced. The Florida Department of Environmental Protection (FDEP) recognized the need to monitor the performance of individual cells along with the entire STA, and in subsequent STA operating permits has mandated the collection of water samples into and out of each cell within an STA so that a phosphorus budget may be developed for each cell of an STA. It is probable that if the STA-1W permit were to be re-written at this time, FDEP would follow the same logic and specify sampling locations at the inflows and outflows of each cell.

Sampling Frequency and Parameters Sampled:
Approximately 3 years ago, the parameters that are sampled at all STAs for cell by cell analysis were standardized. As of May 2005, total phosphorus is measured weekly via autosamplers at 13 stations in STA-1W. Two stations are sampled via autosampler biweekly and one station has been fitted with an autosampler and will come online in the near future. Grab samples are collected from 18 stations within STA1W. Grab samples for alkalinity, calcium, chloride, total suspended solids, ammonia, total Kjeldahl nitrogen, and nitrite+nitrate are collected biweekly; total

phosphorus, orthophosphorus, and total dissolved phosphorus are collected weekly; and total dissolved solids, turbidity, sulfate, and total dissolved Kjeldahl nitrogen are collected biweekly from G310 and ENR012 only. In situ measurements are also collected along with the grab samples. *In situ* measurements include dissolved oxygen, water temperature, pH, and specific conductance. The sample depth is also recorded.

Current and Future Data Uses:
The data collected under ST1W are used in mass balance/regression analysis to calculate a TP budget for each cell and the STA as a whole. The data from Project ST1W will continue to be used in the South Florida Environmental report and many peer-reviewed manuscripts. The data is also included in annual updates and workshops pertaining to the EFA. The STA and Operations staff meet weekly to discuss any specific operational concerns and to provide operational recommendations to District managers.

Data from STA1W is critical for the CERP EAA STAs projects, and is relevant to several ACCELER8 projects in the area. Much of the STA-1W data has been provided to and used in the calibration of the DMSTA model that is being further developed to assist in the sizing of future STAs. The sampling locations may be used in the RECOVER monitoring and Assessment Plan; however, the monitoring locations for the Greater Everglades module have yet to be selected.

Optimization:
Early discussions with District staff identified several potential opportunities for optimization including inclusion of two stations (ENR012 and G310) in the analysis. Additionally, questions were generated that the team felt would be useful for guiding the optimization. These were:

- Can some type of power analysis be used to determine if the level of error observed in the data is acceptable or are there too few sites?
- How comparable are the stations within the project area temporally and spatially?
- Do parameters correlate? Are there redundancies?

Other optimization scenarios were discussed with the District project manager during the course of the investigation. One possibility identified was to a statistical comparison of autosampler and grab sample data. However, previous comparisons done by the District (Jana Newman, personal communication) have shown that the two sampling methods provide comparable results. Thus, this optimization effort was deemed unnecessary. Another possible optimization was to reduce sampling events during dry season when flow is not significant. This was deemed counterproductive since District has observed occasional high spikes during the dry season. The project team considered reduction in the dry season sampling effort, but determined that such changes would only add to the uncertainty in the data due to episodic events and operational considerations that the water quality teams have little control over.

Review of the parameters measured under ST1W (Table 1) reflect the evolution of the measurement program and reveals the program has recently focused on dissolved oxygen, TKN, Total Phosphorous (TPO4), total particulate phosphate (TP), and total suspended solids (TSS). The project team determined that the key variable is Total Phosphorous (TPO4). NOx and TSS were dropped from the optimization list in consultation with the District ST1W project manager. The above parameter set, in addition to flow, is includes the key variables necessary to meet the projects objectives.

Table 1. Number of Station Sampling Events by Year and Parameter

NOTE: Multiple samples may be collected at a particular station

Project Code=ST1W

	Year											
	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	N	N	N	N	N	N	N	N	N	N	N	N
	All	All	All	All	All	All	All	All	All	All	All	All
Parameter												
CHLA		15	26	27	26	26	26	1				
Color							1	26	52	54	52	48
DO	3	47	69	54	51	52	236	487	503	241	927	823
Salinity	3	30	15								86	
TKN	3	257	455	180	180	178	58	439	468	470	467	396
TP	3	532	987	853	823	810	621	724	689	870	964	863
TPO4	3	257	511	464	446	434	239	445	453	664	807	784
TSS	3	258	519	465	416	433	183	442	471	579	572	404
Turbidity		236	449	181	178	178	58	38	52	55	52	50

During the course of the optimization effort several changes to the project, including the sampling design and mandates, were made as the District worked to refine the sampling program and increase understanding regarding the effectiveness of the various cells to treat water. Table 2 conveys the current use (inflow versus outflow) of the eighteen (18) stations that are currently sampled in the project. Note that the treatment area operation calls for several stations to serve in either capacity depending on operational requirements. The summary tables have been updated to reflect the present set of sites sampled. Moreover, the stations listed reflect modifications to the experimental design made as a result of ongoing District assessment of the data. Note also that project objectives require merging of flow data with the water quality data to estimate removal efficiency (e.g. determine mass balance), since phosphorus loading and export out of the STA are the key indicators of system performance. Since flow data and loading estimates were not included as a part of the optimization study, the ability to optimize STA1W was limited.

Table 2. Cell-wise inflow and outflow water quality stations

Type	Cell	Station ID
Inflow	5A	G302
Outflow	5A	G305G, G305N
Inflow	5B	G305G, G305N
Outflow	5B	G327A, G306C, G306G
Inflow	Cell1	G303, G250S (ENR002)
Outflow	Cell1	G253C, G253G
Inflow	Cell2	G255
Outflow	Cell2	G254D, G254B
Inflow	Cell3	G253C, G253G
Outflow	Cell3	G308, G259, G251(ENR012)
Inflow	Cell4	G254B, G254D
Outflow	Cell4	G310
Outflow	Cell4	G309

Meetings in October 2005 determined that little additional statistical optimization from that conducted by the District could be conducted since 1) the sampled sites are each integral to determining phosphorous removal efficiencies, 2) several locations have FLDEP permit requirements (Type I) being applied to them, and 3) there has been an ongoing District effort to optimize the sampling efforts. Moreover, operational protocols drive much of the water movement and timing, thus are difficult to optimize from the water quality perspective. During the meeting it was determined that a revised optimization approach be adopted. Specifically questions regarding the spatial adequacy of water quality stations sampled across a levee were raised. The accuracy of the estimated phosphorous export (outflow) from Cell 5B was identified as potential problem since water quality data from these two sites are often different due to the length of the pathway from the source locations and residence time of the water drawn from the cell at these locations may be different. It was therefore determined that a statistical evaluation should be performed to determine the comparability of the data from stations G306C and G306G and to make recommendations regarding the adequacy of the current design to account for the uncertainty in the mass balance calculations.

Outflow station comparability

Time series of TPO4 concentrations from stations G306C and G306G were plotted for grab samples (Figure 2) and automatic sampler data (Figure 3). The TPO4 data represented in the figures suggest that even though these are stations located on the outflow side of the same cell, the TPO4 concentrations do not necessarily follow each other. This may reflect spatial variation within the cell or be attributed to flow differences. The TPO4 difference between the two stations was examined with an *F*-test, which examines the equality of variances at the 0.05 level of significance. The F-test of both the grab sample data and the autosampler data suggest that there is statistical significant difference (p values <0.05) between the variances of TPO4 data at the Cell 5B outflow stations (Table 3).

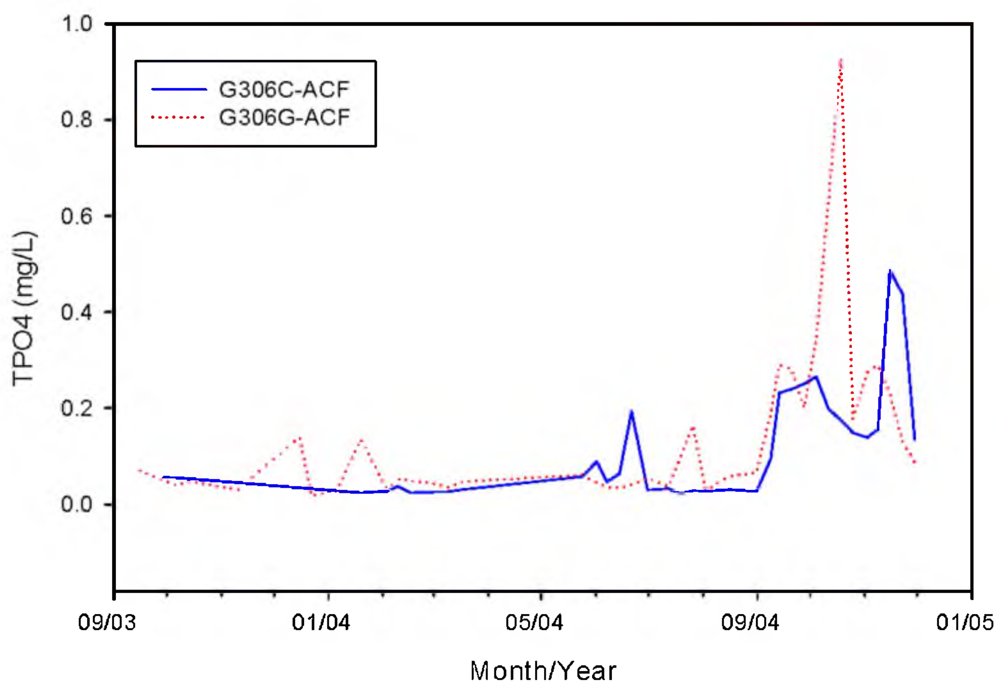


Figure 2. Time series of TPO4 data from outflow stations of cell 5B collected by flow composite sampling

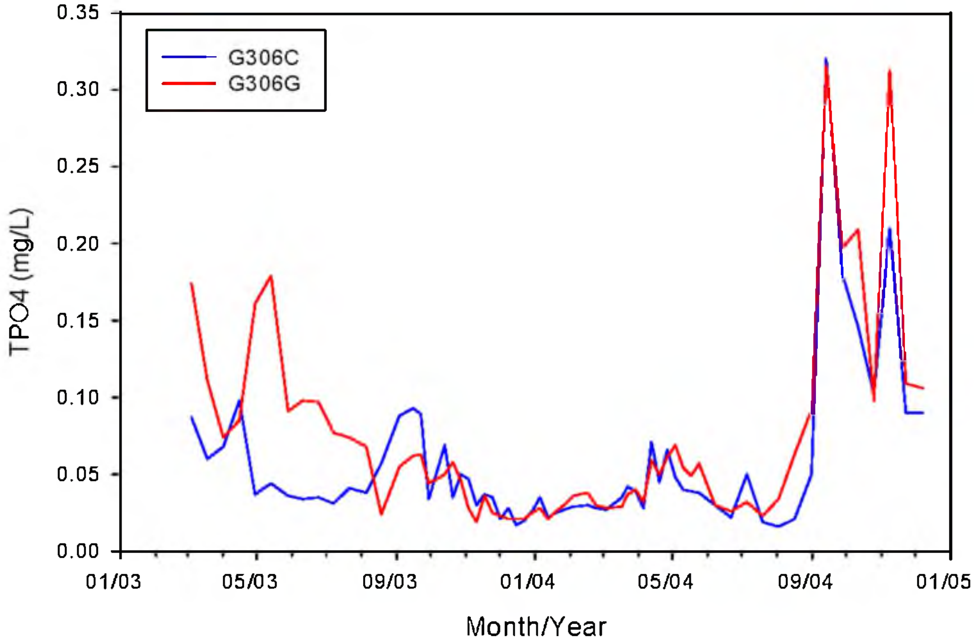


Figure 3. Time series of TPO4 data from outflow stations of cell 5B collected by grab sampling.

Table 3. F-test two sample for variances for the grab samples data and the flow composite automatic sampler data.

Grab Samples

	G306C	*G306G*
Mean	0.0555645	0.070241935
Variance	0.0025362	0.003998186
Observations	62	62
df	61	61
F	0.6343337	
P(F<=f) one-tail	0.0389719	
F Critical one-tail	0.6540937	

Autosampler Flow Composite

	G306C	*G306G*
Mean	0.1145946	0.21875
Variance	0.0129876	0.02329871
Observations	37	32
df	36	31
F	0.5574378	
P(F<=f) one-tail	0.0461897	
F Critical one-tail	0.5649543	

Discussion

The data needs for STA1W are based on District's requirement to be able to understand the workings of the system in terms of phosphorus removal. The current sampling regime has gone through previous internal optimizations to eliminate possible redundancies, thus only limited additional optimizations could be conducted. Moreover, the statistical analysis for this project was limited due to the lack of flow data from which mass balance considerations could be statistically evaluated.

The optimization effort consisted of reviewing the project with the District's project team and evaluating whether the sampling locations of a cell's outflow gave similar results. The analysis indicates that outflows within the same cell can be variable and are not always in sync across the cell boundary. The variability could be as a result of District operations or natural processes acting within the cell. To ensure the uncertainties are better understood, a short-term autosampler study (6 months to 1 year) that samples cell boundaries at a more highly resolved spatial scale and over a range of outflow conditions is recommended. Until more highly resolved spatial data is available, estimates of the optimal number of locations to sample to meet mass balance and efficiency requirement is not possible.

Retention of grab samples to address potential spikes in concentrations levels is recommended as a reasonable alternative to deploying replicated autosamples.

Parameters measured In Situ for Project ST1W as of October 2005.

Station	DO	DEPTH	TEMP	PH	SCOND
G251 (ENR012)	w	w	w	w	w
G253C	w	w	w	w	w
G253G	bw	bw	bw	bw	bw
G254B	bw	bw	bw	bw	bw
G254D	w	w	w	w	w
G255	w	w	w	w	w
G259	w	w	w	w	w
G302	w	w	w	w	w
G303	w	w	w	w	w
G305G	w	w	w	w	w
G305N	w	w	w	w	w
G306C	w	w	w	w	w
G306G	w	w	w	w	w
G308	w	w	w	w	w
G309	w	w	w	w	w
G327A	bw	bw	bw	bw	bw
G250S (ENR002)	w	w	w	w	w
G310	w	w	w	w	w

w = weekly; bw = bi-weekly; gray shading indicates a Type 2 station.

Parameters measured from grab samples for Project ST1W as of October 2005.

Station	ALKA	CA	CL	TSS	NH4	NOX	SO4	TDKN	TDS	TKN	TPO4	OPO4	TDPO4	TURB
G251 (ENR012)	bw	bw	bw	bw	bw	bw	bw	bw	bw	bw	w	w	w	bw
G253C	bw	bw	bw	bw	bw	bw				bw	w	w	w	
G253G	bw	bw	bw	bw	bw	bw				bw	bw	bw	bw	
G254B	bw	bw	bw	bw	bw	bw				bw	w	w	w	
G254D	bw	bw	bw	bw	bw	bw				bw	bw	bw	bw	
G255	bw	bw	bw	bw	bw	bw				bw	w	w	w	
G259	bw	bw	bw	bw	bw	bw				bw	w	w	w	
G302	bw	bw	bw	bw	bw	bw				bw	w	w	w	
G303	bw	bw	bw	bw	bw	bw				bw	w	w	w	
G305G	bw	bw	bw	bw	bw	bw				bw	w	w	w	
G305N	bw	bw	bw	bw	bw	bw				bw	w	w	w	
G306C	bw	bw	bw	bw	bw	bw				bw	w	w	w	
G306G	bw	bw	bw	bw	bw	bw				bw	w	w	w	
G308	bw	bw	bw	bw	bw	bw				bw	w	w	w	
G309	bw	bw	bw	bw	bw	bw				bw	w	w	w	
G327A	bw	bw	bw	bw	bw	bw				bw	bw	bw	bw	
G250S (ENR002)	bw	bw	bw	bw	bw	bw				bw	w	w	w	
G310	bw	bw	bw	bw	bw	bw	bw	bw	bw	bw	w	w	w	Bw

w = weekly; bw = bi-weekly; *not yet operational; gray shading indicates a Type 2 station

Parameters measured by flow or time proportional autosamplers for Project ST1W as of October 2005.

Station	TPO4
G251 (ENR012)	w
G253C	w
G254D	w
G255	w
G259	w
G302	w
G303	w
G305G	w
G305N	w
G306C	w
G306G	w
G308	w
G309	w
G250S (ENR002)	w
G310	w

w = weekly; gray shading indicates a Type 2 station

List of changes from the June 2005 project summary

1. Stations G300 and G301, which were a part of the June 05 project summary, are not included in the sampling station list since the function of those stations is to pump water into Arthur R. Marshall Loxahatchee National Refuge not into STA1W.
2. Stations G251, which is also known as ENR 012, and G310 that was not included in the previous project summary are included in the sampling list.
3. Parameters such as sulfate (SO4), Total Dissolved Kjeldahl Nitrogen (TDKN), Total Dissolved Solids (TDS) and turbidity are included in the grab sampling list.