Appendix 12-4: Evaluation of Naples Bay Water Quality and Hydrologic Data

Taylor Engineering, Inc., June 2005

Evaluation of Naples Bay
Water Quality and Hydrologic Data
Final Report

June 2005

Evaluation of Naples Bay
Water Quality and Hydrologic Data

Prepared for:

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EXECUTIVE SUMMARY

Taylor Engineering applied the Southwest Florida Feasibility Study ACCESS database framework to compile water quality data for Naples Bay and adjacent tributary sampling stations and prepare a water quality database. Upon completion of the database, Taylor Engineering evaluated the data for their usefulness in assessing current conditions, trends, and water quality model setup and calibration. Taylor Engineering also reviewed hydraulic and meteorological data for the project area to determine data availability for setup and calibration of a hydrodynamic model of Naples Bay.

Water quality samples from 1957 to 2003 came from 155 stations throughout the bay and tributaries. Data that summarized water quality conditions in the bay area came from 150 of the 155 stations representing several general locations. Lower Naples Bay included all stations south of the US 41 bridge of the bay excluding tributaries. Upper Naples Bay included all stations above that point excluding tributaries. Tributary locations included (from south to north) Lely Canal, Haldeman Creek, Rock Creek, Gordon River, and Golden Gate Canal. The database also contains a set of stations in the Gulf of Mexico.

The data revealed that sampling programs intermittent in period, location, and parameters sampled. Most of the samples dated later than 1985, but the data record became more consistent in space and time with the advent of current ongoing sampling programs. Those efforts, started in 1999 and 2000, provide the most comprehensive and consistent data within the overall period of record.

Water quality data from 53 stations sampled between 1999 and 2003 provided the basis for an assessment of current conditions. Water quality conditions of concern in the four areas included both chemical and biological parameters. Dissolved oxygen, nitrogen, phosphorus, copper, iron, lead, and zinc often exceeded state water quality standards in more than 10% of the sample sets developed from the data for all samples in a location. Nutrient parameters also frequently exceeded nutrient criteria defined for Charlotte Harbor to the north and Indian River Lagoon to the east. Chlorophyll a concentrations and fecal coliform counts were often elevated relative to the state or regional estuary criteria.

Examination of the entire record for water quality parameters from lower Naples Bay revealed that the lower bay may episodically (as recorded in the early 1990s and again in 2001) become much less saline than normal. The most apparent pattern in the data is a decrease in nitrogen since 1990. The data seem to indicate that dissolved oxygen concentrations have decreased slightly given the number of

exceedances measured recently. However, this decrease may reflect the greatly increased sampling effort since 1999.

Upper Naples Bay did not exhibit the same change in nitrogen concentrations as seen in the lower bay. Total phosphorus has decreased since 1990. As in the lower bay samples, exceedance of dissolved oxygen standards commonly occurred throughout the record.

The less frequently sampled tributaries provide less data for examination. Annual median nitrogen values for Golden Gate Canal, developed from available TN and TKN data, showed a decline in the 1990s. That decline continued through the rest of the data record. The other tributaries did not show that change and generally exhibited a history of water quality problems.

Available hydraulic data provide sufficient information to develop boundary conditions for a hydrodynamic model. Existing hydraulic information and published tide charts would allow limited model calibration. An intensive calibration effort would require collection of tidal information at a set of measuring stations that would collect both hydraulic and water quality data for 48-hour periods in wet and dry seasons. These data collection efforts at key points within the bay would provide the necessary information for intensive model calibration for hydraulic and water quality parameters. These efforts would target — on a schedule from every hour to every six hours — stage, velocity, and water quality measurements (temperature, salinity, dissolved oxygen, turbidity, nitrogen species [TKN and nitrite+nitrate], total phosphorus and dissolved orthophosphorus, and chlorophyll a.

The current monthly water quality sampling program conducted in most areas of the bay could provide most of the data necessary to verify water quality simulations. Five additional sampling sites would ensure complete coverage of water quality conditions and dynamics in Naples Bay south to the confluence of the IWW and Henderson Creek.

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1.0 INTRODUCTION

The South Florida Water Management District (SFWMD) contracted Taylor Engineering to compile a database of long-term water quality data for Naples Bay. Taylor Engineering received instructions to "review the database for its quality, content and applicability and assess its adequacy for hydrodynamic and water quality model calibration and verification" (Scope of Work No. C15989-WO05-05, Professional Science and Engineering Services). Further, "if the database is deemed inadequate for development of a comprehensive set of hydrodynamic and water quality models, an auxiliary data collection program will be recommended."

This report provides this review and recommendations for additional efforts. The report presents the requested analyses in the following order:

- Data organization and review
  - A description of the data sources
  - A summary of the database information, including sampling site locations, plotted in GIS, with a discussion of data location, range, and quality.
  - Database statistics
- Condition / Trend Analysis
  - Evaluation of the general water quality conditions in Naples Bay in space and time.
- Data Gap Evaluation
  - An evaluation of the gaps in the hydrodynamic and water quality dataset with particular focus on the use of these data in the calibration and verification of a preliminary hydrodynamic and water quality model of the bay.
  - Recommendations for data collection efforts sufficient to complete a dataset useful for calibration and validation of Naples Bay hydrodynamics and water quality models.

2.0 DATA ORGANIZATION AND REVIEW

This section provides a general description of the existing water quality data for the Naples Bay surface water system including data sources investigated and general descriptions of the database.

2.1 Data Sources

Taylor Engineering contacted the following organizations identified in the Scope of Services for available hydrodynamic and water quality data associated with Naples Bay:

- Florida Department of Environmental Protection at the Rookery Bay National Estuarine Research Reserve
- City of Naples
- Collier County
- Conservancy of Southwest Florida
- South Florida Water Management District

In addition to these sources, Taylor Engineering downloaded all EPA STORET data for Collier County for January 1 1995 to the present; downloaded data from the FIU Southeastern Environmental Research Center, (SERC-FIU); and reviewed USGS and NOAA online databases. SFWMD/SERC Cooperative Agreements #C-10244 and #C-13178 as well as EPA Agreement #X994621-94-0 supported data provided by the FIU Water Quality Monitoring Network.

Taylor Engineering compared the sample set collected from these sources with a database recently compiled as part of the U.S. Army Corps of Engineers (USACE) Southwest Florida Feasibility Study (SWFFS). Reduction of the full SWFSS dataset to those data within the project watershed provided a basis for comparing the compiled data and the SWFFS database information. Comparison of the two data sets found that the SWFFS dataset contained the same water quality data Taylor Engineering collected and provided additional metadata not readily available to Taylor Engineering. Taylor Engineering added data concerning sample location within the Naples Bay watershed and reviewed the resulting database for quality and consistency.

The dataset provided a row for each parameter value for each station sampled for every sampling date. Each row included all associated details for the parameter. The project database product included the metadata for the SWFFS database, provided in separate tables.

The Taylor Engineering data analyst identified a variety of database errors and took several actions:

- Eliminated from the database sediment data incorrectly identified as surface water data
- Eliminated unflagged, duplicate parameter data from the database when found. (Note: Additional like samples may remain in the database.)
- Removed stations and parameter rows without data
- Corrected errors in latitude and or longitude data describing station locations. Note: Plotting all unique latitude longitude pairs revealed multiple locations with the same station code. Comparison of other data associated with the geographic location data ruled out mislabeling the station code. The GIS analyst revised the incorrect data to reflect the correct location. Typically, either latitude or longitude was incorrect in the third or fourth decimal place. Some station locations remained questionable due to insufficient information or lack of a parallel station in the likely appropriate location.

2.2 Database Characteristics

The compiled database contains data from 155 stations sampled from 1957 to 2003. Various analysis in the report used data from 150 of the sampling stations (Appendix A). Data collected in 2003 and 2004 were generally in agency review and unavailable at the time Taylor Engineering gathered the data.

The 155 stations provided approximately 57,000 data from 679 separate parameters (different parameter names), which reduced to 185 master parameters based on identified or assigned analytic method. These 185 master parameters fit into several categories (Table 2.1). The number of master parameters does not indicate the amount of data associated with a category.

Table 2.1 Categories of Water Quality Parameters Found in the Naples Bay Water Quality Database

Parameter Type	Description	Master Parameters
Biological	Bacterial counts, chlorophyll data, biochemical oxygen demand (BOD)	10
Metals	24 metals in one or more forms with concentration criteria for Florida surface water quality.	34
Mineral	Forms of calcium, carbonate, carbon dioxide, chlorides, magnesium, potassium, manganese, total dissolved solids, salinity, sulfates	28
Nutrient	Forms of nitrogen, phosphorus, and oxygen	21
Physical	Turbidity, light, conductivity, acidity, alkalinity, temperature	10
Radiation	Alpha particle measurements (very few samples)	2
Herbicides, Pesticides, Toxic Chemicals	A wide variety of pollutants with and without concentration criteria in Florida surface water quality Class III standards	76
	Total	181

2.3 Sample Stations

Most of the sampling of the 155 stations in the database occurred in the last quarter century. The database includes 26 stations sampled between 1957 (one station in that decade) and 1990 and 6 stations sampled only in the 1980s, but these 32 stations provided a minor portion of the total parameter values in the database. (Appendix A: Station names, periods of record, and location category). Current water quality evaluations used data from 53 of the 150 stations. The rest of the stations included those within the area of interest and without current data. Some of these samples contained data for only a single parameter (such as *Streptococcus* counts or enterobacterial counts), included only one or two sample dates, or only a few samples providing data only on chemical contaminants. Station period data in Appendix A may mislead the reader, as a station with a one-year period of record could have been sampled only once or twice during that time. The remaining stations were mainly in the Gordon Canal system and north of the bay in the extension of the Gordon River.

The stations (Figure 2.1) sorted into the following locations (different zones within the project area):

- Lower Naples Bay (Figure 2.2: The broader bay south of the US 41 bridge crossing), 49 stations
- Upper Naples Bay (Figure 2.2 North of the US 41 bridge to Golden Gate Canal), 12 stations
- The tributaries (Figure 2.2 from north to south) Gordon River Extension, 6 stations adjacent to the weir plus 21 more in the watershed; Golden Gate Canal, 7 adjacent to the weir and 41 in the watershed; Rock Creek, 4 stations; Haldeman Creek, 7 stations; and Lely Canal, 4 stations.
- Gulf of Mexico (Figure 2.2) 5 stations.

2.4 Data Quality

The data range widely in quality. More than half the parameter values have no STORET code or Standard Method number. Approximately half the data have no depth information. Thus, most analyses required some assumptions about the data. In the absence of depth information, Taylor Engineering assumed a surface sample. A fraction of the data includes flags for a variety of reasons, most notably unverifiable data, and unknown duplicate status of data. Station latitude and longitude data do not always correspond to the station name and description, problems corrected when a clear reason (identical station description for a different station name or station identification code) existed. However, stations with questionable location information remain in the database when resolving the issue became impossible (Figure 2.3). Database users should review station locations and descriptions before they access the data.

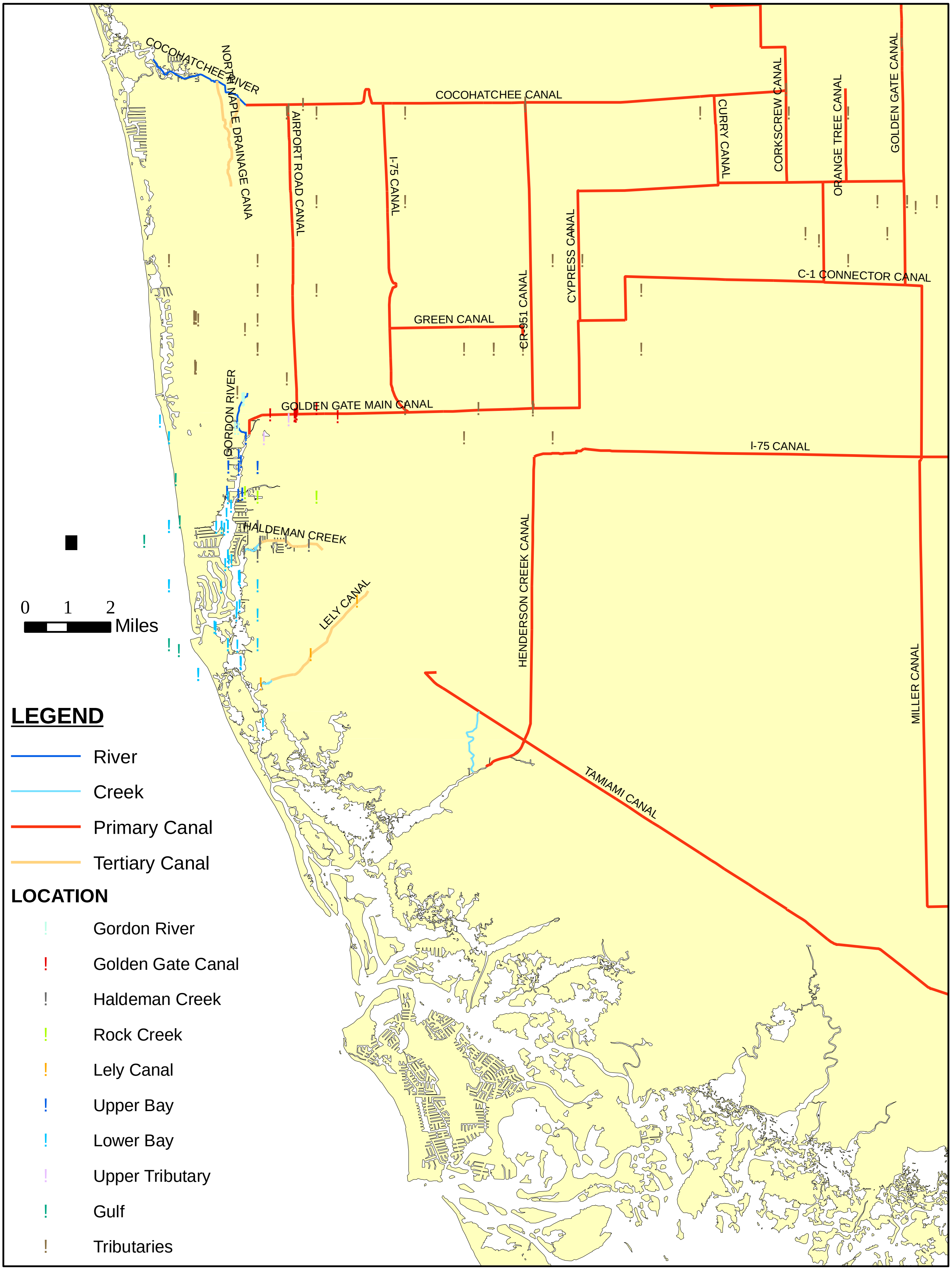

Figure 2.1 All Stations in the Naples Bay Database

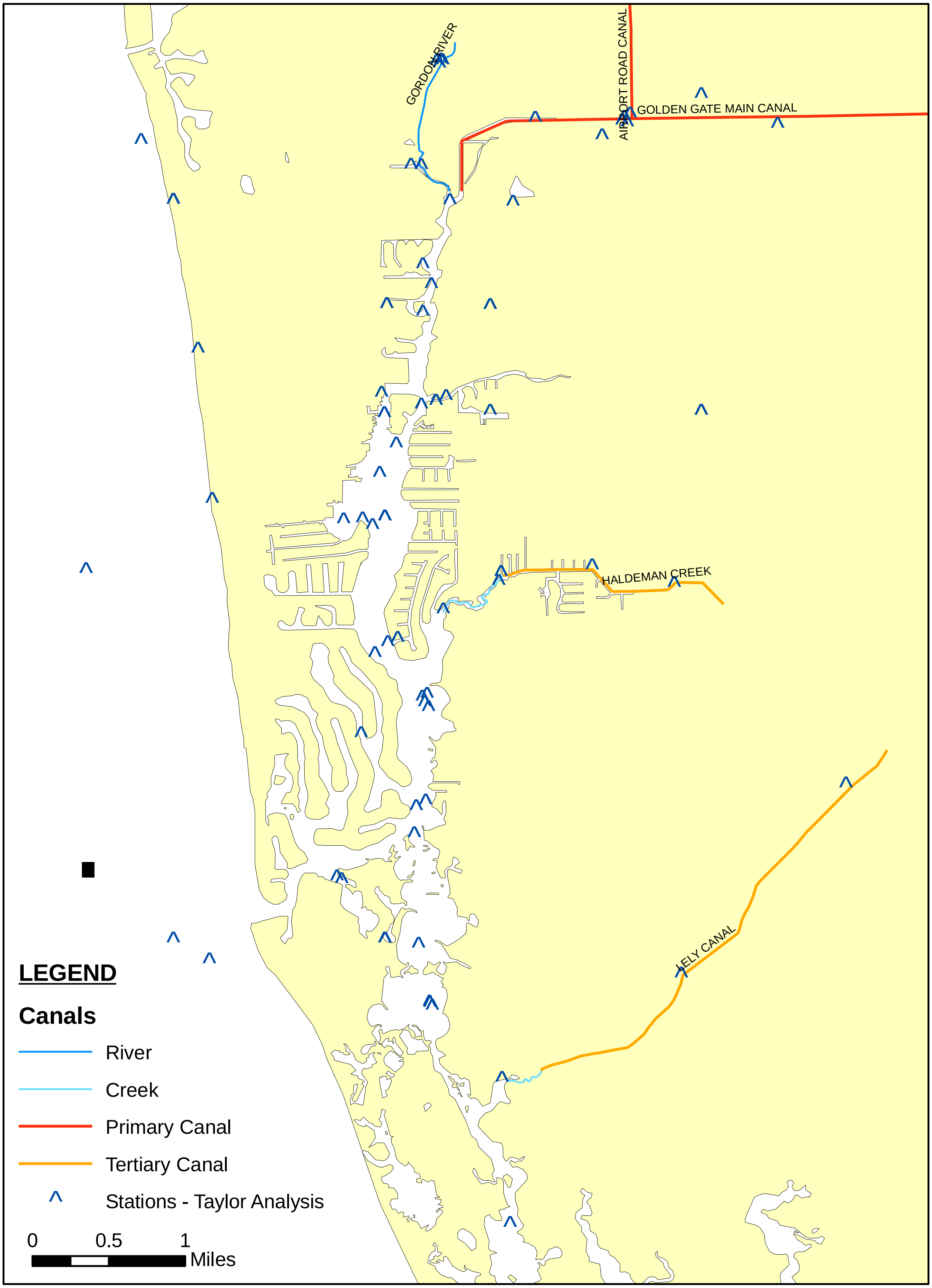

Figure 2.2 Stations Analyzed for Water Conditions and Trends

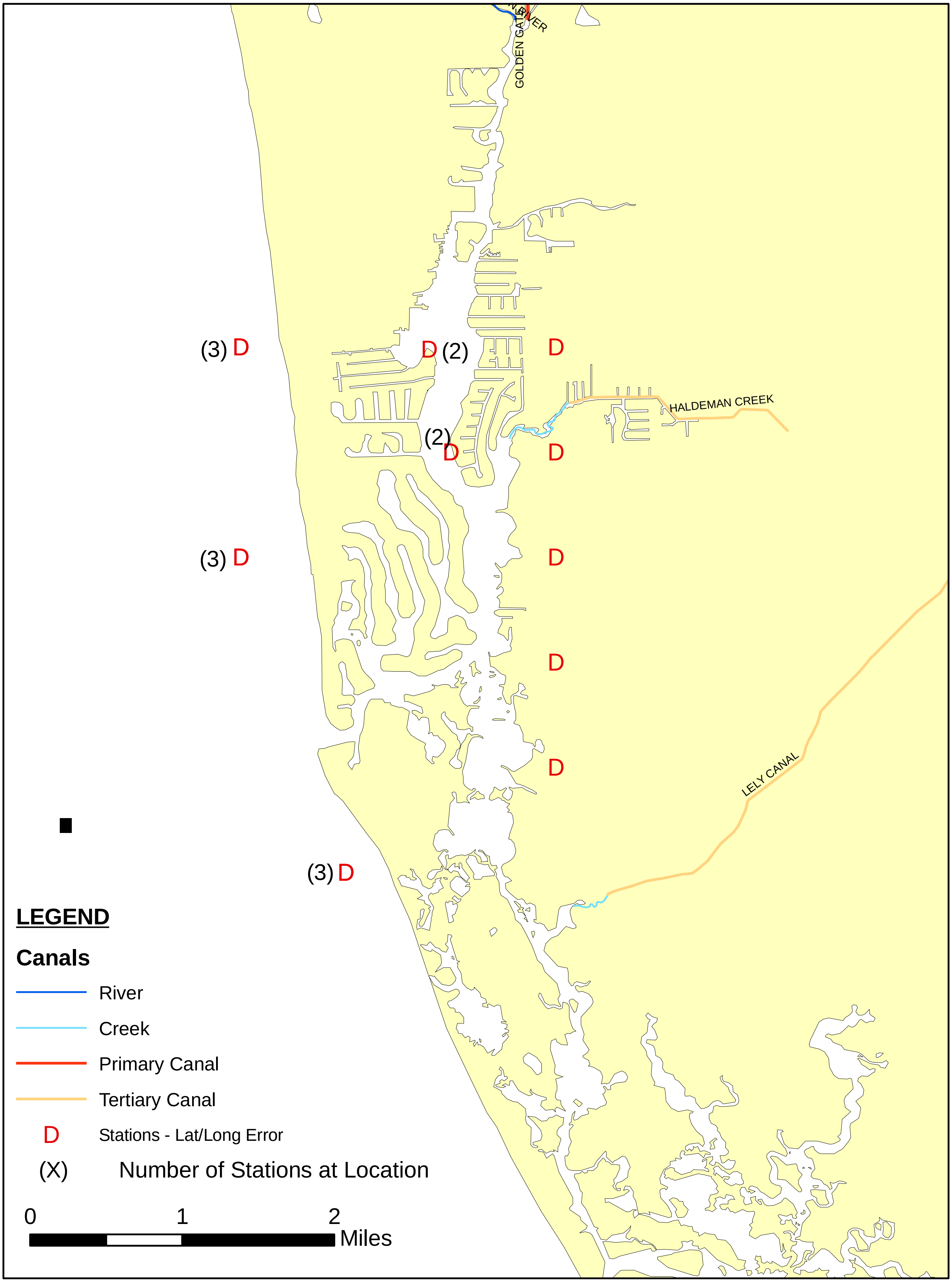

Figure 2.3 Stations with Unresolved Location (Latitude - Longitude) Data

3.0 CURRENT WATER QUALITY CONDITIONS

The summaries of current water quality conditions in Naples Bay for the Lower Bay, Upper Bay, Golden Gate Canal, Haldeman Creek, and Lely Canal considered the available data from 1999 – 2003. Lely Creek samples from a single station provided the current data for that tributary. Resumed only recently, sampling at Rock Creek produced insufficient data to construct a meaningful summary.

Florida numeric water quality standards (Table 3.1) provided the primary means of assessing water quality. Nutrient criteria identified in Janicki (2003) from the Charlotte Harbor Estuary Program (CHNEP) and the Indian River Lagoon SWIM Restoration Program (Table 3.2) provided insight into current conditions. Percent exceedances of numeric criteria provided a measure of impaired water status for the four areas. For fecal coliform counts, the value of 400 counts/100 ml provided the monthly exceedance measure. Insufficient numbers of multiple samples within a month at any station precluded an evaluation of monthly averages over the period of evaluation.

Table 3.1 Numeric Water Quality Criteria, Class III Marine Waters (62-302.530 F.A.C.)

Parameter	**Class III Predominantly Marine Waters**
Aluminum (mg/L)	= 1.5
Arsenic (µg/L)	= 50
Fecal Coliforms (#/100 ml)	= 400 monthly, 800 maximum
Total Coliforms (#/100 ml)	= 1000 monthly, 2400 maximum
Cadmium (µg/L)	= 9.3
Chromium (hexavalent)	= 50
Copper (µg/L)	= 50
Dissolved Oxygen (mg/L)	= 4.0 (marine waters) = 5.0 (freshwater)
Iron (mg/L)	= 0.3
Lead (µg/L)	= 8.5
Phosphorus (mg/L)	= 0.1
Turbidity (NTU)	=29 above natural background
Zinc (µg/L)	= 86

Freshwater dissolved oxygen criterion (D.O. = 5.0 mg/L) applied to tributary sampling station data upstream of weirs.

Table 3.2 Nutrient Criteria from Janicki (2003) applicable to Naples Bay

CRITERIA Source	TP (mg/L)	TN (mg/L)	Chlor a (ug/L)	Secchi Disk depth (m)	Turbidity (NTU)
CHNEP*	0.01	0.40	2.1	0.70	2.2
IRL**	0.053	0.692	3.1	1.44	2.84

*Data for 25th percentile of the data for a parameter
**Not-to-exceed value

Appendix B provides box and whisker plots of key water quality variables from individual lower bay stations for the current conditions period (1999 – 2002).

3.1 Lower Naples Bay Current Conditions

The southern, wider portion of Naples Bay showed elevated levels of many parameters and exceedances of water quality standards for several metals and fecal coliform maximum values. While typically near marine salinity conditions, the bay may experience very low salinity conditions during the summer rainy season. (Table 3.3: Salinity minimum value) The most recent low salinity event recorded in the database occurred in summer 2001 (Figure 3.1). Turbidity was typically low, and median secchi disk depth was 1.2 m. The lower bay data exceeded acceptable CHNEP water quality parameters for TP, chlorophyll a, and turbidity. A large fraction or a majority of the copper, iron, lead, and zinc samples exceeded water quality standards (Table 3.3). Lower Bay sample nutrient values at the 75th percentile and above exceeded all IRL nutrient criteria.

Table 3.3 Summary of Current Water Quality Parameters in Lower Naples Bay

Lower Naples Bay Parameter	N	Min	25th %	Mean	Median	75th %	Max	% Exc
Salinity (‰)	277	0.48	30.20	31.34	34.10	35.60	41.50	N/A
Temperature (^{o}C)	267	5.30	22.30	25.45	26.20	29.30	32.40	N/A
Turbidity (NTU)	166	0.30	2.30	4.60	3.20	5.00	30.40	N/A
Secchi (m)	108	0.40	0.90	1.92	1.20	2.54	8.86	N/A
DO (mg/l)	267	1.50	4.50	5.75	5.60	6.70	19.40	16.1
TP (mg/l)	151	0.0018	0.0313	0.0445	0.0389	0.0525	0.1100	2.0
SRP (mg/l)	124	0.0003	0.0031	0.0088	0.0061	0.0111	0.0530	N/A
TN (mg/l)	124	0.022	0.190	0.339	0.295	0.415	1.550	N/A
NH4 (mg/l)	120	0.00	0.01	0.08	0.01	0.03	5.01	N/A
Chlor A (mg/l)	201	0.15	2.70	6.34	4.80	8.00	87.00	N/A
Fecal (CFU/100 ml)	103	1	3	147	27	130	3200	3.9
TSS (mg/l)	39	1.00	6.00	15.72	8.40	18.20	76.00	N/A
Arsenic (µg/l)	40	0.50	4.30	4.05	5.00	5.00	5.00	0
Cadmium (µg/l)	42	0.05	0.33	2.73	2.50	2.50	12.00	4.8
Chromium (µg/l)	42	1.0	1.0	4.4	2.5	6.0	22.0	0
Copper (µg/l)	42	0.5	2.2	5.9	5.0	5.0	47.0	66.7
Iron (mg/l)	10	0.3	0.4	0.7	0.5	0.5	2.5	90.0
Lead (µg/l)	42	0.5	1.4	6.9	2.5	13.0	26.0	35.7
Zinc (µg/l)	42	5.0	5.0	15.5	5.0	10.0	60.0	28.6

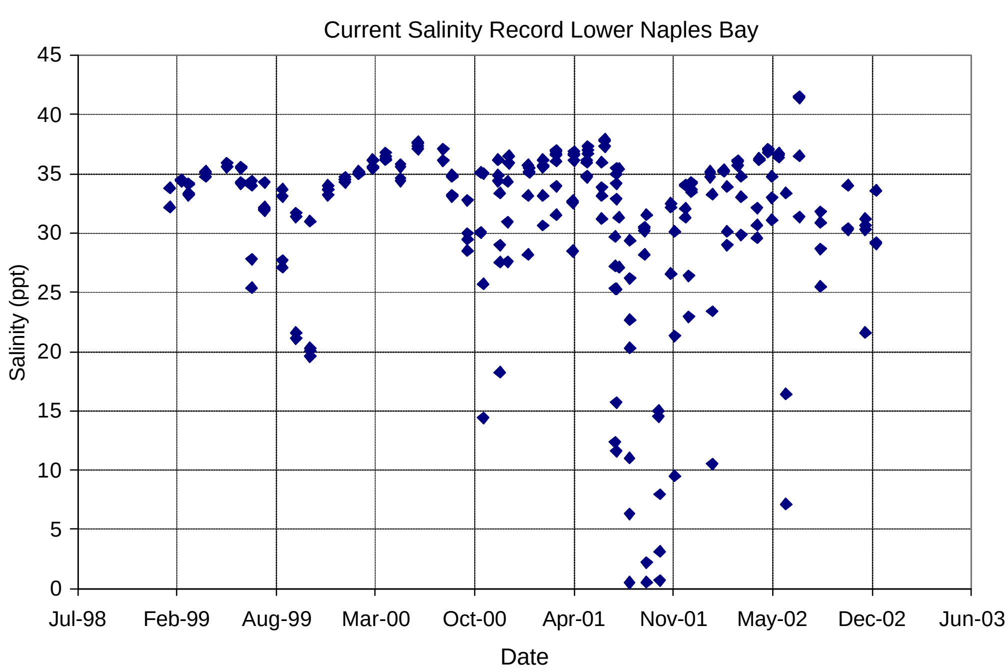

Figure 3.1 Recent (1999 – 2002) Salinity Data, Lower Naples Bay

3.2 Upper Naples Bay Current Water Quality Conditions

Fewer data for current conditions in upper Naples Bay (Table 3.4) reflected sampling of fewer stations over the period and shorter periods of record at individual stations. Relative to the lower bay, the upper bay is less saline, and has slightly lower water clarity (as indicated by secchi disk depth). However, the upper bay also showed slightly lower average turbidity. TP and chlorophyll a levels are higher and 18% of TP samples exceeded 0.1 mg/L. Fecal coliform counts also exceeded standards more frequently in the upper bay. Dissolved oxygen exceedances were infrequent, but present. Metal concentrations and exceedances in the upper bay were similar in frequency to those in the lower bay. Again, water quality conditions exceed CHNEP and IRL standards, and metal exceedances suggest that a bay area impaired with respect to copper, iron, and lead.

Table 3.4 Summary of Current Water Quality Parameters in Upper Naples Bay

Upper Naples bay **Parameter**	**N**	**Min**	**25th %**	**Mean**	**Median**	**75th %**	**Max**	**% Exc**
Salinity (‰)	27	0.48	10.54	21.51	27.59	30.65	34.85	N/A
Temperature (^oC)	27	19.80	24.60	26.58	26.80	29.00	32.30	N/A
Turbidity (NTU)	39	1.60	2.20	3.20	2.67	3.37	9.80	N/A
Secchi (m)	27	0.45	0.85	0.99	1.00	1.10	1.50	N/A
DO (mg/l)	27	3.04	4.26	5.50	5.64	6.22	8.55	11.1
TP (mg/l)	22	0.04	0.04	0.07	0.05	0.09	0.20	18.2
SRP (mg/l)	27	0.01	0.02	0.08	0.04	0.17	0.22	N/A
TN (mg/l)	26	0.14	0.49	0.68	0.63	0.87	1.52	N/A
NH4 (mg/l)	15	0.03	0.05	0.10	0.09	0.11	0.20	N/A
Chlor A (mg/l)	39	1.50	3.20	8.20	5.30	11.70	25.10	N/A
Fecal (CFU/100 ml)	39	3	60	269	142	220	3200	7.7
TSS (mg/l)	23	0.80	1.60	6.49	4.00	12.20	16.20	N/A
Arsenic (µg/l)	23	0.50	5.00	4.17	5.00	5.00	5.00	0
Cadmium (µg/l)	24	0.05	1.50	2.84	2.50	2.50	14.00	8.3
Chromium (µg/l)	24	1.00	1.75	4.04	2.50	3.75	13.00	0
Copper (µg/l)	24	0.50	2.55	4.03	5.00	5.00	8.00	62.5
Iron (mg/l)	5	0.29	0.32	0.83	0.46	0.53	2.53	80.0
Lead (µg/l)	24	0.50	1.75	4.98	2.50	6.00	24.00	16.7
Zinc (µg/l)	24	5	5	16	5	15	60	0.0

Appendix C provides box and whisker plots for salinity, turbidity, nutrients, and fecal coliform data from upper Naples Bay stations.

3.3 Haldeman Creek Current Water Quality Conditions

Haldeman Creek is tidal in the reaches sampled. Salinity levels during winter periods approached marine conditions. The water contained relatively low nutrient (TP, TN, NH4) concentrations, but also showed dissolved oxygen exceedances sufficient to suggest impairment for this parameter. Chlorophyll a statistics were similar to those in upper Naples Bay and were higher than in lower Naples Bay, the receiving waters of Haldeman Creek. Maximum fecal coliform counts exceeded state standards. Copper and iron concentrations most often exceeded water quality standards suggesting impairment of Haldeman Creek with respect to those two parameters.

Table 3.5 Summary of Current Water Quality Parameters in Haldeman Creek

Haldeman Creek Parameter	N	Min	25th %	Mean	Median	75th %	Max	% Exc
Salinity (‰)	40	0.27	20.30	24.41	30.03	32.59	36.40	N/A
Temperature (^{o}C)	40	18.80	24.45	26.23	27.00	29.10	32.30	N/A
Turbidity (NTU)	34	0.90	1.60	2.73	2.41	3.55	5.99	N/A
Secchi (m)	40	0.60	0.95	1.09	1.18	1.20	1.40	N/A
DO (mg/l)	40	2.45	3.67	4.41	4.21	5.18	7.84	45
TP (mg/l)	16	0.01	0.03	0.04	0.04	0.04	0.07	0
SRP (mg/l)	24	0.01	0.01	0.03	0.01	0.04	0.10	N/A
TN (mg/l)	20	0.14	0.31	0.59	0.71	0.81	1.05	N/A
NH4 (mg/l)	10	0.02	0.02	0.09	0.08	0.16	0.19	N/A
Chlor A (mg/l)	34	1.50	4.80	8.21	7.89	11.00	21.90	N/A
Fecal (CFU/100 ml)	34	2	50	330	330	420	1540	5.9
TSS (mg/l)	12	1.80	4.60	8.80	8.10	13.15	17.80	N/A
Arsenic (µg/l)	18	0.5	3.4	4.0	5.0	5.0	5.0	0
Cadmium (µg/l)	19	0.1	0.1	1.9	2.5	2.5	6.0	0
Chromium (µg/l)	19	1.0	1.0	3.4	2.5	2.5	10.0	0
Copper (µg/l)	19	0.5	5.0	13.6	5.0	8.4	150.0	78.9
Iron (mg/l)	6	0.2	0.3	0.4	0.3	0.4	0.7	83.3
Lead (µg/l)								N/A
Zinc (µg/l)	19	5.00	5.00	17.37	5.00	30.00	60.00	0

3.4 Gordon River Tributaries Current Water Quality Conditions

Water quality in the Gordon River above the weir showed low concentrations of dissolved oxygen. All of the samples exceeded (were lower than) the 5 mg D.O. /L state freshwater quality standard (Table 3.6 A). Secchi disk depth ranged from 0.5 m to 1.5 m, averaging about 1.1 meter. All other parameters remained within the state water quality standards.

Table 3.6 A Summary of Current Water Quality Parameters Gordon River above Weir 951

Gordon River Above Weir 951

Parameter	N	Min	25th %	Mean	Median	75th %	Max	% Exc
Salinity (‰)								
Temperature (^oC)	6	26.27	27.18	27.50	27.35	27.99	28.85	N/A
Turbidity (NTU)								
Secchi (m)	5	0.50	1.10	1.16	1.30	1.40	1.50	N/A
DO (mg/l)	6	1.35	2.66	3.04	2.92	3.46	4.95	100
TP (mg/l)	7	0.02	0.03	0.05	0.05	0.06	0.08	0
SRP (mg/l)	6	0.03	0.08	0.09	0.09	0.11	0.15	N/A
TN (mg/l)	7	0.96	1.12	1.47	1.26	1.47	2.88	N/A
NH4 (mg/l)	6	0.03	0.04	0.06	0.05	0.08	0.12	N/A
Chlor A (mg/l)	4	0.85	0.85	14.43	13.43	28.00	30.00	N/A
Fecal (CFU/100 ml)								
TSS (mg/l)								
Arsenic (µg/l)	4	7.00	7.00	8.45	7.40	9.90	12.00	0
Cadmium (µg/l)								
Chromium (µg/l)	12	1.00	1.00	3.30	2.00	6.40	7.40	N/D*
Copper (µg/l)	6	2.80	5.90	8.78	7.50	13.00	16	N/D*
Iron (mg/l)								
Lead (µg/l)	6	0.25	5.00	7.04	7.50	10.00	12.00	N/D*
Zinc (µg/l)	6	1.00	1.00	5.58	4.65	6.80	15.40	N/D*

* N/D No Alkalinity Data Available to Calculate Exceedances

Water quality in the Gordon River location downstream of the weir (Table 3.6 B) was similar in several respects to the upper bay quality. The salinity ranged from less than 1 to 36 ppt. Turbidity was typically low, with a maximum of 6 NTU. Secchi disk depth ranged from 0.55 m to 1.6 m, averaging about 1.1 meter. Almost 89% of the dissolved oxygen data exceeded (lower than) the 4 mg D.O. /L Class III marine water standard. Total phosphorus exceeded 0.1 mg/L in half the samples. As at other locations in Naples Bay, copper and iron concentrations exceeded standards sufficiently to consider the area under impaired waters criteria.

Table 3.6 B Summary of Current Water Quality Parameters at Gordon River Downstream of Weir 951

Gordon River Downstream Weir 951

Parameter	N	Min	25th %	Mean	Median	75th %	Max	% Exc
Salinity (‰)	35	0.42	1.45	13.40	15.11	22.91	30.60	N/A
Temperature (^{o}C)	35	19.70	23.60	25.85	26.40	27.90	31.70	N/A
Turbidity (NTU)	21	0.80	1.20	1.74	1.50	1.90	4.50	N/A
Secchi (m)	35	0.55	1.00	1.12	1.10	1.25	1.60	N/A
DO (mg/l)	35	0.92	1.72	3.13	2.41	3.26	16.10	88.6
TP (mg/l)	4	0.07	0.07	0.10	0.10	0.13	0.14	50.0
SRP (mg/l)	5	0.04	0.05	0.07	0.08	0.08	0.08	N/A
TN (mg/l)	8	0.65	0.76	0.90	0.88	1.08	1.15	N/A
NH4 (mg/l)	2	0.13	0.13	0.15	0.15	0.16	0.16	N/A
Chlor A (mg/l)	21	1.50	1.50	8.36	5.90	8.50	27.80	N/A
Fecal (CFU/100 ml)	21	19	71	186	116	180	840	4.8
TSS (mg/l)	5	1.00	1.00	1.20	1.00	1.00	2.00	N/A
Arsenic (µg/l)	5	0.50	0.50	2.31	2.40	3.67	4.50	0
Cadmium (µg/l)	6	0.05	0.05	0.07	0.05	0.10	0.10	0
Chromium (µg/l)	6	1.00	1.00	1.00	1.00	1.00	1.00	0
Copper (µg/l)	6	0.50	0.50	1.72	1.50	2.20	4	16.7
Iron (mg/l)	5	0.06	0.20	0.22	0.23	0.26	0.36	20.0
Lead (µg/l)	6	0.50	0.50	0.50	0.50	0.50	0.50	0
Zinc (µg/l)	6	10.00	10.00	26.67	30.00	40.00	40.00	0

3.5 Golden Gate Canal Current Water Quality Conditions

Water quality conditions in Golden Gate Canal (Table 3.7) varied more than in the upper bay, the canal's receiving water. Sampling locations included both tailwater and headwater, which influenced the range of salinity, which was very low west of the weir where much of the sampling occurred. Turbidity, although usually low, included a few values several times greater than the typical condition. Water clarity (secchi disk depth) was similar to that in the upper bay locations. Dissolved oxygen levels were indicative of impaired water conditions. Elevated total phosphorus concentrations, typically above 0.1 mg/L, might likely have a negative effect on downstream water quality. Total nitrogen and ammonium ion remained within relatively narrow ranges of concentration, but TN concentrations were higher than CHNEP and

IRL acceptable levels. As with most other locations in the bay, more than 10% of the copper and iron concentration data exceeded state water quality criteria for Class III marine waters.

Table 3.7 Summary of Current Water Quality Parameters in Golden Gate Canal Downstream from the Golden Gate Weir

Golden Gate Canal								
Parameter	**N**	**Min**	**25th %**	**Mean**	**Median**	**75th %**	**Max**	**% Exc**
Salinity (‰)	88	0.00	0.34	7.74	0.37	19.06	31.97	N/A
Temperature (^{o}C)	151	18.10	23.10	25.24	25.00	23.10	33.10	N/A
Turbidity (NTU)	92	0.70	1.50	2.42	2.10	2.90	14.20	N/A
Secchi (m)	134	0.15	1.30	1.55	1.55	1.75	6.00	N/A
DO (mg/l)	151	0.60	4.61	5.48	5.46	6.60	14.00	17.9
TP (mg/l)	57	0.01	0.02	0.03	0.03	0.04	0.10	0
SRP (mg/l)	46	0.002	0.006	0.012	0.010	0.02	0.04	N/A
TN (mg/l)	66	0.12	0.66	0.75	0.74	0.84	1.14	N/A
NH4 (mg/l)	57	0.01	0.03	0.05	0.04	0.07	0.21	N/A
Chlor A (mg/l)	54	1.10	1.50	5.25	3.20	5.90	48.60	N/A
Fecal (CFU/100 ml)	92	2	16	85	31	69	1900	2.2
TSS (mg/l)	66	1.00	4.00	4.56	4.00	4.00	24.00	N/A
Arsenic (µg/l)	11	0.50	0.50	1.99	1.50	3.80	4.28	0
Cadmium (µg/l)	12	0.05	0.05	0.10	0.08	0.10	0.27	0
Chromium (µg/l)	12	1.00	1.00	1.00	1.00	1.00	1.00	0
Copper (µg/l)	12	0.50	0.50	0.80	0.50	0.80	2.20	0
Iron (mg/l)	18	0.25	0.50	2.78	0.50	5.00	12.00	44.4
Lead (µg/l)	12	0.50	0.50	0.66	0.50	0.50	2.37	0
Zinc (µg/l)	12	10.00	10.00	17.50	20.00	20.00	30.00	0

3.6 Lely Canal Current Water Quality Conditions

Water quality conditions in Lely Canal varied by sample station location (Table 3.8). Sampling locations for current conditions included one station at the northern section of the canal. This fact explains the low salinity values measured — between 0.09‰ and 14.74 ‰. Water clarity (secchi disk depth) was lower that the lower bay locations. Dissolved oxygen levels were indicative of impaired water conditions — 54 % of the measurements were below 5 mg/l. Elevated total phosphorus concentrations, typically above 0.1 mg/L, could have a negative effect on downstream water quality. Metal concentrations never exceeded state water quality criteria for Class III fresh waters.

Table 3.8 Summary of Current Water Quality Parameters in Lely Canal

Lely Canal Parameter	N	Min	25th %	Mean	Median	75th %	Max	% Exc
Salinity (‰)	39	0.09	0.32	0.98	0.36	0.38	14.74	N/A
Temperature (^oC)	39	18.10	23.40	26.02	26.50	29.10	32.00	N/A
Turbidity (NTU)	41	0.60	1.30	2.09	1.80	2.40	7.50	N/A
Secchi (m)	35	0.30	0.70	0.97	0.90	1.20	1.60	N/A
DO (mg/l)	31	2.44	3.83	5.00	4.92	5.95	8.83	54.8
TP (mg/l)	25	0.01	0.02	0.04	0.03	0.03	0.17	4.0
SRP (mg/l)	12	0.005	0.005	0.013	0.007	0.01	0.07	N/A
TN (mg/l)	25	0.02	0.55	0.61	0.70	0.80	1.02	N/A
NH4 (mg/l)	22	0.01	0.03	0.06	0.04	0.07	0.21	N/A
Chlor A (mg/l)	24	3.20	3.70	7.67	4.80	10.40	20.30	N/A
Fecal (CFU/100 ml)	26	23	62	142	94	143	700	0
TSS (mg/l)	7	2.00	2.00	4.14	4.00	6.00	9.00	N/A
Arsenic (µg/l)	8	1.70	1.87	2.63	2.49	3.31	4.00	0
Cadmium (µg/l)								
Chromium (µg/l)	1	1.10	1.10	1.10	1.10	1.10	1.10	0
Copper (µg/l)	7	1.90	2.00	2.94	3.20	3.60	4.10	0
Iron (mg/l)	12	0.19	0.27	0.41	0.36	0.54	0.77	0
Lead (µg/l)	1	0.54	0.54	0.54	0.54	0.54	0.54	0
Zinc (µg/l)	2	10.00	10.00	14.00	14.00	18.00	18.00	0

3.7 Gulf of Mexico Current Water Quality Conditions

Current samples from Gulf of Mexico came primarily from a station directly adjacent to Gordon Pass. The data (Table 3.9) showed the effect of Naples Bay water on water quality at the station. Salinity, typically marine (35 ppt) fell as low as 29 ppt during the three-year period of evaluation. Elevated maximum values of nutrients, chlorophyll a, and fecal coliform counts reflected the occasional impact of the bay on the nearshore Gulf Waters. Lead concentrations, measured nine times, exceeded the state water quality standard in six of the nine samples.

Table 3.9 Summary of Current Water Quality Parameters in the Gulf of Mexico

Gulf of Mexico Parameter	N	Min	25th %	Mean	Median	75th %	Max	% Exc
Salinity (‰)	102	29.20	34.30	35.14	35.20	36.30	37.90	N/A
Temperature (^{o}C)	94	7.50	21.40	25.03	25.60	29.40	31.50	N/A
Turbidity (NTU)	55	0.30	1.10	3.51	2.00	3.30	25.10	N/A
Secchi (m)								N/A
DO (mg/l)	94	2.10	5.50	6.36	6.20	6.90	16.80	2.1
TP (mg/l)	50	0.01	0.02	0.03	0.03	0.04	0.09	0
SRP (mg/l)	62	0.00	0.00	0.01	0.01	0.01	0.04	N/A
TN (mg/l)	32	0.05	0.15	0.21	0.18	0.27	0.51	N/A
NH4 (mg/l)	54	0.00	0.00	0.02	0.01	0.02	0.20	N/A
Chlor A (mg/l)	58	0.40	1.30	2.98	2.50	3.60	11.90	N/A
Fecal (CFU/100 ml)	254	1	2	23	4	12	1500	0.8
TSS (mg/l)	9	5.20	5.60	18.61	5.70	43.00	46.20	N/A
Arsenic (µg/l)	9	5	5	5	5	5	5	0
Cadmium (µg/l)	9	2.5	2.5	2.5	2.5	2.5	2.5	0
Chromium (µg/l)	9	2.5	2.5	7.0	2.5	13	19.0	0
Copper (µg/l)	9	0.5	5	4.6	5	5	10.0	0
Iron (mg/l)								
Lead (µg/l)	9	3	8	15.7	18	23	34	66.7
Zinc (µg/l)	9	5	5	5	5	5	5	0

3.8 Summary of Chemical Contaminant Data

Data for a large number of chemical contaminants reside in the database. Collection of the majority of the chemical contaminant (industrial chemicals, herbicides, and pesticides) data occurred in the 1970s. Data from a 1996 and 1997 City of Naples effort to measure chemical contaminants in the waters of the bay and tributaries sampling reside in the database. The results of this sampling effort and those of more recent sampling did not usually exceed detection limits and did not show chemical contamination as a major concern where tested. In 2002, sampling of Townsend Canal near the Berry Grove Pump Station found a variety of chemical contaminants. Few of the detected compounds have numeric water quality standard concentrations, but many have recognized toxicity, a concern if found in the potable water pumped by the Berry Grove Station.

3.9 Summary of Current Water Quality Conditions in Naples Bay

Water quality data from Naples Bay and its tributaries showed several signs of water quality impairment. Dissolved oxygen reached levels of concern in all areas of the bay. One or more of the metals — copper, iron, zinc, and lead concentrations — exceeded water quality standards in the several locations evaluated within the bay and in the Gulf of Mexico. Slightly elevated phosphorus levels in lower Naples Bay increased in upper Naples Bay and in Golden Gate Canal, the main freshwater discharge to the bay. Greater than 10% of the total samples collected in each location except the Gulf of Mexico exceeded state dissolved oxygen standards. Nitrogen levels in the lower bay were close to CHNEP and IRL water quality criteria, but the upper bay concentrations were higher and clearly exceeded those standards. Chlorophyll a values in all locations typically (as mean or median value) exceeded criteria developed for Charlotte Harbor and the Indian River Lagoon.

4.0 WATER QUALITY CONDITIONS OVER TIME

Water quality data were minimally sufficient to provide a picture of current and past water quality conditions. While the database contained a large number of sites (Figure 1.1), the relatively incomplete distribution of the sampling stations in space and time and the inconsistent collection of key parameter data limited the strength of conclusions drawn from the dataset. A few single sampling stations generated data sufficient to develop a trend analysis as long as five years. Therefore, Taylor Engineering approached analysis of potential trends by plotting daily and median values of all available data for comparison. Collection of multiple samples of some parameters such as dissolved oxygen often occurred on the same day. Daily averages of those values plotted with the raw data provided a better understanding of the typical condition at those sites.

The water quality period for any particular parameter with relatively large numbers of data typically extended back no further than the late 1980s. The historic analysis includes samples from the 1970s. Visual examination of superimposed individual and annual median parameter values provided heuristic trend assessment. The trend assessment focuses on traditional water quality parameters: salinity, turbidity, dissolved oxygen, total nutrients, chlorophyll a, and coliform counts. However, the discussions of water quality trend in each location include only present parameter data of particular interest. Not all parameters provided key information in any particular location.

4.1 Lower Naples Bay

Trends in water quality became most apparent in lower Naples Bay. Salinity data suggested that episodes of low salinity have occurred in the lower bay since the late 1980s (Compare Figure 4.1, available historic salinity data, to Figure 3.1, recent salinity data from the lower bay). Turbidity, while occasionally very high, remained relatively consistent for the period of record. Multiple dissolved oxygen measurements occurred within a 24-hour period. Figure 4.2 provides all values and daily average values. D.O. values below 4.0 mg/L increased in recent years, but little difference occurred in daily average values in the data from 1988 to 1994 (Figure 4.2).

Total nitrogen (TN or TKN) concentrations (Figure 4.3) decreased significantly (statistically significant trend line slope) over the period of record (1988 – 2002). Changes in total phosphorus levels did not accompany changes in TN. Orthophosphate concentrations in the 1970s (Figure 4.4) may have been higher than current levels, but insufficient data exist between that time and the present to assess change. Chlorophyll a concentrations varied in the same range throughout the data record. Annual median concentrations of the past five years suggest lower chlorophyll a levels, but only sampling since 2000 included all months of each year. Monthly average chlorophyll a concentrations for the periods before and since January 1, 2000 (Figure 4.5) suggest that recent chlorophyll a levels were less variable and lower than in the previous period (Figure 4.6: average month = 6 mg/m^3 after 2000 and 8 mg/m^3 before that time). However, regular monthly sampling in recent years has produced as many samples as in the rest of the remaining data record. In the data set for the period before 2000, data from two months (April and August) comprised 45% of the data. Data from additional years will determine whether the current data reflect a long-term trend or a short-term condition.

The database provided fecal and total coliforms data dating to 1971. The few data available comprised values that were generally close to current sample values. Recent (1999 — 2002) samples however, included higher total coliform counts than previously recorded.

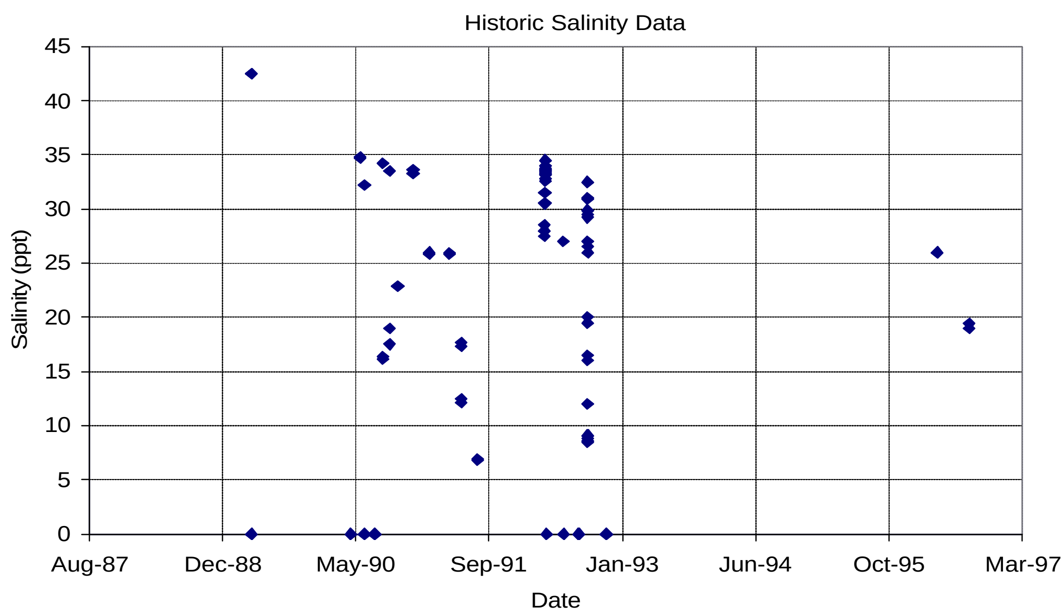

Figure 4.1 Salinity Data for the Lower Bay 1988 – 1997.

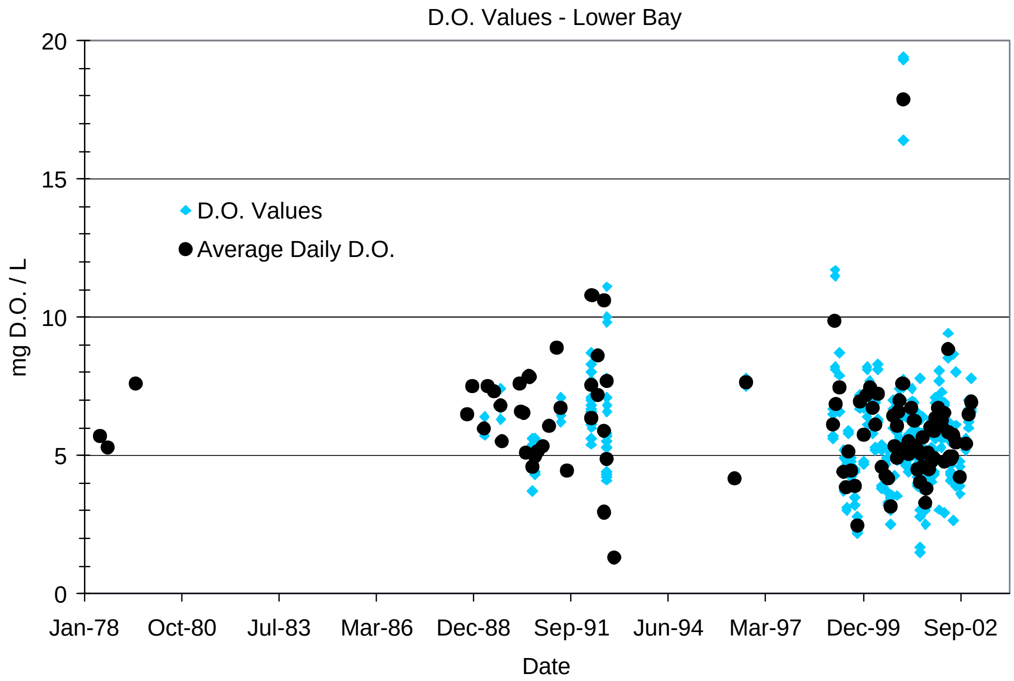

Figure 4.2 All Dissolved Oxygen Values and Daily Average Values for Lower Bay Samples

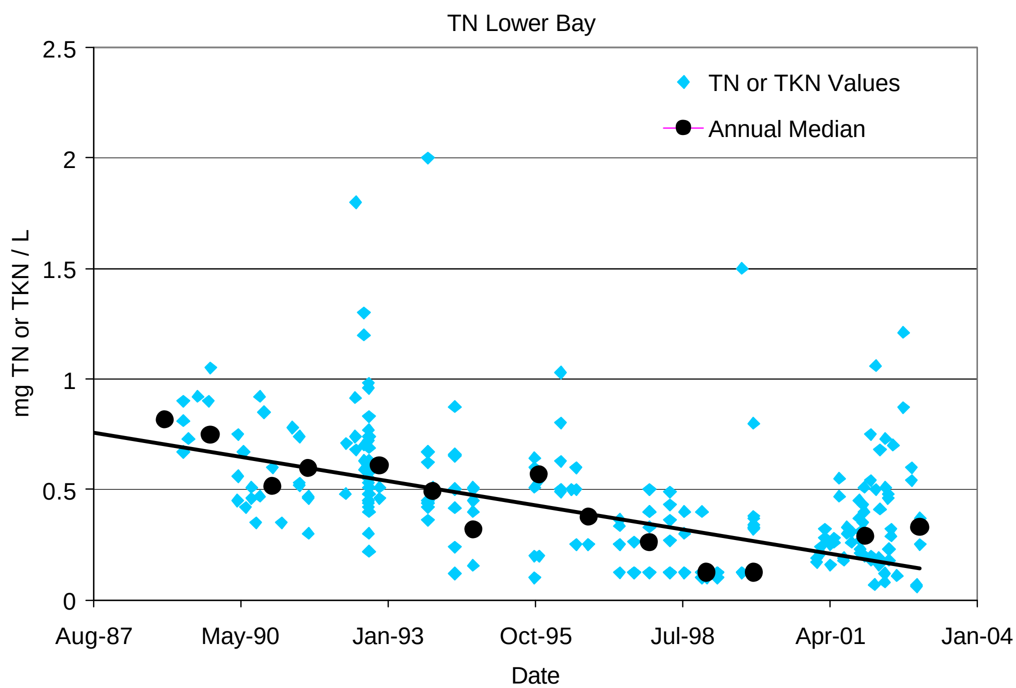

Figure 4.3 Total Nitrogen and Total Kjeldahl Nitrogen Concentrations, Lower Naples Bay.

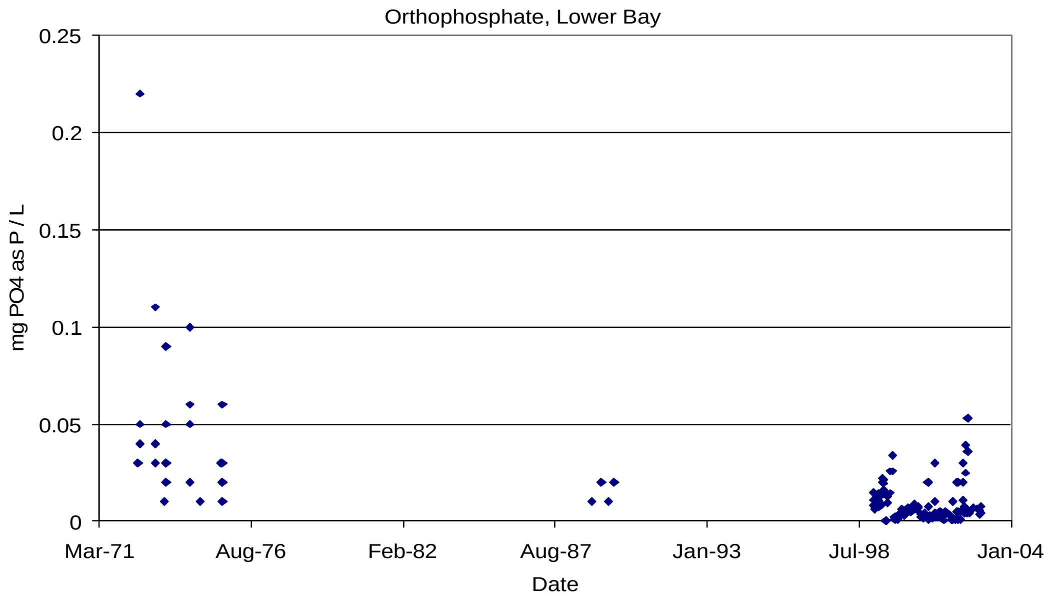

Figure 4.4 Orthophosphate Concentrations with Time, Lower Naples Bay

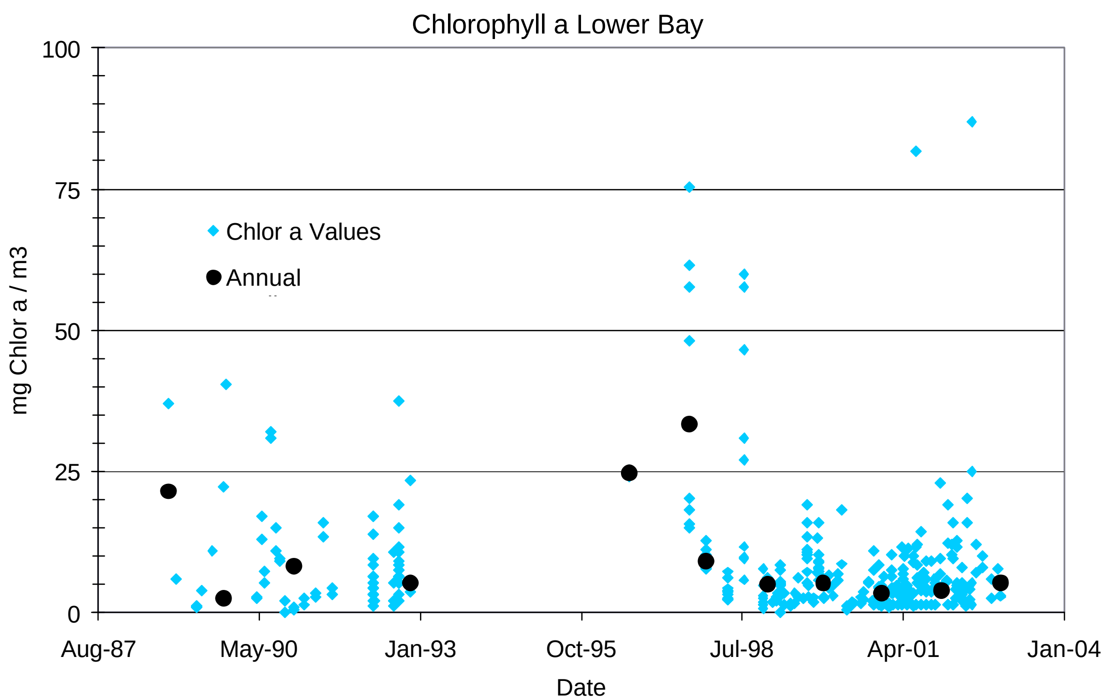

Figure 4.5 .Chlorophyll a Concentration Data and Annual Median Values, Lower Naples Bay

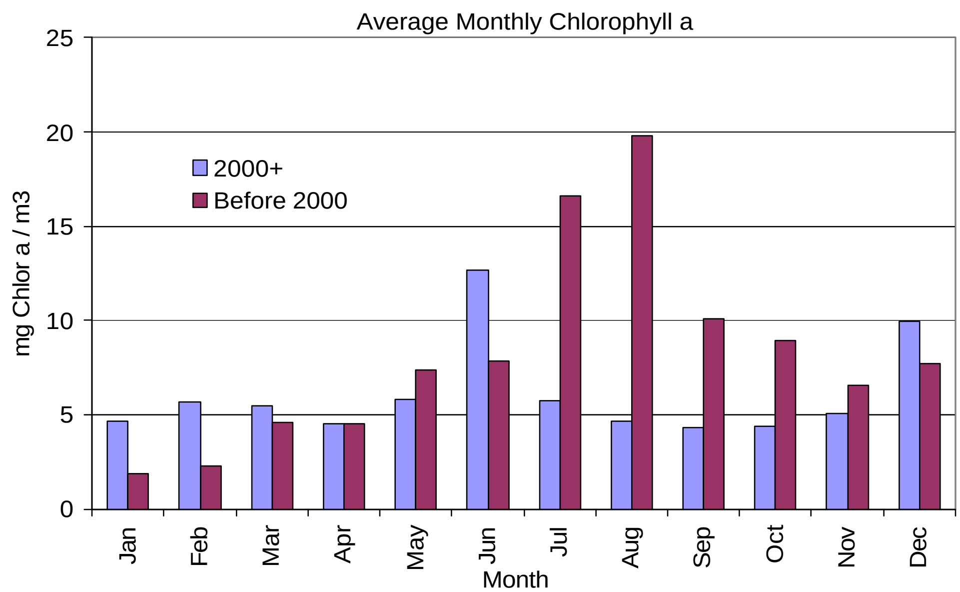

Figure 4.6 Average Monthly Chlorophyll a Concentrations before and after January 1 2000, Lower Naples Bay

4.2 Upper Bay Trend Evaluation

Upper bay data occurred in three clusters: a small dataset from the early 1970s, a second, larger set of samples collected between 1988 and 1994, and data from 1997 to the present. Regular monthly sampling did not begin until the fall of 2000. The salinity data between 1988 and 1994 showed the same range as the current (1999 – 2002) dataset. No patterns appeared in salinity, turbidity, or coliform datasets. Dissolved oxygen concentrations lower than 4.0 mg/L (Figure 4.7) did not decrease greatly between the early 1990s and the current period, although both periods had lower percent exceedances than data from the beginning of the record (Figure 4.7).

Nitrogen data consisted primarily of sets of multiple samples within a 24-hour period, separated by months or years. Combining TN and TKN data provided the largest set of data for review. The available data, plotted with daily average values (Figure 4.8), suggest no pattern of change in concentrations over time.

The phosphorus data collected since early 1992 show a smaller range of values than the previous period of data (Figure 4.9). The data may represent a long-term improvement in water quality for this parameter, but phosphorus in the upper bay has yet to meet the state water quality criterion for phosphorus. Chlorophyll a concentration data showed no clear pattern of change (figure 4.10).

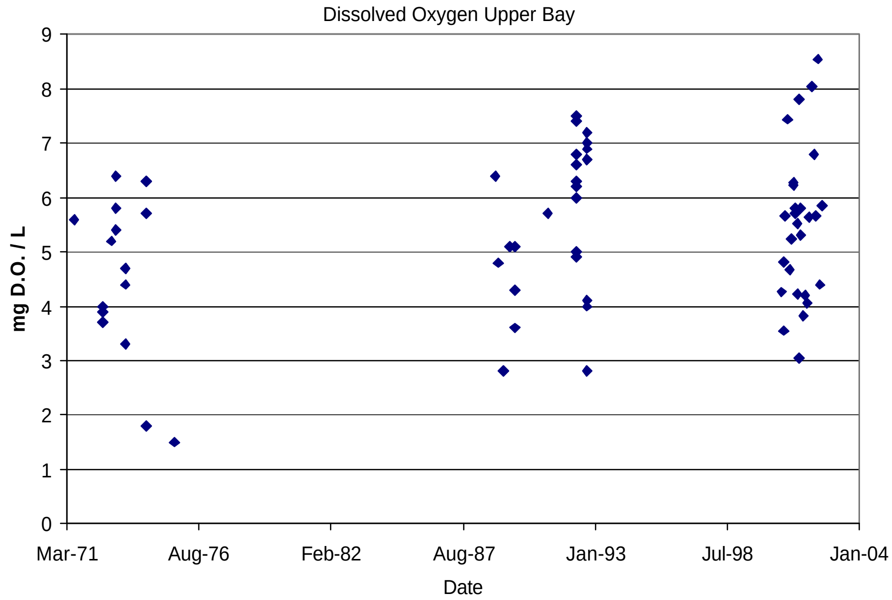

Figure 4.7 Dissolved Oxygen Concentration Data for Upper Naples Bay

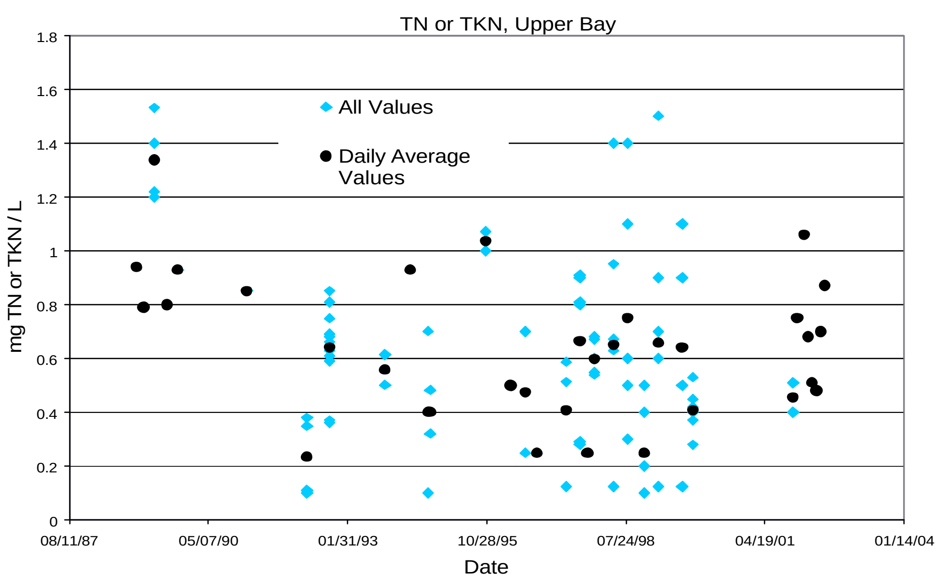

Figure 4.8 TN and TKN Data for Upper Naples Bay

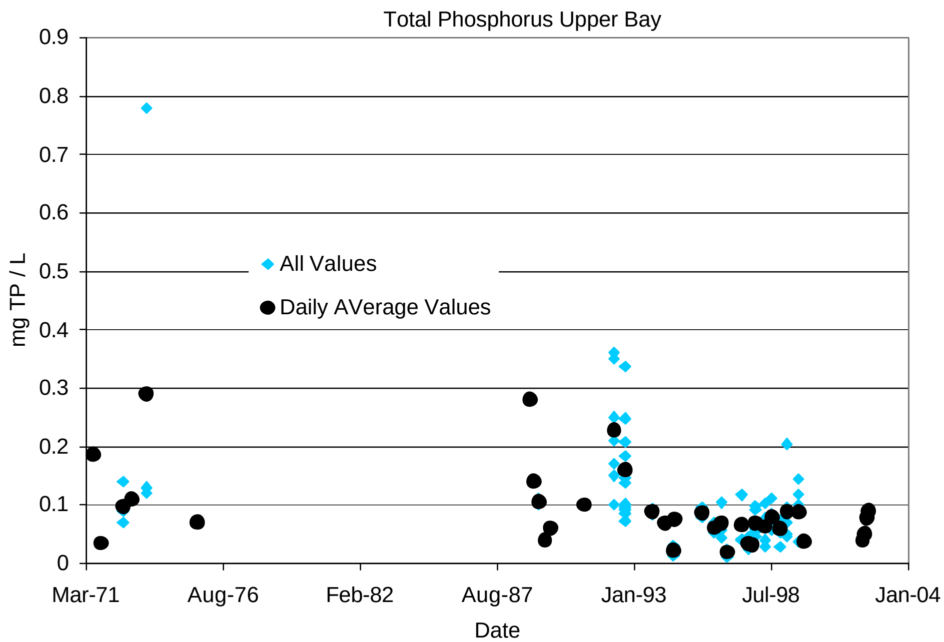

Figure 4.9 Phosphorus Concentration Data and Daily Average Values

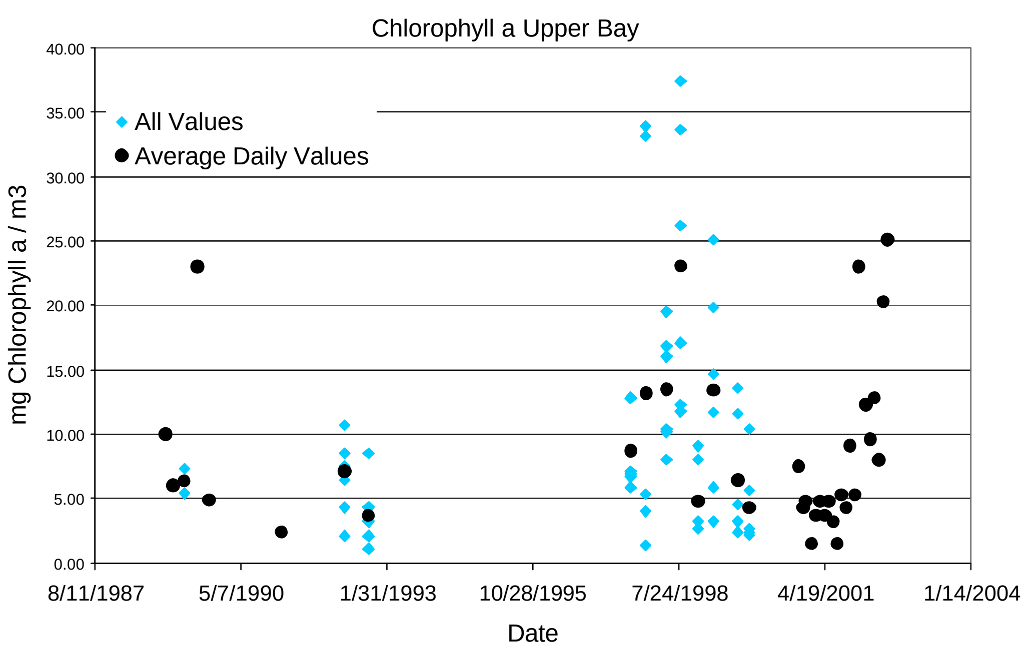

Figure 4.10 Chlorophyll a Data for Upper Naples Bay

4.3 Haldeman Creek

Haldeman Creek sampling has occurred several times each year since 1989. The current sampling effort on the creek began in 1999. Sampling, historically intermittent, now occurs monthly.

Historically, salinity values have ranged from less than 1 to over 30 ppt. Turbidity, typically less than 10 units, has risen as high as 60 NTU. Dissolved oxygen has often fallen below 4 mg /L through the period of record (Figure 4.11). Depth of measurement varied, but did not show a strong influence on the measured dissolved oxygen level (Figure 4.12). Annual median data suggest a recent decline in typical dissolved oxygen concentrations compared to the first half of the 1990s.

TN values varied little over the 12-year period of record, and no trend appeared in the data. Total phosphorus concentrations may have fallen since the early 1990s and, with few exceptions, concentrations have remained below 100 µg/L (Figure 4.13).

Fecal coliform counts since 1989 exceeded 400 counts/100 ml in 18% of the samples. similar exceedances occurred across the period of record, (Figure 4.14).

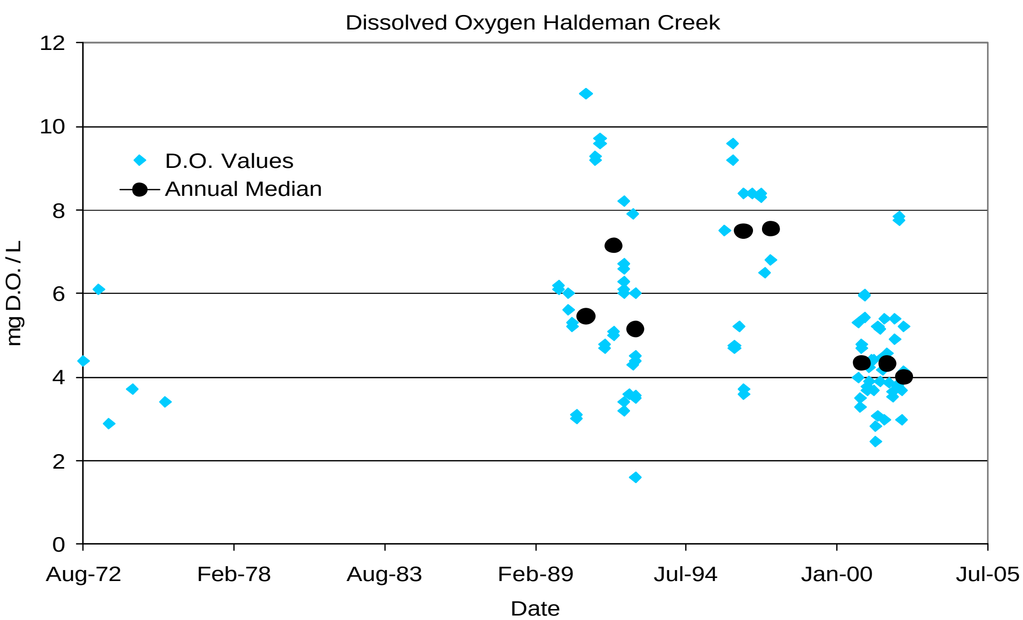

Figure 4.11 Dissolved Oxygen data for Haldeman Creek

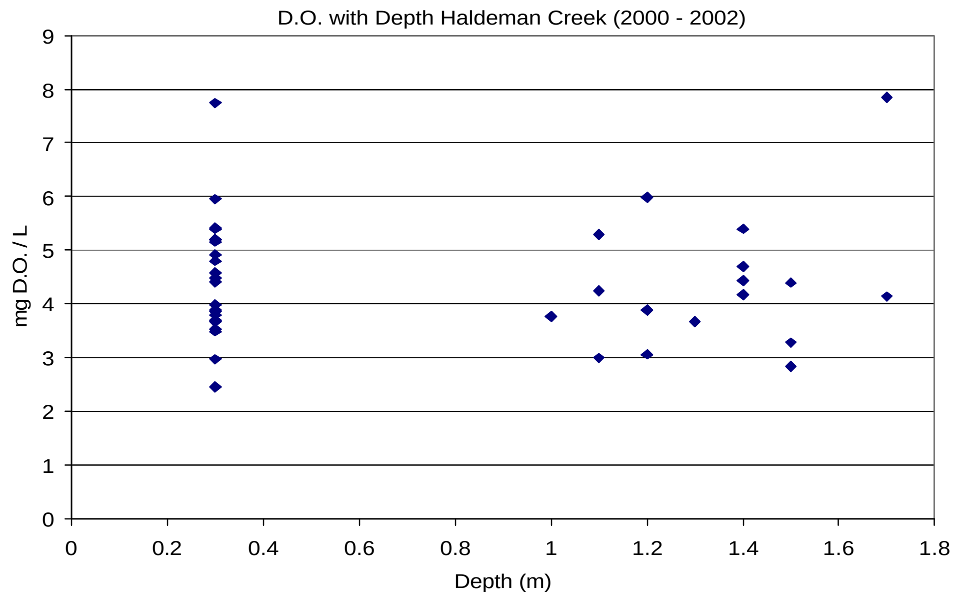

Figure 4.12 Dissolved Oxygen with Depth, from Haldeman Creek

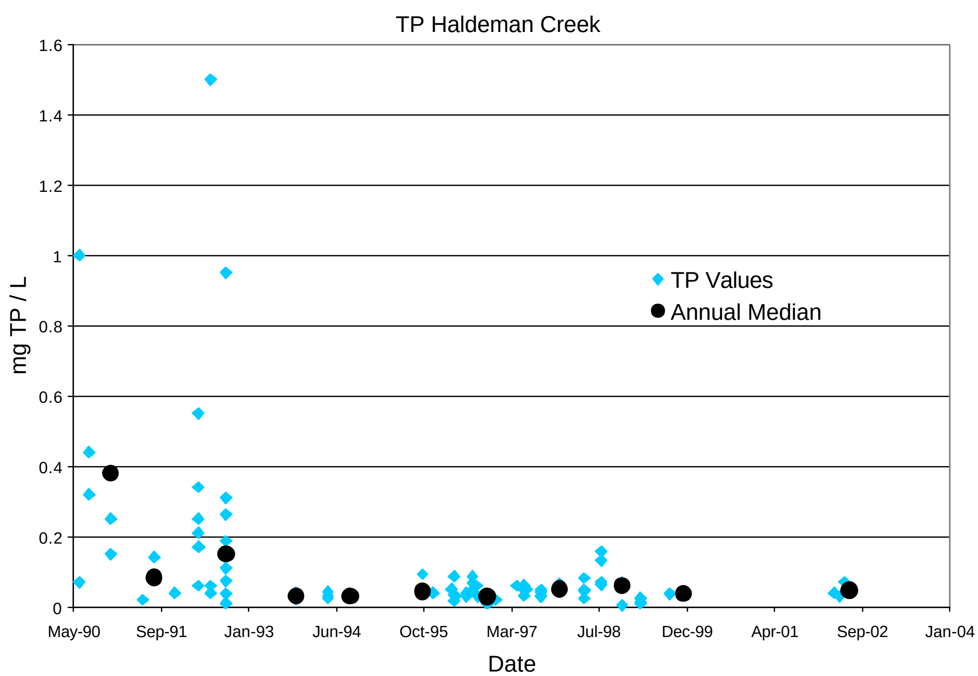

Figure 4.13 Total Phosphorus Data for Haldeman Creek 1990 – 2002

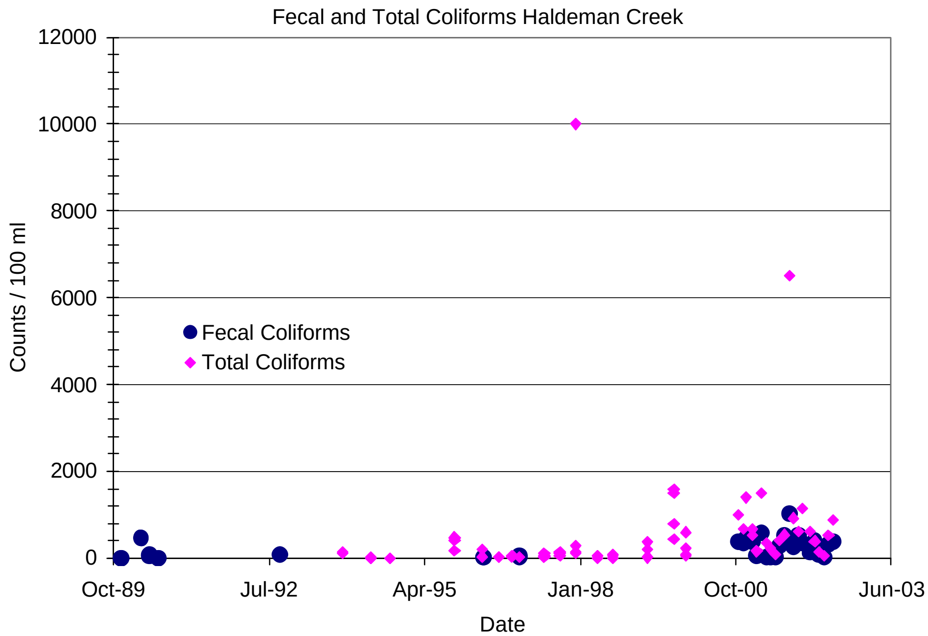

Figure 4.14 Fecal and Total Coliform Counts from Haldeman Creek

4.4 Rock Creek

The sparse sampling record, the result of an inconsistent sampling program, includes 32 samples with 10 dates before 1990 and 22 dates between 1990 and 1997. The available data (Table 4.1) indicate relatively low water quality: Dissolved oxygen less than 4.0 mg/L occurred in 45% of the samples collected over the 10 years of available data. Nutrient concentrations were relatively high through the period, and maximum values for the parameters shown in Table 4.1 all indicate affected conditions.

Table 4.1 Summary of Selected Water Quality Data for Rock Creek

Parameter	n	Min	25th %	Median	Mean	75th%	Max
salinity	54.00	0.00	0.00	2.25	9.55	17.95	32.90
D.O.	70.00	0.55	2.73	4.40	4.30	6.00	9.15
Turbidity	73.00	0.30	1.40	2.40	2.73	3.05	13.19
TP	35.00	0.02	0.06	0.10	0.13	0.18	0.33
TN	51.00	0.10	0.61	0.70	1.46	0.98	32.00
NH4	55.00	0.00	0.03	0.08	0.10	0.16	0.37
Chlor a	40.00	0.17	2.10	5.30	8.31	8.78	58.00

4.5 Golden Gate Canal

The Golden Gate Canal data set shows two breaks in the record of data since the early 1970s. Little sampling occurred in the late 1980s and between 1992 and 1996. Data from the larger system, combined with data near the weir, provided data for analysis of historic conditions. Across the period of record, salinity varied seasonally and with depth. Values near zero between June and November increased to near marine conditions (30 ppt) during winter and spring months. Turbidity remained low in the data record, with a median value of 2.2 NTU and a maximum value of 12 NTU between 1978 and 2002.

More frequently collected Total Nitrogen (TN) -and or Total Kjeldahl Nitrogen (TKN) data provided a large data record for review. TN and TKN data collected between 1996 and 2002 showed lower annual median values than the preceding 20 years of data (Figure 4.15). Little change in total phosphorus levels occurred (Figure 4.16), but greater numbers of high chlorophyll a values (> 10 mg / m^3) have occurred over the past 10 years compared to earlier data (Figure 4.17).

Dissolved oxygen levels (Figure 4.18) have exceeded the water quality criterion (4 mg/L) throughout the period of record. Data before 1998 indicate either no sample depths or record depths of “0”, indicating a surface sample. Dissolved oxygen data collected deeper in the water column (0.1 to 2.7 m) are included after that point. A correlation of 0.2 between depth and dissolved oxygen occur for that period. A difference in recent dissolved oxygen data is the occurrence of extremely high oxygen concentrations, correlated with high chlorophyll a values.

Fecal coliform counts (Figure 4.19) exceeded water quality standards (>400 counts) a number of times across the period of record. However, data since 1995 include most of the values greater than 1,000 counts. The faction of samples exceeding 400 counts/100 ml increased in recent years. More frequent sampling may provide clear evidence of a water quality exceedance condition that has occurred throughout the period of record for this tributary.

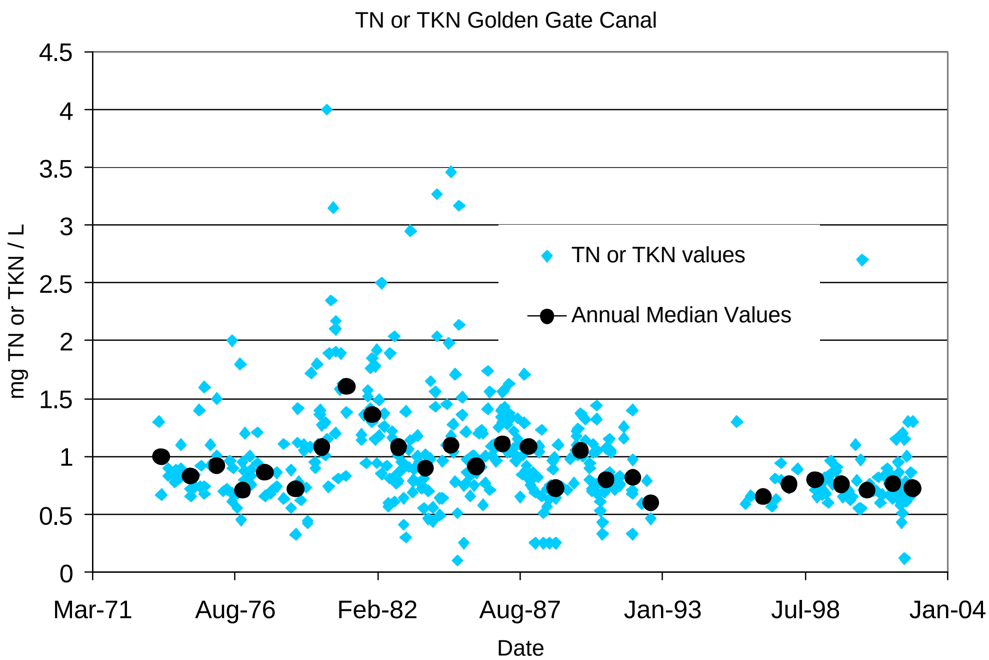

Figure 4.15 Total Nitrogen and TKN Values and Annual Median Values for Golden Gate Canal Stations

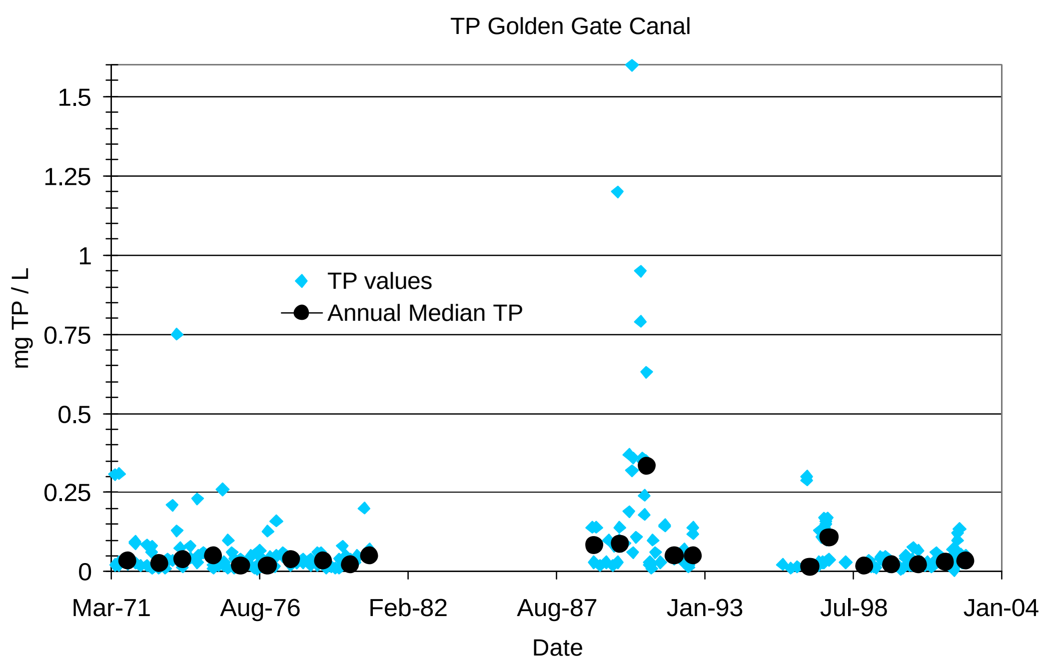

Figure 4.16 All TP Values and Annual Median TP Values for Golden Gate Canal Stations

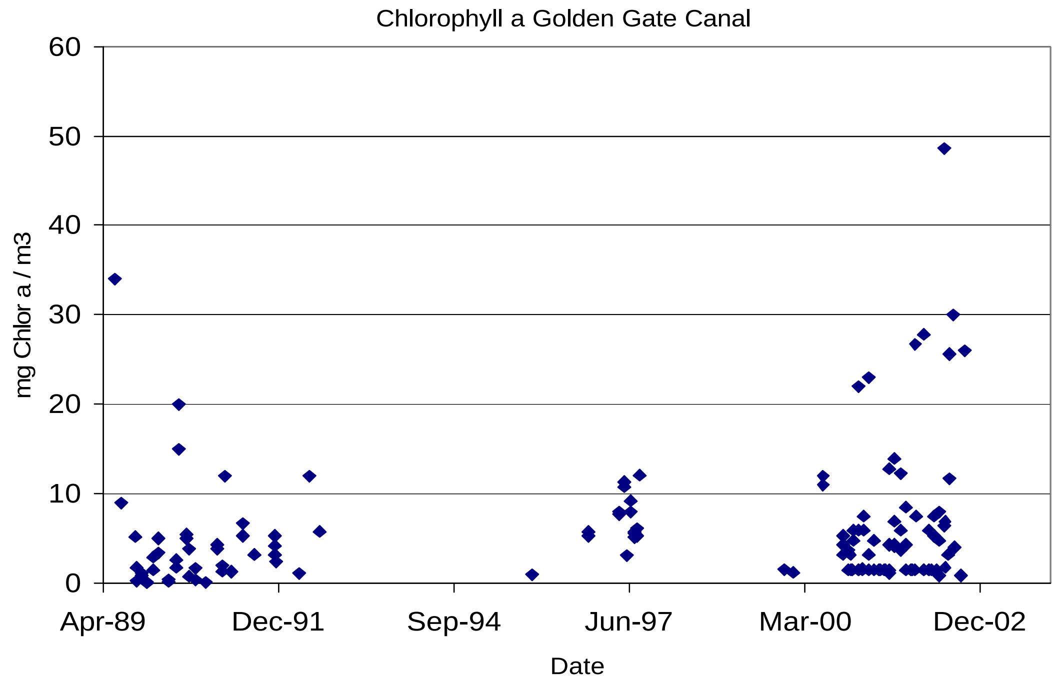

Figure 4.17 Chlorophyll a Values for Golden Gate Canal Stations

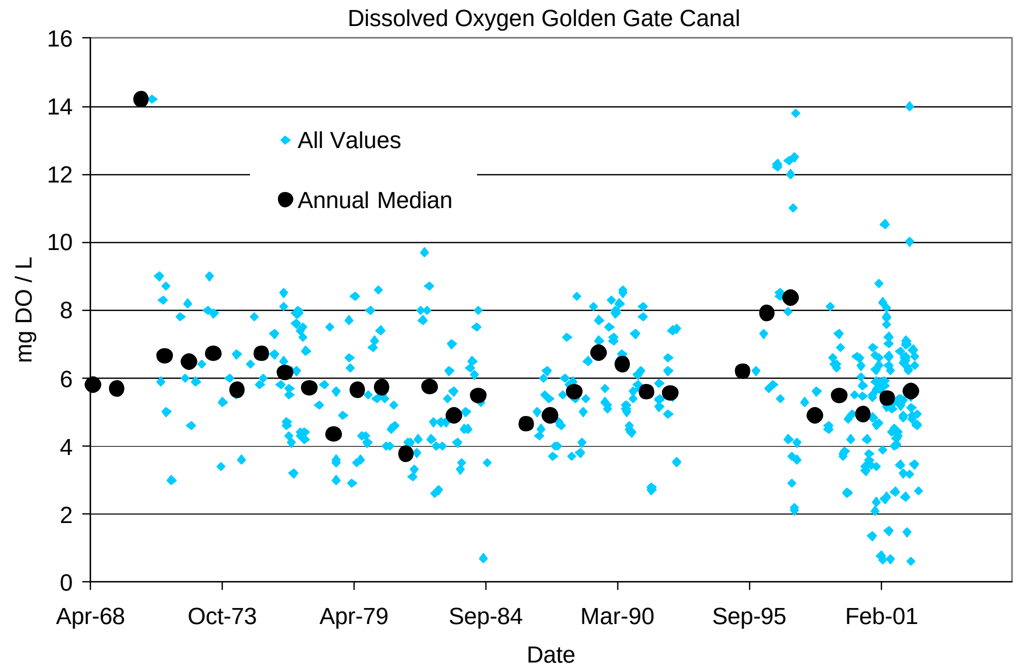

Figure 4.18 Dissolved Oxygen Values and Annual Medians for Golden Gate Canal Stations

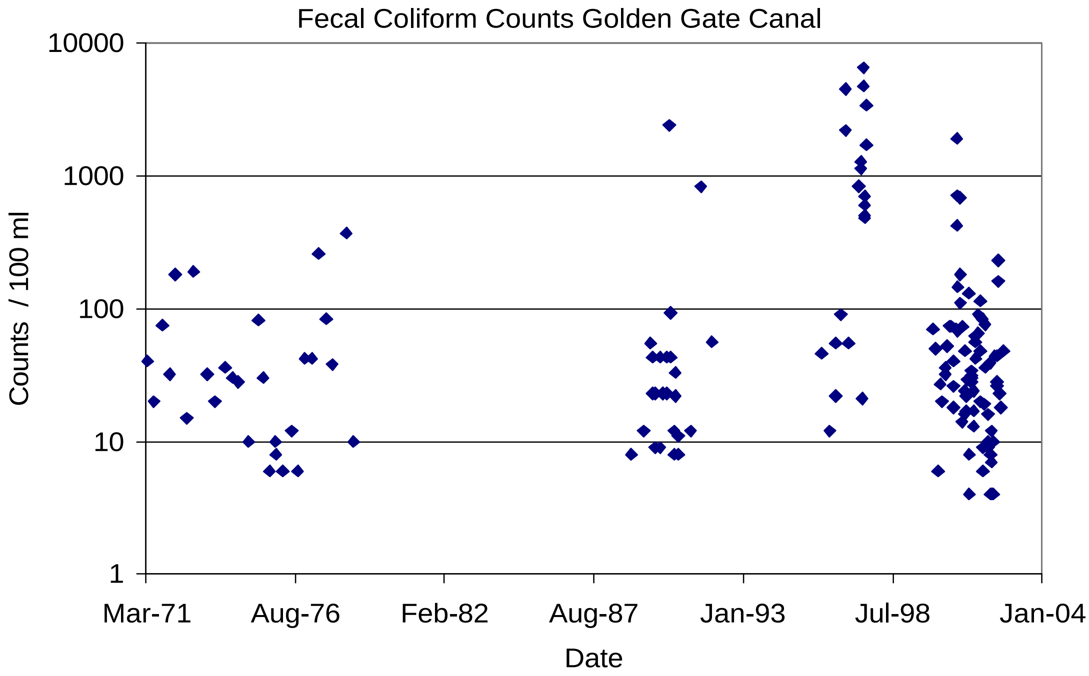

Figure 4.19 Fecal Coliform Counts, Golden Gate Canal Stations

4.6 Gordon River Tributaries

Gordon River tributary sampling occurred only 10 times between 1970 and 1990. No sampling occurred in this area during most of the 1990s. The insufficient data could not provide insight into changes in conditions over time.

4.7 Lely Canal

Lely Canal water quality sampling between 1979 and 1998 yielded samples from four stations, with almost all the data provided by the at the intersection of Lely Canal and US 41. Sampling also occurred on five dates in the mid-1990s at a station midway in the main canal reach and at a station near the Intracoastal Waterway. Salinity and conductivity samples indicated a relatively freshwater (<1 ppt to 5 ppt salinity) canal except at the canal's mouth where salinity varied from about 13 ppt to 27 ppt over the period of record. Water clarity (secchi disk depth) remained high across the data record (median 0.8 m). Fecal coliform, total coliforms and dissolved oxygen regularly (20%, 22% and 30% of sample values respectively) exceeded water quality standards. Exceedances were sufficient to consider the canal impaired under Florida impaired water criteria. Current annual median D.O values (Figure 4.20) suggest a continuing decline in D.O. conditions over the period of record. Total Kjeldahl Nitrogen concentrations may have declined some over the past decade (Figure 4.21). Total phosphorus concentrations however, appear to have changed little over time (Figure 4.22).

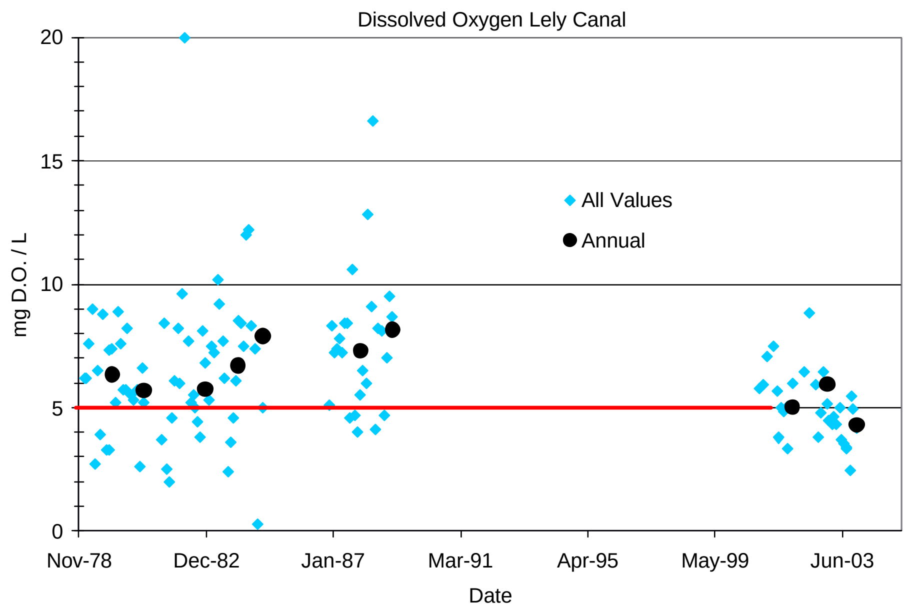

Figure 4.20 Dissolved Oxygen, Lely Canal Stations

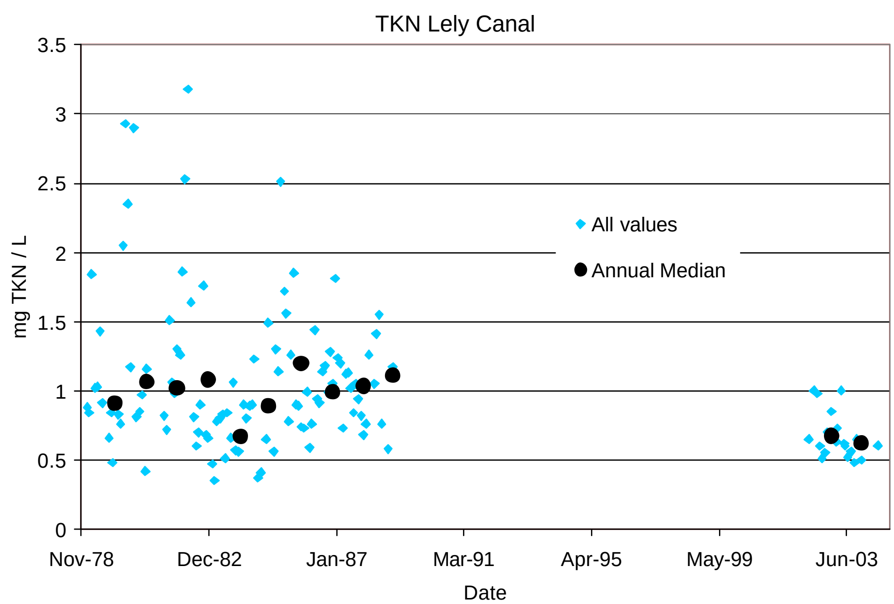

Figure 4.21 Total Kjeldahl Nitrogen Lely Canal Stations

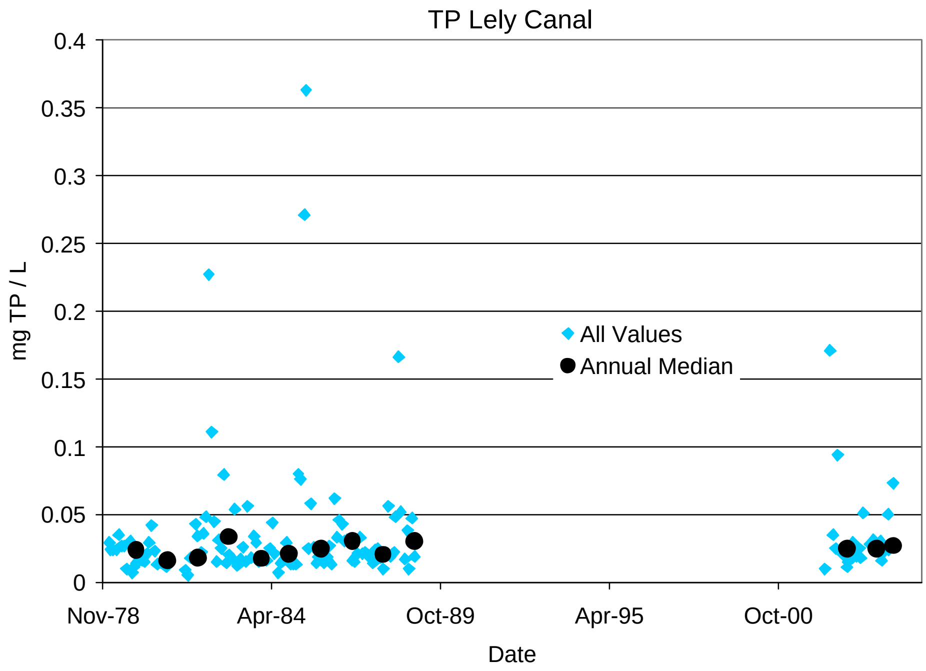

Figure 4.22 Total Phosphorus, Lely Canal Stations

5.0 HYDRAULIC – WATER QUALITY MODELING DATA GAP EVALUATION

5.1 Introduction

Review of the final data set and summary statistics of those data focused on questions related to water quality modeling and long-term monitoring efforts

- Were station locations appropriate to support water quality modeling and long-term monitoring?
- Were the data sufficient to provide overall water quality characterization of Naples Bay?
- What data sets were available to evaluate potential trends, either in the bay as a whole or at specific locations?
- What changes should Taylor Engineering recommend to meet SFWMD objectives for modeling and monitoring Naples Bay?

5.2 Data Trends and Water Quality Conditions Gap Analysis

5.2.1 Sampling Stations Location and Periods

The data record for Naples Bay and its tributaries contains several characteristics that limit statistical trend analysis. Before the current sampling effort, which began at most stations in 1999 or 2000, sampling occurred at quarterly or more infrequent intervals. Monthly sampling occurred most often for a few years and often for only one year. The database contains considerable data from single intensive day efforts, repeated months later, for a few years. Consistent temporal sampling patterns are rare in the database with respect to the total period of record (1970 – 2002)

The current sampling effort covers most of the bay and some of the tributaries (Figure 5.1). Sampling includes

- Dissolved oxygen, salinity, pH, temperature, secchi disk depth, color, turbidity, total suspended solids
- Arsenic, calcium, cadmium, chromium, chloride, fluoride, magnesium, lead, sulfate, zinc
- Ammonium, Nitrate+Nitrite, Total Kjeldahl Nitrogen ,Total Phosphorus, orthophosphate
- Chlorophyll a and Phaeophytin, Fecal and Total Coliform
- Samples collected at the surface supplemented at some stations with deeper water column field parameter measurements.

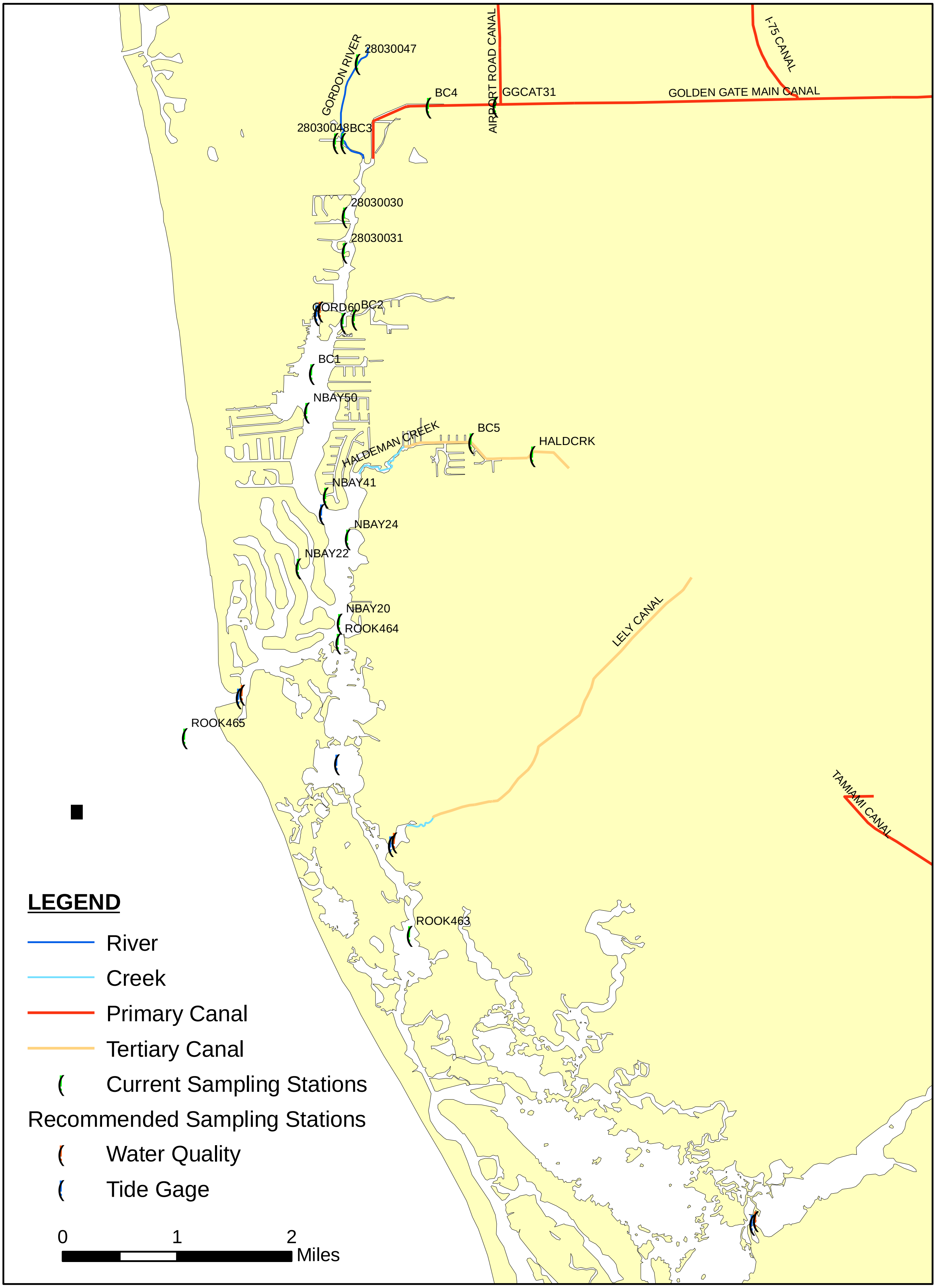

Figure 5.1 Current Sampling Stations and Recommended Station Additions

5.3 Water Circulation and Water Quality Modeling

5.3.1 Introduction

Taylor Engineering proposes a two-dimensional hydrodynamic and water quality model for evaluation of water quality in Naples Bay. The level of complexity represented in a two-dimensional model should provide spatial and temporal dynamics necessary to understand, simulate, and predict water quality conditions at the necessary spatial and temporal scales. This class of model should provide the most cost-effective solution to the challenge of developing a long-term water quality management-planning tool in a relatively short period.

The physical complexity and size of Naples Bay clearly indicate that a one-dimensional model (such as CSTR or a continuously stirred tank reactor simulation model) would not adequately describe or predict the range of water quality conditions found in Naples Bay. However, available hydraulic and water quality data are inadequate for use in a three-dimensional model. Almost all the data represent surface conditions. Multi-depth water quality data, necessary to understand changes through the water column, were unavailable. Further, no velocity measurements (were available. These two factors would constrain modeling efforts in the near future to two dimensions. Therefore, Taylor Engineering evaluated the hydraulic and water quality data gaps to identify the requirements of a two-dimensional model. Two-dimensional modeling would provide the circulation and water quality variation with respect to time and space. Model results would include depth-averaged values of a parameter (e.g., velocity for circulation and DO for water quality) at any given point in the model domain and at any time during the model simulation period. A two-dimensional model cannot provide the variation of a parameter along the vertical axis and thus would not simulate a condition such as a salt wedge.

Data requirements for two-dimensional water circulation and water quality modeling include at least tidal data, flows from tributary sources, and runoff data (typically developed from rainfall). Sufficient data exist to set up and calibrate a model (limited hydraulic model calibration) for the year 2001. Ongoing monthly sampling efforts at key points in the bay and tributaries would provide much of the necessary data for model validation (Figure 5.1). However, calibrating the models in detail would require intensive hydraulic and water quality monitoring.

5.3.2 Data for Physical Forcing in the Model

Tidal circulation provides the primary driving force for water circulation and transport of pollutants within the study area. Secondary forcing mechanisms include wind shear and pollutant dispersion. Therefore, to simulate the water quality in the bay, an hydraulic model must first adequately simulate the tidal circulation in the area. The hydraulic model would require stage or flow input values at its boundaries (measured stage or computed flow). Depending on the modeling software, the input data set may also include (or require) wind data for hydraulic simulation. The water quality model would likewise require water quality parameter input values (measured water quality data) at its boundaries and estimates of loadings within its model domain. Independent estimates could provide pollutant loadings. Dispersion is a well-described physical mechanism built into current water quality models. Most models require only the specification of a dispersion rate.

5.3.3 Model Domain

For this project, Taylor Engineering assumed Naples Bay as the primary area of interest for modeling. Secondary areas of interest included the Gordon River Extension and Lely Canal. Given these areas of interest, the available data suggested a model domain extending from SFWMD flow station 16019 in Golden Gate Canal to the Gordon River Extension weir at the north end of the bay and to the confluence of Marco River and the Gulf of Mexico south of the project area. The domain would also include a portion of the Gulf of Mexico adjacent to the City of Naples and would extend east to the road crossings over Rock Creek (at Highway 31), Haldeman Creek (at US 41), Lely Canal (at US 41), and Henderson Creek at Tamiami Trail. The model domain would extend south to Marco River because the Intracoastal Waterway (IWW) interconnects areas (i.e., Dollar Bay, Shell Bay, etc.) south of Naples Bay. Given the unlikely availability of tidal and water quality data along the IWW, locating the south boundary to Marco River allows application of Gulf tidal data as a model boundary. Further, the areas south of Naples Bay could convey water to and from Naples Bay and significantly affect water quality. Future diversions from Golden Gate Canal through creeks draining to these areas would increase local pollution loading and redistribute pollution loading in Naples Bay. These factors strongly encourage inclusion of these areas in the model domain.

5.3.4 Model Elevation Data

Bathymetric data from the survey in Task 1 of this project would provide the primary elevation data for the model setup. Inclusion of bulkhead survey data for the major canal systems would complete the data necessary for model bathymetric setup in the area of interest. Earlier survey data, nautical charts, and topographic maps might supplement the survey data to provide elevation data for the extensive model domain outside the area of interest.

5.3.5 Model Input Data

The hydraulic and water quality models would require input data for all periods of model simulations at the following points as a minimum (Figure 5.2):

- Stage and water quality at the Gulf of Mexico boundary (Gordon Pass and the confluence of Marco River and Gulf)
- Flow (or stage) and water quality at Station 16019 (Golden Gate Canal)
- Flow (or stage) and water quality at Gordon River Extension weir, Lely Canal, Rock Creek, Haldeman Creek, and Henderson Creek

The hydraulic water quality model requires an intensive calibration dataset. Forty-eight-hour hydraulic and water quality measurements made during the dry and wet seasons would provide sufficient calibration information. Needed information would include:

- Stage and velocity measured hourly at the hydraulic monitoring stations.
- Water quality parameters of interest to include temperature, salinity, dissolved oxygen, turbidity, nitrogen species (TKN and nitrite+nitrate), total phosphorus, dissolved orthophosphorus, and chlorophyll a measured either hourly or once every six hours.
- Proposed stations for intensive hydraulic and water quality calibration monitoring (Figure 5.2) include:
    - Golden Gate Canal weir, Gordon River Extension weir, Rock Creek, Haldeman Creek, Lely Canal and Henderson Creek (weir stage measurements where available, or stage and velocity measurements in the absence of a weir).
    - US 41 crossing over Gordon River (stage, velocity, and water quality measurements)
    - A point of constriction in the bay south of the US 41 crossing (stage, velocity, and water quality measurements)
    - A location at the south end of the project area (stage and velocity monitoring only)
    - Gordon Pass (stage, velocity, and water quality measurements)
    - Confluence of Marco River and the Gulf of Mexico (stage data only)

To provide an optimal dataset to verify the model performance, Taylor Engineering recommends a yearlong hydraulic and water quality data monitoring at the model’s external boundaries and at specific points within the bay. Water quality data collected at least every two weeks would provide an ideal basis to verify water quality predictions. Six-hour average flow at Station 16019 and hourly stage measurement at the other stations would provide sufficient resolution to simulate tidal circulation. Measured stage or rainfall would provide estimates of flows from Golden Gate Canal weir, Gordon River Extension weir, Rock Creek, Haldeman Creek, Lely Canal, and Henderson Creek. Available rainfall data would provide the basis to estimate flows and chemical loads from the contributing watersheds to the bay. Water quality sampling at watershed discharge points would provide model validation data.

5.3.6 Available Hydraulic Data

Hydraulic modeling requires either flow or stage data at the model boundaries for the entire simulation period. In the absence of flow data, a runoff model could simulate flow based on rainfall data. Available hydraulic data (Tables 5.1, 5.2, and 5.3: metadata from SFWMD DBHYDRO database) would include rainfall, stage, and flow measurements.

A comparison of the periods of record of the rainfall, stage, and flow data in Tables 5.1, 5.2, and 5.3 indicated that concurrent measurement of these variables sufficient for hydraulic modeling occurred from January 25, 2001 to June 19, 2002. More recent data from the recommended stations will become available in the DBHYDRO database. The addition of this data will extend the period of concurrent measurements.

The available concurrent flow data (computed from stage data) comes from:

- Golden Gate Canal Weir (Collier County Station DOS536)
- Gordon River Extension weir (DBHYDRO: Dbkey FI256)
- Lely Canal at US 41 (DBHYDRO: Dbkey 16044)
- Henderson Creek at Tamiami Trail (DBHYDRO Dbkey FI251)

Flow data from these stations could serve as the flow boundaries for the hydraulic model.

Concurrent rainfall data from SFWMD COLGOV_R station would provide the means to estimate the runoff flows from Rock Creek. Given the drainage area of the creek, rainfall-runoff modeling could provide the time series of flows from the creek's upstream boundary. SFWMD HALDEMAN_T would provide the stage boundary condition at Haldeman Creek at the US 41 model boundary.

Along the model's western boundary, concurrent stage data from NOAA 8725110 would provide a continuous record of water surface elevation for the model boundary along the Gulf. DBHYDRO could provide stage data for stations along Henderson Creek.

Tidal gauges could provide good model calibration data. However, as of this writing, no available stage data occur within the model domain from January 25, 2001 to June 19, 2002. Therefore, published tidal ranges at the bay could provide limited model calibration. Addition of tidal gauges in the bay (Figure 5.1) would allow a detailed calibration of the tidal behavior of a two-dimensional model.

5.3.7 Recommended Water Quality Data Collection

The insufficient water quality data from the present sampling program preclude calibration of the water quality model. Further, the data cannot support a process level water quality model that might simulate fluctuations in dissolved oxygen. However, the data should suffice for most of the necessary water quality model verification data for a two-dimensional model of the bay. The data from present sampling programs (Figure 5.1) would provide comparison information to evaluate errors in water quality model performance over the simulation period or periods. Additional water quality stations recommended for better water quality model verification would include the following station locations (Figure 5.1):

- Just inside Gordon Pass,
- Within the main passages from residential canal areas on the west side of the bay,
- In the main body of the bay south of Gordon Inlet
- In the IWW at the mouth of Lely Canal
- At a constriction near the mouth of Henderson Creek

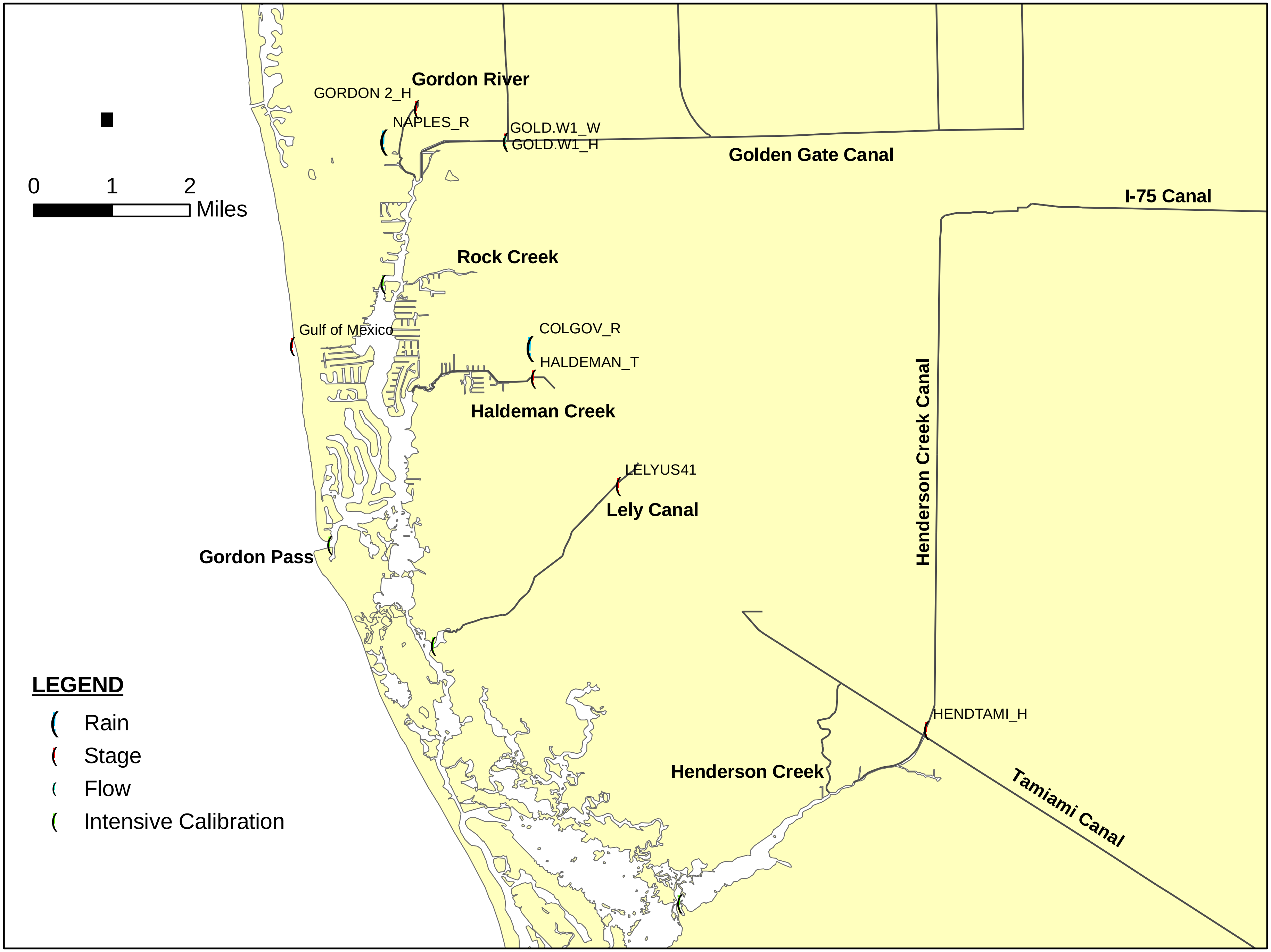

Figure 5.2. Locations for Water Circulation and Water Quality Model Calibration Data

5.4 Summary of Recommendations

Taylor Engineering envisions the use of a two-dimensional model to simulate long-term water circulation and water quality dynamics. This class of model would likely provide sufficient capability to simulate ambient water quality conditions for management of the bay to achieve and maintain Class III water quality standards. However, calibrating the model would require additional sampling and data collection. Additional long-term sampling stations would likely increase the ability to verify model performance, develop management plans, and monitor changes in the system.

Sufficient hydrologic data collected since 2000 from currently active hydrologic stations provide sufficient information for use in developing a limited calibrated water circulation model. Rainfall, flow at Golden Canal weir, and the Gordon River Extension weir, stage measurements from Haldeman Creek, Rock Creek, Lely Canal, Henderson Creek, and from gauges in the Gulf of Mexico would provide most of the data. Taylor Engineering recommends runoff modeling to provide stormwater flows from developed areas of the watershed, particularly the City of Naples.

Given the absence of tide gauges in Naples Bay, published tidal ranges would substitute for direct measurement to provide a limited calibration of the hydraulic model. The addition of several tide gauges would greatly improve hydraulic model calibration and verification capabilities

Intensive 48-hour hydraulic and water quality parameter measurements during the dry and wet seasons would provide the ideal data sets for a detailed calibration of the hydraulic and water quality models.

Data from monthly sampling efforts in the bay, augmented by data from recommended additions to the current sampling network, would provide verification data for the hydraulic and water quality model. The recommended sampling stations would suffice for verification of the model calibration and simulation period performance testing. The new stations would extend the monitored area south to Henderson Creek, potentially affected by proposed changes in the Naples Bay watershed canal drainage system.

Table 5.1 Collier County Rainfall Data

DBKEY	STATION	GROUP	FREQUENCY	AGENCY	START DATE	END DATE	LONGITUDE	LATITUDE
PT210	082850-2	82850	Daily	NOAA	1-Jan-31	26-Jan-97	-81.3869	25.8456
PT211	082850-2	82850	Daily	NOAA	27-Jan-97	28-Dec-01	-81.3869	25.8456
PT308	085359-1	85359	Daily	NOAA			-81.7139	25.9492
PT328	086076-1	86076	Daily	NOAA			-81.7753	26.1522
PT445	086078-1	86078	Daily	NOAA	1-Jul-48	28-Aug-50	-81.8167	26.1167
PT329	086078-2	86078	Daily	NOAA	1-Sep-50	28-Sep-50	-81.8167	26.1500
PT330	086078-3	86078	Daily	NOAA	1-Jun-51	28-May-61	-81.7833	26.1500
PT331	086078-4	86078	Daily	NOAA	1-Jun-61	28-Aug-98	-81.7833	26.1667
PT332	086078-5	86078	Daily	NOAA	21-Feb-84	6-Jun-84	-81.8000	26.1667
PT333	086078-6	86078	Daily	NOAA	1-Sep-98	28-May-00	-81.7883	26.1653
PT334	086078-7	86078	Daily	NOAA	1-Jun-00	4-Apr-01	-81.7878	26.1664
PT335	086078-8	86078	Daily	NOAA	5-Apr-01	28-Jun-01	-81.7878	26.1667
PT336	086078-9	86078	Daily	NOAA	1-Jul-01	28-Dec-01	-81.7158	26.1686
DO534	951EXT_R	951EXT_R	Daily	WMD	19-Jun-96	1-Jun-04	-81.6884	26.3026
DJ225	ASGROW	ASGROW	Daily	WMD			-81.7081	26.2712
5951	BAY WEST_R	BAY WEST	Daily	WMD	26-Apr-80	30-Sep-85	-81.7023	26.2751
DJ226	BCBNAPLE_R	BCBNAPLE	Daily	WMD	1-Dec-90	13-May-97	-81.8081	26.2254
DU536	**COLGOV_R**	**COLGOV_R**	**Daily**	**WMD**	**30-Apr-96**	**1-Apr-05**	**-81.7626**	**26.1298**
5978	COLLIER_R	COLLIER	Daily	WMD	30-Sep-81	31-Mar-05	-81.6581	26.1568
OU145	NAPCON_R	NAPCON_R	Daily	WMD	4-Feb-02	2-Apr-05	-81.7878	26.1672
16633	**NAPLES_R**	**NAPLES**	**Daily**	**WMD**	**8-Jan-91**	**15-Apr-05**	**-81.7898**	**26.1681**

Table 5.2 Collier County Stage Data. with Currently Active Stations in Bold Type

DBKEY	STATION	GROUP	FREQUENCY	AGENCY	START DATE	END DATE	LONGITUDE	LATITUDE
SN319	GG1_H	GG1_H	Daily	WMD	13-Jul-04	22-Sep-04	-81.7742	26.1680
SN321	GG1_T	GG1_T	Daily	WMD	13-Jul-04	22-Sep-04	-81.7742	26.1680
839	GOLD.W1_H	GOLD.W1	Daily	USGS	31-Mar-77	17-May-80	-81.7672	26.1680
840	GOLD.W1_H	GOLD.W1	Daily	USGS	1-Oct-67	3-Oct-84	-81.7672	26.1680
841	GOLD.W1_H	GOLD.W1	Daily	USGS	1-Oct-64	3-Oct-84	-81.7672	26.1680
5382	GOLD.W1_H	GOLD.W1	Daily	WMD	6-Dec-84	19-Oct-94	-81.7672	26.1680
16019	**GOLD.W1_H**	**GOLD.W1**	**Daily**	**WMD**	**19-Oct-94**	**22-Sep-04**	**-81.7672**	**26.1680**
4278	GORDON 2_H	GORDON 2	Daily	WMD	9-Oct-80	14-Aug-95	-81.7837	26.1740
4280	GORDON 2_T	GORDON 2	Daily	WMD	3-Sep-80	30-Oct-89	-81.7837	26.1740
13004	GORDON 2_T	GORDON 2	Daily	WMD	30-Oct-89	5-Nov-03	-81.7837	26.1740
FI256	GORDON 2_H	GORDON 2	Daily	WMD	22-Apr-97	6-Oct-04	-81.7837	26.1740
QS282	GORDON 2_T	GORDON 2	Daily	WMD	5-Nov-03	6-Oct-04	-81.7837	26.1740
MQ906	**HALDEMAN_T**	**HALDEMAN**	**Daily**	**WMD**	**25-Jan-01**	**21-Oct-04**	**-81.7620**	**26.1240**
P6258	NAPLE_T	NAPLE_T	Daily	WMD	2-Nov-00	6-Oct-04	-81.7668	26.1815
5530	GOLD.W2_H	GOLD.W2	Daily	WMD	28-Apr-83	20-Oct-94	-81.7348	26.1684
8725110	**Gulf of Mexico**		**6-minutes**	**NOAA**	**1-Jan-96**	**31-Jan-05**	**-81.8067**	**26.1300**
8725114	Naples Bay North		Daily	NOAA	1-Apr-78	31-Aug-78	-81.7883	26.1367
16044	**LELYUS41**	**LELYUS41**	**Daily**	**WMD**	**20-Jan-95**	**15-Mar-05**	**-81.7462**	**26.1040**
FI256	**GORDON 2_H**	**GORDON 2**	**Daily**	**WMD**	**22-Apr-97**	**06-Apr-05**	**-81.7837**	**26.1740**
FI251	**HENDTAMI_H**	**HENDTAMI**	**Daily**	**WMD**	**14-May-97**	**28-Mar-05**	**-81.6890**	**26.0587**

Table 5.3 Collier County Flow Data

DBKEY	STATION	GROUP	FREQUENCY	AGENCY	START DATE	END DATE	LONGITUDE	LATITUDE
842	GOLD.W1_W	GOLD.W1	Daily	USGS	1-Oct-64	3-Oct-84	-81.767180	26.167968
5386	GOLD.W1_W	GOLD.W1	Daily	WMD	29-Oct-89	30-Dec-97	-81.767180	26.167968
6518	GOLD.W1_W	GOLD.W1	Daily	USGS	27-Aug-81	13-Sep-84	-81.767180	26.167968
DO536	**GOLD.W1_W**	**GOLD.W1**	**Daily**	**WMD**	**30-Sep-91**	**19-Jun-02**	**-81.767180**	**26.167968**

REFERENCES

Janicki Environmental, Inc. 2003. *Water Quality Data Analysis and Report for the Charlotte Harbor National Estuary Program. Prepared for: Charlotte Harbor National Estuary Program*, North Fort Myers, Florida.

APPENDIX A

Station Names, Locations, and Periods of Record

Station Code	Station_NA	Location	Start Date	End Date
3495	GOLDEN GATE CANAL AT C.R. 31	Golden Gate Canal	12/14/1998	8/13/2002
2291300	GOLDEN GATE CANAL AT NAPLES, FLA	Golden Gate Canal	11/27/1965	12/3/1979
28030038	GOLD GATE CAN SR 951 BR	Golden Gate Canal	4/3/1973	7/10/1991
28030053	GOLDEN GATE CANAL BETWEEN SR31/I75UPSTREAM OF	Golden Gate Canal	12/22/1988	12/11/1991
AIRPORT886	Golden Gate Canal Basin	Golden Gate Canal	12/4/1991	8/19/1997
BC4	Downstream weir in Golden Gate Canal across from Bear's Paw Country Club	Golden Gate Canal	10/18/2000	6/19/2002
GGCAT31	Bridge at intersection of Airport Rd and Golden Gate Canal	Golden Gate Canal	1/17/1979	6/6/2002
2291280	GORDON RIVER AT NAPLES,FLA	Gordon River	10/26/1970	9/11/1980
28030047	GORDON R ABOVE WIER 951	Gordon River	8/30/1972	9/11/2002
28030048	GORDON R BEMBURY CANAL	Gordon River	8/30/1972	9/28/1989
BC3	Gordon River Ext. at mouth of canal leading to Main Post Office	Gordon River	10/18/2000	6/19/2002
GORDONRV	Bridge at intersection of Golden Gate Pkwy and Gordon River Extension	Gordon River	7/6/1981	12/19/1988
GRESTA10		Gordon River	7/15/1997	7/15/1997
10		Gulf	10/27/1993	11/15/1999
9573	US Fish & Wildlife Service	Gulf	8/19/1957	11/14/1957
COLLIER316	NAPLES PIER	Gulf	6/18/2001	6/18/2001
COLLIER55	LOWDERMILK PARK BEACH	Gulf	6/18/2001	6/18/2001
ROOK465		Gulf	1/26/1999	12/17/2002
3		Haldeman Creek	10/27/1993	11/15/1999
6		Haldeman Creek	10/27/1993	11/15/1999
28030029	NAP BAY HALD CK	Haldeman Creek	8/30/1972	8/18/1975
BC5	Bridge at intersection of Haldeman Creek and Bayshore Dr.	Haldeman Creek	10/18/2000	6/19/2002
HALD32	Haldeman Creek at end of Palm Lane	Haldeman Creek	4/16/1992	9/22/1992
HALDCRK	Upstream of amil gate at intersection of US41 and Haldeman Creek	Haldeman Creek	12/5/1989	8/20/1997
HALDNB	Junction of Haldeman Creek and Naples Bay	Haldeman Creek	4/16/1992	8/22/1996
LELY	Bridge at intersection of US41 and Lely Main Canal	Lely Canal	12/5/1989	6/15/1998
LELYICW		Lely Canal	4/24/1996	8/22/1996
LMAIN2		Lely Canal	12/20/1995	8/27/1996
4		Lower Bay	11/27/1993	11/15/1999
5		Lower Bay	10/27/1993	11/15/1999
7		Lower Bay	10/27/1993	11/15/1999
8		Lower Bay	10/27/1993	11/15/1999
9		Lower Bay	10/27/1993	11/15/1999
28030004		Lower Bay	1/5/1971	7/28/1975
28030033	NAP BAY YACHT BASIN	Lower Bay	8/30/1972	4/11/1990
28030034	NAP BAY CAN BETW PEL & BL PT	Lower Bay	7/6/1972	6/7/1976
28030035	NAP BAY JAYCEE PK	Lower Bay	8/30/1972	9/28/1989
28030050	NAPLES BAY CANAL BETW ENDS KINGF	Lower Bay	8/30/1972	8/18/1975
260700081472800	NAPLES BAY (FCD STATION)	Lower Bay	9/8/1978	9/8/1978
BC1	Channel Marker 38 in Naples Bay	Lower Bay	10/18/2000	6/19/2002
COL-COL10-017	Collier-COL10-017	Lower Bay	4/10/2001	4/10/2001
COL-COL10-034	Collier-COL10-034	Lower Bay	2/5/2001	2/5/2001
COL-COL10-041	Collier-COL10-041	Lower Bay	5/23/2001	5/23/2001
COL-COL3-939	Collier-COL3-939	Lower Bay	5/23/2001	5/23/2001
COL-COL3-964	Collier-COL3-964	Lower Bay	12/19/2000	12/19/2000
COL-COL3-965	Collier-COL3-965	Lower Bay	4/10/2001	4/10/2001
COL-COL5-889	Collier-COL5-889	Lower Bay	4/10/2001	4/10/2001
COL-COL5-903	Collier-COL5-903	Lower Bay	2/5/2001	2/5/2001
COL-COL5-907	Collier-COL5-907	Lower Bay	5/23/2001	5/23/2001
COL-COL6-617	Collier-COL6-617	Lower Bay	4/10/2001	4/10/2001
COL-COL6-631	Collier-COL6-631	Lower Bay	2/5/2001	2/5/2001
COL-COL6-633	Collier-COL6-633	Lower Bay	5/23/2001	5/23/2001
COL-COL7-009	Collier-COL7-009	Lower Bay	4/10/2001	4/10/2001
COL-COL7-988	Collier-COL7-988	Lower Bay	5/23/2001	5/23/2001
COL-COL7-998	Collier-COL7-998	Lower Bay	2/5/2001	2/5/2001
COL-COL8-972	Collier-COL8-972	Lower Bay	4/10/2001	4/10/2001
COL-COL8-973	Collier-COL8-973	Lower Bay	2/5/2001	2/5/2001
COL-COL8-986	Collier-COL8-986	Lower Bay	5/23/2001	5/23/2001
COL-COL9-716	Collier-COL9-716	Lower Bay	4/10/2001	4/10/2001
COL-COL9-742	Collier-COL9-742	Lower Bay	2/5/2001	2/5/2001
COL-COL9-775	Collier-COL9-775	Lower Bay	5/23/2001	5/23/2001
COLLIER57	GORDONS PASS	Lower Bay	6/18/2001	6/18/2001
COL-NA-ESBAY-1	Collier-Naples Bay-1	Lower Bay	4/25/2001	8/23/2001
COL-NA-ESBAY-2	Collier-Naples Bay-2	Lower Bay	4/25/2001	8/23/2001

Station Code	Station_NA	Location	Start Date	End Date
COL-NA-ESBAY-3	Collier-Naples Bay-3	Lower Bay	4/25/2001	8/23/2001
DOLLAR15	Dollar Bay at Marker 68	Lower Bay	4/15/1992	9/21/1992
GORD10		Lower Bay	4/11/1989	9/21/1992
NBAY20	Naples Bay at Channel Marker 21	Lower Bay	4/16/1992	9/21/1992
NBAY22	Naples Bay at entrance to Treasure Cove	Lower Bay	4/15/1992	12/2/1992
NBAY24	Naples Bay at Marker 24	Lower Bay	4/18/1990	8/22/1996
NBAY41	Naples Bay at mouth of canal entering Royal Harbor	Lower Bay	4/13/1992	9/22/1992
NBAY50	Naples Bay at Marker 31	Lower Bay	4/13/1992	9/22/1992
NTK200120	N 10K Islands - Naples Bay	Lower Bay	10/18/2000	6/19/2002
NTK200121	N 10K Islands - Naples Bay	Lower Bay	7/13/2001	7/13/2001
NTK200121_B	N 10K Islands - Naples Bay	Lower Bay	10/5/2001	10/5/2001
ROOK463	Naples Bay south of Gordon Pass	Lower Bay	1/26/1999	12/17/2002
ROOK464		Lower Bay	1/26/1999	12/17/2002
28030032	NAP BAY ROCK CK	Rock Creek	8/30/1972	9/28/1989
ROCK62	Located at junction of Rock Creek and Harbor Lane adjoining the Brookside Subdivision	Rock Creek	4/13/1992	8/22/1996
ROCKE	Rock Creek	Rock Creek	12/5/1991	8/21/1997
ROCKW	Rock Creek	Rock Creek	12/5/1991	8/20/1997
119001	EV-GAC CORP CANAL CROSSING-NAPLE GGC	Tributaries	3/5/1970	3/25/1970
119002	EV-GAC CNL CROSSING-GOLDEN GATE GGC	Tributaries	3/5/1970	3/25/1970
119003	EV-GAC CNL NR GOLDEN GATE ESTATE GGC	Tributaries	3/5/1970	3/25/1970
119004	EV-GAC CNL RD TO PRODUCE COMPANY GGC	Tributaries	3/5/1970	3/25/1970
2291393	COCOHATCHEE RIVER CANAL AT WILLOUGHBY ACRE BRIDG	Tributaries	5/19/1970	10/10/1979
261009081411400	GOLDIN GATE CA E OF NAPLES, FLA	Tributaries	1/20/1972	1/24/1979
261335081352400	10B GORDON RIVER CANAL AT NAPLES FLA	Tributaries	10/26/1970	1/24/1979
28020265FTM	Cocohatchee River at Immokalee Rd and Palm River Blvd	Tributaries	9/13/2000	8/20/2002
9CN@GGBL	Golden Gate Canal Basin	Tributaries	12/16/1996	8/21/1997
ARN@VAND	Golden Gate Canal Basin	Tributaries	12/12/1996	8/18/1997
ARS@896	Golden Gate Canal Basin	Tributaries	12/9/1996	8/18/1997
BC15	Airport Rd. Canal at entrance to Sam's Club GGC	Tributaries	10/17/2000	6/20/2002
BC23	Bridge at intersection of Main Golden Gate Canal and CR951 (GGCAT951)	Tributaries	10/25/2000	6/6/2002
BC26	Intersection of 951 Canal and Immokalee Rd. Canal ("COCAT951")	Tributaries	10/25/2000	4/3/2002
BRYPUMSW	Surface Water Site on Townsend Canal Downside Berry Grove Pump Station GGC	Tributaries	9/19/2002	3/5/2003
COCAT951	COCOHATCHEE CANAL AT THE JUNCTION OF S.R. 951 AND S.R. 846	Tributaries	1/17/1979	8/18/1998
COCEOF31	Golden Gate Canal basin	Tributaries	12/7/1989	6/15/1998
COCPALM	Bridge at Intersection of Palm River Drive and Coconut Palm River	Tributaries	12/7/1989	8/18/1998
CORK@846	Bridge at intersection of Corkscrew Canal and CR846	Tributaries	12/12/1996	6/11/2002
CYPR@GGB	Golden Gate Canal basin	Tributaries	12/16/1996	8/21/1997
D2886	Golden Gate Canal basin	Tributaries	12/4/1991	8/18/1997
GCB01@20	Golden Gate Canal Basin	Tributaries	12/10/1996	8/19/1997
GCB02@SUN	Golden Gate Canal Basin	Tributaries	12/10/1996	8/19/1997
GGC@858	Bridge at intersection of Golden Gate Canal and CR858	Tributaries	12/16/1996	6/11/2002
GGC@GGBE	Golden Gate Canal Basin	Tributaries	12/16/1996	8/21/1997
GGC@WHITE	Golden Gate Canal Basin	Tributaries	12/16/1996	8/21/1997
GGC05@23	Golden Gate Canal Basin	Tributaries	12/16/1996	8/21/1997
GGC10	Golden Gate Canal Basin	Tributaries	12/4/1991	8/19/1997
GGC14	Golden Gate Canal Basin	Tributaries	12/4/1991	8/18/1997
GGCAT951	Bridge at intersection of Main Golden Gate Canal and CR951	Tributaries	1/17/1979	8/19/1997
LP-BEACH	LAKES PARK - Beach	Tributaries	1/14/1992	7/15/1992
LP-BIRD	LAKES PARK - Bird	Tributaries	1/14/1992	7/15/1992
LP-IONA	LAKES PARK - Iona	Tributaries	5/11/1989	10/6/1999
LP-RAMP	LAKES PARK - Ramp	Tributaries	1/14/1992	7/15/1992
LP-SIGN	LAKES PARK - Sign	Tributaries	1/14/1992	7/15/1992
MGG03@32	Golden Gate Canal Basin	Tributaries	12/10/1996	8/19/1997
ORANGETR	Golden Gate Canal Basin	Tributaries	12/12/1996	8/20/1997
PIPERS	Golden Gate Canal Basin	Tributaries	6/23/1992	8/18/1998
QUAILCK	Golden Gate Canal Basin	Tributaries	9/21/1992	8/18/1998
ROYALP	Gordon River Extension basin	Tributaries	12/4/1991	8/20/1992
WILSON846	Golden Gate Canal Basin	Tributaries	12/9/1997	8/18/1998
126801	SEA GATE CANAL AT MOUTH GR	Tributaries	10/19/1977	10/20/1977
126802	SEA GATE CANAL AT MOUTH LAST ARM GR	Tributaries	10/19/1977	10/20/1977
126803	CLAM BAY AT CONNECTOR TO DOCTORS	Tributaries	10/19/1977	10/20/1977
126804	SEA GATE CANAL AT DEAD END GR	Tributaries	10/19/1977	10/20/1977

Station Code	Station_NA	Location	Start Date	End Date
126805	CLAM BAY NEAR SEA GATE CANAL GR	Tributaries	10/19/1977	10/20/1977
126810	CANAL DEAD END DOCTORS BAY GR	Tributaries	10/20/1977	10/20/1977
126811	CANAL DEAD END DOCTORS BAY GR	Tributaries	10/19/1977	10/20/1977
126813	DOCTORS BAY AT CONNECTOR TO CLAM GR	Tributaries	10/19/1977	10/20/1977
126815	DOCTORS BAY OVERWATER STRUCTURE GR	Tributaries	10/19/1977	10/20/1977
126816	DOCTORS BAY OVER WATER STRUCTURE GR	Tributaries	10/19/1977	10/20/1977
COL-CL-YWEST-3	Collier-Clam Bay West-3	Tributaries	3/1/2001	12/12/2002
GRE896	Gordon River Extension at Pine Ridge Rd.	Tributaries	12/4/1991	8/20/1992
GREEN@SB	Gordon River Extension basin	Tributaries	12/9/1996	8/18/1997
GRESTA1	Gordon River Extension basin	Tributaries	10/28/1996	10/28/1996
GRESTA2	Gordon River Extension basin	Tributaries	10/28/1996	8/4/1997
GRESTA3	Gordon River Extension basin	Tributaries	10/28/1996	8/4/1997
GRESTA4	Gordon River Extension basin	Tributaries	10/28/1996	11/20/1996
GRESTA5	Gordon River Extension basin	Tributaries	10/28/1996	8/4/1997
GRESTA7	Gordon River Extension basin	Tributaries	10/29/1996	8/4/1997
GRESTA8	Gordon River Extension basin	Tributaries	10/29/1996	4/21/1997
I75C@VAN	Golden Gate Canal basin	Tributaries	12/12/1996	8/18/1997
1		Upper Bay	8/31/1994	11/15/1999
2		Upper Bay	8/31/1994	11/15/1999
28030030	NAP BAY GORD R @ PORT AVE	Upper Bay	8/30/1972	6/17/1974
28030031	NAP BAY S OF NAP STP EFF	Upper Bay	8/30/1972	9/28/1989
28030049	NAPLES BAY 5 AV S BR W	Upper Bay	8/30/1972	2/6/1991
260859081472400	10B GORDON RIVER AT US 41 AT NAPLES FLA	Upper Bay	10/26/1970	11/15/1999
261147081470400	10B GORDON RIVER AT US 41 AT NAPLES FLA	Upper Bay	7/13/1972	7/13/1972
BC2	Just inside the mouth of Rock Creek	Upper Bay	4/11/1989	6/19/2002
GORD60	Gordon River at US 41 bridge near Boat Haven	Upper Bay	4/13/1992	9/23/1992
GORD70	Gordon River opposite City of Naples Wastewater Treatment Plant outfall	Upper Bay	4/13/1992	9/23/1992
GORD80	Mid-channel of Gordon River at confluence with reach leading to the Conservancy	Upper Bay	4/13/1992	9/23/1992
260934081464100	10B NAPLES AIRPORT DRAINAGE CANAL NR NAPLE	Upper Bay	3/16/1977	12/3/1979

APPENDIX B

Box and Whisker Plots of Individual Station Data Used to Evaluate Current Water Quality Conditions in Lower Naples Bay

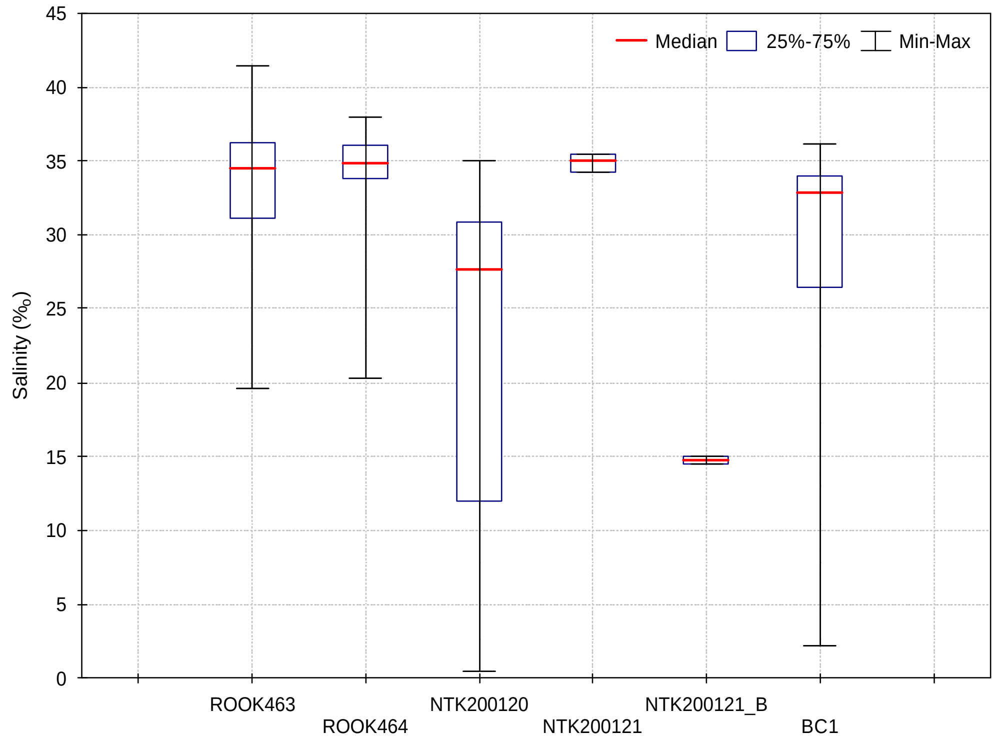

Figure 1. Box Plots for Salinity Data

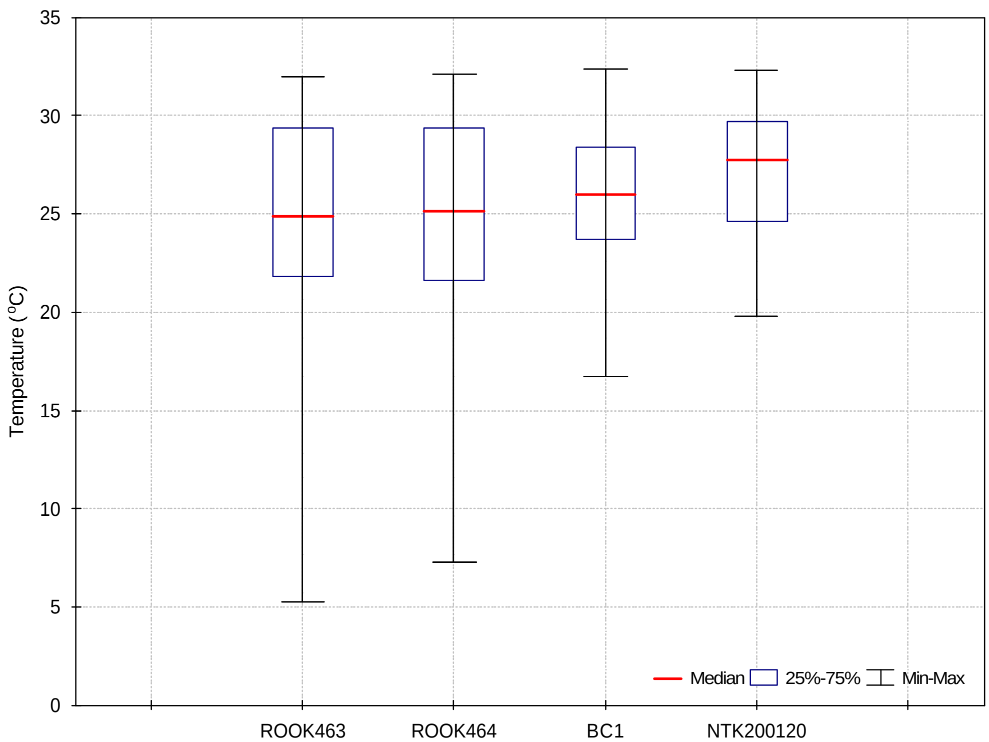

Figure 2. Box Plots for Temperature Data

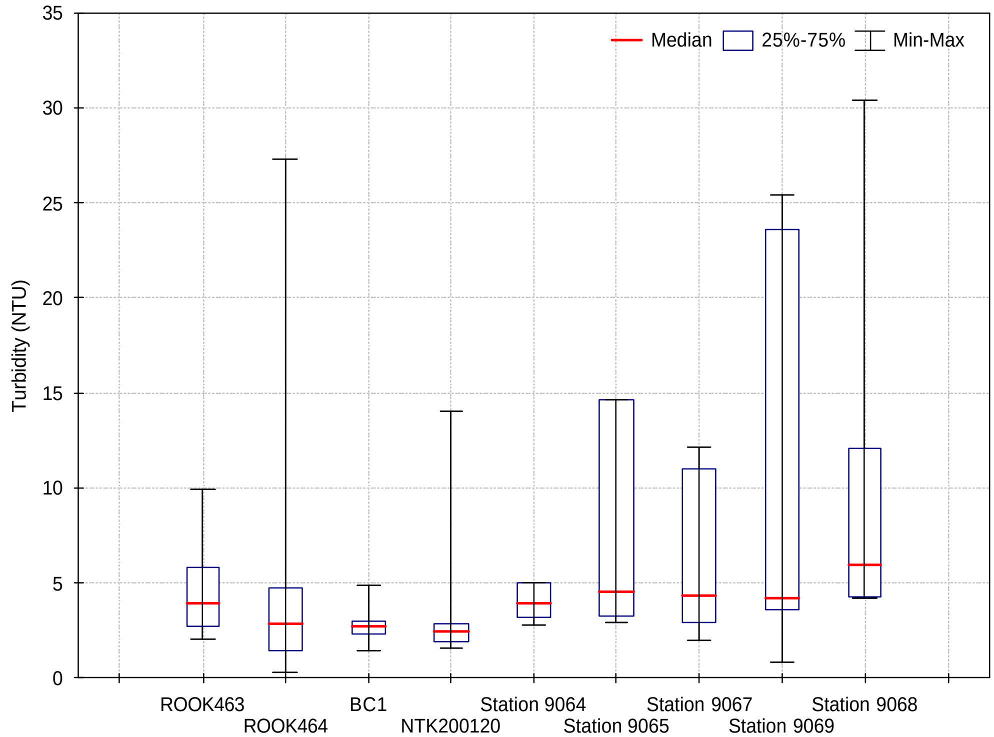

Figure 3. Box Plots for Turbidity Data

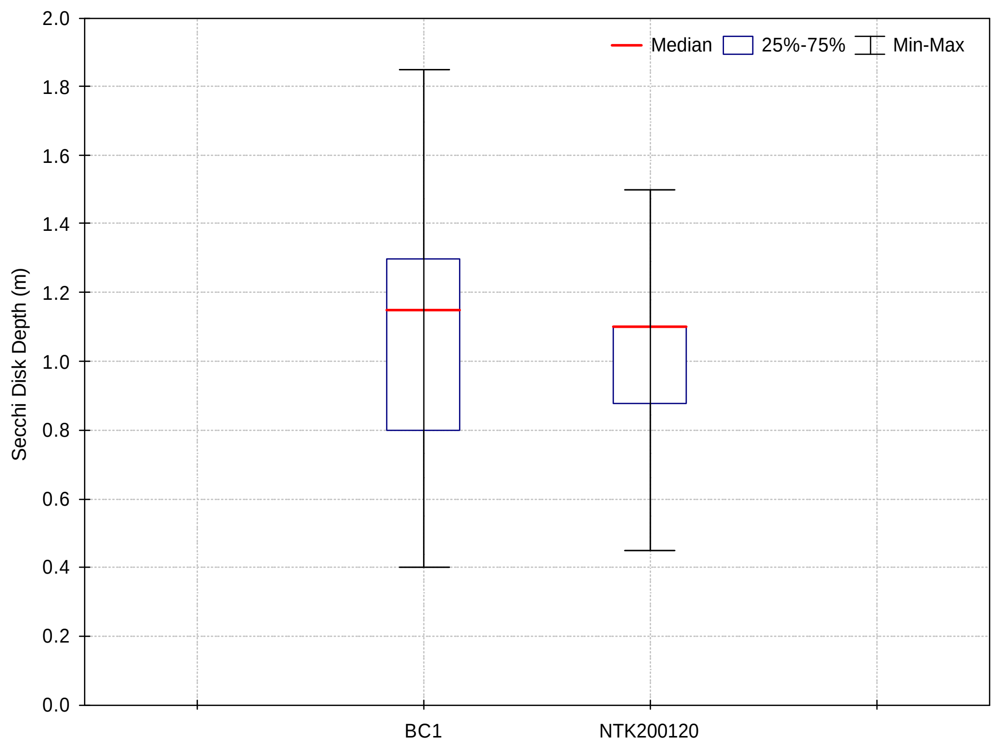

Figure 4. Box Plots for Secchi Disk Depth Data

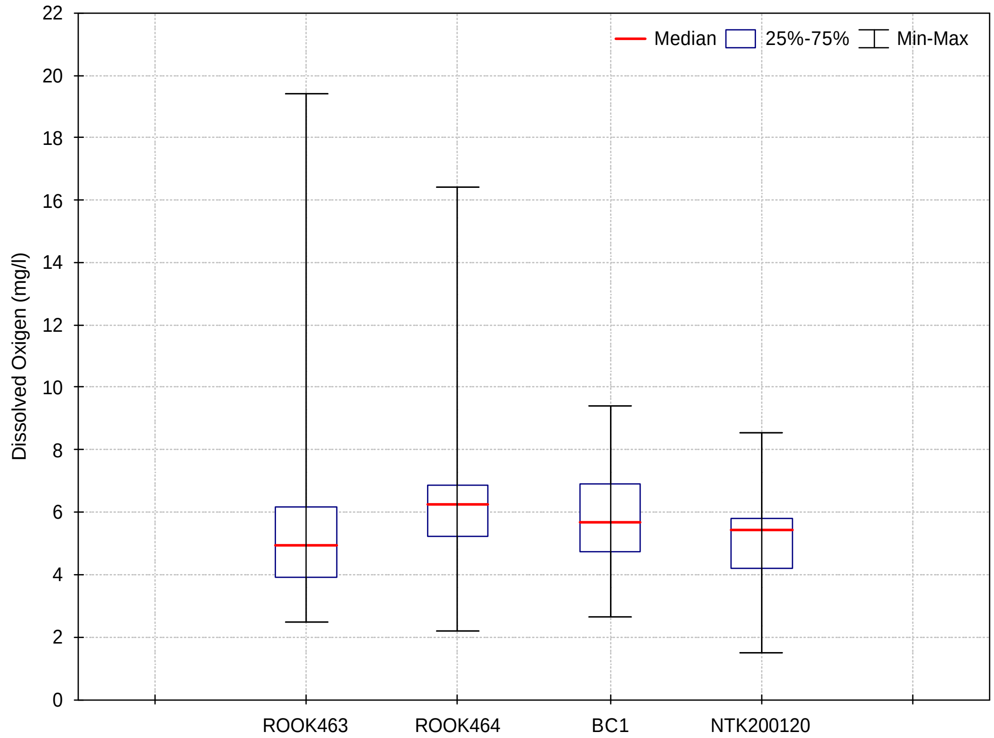

Figure 5. Box Plots for Dissolved Oxygen Data

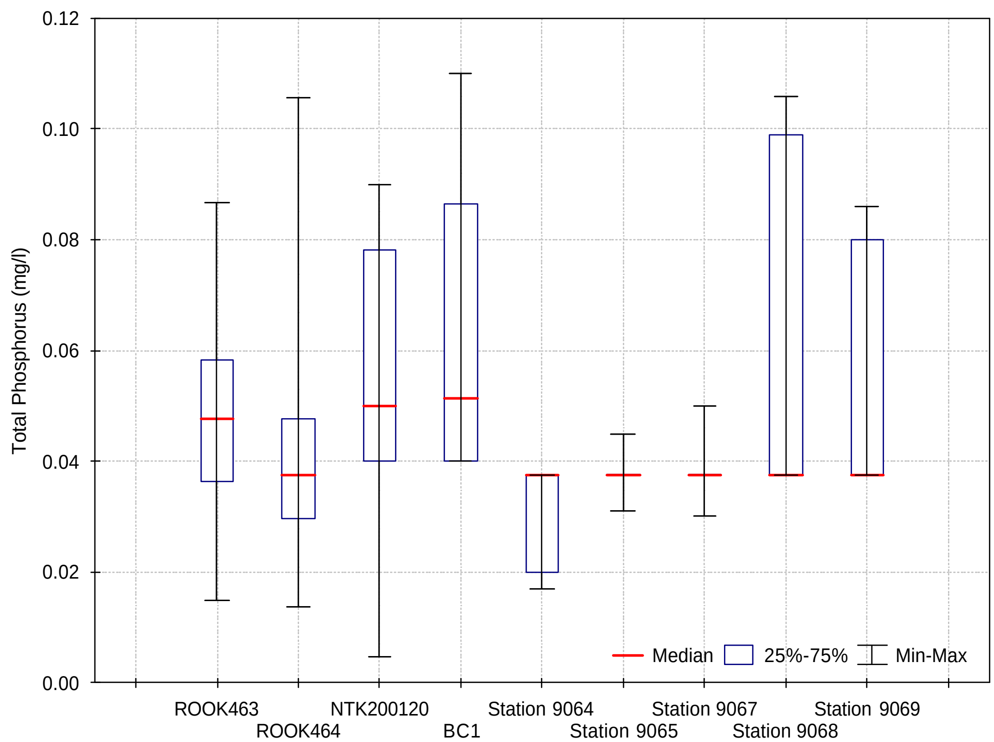

Figure 6. Box Plots for Total Phosphorus Data

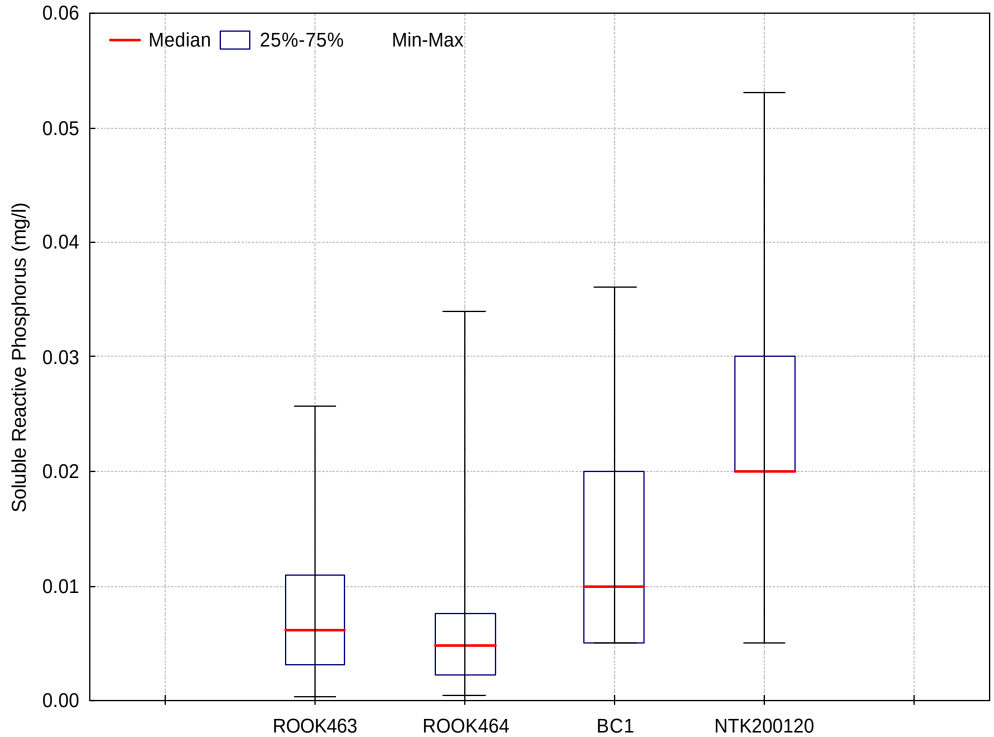

Figure 7. Box Plots for Soluble Reactive Phosphorus Data

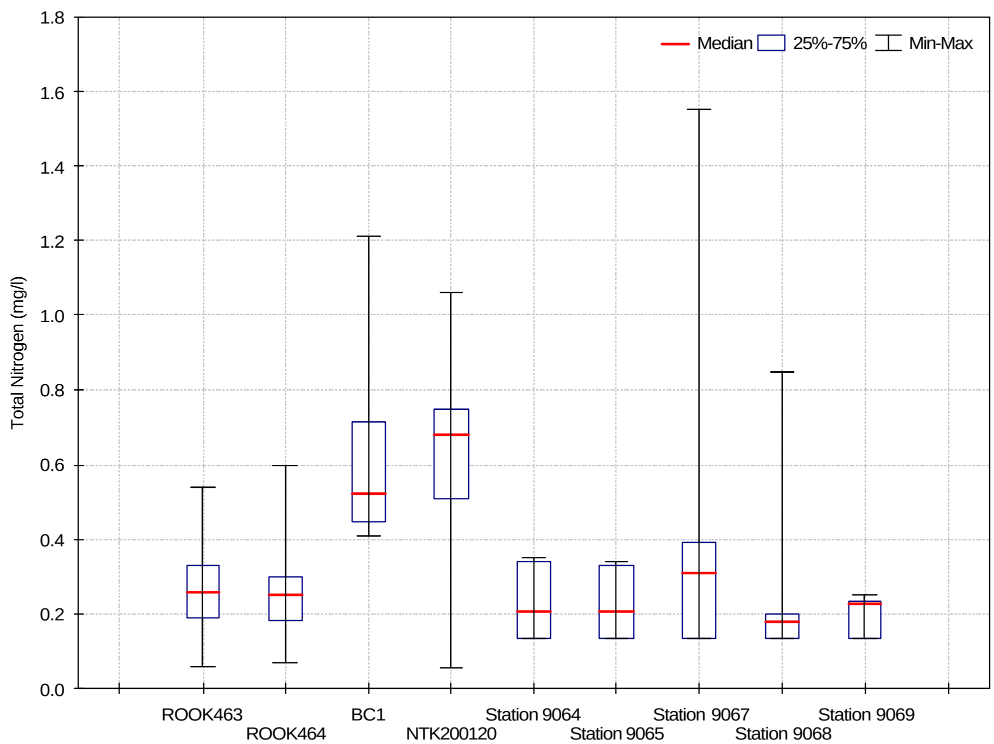

Figure 8. Box Plots for Total Nitrogen Data

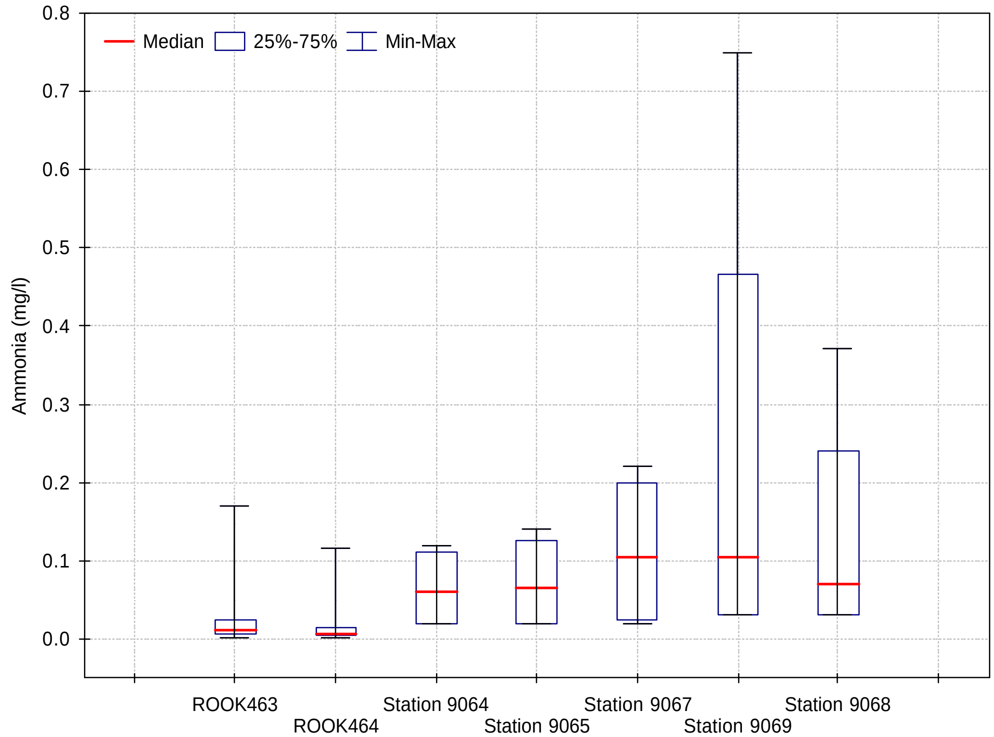

Figure 9. Box Plots for Ammonia Data

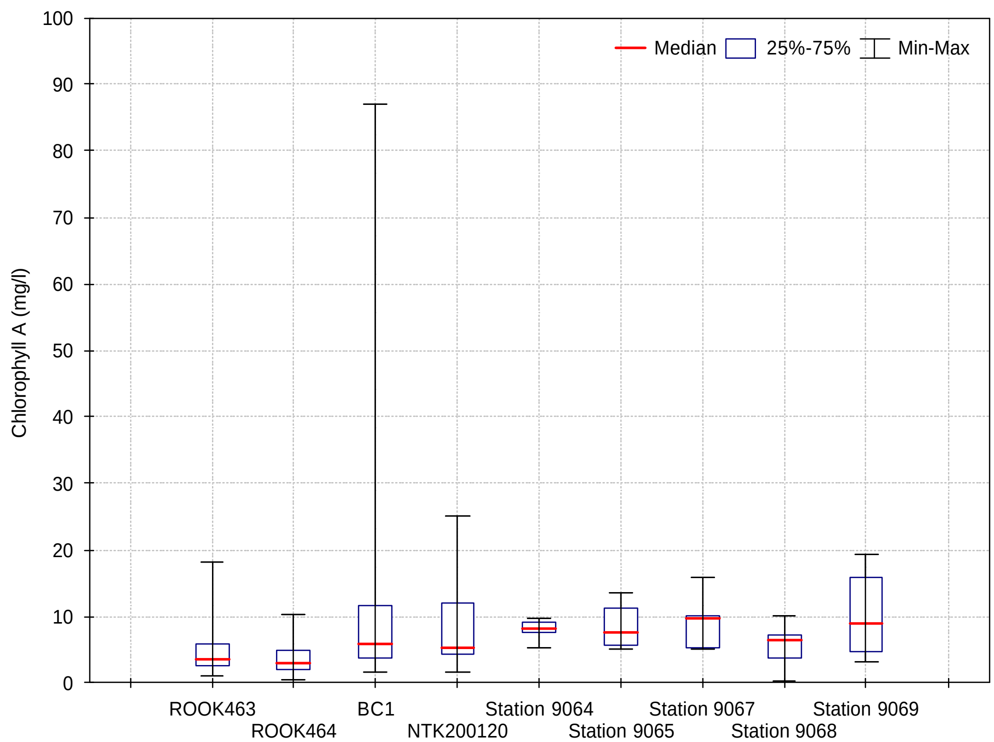

Figure 10. Box Plots for Chlorophyll A Data

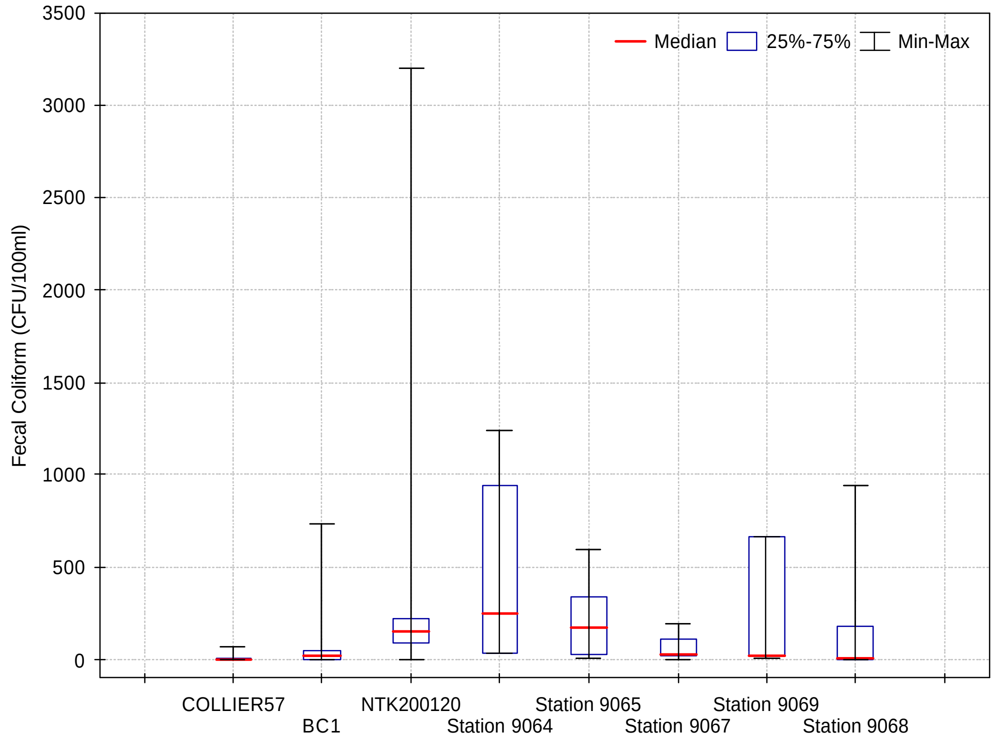

Figure 11. Box Plots for Fecal Coliform Data

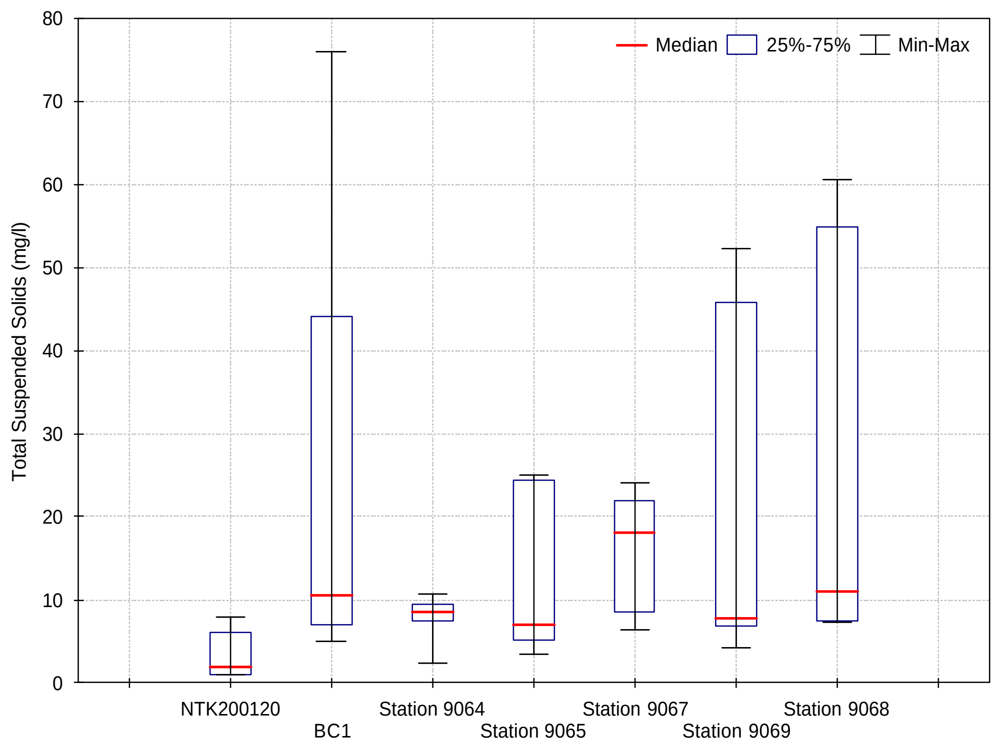

Figure 12. Box Plots for Total Suspended Solids Data

APPENDIX C

Box and Whisker Plots of Individual Station Data Used in to Evaluate Current Water Quality Conditions in Upper Naples Bay

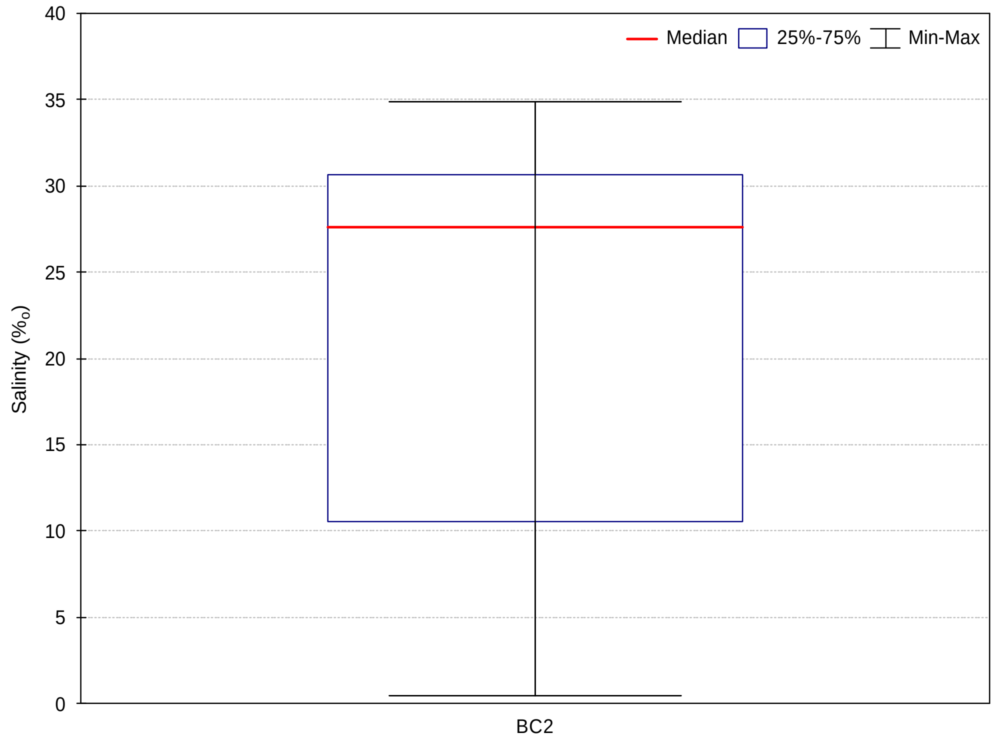

Figure 1. Box Plots for Salinity Data

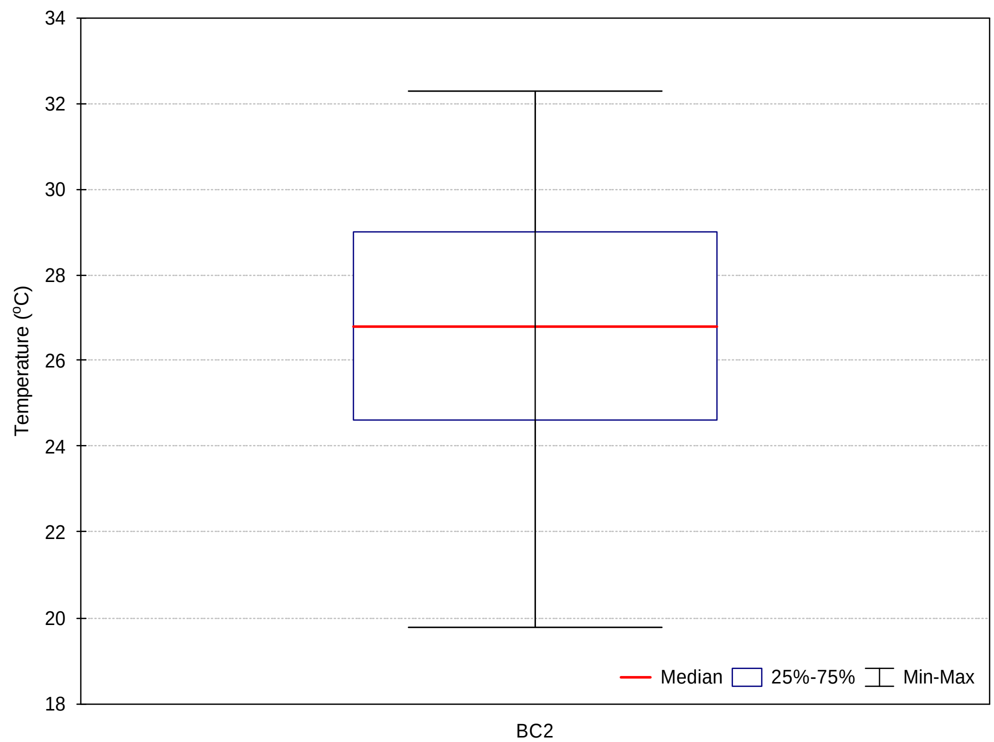

Figure 2. Box Plots for Temperature Data

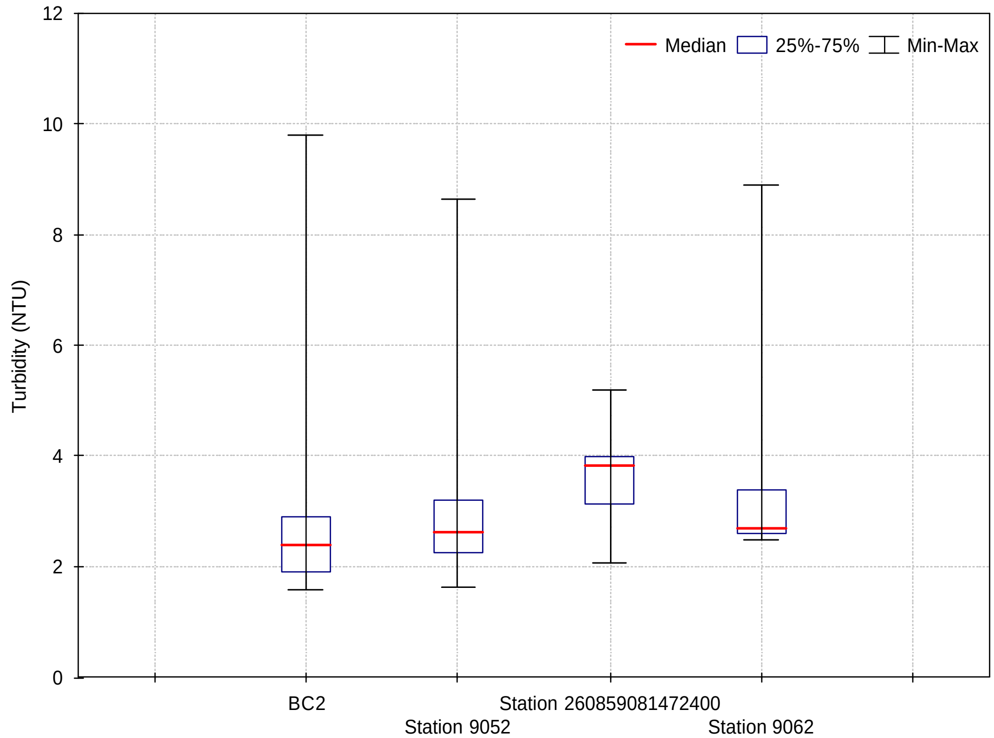

Figure 3. Box Plots for Turbidity Data

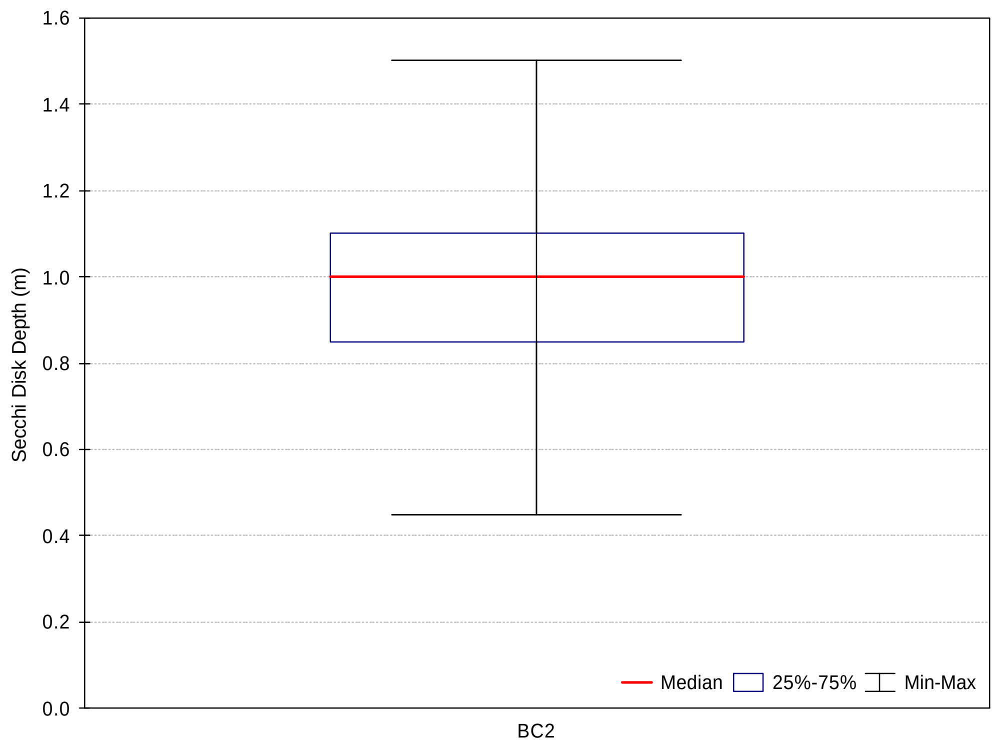

Figure 4. Box Plots for Secchi Disk Depth Data

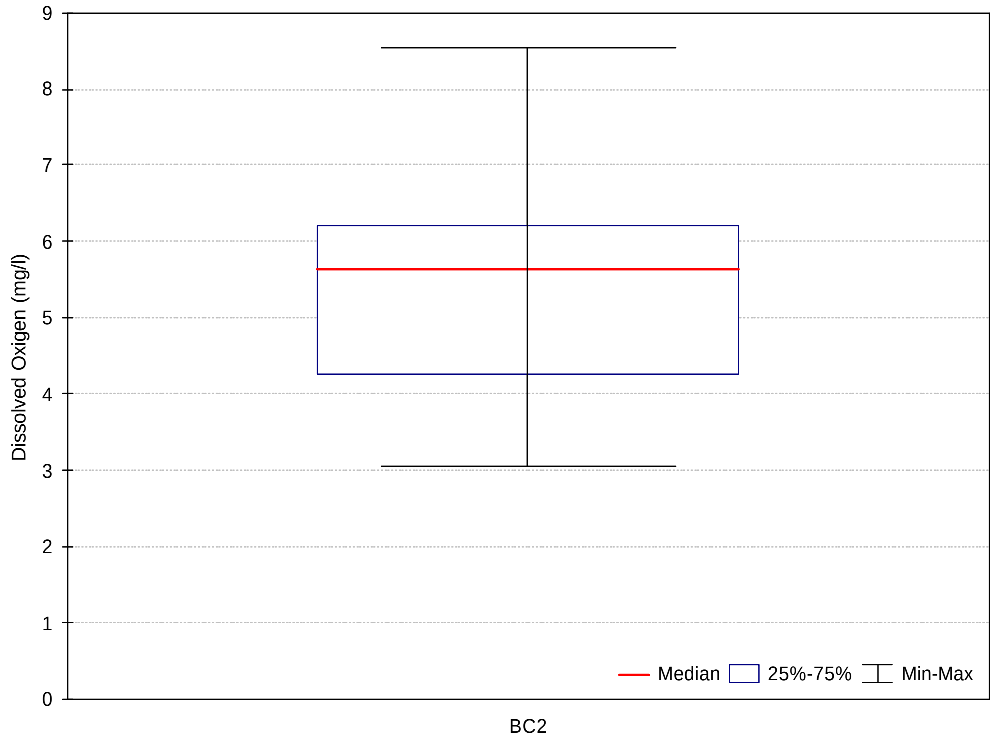

Figure 5. Box Plots for Dissolved Oxygen Data

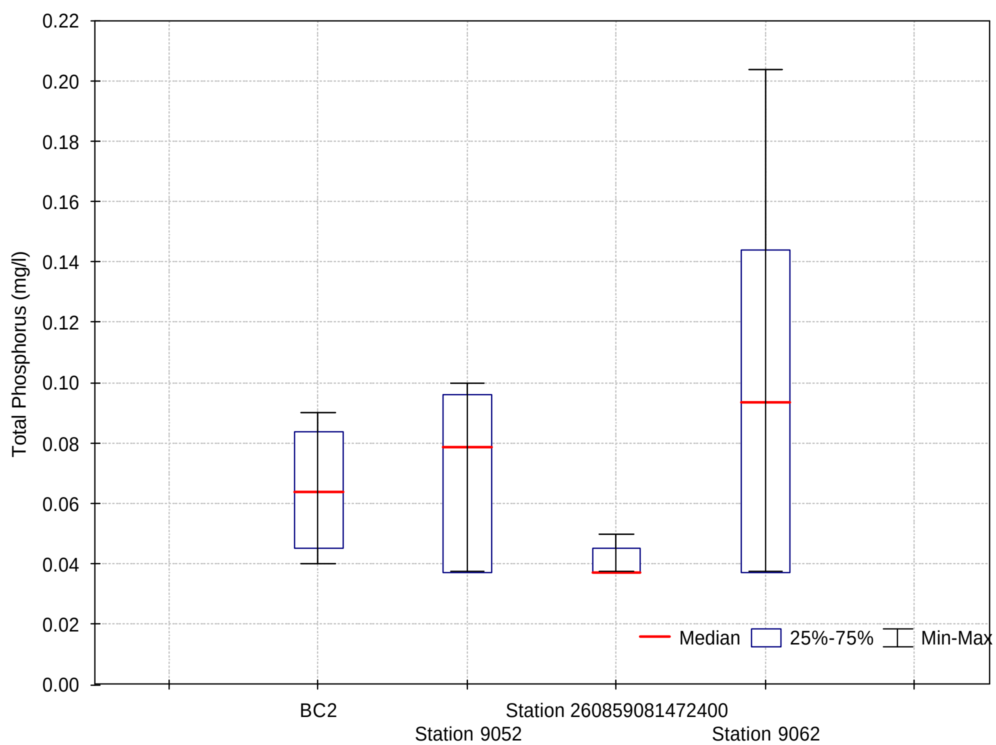

Figure 6. Box Plots for Total Phosphorus Data

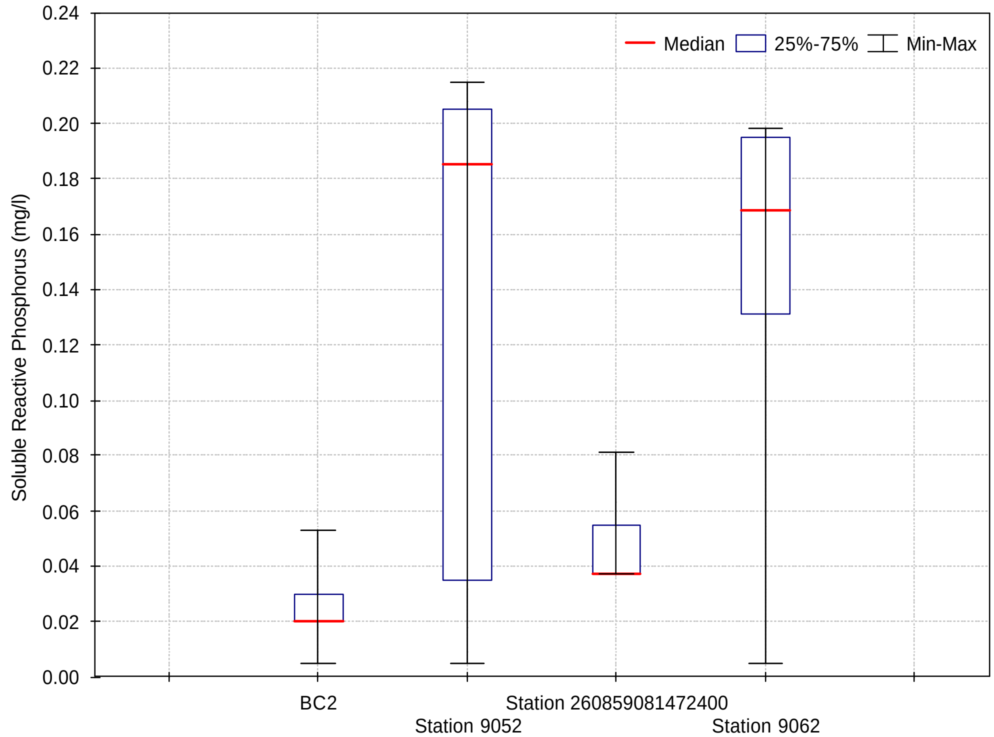

Figure 7. Box Plots for Soluble Reactive Phosphorus Data

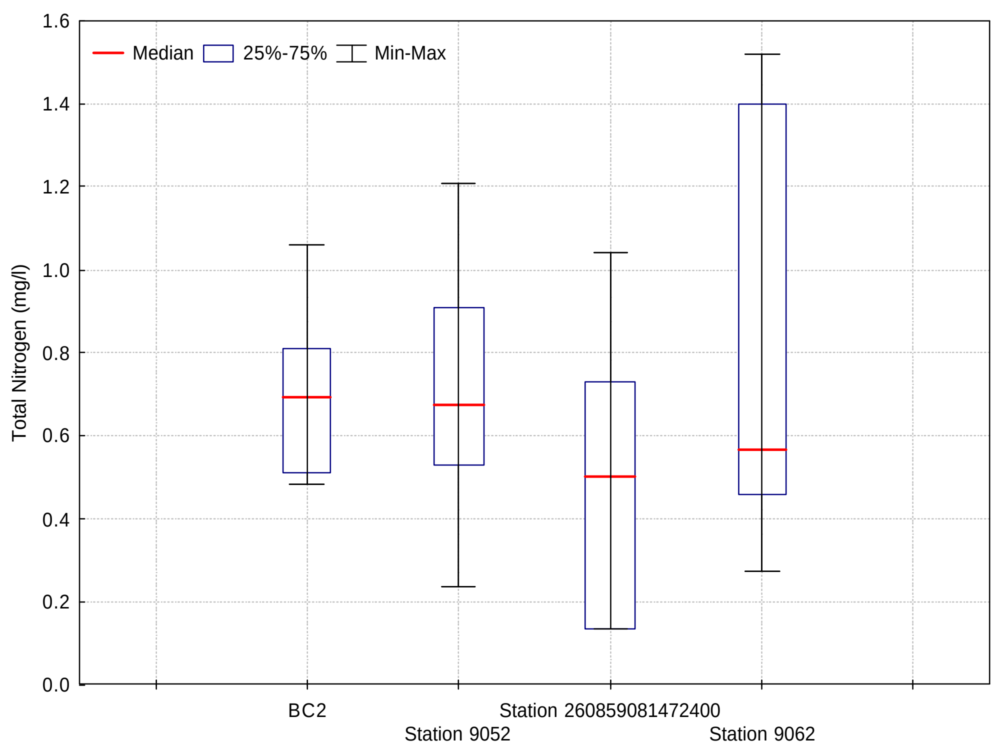

Figure 8. Box Plots for Total Nitrogen Data

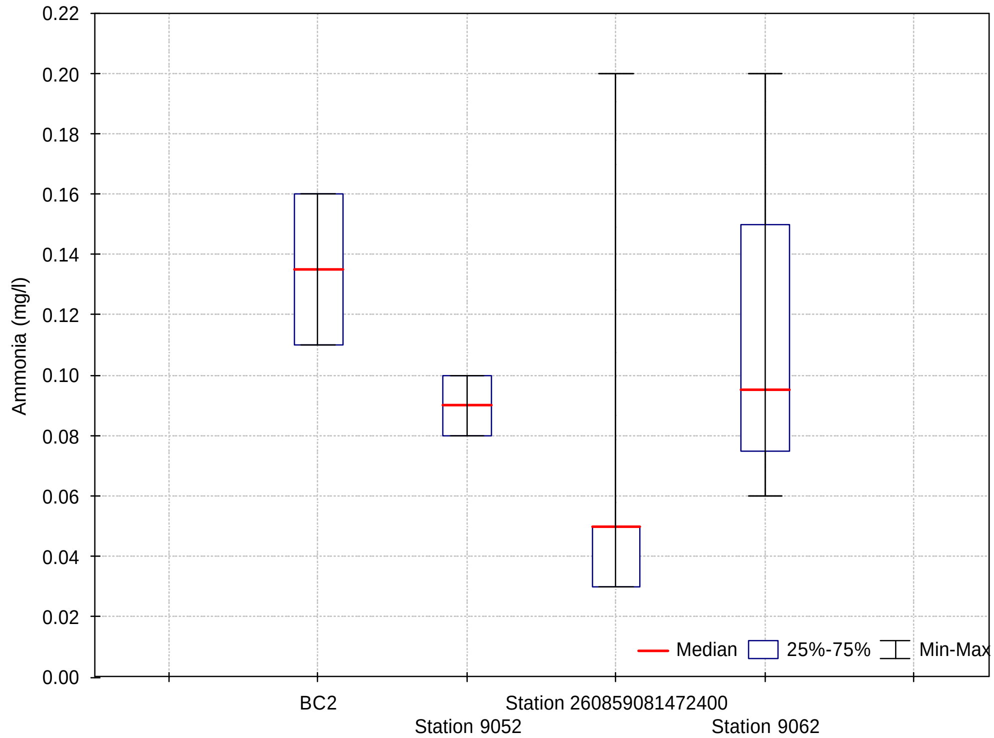

Figure 9. Box Plots for Ammonia Data

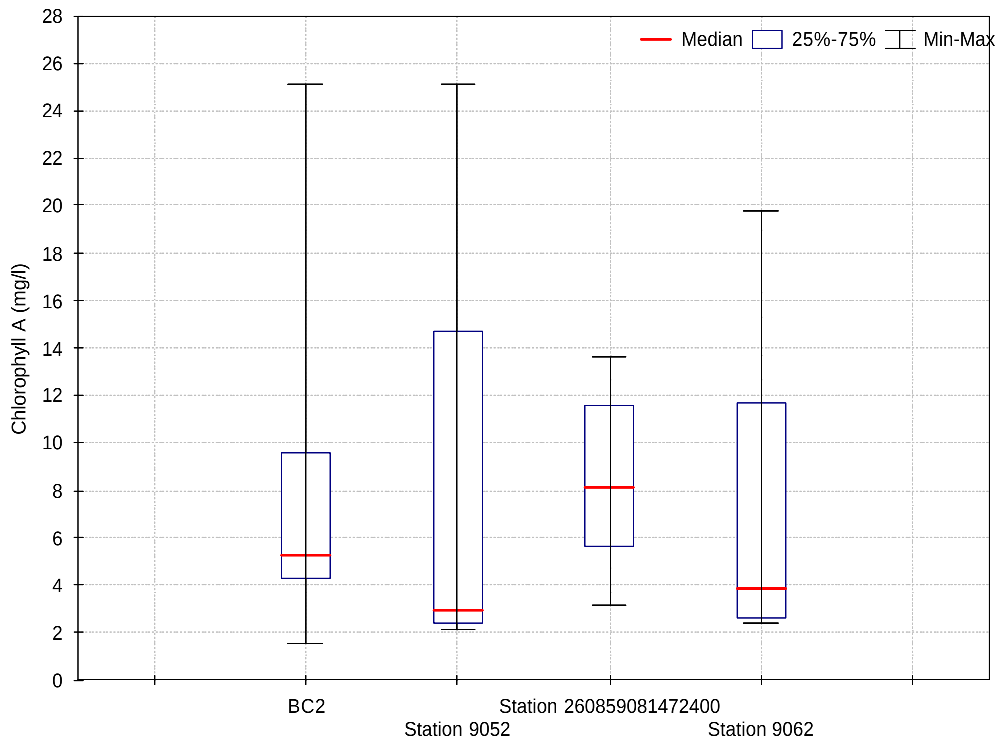

Figure 10. Box Plots for Chlorophyll A Data

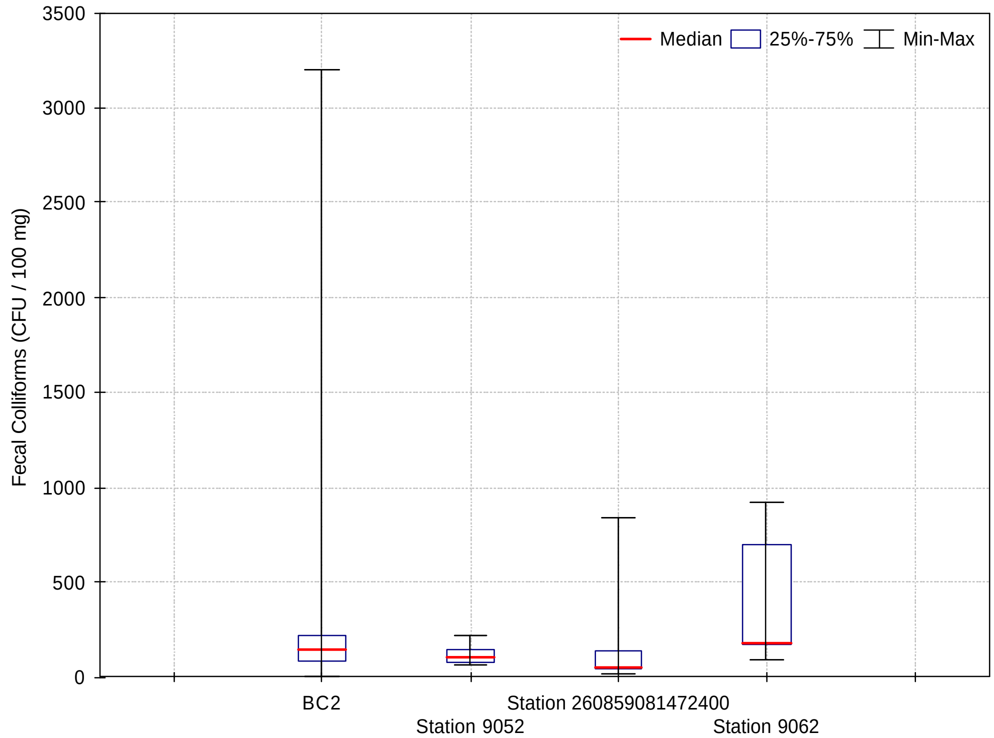

Figure 11. Box Plots for Fecal Coliform Data

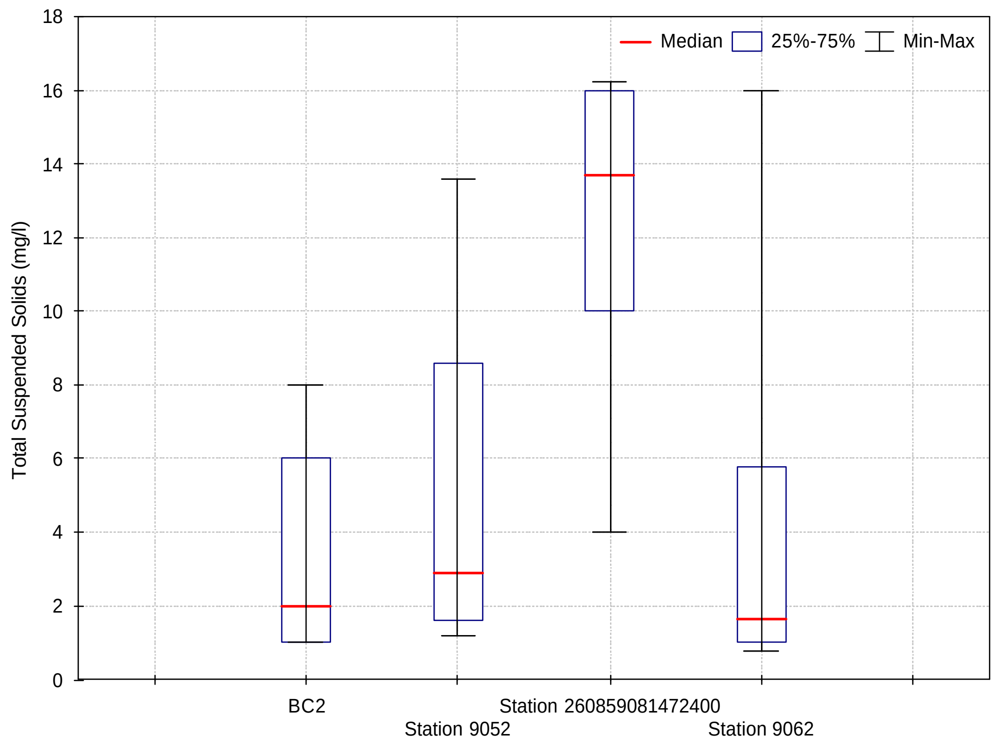

Figure 12. Box Plots for Total Suspended Solids Data