North Port Water Enhancement Project

Prepared for:

4970 City Hall Boulevard
North Port, Florida 34286

Through Cooperative Funding From
The Southwest Florida Water Management District
And The Manasota Basin Board

2379 Broad Street
Brooksville, FL 34604

Prepared by:

5300 West Cypress Street
Suite 200
Tampa, FL 33607-1768

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Acronyms

BMAP	basin management action plan
BMP	best management practice
BOD	biochemical oxygen demand
cfs	cubic feet per second
cfu	colony forming units
COD	chemical oxygen demand
DO	dissolved oxygen
EPA	United States Environmental Protection Agency
FDEP	Florida Department of Environmental Protection
MCL	maximum contamination level
mdl	minimum detection limit
mgd	million gallons per day
NO_x	nitrate + nitrite nitrogen
NO_2	nitrite nitrogen
NO_3	nitrate nitrogen
NTU	nephelometric turbidity units
psu	practical salinity units
SOC	synthetic organic compound
TDS	total dissolved solids
TKN	total kjeldahl nitrogen
TMDL	total maximum daily load
TN	total nitrogen
TOC	total organic carbon
TP	total phosphorus
TSI	trophic state index
TSS	total suspended solids
WBID	water body ID
ug	micrograms
uS	micro-Siemens
USGS	United States Geological Survey

Executive Summary

The purpose of this project was to better characterize the water quality in the City of North Port canal system, and to determine how those waters might impact downstream rivers and bays. This report describes efforts undertaken by PBS&J during 2008 and 2009 to assess water quality and flows within the City's canal system. Water quality and flow were evaluated in terms of potential impacts to drinking water supplies, aquatic wildlife habitat, aesthetic values within the City, and ultimately downstream to the lower Myakka River/upper Charlotte Harbor estuarine system. At the initiation of this project relatively little was known about the conditions within the North Port canal system, and the export of various constituents to the Myakka River and Charlotte Harbor. Ongoing efforts to improve the water quality in those systems provided the impetus for this study, so that future projects can be guided to address the issues of greatest concern for the City of North Port, the Myakka River and Charlotte Harbor. The City of North Port, located within the Myakka River watershed, includes an extensive system of natural streams and man-made canals broadly classified as the Big Slough/Myakkahatchee Creek and the Cocoplum/Snover Waterway canal systems. The canal systems, which are classified by the Florida Department of Environmental Protection (FDEP) as Class III freshwater, serve to convey stormwater and provide stormwater treatment through dry and wet detention segments, function as an important wildlife habitat, and serve as part of the City of North Port's potable water supply system. The water quality characteristics of these systems are to a great degree influenced by the approximately 104 square miles of watershed upstream of the City boundary. Thus, areas outside of the geographic boundaries of the City of North Port substantially impact water quality within these waterway systems.

During the seasonally drier months as well as during extended periods of below-normal rainfall, waters within portions of the Myakkahatchee Creek and the Cocoplum canal systems can become increasingly mineralized (as indicated by increased conductivity). Prior to the study, the following had been identified as potential sources of such increases: 1) impacts from offsite seepage of mineralized groundwater from regional irrigation users; 2) impacts from older, abandoned and free-flowing irrigation wells; and 3) influences from unrecognized tidal influences along the southern boundary of the City's canal network. If anthropogenic (human derived) sources of such water quality deterioration can be identified, potential restorative activities can be undertaken.

In addition to issues of water quality relevant to water supply needs, the waters of the City's Myakkahatchee Creek and Cocoplum canal systems are an important concern for the City of North Port in terms of aesthetic, wildlife and property values. Increases in nutrients have the potential to result in recurrent algal blooms that may lead to associated fish kills. Waters from the City's canal systems and Myakkahatchee Creek/Big Slough further ultimately discharge to the Myakka River, which then flows to Charlotte Harbor. The potential for water quality impacts within Charlotte Harbor have been identified as a regional concern by both the Charlotte Harbor National Estuary Program and the Southwest Florida Water Management District's (the District) Charlotte Harbor Surface Water Improvement and Management (SWIM) Program.

Water quality issues relating to sources of mineralization, nutrient dynamics, bacterial abundance and dissolved oxygen are relevant concerns both locally within the City of North Port, as well as regionally with regard to the lower Myakka River and upper Charlotte Harbor. Thus, a comprehensive water quality assessment has been needed that addresses both water quality issues related to water supply as well as potential water quality/total maximum daily load (TMDL) concerns within the regional Big Slough/Myakkahatchee Creek/City of North Port canal system.

Water quality monitoring in the North Port canal system occurred from April 2008 through March 2009. The constituents of greatest concern were chlorophyll *a*, dissolved oxygen, fecal coliform bacteria, total iron, total nitrogen, total dissolved solids, and specific conductance. At some point in the study period each of these constituents was found in the North Port canal system in a concentration that may be considered problematic. Each of these constituents is discussed briefly below.

Chlorophyll *a* is a measure of the amount of phytoplankton present in the sampled water. As such chlorophyll *a* is used as a proxy for nutrient concentrations (particularly nitrogen). The FDEP guidance level for chlorophyll *a* in freshwater streams is not to exceed 20 ug/l. Measured chlorophyll *a* in the North Port canal system was frequently higher than 20 ug/l during the study. However the relationship between chlorophyll *a* and total nitrogen was weak, indicating that the high chlorophyll *a* levels are not attributable to nitrogen concentrations. Therefore normal methods for reducing chlorophyll *a* concentration by reduction of total nitrogen are unlikely to be successful in this system.

Dissolved oxygen values provide a measure of the amount of oxygen available in the sampled water column. Sufficient dissolved oxygen is important for various wildlife that use the North Port canal system. Low levels of dissolved oxygen have been associated with high levels of pollution and extensive algal blooms, and are therefore often used to indicate systems which are stressed due to anthropogenic influences. The FDEP Class III freshwater standard for dissolved oxygen is not to fall below 5.0 mg/l. Measured dissolved oxygen in the North Port canal system was frequently below the FDEP standard. If these low dissolved oxygen measurements were due to the influence of the City of North Port, they should coincide with elevated levels of pollutants (nitrogen) and with increasing anthropogenic activity. This was not the case in the North Port canal system. The lowest dissolved oxygen values occurred in an area upstream of the developed City of North Port and dissolved oxygen levels were generally higher in the more developed southwest portion of the North Port canal system. Also the measured levels of total nitrogen were low in the North Port canal system. These factors suggest that the low dissolved oxygen values in the North Port canal system are naturally occurring, and the stagnant, warm nature of the canal system water is the main cause.

The fecal coliform bacteria test is a measure of the thermotolerant rod shaped bacteria present in the water sample. High levels of fecal coliform bacteria have been associated with contamination of waterways from human fecal waste. The FDEP Class III standard for fecal coliform bacteria is such that 90% of the samples must be below 400 cfu/100 ml, and all samples must be below 800 cfu/100 ml. Three stations in the North Port canal system violated the FDEP criteria. However, this test does not distinguish between various sources of bacteria, which can include wild animals or livestock, and even naturally occurring soil bacteria such as *Klebsiella* spp. It is quite possible that these higher occurrences of fecal coliform bacteria are due to animals, either wild or domestic, or to naturally occurring soil bacteria.

Total iron provides a measure of the iron, dissolved and particulate, in the water sample. The FDEP standard for iron is 1.0 mg/l of dissolved iron. Total iron was higher than the FDEP dissolved iron standard at several stations during the study period. Some of these stations were located at rusting iron structures, which may have contributed to particulate iron in the water samples. However, total iron values greater than 1.0 mg/l do not necessarily indicate a dissolved iron level above the FDEP standard. Naturally occurring high levels of iron have been found in the adjacent Myakka River. Given the proximity of the Myakka River to the study area it is conceivable that the North Port canal system receives some water which is naturally high in iron.

Total nitrogen provides a measure of the nitrogen, in all forms, present in the water sample. Elevated nitrogen levels are often the root cause of other water quality problems such as high chlorophyll *a* levels or low dissolved oxygen levels. Measured total nitrogen levels within the North Port canal system are quite low relative to normal concentrations in Florida streams. Compared with values published by FDEP (1996 305(b) report) the waters of the North Port canal system have low total nitrogen values across all percentile ranges. Total nitrogen levels tend to be lower within the interior of the canal system than at the upstream inputs to the canal system. These factors indicate that the City of North Port does not have water quality problems related to high nitrogen levels.

Specific conductance is a measure of the electrical conductivity of the water sample. This value can then be converted to salinity (psu) and can be used to develop a relationship with total dissolved solids (TDS). The FDEP Class III standard for specific conductance is 1275 uS/cm. During the dry season specific conductance levels exceeded that standard at a few stations. Specific conductance was generally lower at the inputs to the North Port canal system and increased toward the discharges from the system. Extensive specific conductance investigations were performed in search of point sources of high conductivity water. These transects led to the detection of Nona’s Spring, adjacent to Cocoplum canal near Structure 109. This was the only area in which a high conductivity point source could be detected. Other areas showed more gradual, continuous increases in specific conductance moving downstream. This is characteristic of more disperse non-point sources of water such as mineralized groundwater. Data from the United States Geological Survey (USGS) indicate that groundwater in the vicinity of the City of North Port from a depth of less than 200 feet can have specific conductance values greater than 2,000 uS/cm. The use of this water for local irrigation it may be causing some of the increases in specific conductance. A very strong relationship between specific conductance and TDS was established, such that TDS can be 97% predicted by specific conductance.

Pollutant loadings from the North Port canal system to downstream waterbodies were calculated by multiplying the measured monthly flow out of the system with the measured monthly concentration of total nitrogen and total phosphorus. These loads were then normalized to a pollutant per unit area value that allowed for comparison with other regional systems. Relative to other regional systems the area discharging from the North Port canal system was found to produce low levels of nitrogen and phosphorus per unit area. This was both a function of relatively low concentrations measured within the system, and relatively low discharge from the system. The study period coincided with a regional drought, which in turn caused there to be very little discharge from the system. Had the hydrologic conditions been different (more rain), discharge and therefore loads per unit area would have been higher.

An important aspect of this project wais to provide recommendations for future projects to improve water quality within the North Port canal system. The City of North Port currently engages in a wide variety of best management practices (BMPs) to reduce impacts on the canal system and surrounding waters. The major finding of this report is that those BMPs appear to be effective and that for the most part the North Port canal system is largely a healthy system. There are none the less certain projects that might be undertaken with the aim of improving conditions in the canal system, and protecting the integrity of the canal system for the future. The City of North Port should certainly continue existing BMPs and their proactive attitude toward reduction of stormwater pollution loads to the North Port canal system. In addition the following potential projects may be of interest.

- Construct structures along Cocoplum canal at Como waterway and Crestview waterway at appropriate elevations to inhibit the future potential for salt water intrusion into the North Port canal system.

- Amend canal maintenance procedures to remove problem vegetation from the system rather than spraying it in place.

- Perform maintenance dredging in the canal system to both increase the storage capacity of the canal system and remove potentially problematic organic matter from the canal system.

- Actively track future land use changes and water use permits in the upstream basin as part of an ongoing sourceater protection program and investigate existing sources of high conductivity water in Myakkahatchee Creek upstream of the City.

- Determine the source of fecal coliform bacteria in the North Port canal system. Researchers (including some at USF Tampa) study human specific *Bacteroides* spp., viruses, and genes that would identify whether or not the fecal coliform bacteria in the North Port canal system are anthropogenically derived.

- Assess the residential wells and water treatment systems throughout the City of North Port to determine whether they contribute to the gradual increases in specific conductance and TDS throughout the North Port system.

- Continue the water quality monitoring program that existed prior to this study in order to detect any changes in the canal system, particularly due to future build out of the City of North Port.

While the existing condition of the North Port canal system is very good, undertaking these projects will both improve on the current water quality condition, and serve to protect the North Port canal system in the future.

1.0 Introduction

This project is an effort to better characterize the composition of the waters of the City of North Port canal system, and to determine the effects of those waters in downstream areas. At the initiation of this project relatively little was known about the conditions within the North Port canal system, and the export of various constituents to the Myakka River and Charlotte Harbor. Ongoing efforts to improve the water quality in those systems provided the impetus for this study, so that future projects can be guided to address the issues of greatest concern for the City of North Port, the Myakka River and Charlotte Harbor. The City of North Port, located within the Myakka River watershed, includes an extensive set of man-made canals broadly classified as the Big Slough/Myakkahatchee Creek canal system and the Cocoplum / Snover Waterway system (Figure 1.1). Flow in the canal system is managed by a series of control structures, which direct flow from east to west and from north to south within the system (Figure 1.2). These canals serve to reduce flooding and provide stormwater treatment within the City limits, and also function as important wildlife habitat. The aesthetic value of these canals is a major component of the essence of the City of North Port, and in turn acts to increase the property values of houses located on the waterways. Additionally these waterways serve as part of the City of North Port's water supply system. The City of North Port canal system is classified as a Class III fresh water system in regards to water quality standards.

Approximately seven miles of Big Slough/Myakkahatchee Creek are located within the City boundaries. The portion of the watershed upstream of the City's boundaries is estimated to be approximately 104 square miles, while the total drainage basin is estimated at 195.6 square miles (Ardamann & Assoc. 2007). Thus, areas outside of the geographic boundaries of the City of North Port have the ability to substantially impact water quality within these waterways (Appendix G).

The City of North Port currently relies upon two main sources for its water supply needs: 1) the Myakkahatchee Creek and Cocoplum canal system, and 2) potable water from the Peace River Manasota Regional Water Supply Authority (Authority). Increased use of water from the Myakkahatchee Creek and Cocoplum canal systems would allow for reduced reliance on deliveries from the Authority, thus allowing the Authority to use those same quantities for other regional needs. In this sense, protection and enhancement of water quality within the City of North Port's local waterways would likely benefit water supply on a regional scale.

During extended drought conditions the City of North Port becomes increasingly reliant on the Authority for water supplies during dry months and extended periods of below-normal rainfall, as water within the Myakkahatchee Creek and the Cocoplum canal systems becomes overly mineralized for water supply uses. Seasonal and drought-related decreases in rainfall coincide with decreased water quality within the City's local waterways, due mostly to increased levels of sulfate and an overall increase in mineral content (as indicated by increased conductivity). Potential sources of the increased mineral content include at least the following: 1) impacts from offsite seepage of mineralized groundwater from regional irrigation users, 2) impacts from older, abandoned and free-flowing irrigation wells, and 3) influences from unrecognized tidal influences along the southern boundary of the City's canal network. If anthropogenic (i.e., human-derived) sources of water quality deterioration can be identified, there is a possibility that potential restorative activities can be undertaken. Should offsite movement of irrigation waters be identified as a source of increased mineralization, the Southwest Florida Water Management District's (District) FARMS (Facilitating Agricultural Resource Management Systems) program could be used to address this issue. Should the source of increased mineralization be traced back to influences from abandoned and yet still-flowing irrigation wells, then the District's QWIP (Quality of Water Improvement Program) program could be used to help pay for abandoning such wells. And if the source of increased mineralization is tracked back to eroded and/or damaged banks or weir structures along the southern boundary of the City's canal system, then the appropriate capital improvement projects could be identified to remedy such conditions.

In addition to issues of water quality relevant to water supply needs, the waters of the City's Myakkahatchee Creek and Cocoplum canal are an important concern for the City of North Port in terms of aesthetics and property values for local homeowners. Deterioration of water quality can affect both wildlife habitat value as well as adjacent property values. Increases in nutrients may result in recurrent algal blooms leading to associated diel crashes in dissolved oxygen levels sufficient to cause fish kills. Also, Myakkahatchee Creek and the Cocoplum canal both discharge to the lower Myakka River, which then flows to Charlotte Harbor. Impacts to water quality within Charlotte Harbor have been previously outlined by both the Charlotte Harbor National Estuary Program, and the District's Charlotte Harbor Surface Water Improvement and Management (SWIM) Program.

In its June 2005 Verified List of Impaired Waters for Group 3 basins, Florida Department of Environmental Protection (FDEP) identified portions of the Myakka River below Myakkahatchee Creek (WBIDs 1991a, 1991b and 1991c) as being "impaired" for nutrients (Chlorophyll *a*), fecal coliform bacteria, and dissolved oxygen. The FDEP's most recent Verified Impaired list does not include waters of Big Slough/Myakkahatchee Creek, although the State of Florida's 1998 303(d) list did note that Myakkahatchee Creek was potentially impaired for dissolved oxygen. Having waters listed as "impaired" means that the Lower Myakka River will require either a Total Maximum Daily Load (TMDL) to be calculated, or that a "Reasonable Assurance Plan" should be developed to outline activities to undertake to address identified impairments. If a TMDL is established then a Basin Management Action Plan (BMAP) will need to be developed. The BMAP process consists of working with regional stakeholders to establish the best methods of reducing pollutants, and subsequently monitoring the waterways to ensure that the pollution reduction goals are being met.

Therefore, water quality issues relating to sources of mineralization are relevant to both local and regional water supply concerns. Likewise, other water quality issues such as nutrient dynamics, bacterial abundance and dissolved oxygen are relevant concerns both locally within the City of North Port, as well as regionally with regard to the lower Myakka River and upper Charlotte Harbor. Thus, a comprehensive water quality assessment has been needed that addresses both water quality issues related to water supply as well as potential water quality / TMDL concerns within the regional Big Slough/Myakkahatchee Creek/North Port canal system.

This report describes the efforts undertaken by PBS&J to assist the City of North Port and the District in preserving and/or enhancing water quality within the City's canal system, in terms of potential impacts to drinking water supplies, aquatic wildlife habitat and aesthetic values within the City, and ultimately downstream to the lower Myakka River/upper Charlotte Harbor estuarine system.

Long-term daily rainfall values measured locally at USGS rainfall station (02299484) were used to put hydrologic conditions during the study period into perspective. The historic available period of record for this USGS gaging station dates from October 1993 through the present. The 12 months (April 2008-March 2009) of the study period were generally characterized by below average rainfall (Table 1.1). Monthly rainfall was higher than the long-term average during both April and September of 2008, while rainfalls during each of the other 10 months were below the historic averages. The total rainfall during the 12 months of the study period year was 37.8 inches, compared to an annual average of 47.9 inches over the available period-of-record.

Table 1.1. Study Period and Historical Rainfall

Month	Historical Average Rainfall (in)	Historical Maximum (in)	Historical Median (in)	Historical Minimum (in)	Study Period (in)
April	2.3	6.5	2.4	0.0	3.2
May	1.9	5.9	1.5	0.1	0.7
June	8.4	18.1	7.4	2.2	7.2
July	8.5	13.5	8.8	3.3	7.0
August	8.3	15.9	8.0	4.5	6.7
September	6.6	11.5	6.4	2.1	6.9
October	3.0	8.5	2.1	0.2	2.5
November	1.4	5.2	0.8	0.1	0.2
December	1.7	6.1	1.3	0.2	1.4
January	1.8	4.4	1.8	0.1	0.5
February	1.8	4.8	1.1	0.0	0.3
March	2.2	7.5	1.4	0.3	1.2
Annually	48.1	71.1	47.9	29.8	37.8

*Historical period is October 1993 to April 2008

*Study Period is April 2008 to March 2009

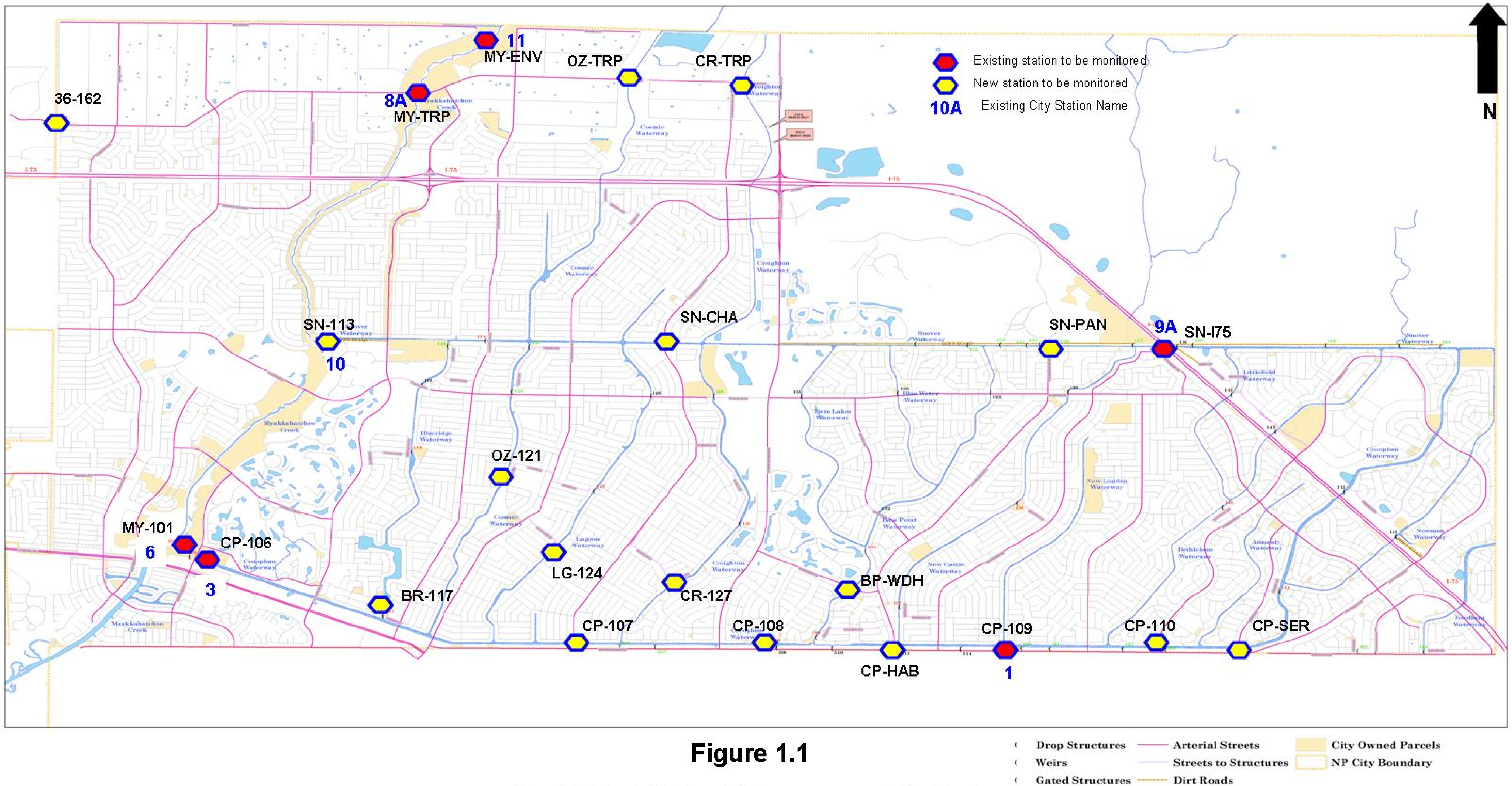


Figure 1.1

North Port Water Enhancement Project

Water Quality Grab Sample Locations

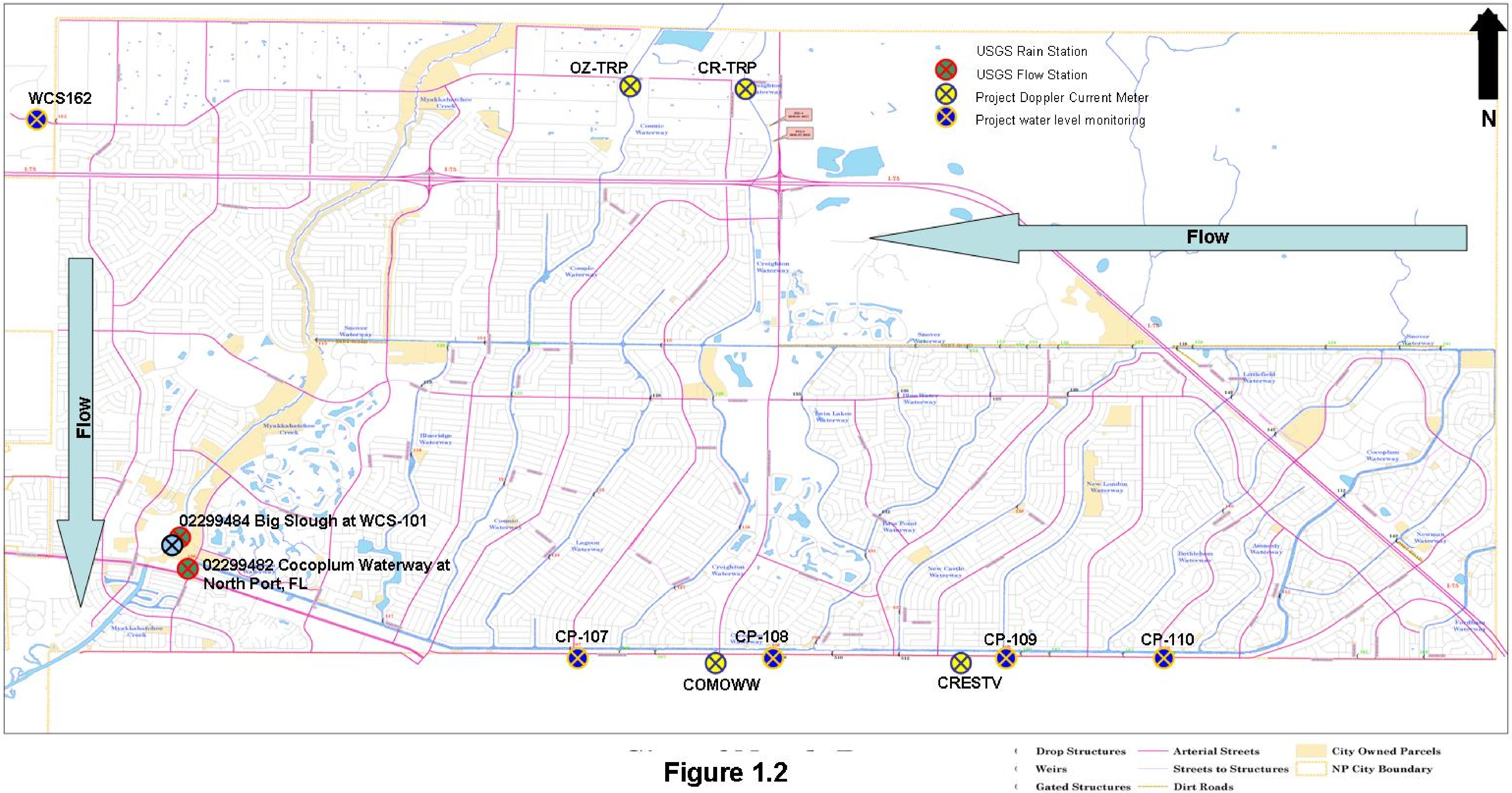


Figure 1.2

North Port Water Enhancement Project

PBS&J Flow & Stage Station Locations

Direction of Flow is North to South and East to West

2.0 Materials and Methods

2.1. Grab and Profile Sampling and Analysis

Monthly water quality sampling was conducted at the seven existing City of North Port sample sites in March 2008, and at the full complement of twenty project sites (Table 2.1) from April 2008 through March 2009. Water quality sampling events consisted of a grab sample taken at mid-depth in the water column, and an *in situ* water column profile with measurements taken at the surface and 0.5 meter increments thereafter. Sample parameters are listed in Tables 2.2 and 2.3. All sampling was conducted according to the appropriate FDEP SOP, as identified in the project QAPP.

Table 2.1. Water Quality Sampling Stations – Descriptions

Existing North Port Station #	Project Station Name	SWFWMD Station Number	Waterway	Structure or Roadway Crossing
	36-162	710426	R-36	Tropicaire Blvd
	BP-WDH	710441	Bass Point	Woodhaven Dr
	BR-117	710442	Blue Ridge	Structure 117
3	CP-106	710445	Cocoplum	Structure 106 (upstream side)
	CP-107	710446	Cocoplum	Structure 107
1	CP-109	710452	Cocoplum	109 (upstream side)
	CP-HAB	710457	Cocoplum	Haberland Blvd
	CP-SER	710458	Cocoplum	Serris Dr
	CR-127	710459	Creighton	Structure 127
	CR-TRP	710461	Creighton	Tropicaire Blvd
	LG-124	710462	Lagoon	Structure 124
6	MY-101	710463	Myakkahatchee Cr	Structure 101 (upstream side)
11	MY-ENV	710465	Myakkahatchee Cr	none (wooden dock)
8A	MY-TRP	710466	Myakkahatchee Cr	Tropicaire Blvd (south side)
	OZ-121	710467	Cosmic	Structure 121
	OZ-TRP	710468	Cosmic	Tropicaire Blvd
10	SN-113	710470	Snover	Structure 113 (upstream side)
9A	SN-I75	710472	Snover	Structure 116
	SN-CHA	710471	Snover	Chamberlain Blvd
	SN-PAN	710473	Snover	Panacea Blvd

Table 2.2. Grab Sample Parameters

Parameter #	Parameter Name	Method	MDL	Units	Stations per event	Events to be sampled
1	Bicarbonate Alkalinity	SM2320B	0.59	mg/l	20	12
2	Carbonate Alkalinity	SM2320B	0.59	mg/l	20	12
3	Biochemical Oxygen	SM5210B	0.3	mg/l	20	12
4	Chemical Oxygen Demand	410.4	7.04	mg/l	20	12
5	Total Calcium	200.7	0.03	mg/l	20	12
6	Total Chloride	300	0.353	mg/l	20	12
7	Total Color	110.2	5	PCU	20	12
8	Total Potassium	200.7	0.169	mg/l	20	12
9	Total Sodium	200.7	0.034	mg/l	20	12
10	Total Sulfate	300	0.339	mg/l	20	12
11	Total Dissolved Solids	SM2540C	7.26	mg/l	20	12
12	Total Suspended Solids	SM2540D	1	mg/l	20	12
13	Turbidity	180.1	0.1	NTU	20	12
Bacteria						
14	Enterococci Bacteria	1600	1	CFU/100ml	20	12
15	Fecal Coliform Bacteria	SM9222D		CFU/100ml	20	12
Metals						
16	Total Cadmium	200.7	0.9	ug/l	20	12
17	Total Copper	200.7	4	ug/l	20	12
18	Total Iron	200.7	29	ug/l	20	12
19	Total Lead	SM3113B	0.67	ug/l	20	12
20	Total Magnesium	200.7	0.006	mg/l	20	12
21	Total Zinc	200.7	3	ug/l	20	12
Nutrients & Chlorophyll						
22	Chlorophyll A	445	0.25	ug/l	20	12
23	Ammonia-Nitrogen	SM4500NH3C	0.006	mg/l	20	12
24	Nitrates (as N)	CALC			20	12
25	Nitrites (as N)	SM4500NO2B	0.004	mg/l	20	12
26	Total Kjeldhal Nitrogen	351.2	0.08	mg/l	20	12
27	Nitrate+Nitrite	353.2	0.004	mg/l	20	12
28	Total Nitrogen (calculated)	351.2 + 353.2			20	12
29	Orthophosphorus	365.3	0.002	mg/l	20	12
30	Total Phosphorus	365.3	0.003	mg/l	20	12
31	Total Organic Carbon	SM5310B	0.3	mg/l	20	12
Pesticides, Oil & Grease						
32	Oil & Grease	1664	0.992	mg/l	2	2
33	SOC's & Pesticides				2	4
	dioxin screen	525	95	ug/l		
	endrin	508.1	0.0019	ug/l		
	γ-BHC (lindane)	508.1	0.0019	ug/l		
	methoxychlor	508.1	0.013	ug/l		
	toxaphene	508.1	0.22	ug/l		
	dalapon	515.3	0.6	ug/l		
	diquat	549.2	0.29	ug/l		
	endothall	548.1	7.6	ug/l		

Parameter #	Parameter Name	Method	MDL	Units	Stations per event	Events to be sampled
	glyphosate	547	0.99	ug/l		
	di(2-ethylhexyl)adipate	525.2	0.22	ug/l		
	oxamyl (vydate)	531.1	0.16	ug/l		
	simazine	508.1	0.018	ug/l		
	di(2-ethylhexyl)phthalate	525.2	0.47	ug/l		
	picloram	515.3	0.037	ug/l		
	dinoseb	515.3	0.096	ug/l		
	hexachlorocyclopentadiene	508.1	0.013	ug/l		
	carbofuran	531.1	0.13	ug/l		
	atrazine	508.1	0.0067	ug/l		
	alachlor	508.1	0.028	ug/l		
	heptachlor	508.1	0.0057	ug/l		
	heptachlorepoxide	508.1	0.00095	ug/l		
	2,4D	515.3	0.054	ug/l		
	2,4,5-TP (silvex)	515.3	0.038	ug/l		
	hexachlorobenzene	508.1	0.011	ug/l		
	benzo(a)pyrene	525.2	0.033	ug/l		
	pentachlorophenol	515.3	0.004	ug/l		
	PCB	508.1	0.095	ug/l		
	1,2-dibromo-3-	504.1	0.0041	ug/l		
	ethylene dibromide	504.1	0.0064	ug/l		
	chlorodane	508.1	0.018	ug/l		

Table 2.3. Field Sample Parameters

Parameter	Units
Temperature	C
Specific Conductance	uS/cm
Salinity	psu
Dissolved Oxygen	mg/l
pH	Standard Units

Water Column profiles were performed using a YSI 650 MDS handheld display with a YSI 6920 V2 sonde equipped with YSI ROX® Optical Dissolved Oxygen Sensor, YSI pH sensor, and YSI temperature and conductivity sensor. Measurements were taken at water surface (0.2 m) and subsequent 0.5 m intervals (i.e. 0.5 m, 1.0 m) until the sonde reached the substrate. The equipment used for water column profile measurements was maintained and calibrated in accordance with FDEP SOP FT 1000. The data were recorded and maintained in accordance with FDEP SOP FD 1000.

In addition to standardized monthly sampling for the listed constituents, quarterly grab samples were collected for both synthetic organic contaminants (SOCs) and pesticides, and two grab samples (during July and January) were collected for oils and grease analysis. Samples for SOCs and pesticides, and oils and grease were collected using a Wildco stainless steel and Teflon

Kemmerer bottle. Samples for all other parameters were collected using a Watermark horizontal polycarbonate water bottle. Samples were collected in accordance with FDEP SOP FS 1000, and chain-of-custody forms were maintained in accordance with FDEP SOP FD 1000. Duplicate and equipment blank samples were collected in accordance with FDEP SOP FQ 1000. All sample analyses were performed by Benchmark Enviroanalytical Laboratories (Benchmark) in North Port and Palmetto, Florida.

Laboratory data were delivered by Benchmark in electronic format. When analysis indicated a concentration below the minimum detection limit the minimum detection limit was reported as the concentration value, and the appropriate data qualifier was inserted. In calculations and analyses these data were utilized. Water quality data were stored in an Access database and verified on a monthly basis as they were received from the lab. Quality control checks performed included frequency counts and visual comparisons using SAS software and GIS software. Water quality graphs and tables were produced using SAS software, while maps were produced with GIS software. Regression analyses were performed using Statgraphics Centurion XV Version 15.0.08.

2.2. Flow and Level Sampling

Sontek Argonaut acoustic doppler current profilers were deployed to measure flow at four sites in the North Port canal system. The Argonaut-SL was utilized in Crestview canal, while the Argonaut-SW was utilized in the other canals. The Argonaut-SL is a side looking unit which was mounted on a pole at mid depth in the canal, and the Argonaut-SW is an up looking unit which was mounted on a base in the center of the canal. The Argonauts were programmed individually based on the site characteristics at the deployment locations. Channel geometry was carefully surveyed and the theoretical flow calculation, which models flow based on channel geometry and measured velocity, was used to generate flow data. Argonaut data were reviewed for acceptable signal to noise ratios (SNR) and variability in noise data prior to data being accepted.

Solinst Levelogger model 3001-15 instruments were deployed at fixed heights from structures 107, 108, 109, and 110 to monitor water level along Cocoplum canal. A Solinst Barologger Model 3001-F5 was deployed to monitor barometric pressure. Each instrument recorded water level (or barometric pressure) at five minute intervals. Water level at each deployed instrument was calculated by subtracting barometric pressure from the Levelogger measurement. The water level was then used to calculate flow out of Cocoplum canal using the equation for a broad crested weir (Georgia Stormwater Management Manual, Section 2.3), or the equation for a sharp crested weir (Georgia Stormwater Management Manual, Section 2.3) where appropriate. The equations are as follow:

Flow over a sharp crested weir:

$$Q=[(3.27+0.4(H/Hc)](L-0.2H)H^{1.5}$$

Where: Q = discharge (cfs)
H = head above weir crest (ft)
Hc = height of weir crest above channel bottom (ft)
L = horizontal weir length (ft)

Flow over a broad crested weir:

$$Q=CLH^{1.5}$$

Where : Q and H are the same as above
C = Broad crested weir coefficient

The broad crested weir coefficient is taken from Table 2.3.2-2 in the Georgia Stormwater Management Manual.

There were several stations for which flow/level data were not available until July 2008 due to some combination of vandalism/theft, and equipment malfunction. The preceding months of April through June were part of the dry-season. The mean monthly load for the remaining dry-season months of November through March was calculated for each discharge location. These numbers were then used as an estimate of loads during the months for which data were not available. Flow is reported by section of Cocoplum canal by summing the discharge from upstream discharge canals according to the following equations:

CP-107 discharge=WCS506 + WCS507 + Como waterway

CP-108 discharge=WCS508 + WCS510 + WCS512 + Crestview canal (only when discharge is positive)

CP-109 discharge=WCS180 + WCS181 + WCS182

CP-110 discharge=WCS183

Flow data for Myakkahatchee Creek and Cocoplum canal were retrieved from the USGS NWIS online data management system. The stations used were "02299472 Big Slough at West Price Blvd near North Port FL" which is a station just upstream of WCS-101 (the site of water quality monitoring station MY-101), and "02299482 Cocoplum Waterway at North Port FL" which is measured at WCS-106 (the site of water quality monitoring station CP-106).

Rainfall data were retrieved from the USGS NWIS online data management system. The station selected was "02299484 Big Slough at WCS-101 at North Port FL". The period of record for this station was longer (1993-2009) than the other USGS gages in the vicinity.

2.3. Data Management and Quality Control

As mentioned in the previous section, all data were maintained in Access databases, and all data management conformed to FDEP SOP FD 1000.

In situ water column profile data were recorded on standard datasheets and visually reviewed prior to being entered into the Access database. Laboratory data were received from Benchmark in Excel, and imported to SAS where frequency counts were performed and data qualifiers were reviewed. Data were then mapped using GIS to review the reported values. After review data were considered accepted and were appended to the Access database.

Solinst level data were imported to SAS and plotted to check for tampering, failure, or out of water situations. When these situations occurred data were flagged to ensure that they would not be used in analysis. Accepted data were appended to the Access database.

The internal quality control checks of the Sontek Argonaut data were reviewed with the Sontek ViewArgonaut Software. After the quality control data were reviewed the flow data were imported to SAS and plotted to further review the data. After this review the accepted data were appended to the Access database.

2.4. Analyses

Descriptive statistics for water quality data were calculated using the Univariate Procedure in SAS. For the purpose of this project the wet period during the study is being defined as July through October, with the dry period being November through June. Tests of relationship between various water quality constituents were performed with the simple regression function in Statgraphics Centurion XV Version 15.0.08.

The objective in calculating the pollutant load leaving the City of North Port Canal system was to be as accurate as possible while being as conservative as possible in the assumptions made in determining estimated loads. Therefore when decisions needed to be made about how to process data feeding the load calculation, such as the unexpected inflows at Crestview canal, the option that produced the higher load estimate was utilized. Pollutant loads were calculated by the following equations:

Sum of (Mean Daily Flow * Mean Concentration) = Monthly Load

Sum of monthly loads = Yearly load

Area normalized load was calculated by:

Yearly load/Total area=Total annual load per unit area

The total estimated drainage area of the North Port basin is 50,652.7 hectares (Ardamann & Associates 2007).

Calculation of loads to the south from Cocoplum Canal was not possible for April-June of 2008 due to missing flow data. The missing data occurred due to a combination of equipment theft and equipment malfunction. After reviewing the available data it was clear that loads were higher in the July through October wet-season than in the dry-season. In order to estimate load for the months with missing data the mean load (of nitrogen and phosphorus constituents only) for all available dry season months was calculated, and this value was used as the estimated load during the missing months.

3.0 Results and Discussion

3.1. Water Quality Results

The following presents the results of the water quality sampling by sampled parameter. Emphasis is placed on discerning geographic and seasonal patterns in analyte concentration, and on comparing the sample concentrations to appropriate published criterion. Tables, graphical summaries, and maps are available in Appendices A-D.

- Appendix A – Annual statistical summaries of individual water quality parameters by sampling location.
- Appendix B – Time series plots of monthly water quality values of each parameter by sampling location.
- Appendix C – Summary maps depicting spatial differences among the sampling station in mean annual levels for each of the measured water quality characteristics.
- Appendix D – Summary description of established maximum contaminate levels (MCL) and common sources of analyzed synthetic organic contaminants (SOCs) and pesticides.

Additionally, the reference numbers referred to from the 1996 FDEP 305(b) report are the state wide median levels calculated for that report.

Ammonia/Ammonium - Mean levels ranged from a high of 0.15 mg/l at station OZ-TRP to a low of 0.04 mg/l at stations CP-107 and BR-117. Concentrations were generally higher at the sample points nearest the inputs to the North Port canal system, and lower at the sample points near the discharges from the North Port canal system. There were also instances of high ammonia/ammonium concentrations at sites CR-127 and OZ-121 in the central portion of the canal system. At most stations ammonia levels were higher during the wet-season and lower during the dry season.

Bicarbonate Alkalinity - Mean levels ranged from 57.12 mg/l at station MY-TRP to 206.25 mg/l at station BP-WDH. The highest levels of bicarbonate alkalinity generally occurred in the southeast portion of North Port, with the lowest levels occurring in the northwest portion. At many of the sampling sites bicarbonate alkalinity was lower in the wet season, although that pattern was not universal.

Biochemical oxygen demand (BOD) - This parameter measures the amount of oxygen removed from the water by existing bacteria over a 5-day period. Mean annual BOD levels among the 20 sampling sites ranged from a low of 0.96 mg/l at station MY-ENV to 4.41 mg/l at station CR-TRP. Spatially, there was no clear geographic pattern in annual average measured BOD levels, although the lowest levels clearly occurred in Myakkahatchee Creek. BOD has a significant linear relationship with chlorophyll *a* levels ($p=0.000$, $r^2=0.63$). Increased levels of chlorophyll *a* were correlated with increased levels of BOD (BOD=1.13842+0.0353236*chlorophyll *a*).

Seasonal patterns in BOD concentration were not consistent spatially across the array of sampling sites.

Cadmium - Levels were universally low among all of the stations, with almost every sample being at or less than the minimum detection level of 0.90 ug/l.

Calcium – Mean annual average concentrations ranged spatially from a low of 45.67 mg/l at station CR-TRP to 131.99 mg/l at station CP-107. Calcium concentrations were generally lower at those sampling sites near the inputs to the North Port canal system, with the exception of Myakkahatchee Creek, which generally had higher calcium levels. At most of the sampling stations calcium concentrations were seasonally lower during the wet-season and higher in the dry-season.

Chloride – Annual mean concentrations among the 20 project sampling locations ranged from a low of 28.66 mg/l at sampling site 36-162 to a high of 151.52 mg/l at station CP-106. Chloride levels were lowest at the stations near the inputs to the North Port canal system and generally showed increases in concentrations as water moved through the City. Chloride levels were, as expected, generally lower in the wet-season when surface flows dominate and higher in the dry-season when groundwater inputs were the major component to the canal systems.

Chlorophyll *a* – Mean annual levels ranged from a low of 3.46 mg/l at sampling site MY-ENV to a high of 87.07 mg/l at station CR-TRP. Mean chlorophyll *a* concentrations were annually much lower at the Myakkahatchee Creek stations than at other project sampling sites. Chlorophyll *a* levels were frequently above the FDEP TMDL guidance level for freshwater systems of 20 ug/l. There was a statistically significant linear relationship ($p=0.000$, $r^2=0.14$) between measured chlorophyll *a* levels and total nitrogen concentrations. However, the resulting r-square value indicates that only approximately 14 percent of the observed variation in phytoplankton abundance can be explained by variation in the availability of nitrogen. Correspondingly, no similar significant linear relationship ($p=0.171$) was observed to exist between measured chlorophyll *a* levels and total phosphorus concentrations. Further comparisons among the sampling sites fail to indicate any general consistent seasonal pattern in chlorophyll *a* concentrations among the sampling locations.

Chemical Oxygen Demand (COD) – This parameter measures the oxygen equivalent of organic matter that is susceptible to oxidation via a chemical oxidant. Annually, mean COD levels ranged from 25.02 mg/l at station CR-127 to 75.38 mg/l at station SN-I75. COD was highest at the stations near inputs to the North Port canal system, and generally lower throughout the canal system. At most stations COD was higher in the wet-season than the dry-season reflecting increased organic loading.

Color – Annual mean color levels spatially ranged from a low of 47.08 platinum cobalt units (PCU) at sampling site CR-127 to a high of 208.33 PCU at station 36-162. Color levels were generally higher at the stations near inputs to the North Port canal system and lower throughout the interior portion of the canal system. As is typical in southwest Florida blackwater aquatic systems, color levels were generally seasonally higher in the wet-season and lower in the dry-season.

Copper – Annual mean concentrations among the project sampling sites ranged from 4.49 ug/l at site CP-SER to 7.93 ug/l at station SN-PAN. Copper levels were usually at or below the method detection limit (mdl) of 4.0 ug/l. Copper levels were higher at the northern extent of the North Port canal system, and in Snover Canal, and lower south of Snover Canal, although the spatial range of annual mean copper values was observed to be relatively small. The Class III water standard for copper is variable depending on the measured hardness of the water. In the North Port canal system copper was occasionally above the Class III standard, with all instances of exceedances having occurred in August 2008.

Dissolved Oxygen (DO) – This water quality parameter is a measure of the oxygen gas dissolved in the sampled water. Mean DO ranged from 1.67 mg/l at sampling site SN-I75 to 6.92 mg/l at station BR-117. DO concentrations were generally observed to decrease with depth, especially during warmer months. Spatially, annual average water column DO concentrations tended to be lower in the northeast portion of the study area and higher in the southwest region. Overall, water column DO levels were generally lower during the warmer months of the year in comparison with the seasonally colder months. Measured DO concentrations were frequently below the FDEP Class III standard of 5.0 mg/l, with measured levels below the standard occurring throughout the year.

Enterococci Bacteria – These bacteria are part of the normal gut flora of warm blooded organisms. The United States Environmental Protection Agency (EPA) has recommended a guidance threshold level of 33 colony forming units (cfu)/100 ml (calculated not to exceed the geometric mean) as a standard to preserve the health of humans swimming in the affected water (EPA 1986). Mean enterococci bacteria levels among the 20 sampling sites within the project study area ranged from 52.50 cfu at station CP-SER to 369.17 cfu at site OZ-TRP. Spatially, there was no clear geographic pattern with regard to observed enterococci concentrations, nor was there any apparent consistent seasonal pattern across stations. While there is no Class III standard specific to enterococci bacteria, observed levels within the North Port canal system were universally found to be above the EPA recommended guideline. It has been noted in other studies that among the three commonly used bacterial indicators (total coliform, fecal coliform, and enterococci) enterococci bacteria levels is the indicator most frequently observed to be in exceedance of the recommended EPA threshold (Noble et al. 2003).

Fecal Coliform Bacteria – Such counts measure a variety of the rod shaped bacteria often present in the water samples. This can include certain bacteria such as *Klebsiella* which may be present in the environment totally independent of the presence of fecal matter. The following summarized the Class III Waters standard for fecal coliform bacteria.

- Not to exceed 200 cfu/100 ml as a monthly mean.
- Not to exceed 400 cfu/100 ml as determined by the 90th percentile of all samples.
- Not to exceed 800 cfu/100 ml at any time.

During the 12 months of project sampling, there was an exceedance of the 800 cfu/100 ml standard at sites SN-113 in October 2008 and 36-162 in July 2008, and a violation of 400 cfu/100 ml 90th percentile standard at station CR-TRP. Fecal coliform levels seem to have been higher in portions of canals near structures, and in areas with extensive vegetative mats, both of which provide habitat for fish and birds. Station SN-113 had the highest annual mean fecal coliform count of 265 cfu/100 ml. Seasonally, fecal coliform bacteria counts at most locations were higher during warmer, wet-season months.

Hardness – This water quality characteristic was calculated using the methodology in SM 2340B. Although hardness was not on the original list of laboratory parameters, hardness was calculated for use in determining the threshold levels for a variety of other constituents, including both cadmium and lead in Class III Waters. Mean hardness levels among the 20 project sampling sites ranged from a low of 159.23 mg/l at station CR-TRP to 489.48 mg/l at MY-ENV. Hardness levels were generally lower in the wet-season and higher in the dry-season reflecting seasonal differences in groundwater influences within the City of North Port canal systems.

Total Iron - The Class III Waters criterion for dissolved iron is 1000 ug/l (1 mg/l). Annually, mean total iron concentrations ranged from 149.85 ug/l at monitoring site BR-117 to 2,434.6 ug/l at station SN-PAN. Iron levels were generally higher in the northeast portion of the sampling area, especially in Snover waterway, and lower to the southwest portions of the City. Iron concentration tended to be higher in the wet-season and lower in the dry-season. Iron levels were frequently observed in exceedance of the Class III criterion for dissolved iron at a number of sampling locations. PBS&J staff performed visual surveys of Snover waterway in conjunction with conductivity transects and no point source of high conductivity water or potential iron sources were identified.

Lead - Mean annual levels ranged from 0.69 ug/l at station LG-124 to 1.01 ug/l at site BP-WDH. Lead concentrations were usually observed to be at or below the mdl of 0.67 ug/l. Spatially, the results fail to indicate any consistent geographic pattern with regard to measured lead concentrations within the study area. There was also no consistent seasonal pattern at or among sampling locations with regard to measured lead concentrations. At no time did measured lead concentrations exceed the FDEP Class III freshwater criterion, which is dependent on the hardness level of the sampled water.

Magnesium – Annual mean concentrations ranged from 8.36 mg/l at site CP-SER to 48.61 mg/l at station MY-ENV. Magnesium levels were spatially the highest in Myakkahatchee Creek and the lowest in the southeast portion of the project sampling area. No consistent pattern was observed relative to seasonal patterns in magnesium concentration across the sample area. However, in Myakkahatchee Creek, magnesium levels were observed to be generally lower during the summer the wet-season and higher in the dry-season.

Nitrate Nitrogen (NO_3) – Annual average concentrations ranged from 0.004 mg/l (the minimum detection level (mdl)) at many sites to 0.024 mg/l at station MY-101. Average nitrate nitrogen concentrations were generally found to be the highest in Myakkahatchee Creek. There was no consistent seasonal pattern in nitrate nitrogen concentrations among the sampling locations, although Myakkahatchee Creek values were higher in the wet-season and lower in the dry-season.

Nitrite Nitrogen (NO_2) – Annual average concentrations among the 20 sampling stations ranged from 0.003 mg/l at several sites to 0.007 mg/l at stations MY-TRP and OZ-TRP. Measured nitrite nitrogen levels were generally higher at stations near inputs to the North Port canal system, and lower in the interior portions of the City's canal systems. The monthly data did not indicate any consistent seasonal pattern in nitrite nitrogen concentrations among the sampling sites.

Nitrate + Nitrite (NOx) Nitrogen – This water quality parameter measures the sum of both inorganic nitrate and nitrite nitrogen concentrations within a sample. Annually, the mean concentration of NOx ranged from 0.004 mg/l (the mdl) at several sites to 0.03 mg/l at station MY-101. Spatially, the lowest average concentrations of NOx were observed in Snover waterway, while the highest average levels occurred in Myakkahatchee Creek. There was no consistent overall seasonal pattern in NOx concentrations among the sampling locations. While there was a significant but very weak linear relationship ($p=0.048$, $r^2=0.015$) between chlorophyll *a* and NOx, the levels of this form of inorganic nitrogen account for less than two percent of the observed variation in chlorophyll *a* concentrations at the monitoring locations.

Oil and Grease - Samples were taken twice during the study period (July 2008 and January 2009) at the two stations discharging to Myakkahatchee Creek (MY-101 and CP-106). The Class III criterion for oils and greases is 5 mg/l. Oils and greases were higher in July than January at both stations, with the highest observed value being 2.79 mg/l at MY-101. Measured concentrations in the samples taken at both stations in January 2009 were at or below the minimum detection limit (mdl) of 0.99 mg/l.

Orthophosphorus – Mean annual concentrations at the project's 20 sampling locations ranged from a low of 0.017 mg/l at station SN-I75 up to 0.409 mg/l at station MY-TRP. Overall, there was no consistent geographic pattern apparent in observed mean orthophosporus concentration. Orthophosphorus levels at many of the sampling sites were generally higher in the wet-season than during the dry-season.

Potassium – Annual average concentrations among the station ranged from 0.74 mg/l at site CR-TRP to 12.76 mg/l at MY-ENV. Potassium levels were generally higher at stations near inputs to the North Port canal system (except station CP-SER) and lower in the southeast portion of the sampling area. There was no consistent seasonal pattern in potassium concentration across the sampled stations.

Sodium – Average annual concentrations at the sites ranged from 19.38 mg/l at station MY-ENV to 79.28 mg/l at station CP-106. Sodium levels were generally lower at the input sites to the North Port canal system and increased in both the Cocoplum and Snover waterway systems as water moved downstream toward Myakkahatchee Creek. Measured sodium concentrations were generally lower during the wet-season and indicated marked increases during the dry-season.

Specific Conductance – The range of annual average concentrations among the stations ranged from a low of 442 uS/cm at site CR-TRP to a high of 1039 uS/cm at station CP-106. Measured *in situ* specific conductance levels were generally lower at the stations near the inputs to the North Port canal system and increased toward Myakkahatchee Creek, with specific conductance levels generally lower in the wet-season. The Class III criterion for specific conductance is 1275 uS/cm. Exceedances of this standard were rare and occurred only in the dry-season near the end of the study period (February – March 2009). These results, combined with those found for sodium, clearly indicate the influences of groundwater contributions to the North Port canal systems during the drier months of the year.

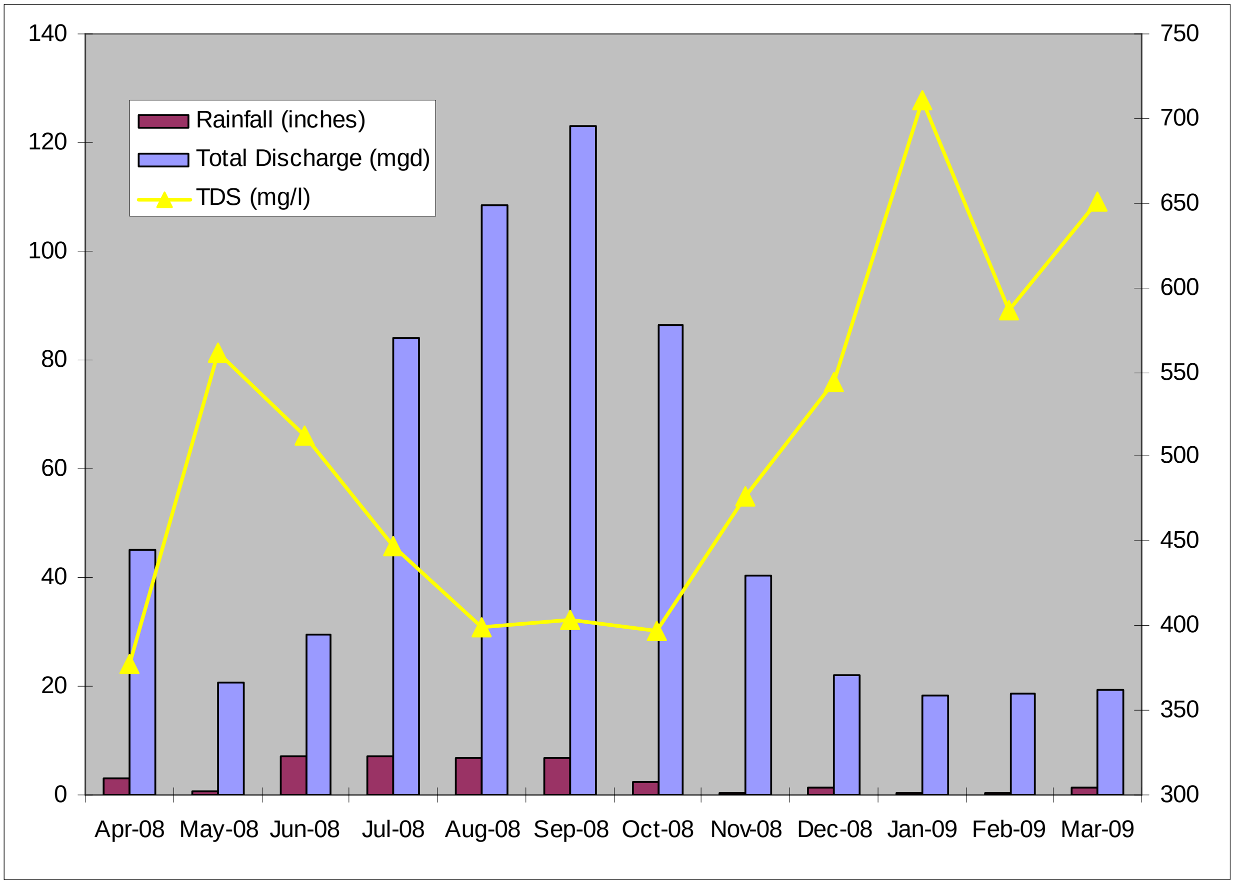
Sulfate – Mean annual levels ranged from 2.72 mg/l at sampling site SN-I75 to 371.35 mg/l at station MY-ENV. Annually averaged, sulfate levels were substantially higher in Myakkahatchee Creek than at other locations monitored in the City. Sulfate was generally lower at the stations near inputs to the North Port canal system and increased as water moved downstream through the system. Sulfate concentrations in Myakkahatchee Creek were lower in the wet-season and higher in the dry-season months. Sulfate levels at the other sampling locations outside Myakkahatchee Creek fail to show any consistent similar seasonal pattern.

Total Dissolved Solids (TDS) – Mean annual values among the sampling sites ranged from 280.0 mg/l at station CR-TRP to 688.0 at station MY-ENV. Like the spatial pattern observed for both sodium and conductivity, average TDS concentrations were generally lower at stations near inputs to the North Port canal system and progressively increased downstream towards Myakkahatchee Creek. TDS concentrations in Myakkahatchee Creek, by comparison, were the highest at the upstream end (station MY-ENV), and decreased toward the discharge at station MY-101. TDS levels were generally seasonally lower during wet-season months and higher during the dry-season, again reflecting the influences of groundwater. This pattern of seasonal variability is shown in Figure 3.1.

Total Kjeldahl Nitrogen (TKN) – This water quality parameter represents a combined measure of the total organic nitrogen and ammonia/ammonium in the sample. Annually, mean TKN concentrations ranged from a low of 0.58 mg/l at station LG-124 up to 1.36 mg/l at sampling sites 36-162 and CR-TRP. Spatially, there was no consistent geographic pattern among the stations with regard to annual mean TKN concentrations. TKN levels at the sampling locations were in general seasonally higher during the wet-season and lower in the dry-season.

Total Nitrogen (TN) - This calculated value combines TKN with Nitrate+Nitrite nitrogen to provide an estimate of combined inorganic and organic nitrogen within the sample. Annual average concentrations among the stations ranged from 0.58 mg/l at site LG-124 to 1.36 mg/l at locations 36-162 and CR-TRP. No consistent geographic pattern was observed during the study period among the sampling sites with regard to average TN concentrations. Levels were generally observed to be higher during the wet-season when compared with the dry-season months. Overall, TKN concentrations constituted the vast majority of the total nitrogen measured at the monitoring locations during the study period. The reference level (state average for river systems) for total nitrogen in the 1996 FDEP 305(b) report is 1.6 mg/l. The majority of samples collected at the 20 locations monitored during this study were below 1.6 mg/l, and the mean for all stations was below the FDEP reference level.

Figure 3.1. Variability of Total Dissolved Solids relative to Rainfall and Discharge from the North Port Canal System



Total Organic Carbon (TOC) – This water quality parameter measures all forms of organic carbon in the water sample (and excludes inorganic carbon). Mean annual TOC concentrations among the sampling sites ranged from a low of 8.96 mg/l at station CR-127 to a high of 26.11 mg/l at location SN-I75. On average, TOC concentrations were higher at stations near inputs to the North Port canal system and lower toward the south central portion of the sample area. Higher levels of TOC were observed at many stations during the wet-season months and lower in the dry-season. The reference level for TOC in the 1996 FDEP 305(b) report is 21 mg/l, a level that was frequently exceeded at a number of sites during the study period.

Total Alkalinity – Mean levels annually ranged among the sampling sites from 57.12 mg/l at station MY-TRP to 240.89 at station CP-109. Total alkalinity was generally lower in the northern portion of the sampling area and higher in the southern portion. Total alkalinity was lower during the wet-season and higher in the dry-season, reflecting the relative seasonal contributions of groundwater to the North Port canal systems. The Class III standard for total alkalinity is a minimum level of 25 mg/l. No sample during the study had a total alkalinity level below 25 mg/l.

Total Phosphorus (TP) – Annually averaged levels ranged from 0.033 mg/l at sampling site SN-I75 to 0.493 mg/l at station MY-TRP. No consistent geographic pattern in average TP concentrations was apparent among the sampling sites over the 12 month study period. Measured TP concentrations at the sampling sites were higher during the wet-season and lower in the dry-season. The reference level for TP in the 1996 FDEP 305(b) report is 0.24 mg/l. TP concentrations at the sampling sites were often above 0.24 mg/l during the study period, in part reflecting the unusually high natural background levels due to the unique geological phosphate rich deposits that characterize much of southwest Florida. The highest TP levels were found in Myakkahatchee creek, and in the North Port Estates area.

Total Suspended Solids (TSS) – Mean annual levels at the monitoring locations ranged from 1.94 mg/l at station CP-SER to 25.31 mg/l at SN-CHA. Higher levels of TSS were generally observed in the northeast portion of the study area. No consistent seasonal pattern in TSS was observed during the study period. The reference level for TSS presented in the 1996 FDEP 305(b) report is 12.5 mg/l, a level that was exceeded a number of times at several stations during the study.

Turbidity – The annual average of measured levels at the sampling sites ranged from a low of 2.26 NTU (Nephelometric Turbidity Units) at station CP-SER up to 25.0 NTU at CR-TRP. The observed spatial pattern of turbidity was similar to that of TSS levels, being higher in the northeast portion of the sample area and lower elsewhere in the North Port canal system. The reference level for turbidity in the 1996 FDEP 305(b) report is 12.2 NTU. With the exception of those stations in the northeast portion of the sample area, the waters of the North Port canal system were generally below this reference level.

Zinc – Measured concentrations ranged from the method detection limit (mdl) of 1.40 ug/l at several stations up to 6.58 ug/l at station 36-162. The majority of the samples analyzed at all of the sampling locations except stations 36-162 and SN-I75 were at or below the mdl of 1.40 ug/l. The measured zinc concentrations were generally higher at locations near the inputs to the North Port canal system, while lower concentrations were observed in the interior of the City’s canal systems. There was very little seasonal variation in zinc concentration during the study period. The Class III standard for zinc is dependent upon the hardness of the sampled water. None of the samples from any of the stations had zinc levels above the Class III standard.

Synthetic Organic Contaminants - There are a number of constituents in the category of synthetic organic contaminants (SOCs) and pesticides. Specific information regarding the maximum contamination levels (MCLs) and the health effects of these contaminants is available in Appendix D. Sampling for SOCs and pesticides occurred quarterly (in June, September and December of 2008, and March 2009) at stations CP-106 and MY-101. There were no instances of analyzed contaminants exceeding the applicable drinking water standards during these four sampling events.

3.2. Specific Conductance Investigation Results

Extensive specific conductance transects were performed in Cocoplum canal, Snover canal, Blueridge canal, and in the upstream and downstream portions of canals intersecting Price Boulevard. The goal of these transects was to identify previously unknown point sources of water that affect the water quality within the North Port canal system. From this effort Nona’s

Spring was identified as a point source to Cocoplum canal, just upstream of Structure 109 through corrugated steel pipes. The flow rate at the discharge point was estimated by capturing water from the discharge pipe and measuring the volume discharged over a known time. Measured flow at the discharge point was 0.102 mgd. A grab sample was taken from the spring, which was found to be up to 7 meters deep, and had a specific conductance range of 5459 to 5880 uS/cm (corresponding salinity range of 2.9 to 3.2 psu). The results of the grab sample are presented in Table 3.1. No other point sources were identified during the conductivity transects. Data from the transects indicate a continuous and gradual increase in specific conductance as one moved downstream in the system. Data from the USGS (station numbers 270351082053501, 270432082085704, 270432082085706) indicate that groundwater in the vicinity of the City of North Port, at depths of less than 200 feet can have specific conductance levels ranging from 675 to over 2000 uS/cm. If residential wells in this depth range are being utilized they may be contributing to this gradual increase in specific conductance.

Table 3.1. Results of a grab sample from Nona's Spring

Analyte Name	Result	Result Units
Ammonia Nitrogen	0.235	mg/l
Bicarbonate Alkalinity	110	mg/l
Biochemical Oxygen Demand	0.961	mg/l
Cadmium	0.9	ug/l
Calcium	209	mg/l
Carbonate Alkalinity	0.594	mg/l
Chemical Oxygen Demand	26.3	mg/l
Chloride	1715	mg/l
Chlorophyll a	11.8	mg/m3
Color	15	PCU
Copper	4	ug/l
Iron	40.8	ug/l
Lead	0.67	ug/l
Magnesium	154	mg/l
Nitrate Nitrogen	0.004	mg/l
Nitrate + Nitrite Nitrogen	0.019	mg/l
Nitrite Nitrogen	0.003	mg/l
Orthophosphorus	0.037	mg/l
Potassium	26.9	mg/l
Sodium	911	mg/l
Sulfate	498	mg/l
Total Alkalinity	110	mg/l
Total Dissolved Solids	3512	mg/l
Total Kjeldahl Nitrogen	0.302	mg/l
Total Nitrogen	0.321	mg/l
Total Organic Carbon	3.76	mg/l
Total Phosphorus	0.041	mg/l
Total Suspended Solids	3.33	mg/l
Turbidity	1.38	NTU
Zinc	1.4	ug/l

3.3. Flow Results

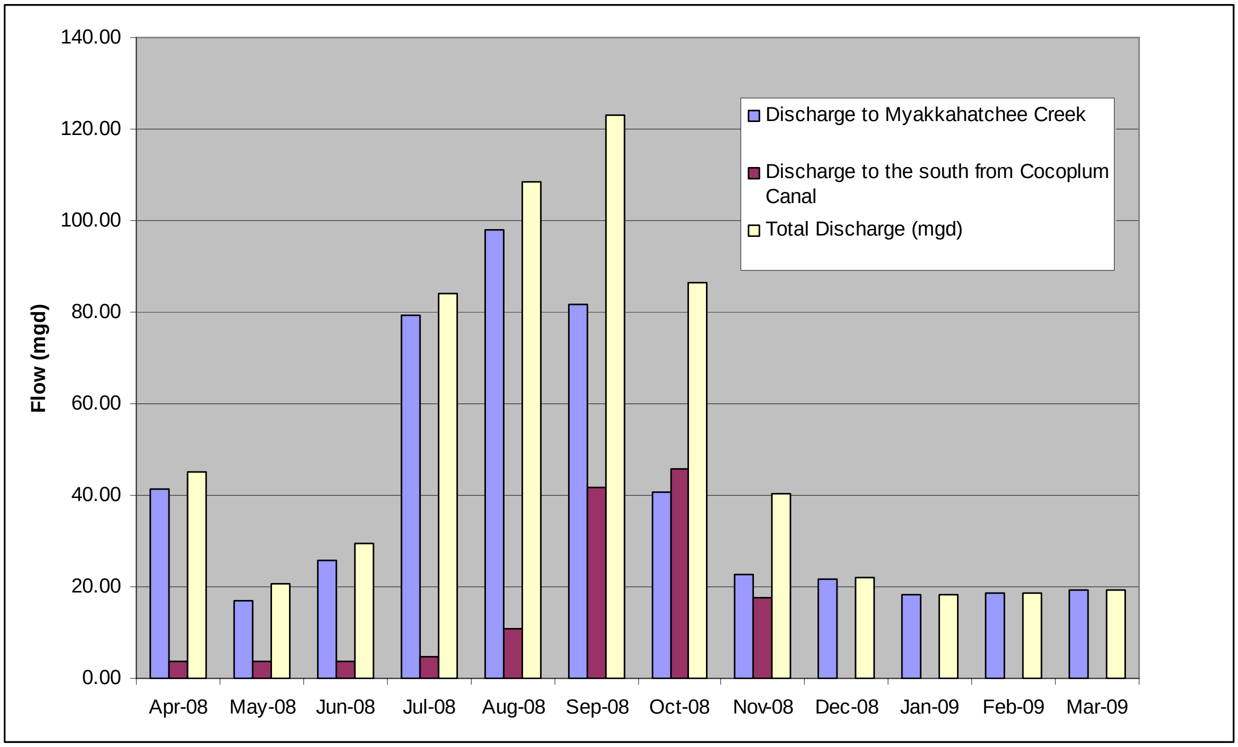
The North Port canal system is controlled by an extensive series of fixed and gated structures. These structures act to move water to the south and west through North Port. Waters along the northern and eastern boundaries are considered incoming to the city, and waters along the southern boundary are considered outgoing from the city. There are seven locations for which flow data were measured either directly using water level recorders and acoustic doppler flow sensors deployed specifically for the study, or retrieved from the existing long-term USGS flow gages in support of calculating loads from the North Port canal system (Table 3.2). Additionally, a water level sensor was deployed in R-36 canal at Structure 162 (station 36-162). The water level at that structure was recorded throughout the study. Frequent operation of the gate at Structure 162 made accurate calculation of flow at that structure impossible. There were also sensors deployed along Tropicaire Boulevard in Cosmic and Creighton canals. These canals did not provide substantial flow into the system. As expected, flows were highest during the five month wet-season (July-October) and lowest in the remaining dry-season months. Flow to Myakkahatchee Creek through Structures 106 (CP-106) and 101 (MY-101) peaked earlier than flow to the south from the sections of Cocoplum canal. The flow from the discharge points in the North Port canal system is controlled by operation of the many gated structures throughout the canal system. Total discharge from the system peaked in September (123.10 mgd) while peak flow to Myakkahatchee Creek occurred in August (97.80 mgd) and peak flow from segments of Cocoplum canal occurred in October (45.79 mgd) (Figure 3.2). It is important to note that in other years this pattern may not hold true, as the flow patterns in the North Port canal system will change dependent upon gate operation.

Table 3.2. Discharge from the North Port canal system

Project Month	MY-101 Mean Discharge (mgd)	CP-106 Mean Discharge (mgd)	CP-107 Mean Discharge (mgd)	CP-108 Mean Discharge (mgd)	CP-109 Mean Discharge (mgd)	CP-110 Mean Discharge (mgd)
Apr-08	15.78	25.74	*0.04	*0.23	*3.28	*0.07
May-08	2.41	14.64	*0.04	*0.23	*3.28	*0.07
Jun-08	7.03	18.72	0.04	*0.23	*3.28	*0.07
Jul-08	42.87	36.33	0.05	1.07	0.00	3.79
Aug-08	59.61	38.20	0.11	7.24	0.00	3.36
Sep-08	41.92	39.61	0.21	14.42	3.16	23.77
Oct-08	18.18	22.60	0.19	6.41	30.29	8.90
Nov-08	5.03	17.69	0.05	1.11	16.30	0.30
Dec-08	5.18	16.67	0.05	0.04	0.00	0.03
Jan-09	2.87	15.38	0.03	0.00	0.00	0.01
Feb-09	3.10	15.42	0.07	0.00	0.00	0.00
Mar-09	2.32	16.93	0.00	0.00	0.08	0.00

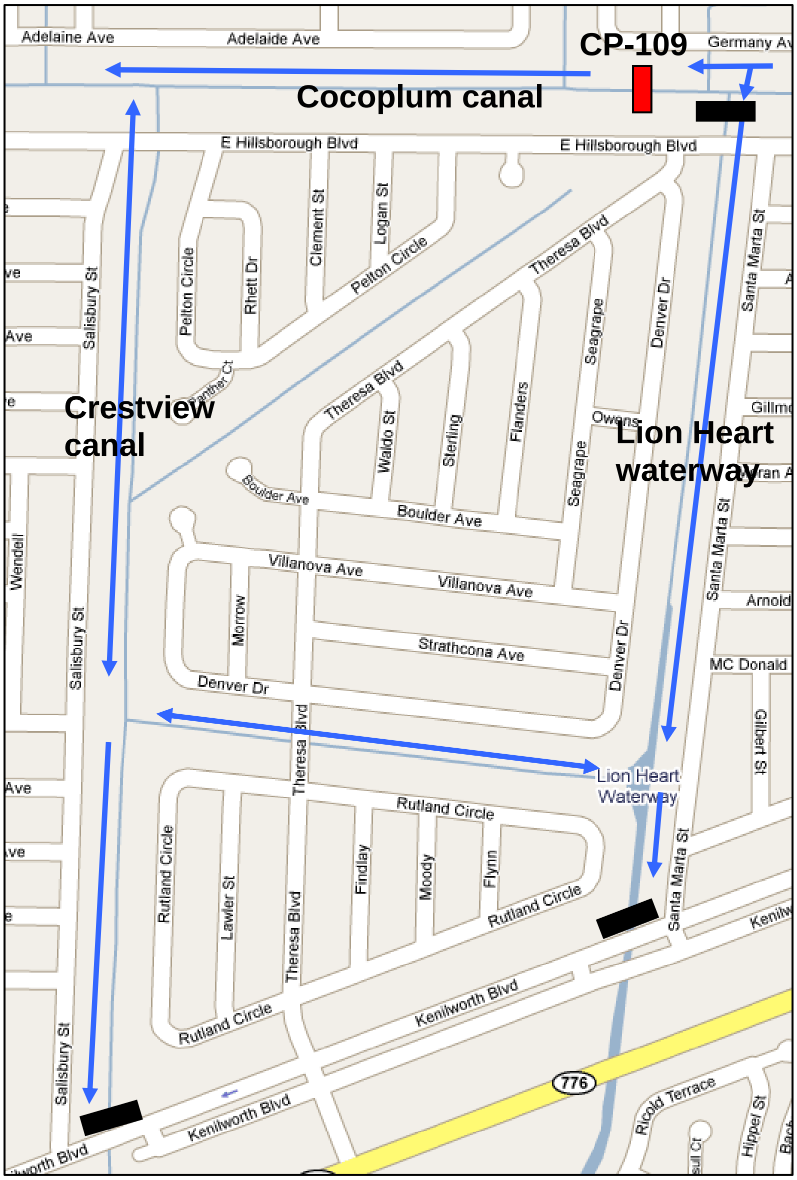
*indicates that a missing value is replaced by the dry season mean

Figure 3.2. Discharge from the North Port canal system



The acoustic flow meter at Crestview canal measured negative flow during much of the study period. This indicates unexpected flow into the system from the south. An investigation of the canal system to the south of the City of North Port found that Crestview and Lion Heart canals act to effectively divert water around Structure 109 and back into the North Port canal system. The pathway for this is shown in Figure 3.3. There was a large (>2 foot) head differential at Structure 109. Water flowing over the weir at Lion Heart canal would flow through the culvert under Theresa Blvd. and back up Crestview canal. There are structures located on both Crestview and Lion Heart canals at Kenilworth Boulevard, which stop water from flowing to the south at those points except at higher water levels. In keeping with our desire to be conservative in generating load estimates, these inflows to Crestview were not subtracted from the total measured outflow.

Figure 3.3. Depiction of the flow pathway from the weir at Lion Heart canal back to Cocoplum canal via Crestview canal



3.4. Calculated Pollutant Loads

The pollutants of primary concern in terms of loads from the North Port canal system are nitrogen and phosphorus. During the study period the majority of nitrogen and phosphorus loads were discharged to Myakkahatchee Creek via structures 101 and 106 (Table 3.3). Estimated loads of both nitrogen and phosphorus were higher during the four wet-season months (July-October) than during the remaining eight dry-season months (Figures 3.4-3.5; Table 3.4). The loadings to Myakkahatchee Creek were higher than loadings to the south of Cocoplum canal in all months except October 2008.

Table 3.3. Calculated loads from the North Port canal system during the study year

Analyte	Load to Myakkahatchee Creek at MY-101 (metric tons)	Load to Myakkahatchee Creek at CP-106 (metric tons)	*Load to the south from section CP-107 (metric tons)	*Load to the south from section CP-108 (metric tons)	*Load to the south from section CP-109 (metric tons)	*Load to the south from section CP-110 (metric tons)
Nitrate + Nitrite	1.23	0.13	0	0.02	0.12	0.16
Total Kjeldahl Nitrogen	25.33	23.86	0.11	3.59	5.87	6.71
Total Nitrogen	26.57	23.87	0.11	3.59	5.99	6.87
Total Phosphorus	10.19	2.81	0.02	0.72	1.7	1.13

*indicates that dry season mean has been used to calculate a portion of the total

Table 3.4. Calculated monthly total nitrogen load from the North Port canal system during the study year

Project Month	Load to Myakkahatchee Creek at MY-101 (metric tons/yr)	Load to Myakkahatchee Creek at CP-106 (metric tons/yr)	*Load to the south from section CP-107 (metric tons/yr)	*Load to the south from section CP-108 (metric tons/yr)	*Load to the south from section CP-109 (metric tons/yr)	*Load to the south from section CP-110 (metric tons/yr)
APR08	1.132	1.401	0.004	0.026	0.204	0.011
MAY08	0.171	0.969	0.004	0.026	0.204	0.011
JUN08	0.557	1.722	0.006	0.026	0.204	0.011
JUL08	3.441	3.321	0.006	0.066	0.000	0.398
AUG08	11.751	4.527	0.010	0.719	0.000	0.394
SEP08	5.904	4.768	0.025	1.835	0.589	4.778
OCT08	2.432	1.506	0.037	0.759	3.768	1.212
NOV08	0.443	1.464	0.004	0.128	1.015	0.050
DEC08	0.254	1.002	0.007	0.003	0.000	0.004
JAN08	0.160	0.931	0.003	0.000	0.000	0.001
FEB08	0.194	1.123	0.005	0.000	0.000	0.000
MAR08	0.134	1.134	0.000	0.000	0.006	0.000

*indicates that dry season mean has been used to calculate a portion of the total

Figure 3.4. Monthly total nitrogen load from the North Port canal system during the project year

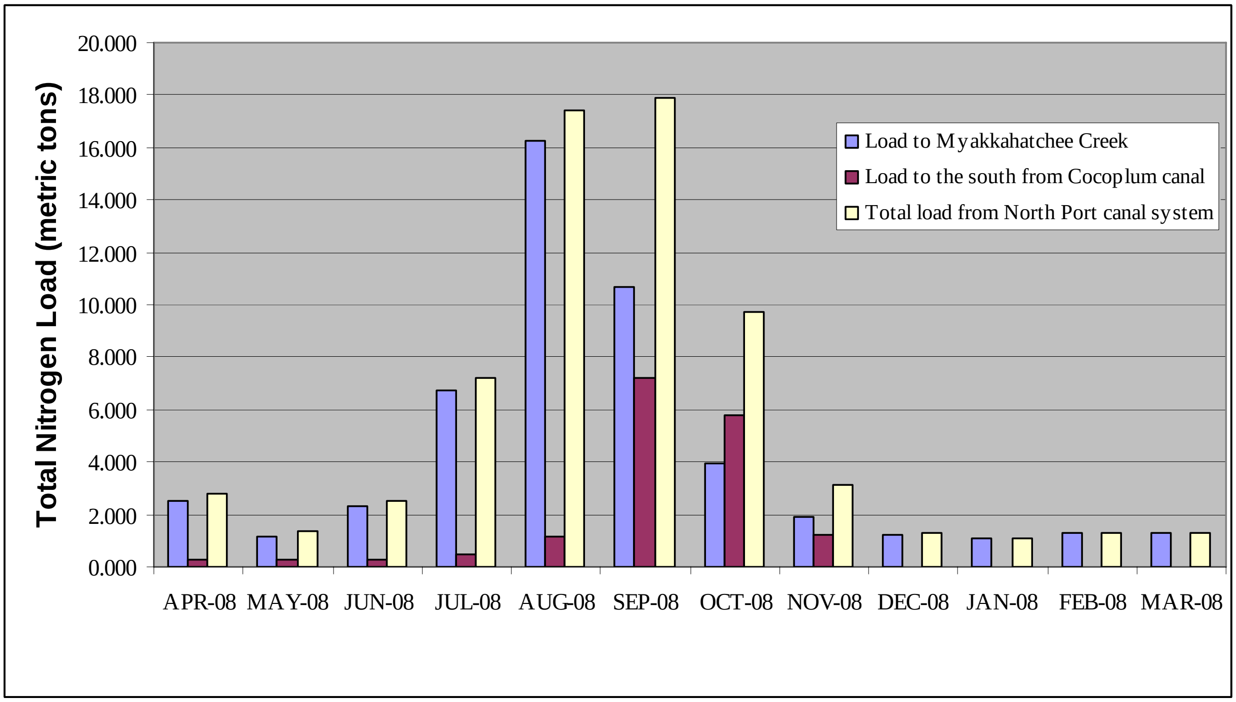
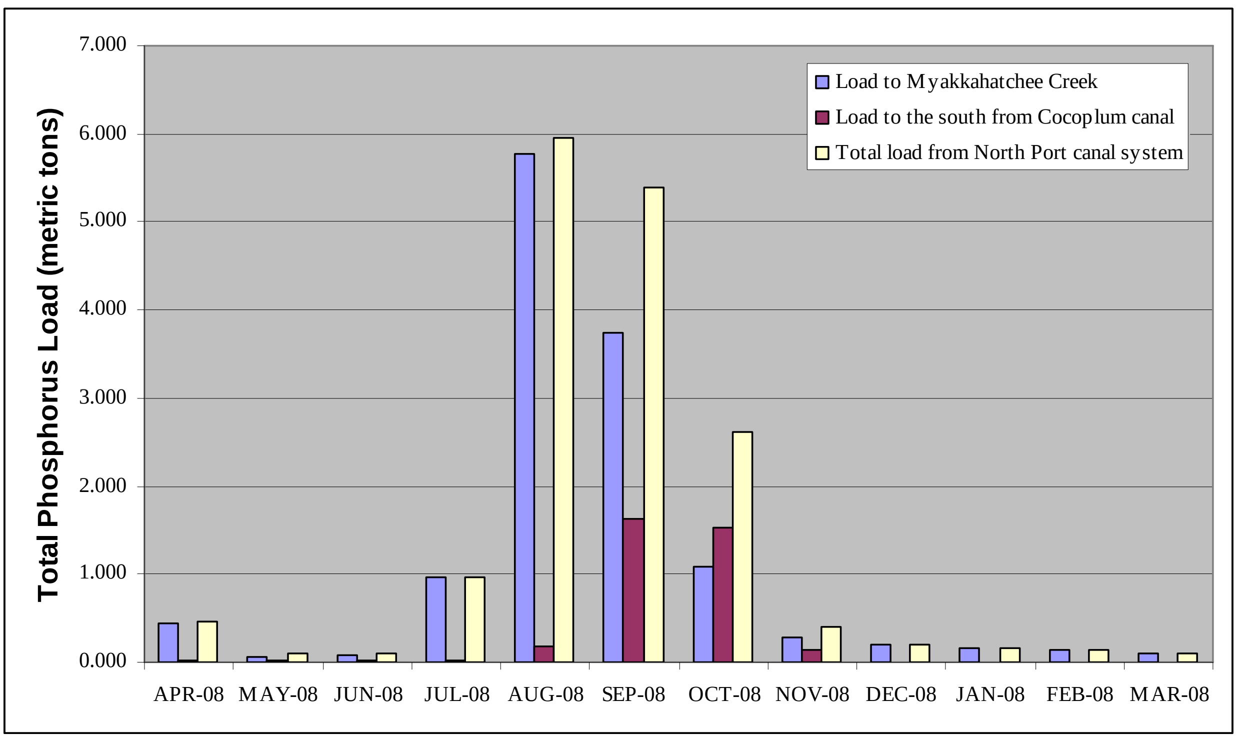


Figure 3.5. Monthly total phosphorus load from the North Port canal system during the project year



3.5. Discussion

3.5.1. Background on water quality issues related to Charlotte Harbor

Charlotte Harbor, Florida's second largest open water estuary is a coastal plain estuary with an average water depth of 2.4 m (McPherson et al. 1996). Charlotte Harbor is generally viewed as one of the most productive estuarine systems in Florida, due in part to its reputation as a world-class destination for recreational fishing (SWFWMD 2000). The major sources of freshwater inflow into Charlotte Harbor are the Peace and the Myakka Rivers. The Peace River watershed, at approximately 2,350 square miles in size, is nearly four times as large as the Myakka River watershed (602 square miles; Hammett 1990). Approximately 408 square miles of land drain into Charlotte Harbor directly, including most of Charlotte County south of the City of Punta Gorda, and most of the Cape Haze Peninsula.

The Peace River is naturally enriched with phosphate from the Bone Valley formation, with additional historical increases associated with phosphate mining activities, including occasional catastrophic releases (Froelich et al. 1985). Phosphorus concentrations in the Peace River and Charlotte Harbor are considerably higher than the median value for Florida estuaries (FDEP 1994), and both nitrogen concentrations and chlorophyll *a* values are often higher than median values for both streams and estuaries (FDEP 1994). However, recent trends have shown substantial declines in phosphate concentrations within the Peace River and more moderate declines within the Harbor itself (PBS&J 2007).

While water quality in the open waters of Charlotte Harbor is mostly considered "good" (based on the State of Florida's Trophic State Index - TSI), portions of the Peace and Myakka rivers are characterized as having only "fair" or even "poor" water quality (Morrison et al. 1998; SWFWMD 2000). The upper reaches of the Peace River are notable for their elevated concentrations of nutrients and total suspended solids, most notably in those portions of the upper Peace River closest to Lake Hancock (SWFWMD 2000, PBS&J 2007).

Analyses of data collected over the past twenty years suggest that, for the most part, Charlotte Harbor's water quality is highly variable but non-trending, with the exception of the downward trend in phosphorus concentrations (SWFWMD 2000). However, water quality monitoring efforts collecting data to track changes over time began only in the 1970s. Also, variation in seagrass biomass and productivity in Charlotte Harbor does not seem to correlate with variation in modeled nitrogen loads (Tomasko and Hall 1999) and thus does not allow for seagrass mapping efforts (which date back to the 1950s) to act as a surrogate for trends in nutrient loading, as opposed to methodologies being applied to both Tampa and Sarasota bays (Tomasko et al. 2005).

Within Charlotte Harbor, phytoplankton growth in the estuary is controlled by the availability of nitrogen (McPherson et al. 1990, 1996; Montgomery et al. 1991). Information derived from dated sediment cores (Turner et al. 2006) indicates the following pattern has occurred, in terms of watershed-wide nitrogen loads: 1) between 1900 and the 1980s, a substantial increase in nitrogen loads occurred, with most of the increase associated with urbanization and agricultural development in the years after World War II; 2) during the 1980s and 1990s, nitrogen loads to

Charlotte Harbor decreased, perhaps due to better control of point source discharges (both domestic and industrial); and 3) since the mid-1990s, further increases in nitrogen loads occurred, perhaps from increased non-point source loads associated with continued urbanization.

At least three pollutant loading models have been developed for the Charlotte Harbor watershed, and the results from these models can be used to compare nutrient loads from the Myakkahatchee Creek watershed calculated here to other locations within the Charlotte Harbor watershed.

3.5.2. Implications of results to TMDL process

Section 303(d) of the Federal Clean Water Act requires states such as Florida to submit lists of surface waters that do not meet applicable water quality standards (impaired waters) and to establish Total Maximum Daily Loads (TMDLs) for these waters. TMDLs establish the maximum amount of a pollutant that a water body can assimilate without causing exceedances of water quality standards.

Chapter 99-223, Laws of Florida, outlines the process by which the 303(d) list of impaired water bodies is refined through more detailed water quality assessments. In Florida, the FDEP relies upon the Impaired Waters Rule (IWR; Chapter 62-303, F.A.C.) for the identification of water quality impairments. The IWR is used for evaluating whether waters meet their designated uses, which include primary contact and recreation use (Class III, or "swimmable/fishable"), shellfish consumption use (Class II), and drinking water use (Class I). Waters verified as not meeting any of their designated uses are to be listed on the state's 303(d) list.

The IWR is also based on the presumption that "impairment" should not be due to single and/or rare events. Instead, the IWR is based on a binomial assessment wherein the number of "failures" is compared to the number of "non-failures." The IWR requires a minimum sample size of ten, with restrictions as to seasonality (all seasons must be sampled) and impairment is then based upon the number of exceedances relative to the total number of samples. The IWR provides the number of exceedances needed for a given site to be placed on the planning list with at least 80 percent confidence that the exceedance rate is greater than or equal to 10 percent. For the Verified List, the IWR provides the number of exceedances needed for at least 90 percent confidence that the exceedance rate is greater than or equal to 10 percent for the site. In addition, data used for compiling the planning list can be up to 10 years old, while data for developing the Verified List can be no more than 7 ½ years old.

Implementation of TMDLs can combine regulatory, non-regulatory, or incentive-based activities, as long as it is reasonable to assume that such actions will likely have an ability to bring about the necessary reduction in pollutant loading. Non-regulatory actions may include development and implementation of Best Management Practices (BMPs), pollution prevention activities, and habitat preservation or restoration. Regulatory actions, which are of significant importance to local governments such as the City of North Port, may include the revision of wastewater, stormwater, or environmental resource permits to ensure they are consistent with the TMDL findings. These permit modifications can include numeric effluent limitations or requirements to use a combination of structural and non-structural BMPs.

3.5.3. Dissolved Oxygen

Florida's 1998 Section 303(d) list identified eight water bodies in the Myakka River watershed as not supporting their designated uses due to pathogens, turbidity, total suspended solids, nutrients, dissolved oxygen (DO) and biological oxygen demand (BOD) impairments. The listed segments include Owen Creek, Upper Myakka River, Upper Myakka Lake, Mud Lake Slough, Big Canal Slough, Deer Prairie Slough, Lower Myakka River and Warm Mineral Springs.

EarthJustice sued the EPA for failing to comply with the Clean Water Act in setting TMDLs. The establishment of TMDLs by the end of 2001 for the listed verified impaired water bodies in the Myakka River watershed were included as part of the subsequent settlement agreement. EPA utilized a two dimensional Watershed Source Assessment Model (WAMVIEW) that incorporated both surface and groundwater flows in assessing TMDLs for the freshwater portions of the Myakka River. The model applied land use data in determining loadings and assimilative capacities of the various river segments. EPA utilized this model to rank potential pollution sources, identify specific areas with pollution related water quality problems, and assess abatement strategies. Two additional models, an Environmental Fluid Dynamics model (EFDC) and the Water Quality Analysis Simulation Program (WASP) simulation model were used in assessing TMDLs for the tidal portions of the Myakka River.

Ultimately EPA did not develop TMDLs for dissolved oxygen for the Myakka River basin, because it was determined that the low levels of background concentrations observed in the Myakka River appeared to represent dissolved oxygen concentrations not greatly impacted by anthropogenic (human derived) sources of oxygen demand or supply.

The ongoing water quality standard for dissolved oxygen in the freshwater water bodies of the Myakka watershed continues to be based on Florida's statewide criteria of 5.0 mg/L. However, evidence indicates that background dissolved oxygen concentrations throughout the Myakka Basin characteristically fall below 5.0 mg/l due to geomorphology, hydrology, and natural processes. EPA suggested Ogleby Creek as a potential background reference stream in the Upper Myakka River basin that can be regionally used to represent unimpacted natural DO concentrations. Continuous monitoring conducted by FDEP personnel in Ogleby Creek indicated that DO concentrations during peak productivity periods often drop below 4 mg/l diurnally. EPA's further examination of historic dissolved oxygen data collected between 1978 and 1998 indicated no significant trend in annual minimum, annual mean, or annual maximum dissolved oxygen concentration (CHEC 1999).

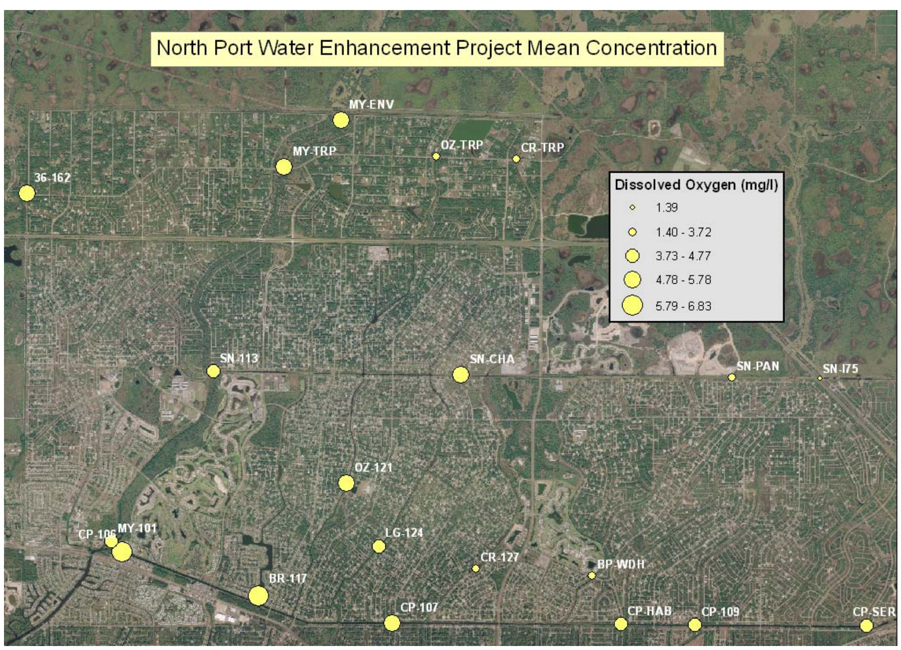
EPA concluded that no possible load reductions were available to increase the measured water parameters above a DO measurement of 5 mg/l due to the natural existing conditions within the watershed. EPA would have had to establish a TMDL such that no anthropogenic oxygen demanding material would have been allowed to enter these waterbody since TMDLs are designed by regulation to reduce any pollutant loading to achieve water quality standards. EPA concluded that a more valid course was the establishment of site specific targets (versus the State's DO criteria of 5 mg/L) for such water bodies to better reflect natural conditions.

The recent TMDL report (FDEP 2008) for the Gordon River (Collier County), which is also a predominantly freshwater canal system, applies Florida's Surface Water Quality Standard (Rule 62-302, F.A.C.) that dissolved oxygen (DO) concentration shall not be less than 5.0 mg/l, and that "Normal daily and seasonal fluctuations above these levels shall be maintained." (Note that while fluctuations above 5.0 mg/l are expected, no considerations are made for fluctuations below 5.0 mg/l.)

The binomial distribution rule still applies, in that DO values below 5.0 mg/l can be tolerated without a location being classified as "Verified Impaired" so long as these values do not comprise more than 10 percent of the values for any given site. If a mean DO value is below 5.0 mg/l for any site, it would thus fail the existing DO standard for freshwater systems, as this would likely only occur if more than 10 percent of samples were below 5.0 mg/l.

In contrast, the DO standard for predominantly marine waters allows for deviations below 5.0 mg/l, as long as levels do not fall below 4.0 mg/l. As such, the "screening" level DO value used in this report is 5.0 mg/l. As is shown in Figure 3.6, mean DO levels were below the 5.0 mg/l standard at 13 of 20 sample locations. Sites with DO levels below the 5.0 mg/l standard were mostly located either along the northern periphery of the City of North Port (i.e., stations OZ-TRP and CR-TRP), along the eastern periphery (i.e., monitoring sites SN-PAN and SN-175), or along the southern periphery within Cocoplum canal (sites CP-HAB, CP-109, CP-110, and CP-SER). However, stations within the interior portion of the North Port canal system also had mean DO levels below the standard (i.e., LG-124, CR-127, and BP-WDH).

Figure 3.6. Mean dissolved oxygen (mg/l) during the project year



All sites had a least one DO reading below 5.0 mg/l (Appendix A, p. A-12) and 14 of the 20 sites had at least one DO reading below 2.0 mg/l.

While the majority of sites sampled do indeed appear to meet the criteria needed to become listed as "Verified Impaired" for DO, it is important to note that the existing DO standard for the State of Florida is not always an appropriate one. In a study done in the eastern Everglades, McCormick et al. (1997) found that "…even at reference sites, O_2 was less than the 5 mg l^{-1} water quality standard for other water bodies (State of Florida Class III Standards) from 40 to 70 % of time." In their assessment of DO standards for the Everglades, FDEP developed an algorithm incorporating water temperature and the time of day to create a more relevant DO standard (Weaver and Payne 2004). The proposed "standard" is actually a range of values, rather than a single value. The range of expected values was typically lower than the existing standard of 5.0 mg/l for all but the coldest months of the year.

Even outside Southwest Florida, FDEP has recognized that the existing DO standard of 5.0 mg/l for freshwater systems can be inappropriate. The proposed site-specific alternative criterion for DO for Long Branch (Orange County) was set at 2.6 mg/l (Gao 2005).

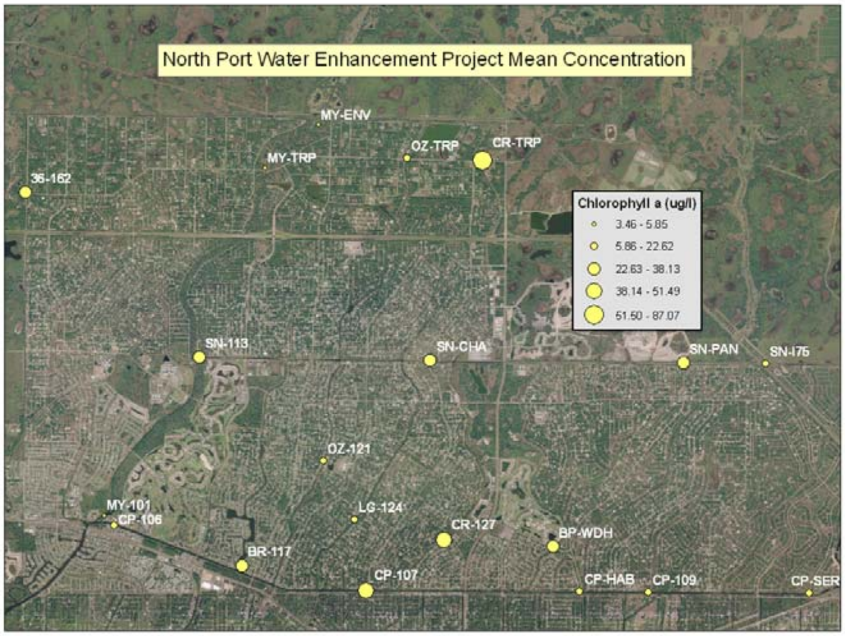
Although DO levels in the North Port canal system may reflect some level of anthropogenic influence, it is equally if not more likely that the existing DO standard of 5.0 mg/l is an unrealistic one for the City of North Port's existing canals. This background indicates that the development of a site specific alternative criterion (SSAC) for DO may be the best option for the North Port canal system.

3.5.4. Nutrient Impairment

As is the case for the Gordon River (Collier County) it is likely that FDEP would expect the canal system in North Port to meet water quality standards for streams or stream segments, rather than those for lakes, as the canal system was constructed, and currently functions, to convey water. As such, these canals would be included on the planning list for nutrients if the following conditions are observed (Rule 62-303.351): 1) algal mats are present in sufficient quantities to pose a nuisance or hinder reproduction of a threatened or endangered species; or 2) annual mean chlorophyll *a* concentrations exceed 20 µg/l or annual mean chlorophyll *a* values have increased by more than 50 percent over "historical values" for at least two consecutive years.

As such, the "screening" level used in this report to test for nutrient impairment is whether or not annual mean chlorophyll *a* concentrations at any given location exceed 20 µg / liter. Figure 3.7 shows mean chlorophyll *a* values for all sites. Eleven of 20 sampled locations had mean chlorophyll *a* values higher than 20 µg / liter.

Figure 3.7. Mean chlorophyll *a* (mg/l) during the project year



Of the many factors that can influence levels of chlorophyll *a*, those that are discussed below are the interactive relationships between "color" (i.e., tannins), nitrogen, and chlorophyll *a*.

Potential Influence of Color on Nutrient-Chlorophyll a Relationships

As seen in Figures 3.8 and 3.9, levels of both color and total nitrogen (TN) are typically lower within the interior sites of the canal system, as compared to sites located on the periphery.

Figure 3.8. Mean color (PCU) during the project year

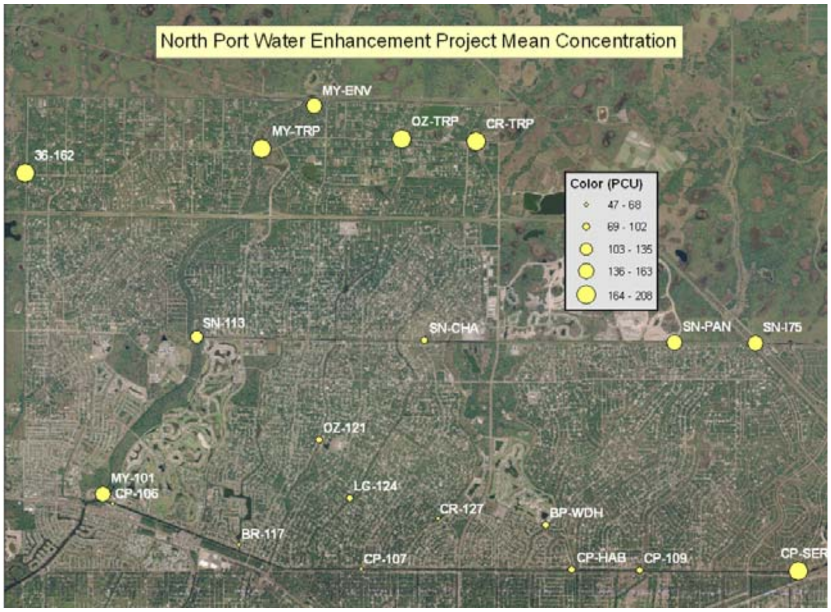
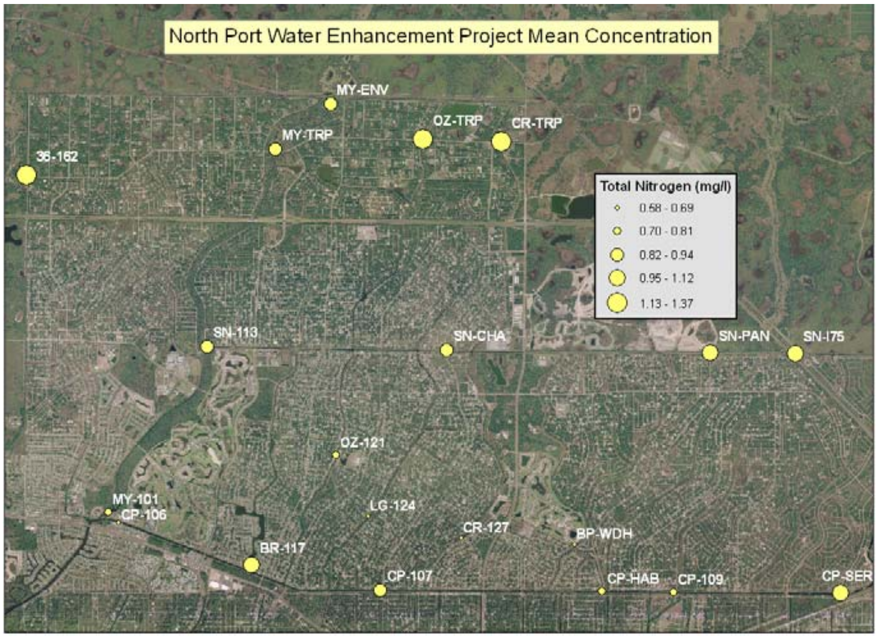


Figure 3.9. Mean total nitrogen (mg/l) during the project year



High color values can be associated with surficial runoff from natural systems, rather than groundwater. Color acts to moderate algal growth by attenuating sunlight. Project mean levels of color were generally above 140 PCU for stations within either the Myakkahatchee Creek (sampling sites MY-ENV, MY-TRP and MY 101) or along the northern (sites OZ-TRP and CR-TRP) and eastern (stations SN-175 and CP-SER) peripheries of the canal system. In contrast, interior locations typically have color levels less than 100 PCU.

A similar pattern exists for levels of TN. Mean TN values typically exceed 1.0 mg/l for stations along the northern and eastern periphery of the canal system, while most interior stations have mean TN values below 1.0 mg/l.

The spatial distribution of TN values alone, with higher values along the periphery of the canal system, and lower values (on average) within the canal system, suggests that development within the City of North Port does not seem to be associated with increased nitrogen concentrations within the canal systems. Although the nitrogen levels along the periphery of the North Port canal system were higher than the measured levels in the interior of the system, they were still not low relative to the reference levels in the 1996 FDEP 305(b) report. Further, the levels of TN within the canal system at interior locations are considerably lower than levels expected for an urbanized landscape such as the City of North Port.

Within the boundaries of the City of North Port, the dominant land use feature, using the Florida Land Use/Cover Classification System (FLUCCS) is low-density single family residential. The pollutant loading model constructed for the Charlotte Harbor watershed for the District's Surface Water Improvement and Management (SWIM) Program indicates that event mean concentration (EMC) values for such a land use would be expected to average 1.9 mg/l TN (Table 1.3 in Coastal Environmental, Inc. 1995). An EMC value, also referred to as a flow-weighted average, is the concentration of a pollutant measured over the hydrographic curve of discharge during a rain event. In contrast, most interior canal stations had average TN concentrations less than half that amount. The highest average TN value found (1.37 mg/l at station 36-162) was 28 percent lower than the expected EMC value for that land use type. An important finding of this water quality sampling effort is that TN concentrations within the North Port canal system are quite a bit lower than they were expected to be, based on the existing pollutant loading model for Charlotte Harbor.

The FDEP 1996 305(b) report contains an analysis of reported nutrient concentrations for Florida streams. When these reported TN concentrations are compared with the measured TN concentrations within the City of North Port canal system, it is apparent that TN values in the North Port canal system are lower than the expected values at all listed percentiles (Table 3.5). When the comparison is made on a station by station basis, there were some stations that were higher than expected, and some that were lower than expected. It is noteworthy that the four stations with the highest median TN levels were all stations located on the incoming periphery of the North Port canal system (CR-TRP, OZ-TRP, SN-I75, 36-162). The stations with the lowest median TN levels were all located either in the interior, or toward the discharging periphery of the North Port canal system (Appendix A)

Table 3.5. Comparison of measured total nitrogen in the North Port canal system with expected values from the FDEP 1996 305(b) report

Percentile	1996 305(b) TN (mg/l)*	North Port TN (mg/l)
10	0.55	0.46
20	0.75	0.54
30	0.9	0.64
40	1	0.76
50	1.2	0.84
60	1.4	0.93
70	1.6	1.03
80	2	1.21
90	2.7	1.54

* from Table 2-5 in the FDEP 1996 305(b) report

Two possibilities exist to explain the general pattern wherein TN concentrations in interior sites are lower than sites along the periphery of the canal system. First, it could be that the City's neighborhoods load nitrogen through stormwater and/or groundwater contributions (including inputs from septic tank systems) at concentrations lower than the mostly undeveloped landscapes outside the City's boundaries. Higher TN values in incoming waters might be diluted by lower values from the urban landscape. Second, it is possible that TN within the water brought into the interior portions of the canal system is assimilated by submerged and/or emergent vegetation, and that these plants (i.e., cattails, water lettuce, Hydrilla, etc.) function as a nutrient sink for nitrogen.

These two processes are not mutually exclusive. It could be that emergent and submerged vegetation within the canal systems act to take up nitrogen from the water column, while the low density single family residential landscape does not appear to be overwhelming such uptake mechanisms with additional loads. The predominance of swale systems for most of the residential neighborhoods might be capable of producing a similar effect as that of low impact development guidelines, wherein stormwater loads are filtered into the surficial aquifer, rather than being loaded into nearby surface waters via curbs and gutters and storm drains. While the urban land use features of the City of North Port do not appear to be loading high levels of additional nitrogen into the water column, the canal systems, due in part to their lower levels of color, appear to be more susceptible to turning available nutrients into phytoplankton.

In a recent report conducted on the Winter Haven Chain of Lakes, it was found that lakes with low levels of color (i.e., low levels of tannins) were able to transform nutrients into phytoplankton more easily than the typical lake in Florida (PBS&J 2008). In contrast, lakes with high levels of color did not exhibit any relationship between nutrients and phytoplankton. The conclusion reached in this report was that tannins act to moderate the transformation of nutrients into phytoplankton, perhaps via their ability to reduce water clarity and thus phytoplankton growth rates.

Within the City of North Port, sites with color levels higher than 140 PCU (mostly located on the periphery of the canal system) exhibit the same type of response as that seen in the Winter Haven Chain of Lakes. For those stations with mean color values higher than 140 PCU (mostly located on the periphery of the canal system) the linear relationship between chlorophyll *a* and total nitrogen is:

$$\text{Chl-}a = (31.06 \text{ x TN}) - 9.62;\ r^2 = 0.13;\ p < 0.01$$

For stations with mean color values less than 140 PCU (mostly located in the interior locations of the canal system) the linear relationship between chlorophyll *a* and total nitrogen is:

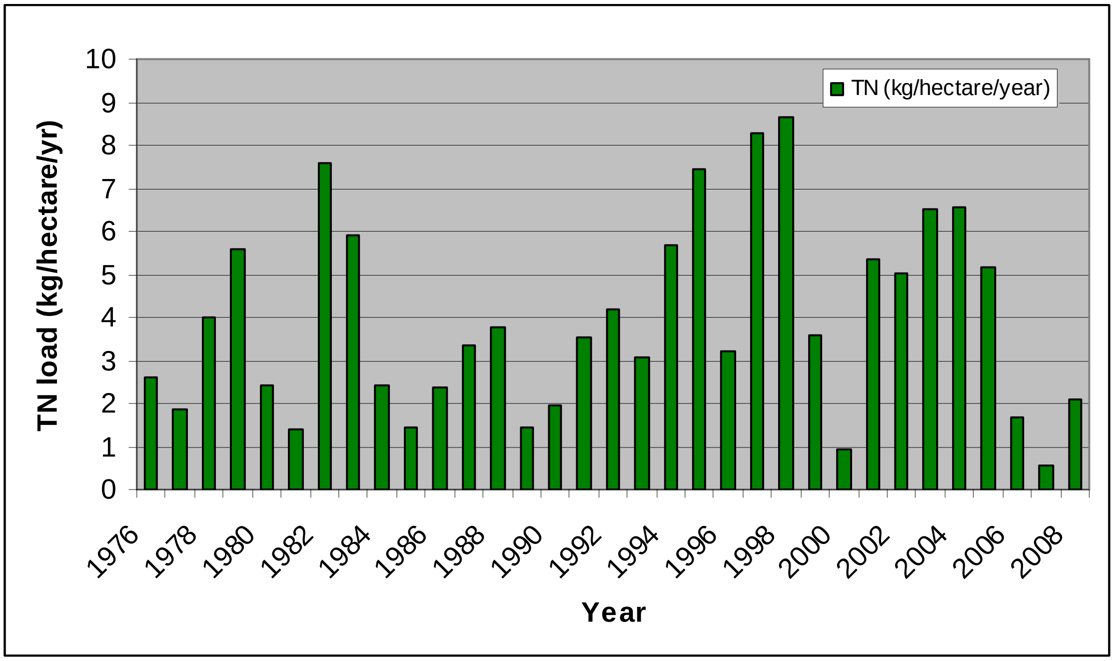
$$\text{Chl-}a = (66.34 \text{ x TN}) - 22.18;\ r^2 = 0.31;\ p < 0.01$$

Sites located within the interior of the canal system have a more robust relationship (a higher r^2 value) between nutrients and chlorophyll *a*. Also, for a given nutrient level, interior locations are likely to produce more phytoplankton. Using the equations shown above, a location on the periphery of the canal system, with higher levels of color, would be expected to have a chlorophyll *a* value of 21 µg/l with a TN value of 1.0 mg/l. Sites within the interior of the canal system, with lower levels of color, would be expected to have a chlorophyll *a* value of 44 µg/l with a TN value of 1.0 mg/l. This greater sensitivity within the interior locations of the canal system suggests special attention should be paid to ensuring nutrient concentrations do not increase over time.

An additional assessment was then carried out to examine the relative importance of the North Port canal system nitrogen loads, as they relate to nitrogen loads to Charlotte Harbor from other systems. Using flow and water quality from gaged locations, and by developing flow estimates from ungaged structures, a loading estimate was developed for both phosphorus and nitrogen from the North Port canal system. These numbers, especially for nitrogen, can be used to compare nitrogen load (metric tons/yr) and area normalized nitrogen yield (kg/hectare of watershed/yr) estimates with prior estimates from both Charlotte Harbor and elsewhere. It should be noted that the loading estimates listed here are from the12 month project period (April 2008 through March 2009) and that there can be large interannual variability in loading due to variability in rainfall.

During the 12 months sampled for this project, the amount of nitrogen (as TN) loaded into the Myakka River from the canal systems either flowing through, or originating within, the City of North Port canal system was calculated to be 67 metric tons of TN. The mean annual load estimate from the Peace River watershed for the years 1985 to 1991 equaled 1,633 metric tons of TN (Coastal Environmental, Inc. 1995). During 1998, which was a wet year, the estimated nitrogen load from the Peace River was 5,013 metric tons of TN (CHEC 2001). The technique used for estimating North Port loads (i.e., measured flows multiplied by measured nutrient concentrations on a monthly basis) was applied to the summed total of the Peace River at Arcadia plus Joshua Creek at Nocatee plus Horse Creek at Arcadia sites (the gaged Lower Peace River) for each year from 1976 to 2008 (Figure 3.10). The long-term annual average nitrogen load (1976 to 2008) for these locations combined is an estimated 1,745 metric tons of TN. During 2008, TN loads from these locations were 925 metric tons of TN. Additional nitrogen loads enter Charlotte Harbor from the portion of the Peace River watershed below these gage sites, as well as loads coming from both the Myakka River and the ungaged portions of the Charlotte Harbor watershed that drain directly to the Harbor itself. The total nitrogen load coming from the City of North Port's canal system during the study period was somewhere between 1 and 4 percent of the total nitrogen load coming from the gaged watershed of the Peace River described above. As stated previously, this study was conducted during a prolonged regional drought. Had the study been conducted during a wetter hydrologic period the results of the study may have been markedly different, as flow is a major component of the loading equation.

Figure 3.10. Area normalized nitrogen load in the gaged Lower Peace River



Nutrient loads can vary dramatically depending on the size of the watershed used to estimate any given load. To account for this, loads can be divided by the size of the watershed that contributes to that load (referred to as area normalization). A commonly used unit for such comparisons is kg/hectare of watershed/yr.

CHEC (2001) estimated sub-basin nitrogen yields (kg TN/ha of watershed/yr) for 10 sub-basins of the Charlotte Harbor watershed for Water Year (WY) 1998 (October 1997 to September 1998) and also for 4 sub-basins in WY 1999. Loads were measured, not modeled, and were based on monthly water samples multiplied by average monthly flows at fixed sites throughout the watershed.

For WY 1998, nitrogen yields varied from a low of 6.5 kg TN/ha of watershed/yr for the Shell Creek sub-basin to a high of 22.1 kg TN/ha of watershed/yr for the Saddle Creek at P-11 sub-basin. The high value for the Saddle Creek sub-basin reflects the influence of the very poor water quality that discharges from Lake Hancock. For WY 1999, which was a much drier time period, nitrogen yields varied from a low of 2.5 kg TN/ha of watershed/yr for the Peace River at Arcadia sub-basin to a high of 4.9 kg TN/ha of watershed/yr for the Shell Creek sub-basin. In contrast, the TN yield estimated for the City of North Port was 1.3 kg TN/ha of watershed/yr, a value almost 50 percent lower than the lowest yield reported for both WY 1998 and WY 1999.

From the perspective of nitrogen loads per unit area, the City of North Port is clearly not a problem area for nitrogen loads to Charlotte Harbor. Instead, the nitrogen yield estimated from the City of North Port is similar to nitrogen yield estimates derived for undeveloped landscapes (Kennish et al. 2007).

For phosphorus, which is not the limiting nutrient for algal growth in Charlotte Harbor (Montgomery et al. 1991, Turner et al. 2006), a similar pattern appears – North Port loads are quite low compared to other portions of the Charlotte Harbor watershed. During WY 1998, total phosphorus yields ranged from a low of 0.7 kg TP / ha of watershed / yr for the Shell Creek sub-basin to a high of 4.9 kg TP / ha of watershed / yr for the Peace River at Zolfo Springs sub-basin. During the much drier WY 1999 period, phosphorus yields ranged from a low of 0.3 kg TP / ha of watershed / yr in the Peace Creek Canal and Saddle Creek sub-basins to a high of 1.9 kg TP / ha of watershed / yr in the Myakka River near Sarasota sub-basin (CHEC 2001). In contrast, the calculated phosphorus yield from this study is 0.3 kg TP / ha of watershed / yr, equal to the lowest yields found from the Charlotte Harbor watershed.

In addition to the above analyses, loads in Myakkahatchee Creek were calculated upstream at Tropicaire Blvd. (station MY-TRP), for comparison with loads downstream at Structure 101 (station MY-101; Table 3.6). The major point source between those two points on Myakkahatchee Creek is Snover waterway. The total load of nitrogen discharged during the study period increased from 25.4 metric tons at sampling station MY-TRP to 26.6 metric tons at sampling station MY-101. This is expected, as additional flow carries additional nitrogen loads into the system. The area normalized load was actually higher upstream at MY-TRP (1.21 kg/hectare/yr) than downstream at MY-101 (1.14 kg/hectare/yr). The project mean nitrogen concentration at MY-TRP was higher (0.91 mg/l) than the mean concentration at MY-101 (0.75), which explains this reduction in area normalized nitrogen load. As mentioned above, this finding indicates that the North Port canal system is providing some combination of dilution and treatment that is acting to reduce the area normalized nitrogen load through the system.

Table 3.6. Comparison of total and area normalized loads in Myakkahatchee Creek at Tropicaire Blvd and at Structure 101

Analyte Name	Total Nitrogen Load in Myakkahatchee Creek at Tropicaire Blvd (metric tons/yr)	Total Nitrogen Load in Myakkahatchee Creek at Structure 101 (metric tons/yr)	Area Normalized Nitrogen Load in Myakkahatchee Creek at Tropicaire Blvd (kg/hectare/yr)	Area Normalized Nitrogen Load in Myakkahatchee Creek at Structure 101 (kg/hectare/yr)
Total Nitrogen	25.36	26.57	1.21	1.14
Total Phosphorus	10.51	10.19	0.50	0.44

3.5.5. Bacterial Impairment

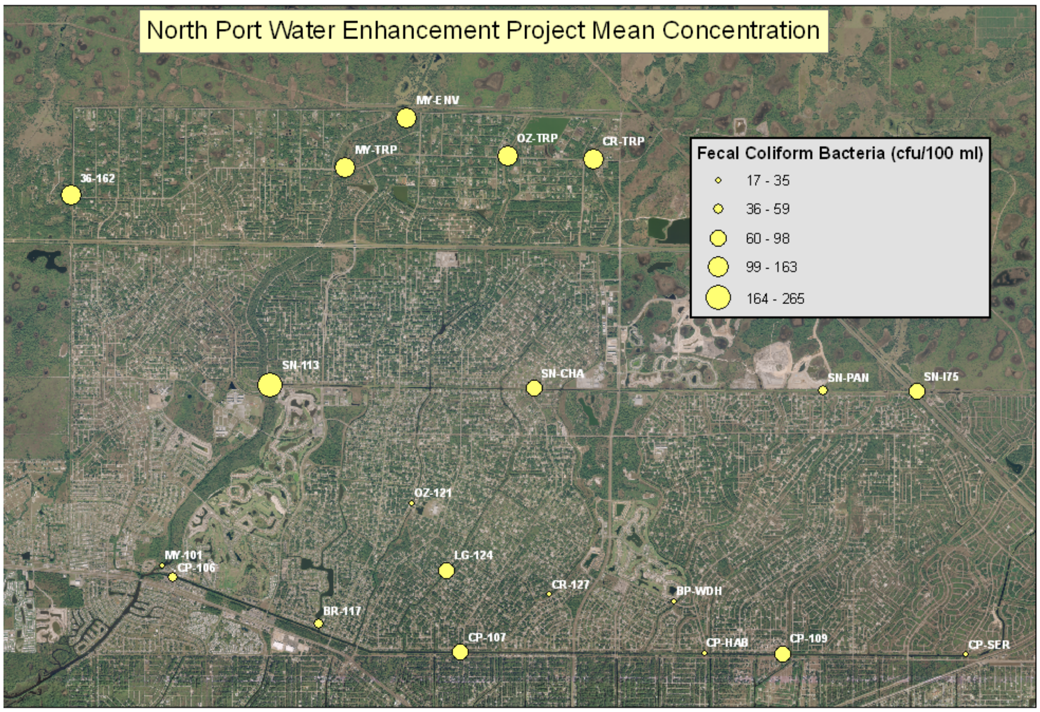
In the State of Florida, numeric criteria for bacterial quality are expressed in terms of concentrations of fecal coliform bacteria. The water quality criteria for protection of Class III waters, as established by Chapter 62-302, F.A.C., states the following:

The most probable number (MPN) or membrane filter (MF) counts per 100 ml of fecal coliform bacteria shall not exceed a monthly average of 200, nor exceed 400 in 10 percent of the samples, nor exceed 800 on any one day.

According to FDEP, monthly averages "…shall be expressed as geometric means based on a minimum of ten samples taken over a thirty-day period." As most sampling programs, including this one, do not have ten samples per month, FDEP has decided that the appropriate criterion for TMDL purposes is that fecal coliform bacteria should not exceed 400 cfu / 100 ml.

For the analysis in this report the value of 400 colony forming units (cfu) per 100 ml will be used for screening. With monthly sampling over a twelve month period, a single sample greater than 400 cfu / 100 ml would be roughly equivalent (8 percent) to the 10 percent guidance given by the state.

Figure 3.11. Annual mean fecal coliform bacteria (cfu/100 ml) during the project year



Elevated levels of fecal coliform bacteria do not, by themselves, definitively indicate the source of the bacteria, as outlined below. In the U.S. and elsewhere, total coliform bacteria have been used for over a century as indicators of fecal contamination of water supplies. This was largely due to the inability of prior efforts to detect the presence of the specific bacteria that were later shown to have caused outbreaks of cholera and typhoid fever – *Vibrio cholerae* and *Salmonella typhi*, respectively (National Research Council 2004).

It was soon determined that a variety of bacteria that tested positive for total coliform bacteria were not fecally-derived. This led to the development of the test for "fecal coliform bacteria" which are also referred to as "thermotolerant bacteria." A major refinement associated with the fecal coliform bacteria assay is the use of a higher incubation temperature. The use of a higher incubation temperature is in turn based in large part on studies conducted in the Ohio River basin. From those studies, it was shown that approximately 18 percent of the total coliform bacteria in any given raw water sample would likely test positive using the fecal coliform bacteria test (National Research Council 2004). As the use of a total coliform bacteria standard of 1,000 cfu/100 ml was widespread, the National Technical Advisory Committee of the U.S. Federal Water Pollution Control Administration (a precursor to the U.S. EPA) converted the existing standard of 1,000 cfu/100 ml to a lower fecal coliform standard of 200 cfu / 100 ml (0.18 x 1,000 = 180; 180 then rounded up to 200).

The value of 200 cfu / 100 ml was thus derived from a conversion factor from the original guidance of 1,000 cfu / 100 ml for total coliform bacteria. The use of 400 cfu / 100 ml for fecal coliform bacteria appears to be the result of a desire by FDEP to use a protective number for maintaining waters safe for recreational use and/or bodily contact. Fecal coliform bacteria do not, however, have to be from fecal material, a conclusion reached by FDEP in its TMDL report (FDEP 2006) for fecal coliform bacteria in Wagner Creek (Dade County, Florida).

Partly in response to the issue of the non-specificity of fecal coliform bacteria as indicators of humans as a cause, preliminary source identification efforts were conducted within the Wagner Creek basin. A similar effort might be appropriate for the canal systems of the City of North Port.

3.5.6. Iron Impairment

Iron is one of the major common constituents of rocks and soils, generally comprising approximately 2 percent (20,000 mg/kg) of the earth's continental crust. Iron is an essential biological nutritional element, although excessive exposure (principally though ingestion) has been shown to have adverse effects. The bioavailability of iron is an important consideration in assessing exposure pathways in aquatic systems since iron in sediment often exists as poorly soluble salts, or particles of inert, insoluble materials. The inherent insolubility of iron at neutral to higher pH levels such as predominantly occurs in the North Port canal system tends to greatly reduce much of its direct bioavailability through the food chain.

Outside of Florida, iron is a common component of mine drainage and elevated levels have been shown to have detrimental effects on aquatic life. Understanding the direct impacts of iron associated with mine drainage is complex, as elevated dissolved iron levels in such instances are typically associated with very low pH conditions, which also severely disrupts aquatic organisms in such impacted systems. Dissolved iron typically forms precipitates, such as ferric hydroxide, as pH levels increase above 3.5, and EPA studies have indicated that such iron precipitates generally have limited negative influences on the aquatic organisms in impacted streams.

As specified within Rule 62-302.530 of the Florida Administrative Code, dissolved iron concentrations in Class III waters (freshwater/recreational) of less than 1.0 mg/l (1000 ug/l) meet the established criteria for surface water quality. The established water quality criteria for all other waters classifications, including Class III marine, require ambient concentrations below 0.3 mg/l, as moderate levels of exposure are not considered to pose a serious health threat.

In late 2004 PBS&J provided Sarasota County and FDEP staff with a series of analyses regarding historic iron concentrations from both the Horse Creek and lower Peace River in support of the County's contention that FDEP's draft impairments for iron concentrations in the

Myakka River system represented natural conditions. These analyses resulted in FDEP's delisting of segments of the Myakka River as impaired for iron. Data from IWR2002_Run18 showed that ambient iron concentrations within the freshwater and tidal Myakka River often exceeded the 1.0 mg/l and 0.3 mg/l standard established for Class III freshwater and estuarine systems under Rule 62-302.530 of the FAC. However, iron concentrations above this standard were found not to be specifically unique to specific water body segments within the lower southwest areas of Sarasota County. Table 3.7 indicates long-term dissolved iron concentrations at three sampling sites along the lower Peace River between Arcadia and the US 41 Bridge near Punta Gorda. As shown, ambient concentration in the lower Peace River typically meet the 1.0 mg/l standard in the freshwater portions of the river, but often exceed the 0.3 mg/l standard in the brackish estuarine segments of the lower river estuary.

Table 3.7. Statistical Summary of Dissolved Iron Concentrations in the Lower Peace River

Lower Peace River	Sample Depth	Number of Samples	Mean (mg/l)	Median (mg/l)	Minimum (mg/l)	Maximum (mg/l)
US41 Bridge	Surface	106	0.210	0.180	0.10	1.320
US41 Bridge	Bottom	106	0.330	0.250	0.10	2.590
Near Horse Creek	Surface	107	0.280	0.260	0.10	0.880
Near Horse Creek	Bottom	107	0.310	0.300	0.10	0.920
Arcadia Bridge	Surface	74	0.260	0.220	0.10	2.000

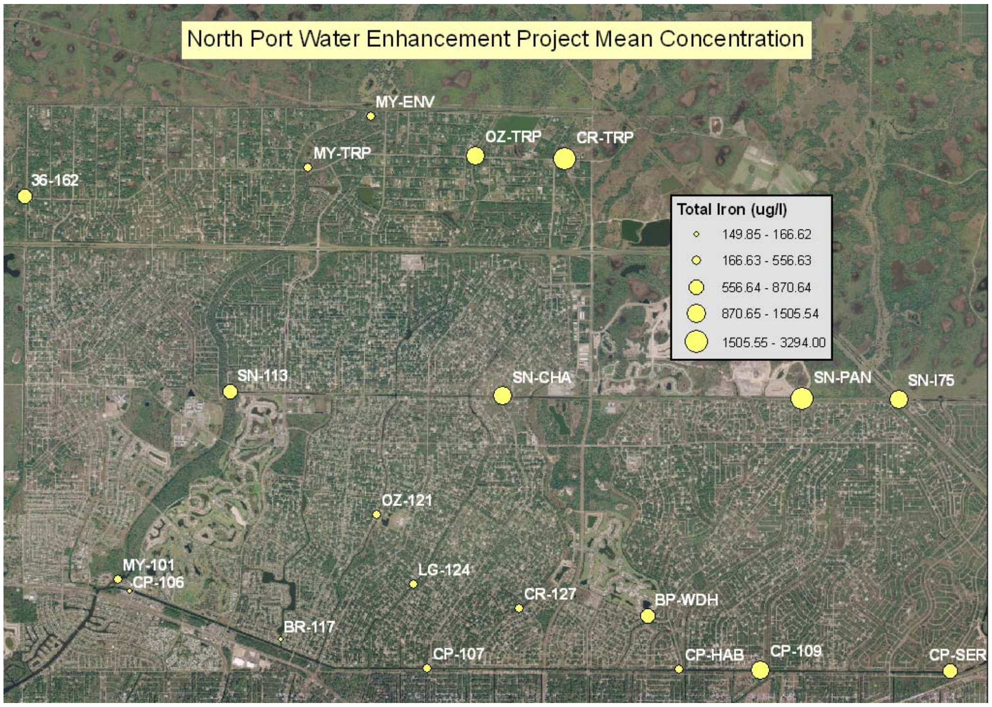
Table 3.8 further summarizes long-term information regarding iron concentrations (analyzed for both total and dissolved) from the long-term USGS gaging/water quality monitoring site on lower Horse Creek. Analyses of these data indicated an apparent long-term pattern of increasing levels between measurements taken in the 1960 and values from the 1980s and 1990s.

Table 3.8. Statistical Summary of USGS Lower Horse Creek Iron Data (Gage 2297310)

Measurement	Number of Samples	Mean (mg/l)	Median (mg/l)	Minimum (mg/l)	Maximum (mg/l)
Total Iron	17	0.730	0.690	0.440	1.500
Dissolved Iron	28	0.250	0.150	0.10	0.650

It is possible that historic increases in iron levels in many southwest Florida freshwater systems reflect the expansion of more water intense agriculture within these watersheds and the runoff of groundwater (particularly during the Spring dry-season) associated with agricultural groundwater pumping. Long-term data collected in conjunction with the District's ambient ground water monitoring program of sampling for the regional surficial aquifer have shown the range of variability as well as the often very high iron concentrations within surficial aquifer in southwest Florida. Figure 3.12 spatially depicts annual average iron concentrations among the 20 City of North Port monitoring locations. This summary of the data collected over the 12 months of sampling suggest that the highest observed levels of iron were influenced by surficial waters entering the canal system from the east and northeast.

Figure 3.12. Mean total iron (ug/l) during the project year



4.0 Conclusions and Recommendations

The City of North Port canal system is a man made fresh water system that was designed to function as both a flood control, and a wet detention system. The drainage basin that includes the City of North Port consists of 195.6 square miles of land (at the southern extent of the City), 104 of which are upstream of the City. Thus City lands are less than half the contributing watershed at the discharge points from the City. The City of North Port has engaged in a variety of best management practices (BMPs) aimed at reducing the pollutant contribution from City lands. These BMPs include:

- Providing 100% more dry treatment volume than is required by the SWFWMD
- Minimization of impervious surfaces
- Creation of bioretention swales
- Use of rain cisterns
- Reuse of stormwater runoff for irrigation
- Weekly curbside pickup of oil, oil filters, and batteries
- An annual hazardous waste event
- Aeration of wet detention ponds
- Fertilizer restriction ordinances
- Illicit discharge inspection staff
- 1 inch of dry pond treatment, instead of the District mandated 0.5 inch
- Organized community clean up events
- Public education on methods for pollution reduction
    - Brochures and mailed newsletters
    - Television programming
    - Newspaper articles
    - Education expos and festivals

These actions provide additional benefit in terms of reducing pollutant loads from the City, which already has in place an extensive wet/dry detention and heavily vegetated swale system to transport stormwater runoff. This combination of factors has resulted in the delivery of relatively low pollutant loads to the North Port canal system within City boundaries. This is evidenced by the analysis of nitrogen and phosphorus load in Myakkahatchee Creek, between Tropicaire Blvd. and Structure 101 (Table 3.4).

Although the City is actively involved in reducing pollutant loads, there are some water quality constituents that have been found to exceed the currently mandated levels. Combined, the findings from this report support the following conclusions, as related to water quality and TMDL issues:

1. DO levels at some locations within the City of North Port's canal systems do not meet existing state standards of 5.0 mg/l.

2. DO levels in many reference site locations within the Myakka River watershed (of which portions of the City of North Port are a part) and throughout many areas of Florida also do not meet FDEPs existing standards.

3. The City of North Port should consider working with FDEP to develop site specific alternative criteria for DO for its canal systems to ensure time and efforts are not spent trying to “fix” an impairment that does not truly exist.

4. Levels of chlorophyll *a* at some locations within the City of North Port’s canal system do not meet existing state standards of 20 µg /liter, despite relatively low levels of total nitrogen during the study period.

5. Levels of total nitrogen (TN) were typically lower at stations located within the interior of the canal system relative to stations on the periphery of the canals.

6. Levels of TN are typically lower than the reference levels for natural Florida streams generated in the 1996 FDEP 305(b) report.

7. The finding of TN values lower than expected values suggest that either or both of two phenomena are occurring: a) nutrient loads to the canals from the residential neighborhoods are lower than expected (based on loading models for Charlotte Harbor); b) and/or the significant amount of submerged and emergent vegetation within the canal systems acts as a sink for nutrients.

8. Compared to other locations within the Charlotte Harbor watershed, the City of North Port appears to contribute nitrogen at a much lower rate, on a per hectare basis, than other sub-basins – the City of North Port is not a problem area for nitrogen loading.

9. Compared to other locations within the Charlotte Harbor watershed, the City of North Port appears to load phosphorus at a rate similar to the least polluting sub-basins – the City of North Port is not a problem area for phosphorus loading.

10. Fecal coliform bacteria concentrations at three of the twenty locations within the City of North Port’s canal system do not meet existing state standards. As fecal coliform bacteria can originate from almost any organism (including birds or fishes), and even occur naturally in sediments, specific actions to ameliorate bacteria levels should be postponed until the completion of a more refined source identification effort.

An appropriate response to the noted issues with water quality, as they relate to potential TMDLs, would include maintaining the existing swale systems for stormwater runoff, and continuing the existing BMPs. Additionally, the City of North Port should ensure that the canal maintenance procedures do not result in unacceptable adverse impacts to water quality. Current procedure is to spray problem vegetation with herbicide and allow the vegetation to sink and decompose in the canal. Decomposing organic material has the potential to reduce dissolved oxygen levels, and to release nutrients stored in the plant tissue. The City of North Port has considered harvesting the material and disposing of it outside of the canal system, but found that option to be too costly. The City has an ongoing effort to prioritize portions of the canal system for dredging. Dredging is a method to remove organic material which has settled to the canal floor.

The water within the North Port canal system does not always meet existing state standards for dissolved oxygen or chlorophyll *a*. For dissolved oxygen, it is entirely possible that dissolved oxygen levels would also "fail" state standards at reference sites outside of the City's canal system. For chlorophyll *a*, the low levels of nitrogen within the canals suggest that nitrogen loads are not overly problematic, and it would likely not be very cost effective to attempt to meet load reduction goals that could come out of a traditional pollutant loading model/water quality response model attempt at TMDL development. For fecal coliform bacteria, source identification investigation would be appropriate prior to any attempts to address this issue via stormwater retrofits or any other types of capital improvement projects. If the sources of fecal coliform are not anthropogenic in nature then projects such as septic tank removal would not be expected to reduce the fecal coliform levels. In the case of iron, naturally occurring high iron sediments and ground water likely contribute a substantial proportion of the measured iron.

The existing infrastructure and BMPs instituted by the City of North Port seem to be minimizing the impact of stormwater runoff from the residential and commercial development within the City boundaries by mimicking the expected performance of low impact development. Water quality impairments are thus more likely due to issues relating to regionally-inappropriate water quality standards (dissolved oxygen and possibly fecal coliform bacteria) or long residence time (chlorophyll *a*).

An important aspect of this project is to provide recommendations for future projects to improve water quality within the North Port canal system. The City of North Port currently engages in a wide variety of best management practices (BMPs) to reduce their impact on the canal system and surrounding waters. The major finding of this report is that those BMPs appear to be working very well and that for the most part the North Port canal system is a healthy system. There are none the less a number of projects that might be undertaken with the aim of improving conditions in the canal system, and protecting the integrity of the canal system for the future. The City of North Port should certainly continue their existing BMPs and their proactive attitude toward reduction of their stormwater pollution load to the North Port canal system. In addition the following potential projects may be of interest.

- Construct structures along Cocoplum canal at Como waterway and Crestview waterway at appropriate elevations to inhibit the future potential for salt water intrusion into the North Port canal system.

- Amend canal maintenance procedures to remove problem vegetation from the system rather than spraying it in place.

- Perform maintenance dredging in the canal system to both increase the storage capacity of the canal system and remove potentially problematic organic matter from the canal system.

- Actively track future land use changes and water use permits in the upstream basin as part of an ongoing sourceater protection program and investigate existing sources of high conductivity water in Myakkahatchee Creek upstream of the City.

- Determine the source of fecal coliform bacteria in the North Port canal system. Researchers (including some at USF Tampa) study human specific *Bacteroides* spp., viruses, and genes that would identify whether or not the fecal coliform bacteria in the North Port canal system are anthropogenically derived.

- Assess the residential wells and water treatment systems throughout the City of North Port to determine whether they contribute to the gradual increases in specific conductance and TDS throughout the North Port system.

- Continue the water quality monitoring program that existed prior to this study in order to detect any changes in the canal system, particularly due to future build out of the City of North Port.

While the existing condition of the North Port canal system is very good, undertaking these projects will both improve on the current water quality condition, and serve to protect the North Port canal system in the future.

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