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Technical Memorandum

To: Mac Hatcher, PM Collier County

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Date: January 2011

Re: Watershed Model Update and Plan Development
Contract 08-5122, PO 4500106318
Element 2, Task 2: Quality of Discharge

1.0 Objective

This Technical Memorandum addresses Element 2, Task 2: Quality of Discharge. The objective of this task is to characterize the water quality of fresh water discharges delivered to the following four estuaries in Collier County:

- Wiggins Pass
- Naples Bay
- Rookery Bay
- Ten Thousand Islands (TTI)

Six watersheds were evaluated that discharge fresh water to these four estuaries (**Figure 1**). The Wiggins Pass estuary receives runoff from the Cocohatchee-Corkscrew watershed. The Golden Gate-Naples Bay and Rookery Bay watersheds discharge into Naples Bay and Rookery Bay estuaries, respectively. Three watersheds comprise the drainage area to the Ten Thousand Islands estuary: Faka Union, Fakahatchee, and Okaloacoochee-SR29.

2.0 Water Quality Data

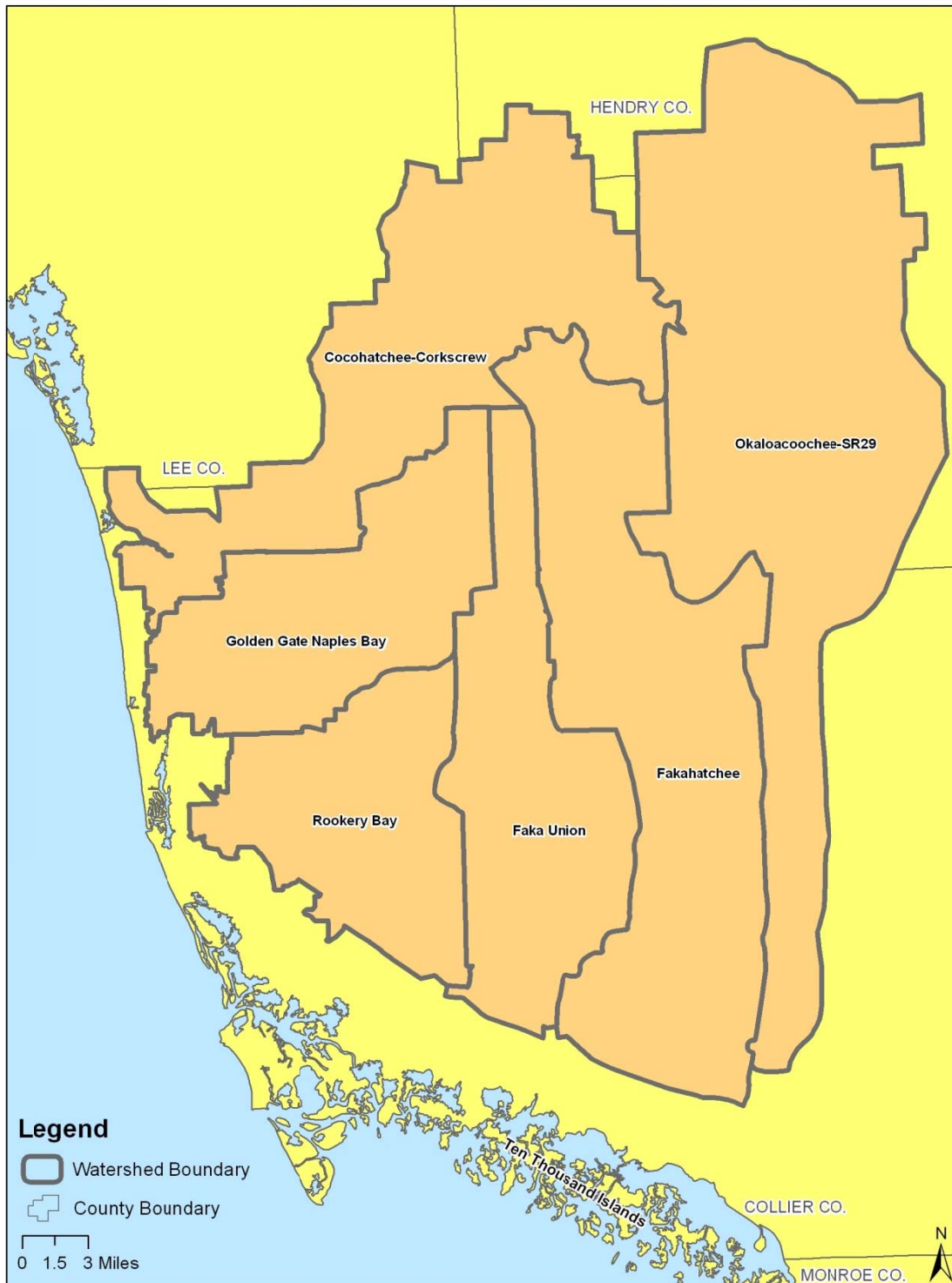
To accurately characterize the water quality of the discharge waters from priority watersheds in Collier County, in addition to the review of the available reports, PBS&J analyzed available water quality data for Cocohatchee-Corkscrew, Golden Gate - Naples Bay, Rookery Bay, Faka Union, Okaloacoochee - SR29, and Fakahatchee watersheds. The data used for the analyses included the IWR Run 39 data (supplied by FDEP), as well as data from Florida STORET, Collier County, City of Naples, and the Rookery Bay National Estuarine Research Reserve (RBNERR). This resulted in an updated and comprehensive database of water quality data.



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Figure 1-1. Collier County Watersheds and Water Quality Stations



All available water quality data were subject to a quality assurance / quality control procedure. It should be noted that the analyses were conducted using data from the most recent ten year time period (2000 to 2009) to minimize the effect of temporal variations. Also, it was determined that the majority of water quality data available was collected during this ten year period.

As all water quality stations retrieved from the IWR database or Florida STORET were previously assigned to a WBID by FDEP, water quality station data provided by Collier County, City of Naples, or RBNERR were assigned to a WBID and watershed based on location coordinates.

3.0 Analysis Methodology

To focus on the assessment of watershed discharges in the receiving estuaries, only the most downstream water quality stations in each watershed were included in the analysis. **Table 1** lists the stations by watershed. As described later in more detail, the data was analyzed for the TMDL planning and verified periods. Data from all stations were used for the verified period analysis, whereas the planning period analysis included all stations except 21FLNAPLGORDJOE and Gord60, both in the Golden Gate / Naples watershed.

Table 1. Sampling Stations by Watershed

Watershed	Sampling Station
Cocohatchee – Corkscrew	28030036
Golden Gate / Naples Bay	21FLNAPLGORDJOE
	HC@Bayshore
	BC2
	Gord60
Rookery Bay	21FLSWMLELY
	HendersonCrk at US41
Faka Union	21FLSFWMFAKA
	FAKAUPOI
Fakahatchee	21FLSFWMBC21
	21FLSFWMBC19
	21FLSFWMBC18
Okaloacoochee-SR 29	BARRIVN

An important factor considered in the analysis was that many of the sampling stations are subject to tidal effects, especially during the dry season, Effects extend as far inland as the Tamiami Trail. This situation creates two data analysis problems: a) data does not reflect watershed conditions because the discharges are diluted by estuarine waters, and b) the chemistry of the discharges fluctuates from freshwater to marine conditions.

To control for this situation, water quality data from the selected stations was queried so that data analysis was restricted to those times when specific conductance ($\mu\text{mhos} / \text{cm}$ at 25°C) was below 4,700 (equivalent to FDEP's threshold for marine waters of 1,500 mg chloride / liter). Samples representing the "freshwater" condition were thus considered representative of the surface water quality discharging into the estuaries.

The subsequent analysis methodology included the following steps:

1. The water quality data sets were compared to existing water quality criteria for the impairment parameters associated with each estuary.
2. The mean, minimum, maximum and percent exceedances of such criteria were quantified and displayed for each station within each watershed.
3. A review of data from the Planning Period was conducted, with data restricted to between January 1995 and December 2004.
 - a. For inclusion on the Planning List, impairments for dissolved oxygen and metals concentrations would have to occur in at least 10 percent of samples, with an 80 percent confidence level using a binomial distribution.
 - i. For samples of 10 to 15, this requires 3 exceedances.
 - ii. For samples from 16 to 23, this requires 4 exceedances.
 - iii. For samples from 24 to 31, this requires 5 exceedances
 - iv. For samples from 32 to 39, this requires 6 exceedances
 - v. For samples from 40 to 47, this requires 7 exceedances.
4. A review of data from the Verified Period was conducted, with data restricted to between January 2000 and June 30, 2007.
 - a. For inclusion on the Verified List, impairments for dissolved oxygen and metals would have to occur in at least 10 percent of samples, with a 90 percent confidence level using a binomial distribution.
 - i. For samples of 20 to 25, this requires 5 exceedances.
 - ii. For samples from 26 to 32, this requires 6 exceedances.
 - iii. For samples from 33 to 40, this requires 7 exceedances
 - iv. For samples from 41 to 47, this requires 8 exceedances
 - v. For samples from 48 to 55, this requires 9 exceedances.
5. For nutrient concentrations, discharge data were compared to two separate potential criteria.
 - i. FDEP's screening criteria for streams uses the 75th percentile of values in STORET. These values are 1.6 mg total nitrogen (TN) / liter and 0.22 mg total phosphorus (TP) / liter
 - ii. FDEP's Hendry Creek TMDL used target TN and TP values of 0.74 and 0.04 mg / liter, respectively.

4.0 Analysis Results

This section presents the results and discussion of the water quality characterization of the watershed discharges into each of the estuary systems in Collier County based on the identified sampling stations. Tables 2 through 9 show data statistics, as well as percent exceedance of the water quality/ screening criteria for dissolved oxygen, total phosphorus, total nitrogen, and fecal coliform concentration associated with the TMDL planning and verified periods. Following are descriptions of the results by watershed and estuary.

4.1. Wiggins Pass

Wiggins Pass is the receiving water for the Cocohatchee-Corkscrew watershed. It is located within WBID 3259A (Cocohatchee River) and is presently listed as impaired for three water quality parameters; dissolved oxygen, fecal coliforms and iron. As shown in Tables 2 through 9, the data available at Station 28030036 is very limited. Therefore, definite statistical conclusions are not possible, but general conclusions have been derived for this analysis for each impairment parameter.

4.1.1. Dissolved Oxygen

The limited data available shows that the dissolved oxygen concentration in the watershed discharge does not meet the 4 mg/L standard for the estuary. The cause of the depleted oxygen level could be attributed to excessive nutrient concentrations. The data available shows that the concentration of TN in the two discharge samples exceeds the Hendry Creek TMDL target for both the planning and verified periods. However, only one of the samples exceeds the screening criteria for Florida streams. In terms of TP, it exceeds the Hendry Creek TMDL target in one of the samples, but never exceeds the Florida streams criteria.

Another cause of low dissolved oxygen concentrations in the watershed discharge is the groundwater in the canal flow. As described for the stream water quality analysis, the annual average groundwater contribution to the flow in the Cocohatchee Canal is about 40 percent of the total flow and increases to 65 percent during the dry season.

Data collected in Wiggins Pass itself has indicated that low dissolved oxygen levels appear to be evident in the estuary's upstream portions of Wiggins Pass. This supports the notion that watershed discharges may affect that portion of the estuary. Groundwater discharges are likely having a larger impact on dissolved oxygen levels than nutrient concentrations. However, more data coupled with in-stream water quality modeling are necessary to determine if the watershed discharges are the cause of the low dissolved oxygen levels in the estuary.

4.1.2. Fecal Coliform

One of the two samples analyzed for the planning period evaluation exceeds the water quality criteria for the estuary. So does the only sample that is included in the verified period analysis.

Therefore it can be concluded that there is the possibility that the estuary is affected by watershed discharges of fecal coliform bacteria. Bacteria source evaluations are necessary to confirm the condition.

4.1.3. Iron

No data for iron is available at the sampling stations considered for data analysis. Although sources have not been confirmed, it is possible that groundwater discharges through the canal system as described for dissolved oxygen is an important cause of the elevated iron levels. Other activities such as mine drainage, sewage treatment plant outfalls, or landfill leachate from industrial scrap yards (e.g., junkyards for cars) are potential sources, although not likely to be the main cause of the elevated iron levels in this case.

4.2. Naples Bay Estuary

Naples Bay is located within WBID 3278R (Naples Bay-Coastal Segment) and is presently listed as impaired for four parameters; dissolved oxygen, fecal coliforms, copper and iron. Naples Bay is the receiving water for the Golden Gate- Naples Bay watershed and Gordon River Extension.

4.2.1. Dissolved Oxygen

Data available at the two stations analyzed for planning period conditions and the four stations with data available for the verified period analysis show that the dissolved oxygen concentration in the discharges do not meet the estuary water quality standard. As indicated for Wiggins Pass, the cause of the depleted oxygen levels could be attributed to excessive nutrient concentrations. However, neither TN nor TP concentrations in the watershed discharges exceed the Florida stream screening standards, although in most cases they exceed the Hendry Creek TMDL target for both the planning and verified periods. In summary, from the data available it is not clear if TN and TP discharges from the watershed are causing the lower dissolved oxygen levels.

Another cause of low dissolved oxygen concentrations may be the discharge of groundwater. As described for the stream water quality analysis, the annual average groundwater contribution to the flow in the Golden Gate Canal is about 60 percent of the total flow and increases to almost 80 percent during the dry season.

Similar to Wiggins Pass, groundwater discharges are likely having a larger impact on dissolved oxygen levels than nutrient concentrations. However, more data coupled with in-stream water quality modeling are necessary to determine if the watershed discharges are the cause of the low dissolved oxygen levels in the estuary. Low dissolved oxygen levels appear to be evident in the estuary's upstream portions. Therefore, watershed discharges likely affect that portion of the estuary.

4.2.2. Fecal Coliform

The data analyzed indicate that fecal coliform concentrations exceed the standard at most discharge locations. Therefore it can be concluded that there is the possibility that the estuary is affected by watershed discharges of fecal coliform bacteria. However, significant more bacteria source evaluations are necessary to confirm this condition.

4.2.3. Iron and Copper

No data for iron exist at the stations analyzed herein. Similar to the discussion for Wiggins Pass, although sources have not been confirmed, it is possible that groundwater discharges through the canal system are an important cause of the elevated iron levels. Other activities such as mine drainage, sewage treatment plant outfalls, or landfill leachate from industrial scrap yards (e.g., junkyards for cars) are potential sources, although not likely the main iron source of the elevated iron levels.

Data for copper at the discharge stations were not analyzed, but discharges of copper into the estuary could be from anthropogenic sources, such as its use as an algacide to prevent algae growth. High measured concentrations could also result from site characteristics of the sampling locations, such as effects of leaching from boardwalks and pilings that are constructed from pressure-treated lumber.

4.3. Rookery Bay Estuary

Rookery Bay is the receiving water for the Rookery Bay watershed. The estuary is located within WBID 3278U (Rookery Bay-Coastal Segment) and, similar to the other previously described two estuaries, is presently listed impaired for dissolved oxygen and fecal coliforms. However, this estuary is also listed impaired for nutrients, which are potential causes for the low dissolved oxygen concentrations.

4.3.1. Dissolved Oxygen and Nutrients

Data available at the two stations analyzed for planning period conditions and the four stations with data available for the verified period analysis show that the dissolved oxygen concentration in the discharges do not meet the estuary water quality standard. Causes of the depleted oxygen level could be attributed to excessive nutrient concentrations, as well as groundwater inflows. In spite of the estuary being listed for nutrient impairment, data at the watershed discharge point indicate that TN and TP concentrations are below the Florida screening criteria for streams for both the planning and verified period analysis. In addition, total phosphorus exceeds the Hendry Creek TMDL criterion less than 20 percent of the time. The exceedance of the Hendry Canal standard for total nitrogen ranges between 35 and 55 percent for the planning period and 33 and 38 percent for the verified period.

As mentioned previously, another cause of low dissolved oxygen concentrations may be the discharge of groundwater. As described for the stream water quality analysis, the annual average groundwater contribution to the estuary is about 55 percent of the total flow and increases to about 80 percent during the dry season.

In summary, there is the possibility that nitrogen concentrations are contributing to the lower dissolved oxygen concentration in the estuary. However, the measured concentrations are generally low. Groundwater contribution is likely an important factor causing the observed conditions.

4.3.2. Fecal Coliform

The estuary fecal coliform water quality criterion at the watershed discharge point is exceeded between approximately 60 and 75 percent of the time. Therefore it is likely that the estuary is affected by watershed discharges. Additional bacteria source evaluations are necessary to confirm this condition.

4.3.3. Ten Thousand Islands Estuary

The Ten Thousand Islands is the receiving water for the Faka-Union, Fakahatchee, and Okaloacoochee/SR29 watersheds. It is located within WBID 3259M (Ten Thousand Islands) and is presently not listed as impaired for any parameter. The watersheds largely remain in undeveloped conditions.

No detailed water quality evaluation of the discharge characteristics was conducted. However, per the data provided in Tables 2 through 9, the percent of time dissolved oxygen concentrations in the watershed discharges are below the standard range from 24 to 85 percent during the planning and verified periods. This is likely the result of discharges from the wetland systems present in the watersheds coupled with groundwater contributions to the total flow in the canals. Total phosphorus and total nitrogen concentrations are below the screening criteria for Florida streams, but nitrogen levels exceed the Hendry Creek criteria in the Fakahatchee watershed. Fecal coliform data also shows values above the estuarine criterion around 60 percent of the time.

5.0 Summary and Conclusions

The Collier County estuaries are impaired primarily for dissolved oxygen and fecal coliforms. Rookery Bay is also impaired for nutrients. Data show that the watershed discharges do not meet the water quality standards for dissolved oxygen and fecal coliforms either. Therefore, it is likely that the watershed conditions are impacting the receiving estuaries. However, causative parameters for the observed low oxygen levels are not clear. Nutrient concentrations in the discharges are commonly below the screening criteria for Florida streams and only exceed the TMDL target established for Hendry Creek. Fecal coliforms are indicators of pathogenic organisms and are used to identify potential health threats. However, as described in other technical memos, fecal coliform bacteria may not be an appropriate indicator for pathogenic diseases in sub-tropical climates. Further source identification efforts are warranted.

Other parameters of impairment concern are iron and copper. Iron appears to be caused by the groundwater discharges through the canal network, although other sources are possible. High copper concentrations may be the result of anthropogenic impacts such as the use of copper sulfate as an algaecide to prevent algae growth in ponds or for leaching from boardwalks and pilings that are constructed from pressure-treated lumber.

**Table 2. Data Analysis - Dissolved Oxygen Concentration.
Planning period (January 1995 – December 2004)**

Watershed	Station	Sample Size	Mean	Min.	Max.	Percent exceedance (< 5 mg / L)
Cocohatchee – Corkscrew	28030036	2	6.00	4.70	7.30	50
Golden Gate / Naples Bay	BC2	28	4.05	2.74	5.56	80
	HC@Bayshore	14	3.82	2.34	5.40	86
Rookery Bay	21FLSWMLEY	42	4.98	1.41	8.37	52
	HendersonCrk@41	13	6.13	4.73	0.28	15
Faka Union	21FLSFWMFAKA	48	6.46	2.92	9.83	25
	FAKAUPOI	29	6.12	3.60	8.92	24
Fakahatchee	21FLSFWMBC21	34	4.41	0.84	8.80	71
	21FLSFWMBC19	34	2.82	0.24	7.98	88
	21FLSFWMBC18	37	3.02	0.60	8.06	86
Okaloacoochee-SR 29	BARRIVN	28	4.24	2.72	7.87	82

**Table 3. Data Analysis - Dissolved Oxygen Concentration.
Verified period (January 2000 – June 30, 2007)**

Watershed	Station	Sample Size	Mean	Min.	Max.	Percent exceedance (< 5 mg / L)
Cocohatchee – Corkscrew	28030036	1	3.36	3.36	3.36	100
Golden Gate / Naples Bay	21FLNAPLGORDJOE	1	3.90	3.90	3.90	100
	HC@Bayshore	19	3.80	2.34	5.40	89
	BC2	15	3.89	2.74	5.56	87
	Gord60	2	4.31	4.20	4.41	100
Rookery Bay	21FLSWMLELY	59	4.77	1.41	8.37	54
	HendersonCrk@41	19	5.87	3.64	9.28	21
Faka Union	21FLSFWMFAKA	64	6.53	2.92	10.39	27
	FAKAUPOI	35	6.01	3.60	8.92	29
Fakahatchee	21FLSFWMBC21	42	4.20	0.84	8.80	74
	21FLSFWMBC19	44	2.85	0.24	7.98	84
	21FLSFWMBC18	48	3.05	0.30	8.06	85
Okaloacoochee-SR 29	BARRIVN	36	4.12	2.38	7.87	83

**Table 4. Data Analysis - Total Phosphorus.
Planning period (January 1995 – December 2004)**

Watershed	Station	Sample Size	Mean	Min.	Max.	Percent exceedance (> 0.04 mg/L) ¹	Percent exceedance (>0.22 mg/L) ²
Cocohatchee – Corkscrew	28030036	2	0.05	0.03	0.07	50	0
Golden Gate / Naples Bay	HC@Bayshore	15	0.06	0.04	0.08	93	0
	BC2	10	0.06	0.03	0.09	80	0
Rookery Bay	21FLSWMLELY	39	0.03	0.01	0.09	13	0
	HendersonCrk@41	10	0.01	0.01	0.03	0	0
Faka Union	21FLSFWMFAKA	44	0.01	0.00	0.03	0	0
	FAKAUPOI	23	0.03	0.00	0.34	9	0
Fakahatchee	21FLSFWMBC21	30	0.01	0.00	0.04	0	0
	21FLSFWMBC19	31	0.02	0.01	0.06	6	0
	21FLSFWMBC18	32	0.01	0.00	0.04	3	0
Okaloacoochee-SR 29	BARRIVN	26	0.02	0.01	0.05	4	0

- 1 Hendry Creek TMDL Criteria
- 2 Florida Streams Screening Criteria

**Table 5. Data Analysis - Total Phosphorus.
Verified period (January 2000 – June 30, 2007)**

Watershed	Station	Sample Size	Mean	Min.	Max.	Percent exceedance (> 0.04 mg/L) ¹	Percent exceedance (>0.22 mg/L) ²
Cocohatchee – Corkscrew	28030036	1	0.07	0.07	0.07	100	0
Golden Gate / Naples Bay	21FLNAPLGORDJOE	1	0.04	0.04	0.04	0	0
	HC@Bayshore	18	0.06	0.04	0.11	89	0
	BC2	13	0.05	0.03	0.09	85	0
	Gord60	2	0.04	0.03	0.06	50	0
Rookery Bay	21FLSWMLELY	51	0.03	0.01	0.09	18	0
	HendersonCrk@41	16	0.02	0.01	0.05	6	0
Faka Union	21FLSFWMFAKA	56	0.01	0.00	0.03	0	0
	FAKAUPOI	28	0.01	0.00	0.06	4	0
Fakahatchee	21FLSFWMBC21	36	0.01	0.00	0.06	3	0
	21FLSFWMBC19	38	0.02	0.00	0.06	5	0
	21FLSFWMBC18	39	0.01	0.00	0.04	3	0
Okaloacoochee-SR 29	BARRIVN	32	0.02	0.01	0.05	3	0

- 1 Hendry Creek TMDL Criteria
- 2 Florida Streams Screening Criteria

**Table 6. Data Analysis - Total Nitrogen.
Planning period (January 1995 – December 2004)**

Watershed	Station	Sample Size	Mean	Min.	Max.	Percent exceedance (> 0.74 mg/L) ¹	Percent exceedance (>1.6 mg/L) ²
Cocohatchee – Corkscrew	28030036	2	1.26	0.75	1.78	100	50
Golden Gate / Naples Bay	HC@Bayshore	13	1.05	0.04	5.98	46	8
	BC2	9	0.86	0.27	1.08	78	0
Rookery Bay	21FLSWMLELY	40	1.68	0.01	4.30	35	2
	HendersonCrk@41	11	0.78	0.58	1.02	55	0
Faka Union	21FLSFWMFAKA	44	0.38	0.01	1.22	5	0
	FAKAUPOI	27	0.36	0.01	0.71	0	0
Fakahatchee	21FLSFWMBC21	32	0.80	0.01	2.70	56	3
	21FLSFWMBC19	32	0.82	0.01	1.50	56	0
	21FLSFWMBC18	36	0.62	0.01	1.30	31	0
Okaloacoochee-SR 29	BARRIVN	26	0.57	0.02	1.02	15	0

- 1 Hendry Creek TMDL Criteria
2 Florida Streams Screening Criteria

**Table 7. Data Analysis - Total Nitrogen.
Verified period (January 2000 – June 30, 2007)**

Watershed	Station	Sample Size	Mean	Min.	Max.	Percent exceedance (> 0.74 mg/L) ¹	Percent exceedance (>1.6 mg/L) ²
Cocohatchee – Corkscrew	28030036	1	1.00	1.00	1.00	100	0
Golden Gate / Naples Bay	21FLNAPLGORDJOE	1	1.03	1.03	1.03	100	0
	HC@Bayshore	17	0.93	0.03	5.98	47	6
	BC2	13	0.70	0.04	1.08	54	0
	Gord60	2	1.23	1.11	1.34	100	0
Rookery Bay	21FLSWMLELY	52	0.65	0.01	4.30	33	2
	HendersonCrk@41	16	0.63	0.06	1.02	38	0
Faka Union	21FLSFWMFAKA	55	0.36	0.01	1.22	4	0
	FAKAUPOI	31	0.32	0.01	0.71	0	0
Fakahatchee	21FLSFWMBC21	38	0.72	0.01	2.70	50	3
	21FLSFWMBC19	40	0.78	0.01	1.64	52	2
	21FLSFWMBC18	43	0.59	0.01	1.65	28	2
Okaloacoochee-SR 29	BARRIVN	32	0.49	0.01	1.02	12	0

- 1 Hendry Creek TMDL Criteria
2 Florida Streams Screening Criteria

**Table 8. Data Analysis - Fecal Coliform.
Planning period (January 2000 – June 30, 2007)**

Watershed	Station	Sample Size	Mean	Min.	Max.	Percent exceedance (> 43/100ml)
Cocohatchee – Corkscrew	28030036	2	140.00	10.00	270.00	50
Golden Gate / Naples Bay	HC@Bayshore	15	829.00	142.00	3,627.00	100
	BC2	9	573.33	70.00	3,200.00	10
Rookery Bay	21FLSWMLELY	40	191.78	11.00	2,600.00	65
	HendersonCrk@41	11	172.82	17.00	440.00	73
Faka Union	21FLSFWMFAKA	45	104.98	1.00	560.00	51
	FAKAUPOI	25	27.36	1.00	340.00	12
Fakahatchee	21FLSFWMBC21	32	421.41	6.00	5,300.00	47
	21FLSFWMBC19	33	324.48	3.00	1,386.00	73
	21FLSFWMBC18	36	289.69	9.00	5,450.00	61
Okaloacoochee-SR 29	BARRIVN	28	371.00	33.00	2,300.00	93

**Table 9. Data Analysis - Fecal Coliform.
Verified period (January 2000 – June 30, 2007)**

Watershed	Station	Sample Size	Mean	Min.	Max.	Percent exceedance (> 43/100ml)
Cocohatchee – Corkscrew	28030036	1	200.00	20.00	200.00	100
Golden Gate / Naples Bay	21FLNAPLGORDJOE	1	1.00	1.00	1.00	0
	HC@Bayshore	18	856.83	61.00	3,627.00	100
	BC2	14	402.86	40.00	3,200.00	93
	Gord60	2	76.00	72.00	80.00	100
Rookery Bay	21FLSWMLELY	52	159.96	11.00	2,600.00	63
	HendersonCrk@41	16	186.81	17.00	576.00	75
Faka Union	21FLSFWMFAKA	47	101.38	1.00	560.00	49
	FAKAUPOI	27	25.96	1.00	340.00	11
Fakahatchee	21FLSFWMBC21	37	369.41	6.00	5,300.00	46
	21FLSFWMBC19	42	282.86	3.00	1,386.00	69
	21FLSFWMBC18	41	277.12	9.00	5,450.00	59
Okaloacoochee-SR 29	BARRIVN	36	321.86	20.00	2,300.00	89

6.0 References

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