PROPOSED

TOTAL MAXIMUM DAILY LOAD (TMDL)

For

Dissolved Oxygen and Nutrients

In

Butcher Pen Creek (2322)

Lower St. Johns River Basin, Florida

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LIST OF ABBREVIATIONS

AWT	Advanced Waste Treatment
BMP	Best Management Practices
BOD	Biochemical Oxygen Demand
CBOD	Carbonaceous Biological Oxygen Demand
CBODu	Ultimate Carbonaceous Biological Oxygen Demand
CFS	Cubic Feet per Second
DEM	Digital Elevation Model
DMR	Discharge Monitoring Report
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
F.A.C.	Florida Administrative Code
GIS	Geographic Information System
HUC	Hydrologic Unit Code
JEA	Jacksonville Electrical Authority
LA	Load Allocation
MGD	Million Gallons per Day
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer Systems
NASS	National Agriculture Statistics Service
NLCD	National Land Cover Data
NPDES	National Pollutant Discharge Elimination System
PLRG	Pollutant Load Reduction Goal
Rf3	Reach File 3
RM	River Mile
SOD	Sediment Oxygen Demand
TBN	Total Bioavailable Nitrogen
TBP	Total Bioavailable Phosphorus
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
USGS	United States Geological Survey
WBID	Water Body Identification
WLA	Waste Load Allocation
WMP	Water Management Plan

SUMMARY SHEET
Total Maximum Daily Load (TMDL)

1. **303(d) Listed Waterbody Information**

State: Florida

HUC: 03080103

Impaired Waterbodies for TMDLs (1998 303(d) List):

WBID	Segment Name and Type	River Basin	County	Constituent(s)
2322	Butcher Pen Creek (freshwater stream)	Lower St. Johns	Duval	Dissolved Oxygen, Nutrients

2. **TMDL Endpoint (i.e., Target):**

The State of Florida water quality criteria for dissolved oxygen (DO) in freshwater streams require in no case shall the concentration be less than 5 mg/L. Therefore, the DO target is a concentration of 5 mg/L. The State of Florida has narrative water quality criteria for nutrients requiring in no case shall nutrient concentrations of a body of water be altered so as to cause an imbalance in natural populations of aquatic flora or fauna. The Total Nitrogen (TN) allocation is set to achieve a reduction of 22 percent as indicated in the Lower St. Johns River TMDL. By achieving the DO standard, nutrient loadings will be reduced resulting in a natural balance of flora and fauna in the creek.

3. **TMDL Approach**

The Pollutant Load Screening Model (PLSM) was used to estimate seasonal nutrient (TN and TP) and BOD loadings from nonpoint sources in the watershed. BOD loads were converted to CBOD for input to the Water Quality Analysis Simulation Program (WASP) model for simulation of instream DO and nutrient concentrations.

4. **TMDL Allocation:**

Stream Name / WBID	Parameter	WLA		LA (lb/day)	TMDL (lb/day)	Percent Reduction
		Continuous (lb/day)	MS4 (reduction)			
Butcher Pen Creek (2322)	BOD	N/A	50%	1.78	1.78	50%
	TN	N/A	22%	9.91	9.91	22%

5. **Endangered Species (yes or blank):** Yes

6. **EPA Lead on TMDL (EPA or blank):** EPA

7. **TMDL Considers Point Source, Nonpoint Source, or both:** Nonpoint

8. **Major NPDES Discharges to surface waters in the watershed:** None

TOTAL MAXIMUM DAILY LOAD (TMDL)
DISSOLVED OXYGEN AND NUTRIENTS IN BUTCHER PEN CREEK (WBID 2322)

1. INTRODUCTION

Section 303(d) of the Clean Water Act requires each state to list those waters within its boundaries for which technology based effluent limitations are not stringent enough to protect any water quality standard applicable to such waters. Listed waters are prioritized with respect to designated use classifications and the severity of pollution. In accordance with this prioritization, states are required to develop Total Maximum Daily Loads (TMDLs) for those water bodies that are not meeting water quality standards. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and in-stream water quality conditions, so that states can establish water quality based controls to reduce pollution from both point and non-point sources and restore and maintain the quality of their water resources (USEPA, 1991). The TMDLs described in this report are being established pursuant to EPA commitments in the 1998 Consent Decree in the Florida TMDL lawsuit (Florida Wildlife Federation, et al. v. Carol Browner, et al., Civil Action No. 4: 98CV356-WS, 1998).

Florida Department of Environmental Protection (FDEP) developed a statewide, watershed-based approach to water resource management. Under the watershed management approach, water resources are managed on the basis of natural boundaries, such as river basins, rather than political boundaries. The state's 52 basins are divided into 5 groups. Water quality is assessed in each group on a rotating five-year cycle. Butcher Pen Creek is in the group 3 basin and was first assessed in 2002 with plans to revisit water management issues in 2007. FDEP established five water management districts (WMD) responsible for managing ground and surface water supplies in the counties encompassing the districts. The streams are located in the Lower St. Johns River basin and are managed through the St. Johns Water Management District (SJRWMD).

For the purpose of planning and management, the WMDs divided the district into planning units defined as either an individual primary tributary basin or a group of adjacent primary tributary basins with similar characteristics. Butcher Pen Creek is within the Ortega River Planning Unit. These planning units contain smaller, hydrological based units called drainage basins, which are further divided into "water segments"; each assigned a unique Waterbody IDentification (WBID) number. A water segment usually contains only one unique waterbody type (stream, lake, cannel, etc.).

2. PROBLEM DEFINITION

Florida's 1998 Section 303(d) list identified Butcher Pen Creek (WBID 2322) as impaired for dissolved oxygen (DO) and nutrients. The stream is located in Duval County within the urban areas of the City of Jacksonville (see Figure 1). Butcher Pen Creek is also listed for fecal and total coliforms. EPA is proposing TMDLs for these parameters as separate reports.

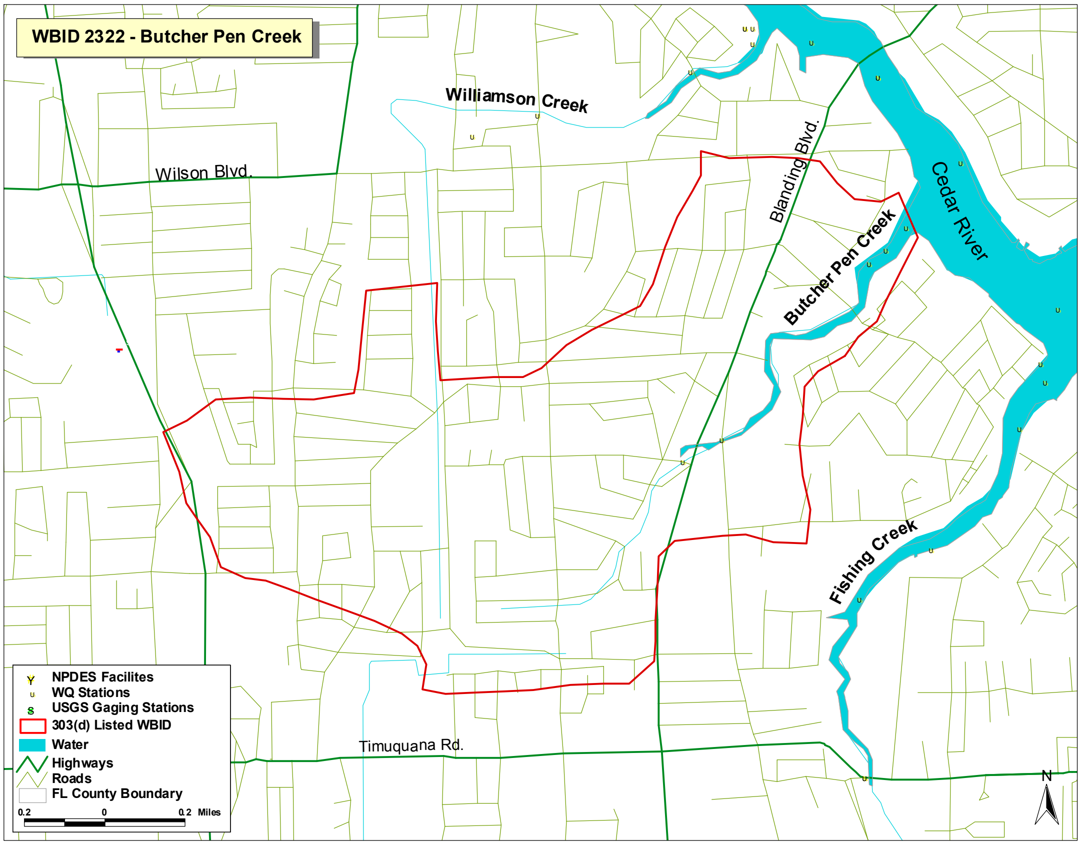

Figure 1. Location of Butcher Pen Creek

3. WATERSHED DESCRIPTION

The St. Johns River is a large river system flowing from south to north just inland from the eastern coast of central and northern Florida and drains a watershed covering approximately 9500 square miles before discharging into the Atlantic Ocean east of the City of Jacksonville. The St. Johns River has been divided into three subwatersheds commonly referred to as the Upper, Middle and Lower St. Johns River. The following description of the watershed is from the Lower St. Johns Basin Status Report (FDEP, 2003). This document should be consulted for additional details.

Butcher Pen Creek (WBID 2322) is located in south central Duval County in the Ortega River Planning Unit. The stream is a tributary to Cedar River which discharges into Ortega River before flowing into the St. Johns River. The Butcher Pen Creek watershed is within the City of Jacksonville MS4 jurisdiction. Land cover in the WBID is predominately urban and residential area accounts for about 80% of the land use in the WBID (see Table 1).

Table 1. Land use distribution

Description	Area (acre)	Percentage
Residential	652	80.0%
Commercial, Industrial, & Public	106	13.0%
Agriculture	0	0%
Rangeland	0	0%
Forest	2	0.3%
Water	8	0.9%
Wetlands	23	2.8%
Barren & Extractive	0	0%
Transportation & Utilities	24	3.0%
Total	814	100%

4. WATER QUALITY STANDARD AND TARGET IDENTIFICATION

The impaired WBID is designated as Class III freshwater. The designated use of Class III waters is recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife. Class III waters are further categorized based on fresh or marine waters. The water quality criteria for protection of Class III waters are established by the State of Florida in the Florida Administrative Code (F.A.C.), Section 62-302.530. The individual criteria should be considered in conjunction with other provisions in water quality standards, including Section 62-302.500 F.A.C. [Surface Waters: Minimum Criteria, General Criteria] that apply to all waters unless alternative or more stringent criteria are specified in F.A.C. Section 62-302.530.

Dissolved Oxygen Target

The State of Florida has numeric water quality criteria for DO requiring in no case shall concentrations be less than 5 mg/L. The target for the TMDL is reduction in sources contributing to low DO such that a DO of 5 mg/L is achieved in the stream. Dissolved oxygen is not a pollutant; therefore, the TMDL targets pollutants causing low dissolved oxygen. The causative pollutant for the TMDL is elevated BOD and nutrient loadings.

Nutrient Target

The State of Florida has narrative water quality criteria for nutrients requiring in no case shall nutrient concentrations of a body of water be altered so as to cause an imbalance in natural populations of aquatic flora or fauna. The target for the TMDL is nutrient loadings of total nitrogen (TN) and Biochemical Oxygen Demand (BOD) derived from modeling scenarios. TN is targeted as data indicates nitrogen is the limiting nutrient (see Table 3). An assumption of this TMDL is achieving the DO standard will result in reduced nutrient loadings providing a natural balance of flora and fauna in the creek.

5. WATER QUALITY ASSESSMENT AND DEVIATION FROM TARGET

FDEP maintains ambient monitoring stations throughout the basin. Water quality monitoring stations within the impaired WBIDs are listed in Table 2. Data collected during the listing cycle (1996-2002) was used in the analysis. Table 3 provides a statistical summary of water quality data collected in the WBID. The number of observations shown in Table 2 is the total observations of all parameters shown in Table 3. Data used to calculate these statistics is provided in Appendix A. Data are not available to evaluate improvements in water quality resulting from implementations of stormwater Best Management Practices (BMPs). For purposes of this report only, BOD refers to 5-day BOD (or BOD5).

Table 2. Monitoring stations

Station ID	Station Name	Sampling Period	Number of Observations
Butcher Pen Creek (WBID 2324)			
21FLA 20030082	Butcher Pen Cr upstream Cedar R	5/26/2002 – 12/3/2002	12
21FLA 20030580	Butcher Pen Cr at Blanding Blvd	9/1/1998 – 12/3/2002	42
21FLA 20030760	Butcher Pen Cr at Wesconnett Blvd	5/16/2002 – 1/10/2002	13
21FLJXWQCR2	Butcher Pen Cr at Wesconnett Blvd	1/31/1996 – 12/10/2002	42

Table 3. Summary of Water Quality Monitoring Data (1996 – 2002)

Parameter	No. of Samples	Minimum	Maximum	Average
BOD (mg/L)	2	0.5	1.0	5.392
Chlorophyll-a (µg/L)	2	7.8	56	31.9
DO (mg/L)	53	1.380	12.250	5.392
Ammonia (mg/L)	9	0.106	0.666	0.286
Nitrate-Nitrite (mg/L)	12	0.019	0.370	0.162
Total Kjeldahl Nitrogen (mg/L)	12	0.490	1.700	0.988
Total Organic Carbon (mg/L)	8	8.5	15	12.1
Total Phosphorus (mg/L)	12	0.100	0.860	0.263
Total Nitrogen (mg/L)	12	0.608	1.720	1.151
TN:TP Ratio	12	1.650	9.214	5.553

Most of the DO violations were measured in 2002, which was an above average wet year. A comparison of DO samples collected at the monitoring stations with respect to the water quality criteria is shown in Table 4. The distribution of DO measurements over the listing period is shown in Figure 2. There is one BOD measurement in the stream and it was collected in 1997; hence a correlation could not be made between elevated BOD levels and depressed DO concentrations. Of the DO measurements recorded in Butcher Pen Creek about 40 percent of the samples violate the water quality criteria (i.e., measurements less than 5 mg/L).

Chlorophyll-a and nutrient data are limited to samples collected in 2002. Chlorophyll-a data is often used to assess nutrient impairment in streams and rivers. Of the chlorophyll-a (chla) measurements collected in the WBID only two values do not have data qualifiers; hence, the data does not provide insight as to the extent of the nutrient impairment (see Appendix A). During the listing cycle, nutrient and DO data were collected at the same time at sampling station 21FLA 20030580, located at River Mile (RM) 0.98; however, there are too few observations to develop statistically significant correlations.

Table 4. Comparison of DO samples collected in WBID with respect to water quality criteria

Station	No. of Observations	No. Samples Exceeding DO Criteria	Percent Samples Exceeding DO Criteria
21FLA 20030082	8	3	37.5%
21FLA 20030580	8	6	75.0%
21FLJXWQCR2	37	13	35.1%
All Location	53	22	41.5%

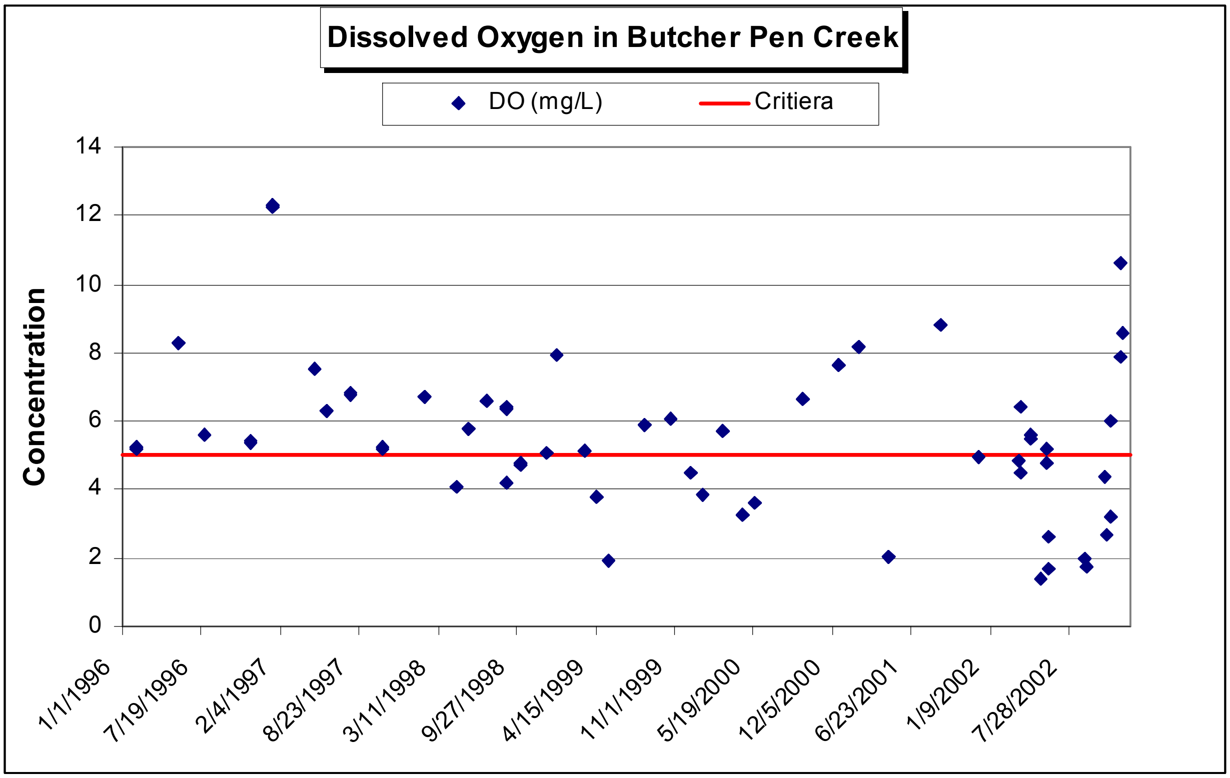

Figure 2. Dissolved Oxygen measurements collected in Butcher Pen Creek

6. SOURCE ASSESSMENT

An important part of the TMDL analysis is the identification of source categories, source subcategories, or individual sources of nutrients in the watershed and the amount of pollutant loading contributed by each. Sources are broadly classified as either point or non-point sources. A point source is defined as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. Point source discharges of industrial wastewater and treated sanitary wastewater must be authorized by National Pollutant Discharge Elimination System (NPDES) permits.

Non-point sources of pollution are diffuse sources that cannot be identified as entering a waterbody through a discrete conveyance at a single location. Land cover within the WBID can be used as an indication of potential sources. Nonpoint sources addressed in this study primarily include loadings from surface runoff and base flow from the surficial aquifer (including the septic tank). The majority of the pollutants impacting the DO concentration in the stream are likely generated from urban development.

In DO-impaired waters source assessments often target nutrients and BOD. The limiting nutrient, generally nitrogen or phosphorus, is defined as the nutrient that limits plant growth when it is not available in sufficient quantities. The ratio of nitrogen to phosphorus is used as a first cut to determine the limiting nutrient. An N:P ratio less than 10 implies nitrogen is the limiting nutrient, a ratio greater than 30 implies phosphorus is the limiting nutrient, and a ratio between 10 and 30 implies both nitrogen and phosphorus are co-limiting nutrients. The limiting nutrient in Butcher Pen Creek is nitrogen as the available data indicates the N:P ratio is on average less than 10 (see Table 3). This implies sources of nitrogen are a major contribute to water quality impairment.

6.1 Point Sources

There are no facilities permitted to discharge treated effluent into surface waters in the Butcher Pen Creek watershed. Municipal Separate Storm Sewer Systems (MS4s) may also discharge pollutants to waterbodies in response to storm events. Currently, large and medium MS4s serving populations greater than 100,000 people are required to obtain a NPDES storm water permit. In March 2003, small MS4s serving urbanized areas will be required to obtain a permit under the Phase II storm water regulations. An urbanized area is defined as an entity with a residential population of at least 50,000 people and an overall population density of 1,000 people per square mile.

The municipal area of the City of Jacksonville (FLS000012) is covered under the Phase I MS4 permit and includes the Butcher Pen Creek watershed. A requirement of the MS4 permit is the development of a Master Stormwater Management Plan. Implementation of this plan addresses water quality and flooding problems according to a priority list. Water quality in Butcher Pen Creek was considered a priority issue in this plan.

In 1997 the city of Jacksonville's Department of Pubic Utilities Water and Sewer Operations merged with the Jacksonville Electric Authority (JEA), which now provides more than 80 percent of water and sewer service to residents of Duval County. JEA monitors water quality in the creek as part of the MS4 requirements for the City. JEA anticipates better management of stormwater runoff and capital improvement plans to address flooding issues will result in improved water quality in the Jacksonville area.

The WLA for the MS4 is expressed in terms of percent reduction. Given the available data, it is not possible to estimate loadings in units of pounds per day (lb/day) coming exclusively from the MS4 area. Although the aggregate wasteload allocation for storm water discharges is expressed in numeric form, percent reduction, based on the information available today, it is infeasible to calculate numeric WLAs for individual storm water outfalls because discharges from these sources can be highly intermittent, are usually characterized by very high flows occurring over relatively short time intervals, and carry a variety of pollutants whose nature and extent varies according to geography and local land use. Water quality impacts, in turn, also depend on a wide range of factors, including the magnitude and duration of rainfall events, the time period between events, soil conditions, fraction of land that is impervious to rainfall, other land use activities, and the ratio of storm water discharge to receiving water flow.

This TMDL assumes for the reasons stated above that it is infeasible to calculate numeric water quality-based effluent limitations for BOD from storm water discharges. Therefore, in the absence of information presented to the permitting authority showing otherwise, the WLA for the City of Jacksonville is expressed in narrative form (e.g., as best management practices), provided that (1) the permitting authority explains in the permit fact sheet the reasons it expects the chosen BMPs to achieve the aggregate wasteload allocation for these stormwater discharges; and (2) the state will perform ambient water quality monitoring for nutrients for the purpose of determining whether the BMPs in fact are achieving such aggregate wasteload allocation.

The percent reduction calculated for nonpoint sources is assigned to the MS4 as violations from both sources typically occur in response to storm events. Permitted MS4s will be responsible for reducing only the loads associated with stormwater outfalls which it owns, manages, or otherwise has responsible control. MS4s are not responsible for reducing other nonpoint source loads within its jurisdiction. All future MS4s permitted in the area are automatically prescribed a WLA equivalent to the percent reduction assigned to the LA.

6.2 Non-point Sources

Land development influences the delivery of water quality constituents to surface waters in two fundamental ways. Through fertilization, lawn maintenance, manure spreading, septic tank operation, vehicular use, etc., nutrients and other pollutants are added to the land surface or to shallow groundwater in excess of natural land cover conditions (i.e., native forest, wetland). Unlike the situation that tends to predominate on developed lands, natural land covers are highly conservative of essential growth nutrients, and thus labile nutrient forms tend to be retained within these terrestrial ecosystems. In addition, the creation of impervious surfaces, drainage development, and the destruction of near stream wetlands increases the amount of rainfall that ultimately ends up as runoff, thus increasing the pollutant exporting capability in developed landscapes. Thus, the process of nonpoint source pollution has both chemical and hydrologic components (Hendrickson, 2002).

The Butcher Pen Creek watershed is predominately urban. Debris carrying nutrients and other pollutants washes off roads and other impervious surfaces and discharges into the stream during storm events. Potential pollutant sources contributing to impairment include: animal waste, fertilizer application to lawns, golf courses, and other grassed areas, and malfunctioning septic tank systems.

Jacksonville Electrical Authority (JEA) funded a project, known as the Tributary Pollution Assessment Project (TPAP) to develop a standard manual for conducting sanitary surveys. The manual will be used to assess the health of a watershed and potential sources of pollution. This information will be used by JEA to concentrate repair efforts and to identify areas of failing septic tanks. The Butcher Pen Creek watershed is considered a priority watershed in this study.

Stormwater runoff from urban areas can be a significant source of pollutants to a stream. In 1982, Florida became the first state in the country to implement statewide regulations to address the issue of nonpoint source pollution by requiring new development and redevelopment to treat stormwater before it is discharged. The Stormwater Rule, as outlined in Chapter 403 Florida Statutes (F.S.), was established as a technology-based program that relies upon the implementation of BMPs that are designed to achieve a specific level of treatment (i.e., performance standards) as set forth in Chapter 62-40, F.A.C.

Florida's stormwater program is unique in having a performance standard for older stormwater systems that were built before the implementation of the Stormwater Rule in 1982. This rule states: "the pollutant loading from older stormwater management systems shall be reduced as needed to restore or maintain the beneficial uses of water" (Section 62-4-.432 (5) (c), F.A.C.).

Nonstructural and structural BMPs are an integral part of the State's stormwater programs. Nonstructural BMPs, often referred to as "source controls", are those that can be used to prevent the generation of NPS pollutants or to limit their transport off-site. Typical nonstructural BMPs include public education, land use management, preservation of wetlands and floodplains, and minimizing impervious surfaces. Technology-based structural BMPs are used to mitigate the increased stormwater peak discharge rate, volume, and pollutant loadings that accompany urbanization.

7. ANALYTICAL APPROACH

The SJRWMD Pollutant Load Screening Model (PLSM) was used to calculate the concentration and load of Biochemical Oxygen Demand (BOD) entering Butcher Pen Creek from nonpoint sources (Mundy and Bergman, 1998). The U.S. EPA Water Quality Analysis Simulation Program version 7 (WASP7) was applied as the water quality model (Wool, et. al., 2001). The eutrophication component of WASP was used to simulate the complex nutrient transport and cycling in the river, as well as determining the dissolved oxygen sag within river. The purpose of the modeling exercise was to determine what reductions in BOD loads to the river would have to occur to protect the water body's designated use and achieve water quality standards for dissolved oxygen and nutrients.

7.1 PLSM Model

PLSM utilizes a computer-driven geographic information system framework to calculate constituent loads as the product of water quality concentration associated with certain land use practices, and runoff water volume associated with those same practices. The computational approach of the PLSM is similar to that of the Surface Water Management Model (SWMM) screening level tool. (Hendrickson, 2002) The model's nonpoint source pollutant concentrations are specific to one of 20 different land use classes. Water quantity is determined through a hybrid of the SCS curve number method, and is the product of rain volumes and a coefficient (referred to as the runoff coefficient, or RC, with values ranging from 0 to 0.9) relating the propensity of various land use and soil hydrologic group combinations to generate runoff. Each landuse category is assumed to transport a characteristic mass load of pollutant from one unit of area form one unit of effective rain. Figure 3 displays the computational framework of PLSM.

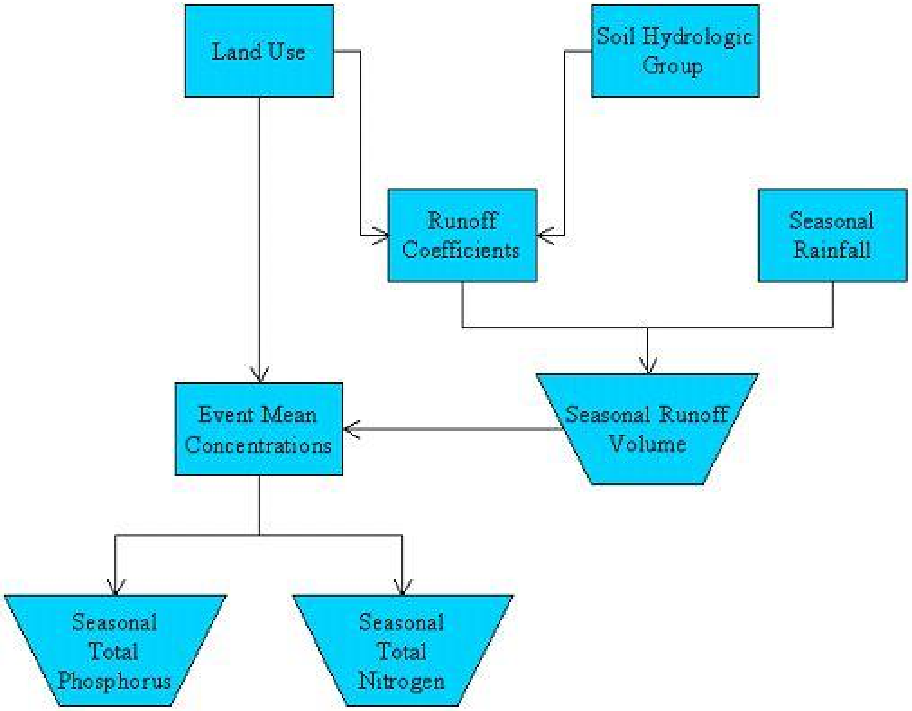

Figure 3. PLSM Conceptual Framework

7.1.1 PLSM Setup

In this application of PLSM, the model was run within Microsoft Excel and it first calculated seasonal area-weighted runoff coefficients and flow-weighted concentrations for nutrients (nitrogen and phosphorus) and BOD based upon the area within the WBID of unique land use and soil hydrologic group combinations. This was accomplished by following the procedure outlined in Hendrickson and Konwinski (1998). The inputs required to administer PLSM are provided here. PLSM is calibrated by matching simulated pollutant loads and total discharge volumes to observed values.

Land Use
Data from the standard 2000 Florida Land Use, Cover and Forms Classification System (FLUCCS) code was obtained from SJRWMD and the South Florida Water Management District (SFWMD). This data was then aggregated into 20 distinct categories as defined in Table 5.

Table 5. Landuse Categories

Category ID	Category Label	Category Description
1	LDR	Low Density Residential
2	MDR	Medium Density Residential
3	HDR	High Density Residential
4	LC	Commercial, Low
5	HC	Commercial, High
6	I	Industrial

Category ID	Category Label	Category Description
7	M	Mining
8	RO	Range/Open Land
9	AGGEN	General, Agricultural
10	NAGEN	General, Non-Agricultural
91	PAST	Pasture
92	CROPS	Crops
93	CITRUS	Citrus
94	AGMISC	Agricultural, Miscellaneous
95	ANIM	Animal
101	FOR	Forested
102	SILV	Silviculture
103	WATER	Water
104	WETLDS	Wetlands
105	BARREN	Barren

Soils
The Soil Survey Geographic Database (SSURGO), developed by the Natural Resource Conservation Service, was used in PLSM and was obtained from SJRWMD and SFWMD. Soils in PLSM are classified based specifically on their hydrologic group rating of A, B, C and D. Additional soil groups found within the SJRWMD dataset were group U (urban), which allows relatively average drainage, and Group X soils, for which drainage characteristics were unknown. Group U soils were ultimately handled as group C soils. Further, for this process, soils identified in the dataset as B/D and C/D soils were considered as B and C hydrologic group ratings, respectively. Landuse and soils data was then cross-referenced to provide the total area of each specific landuse-soils combination within each TMDL segment. These values were then applied directly to the model.

Rainfall
Rainfall data required to calculate runoff volumes and thus loads in PLSM was obtained from data collected at the Jacksonville International Airport (JAX). Rainfall measurements were available from this station from 1949 to the present.

Long-term rainfall data collected at this station was processed to obtain overall seasonal averages. The seasons used were not the Julian seasons but modified seasons corresponding to hydrologic and meteorological patterns within Florida, and were comprised of a cool, moderately wet winter season from December through March characterized by regular frontal storm events; a hot, dry spring/summer from April through July; and a hot, wet summer/fall from August through November characterized by afternoon convective thunderstorms and tropical systems.

7.1.2 PLSM Calculations

Area-Weighted Runoff Coefficients
PLSM provides runoff coefficients based on the combination of soil type and land use inputs provided. Runoff coefficients are then multiplied by seasonal rainfall to determine a seasonal runoff volume from each particular combination of landuse and soil type. Runoff coefficients indicate the fraction of loads originating from the catchment that actually reach the stream. A value of 1 means the full load reaches the stream.

Event Mean Concentrations

The event mean concentration (EMC) reflects the average concentration of a parameter that would be found in surface water running off from an area of land with a consistent soil and land use. PLSM generates event mean concentrations for Total Nitrogen (TN), Total Phosphorus (TP), BOD, Total Inorganic Nitrogen (TIN), Phosphate (PO_4), Labile Total Organic Carbon (LTOC), and Refractory Total Organic Carbon (RTOC) based on calibrations as conducted in Hendrickson and Konwinski (1998) and the varying landuse-soils combinations that were provided.

EMCs provided in the PLSM for Total Nitrogen and Total Phosphorus include both a labile (reactive) and refractory (inert) component. A supplemental study provided by J. Hendrickson, outlines a method by which nutrient loads may be partitioned into labile and refractory components (Hendrickson, 2005). With these, it is possible to identify the total bioavailable nitrogen (TBN) and the total bioavailable phosphorus (TBP) loads which impact the system, and for which a TMDL may be calculated. For this study, the formulas outlined in Hendrickson (2005) were applied to the EMCs for TN and TP to obtain EMCs specific to TBN and TBP for each landuse category. The subsequent event mean concentrations were applied to the seasonal runoff volume to calculate average seasonal TBN and TBP loads for each landuse-soil combination. The sum of all loads within a drainage basin was calculated to develop total seasonal loads for TBN and TBP.

7.2 WASP Model

Butcher Pen Creek was divided into two segments for the WASP model corresponding to monitoring stations in the WBID. Segmentation was based on the limited data available to characterize water quality in the model. Model segmentation was based on the Grid Based Mercury Model (GBMM). The GBMM is a GIS environment extension that aids in defining the segmentation and boundary conditions for the WASP7 model input file. The GBMM extension utilizes the National Hydrography Dataset (NHD) and the National Elevation Dataset (NED) along with various other coverages, including watershed boundary, weather data and soils. GBMM was used to predict inflows to the WASP model where there are no continuous flow gages. GBMM predicts runoff as a function of landuse (pervious/impervious area), slope, soil type, infiltration and evaporation. When the GBMM was executed, two ASCII files were produced for use in building the WASP7 application for Butcher Pen Creek. Those were the segment.txt and the flow.txt files. The segment.txt file contained the following information for each segment:

- Segment Name,
- Segment Number,
- Length (m),
- Width (m),
- Depth Multiplier,
- Velocity Multiplier,
- Slope (m/m), and
- Mannings Roughness.

The flow.txt file contains two important pieces of information, 1) how the segments were connected to one another, and 2) a time series of flow for each individual segment drainage area.

7.2.1 WASP Input

WASP requires BOD to be input as ultimate carbonaceous BOD (CBODu). To determine the loading of BOD to each segment, the PLSM loads for the entire WBID was area-weighted to the segment drainage area. The units were then converted from (lb/d) to (kg/d) by dividing (lb/d) by 2.2046. The BOD estimates were converted to CBODu by multiplying the BOD load by an f-ratio of 3.0.

Total Bioavailable Nitrogen and Phosphorus are portioned into detrital components for input in WASP. Using the Total Nitrogen and Total Bioavailable Nitrogen results from PLSM, loads of Ammonia, Nitrate+Nitrite and Detrital Nitrogen were determined. Detrital Nitrogen was calculated using the following equation.

Total Detrital Nitrogen (lb/d) = Total Nitrogen (lb/d) – Total Bioavailable Nitrogen (lb/d)

To determine the Ammonia and Nitrate+Nitrite loads, available data from the WBID were analyzed. For days when Ammonia and Nitrate+Nitrite were measured, a ratio was calculated as Ammonia divided by Nitrate+Nitrite. Then all ratios were averaged to determine a representative ratio of 1.776. Loads were calculated using the following equations.

Nitrate+Nitrite (lb/d) = Total Bioavailable Nitrogen (lb/d) / (1 + 1.776)

Ammonia (lb/d) = Total Bioavailable Nitrogen (lb/d) – Nitrate+Nitrite (lb/d)

Loadings of Orthophosphate and Detrital Phosphorus were determined using the Total Phosphorus and Total Bioavailable Phosphorus results from PLSM. It was assumed that all of the Total Bioavailable Phosphorus was equivalent to Orthophosphate. Detrital Phosphorus was calculated using the following equation.

Total Detrital Phosphorus (lb/d) = TP (lb/d) – Total Bioavailable Phosphorus (lb/d)

Nitrogen and phosphorus loads were then converted to metric units and the segment loadings were estimated based on an area-weighting. This procedure was repeated for each season. Seasonal loadings input in WASP are presented in Table 6.

Table 6. Nutrient Loadings in WASP

Parameter	Season 1 Load (kg/day)	Season 2 Load (kg/day)	Season 3 Load (kg/day)
CBOD	2.78	2.51	4.84
Ammonia	1.906	2.059	3.301
Nitrate	1.073	1.160	1.860
Detrital Nitrogen	0.478	0.236	0.6009
Orthophosphate	0.5518	0.8227	1.662
Detrital Phosphorus	0.023	0.0164	0.0541

WASP7 was setup to simulate a modified Streeter-Phelps equation for DO and CBODu and Sediment Oxygen Demand (SOD). SOD is defined as the rate of oxygen consumption exerted by bottom sediments on overlying water. Constants for DO and CBODu were selected based on literature values and experience modeling in Florida and are presented in Table 7.

Table 7. Constants used in WASP7 model for simulating DO, CBODu, and nutrients

Parameter Simulated	Constant	Value
DO	Minimum Reaeration Rate (per day)	0.5
	Theta—Reaeration Temperature Correction	1.0477
	Oxygen to Carbon Stoichiometric Ratio	2.67
CBOD1 (ultimate)	BOD (1) Decay Rate Constant @ 20^0 C (per day)	0.20
	BOD(1) Decay Rate Temperature Correction Coefficient	1.04
	BOD(1) Half Saturation Oxygen Limit (mg O/L)	0.5
Ammonia	Nitrification Rate Constant @ 20^0 C (per day)	0.15
	Nitrification Temperature Coefficient	1.07
Nitrate	Denitrification Rate Constant @ 20^0 C (per day)	0.05
	Denitrification Temperature Coefficient	1.045
Organic Nitrogen	Dissolved Organic Nitrogen Mineralization Rate Constant @ 20^0 C (per day)	0.1
	Dissolved Organic Nitrogen Mineralization Temperature Coefficient	1.08
Organic Phosphorus	Mineralization Rate Constant for dissolved organic P @ 20^0 C (per day)	0.1
	Dissolved Organic P Mineralization Temperature Coefficient	1.08
Detritus	Detritus Dissolution Rate (1/day)	0.1
	Temperature correction for detritus dissolution	1.08

7.2.2 WASP Calibration

Nutrient and DO data available to characterize the Butcher Pen Creek WBID was observed at monitoring station 21FLA 20030580, located at River Mile (RM) 0.98. Thus, choices were limited while trying to develop model forcing time series. Therefore, this station was used to parameterize the condition of the water entering the WASP7 network.

SOD is a major component of the Butcher Pen Creek WASP model. SOD data are not available in the WBID, thus model parameters were based on literature values. After the calibration process, SOD was set to 2.0 $g/m^2/d$ for all segments.

Once model input forcings and parameters were developed, model calibration was an iterative process. During the calibration process it was determined that the dominant parameter was SOD. Therefore, calibration of the model was performed by adjusting SOD until the simulated dissolved oxygen values were close to the measured values.

Model simulations of DO were compared to observed data collected in the WBID at the downstream station Segment 2 (RM 0.98). Model year 2002 was selected as the critical period as the lowest DO measurements were observed in this time period. Observed and simulated concentrations are presented in Figure 4. In consideration of the uncertainty in model forcing information and assumptions, the model simulations are considered reasonable.

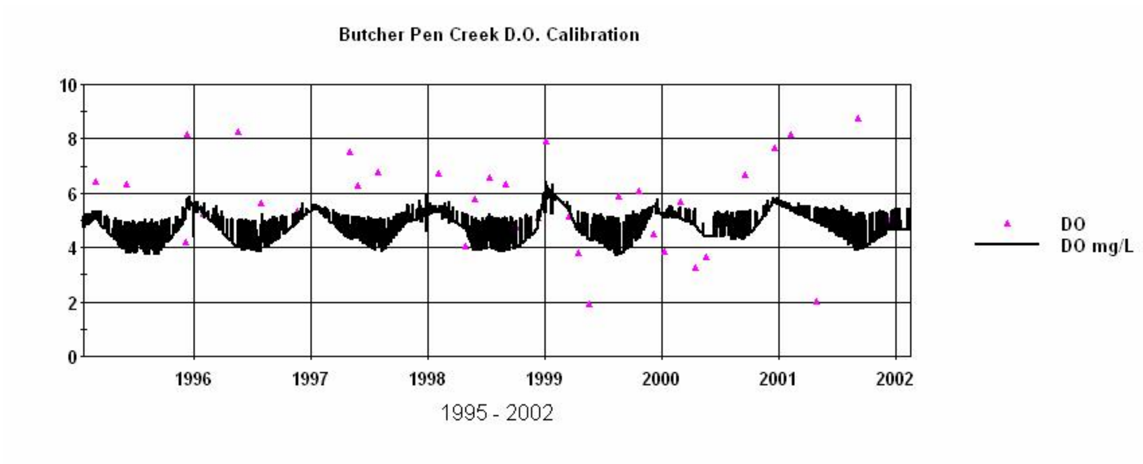

Figure 4. Dissolved Oxygen calibration at Station 21FLA 20030580 (RM 0.98, WASP Segment 2)

7.2.3. WASP Results

After the model was calibrated to SOD, allocation scenarios were evaluated at segment 2. Model SOD values were reduced until DO standards were achieved at all times. Acceptable DO levels were achieved with an SOD value of 1.0 g/m^2/day. Since load allocations cannot be made for SOD, a relationship between CBODu and SOD was needed. Hence, the goal was to determine what reduction in the watershed CBODu load would result in an SOD value of 1.0 g/m^2/day.

WASP7 does not have a sediment diagenesis algorithm to predict SOD based on instream loads of CBOD. The SOD spreadsheet model developed by Quantitative Environmental Analysis (QEA) and modified by Dr. James Martin at Mississippi State University (MSU) was implemented to determine the relative change in SOD by reducing the watershed load of CBODu and nutrients (Martin, 2002). The SOD spreadsheet model was run on segment 2 and was used to determine the watershed load reduction. Results of the SOD spreadsheet model indicate a 50 percent reduction in watershed loadings of CBOD is needed for Butcher Pen Creek to attain DO standards.

8. DETERMINATION OF TMDL

The TMDL process quantifies the amount of a pollutant that can be assimilated in a waterbody, identifies the sources of the pollutant, and recommends regulatory or other actions to be taken to achieve compliance with applicable water quality standards based on the relationship between pollution sources and in-stream water quality conditions. A TMDL can be expressed as the sum of all point source loads (Waste Load Allocations), non-point source loads (Load Allocations), and an appropriate margin of safety (MOS), which takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$TMDL = \Sigma\ WLAs + \Sigma\ LAs + MOS$$

The objective of a TMDL is to allocate loads among all of the known pollutant sources throughout a watershed so that appropriate control measures can be implemented and water quality standards achieved. 40 CFR §130.2 (i) states that TMDLs can be expressed in terms of mass per time (e.g. pounds per day), toxicity, or other appropriate measure. The BOD TMDL is expressed as a daily load based on annual average seasonal loads. The season with the highest BOD load is selected as the TMDL s this represents the maximum load the stream can assimilate and maintain standards. The Total Nitrogen TMDL is being proposed to achieve the downstream TMDL for the Lower St. Johns River (FDEP, 2004).

8.1 Critical Conditions

The critical period for the simulations was selected as 2002 as this is when most of the low DO levels were measured in the stream. Model results were evaluated as seasonal loads. Season 3 in 2002 producing the highest allowable BOD and TN load was selected as the critical condition. By achieving the DO criteria during 2002, model results indicate water quality standards are achieved during all other time periods.

8.2 Existing Conditions

Existing conditions are based on modeling simulations of DO over a seven year time period. This period of time was selected because of monitoring data available to calibrate the water quality model. Nonpoint source loadings were derived from 2000 landuse data. Seasonal BOD and TN loads representing existing conditions simulated in WASP are shown in Table 8. WASP CBODu results were converted to BOD using the procedure outlined in Section 7.2.1. Seasonal TN values are the sum of ammonia, nitrate, and detrital nitrogen loadings presented in Table 6.

Table 8. TN and BOD loads for existing conditions

Parameter	Season1 (lb/day)	Season 2 (lb/day)	Season 3 (lb/day)
BOD	2.04	1.84	3.56
TN	7.62	7.62	12.70

8.3 Margin of Safety

There are two methods for incorporating a MOS in the analysis: a) implicitly incorporate the MOS using conservative model assumptions to develop allocations; or b) explicitly specify a portion of the TMDL as the MOS and use the remainder for allocations. An implicit MOS was used in the analysis by meeting water quality criteria during the worst case condition in the simulation time period. Conservative modeling assumptions were used in the analysis in the selection of the F ratio used to convert BOD to CBOD. By using an F ratio on the high end of the range reported in the literature a conservative estimated (i.e., higher) of the CBOD load was used in the model than what would have been calculated using a smaller value.

8.4 Determination of TMDL, LA and WLA

The TMDL allocations are based on reductions from existing loads generated for Season 3, as model results indicate the highest loads transported in the stream occur between December and March (Season 3). The allocation loads represent the maximum load the stream can assimilate and maintain DO standards. To achieve the allocated BOD load, a 50 percent reduction is required from the existing load of 3.56 lb/day, or 1.78 lb/day. The allocation to TN is being proposed to achieve the downstream TMDL for the Lower St. Johns River (FDEP, 2004). The existing TN load of 12.7 lb/day is reduced 22 percent to obtain the allocated load of 9.91 lb/day. BOD and TN reductions apply to both the MS4 and nonpoint sources in the watershed. TMDL components are summarized in Table 9.

Table 9. Summary of TMDL Components for Butcher Pen Creek (WBID 2322)

Parameter	WLA		LA (lb/day)	TMDL (lb/day)	Percent Reduction
	Continuous	MS4 (reduction)			
BOD	N/A	50%	1.78	1.78	50%
TN	N/A	22%	9.91	9.91	22%

8.4.1 Waste Load Allocations

There are no NPDES facilities discharging to surface waters in the Butcher Pen Creek. Only facilities discharging pollutants directly into streams and MS4 areas are assigned a WLA. The WLAs are expressed separately for continuous discharge facilities and MS4 areas as the former discharges during all weather conditions whereas the later discharges in response to storm events. Any future facility permitted to discharge to surface waters in the watershed that adversely impact DO or the natural balance of aquatic flora and fauna will be required to meet end-of-pipe limits that do not cause or contribute to impairment in the stream.

The City of Jacksonville MS4 impacts Butcher Pen Creek. The WLA assigned to the MS4 area is expressed in terms of percent reduction of BOD loads required to attain the target. With the available water quality data it is not possible to calculate the WLA in terms of load or isolate the loading discharging exclusively from the MS4 areas.

8.4.2 Load Allocations

The primary mode of transport of BOD to the stream is during a storm event. Nutrient data were collected primarily in 2002, and during select dates in other years. Modification of the land surface from a pervious land cover to an impervious surface results in higher peak flow rates that wash BOD and nutrient-enriched water into the stream. Nonpoint source pollution and MS4 runoff is responsible for the low DO measurements in the stream. Reductions in BOD and TN loadings of 50 percent throughout the watershed should result in attainment of standards.

8.5 Seasonal Variation

Seasonal variation was incorporated in the analysis by simulating loads during the various seasons by using the entire period of record of data collected in the WBID. This incorporates changes in water temperature, rainfall, and rainfall intensity.

9. RECOMMENDATIONS

Controlling sources contributing to reduced DO concentrations should be the focus of implementing this TMDL. FDEP employs the Basin Management Action Plan (B-MAP) as the mechanism for developing strategies to accomplish the necessary load reductions. Components of a B-MAP are:

- Allocations among stakeholders
- Listing of specific activities to achieve reductions
- Project initiation and completion timeliness
- Identification of funding opportunities
- Agreements
- Local ordinances
- Local water quality standards and permits
- Follow-up monitoring

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APPENDIX A WATER QUALITY DATA

Table A- 1. Guide to Water Quality Remark Codes (Rcode column in data tables)

Remark Code	Definition	Use in TMDL
A	Value reported is mean of two or more samples	Data included in analysis as reported
E	Extra sample taken in compositing process	Data included as average
I	The value reported is less than the practical quantification limit and greater than or equal to the method detection limit.	Data included in analysis as reported
J	Estimated. Value shown is not a result of analytical measurement.	Data not included in analysis as reported
K	Off-scale low. Actual value not known, but known to be less than value shown	Data included in analysis as reported
L	Off-scale high. Actual value not known, but known to be greater than value shown	Data included in analysis as reported
Q	Sample held beyond normal holding time	**Data used in analysis – samples held on on ice; actual concentration is expected to be at least as high as the value reported.**
T	Value reported is less than the criteria of detection	Data included in analysis if the reported value is below criteria; otherwise, reported value is not used in the analysis
U	Material was analyzed for but not detected. Value stored is the limit of detection.	Data not included in analysis
<	NAWQA – actual value is known to be less than the value shown	Data included in analysis
$	Calculated by retrieval software. Numerical value was neither measured nor reported to the database, but was calculated from other data available during generation of the retrieval report.	Data not included in analysis

Table A- 2. Water quality data collected in Butcher Pen Creek

Parameter	Station	Date	Time	Result	Remark Code
Biochemical Oxygen Demand (mg/L)	21FLA 20030580	9/1/1998	1230	0.5	K
	21FLJXWQCR2	5/31/1997	944	1.0	
Chlorophyll-a (µg/L) - corrected	21FLSJWMLSJ910	5/11/1992	1015	27.26	
		8/7/1992	900	6.68	
		11/7/1992	800	85.8	
		1/20/1993	1000	9.89	
	21FLA 20030580	9/1/1998	1230	1	U
		3/26/2002	1125	1	&
		4/21/2002	845	1	&
		5/30/2002	1130	56	
		6/6/2002	1130	1.7	U
		10/28/2002	1439	1	&
		11/10/2002	925	1.4	U
	21FLA 20030760	5/16/2002	1230	7.8	
		9/9/2002	1115	980	U
		12/10/2002	1215	1	&
Dissolved Oxygen (mg/L)	21FLA 20030082	3/26/2002	1150	6.4	
		4/21/2002	830	5.6	
		5/30/2002	1115	5.2	
		6/6/2002	1105	2.6	
		9/3/2002	1200	2	
		10/28/2002	1420	4.4	
		11/10/2002	950	6	
		12/3/2002	1146	10.6	
	21FLA 20030580	9/1/1998	1230	4.2	
		3/26/2002	1125	4.5	
		4/21/2002	845	5.5	
		5/30/2002	1130	4.8	
		6/6/2002	1130	1.7	
		10/28/2002	1439	2.7	
		11/10/2002	925	3.2	
		12/3/2002	1120	7.9	
	21FLJXWQCR2	2/3/1996	906	5.2	
		2/3/1996	906	5.23	
		5/20/1996	1431	8.3	
		5/20/1996	1431	8.29	
		7/29/1996	1032	5.6	
		7/29/1996	1032	5.62	
		11/21/1996	945	5.37	
		11/21/1996	945	5.4	
		1/15/1997	1112	12.25	
		1/15/1997	1112	12.3	

Parameter	Station	Date	Time	Result	Remark Code
Dissolved Oxygen (mg/L)	21FLJXWQCR2	5/1/1997	1456	7.5	
		5/1/1997	1456	7.53	
		5/31/1997	944	6.28	
		5/31/1997	944	6.3	
		7/30/1997	1316	6.8	
		7/30/1997	1316	6.77	
		10/22/1997	1007	5.24	
		10/22/1997	1007	5.2	
		2/2/1998	1306	6.73	
		2/2/1998	1306	6.7	
		4/28/1998	1020	4.1	
		4/28/1998	1020	4.08	
		5/26/1998	1356	5.79	
		5/26/1998	1356	5.8	
		7/13/1998	1156	6.57	
		7/13/1998	1156	6.6	
		9/1/1998	1110	6.4	
		9/1/1998	1110	6.36	
		10/7/1998	1038	4.75	
		10/7/1998	1038	4.8	
		12/10/1998	1330	5.1	
		12/10/1998	1330	5.08	
		1/5/1999	1024	7.93	
		1/5/1999	1024	7.93	
		3/17/1999	1004	5.13	
		3/17/1999	1004	5.13	
		4/14/1999	1144	3.8	
		4/14/1999	1144	3.8	
		5/19/1999	1006	1.95	
		5/19/1999	1006	1.95	
		8/18/1999	1057	5.9	
		8/18/1999	1057	5.9	
		10/23/1999	852	6.08	
		10/23/1999	852	6.08	
		12/11/1999	951	4.51	
		12/11/1999	951	4.51	
		1/10/2000	1014	3.85	
		1/10/2000	1014	3.85	
		3/1/2000	1100	5.71	
		3/1/2000	1100	5.71	
		4/20/2000	950	3.28	
		4/20/2000	950	3.28	
		5/20/2000	954	3.64	
		5/20/2000	954	3.64	
		9/19/2000	1356	6.66	
		9/19/2000	1356	6.66	

Parameter	Station	Date	Time	Result	Remark Code
Dissolved Oxygen (mg/L)	21FLJXWQCR2	12/18/2000	1313	7.65	
		12/18/2000	1313	7.65	
		2/8/2001	1354	8.17	
		2/8/2001	1354	8.17	
		4/26/2001	1034	2.02	
		4/26/2001	1034	2.02	
		9/5/2001	1451	8.78	
		9/5/2001	1451	8.78	
		12/11/2001	1410	4.98	
		12/11/2001	1410	4.98	
		12/11/2001	1410	4.98	
		3/20/2002	1238	4.84	
		5/16/2002	1130	1.38	
		9/9/2002	1200	1.75	
		12/10/2002	1200	8.57	
Ammonia (mg/L)	21FLA 20030580	9/1/1998	1231	0.049	A
		3/26/2002	1125	0.1694	
		4/21/2002	845	0.1815	
		5/30/2002	1130	0.4961	
		6/6/2002	1130	0.6655	
		10/28/2002	1439	0.2178	
		11/10/2002	925	0.2178	
	21FLA 20030760	5/16/2002	1230	0.3872	
		12/10/2002	1215	0.1331	
Nitrate-Nitrite (mg/L)	21FLA 20030580	9/1/1998	1231	0.37	
		3/26/2002	1125	0.048	
		4/21/2002	845	0.28	
		5/30/2002	1130	0.02	U
		6/6/2002	1130	0.019	
		10/28/2002	1439	0.16	
		11/10/2002	925	0.091	
	21FLA 20030760	5/16/2002	1230	0.048	
		9/9/2002	1115	0.15	
		12/10/2002	1215	0.25	
	21FLJXWQCR2	5/31/1997	944	0.323	
Total Kjeldahl Nitrogen (mg/L)	21FLA 20030580	9/1/1998	1231	0.92	J
		3/26/2002	1125	0.56	
		4/21/2002	845	0.73	
		5/30/2002	1130	1.7	
		6/6/2002	1130	1.4	
		10/28/2002	1439	0.98	
		11/10/2002	925	0.96	
	21FLA 20030760	5/16/2002	1230	1.6	
		9/9/2002	1115	0.92	
		12/10/2002	1215	0.66	

Parameter	Station	Date	Time	Result	Remark Code
Total Organic Carbon (mg/L)	21FLA 20030580	9/1/1998	1231	10	
		4/21/2002	845	12	
		5/30/2002	1130	13	
		6/6/2002	1130	9.9	
		10/28/2002	1439	14	
		11/10/2002	925	15	
	21FLA 20030760	9/9/2002	1115	14	
		12/10/2002	1215	8.5	
Total Phosphorus (mg/L)	21FLA 20030580	9/1/1998	1231	0.14	
		3/26/2002	1125	0.18	
		4/21/2002	845	0.15	
		5/30/2002	1130	0.41	
		6/6/2002	1130	0.86	
		10/28/2002	1439	0.18	
		11/10/2002	925	0.28	
	21FLA 20030760	5/16/2002	1230	0.36	
		9/9/2002	1115	0.21	
		12/10/2002	1215	0.14	
Total Nitrogen (mg/L)	21FLA 20030580	9/1/1998	1231	1.29	J
		3/26/2002	1125	0.608	
		4/21/2002	845	1.01	
		5/30/2002	1130	1.72	
		6/6/2002	1130	1.419	
		10/28/2002	1439	1.14	
		11/10/2002	925	1.051	
	21FLA 20030760	5/16/2002	1230	1.648	
		9/9/2002	1115	1.07	
		12/10/2002	1215	0.91	