Revised

Total Maximum Daily Load

Evaluation

for

Three Stream Segments

in the

Savannah River Basin

for

Dissolved Oxygen

Submitted to:
The U.S. Environmental Protection Agency
Region 4
Atlanta, Georgia

Submitted by:
The Georgia Department of Natural Resources
Environmental Protection Division
Atlanta, Georgia

September 2007

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EXECUTIVE SUMMARY

The State of Georgia assesses its water bodies for compliance with water quality standards criteria established for their designated uses as required by the Federal Clean Water Act (CWA). Assessed water bodies are placed into one of three categories with respect to designated uses: 1) supporting, 2) partially supporting, or 3) not supporting. These water bodies are found on Georgia's 305(b) list as required by that section of the CWA that defines the assessment process, and are published in *Water Quality in Georgia* every two years (GA EPD, 2002-2003).

Some of the 305(b) partially and not supporting water bodies are also assigned to Georgia's 303(d) list, also named after that section of the CWA. Water bodies on the 303(d) list are required to have a Total Maximum Daily Load (TMDL) evaluation for the water quality constituent(s) in violation of the water quality standard. The TMDL process establishes the allowable pollutant loadings or other quantifiable parameters for a water body based on the relationship between pollutant sources and in-stream water quality conditions. This allows water quality-based controls to be developed to reduce pollution and to restore and maintain water quality.

The State of Georgia has identified three (3) stream segments, located in the Savannah River Basin, as water quality limited due to dissolved oxygen (DO). These waterbodies were included in the State's 2002 303(d) list. This report presents the dissolved oxygen TMDLs for these segments.

Part of the TMDL analysis is the identification of potential source categories. Sources are broadly classified as either point or nonpoint sources. A point source is defined as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. Nonpoint sources are diffuse, and generally, but not always, involve accumulation of oxygen demanding substances on land surfaces that wash off as a result of storm events.

The process of developing the dissolved oxygen TMDL for the Savannah River Basin included developing computer models for the listed segments. Georgia DOSAG, a steady state water quality model developed by the Georgia Environmental Protection Division (GA EPD) was used for each listed segment. These models were calibrated to data collected in the Savannah River Basin in the summer of 2002.

Management practices may be used to help reduce and/or maintain the Ultimate Oxygen Demand (UOD) loads. These include:

- Compliance with the requirements of the NPDES permit program; and
- Application of Best Management Practices (BMPs) appropriate to nonpoint sources.

The amount of oxygen demanding substances delivered to a stream is difficult to determine. However, by requiring and monitoring the implementation of these practices, such efforts will improve stream water quality and represent a beneficial measure of TMDL implementation.

1.0 INTRODUCTION

1.1 Background

The State of Georgia assesses its water bodies for compliance with water quality standards criteria established for their designated uses as required by the Federal Clean Water Act (CWA). Assessed water bodies are placed into one of three categories with respect to designated uses: 1) supporting, 2) partially supporting, or 3) not supporting. These water bodies are found on Georgia's 305(b) list as required by that section of the CWA that defines the assessment process, and are published in *Water Quality in Georgia* every two years (GA EPD, 2002-2003).

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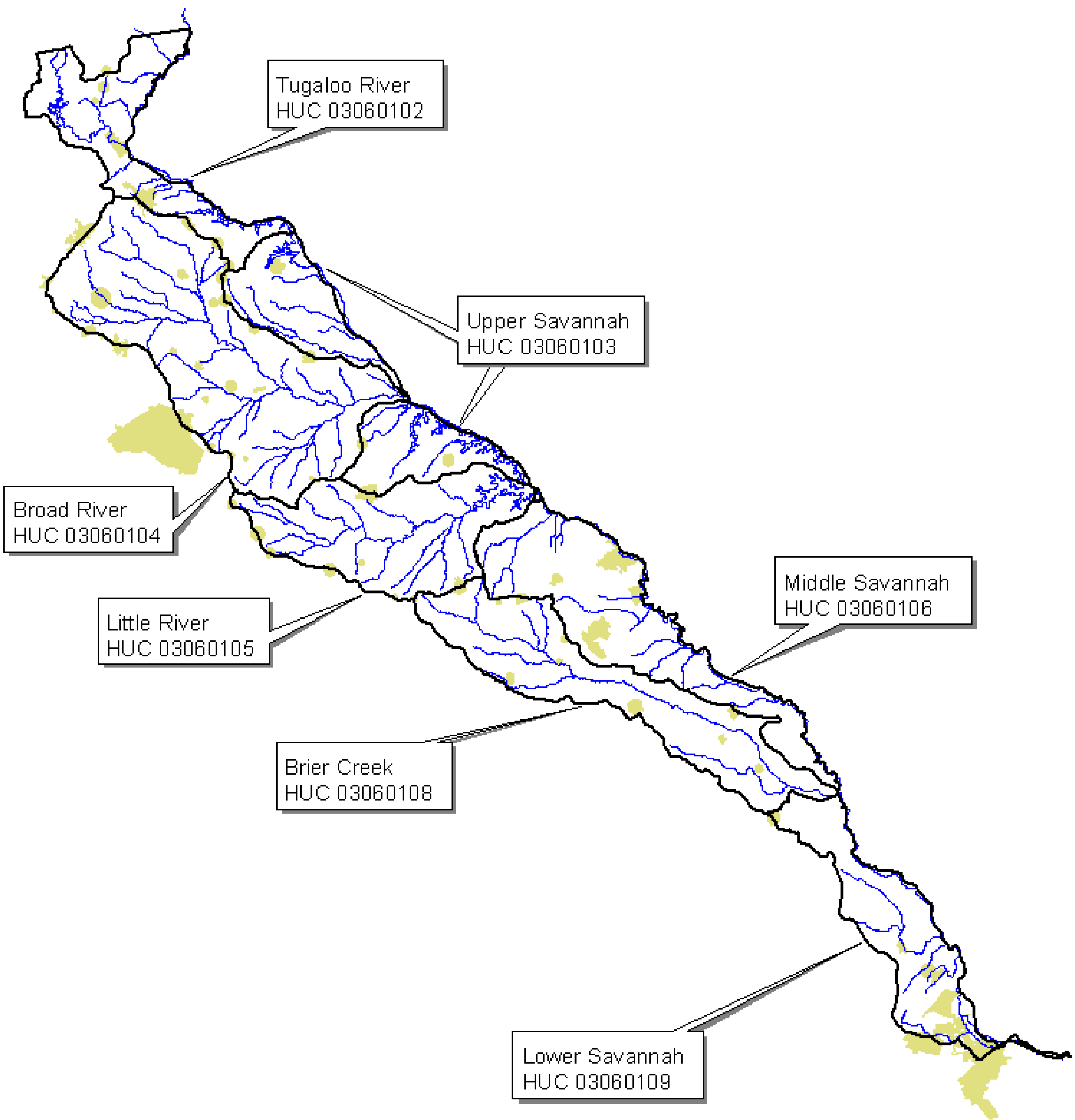
The State of Georgia has identified three (3) stream segments located in the Savannah River Basin as water quality limited due to dissolved oxygen (DO). These waterbodies were included in the State's 2002 303(d) list. This report presents the DO TMDLs for the listed segments in the Savannah River Basin identified in Table 1.

1.2 Watershed Description

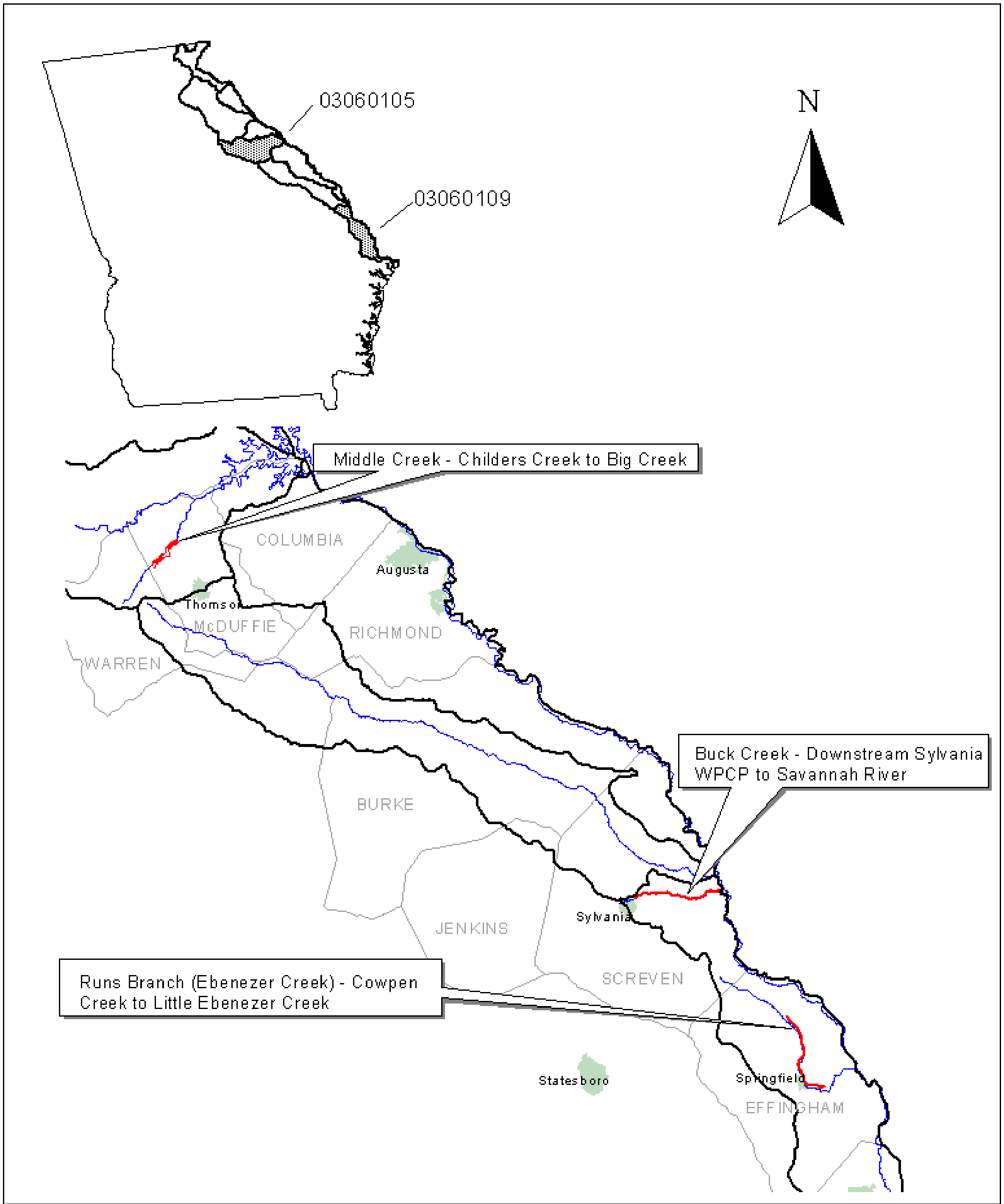
The Savannah River Basin is located along the eastern portion of Georgia, encompassing approximately 5,821 square miles. The Savannah River Basin is bordered by the Chattahoochee and Oconee River Basins to the west and the Ogeechee River Basin to the south. The headwaters of the Savannah River originate in the Blue Ridge Province in Georgia, and North and South Carolinas. The Savannah River defines the state boundary between Georgia and South Carolina, and ultimately flows into the Atlantic Ocean. The Savannah River Basin contains parts of the Piedmont and Coastal Plain physiographic provinces, which extend throughout the southeastern United States.

The USGS has divided the Savannah River Basin into seven sub-basins, or Hydrologic Unit Codes (HUCs). Figure 1 shows the location of these sub-basins. Figure 2 shows the location of the three listed dissolved oxygen segments in the Savannah River Basin and the associated counties.

The land use characteristics of the Savannah River Basin watersheds were determined using data from the National Land Cover Dataset (NLCD) for Georgia. This coverage is based on Landsat Thematic Mapper digital images developed in 1995. The classification is based on a modified Anderson level one and two system. Table 2 lists the land cover distribution and associated percent land cover.



TMDL Evaluation - Dissolved Oxygen Savannah River Basin	Figure 1. Location of the Savannah River Basin



TMDL Evaluation - Dissolved Oxygen Savannah River Basin	Figure 2. Impaired Stream Segments in HUCs 03060105 and 03060109

Table 1. Waterbodies Listed For Dissolved Oxygen in the Savannah River Basin

Stream Segment	Location	Segment Length (miles)	Designated Use	Listing
Buck Creek	Downstream Sylvania WPCP to Savannah River (Screven Co.)	12	Fishing	NS
Middle Creek	Childers Creek to Big Creek (tributary to Clark Hill Lake), near Wrightsboro (McDuffie Co.)	6	Fishing	PS
Runs Branch (Ebenezer Creek)	Cowpen Creek to Little Ebenezer Creek near Clyo (Effingham Co.)	11	Fishing	NS

Notes:
PS = Partially Supporting designated use
NS = Not Supporting designated use

Table 2. Savannah River Basin Land Coverage

Stream/Segment	Land use Categories - Acres (Percent)													
	Open Water	Residential	High Intensity Commercial, Industrial, Transportation	Bare Rock, Sand, Clay	Quarries, Strip Mines, Gravel Pits	Transitional	Forest	Row Crops	Pasture, Hay	Other Grasses (Urban, recreational; e.g. parks, lawns)	Woody Wetlands	Emergent Herbaceous Wetlands	Total	Land use Source
Buck Creek	147 (0.4)	777 (2.4)	55 (0.2)	14 (0.0)	- (0.0)	1,225 (3.8)	14,074 (43.0)	9,716 (29.7)	1,299 (4.0)	43 (0.1)	5,283 (16.2)	64 (0.2)	32,698	NLCD
Middle Creek	61 (0.3)	136 (0.6)	134 (0.6)	28 (0.1)	218 (0.9)	1,393 (6.0)	18,103 (78.0)	2,309 (10.0)	545 (2.3)	16 (0.1)	256 (1.1)	2 (0.0)	23,201	NLCD
Runs Branch (Ebenezer Creek)	229 (0.2)	683 (0.6)	29 (0.0)	25 (0.0)	- (0.0)	5,394 (4.5)	51,346 (42.9)	24,687 (20.6)	3,300 (2.8)	19 (0.0)	33,657 (28.1)	415 (0.3)	119,783	NLCD

1.3 Water Quality Standard

The water use classification for the listed stream segments in the Savannah River Basin is Fishing. No segments in the Savannah River Basin are classified as trout streams. The criterion violated is listed as dissolved oxygen. The potential causes listed include municipal facilities and nonpoint source runoff. The use classification water quality standards for dissolved oxygen, as stated in Georgia's *Rules and Regulations for Water Quality Control (GA EPD, 2004)*, Chapter 391-3-6-.03(6)(c)(i), are:

> A daily average of 6.0 mg/L and no less than 5.0 mg/L at all times for waters designated as trout streams by the Wildlife Resources Division. A daily average of 5.0 mg/L and no less than 4.0 mg/L at all times for waters supporting warm water species of fish.

Certain waters of the State may have conditions where dissolved oxygen is naturally lower than the numeric criteria specified above and therefore cannot meet these standards unless naturally occurring loads are reduced or streams are artificially or mechanically aerated. This is addressed in Georgia's *Rules and Regulations for Water Quality Control*, Chapter 391-3-6-.03(7):

> *Natural Water Quality*. It is recognized that certain natural waters of the State may have a quality that will not be within the general or specific requirements contained herein. These circumstances do not constitute violations of water quality standards. This is especially the case for the criteria for dissolved oxygen, temperature, pH and fecal coliform. NPDES permits and Best Management Practices will be the primary mechanisms for ensuring that the discharges will not create a harmful situation.

EPA dissolved oxygen criteria are used to address these situations. Alternative EPA limits are defined as 90 percent of the naturally occurring dissolved oxygen concentration at critical conditions (USEPA, 1986).

> Where natural conditions alone create dissolved oxygen concentrations less than 110 percent of the applicable criteria means or minima or both, the minimum acceptable concentration is 90 percent of the natural concentration.

Accordingly, if the naturally occurring DO exceeds GA EPD numeric limits at critical conditions, then the GA EPD numeric limits apply. If naturally occurring DO is lower than the GA EPD numeric limits, then 90% of the natural DO will become the minimum allowable.

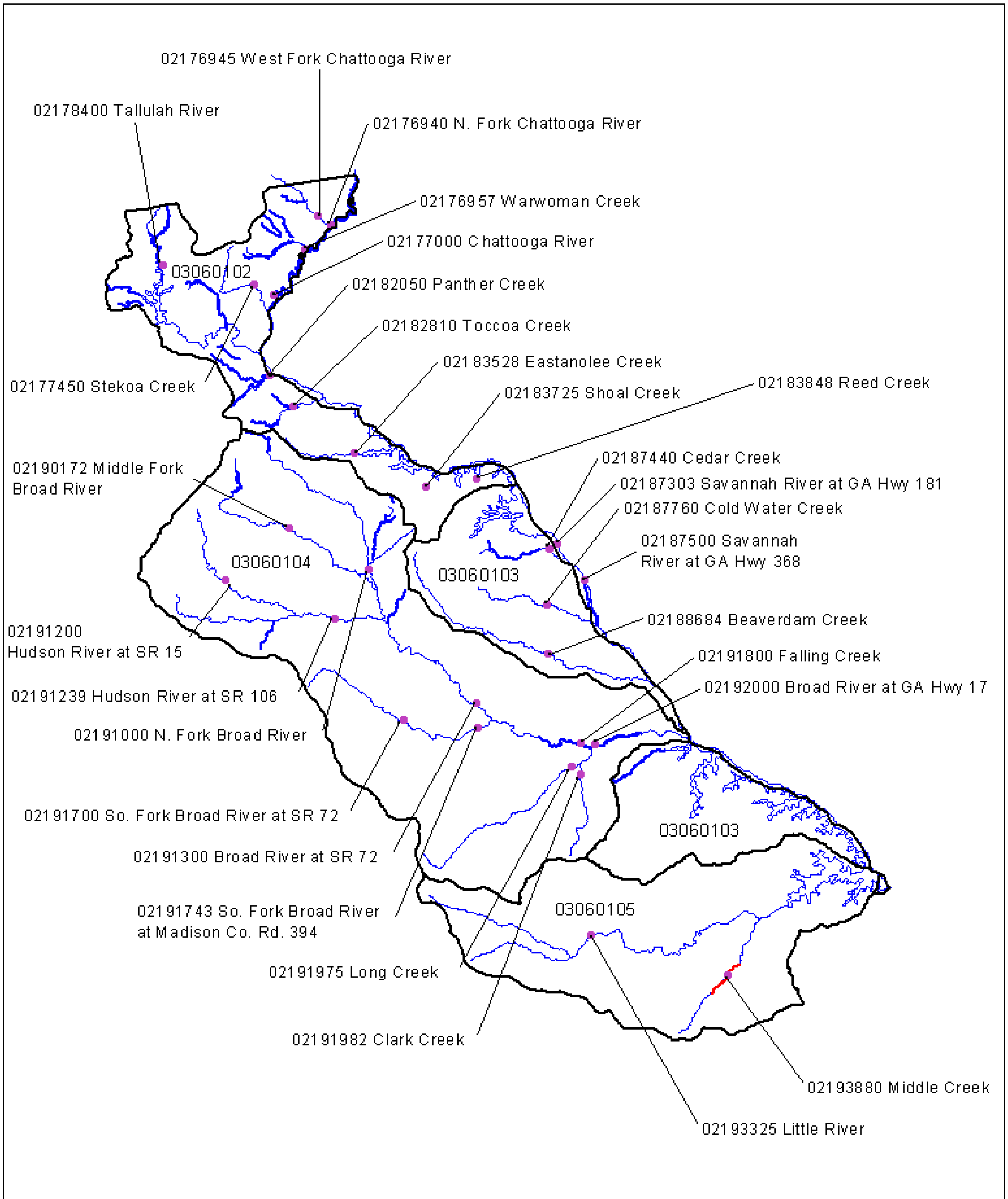
2.0 WATER QUALITY ASSESSMENT

During 2002, the United States Geological Survey (USGS) collected water quality data at fifty-three (53) USGS Stations in the Savannah River Basin. Figure 3 shows the GA EPD/USGS water quality and USGS flow stations that were sampled during 2002. Of these, a total of seven stations had DO standard violations requiring 303(d) listing of the corresponding stream segments in 2002. TMDLs were previously developed for the stream segments corresponding to four of these seven stations. Appendix A provides the water quality data for the three remaining stations corresponding with the listed segments in this TMDL document, and includes flow, DO, temperature, 5-day biochemical oxygen demand, and ammonia data.

In general, these data show that low dissolved oxygen values usually occurred during the summer months as shown in Figure 4. Furthermore, these values were usually limited to headwater streams where the drainage areas are relatively small and dry weather flows are low, intermittent, or zero. In larger watersheds where the flows are higher, the dissolved oxygen concentrations usually met the minimum standard of 4.0 mg/L and the daily average of 5.0 mg/L.

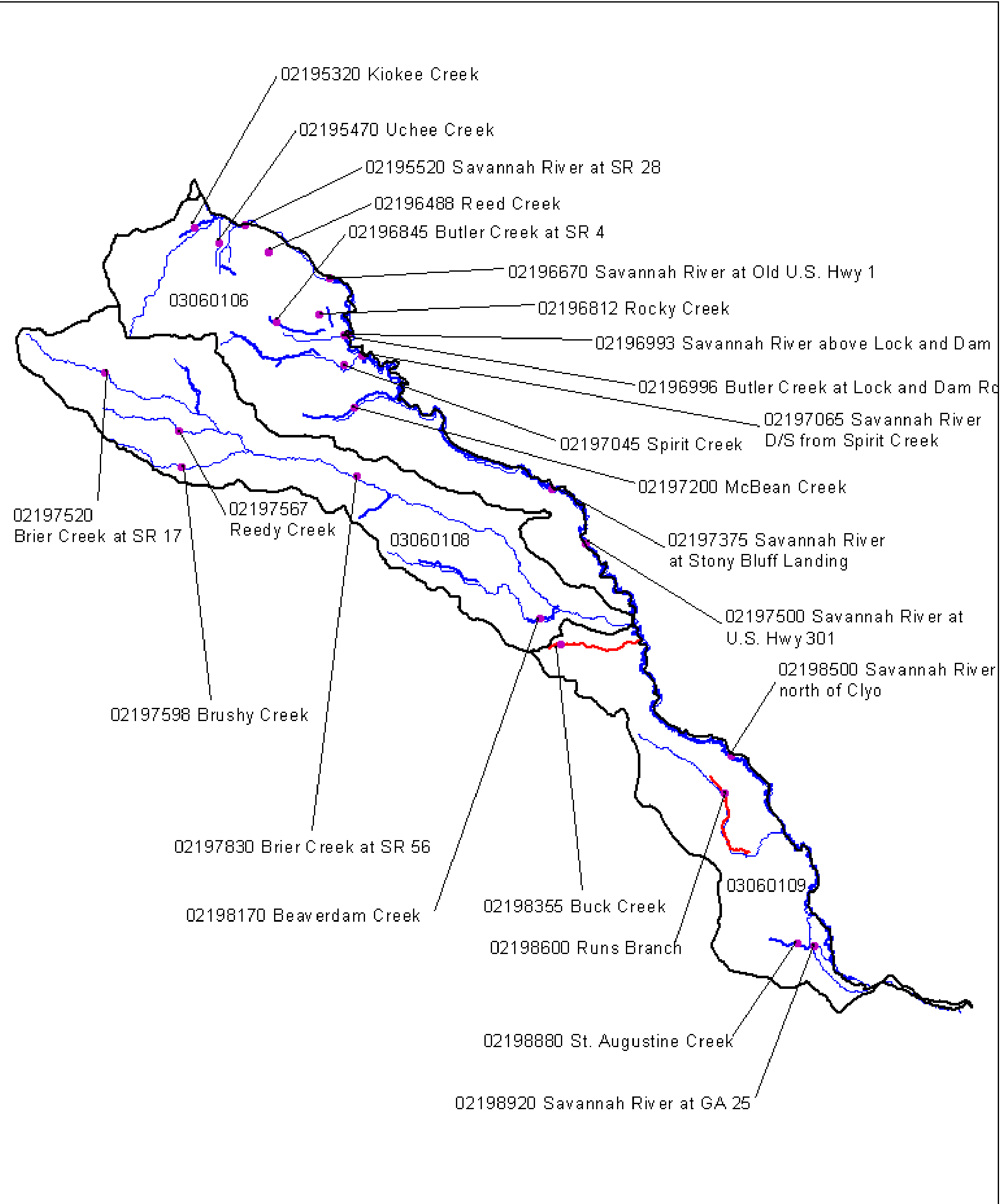
All field data relevant to the Savannah River Basin were compiled by GA EPD and included in electronic database files. The data are managed using either the Water Resources Database (WRDB), a software database that was developed by GA EPD or the EXCEL database management software. Project data file(s) contain the following information:

1. Historic trend monitoring data through 2002;
2. 2002 GA EPD/USGS water quality data; and
3. Historic USGS daily average flow data through December 31, 2002.



TMDL Evaluation - Dissolved Oxygen
Savannah River Basin

Figure 3a. 2002 USGS Water Quality Monitoring Stations Located in the Savannah River Basin



TMDL Evaluation - Dissolved Oxygen Savannah River Basin	Figure 3b. 2002 USGS Water Quality Monitoring Stations Located in the Savannah River Basin

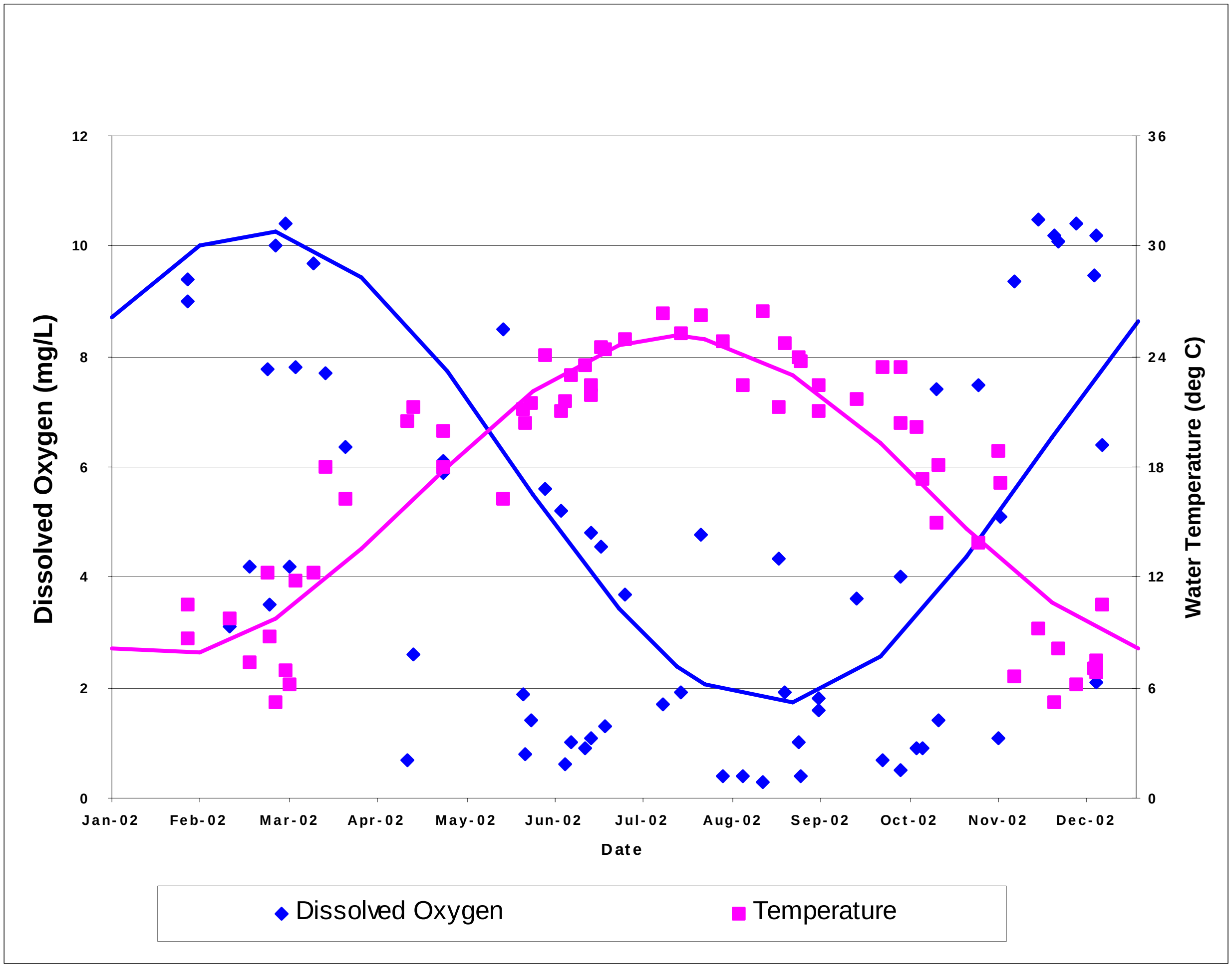


Figure 4. 2002 Dissolved Oxygen and Temperature Data for the Savannah River Basin Monitoring Stations

3.0 SOURCE ASSESSMENT

An important part of the TMDL analysis is the identification of potential source categories. Sources are broadly classified as either point or nonpoint sources. A point source is defined as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. Nonpoint sources are diffuse, and generally, but not always, involve accumulation of oxygen demanding substances on land surfaces that wash off as a result of storm events.

3.1 Point Source Assessment

Title IV of the Clean Water Act establishes the National Pollutant Discharge Elimination System (NPDES) permit program. Basically, there are two categories of NPDES permits: 1) municipal and industrial wastewater treatment facilities, and 2) regulated storm water discharges.

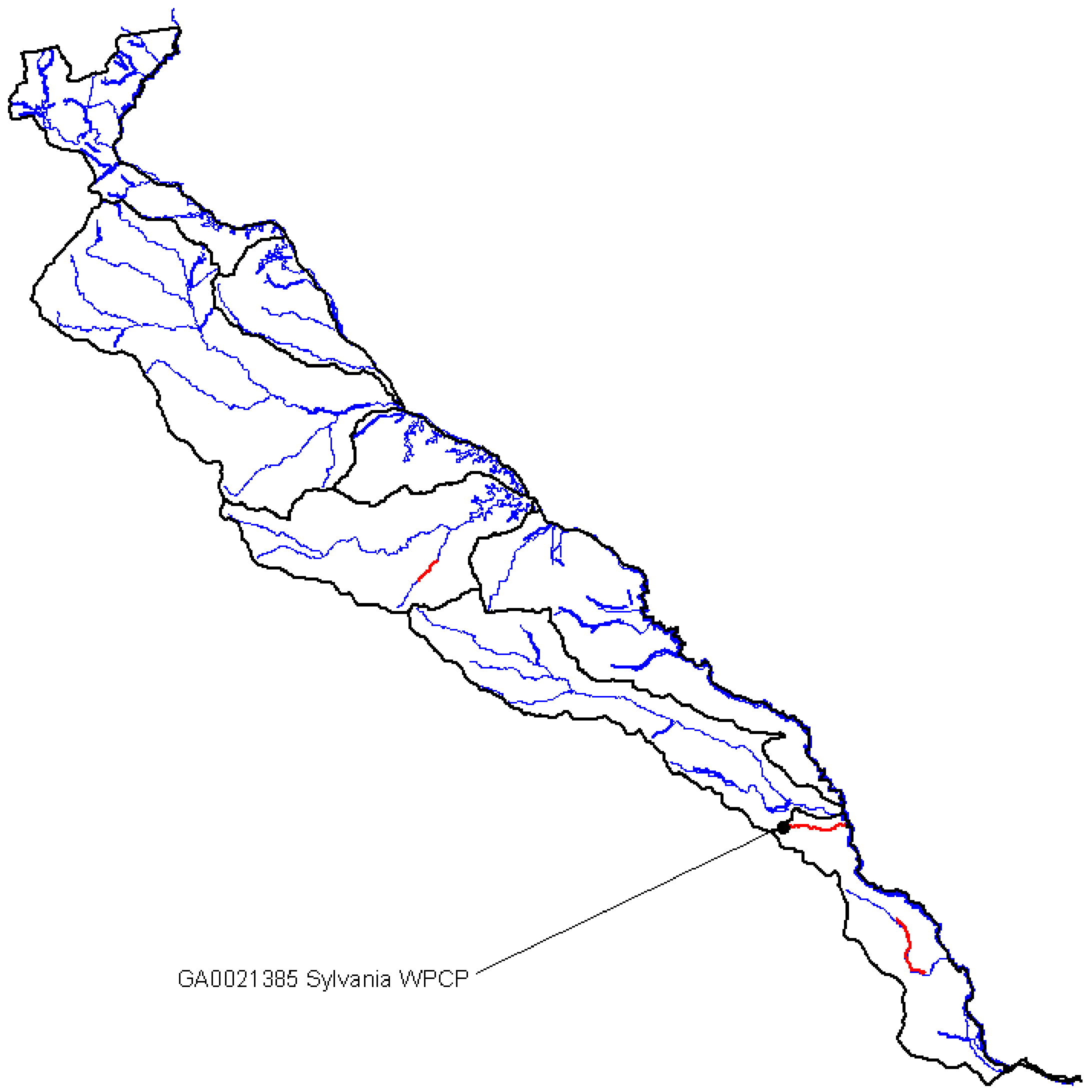
3.1.1 Wastewater Treatment Facilities

In general, industrial and municipal wastewater treatment facilities have NPDES permits with effluent limits. These permit limits are either based on federal and state effluent guidelines (technology-based limits) or water quality standards (water quality-based limits).

EPA has developed technology-based limits, which establish a minimum standard of pollution control for municipal and industrial discharges without regard for the quality of the receiving waters. These are based on Best Practical Control Technology Currently Available (BPT), Best Conventional Control Technology (BCT), and Best Available Technology Economically Achievable (BAT). The level of control required by each facility depends on the type of discharge and the pollutant.

EPA and the States have also developed numeric and narrative water quality standards. Typically, these standards are based on the results of aquatic toxicity tests and/or human health criteria and include a margin of safety. Water quality-based effluent limits are set to protect the receiving stream. These limits are based on water quality standards that have been established for a stream based on its intended use and the prescribed biological and chemical conditions that must be met to sustain that use.

Municipal and industrial wastewater treatment facilities' discharges may contribute oxygen-demanding substances to the receiving waters. There is one NPDES permitted discharge with effluent limits for oxygen consuming substances identified in the Savannah River Basin watershed upstream from a listed segment. This discharge is classified as major, with a discharge of 1.0 million gallons per day (MGD) or more. Figure 5 provides the location of the NPDES discharge and Table 3 provides the permitted flow, as well as the 5-day Biochemical Oxygen Demand (BOD_5), ammonia (NH_3), and DO concentrations for the municipal treatment facility.



TMDL Evaluation - Dissolved Oxygen Savannah River Basin	Figure 5. Location of the NPDES Discharge in the Savannah River Basin

Table 3. NPDES Facility in the Savannah River Basin

Facility Name	NPDES Permit No.	Receiving Stream	NPDES Permit Limits			
			Average Monthly Flow (MGD)	Average Monthly BOD_5 (mg/L)	Average Monthly NH_3 (mg/L)	Minimum DO (mg/L)
Lower Savannah Basin (HUC 03060109)						
Sylvania WPCP	GA0021385	Buck Creek	1.51	30	2	5

Combined sewer systems convey a mixture of raw sewage and storm water in the same conveyance structure to the wastewater treatment plant. These are considered a component of municipal wastewater treatment facilities. When the combined sewage and storm water exceed the capacity of the wastewater treatment plant, the excess is diverted to a combined sewage overflow (CSO) discharge point. There are no permitted CSO outfalls in the Savannah River Basin.

3.1.2 Regulated Storm Water Discharges

Some storm water runoff is covered under the NPDES Permit Program. It is considered a diffuse source of pollution. Unlike other NPDES permits that establish end-of-pipe limits, storm water NPDES permits establish controls “to the maximum extent practicable” (MEP). Currently, regulated storm water discharges that may contain oxygen demanding substances consist of those associated with industrial activities, including construction sites one acre or greater, and large, medium, and small municipal separate storm sewer systems (MS4s) that serve populations of 50,000 or more.

Storm water discharges associated with industrial activities are currently covered under a General Storm Water NPDES Permit. This permit requires visual monitoring of storm water discharges, site inspections, implementation of BMPs, and record keeping.

Storm water discharges from MS4s are very diverse in pollutant loadings and frequency of discharge. At present, all cities and counties within the state of Georgia that had a population of greater than 100,000 at the time of the 1990 Census are permitted for their storm water discharge under Phase I. This includes 60 permittees, with about 45 located in the greater Atlanta metro area. Table 4 lists those counties and communities located in the Savannah River Basin that are covered by the Phase I General Storm Water Permits.

Table 4. Phase I Permitted MS4s in the Savannah River Basin

Name	Permit No.	Watershed
Augusta – Richmond County	GAS000200	Savannah
Bloomingdale	GAS000207	Savannah
Chatham County	GAS000206	Ogeechee, Savannah
Garden City	GAS000208	Ogeechee, Savannah
Pooler	GAS000209	Ogeechee, Savannah
Port Wentworth	GAS000210	Savannah
Savannah	GAS000205	Ogeechee, Savannah
Tybee	GAS000212	Ogeechee, Savannah

Source: NonPoint Source Program, GA EPD, Atlanta, Georgia, 2003.

Phase I MS4 permits require the prohibition of non-storm water discharges (i.e., illicit discharges) into the storm sewer systems and controls to reduce the discharge of pollutants to the maximum extent practicable, including the use of management practices, control techniques and systems, as well as design and engineering methods (Federal Register, 1990). A site-specific Storm Water Management Plan (SWMP) outlining appropriate controls is required by and referenced in the permit.

As of March 10, 2003, small MS4s serving urbanized areas are required to obtain a storm water 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 at least 1,000 people per square mile. Thirty counties and 56 communities within the state of Georgia are permitted under the Phase II regulations. Table 5 lists those counties and communities located in the Savannah River Basin that are covered by the Phase II General Storm Water Permit, GAG610000.

Table 5. Phase II Permitted MS4s in the Savannah River Basin

Permitee	Watershed
Augusta – Columbia County	Savannah
Grovetown	Savannah
Hephzibah	Savannah

Source: NonPoint Source Program, GA EPD, Atlanta, Georgia, 2004.

3.1.3 Confined Animal Feeding Operations

Confined livestock and confined animal feeding operations (CAFOs) are characterized by high animal densities. This results in large quantities of fecal material being contained in a limited area. Processed agricultural manure from confined hog, dairy cattle, and select poultry operations is generally collected in lagoons. It is then applied to pastureland and cropland as a fertilizer during the growing season, at rates that often vary monthly. Runoff during storm events may carry surface residual containing oxygen demanding substances to nearby surface waters.

In 1990, the State of Georgia began registering CAFOs. Many of the CAFOs were issued land application or NPDES permits for treatment of wastewaters generated from their operations. The type of permit issued depends on the operation size (i.e., number of animal units). Table 6 presents the swine and non-swine (primarily dairies) CAFOs located in the Savannah River Basin that are registered or have land application permits.

Table 6. Registered CAFOs in the Savannah River Basin

Name	City	County	Animal Type	Total No. of Animals	Permit No.
Beasley Farms	Lavonia	Hart	Swine	1,960	GAU700000
Boling Farm	Homer	Banks	Swine	2,800	GA0038172
Boyceland Dairy Farm	Blythe	Burke	Dairy	480	GAU700000
Bridges Farm (J.M. Bridges)	Lexington	Oglethorpe	Swine	3,750	Pending
Dean Pierce	Stephens	Oglethorpe	Swine	3,840	GA0038229
Gold Kist Pork Stephens Gilt Center	Stephens	Oglethorpe	Swine	1,600	GAU700000
Harmony Grove Dairy Farm, L.L.C.	Hephzibah	Burke	Dairy	650	GAU700000
Harmony Grove Dairy, L.L.C.	Waynesboro	Burke	Dairy	950	GAG930000
Hillcrest Farms Inc.	Dearing	McDuffie	Dairy	340	GAU700000
Hudson Farms	Elberton	Elbert	Swine	4,000	GA0037915
Indian Creek Farm	Lexington	Oglethorpe	Swine	1,200	GAU700000
Kinder Dairy	Royston	Hart	Dairy	400	GAU700000
Lee Arrendale State Prison	Alto	Banks	Swine	4,000	GA0038245
Martin Dairy Farm	Bowersville	Hart	Dairy	600	GAU700000
Mossland Farms, Inc.	Stephens	Oglethorpe	Swine	2,475	GAU700000
Smith Dairy Farms Inc.	Rayle	Wilkes	Dairy	750	GAG930007
Smith's Egg Farm	Lavonia	Franklin	Poultry	170,000	GAG930002
Still Water Farm	Danielsville	Madison	Swine	1,300	GAU700000
Stocks Farms Inc.	Crawford	Oglethorpe	Swine	1,950	GAU700000
Taliaferro Co. Farm L.L.C.	Sharon	Taliaferro	Swine	2,450	GAU700000
Thompson Brother's Dairy	Warrenton	Warren	Dairy	250	GAU700000
Twin Line Dairies	Dewey Rose	Elbert	Dairy	1,000	GAG930001
Walker Turkey Farm, Inc.	Lexington	Oglethorpe	Swine	3,750	Pending
Whitaker Farm	Harlem	McDuffie	Dairy	300	GAU700000

Source: Permitting Compliance and Enforcement Program, GA EPD, Atlanta, Georgia, 2004

3.2 Nonpoint Source Assessments

In general, nonpoint sources cannot be identified as entering a waterbody through a discrete conveyance at a single location. Typical nonpoint sources of oxygen demanding substances come from materials being washed into the rivers and streams during storm events. In 2002, many streams in the Savannah River Basin were dry, or had ponded areas and stagnant pools as a result of a five-year drought in Georgia. Due to the lack of rainfall during the summer of 2002, stormwater did not contribute to significant wash off of materials into the streams. Constituents that may have washed off of land surfaces in previous months or years had either: 1) flushed out of the system along with the water column flow; or 2) settled out and became part of the stream channel bottom.

In this manner, historic wash off of settleable materials accumulates and exerts sediment oxygen demand (SOD). Constituents of concern from surface washoff include the fractions of ammonia and BOD_5 that become an integral part of channel bottom sediments, thus becoming a potential source of SOD. Table 2 provides the land cover distributions for the listed Savannah River watersheds. These data show that the watersheds are predominately forested, with approximately 54.6 percent (ranging from 42.9 to 78.0 percent) of forest land use. Agriculture is the next predominate land use, with approximately 20.1 percent row crops (ranging from 10.0 to 29.7 percent). Approximately 15.1 percent (ranging from 1.1 to 28.1 percent) of the land use in these watersheds is woody wetlands. Transitional land use makes up approximately 4.8 percent (ranging from 3.8 to 6.0 percent) of these watersheds.

In addition to nonpoint sources of SOD associated with land disturbing activities, most of the streams in the Savannah River Basin receive significant natural contributions of oxygen demanding organic materials from local wetlands and forested stream corridors. The following sources of naturally occurring organic materials have been identified:

- Adjacent wetlands, swamps, and marshes with organically rich bottom sediments; and
- Direct leaf litterfall onto water surfaces and adjacent floodplains from overhanging trees and vegetation.

Leaf litterfall is a major contributor to the amount of dissolved organic matter in the stream water column and the amount of SOD being exerted. Many streams in southern Georgia are also referred to as “blackwater” streams because of highly colored humic substances leached from surrounding marshes and swamps. In addition, low dissolved oxygen in blackwater streams is very common in the summer months when the temperatures are high and the flows are low (Meyer, 1992). The oxygen demanding effects of leaf litterfall are reflected in two ways: 1) by lowering the DO saturation of water entering the channel from adjacent swampy areas caused by decaying vegetation; and 2) by increasing SOD associated with vegetation decaying on stream channel bottoms.

3.2.1 Land Application Systems

Many smaller communities use land application systems (LAS) for treatment of their sanitary wastewater. These facilities are required through LAS permits to treat all their wastewater by land application and are to be properly operated as non-discharging systems that contribute no runoff to nearby surface waters. However, runoff during storm events may carry surface residual containing oxygen demanding substances to nearby surface waters. Some of these facilities may also exceed the ground percolation rate when applying their wastewater, resulting in surface runoff. If not properly bermed, this runoff, which contains oxygen demanding substances, may discharge to nearby surface waters. In addition, water that percolates through the LAS and becomes groundwater that enters the stream as baseflow may contribute nutrient loads, which could promote the growth of aquatic plants in the stream. There are fifteen permitted LAS systems located in the Savannah River Basin (Table 7).

Table 7. Permitted Land Application Systems in the Savannah River Basin

LAS Name	County	Permit No.	Type	Flow (MGD)
Atlanta International Drag	Banks	GA02-023	Municipal	0.07
Banks County Industrial LAS	Banks	GA02-181	Municipal	0.045
Coastal Water & Sewer Co.	Effingham	GA02-234	Private	0.13
Columbia County Prison	Columbia	GA02-002	Municipal	0.01
Crider Poultry, Lincoln	Lincoln	GA01-570	Industrial	0.11
Dearing LAS	McDuffie	GA02-007	Municipal	0.09
Fieldale Corp.	Stephens	GA01-369	Industrial	
Franklin County LAS	Franklin	GA02-065	Municipal	0.075
Grovetown LAS	Columbia	GA02-222	Municipal	0.58
Hartwell LAS	Hart	GA02-114	Municipal	1.75
Norwood LAS	Warren	GA02-258	Municipal	0.05
Savannah Reuse LAS	Chatham	GA02-198	Municipal	2.0
Springfield LAS	Effingham	GA0020770	Municipal	0.5
Terra Renewal Services	Elbert	GA01-507	Industrial	
Thomson LAS	McDuffie	GA02-252	Municipal	0.171
Twin Dairies, Inc.	Elbert	GA01-436	Industrial	0.01

Source: Permitting Compliance and Enforcement Program, GA EPD, Atlanta, Georgia, 2004

4.0 TECHNICAL APPROACH

The first step of the technical approach for these TMDLs was to select the models that can be effectively used to analyze the Savannah River DO resources. After appropriate models are selected, data is gathered to develop and calibrate the models. The calibrated models are then used to establish the TMDL during critical conditions. The modeling approach is described in the following sections.

4.1 Model Selection and Structure

Various analyses were performed to correlate the measured low DO concentrations to basic causes such as point and nonpoint contributions, flow conditions, stream and watershed characteristics, seasonal temperature effects, and others. From these analyses, the low DO values were found to coincide with low or zero flows, slow stream velocities, shallow water depths, and high temperatures. Inflows of very low DO waters from adjacent marshes and forested swamps compounded the situation. Since the impairments noted in 2002 occurred during sustained periods of low flows, a steady-state modeling approach was selected.

USGS quadrangle maps and navigational maps along with Arcview and MapInfo spatial graphics files were used to develop drainage areas, stream lengths, bed slopes, segment geometry, and other physical input data for each model. Appendix B provides a summary of each model structure.

4.1.1 Georgia DOSAG

Georgia DOSAG is a one-dimensional steady state water quality model that was developed by the GA EPD. The model was selected for the following reasons:

- It conforms to GA EPD standard practices for developing wasteload allocations;
- It works well for low flow and high temperature conditions;
- It can be developed with a limited dataset; and
- It is able to handle branching tributaries and both point and nonpoint source inputs.

Georgia DOSAG computes DO using an enhanced form of the Streeter-Phelps equation (Thomann and Mueller, 1987). The model applies the equation to each stream reach over small incremental distances. The model also provides a complete spatial view of a system, upstream to downstream. This allows the modeler to understand the important differences in stream behavior at various locations throughout a basin.

Georgia DOSAG consists of a mainstem and may include up to six branches. DOSAG can also include tributaries, water intakes, and dams, as well as point sources. A total of three DOSAG models were developed to represent the three freshwater listed segments in the Savannah River Basin. The models and the listed segments they include are as follows:

- Buck Creek
- Middle Creek
- Runs Branch (Ebenezer Creek)

4.2 Model Calibration

The model calibration period was determined from an examination of the USGS 2002 water quality data for the listed segments. The data examined included streamflow, DO, water temperature, BOD_5, and ammonia. The combination of the lowest flow, lowest DO, and highest water temperature defined the critical modeling period. For the listed segments, June through September was found to be the critical period. The calibration models were run to simulate an average DO from this period.

The average summer DO and average annual BOD_5 and ammonia values were extracted from the 2002 dataset for each sampling station. Table 8 provides a summary of the 2002 monitoring data used to develop data for the model calibration. Headwater and tributary water quality boundaries were developed from these instream field data, expected low DO saturation values (Meyer, 1992), and GA EPD standard modeling practices (GA EPD, 1978). BOD_5 was converted to Ultimate Carbonaceous Biochemical Oxygen Demand ($CBOD_U$) by multiplying by an f-ratio of 2.5 (GA EPD, 1978), and ammonia was converted to Ultimate Nitrogenous Biochemical Oxygen Demand ($NBOD_U$) by multiplying by the stoichiometric conversion factor of 4.57. Water temperatures were varied across the basin in accordance with the summer sampling data.

Table 8. Summary of the 2002 Monitoring Data for the Savannah River Basin

Monitoring Station	Avg Annual BOD_5 (mg/L)	Avg Annual NH_3 (mg/L)	Avg Summer Flow (cfs)	Avg Summer DO (mg/L)	Max Summer Temperature (deg C)
Little River Basin					
Middle Creek 02193880	1.0	0.13	4.2	3.56	25.3 (July)
Lower Savannah River Basin					
Buck Creek 02198355	4.4	1.21	-	0.75	26.5 (Sept)
Runs Branch 02198600	2.0	0.05	89.7	2.74	26.2 (July)

Average monthly discharge flows, BOD_5, NH_3, and DO concentrations for the discharges were obtained from 2002 Discharge Monitoring Reports (DMRs). These data were input into the calibration model. BOD_5 was converted to $CBOD_U$ by multiplying by an f-ratio of 2 if the BOD_5 is greater than 20 mg/L and an f-ratio of 3 if the BOD_5 is 20 mg/L or less (GA EPD, 1978). Ammonia was converted to $NBOD_U$ by multiplying by 4.57. Table 9 provides a summary of the actual discharge from the Sylvania WPCP for calendar year 2002.

Table 9. Summary of NPDES Discharges During 2002

Facility Name	NPDES Permit No.	Actual Discharge for Calendar Year 2002			
		Flow (MGD)	BOD_5 (mg/L)	NH_3 (mg/L)	DO (mg/L)
Sylvania WPCP	GA0021385	0.67	12.8	0.45	6.7

In shallow streams, SOD is an important part of the oxygen budget. However, there are no field SOD measurements in the Savannah River Basin. In the South 4 Basins, there are several SOD measurements that ranged from 0.9 to 1.9 g/m^2/day. An examination of South 4

SOD results was performed in order to develop realistic SOD values that could be applied to the Savannah DOSAG models.

Results from the 1998 South 4 calibrated models of existing conditions were compiled and summarized. An average value of existing SOD was determined to be 1.35 g/m^2/day. This represented 12 models that had mixed land uses and varying degrees of point source activity. When the same 12 models were analyzed under natural conditions (assuming zero point source discharges and completely forested watersheds), SOD averaged 1.25 g/m^2/day. These two values were adopted for the Savannah models to represent SOD for: 1) mixed land uses, including agriculture; and 2) natural or totally forested watersheds, respectively. From this, the anthropogenic nonpoint source contributions, those caused by land disturbing activities, are accounted for in the 0.1 g/m^2/day difference between the two adopted SOD values.

Stream velocities were calculated using the soil equation based on either the Atlantic Coastal Flatwoods or Southern Coast Plain soil provinces coefficients. The kinetic rates and input parameters developed during model calibration are provided in Table 10. These parameters include the carbonaceous BOD (CBOD) decay rate, nitrogenous BOD (NBOD) decay rate, SOD rate, and the Tsivoglou reaeration coefficient used to determine stream reaeration.

Table 10. DOSAG Modeling Parameters

Parameter	Values
CBOD Decay Rate (1/day)	0.1
NBOD Decay Rate (1/day)	0.25
SOD (g/m^2/day)	1.25-1.35
Reaeration Coefficient	0.054

The Savannah River Basin DOSAG models were calibrated at locations where the USGS collected discrete water quality data during 2002. Appendix C provides the DO calibration curves plotted with the data from monitoring stations in the listed segments.

4.3 Critical Conditions Models

The critical conditions models were used to assess the dissolved oxygen standard and to determine if problems exist requiring regulatory intervention. Model critical conditions were developed in accordance with GA EPD standard practices (GA EPD, 1978).

For the three listed segments in the Savannah River Basin, only Middle Creek and Runs Branch had both water quality and daily flow data for the year 2002. Since low flow data were limited at best, low flow analyses of the available Savannah River Basin flow data were performed. Data from the adjacent long-term USGS gages were analyzed to determine 7-day, 10-year minimum flows (7Q10s). Productivity factors, in cubic feet per second (cfs) per square mile, were computed by dividing the 7Q10s by the watershed areas at the gages. Table 11 summarizes the low-flow analyses and Figure 6 shows the proximity of these USGS long-term gages to the listed stream segments. The 7Q10 productivity factors developed from the USGS data were used to develop model input for the Savannah River Basin DOSAG models by multiplying them by the listed segment watershed drainage areas.

Critical water temperatures were determined by examining the 2002 water quality data and the long-term trend monitoring data. Harmonic sine functions were developed for the historical data from all of the long-term monitoring stations. The highest summer-time temperature from either the 2002 water quality data or the harmonic fit was used to represent each of the listed segments.

Table 11. Low-Flow Analysis Summary for the Savannah River Basin

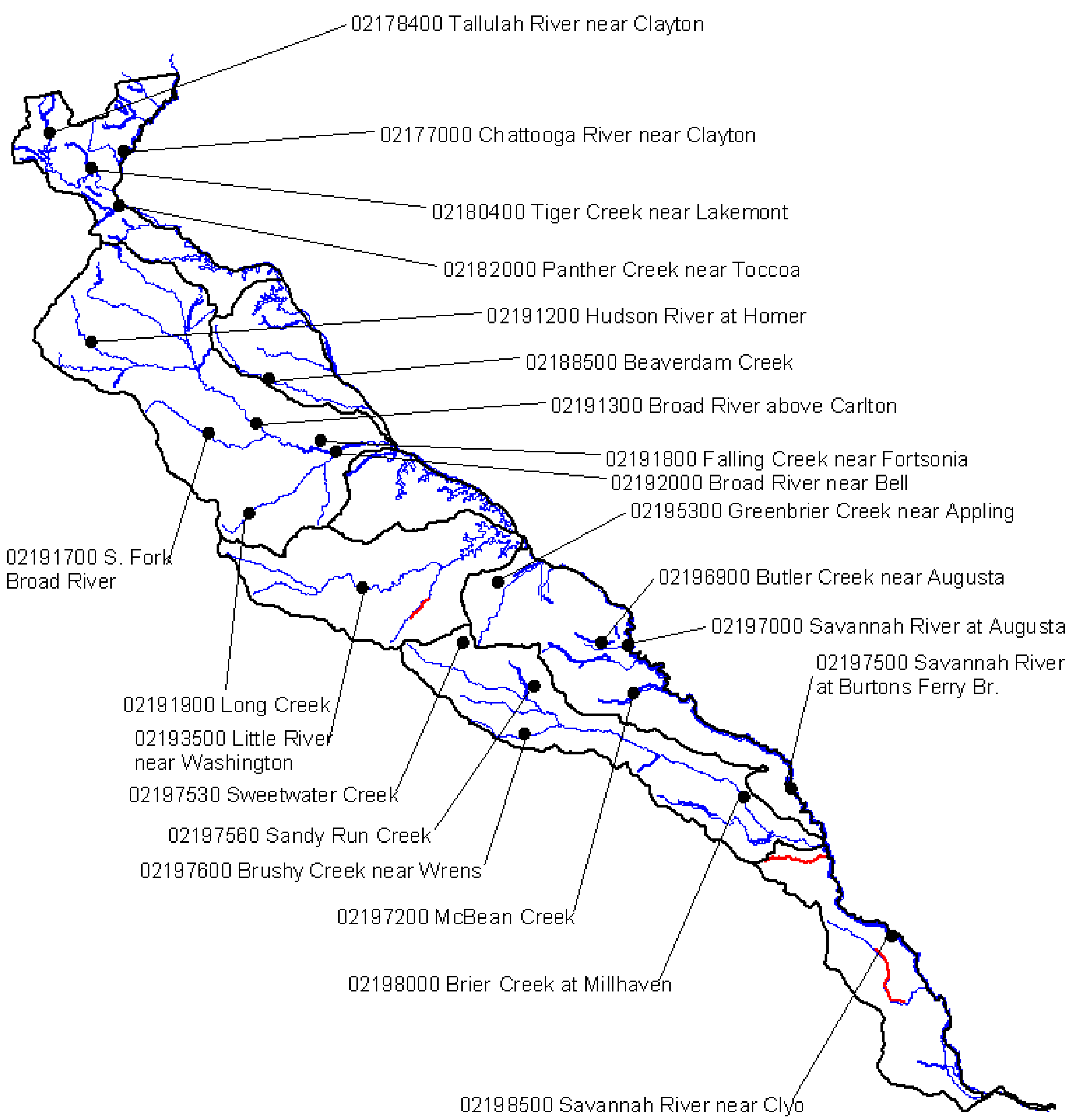
DO TMDL Segment	Drainage Area (sq. miles)	7Q10 (cfs)	Productivity Factor (cfs/sq. mile)
LITTLE RIVER HUC 03060105			
02193500 Little River near Washington	291	5.2	0.018
MIDDLE SAVANNAH HUC 03060106			
02195300 Greenbrier Creek near Appling	33	0.8	0.025
02196900 Butler Creek near Augusta	29	9.4	0.324
02197000 Savannah River at Augusta	7,508	5,400	0.719
02197200 McBean Creek	71	31	0.437
02197500 Savannah River at Burtons Ferry Br.	8,650	5,800	0.671
BRIER CREEK HUC 03060108			
02197530 Sweetwater Creek	7	0.2	0.030
02197560 Sandy Run Creek	33	12	0.364
02197600 Brushy Creek near Wrens	28	6	0.214
02198000 Brier Creek at Millhaven	646	115	0.178
LOWER SAVANNAH HUC 03060109			
02198500 Savannah River near Clyo	9,850	6,700	0.680

Source: Carter, R.F., E.H. Hopkins and H.A. Perlman, 1988

Point sources were incorporated into the critical conditions models at their current NPDES permit limits. For NPDES permits that do not have DO and/or ammonia limits, values of 2 mg/L and 17.4 mg/L were assumed, respectively. Water quality boundaries, the SOD rate, and all other modeling rates and constants were the same as those in the calibrated models.

4.4 Natural Conditions Models

For the natural conditions models, two changes were made to the critical conditions models. First, the SOD was changed from 1.35 g/m^2/ day to 1.25 g/m^2/day to reflect the change from mixed land uses to natural or completely forested land uses. Second, all point source discharges were completely removed from the model. All other model parameters remained the same. These models were used to determine the natural dissolved oxygen concentrations during critical conditions. These models predicted the natural dissolved oxygen concentrations, during the critical summer months, to be less than 5.0 mg/L. It is important to note: 1) even though DO was found to be low in the summer of 2002, the results are even lower at standard critical conditions; and 2) the summer of 2002 conditions are very close to critical conditions and compare favorably with the target of 90 percent of the natural DO standard. Results of natural conditions runs are plotted in the graphs in Appendix C along with the calibration and critical conditions results for comparison.



TMDL Evaluation - Dissolved Oxygen Savannah River Basin	Figure 6. Location of the USGS Low Flow Gaging Stations in the Savannah River Basin

5.0 TOTAL MAXIMUM DAILY LOADS

A TMDL is the amount of a pollutant that can be assimilated by the receiving waterbody without exceeding the applicable water quality standard. A TMDL is the sum of the individual waste load allocations (WLAs) from point sources and load allocations (LAs) from nonpoint sources, as well as the natural background (40 CFR 130.2) for a given waterbody. The TMDL must also include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the water quality response of the receiving water body (USEPA, 1991). TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measures. For oxygen demanding substances, this TMDL is expressed in lbs/day.

A TMDL can be expressed as follows:

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

This TMDL determines the allowable oxygen demanding loads to the listed segments in the Savannah River Basin. The following sections describe the various oxygen demanding sources which may contribute loads to the TMDL components.

5.1 Waste Load and Load Allocations

The WLA is the portion of the receiving water's loading capacity that is allocated to existing or future point sources. There is one NPDES permitted facility in the Savannah River watershed that affects instream dissolved oxygen. Waste load allocations are provided to the point sources from municipal wastewater treatment system. Table 11 lists the WLAs required to meet the target DO standard.

The Georgia DOSAG critical conditions models were used to determine the WLAs for the discharges upstream from the listed segments in order to meet the DO standards. Allocations are based on EPA Dissolved Oxygen Criteria, which states that if the natural dissolved oxygen is less than the standard, then only a 10 percent reduction in the natural condition is allowed. The target limits are defined as 90 percent of the naturally occurring dissolved oxygen concentration at critical conditions. Appendix C contains plots of the DO concentrations resulting from the TMDL loads versus the target DO Standard. Note that if the TMDL plot is higher than the target DO Standard plot, there is additional assimilative capacity in the stream available for future WLA.

When a wasteload allocation predicts the critical dissolved oxygen concentrations to be less 3.0 mg/L, the biological integrity of the stream will need to be evaluated. The biological evaluation should include a habitat assessment, aquatic macroinvertebrate community assessment, fish community assessment, and in-situ physical and chemical measurements. The most updated Standard Operating Procedures (SOP) should be used for the macroinvertebrate and fish assessments.

The TMDL will be used to assess permit renewals. If necessary, GA EPD may modify the WLAs during the NPDES permitting process. The assimilative capacity might not be fully allocated for all of the listed segments. Future wasteload allocations might be allowed if the discharge does not result in a concentration lower than 90 percent of the natural dissolved oxygen concentration during critical conditions. However, it should be noted that the SOD

Table 12. Savannah River Basin WLAs

Facility Name	NPDES Permit No.	Receiving Stream	NPDES Permit Limits			
			Average Monthly Flow (MGD)	Average Monthly BOD_5 (mg/L)	Average Monthly NH_3 (mg/L)	Minimum DO (mg/L)
Buck Creek						
Sylvania WPCP	GA0021024	Buck Creek	1.51	5	1	6

rates used in the TMDL allocation models were based on model predictions and may need to be verified before WLAs are implemented.

State and Federal Rules define storm water discharges covered by NPDES permits as point sources. However, storm water discharges are from diffuse sources and there are multiple storm water outfalls. Storm water sources (point and nonpoint) are different than traditional NPDES permitted sources in four respects: 1) they do not produce a continuous (pollutant loading) discharge; 2) their pollutant loading depends on the intensity, duration, and frequency of rainfall events, over which the permittee has no control; 3) the activities contributing to the pollutant loading may include the various allowable activities of others, and control of these activities is not solely within the discretion of the permittee; and 4) they do not incorporate wastewater treatment plants that control specific pollutants to meet numeric limits.

The intent of storm water NPDES permits is not to treat the water after collection, but to reduce the exposure of storm water to pollutants by implementing various controls. It would be infeasible and prohibitively expensive to control pollutant discharges from each storm water outfall. Therefore, storm water NPDES permits require the establishment of controls or BMPs to reduce pollutants entering the environment.

The Georgia DOSAG Savannah River Basin models were run under critical conditions, assuming 7Q10 flows and dry weather conditions. Because the critical conditions occur when there are no storm events, no numeric allocation is given to the waste load allocations from storm water discharges associated with MS4s (WLAsw).

The nonpoint source loads for the existing LA and TMDL were computed from the model boundary conditions, which include the stream, tributary, and headwater model boundaries under critical conditions. The partitioning of allocations between point (WLA) and nonpoint (LA) sources shown in Table 13 is based on modeling results and professional judgment.

Buck Creek has been found to have high background BOD_5 and ammonia levels. Additional monitoring should be conducted in this stream in order to determine the source of these elevated levels.

5.2 Seasonal Variation

The low flow, high temperature critical conditions incorporated in this TMDL are assumed to represent the most critical design conditions and to provide year-round protection of water quality. This TMDL is expressed as a total load during the critical low flow period.

5.3 Margin of Safety

The MOS is a required component of TMDL development. As specified by section 303(d) of the CWA, the margin of safety must account for any lack of knowledge concerning the relationship between effluent limitations and water quality. There are two basic methods for incorporating the MOS: 1) implicitly incorporate the MOS using conservative model assumptions to develop allocations, or 2) explicitly specify a portion of the TMDL as the MOS and use the remainder for allocations.

For this TMDL, the MOS was implicitly incorporated in the use of the following conservative modeling assumptions:

- Critical 7Q10 flows;
- Hot summer temperatures;
- Conservative reaction rates; and
- The assumption that all point sources continuously discharge at their NPDES permit limits for the same critical period.

Table 13. TMDL Loads for the Savannah River Basin under Critical Conditions

Stream Segment	WLA (lbs/day)	WLAsw (lbs/day)	LA (lbs/day)	TMDL (lbs/day)
Buck Creek	246	NA	265	511
Middle Creek	-	NA	22.9	22.9
Runs Branch (Ebenezer Creek)	-	NA	37.7	37.7

Note: TMDL expressed as Ultimate Oxygen Demand (UOD), which includes the Carbonaceous Biochemical Oxygen Demand (CBOD) and the Nitrogenous Biochemical Oxygen Demand (NBOD).
NA = no storm water discharges associated with MS4s contributing to the listed segment during critical conditions

6.0 RECOMMENDATIONS

6.1 Monitoring

Water quality monitoring is conducted at a number of locations across the State each year. The GA EPD has adopted a basin approach to water quality management that divides Georgia's major river basins into five groups. This approach provides for additional sampling work to be focused on one of the five basin groups each year, and offers a five-year planning and assessment cycle (GA EPD, 1996). The Savannah and Ogeechee River Basins were the basins of focused monitoring in 2002 and will again receive focused monitoring in 2007.

The revised TMDL Implementation Plans for the listed streams in the Savannah River Basin will include monitoring plans which describe pertinent current or impending water quality monitoring activities, recommended future monitoring activities, and suggest procedures for coordinating those activities.

6.2 Reasonable Assurance

The GA EPD is responsible for administering and enforcing laws to protect the waters of the State. The TMDL implementation will be conducted using a phased approach. Permitted discharges will be regulated through the NPDES permitting process described in this report. The permittee may be required to perform temperature and dissolved oxygen monitoring upstream and downstream of the point source. The target WLA reduction needed may not be implemented until sufficient data has been collected to verify the model assumptions. If it is determined that the model assumptions need to be modified, the target WLA reductions will be re-evaluated based on the new data collected during critical conditions, and the TMDL will be reallocated.

The GA EPD is the lead agency for implementing the State's Nonpoint Source Management Program. Regulatory responsibilities that have a bearing on nonpoint source pollution include establishing water quality standards and use classifications, assessing and reporting water quality conditions, and regulating land use activities that may affect water quality. Georgia is working with local governments, agricultural, and forestry agencies such as the Natural Resources Conservation Service, the Georgia Soil and Water Conservation Commission, and the Georgia Forestry Commission, to foster the implementation of BMPs that address nonpoint source pollution. In addition, public education efforts are being targeted to individual stakeholders to provide information regarding the use of BMPs to protect water quality.

6.3 Public Participation

A thirty-day public notice period is being provided for this TMDL. During that time, the availability of the TMDL will be publicly noticed, a copy of the TMDL will be provided upon request, and the public is invited to provide comments on the TMDL.

7.0 INITIAL TMDL IMPLEMENTATION PLAN

GA EPD has coordinated with EPA to prepare this Initial TMDL Implementation Plan for this TMDL. GA EPD has also established a plan and schedule for development of a more comprehensive implementation plan after this TMDL is established. GA EPD and EPA have executed a Memorandum of Understanding that documents the schedule for developing the more comprehensive plans. This Initial TMDL Implementation Plan includes a list of best management practices and provides for an initial implementation demonstration project to address one of the major sources of pollutants identified in this TMDL while State and/or local agencies work with local stakeholders to develop a revised TMDL implementation plan. It also includes a process whereby GA EPD and/or Regional Development Centers (RDCs) or other GA EPD contractors (hereinafter, "GA EPD Contractors") will develop expanded plans (hereinafter, "Revised TMDL Implementation Plans").

This Initial TMDL Implementation Plan, written by GA EPD and for which GA EPD and/or the GA EPD Contractor are responsible, contains the following elements.

1. NPDES permit discharges are a primary source of excessive pollutant loading, where they are a factor. Any wasteload allocations in this TMDL will be implemented in the form of water-quality based effluent limitations in NPDES permits issued under CWA Section 402. [See 40 C.F.R. § 122.44(d)(1)(vii)(B)]. Nonpoint sources are the secondary cause of excessive pollutant loading in most cases. EPA has identified a number of management strategies for the control of nonpoint sources of pollutants, representing some BMPs. The "Management Measure Selector Table" shown below identifies these management strategies by source category and pollutant.

2. GA EPD and the GA EPD Contractor will select and implement one or more BMP demonstration projects for each River Basin. The purpose of the demonstration projects will be to evaluate by River Basin and pollutant parameter the site-specific effectiveness of one or more of the BMPs chosen. GA EPD intends that the BMP demonstration project be completed before the Revised TMDL Implementation Plan is issued. The BMP demonstration project will address the major pollutant categories of concern for the respective River Basin as identified in the TMDLs. The demonstration project need not be of a large scale, and may consist of one or more measures from the Table or equivalent BMP measures proposed by the GA EPD Contractor and approved by GA EPD. Other such measures may include those found in EPA's "*Best Management Practices Handbook*," the *"NRCS National Handbook of Conservation Practices*," or any similar reference, or measures that the volunteers, etc., devise that GA EPD approves. If for any reason the GA EPD Contractor does not complete the BMP demonstration project, GA EPD will take responsibility for doing so.

3. As part of the Initial TMDL Implementation Plan, the GA EPD brochure entitled *"Watershed Wisdom -- Georgia's TMDL Program*" will be distributed by GA EPD to the GA EPD Contractor for use with appropriate stakeholders for this TMDL. Also, a copy of the video of that same title will be provided to the GA EPD Contractor for its use in making presentations to appropriate stakeholders on TMDL Implementation Plan development.

4. If for any reason the GA EPD Contractor does not complete one or more elements of a Revised TMDL Implementation Plan, GA EPD will be responsible

for getting that (those) element(s) completed, either directly or through another contractor.

5. Revised TMDL Implementation Plans will be completed and accepted by EPD by the end of June 2007.

6. The GA EPD Contractor helping to develop the Revised TMDL Implementation Plan, in coordination with GA EPD, will work on the following tasks involved in converting the Initial TMDL Implementation Plan to a Revised TMDL Implementation Plan:

   A. Generally characterize the watershed;
   B. Identify stakeholders;
   C. Verify the present problem to the extent feasible and appropriate (e.g., local monitoring);
   D. Identify probable sources of pollutant(s);
   E. For the purpose of assisting in the implementation of the load allocations of this TMDL, identify potential regulatory or voluntary actions to control pollutant(s) from the relevant nonpoint sources;
   F. Determine measurable milestones of progress;
   G. Develop a monitoring plan, taking into account available resources, to measure effectiveness; and
   H. Complete and submit to GA EPD the Revised TMDL Implementation Plan.

7. The public will be provided an opportunity to participate in the development of the Revised TMDL Implementation Plan and to comment on it before it is finalized.

8. The Revised TMDL Implementation Plan will supersede this Initial TMDL Implementation Plan once GA EPD accepts the Revised TMDL Implementation Plan.

Management Measure Selector Table

Land Use	**Management Measures**	*Fecal Coliform*	*Dissolved Oxygen*	*pH*	*Oxygen demanding substances*	*Temperature*	*Toxicity*	*Mercury*	*Metals (copper, lead, zinc, cadmium)*	*PCBs, toxaphene*
Agriculture	1. Oxygen demanding substances & Erosion Control	_	_		_	_				
	2. Confined Animal Facilities	_	_							
	3. Nutrient Management	_	_							
	4. Pesticide Management		_							
	5. Livestock Grazing	_	_		_	_				
	6. Irrigation		_		_	_				
Forestry	1. Preharvest Planning				_	_				
	2. Streamside Management Areas	_	_		_	_				
	3. Road Construction & Reconstruction		_		_	_				
	4. Road Management		_		_	_				
	5. Timber Harvesting		_		_	_				
	6. Site Preparation & Forest Regeneration		_		_	_				
	7. Fire Management	_	_	_	_	_				
	8. Revegetation of Disturbed Areas	_	_	_	_	_				
	9. Forest Chemical Management		_			_				
	10. Wetlands Forest Management	_	_	_		_		_		

Land Use	**Management Measures**	*Fecal Coliform*	*Dissolved Oxygen*	*pH*	*Oxygen demanding substances*	*Temperature*	*Toxicity*	*Mercury*	*Metals (copper, lead, zinc, cadmium)*	*PCBs, toxaphene*
Urban	1. New Development	–	–		–	–			–	
	2. Watershed Protection & Site Development	–	–		–	–		–	–	
	3. Construction Site Erosion and Oxygen demanding substances Control		–		–	–				
	4. Construction Site Chemical Control		–							
	5. Existing Developments	–	–		–	–			–	
	6. Residential and Commercial Pollution Prevention	–	–							
Onsite Wastewater	1. New Onsite Wastewater Disposal Systems	–	–							
	2. Operating Existing Onsite Wastewater Disposal Systems	–	–							
Roads, Highways and Bridges	1. Siting New Roads, Highways & Bridges	–	–		–	–			–	
	2. Construction Projects for Roads, Highways and Bridges		–		–	–				
	3. Construction Site Chemical Control for Roads, Highways and Bridges		–							
	4. Operation and Maintenance-Roads, Highways and Bridges	–	–			–			–	

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APPENDIX A

Water Quality Data

2002 Monitoring Water Quality Stations

Stream Segment	Location	USGS Monitoring Station No.	Monitoring Station Description
Buck Creek	Downstream Sylvania WPCP to Savannah River (Screven Co.)	02198355	Buck Creek at Brannens Bridge Road near Sylvania, Georgia
Middle Creek	Childers Creek to Big Creek (tributary to Clark Hill Lake), near Wrightsboro (McDuffie Co.)	02193880	Middle Creek near Wrightsboro, Georgia
Runs Branch (Ebenezer Creek)	Cowpen Creek to Little Ebenezer Creek near Clyo (Effingham Co.)	02198600	Runs Branch near Clyo, Georgia

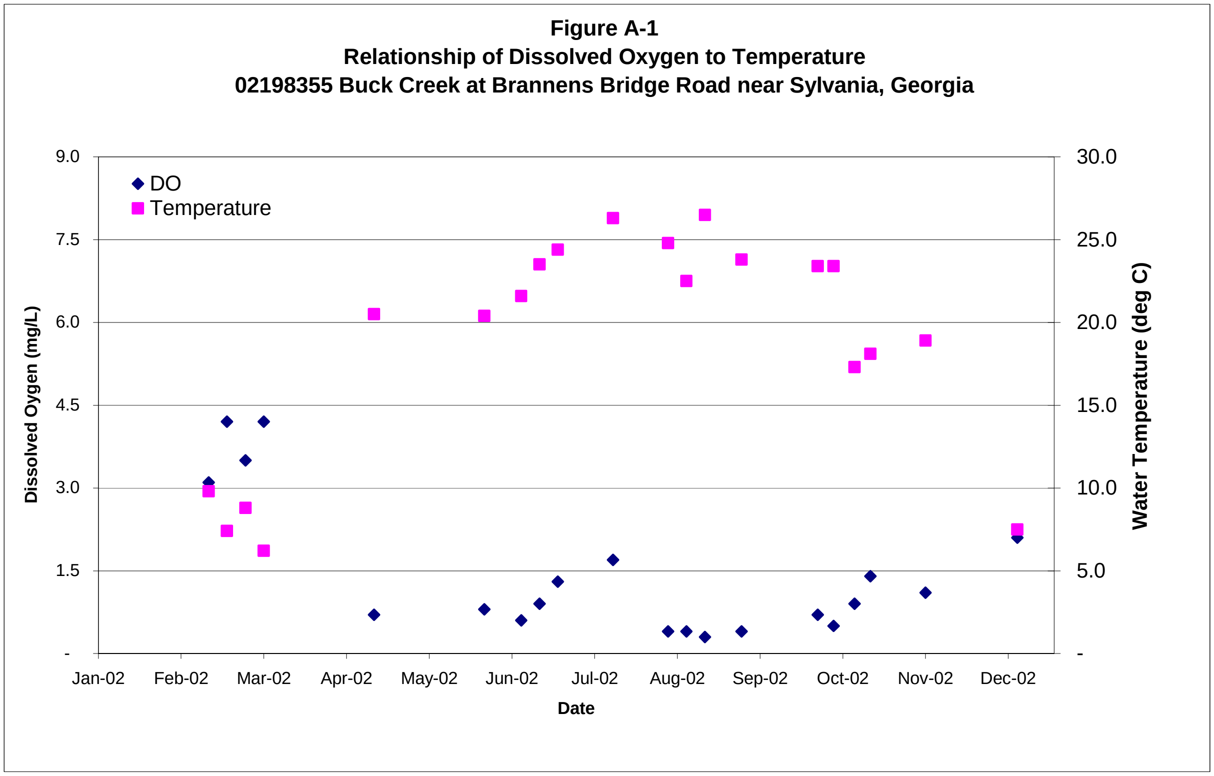
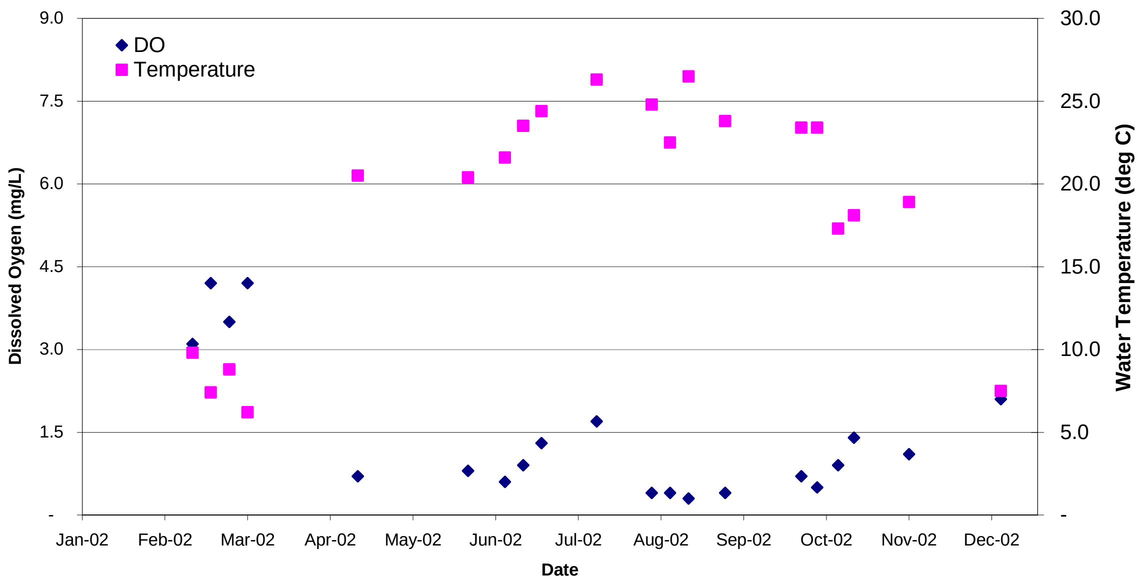


Table A-1. Data for Figure A-1

Date	Dissolved Oxygen (mg/L)	Water Temperature (deg C)	TOC (mg/L)	BOD_5 (mg/L)	Ammonia (mg/L)
12-Feb-02	3.1	9.8	1.0	2.0	0.83
19-Feb-02	4.2	7.4	-	-	-
26-Feb-02	3.5	8.8	-	-	-
5-Mar-02	4.2	6.2	9.7	3.4	4.90
16-Apr-02	0.7	20.5	8.1	2.6	0.52
28-May-02	0.8	20.4	14.0	2.4	0.53
11-Jun-02	0.6	21.6	-	-	-
18-Jun-02	0.9	23.5	-	-	-
25-Jun-02	1.3	24.4	27.0	6.5	1.00
16-Jul-02	1.7	26.3	11.0	2.2	0.91
6-Aug-02	0.4	24.8	11.0	8.6	0.64
13-Aug-02	0.4	22.5	-	-	-
20-Aug-02	0.3	26.5	-	-	-
3-Sep-02	0.4	23.8	13.0	8.8	2.00
2-Oct-02	0.7	23.4	8.0	5.1	0.54
8-Oct-02	0.5	23.4	-	-	-
16-Oct-02	0.9	17.3	-	-	-
22-Oct-02	1.4	18.1	-	-	-
12-Nov-02	1.1	18.9	13.0	6.0	1.30
17-Dec-02	2.1	7.5	8.0	0.6	0.12

Figure A-1
Relationship of Dissolved Oxygen to Temperature
02198355 Buck Creek at Brannens Bridge Road near Sylvania, Georgia



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26-Feb-02	3.5	8.8	-	-	-
5-Mar-02	4.2	6.2	9.7	3.4	4.90
16-Apr-02	0.7	20.5	8.1	2.6	0.52
28-May-02	0.8	20.4	14.0	2.4	0.53
11-Jun-02	0.6	21.6	-	-	-
18-Jun-02	0.9	23.5	-	-	-
25-Jun-02	1.3	24.4	27.0	6.5	1.00
16-Jul-02	1.7	26.3	11.0	2.2	0.91
6-Aug-02	0.4	24.8	11.0	8.6	0.64
13-Aug-02	0.4	22.5	-	-	-
20-Aug-02	0.3	26.5	-	-	-
3-Sep-02	0.4	23.8	13.0	8.8	2.00
2-Oct-02	0.7	23.4	8.0	5.1	0.54
8-Oct-02	0.5	23.4	-	-	-
16-Oct-02	0.9	17.3	-	-	-
22-Oct-02	1.4	18.1	-	-	-
12-Nov-02	1.1	18.9	13.0	6.0	1.30
17-Dec-02	2.1	7.5	8.0	0.6	0.12

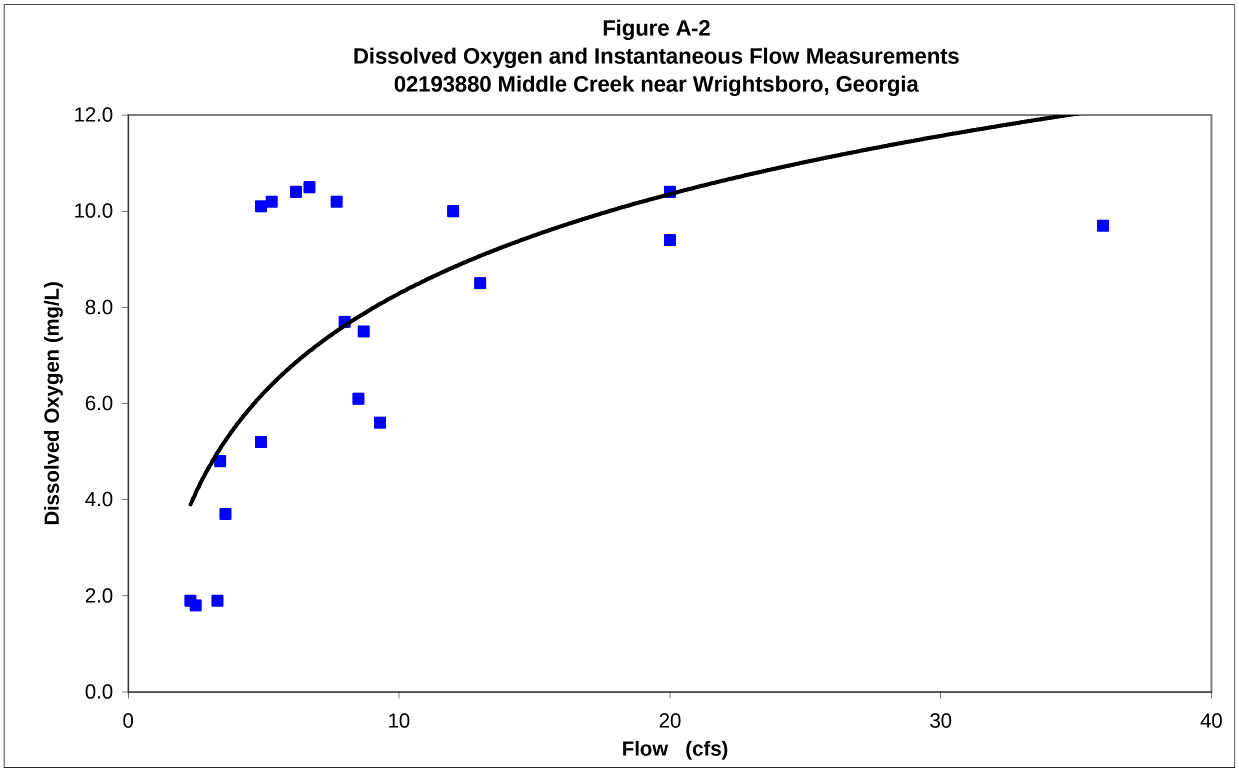


Table A-2. Data for Figure A-2

Date	Instantaneous Flow On Sample Day (cfs)	Dissolved Oxygen (mg/L)	Water Temperature (deg C)	TOC (mg/L)	BOD_5 (mg/L)	Ammonia (mg/L)
28-Jan-02	20.0	9.4	8.7	4.4	1.1	
28-Feb-02	12.0	10.0	5.2	4.1	1.7	0.07
4-Mar-02	20.0	10.4	6.9			
14-Mar-02	36.0	9.7	12.3			
18-Mar-02	8.0	7.7	18.0	4.2	0.2	0.09
29-Apr-02	8.5	6.1	20.0	4.8	0.7	0.16
20-May-02	13.0	8.5	16.3	7.3	1.4	0.07
4-Jun-02	9.3	5.6	24.1			
10-Jun-02	4.9	5.2	21.0			
20-Jun-02	3.4	4.8	22.5	4.1	1.3	0.14
2-Jul-02	3.6	3.7	24.9			
22-Jul-02	3.3	1.9	25.3	4.8	1.6	0.20
28-Aug-02	2.3	1.9	24.7			
9-Sep-02	2.5	1.8	22.4	4.3	0.9	0.36
5-Nov-02	8.7	7.5	13.9	4.6	0.3	0.08
26-Nov-02	6.7	10.5	9.2	3.9	0.8	0.10
2-Dec-02	5.3	10.2	5.2			
3-Dec-02	4.9	10.1	8.1			
10-Dec-02	6.2	10.4	6.2			
17-Dec-02	7.7	10.2	6.8	6.1	1.1	0.06

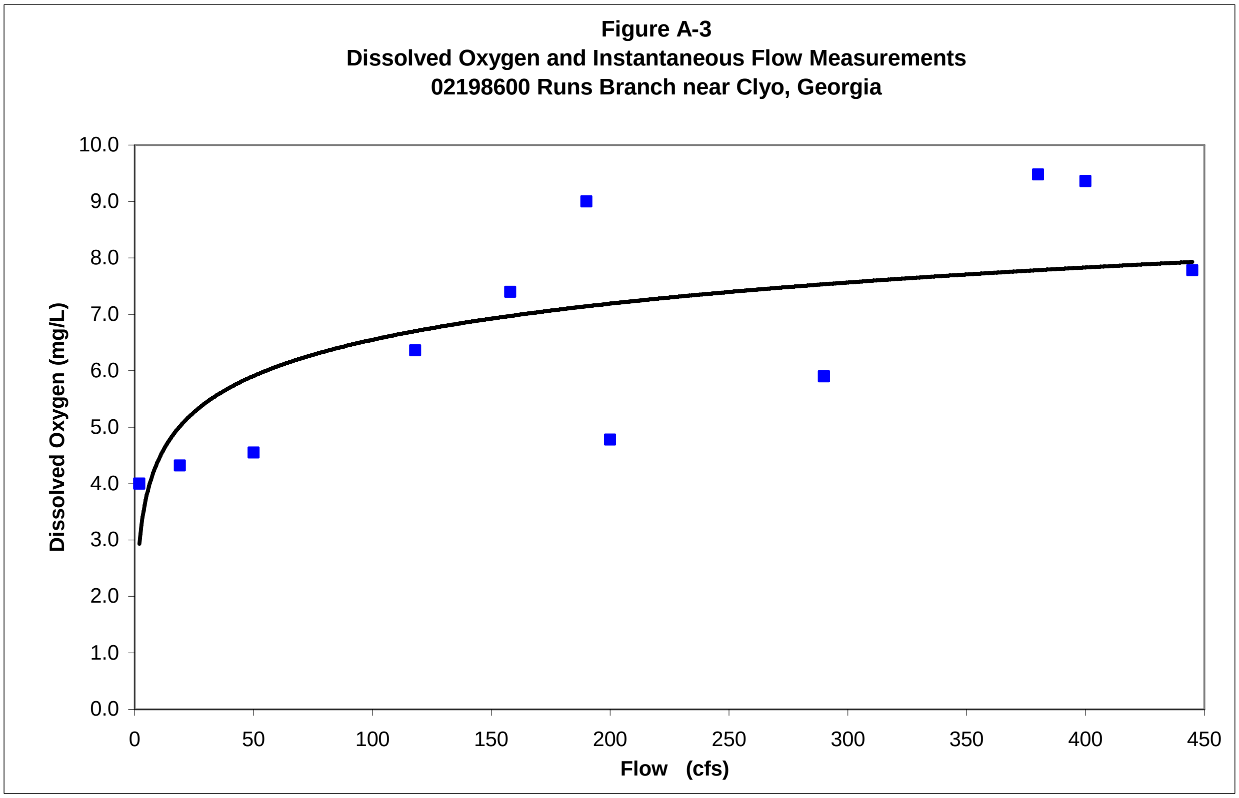


Table A-3. Data for Figure A-3

Date	Instantaneous Flow On Sample Day (cfs)	Dissolved Oxygen (mg/L)	Water Temperature (deg C)	TOC (mg/L)	BOD_5 (mg/L)	Ammonia (mg/L)
28-Jan-02	190	9.0	10.5	21.0	1.2	0.03
25-Feb-02	445	7.8	12.2	33.0	1.0	0.03
7-Mar-02		7.8	11.8	43.0	5.2	0.05
25-Mar-02	118	6.4	16.3	22.0	1.0	0.03
18-Apr-02		2.6	21.2	52.0	1.9	0.10
29-Apr-02	290	5.9	18.0	27.0	1.6	0.03
27-May-02		1.9	21.1	25.0	1.3	2.00
30-May-02		1.4	21.5	56.0	6.1	0.08
13-Jun-02		1.0	23.0			
20-Jun-02		1.1	21.9			
24-Jun-02	50	4.6	24.5	38.0	1.2	0.04
29-Jul-02	200	4.8	26.2	39.0	1.1	0.03
26-Aug-02	19	4.3	21.2	39.0	1.2	0.03
2-Sep-02		1.0	24.0			
9-Sep-02		1.6	21.0			
23-Sep-02		3.6	21.7	37.0	1.1	0.03
8-Oct-02	2	4.0	20.4			
14-Oct-02		0.9	20.2			
21-Oct-02	158	7.4	15.0	31.0	2.0	0.03
13-Nov-02		5.1	17.1	43.0	1.8	0.02
18-Nov-02	400	9.4	6.6	32.0	1.0	0.03
16-Dec-02	380	9.5	7.0	29.0	1.0	0.03
19-Dec-02		6.4	10.5	33.0	0.7	0.01

APPENDIX B

Model Structure

B-1. Buck Creek Model Structure – Watershed Designation

Reach	Type	Reach Name	Reach Length (mile)	Drainage Area (mi^2)	Elevation Change(ft)
Buck Creek					
		Headwater		3.23	
1	D	Sylvania WPCP	-	-	-
2	S	Sylvania WPCP to RM 11.8	0.56	0.72	1.7
3	S	RM 11.8 to RM 11.35	0.56	0.72	1.7
4	S	RM 11.35 to Brannens Bridge Rd.	0.57	0.72	1.7
5	S	Brannens Bridge Rd. to Unnamed Branch	1.26	2.48	6.5
6	B	Unnamed Branch Junction	-	-	-
7	S	Unnamed Branch to RM 8.46	0.94	4.18	4.7
8	S	RM 8.46 to South Prong Branch	1.67	3.78	9.4
9	B	South Prong Branch	-	-	-
10	S	South Prong Branch to RM 5.1	1.65	6.79	9.2
11	S	RM 5.1 to RM 3.54	1.60	3.35	9.0
12	S	RM 3.54 to RM 2.17	1.37	1.97	7.6
13	S	RM 2.17 to RM 1.33	0.84	1.75	4.7
14	S	RM 1.33 to EOM	1.33	1.15	7.4
Unnamed Branch					
		Headwater		4.33	
15	S	Headwater to RM 12.25	1.15	3.62	5.6
16	S	RM 12.3 to Buck Creek	1.59	2.54	7.8
South Prong					
		Headwater		5.94	
17	S	Headwater to RM 8.0	0.92	2.18	13.0
18	S	RM 8.0 to Buck Creek	1.23	1.60	9.8

Note: S: Stream
B: Branch
D: Discharge

B-2. Middle Creek Model Structure – Watershed Designation

Reach Type		Reach Name	Reach Length (mile)	Drainage Area (mi^2)	Elevation Change(ft)
Middle Creek					
		Headwater		5.17	
1	S	Hwy 20	1.70	3.59	22.5
2	S	Railroad Crossing	1.48	3.49	19.6
3	D	GA0002321 – Martin Marietta Quarry	-	-	-
4	S	Quarry with discharge	1.21	1.44	12.7
5	S	U/S End Listed Reach	0.79	1.11	8.3
6	B	Childers Creek Junction	-	-	-
7	S	RM 6.3 to RM 4.6	1.70	2.73	17.5
8	S	RM 4.6 to RM 3.3	1.35	1.58	14.2
9	T	Little Creek Tributary	-	3.90	-
10	S	RM 3.3 to RM 2.4	0.89	1.08	9.0
11	S	RM 2.4 to RM 1.8	0.58	1.08	5.9
12	S	RM 1.8 to RM 1	0.90	1.32	9.1
13	S	RM 1 to EOM	0.88	0.60	8.9
Childers Creek					
		Headwater		2.00	
14	S	To Hwy 20	1.16	2.66	17.8
15	T	Unnamed Tributary to Childers Creek	-	2.48	-
16	S	Mouth of Childers Creek	1.90	2.02	29.2

Note: S: Stream
T: Tributary
B: Branch
D: Discharge

B-3. Runs Branch Model Structure – Watershed Designation

Reach Type		Reach Name	Reach Length (mile)	Drainage Area (mi^2)	Elevation Change(ft)
Runs Branch					
		Headwater		12.37	
1	S	Headwater to RM 24	3.41	13.27	16.3
2	T	Devils Branch Tributary (RM 24)	-	11.61	-
3	S	RM 24 to RM 22	2.01	5.98	9.6
4	S	RM 22 to Cowpen Branch	2.14	4.47	10.2
5	B	Cowpen Branch	-	-	-
6	S	Cowpen Branch to Clyo-Shawnee Rd.	1.44	3.91	5.7
7	S	Clyo-Shawnee Rd. to Sisters Ferry Rd.	1.45	9.64	5.8
8	S	Sisters Ferry Rd. to RM 15.4	1.96	13.45	7.8
9	S	RM 15.4 to Turkey Creek	1.76	3.36	7.0
10	B	Turkey Creek	-	-	-
11	S	Turkey Creek to RM 11.4	2.22	4.27	7.6
12	S	RM 11.4 to Jacks Branch	0.59	8.22	2.0
13	T	Jacks Branch Tributary	-	13.86	-
14	S	Jacks Branch Tributary to RM 9.7	1.07	2.25	3.7
15	D	GA0020770 Springfield Pond LAS (RM 9.7)	-	-	-
16	S	RM 9.7 to RM 8.7	1.04	4.47	3.6
17	S	RM 8.7 to Little Ebenezer Creek	1.52	2.35	5.2
18	T	Little Ebenezer Creek Tributary	-	16.71	-
19	S	Little Ebenezer Creek to Long Bridge Rd.	2.09	2.15	2.8
20	S	Long Bridge Rd. to RM 4	1.12	3.14	1.6
21	S	RM 4 to RM 3	1.06	1.48	1.6
22	S	RM 3 to RM 1.6	1.35	1.24	1.9
23	S	RM 1.6 to EOM	1.59	1.52	2.2
Cowpen Branch					
		Headwater		13.01	
24	S	Headwater to RM 20	2.05	6.35	13.1
Turkey Creek					
		Headwater		12.35	
25	S	Headwater to Sweet Gum Rd.	2.97	15.78	23.0
26	S	Sweet Gum Rd. to Runs Branch confluence	3.84	9.37	26.2

Note: S: Stream
T: Tributary
B: Branch
D: Discharge

APPENDIX C

Calibration, Natural Conditions, and TMDL Model Curves

Figure C-1
DOSAG Model Results
Buck Creek

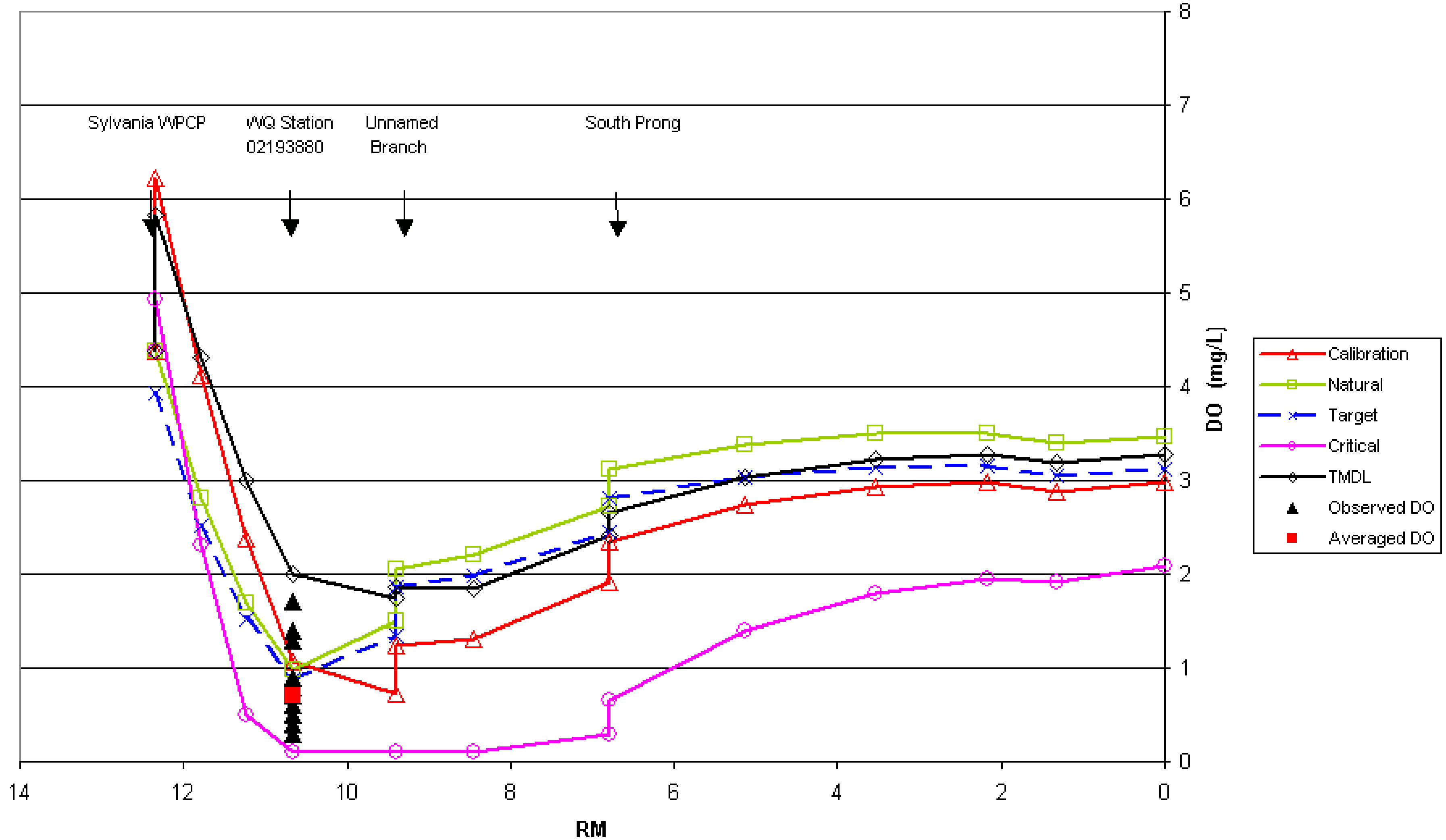


Figure C-2
DOSAG Model Results
Middle Creek

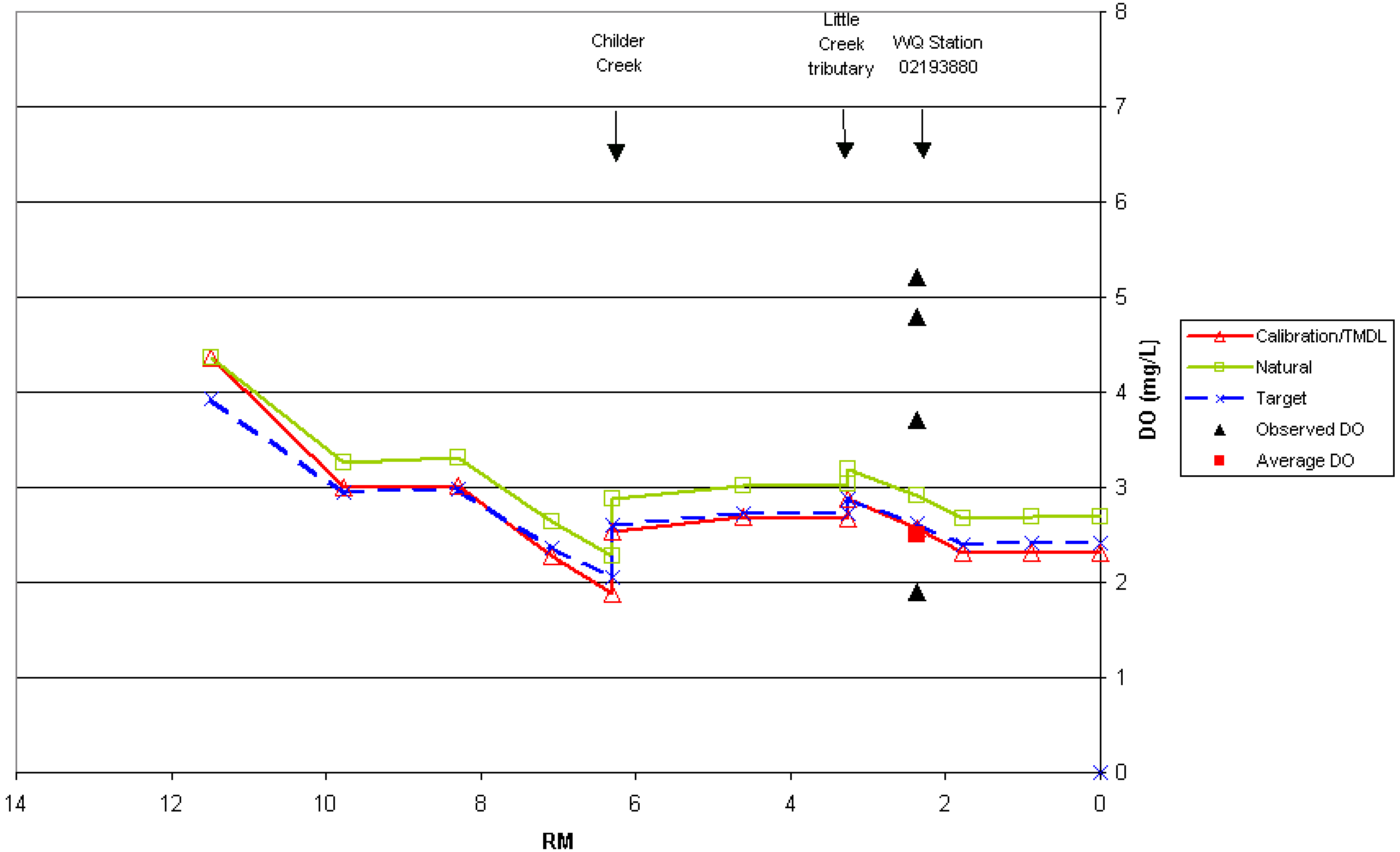
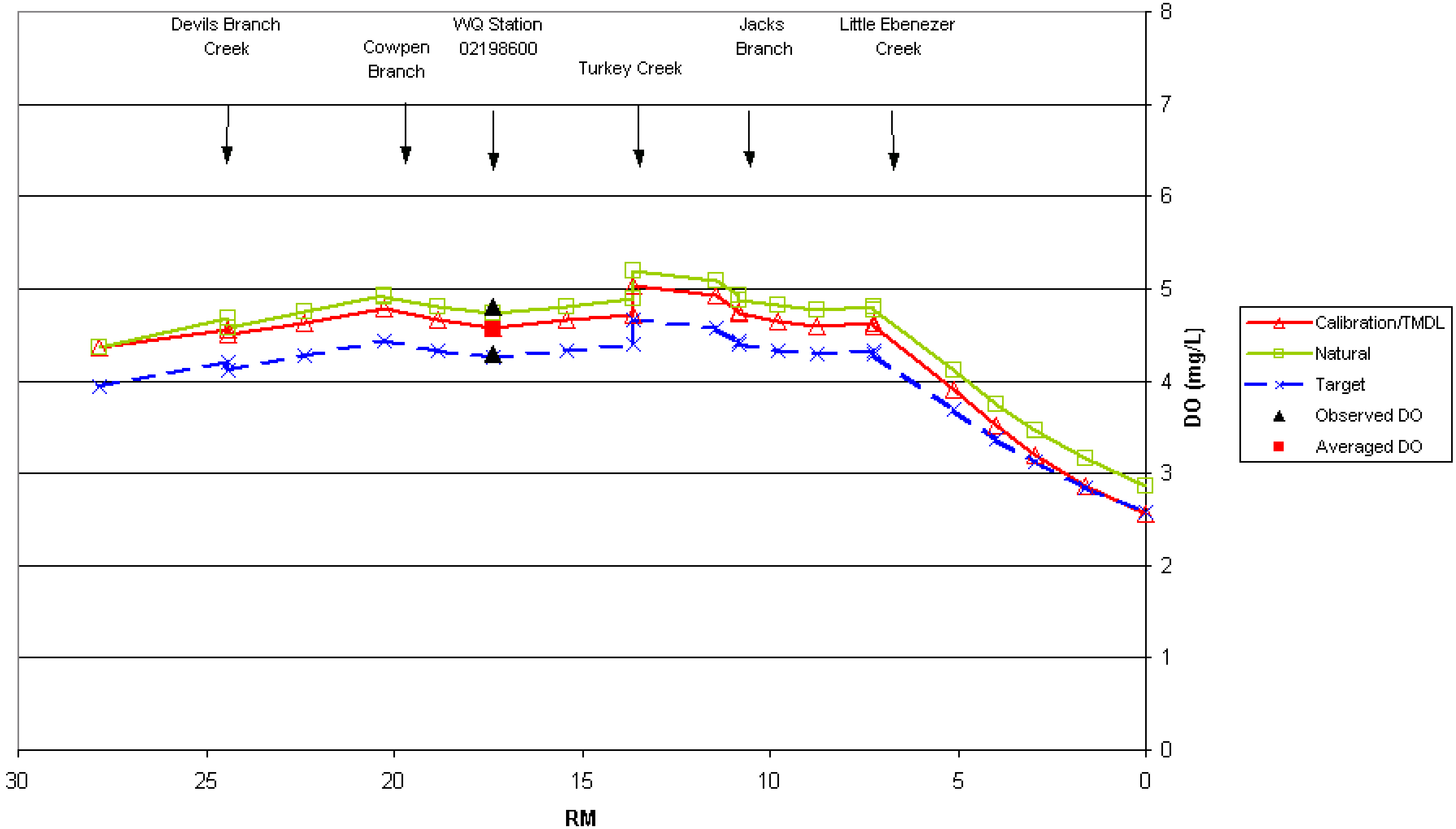


Figure C-3
DOSAG Model Results
Runs Branch (Ebenezer Creek)



APPENDIX D

Daily Oxygen Demanding Substances Load Summary Memorandum

SUMMARY MEMORANDUM
Average Annual Oxygen Demanding Substances Load
Buck Creek

1. 303(d) Listed Waterbody Information

State: Georgia
County: Screven

Major River Basin: Savannah
8-Digit Hydrologic Unit Code(s): 03060109

Waterbody Name: Buck Creek
Location: D/S Sylvania WPCP to Savannah River
Stream Length: 12 miles
Watershed Area: 51.1 square miles
Tributary to: Savannah River
Ecoregion: Southeastern Plains and Southern Coastal Plain

Constituent(s) of Concern: Dissolved Oxygen

Designated Use: Fishing (not supporting designated use)

Applicable Water Quality Standards:

A daily average of 6.0 mg/L and no less than 5.0 mg/L at all times for waters designated as trout streams by the Wildlife Resources Division. A daily average of 5.0 mg/L and no less than 4.0 mg/L at all times for waters supporting warm water species of fish.

***Natural Water Quality*. It is recognized that certain natural waters of the State may have a quality that will not be within the general or specific requirements contained herein. These circumstances do not constitute violations of water quality standards. This is especially the case for the criteria for dissolved oxygen, temperature, pH and fecal coliform. NPDES permits and Best Management Practices will be the primary mechanisms for ensuring that the discharges will not create a harmful situation.**

2. TMDL Development

Analysis/Modeling: Georgia DOSAG – Steady state water quality model developed by Georgia Environmental Protection Division.

Calibration Data: USGS field data from summer 2002.

Critical Conditions:
(1) 7Q10 flows based on low-flow analysis of available data from the Savannah River Basin.
(2) Temperatures were derived from historic trend monitoring data in *Stream-Temperature Characteristics in Georgia (USGS, 1997).*
(3) No point source discharges at current conditions.
(4) Velocities, kinetic rates, reaeration rates, and boundary conditions as per the guidance provided in the Georgia DOSAG Modeling Procedures Manual.

(5) Same depths, velocities, kinetic rates, reaeration rates, and boundary conditions as calibration conditions.

3. Allocation Watershed/Stream Reach:

Wasteload Allocations (WLA):	
Sylvania WPCP	**246 lbs/day**
Wasteload Allocations (WLAsw):	**NA**
Load Allocation (LA):	**265 lbs/day**
TMDL:	**511 lbs/day**

*** TMDL expressed as Ultimate Oxygen Demand (UOD), which includes Carbonaceous Biochemical Oxygen Demand (CBOD) and Nitrogenous Biochemical Oxygen Demand (NBOD).**

Margin of Safety (MOS): **Implicit, based on the following conservative assumptions:**
(1) Drought streamflows persist through the critical summer months at monthly 7Q10 flow values.
(2) Hot summer temperatures, based on the historical record, persist for the same critical period.
(3) DO saturation, for all flows entering the system, equal those measured during the low DO period in the summer of 2002.
(4) Water depths are shallow, generally one foot, which increases the effect of SOD.
(5) Water velocities are sluggish, which intensifies the effect of BOD decay.
(6) All point sources discharge continuously at their NPDES permit limits for the same critical period.

SUMMARY MEMORANDUM
Average Annual Oxygen Demanding Substances Load
Middle Creek

1. 303(d) Listed Waterbody Information

State: Georgia
County: McDuffie

Major River Basin: Savannah
8-Digit Hydrologic Unit Code(s): 03060105

Waterbody Name: Middle Creek
Location: Childers Creek to Big Creek near Wrightsboro
Stream Length: 6 miles
Watershed Area: 36.3 square miles
Tributary to: Little River
Ecoregion: Piedmont

Constituent(s) of Concern: Dissolved Oxygen

Designated Use: Fishing (partially supporting designated use)

Applicable Water Quality Standards:

A daily average of 6.0 mg/L and no less than 5.0 mg/L at all times for waters designated as trout streams by the Wildlife Resources Division. A daily average of 5.0 mg/L and no less than 4.0 mg/L at all times for waters supporting warm water species of fish.

***Natural Water Quality*. It is recognized that certain natural waters of the State may have a quality that will not be within the general or specific requirements contained herein. These circumstances do not constitute violations of water quality standards. This is especially the case for the criteria for dissolved oxygen, temperature, pH and fecal coliform. NPDES permits and Best Management Practices will be the primary mechanisms for ensuring that the discharges will not create a harmful situation.**

2. TMDL Development

Analysis/Modeling: Georgia DOSAG – Steady state water quality model developed by Georgia Environmental Protection Division.

Calibration Data: USGS field data from summer 2002.

Critical Conditions:
(1) 7Q10 flows based on low-flow analysis of available data from the Savannah River Basin.
(2) Temperatures were derived from historic trend monitoring data in ***Stream-Temperature Characteristics in Georgia (USGS, 1997).***
(3) No point source discharges at current conditions.
(4) Velocities, kinetic rates, reaeration rates, and boundary conditions as per the guidance provided in the Georgia DOSAG Modeling Procedures Manual.

(5) Same depths, velocities, kinetic rates, reaeration rates, and boundary conditions as calibration conditions.

3. Allocation Watershed/Stream Reach:

Wasteload Allocations (WLA):	**NA**
Wasteload Allocations (WLAsw):	**NA**
Load Allocation (LA):	**22.9 lbs/day**
TMDL:	**22.9 lbs/day**

*** TMDL expressed as Ultimate Oxygen Demand (UOD), which includes Carbonaceous Biochemical Oxygen Demand (CBOD) and Nitrogenous Biochemical Oxygen Demand (NBOD).**

Margin of Safety (MOS): **Implicit, based on the following conservative assumptions:**
(1) Drought streamflows persist through the critical summer months at monthly 7Q10 flow values.
(2) Hot summer temperatures, based on the historical record, persist for the same critical period.
(3) DO saturation, for all flows entering the system, equal those measured during the low DO period in the summer of 2002.
(4) Water depths are shallow, generally one foot, which increases the effect of SOD.
(5) Water velocities are sluggish, which intensifies the effect of BOD decay.
(6) All point sources discharge continuously at their NPDES permit limits for the same critical period.

SUMMARY MEMORANDUM
Average Annual Oxygen Demanding Substances Load
Runs Branch (Ebenezer Creek)

1. 303(d) Listed Waterbody Information

State: Georgia
County: Effingham

Major River Basin: Savannah
8-Digit Hydrologic Unit Code(s): 03060109

Waterbody Name: Runs Branch (Ebenezer Creek)
Location: Cowpen Creek to Little Ebenezer Creek near Clyo
Stream Length: 11 miles
Watershed Area: 187.2 square miles
Tributary to: Savannah River
Ecoregion: Southern Coastal Plain

Constituent(s) of Concern: Dissolved Oxygen

Designated Use: Fishing (not supporting designated use)

Applicable Water Quality Standards:

A daily average of 6.0 mg/L and no less than 5.0 mg/L at all times for waters designated as trout streams by the Wildlife Resources Division. A daily average of 5.0 mg/L and no less than 4.0 mg/L at all times for waters supporting warm water species of fish.

***Natural Water Quality*. It is recognized that certain natural waters of the State may have a quality that will not be within the general or specific requirements contained herein. These circumstances do not constitute violations of water quality standards. This is especially the case for the criteria for dissolved oxygen, temperature, pH and fecal coliform. NPDES permits and Best Management Practices will be the primary mechanisms for ensuring that the discharges will not create a harmful situation.**

2. TMDL Development

Analysis/Modeling: Georgia DOSAG – Steady state water quality model developed by Georgia Environmental Protection Division.

Calibration Data: USGS field data from summer 2002.

Critical Conditions:
(1) 7Q10 flows based on low-flow analysis of available data from the Savannah River Basin.
(2) Temperatures were derived from historic trend monitoring data in *Stream-Temperature Characteristics in Georgia (USGS, 1997).*
(3) No point source discharges at current conditions.
(4) Velocities, kinetic rates, reaeration rates, and boundary conditions as per the guidance provided in the Georgia DOSAG Modeling Procedures Manual.

(5) Same depths, velocities, kinetic rates, reaeration rates, and boundary conditions as calibration conditions.

3. Allocation Watershed/Stream Reach:

Wasteload Allocations (WLA):	**NA**
Wasteload Allocations (WLAsw):	**NA**
Load Allocation (LA):	**37.7 lbs/day**
TMDL:	**37.7 lbs/day**

*** TMDL expressed as Ultimate Oxygen Demand (UOD), which includes Carbonaceous Biochemical Oxygen Demand (CBOD) and Nitrogenous Biochemical Oxygen Demand (NBOD).**

Margin of Safety (MOS): **Implicit, based on the following conservative assumptions:**
(1) Drought streamflows persist through the critical summer months at monthly 7Q10 flow values.
(2) Hot summer temperatures, based on the historical record, persist for the same critical period.
(3) DO saturation, for all flows entering the system, equal those measured during the low DO period in the summer of 2002.
(4) Water depths are shallow, generally one foot, which increases the effect of SOD.
(5) Water velocities are sluggish, which intensifies the effect of BOD decay.
(6) All point sources discharge continuously at their NPDES permit limits for the same critical period.