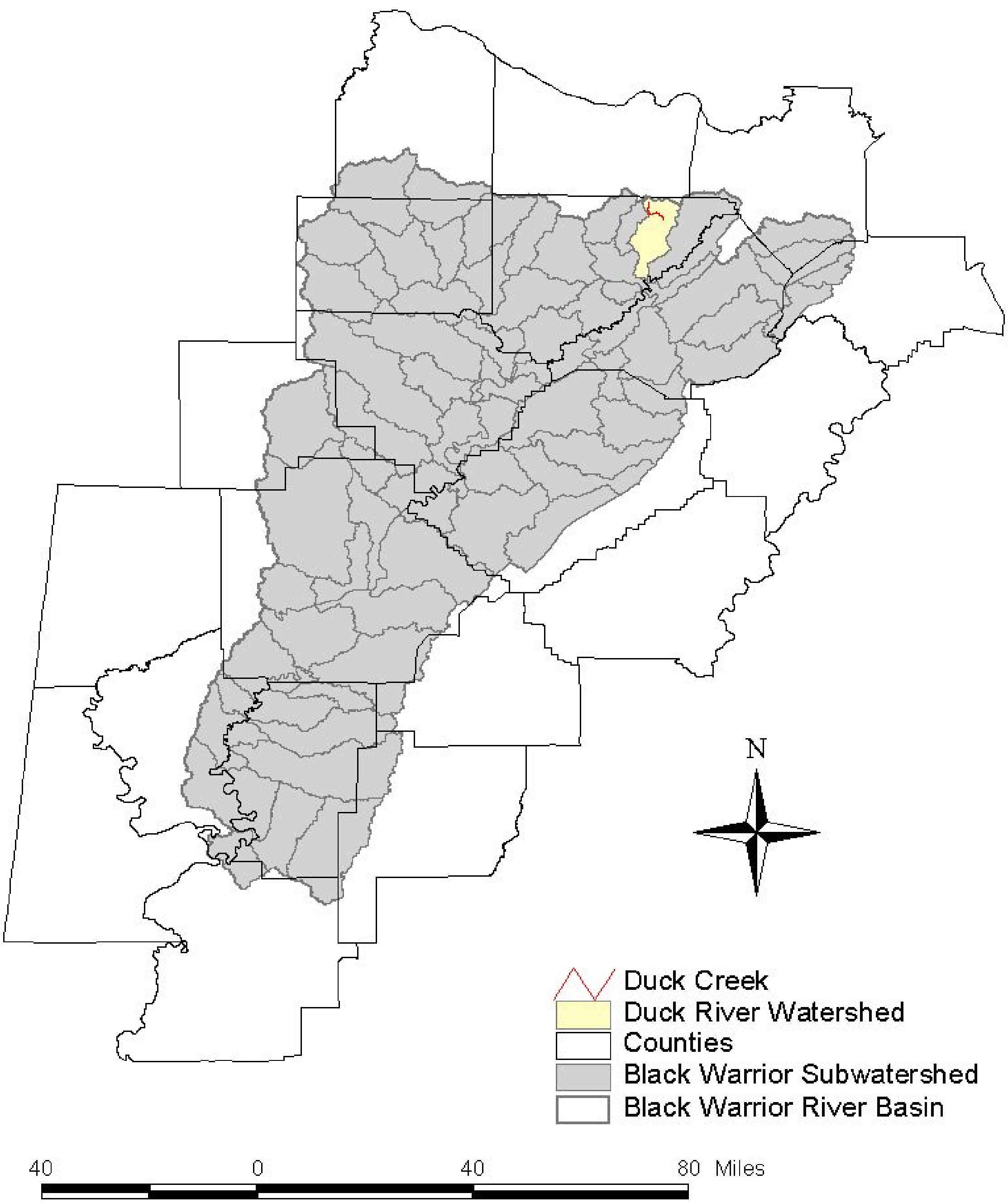
Alabama Department of Environmental Management

TMDL Development for

Duck Creek AL/03160109-020_01
Low Dissolved Oxygen/Organic Loading

Water Quality Branch
Water Division
February 2002

Duck Creek Watershed in the Black Warrior Basin



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1.0 Executive Summary

This report contains one or more Total Maximum Daily Loads (TMDLs) for waterbody segments found on Alabama's 1996 and/or 1998 Section 303(d) List(s) of Impaired Waterbodies. Because of the accelerated schedule required by the consent decree, many of these TMDLs have been prepared out of sequence with the State's rotating basin approach. The implementation of the TMDLs contained herein will be prioritized within Alabama's rotating basin approach.

The amount and quality of data on which this report is based are limited. As additional information becomes available, the TMDLs may be updated. Such additional information may include water quality and quantity data, changes in pollutant loadings, or changes in land use within the watershed. In some cases, additional water quality data may indicate that no impairment exists.

Duck Creek, a part of the Black Warrior basin, is located in Cullman County near Fairview, Alabama. It has been on the State of Alabama's §303(d) use impairment list since 1992 for organic enrichment/low dissolved oxygen (O.E./D.O.). Its use classification is Fish and Wildlife (F&W).

Water quality data or information collected in 1988 and 1991 identified dissolved oxygen impairments for Duck Creek.

The following report addresses the results of the TMDL analysis for O.E./D.O. In accordance with ADEM water quality standards, the minimum dissolved oxygen concentration in a stream classified as Fish and Wildlife is 5.0 mg/l. For the purpose of this TMDL, a minimum dissolved oxygen level of 5.0 mg/l will be implemented allowing for an implicit margin of safety resulting from conservative assumptions used in the dissolved oxygen model.

A summary of the TMDL for the watershed is provided in the tables presented below. The pollutants shown in the tables include ultimate carbonaceous biochemical oxygen demand ($CBOD_u$) and nitrogenous biochemical oxygen demand (NBOD), the principle causes for observed low dissolved oxygen concentrations. $CBOD_u$ is a measure of the total amount of oxygen required to degrade the carbonaceous portion of the organic matter present in the water. NBOD is the amount of oxygen utilized by bacteria as they convert ammonia to nitrate. Because organic nitrogen can be converted to ammonia, its potential oxygen demand is included in the NBOD component of the TMDL. Table 1-1 lists allowable pollutant loadings by source (point and non-point sources) for the summer (Critical) season (May through November). Table 1-2 lists allowable pollutant loadings by source (point and non-point sources) for the winter season (December through April).

Table 1-1. Maximum Allowable Pollutant Loads by Source – Summer

Pollutant	Point Source Loads (lbs./day)	Non-point Source Loads (lbs./day)
$CBOD_u$	9.4	6.6
NBOD	6.6	7.7
Total	16.0	14.3

Table 1-2. Maximum Allowable Pollutant Loads by Source – Winter

Pollutant	Point Source Loads (lbs./day)	Non-point Source Loads (lbs./day)
$CBOD_u$	9.4	665
NBOD	45.7	1047
Total	55.1	1712

2.0 Basis for §303(d) Listing

2.1 Introduction

Section 303(d) of the Clean Water Act (CWA) as amended by the Water Quality Act of 1987 and EPA's Water Quality Planning and Management Regulations [(Title 40 of the Code of Federal Regulations (CFR), Part 130)] require states to identify waterbodies which are not meeting water quality standards applicable to their designated use classifications. The identified waters are prioritized based on severity of pollution with respect to designated use classifications. Total maximum daily loads (TMDLs) for all pollutants causing violation of applicable water quality standards are established for each identified water. Such loads are established at levels necessary to implement the applicable water quality standards with seasonal variations and margins of safety. The TMDL process establishes the allowable loading 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 State of Alabama has identified Duck Creek as being impaired by organic loading (i.e., $CBOD_u$ and NBOD) for a length of 6.4 miles, as reported on the 1992, 1994, 1998, and draft 2000 §303(d) list(s) of impaired waters. Duck Creek is prioritized as "high " on the list(s). Duck Creek is located in Cullman County and lies within the Duck River watershed of the Black Warrior basin.

The TMDL developed for Duck Creek illustrates the steps that can be taken to address a waterbody impaired by low dissolved oxygen levels. The TMDL is consistent with a phased-approach: estimates are made of needed pollutant reductions, load reduction controls are implemented, and water quality is monitored for plan effectiveness. Flexibility is built into the plan so that load reduction targets and control actions can be reviewed if monitoring indicates continuing water quality problems.

2.2 Problem Definition

Duck Creek flows into Duck River, which has a drainage area of 63 sq miles. Dry weather flows for the watershed are relatively low, or zero. Water quality data collected for the watershed in 1988 and 1991, indicated that dissolved oxygen impairments occurred primarily during the summer months (May through November). The percentage of the dissolved oxygen data not meeting the minimum water quality standard in 1988 and 1991 was 34%. In 1997 ADEM preformed monthly sampling on Duck Creek from May till August and an intensive survey in October. During this sampling event 40 Dissolved Oxygen samples were taken. Only one of these samples was in violation of the 5 mg/l criteria and it was taken during a period of zero flow.

Generally, depressed in-stream D.O. concentrations may be caused by several sources including the decay of oxygen demanding waste from both point and non-point sources, algal respiration, sediment oxygen demand or other sources. It is believed based on available data that the low dissolved oxygen concentrations observed in this watershed are due to (describe source of problem i.e., low flow, point source, or nonpoint source impacts) persistent flow conditions at or below the $7Q_{10}$ and high temperatures, occurring during summer months, and are not the result of algal dynamics.

Waterbody Impaired: Duck Creek – From Duck River to its source

Water Quality Standard Violation: Dissolved Oxygen

Pollutant of Concern: Organic Enrichment ($CBOD_u$/NBOD)

Water Use Classification: Fish and Wildlife

The impaired stream segment, Duck Creek, is classified as Fish and Wildlife. Usage of waters in this classification is described in ADEM Admin. Code R. 335-6-10-.09(5)(a), (b), (c), and (d).

(a) Best usage of waters:

Fishing, propagation of fish, aquatic life, and wildlife, and any other usage except for swimming and water-contact sports or as a source of water supply for drinking or food processing purposes.

(b) Conditions related to best usage:

The waters will be suitable for fish, aquatic life and wildlife propagation. The quality of salt and estuarine waters to which this classification is assigned will also be suitable for the propagation of shrimp and crabs.

(c) Other usage of waters:

It is recognized that the waters may be used for incidental water contact and recreation during June through September, except that water contact is strongly discouraged in the vicinity of discharges or other conditions beyond the control of the Department or the Alabama Department of Public Health.

(d) Conditions related to other usage:

The waters, under proper sanitary supervision by the controlling health authorities, will meet accepted standards of water quality for outdoor swimming places and will be considered satisfactory for swimming and other whole body water-contact sports.

Low D.O./Organic Loading Criteria:

Alabama's water quality criteria document (ADEM Admin. Code R. 335-6-10-.09-(5)(e)(4.)) states that for a diversified warm water biota, including game fish, daily dissolved oxygen concentrations shall not be less than 5 mg/l at all times; except under extreme conditions due to natural causes, it may range between 5 mg/l and 4 mg/l, provided that the water quality is favorable in all other parameters. The normal seasonal and daily fluctuations shall be maintained above these levels. In no event shall the dissolved oxygen level be less than 4 mg/l due to discharges from existing hydroelectric generation impoundments. All new hydroelectric generation impoundments, including addition of new hydroelectric generation units to existing impoundments, shall be designed so that the discharge will contain at least 5 mg/l dissolved oxygen where practicable and technologically possible. The Environmental Protection Agency, in cooperation with the State of Alabama and parties responsible for impoundments, shall develop a program to improve the design of existing facilities.

3.0 Technical Basis for TMDL Development

3.1 Water Quality Target Identification

The minimum dissolved oxygen concentration in a stream classified as Fish and Wildlife is 5.0 mg/l. For the purpose of this TMDL, a minimum dissolved oxygen level of 5.0 mg/l will be implemented allowing for an implicit margin of safety resulting from conservative assumptions used in the dissolved oxygen model. The target $CBOD_u$ and NBOD concentrations are concentrations that, in concert with the nitrification of ammonia, will not deplete the dissolved oxygen concentration below this level as a result of the decaying process.

3.2 Source Assessment

3.2.1. General Sources of $CBOD_u$ and NBOD

Both point and non-point sources may contribute $CBOD_u$ and NBOD (i.e., organic loading) to a given waterbody. Potential sources of organic loading are numerous and often occur in combination. In rural areas, storm runoff from row crops, livestock pastures, animal waste application sites, and feedlots can transport significant loads of organic loading. Nationwide, poorly treated municipal sewage comprises a major source of organic compounds that are hydrolyzed to create additional organic loading. Urban storm water runoff, sanitary sewer overflows, and combined sewer overflows can be significant sources of organic loading.

All potential sources of organic loading in the watershed were identified based on an evaluation of current land use/cover information on watershed activities (e.g., agricultural management activities). The source assessment was used as the basis of development of the model and ultimate analysis of the TMDL allocations. The organic loading within the watershed included both point and non-point sources.

3.2.2. Point Sources in the Duck Creek Watershed

ADEM maintains a database of current NPDES permits and GIS files that locate each permitted outfall. This database includes municipal, semi-public/private, industrial, mining, industrial storm water, and concentrated animal feeding operations (CAFOs) permits. Table 3-1, below, shows the permitted point sources in the watershed that discharge into or upstream of the impaired segment. Included in Table 3-1 is the percent of the facility wastewater flow of the $7Q_{10}$ .Table 3-2 contains the permit limitations for the significant point sources that were considered in the model development. Figure 3-1 shows the location of each facility considered a significant source relative to the impaired segment.

Table 3-1. Contributing Point Sources in the Duck Creek Watershed.

NPDES Permit	Type of Facility (e.g., CAFO, Industrial, Municipal, Semi-Public/Private, Mining, Industrial Storm Water)	Facility Name	Significant Contributor (Yes/No) (% of $7Q_{10}$)
AL/0051098	Semi-Public/Private	Fairview School	Yes (20%)
ALA000126	CAFO	Berry Rosco Farm	No (0%)
ALA000316	CAFO	Dunn Farm	No (0%)
ALA000201	CAFO	Albert Absher Farm	No (0%)

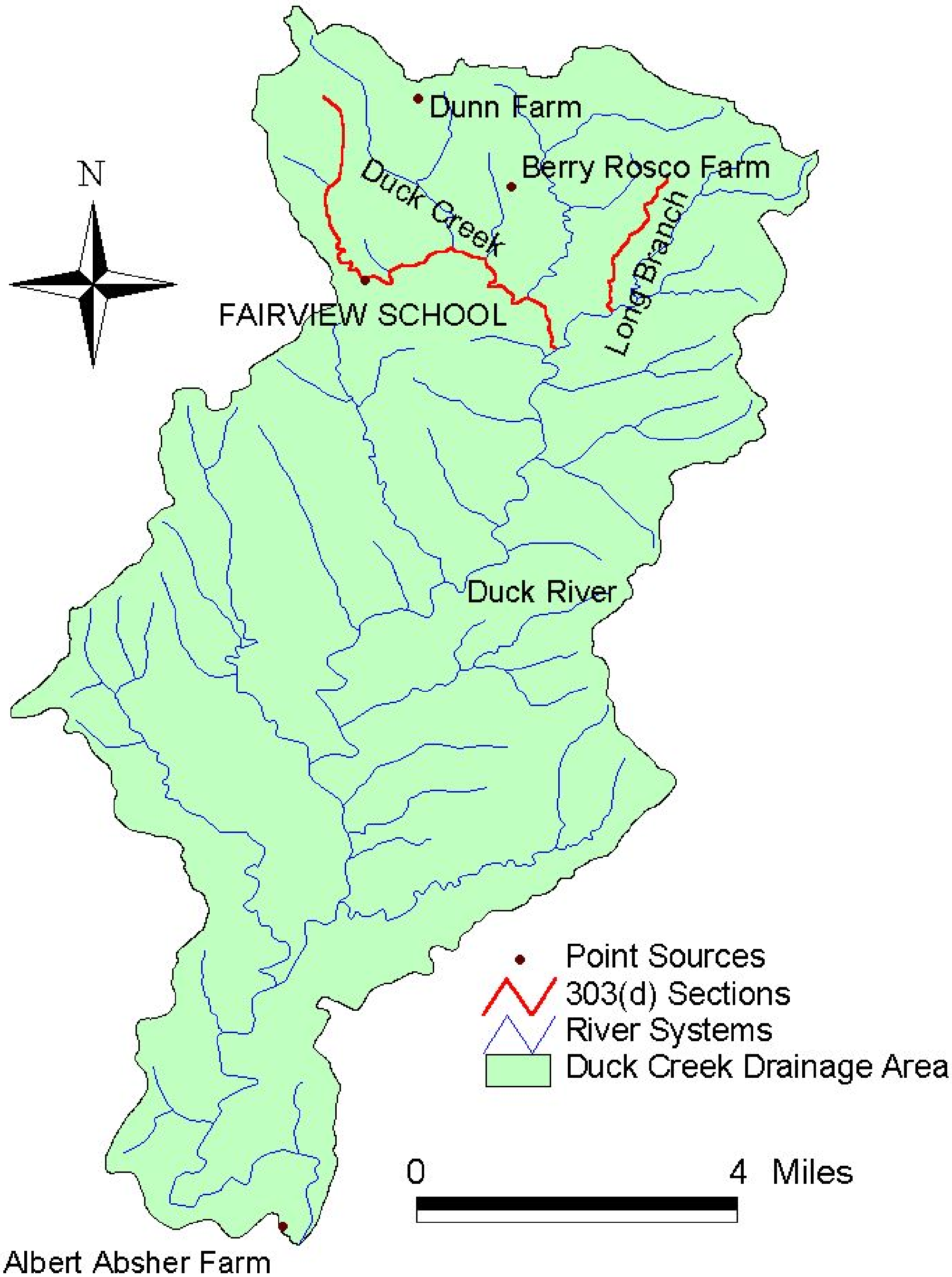
Note: Storm water discharges listed in the above table were marked as not being significant contributors since the discharge cannot cause nor contribute to a water quality violation. These discharges also would not occur during low flow conditions. However, storm water contributions are taken into account indirectly through SOD component. Construction storm water discharges are not listed as these discharges do not occur during low flow and generally do not contribute directly to the organic loading.

Table 3-2. NPDES Permit Limits for Significant Contributing Point Sources

NPDES Permit	Facility Name	Permit Limitations - Summer							Permit Limitations - Winter				
		Flow (MGD)	BOD_5 (MG/L)			NH_3-N (MG/L)		DO (MG/L)	Flow (MGD)		BOD_5 (MG/L)		NH_3-N
		Max	Monthly Ave	Weekly Avg	Monthly Ave	Weekly Avg	Min	Max	Monthly Ave	Weekly Avg	Monthly Ave	Weekly Avg	Min
AL/0051098	Fairview School	0.03	25	37.5	2.9	4.35	3	0.03	25	37.5	20	30	0

Notes: n/a = not applicable. Flows listed for municipal and industrial permits are design flow and long term average flows, respectively. The flows listed for industrial permits may or may not be limited by the permit, but are included for the purpose of calculating the percent of the $7Q_{10}$.

Figure 3-1. Location Map of Significant Point Sources



3.2.3. Non-Point Sources in the Duck Creek Watershed

Shown in Table 3-3, below, is a detailed summary of land usage in the Duck Creek watershed. A land use map of the watershed is presented in Figure 3-2. The predominant land uses within the watershed are Forest, Pasture, and Row Crops. Their respective percentages of the total watershed are 44.3, 37.7, and 17.2%.

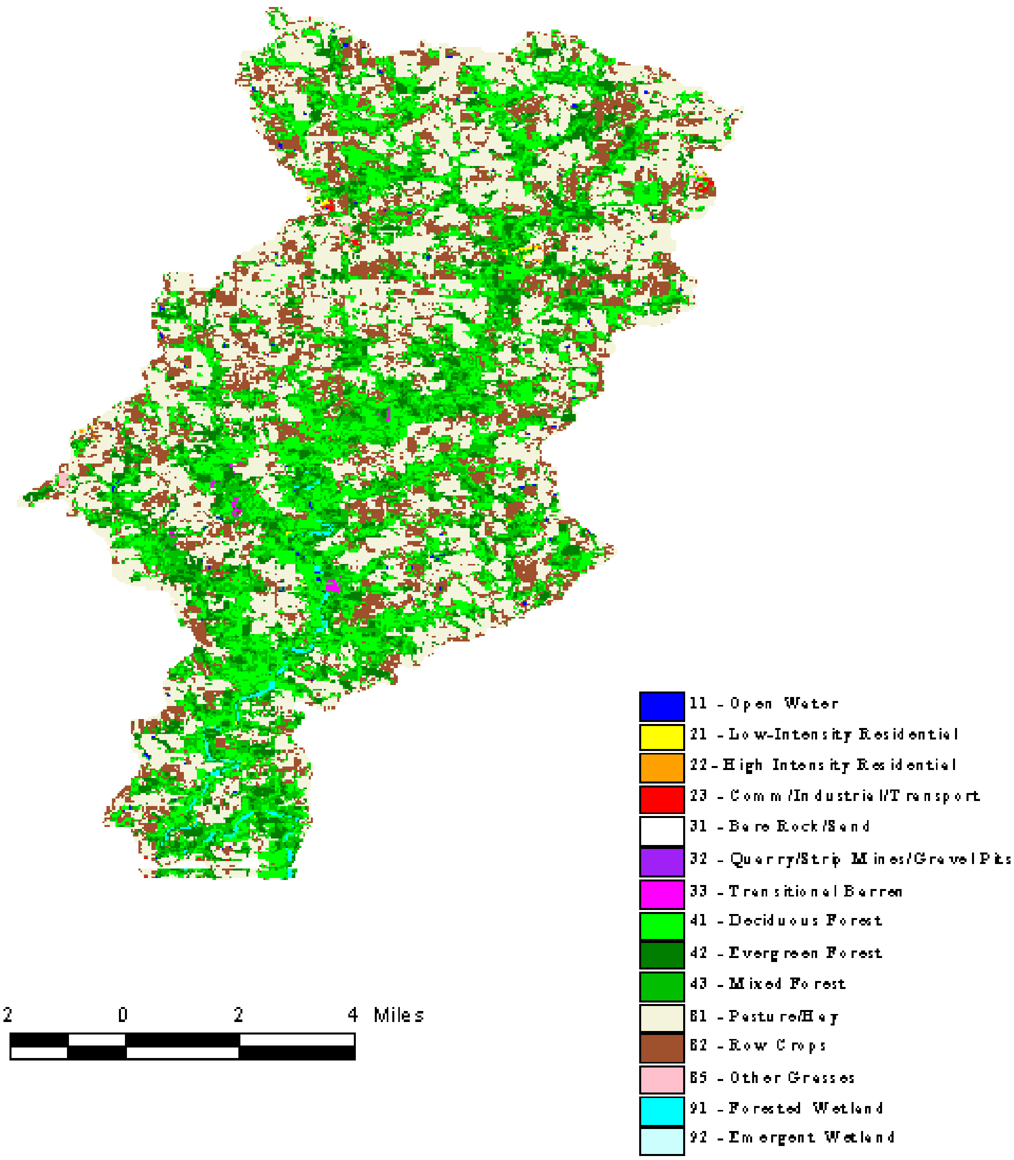
Table 3-3. Land Use in the Duck Creek Watershed.

Landuse (acres/percent)	acres	sq. miles	%
Deciduous Forest	7124	11.1	17.7%
Evergreen Forest	3684	5.8	9.1%
High Intensity Commercial/Industrial/Transportation	59	0.1	0.1%
High Intensity Residential	9	0.0	0.0%
Low Intensity Residential	44	0.1	0.1%
Mixed Forest	6885	10.8	17.1%
Open Water	107	0.2	0.3%
Other Grasses (Urban/recreational; e.g. parks law	43	0.1	0.1%
Pasture/Hay	15199	23.7	37.7%
Row Crops	6928	10.8	17.2%
Transitional	44	0.1	0.1%
Woody Wetlands	160	0.3	0.4%
Total	**40287**	**62.9**	**100%**

The predominant land uses of forest, pasture, and row crops make up 99.2% of the watershed. The other 0.8% of the land uses, except open water, was combined into one category (other) for modeling purposes. Each land use has the potential to contribute to the organic loading in the watershed due to organic material on the land surface that potentially can be washed off into the receiving waters of the watershed. Information on agricultural and management activities and watershed characteristics were obtained through coordination with the ADEM Mining and Non-Point Section, the Alabama Cooperative Extension System, and the USDA-Natural Resources Conservation Service (NRCS).

The major sources of organic enrichment from non-point sources within the Duck Creek watershed are the Forest, Pasture, and Row Crops land uses. Compared to other land uses organic enrichment from forested land is normally considered to be small. This is because forested land tends to serve as a filter of pollution originating within its drainage areas. However, organic loading can originate from forested areas due to the presence of wild animals such as deer, raccoons, turkeys, waterfowl, etc. Control of these sources is usually limited to land management best management practices (BMPs) and may be impracticable in most cases. In contrast to forested land, agricultural land can be a major source of organic loading. Runoff from pastures, animal operations, improper land application of animal wastes, and animals with access to streams are all mechanisms that can introduce organic loading to waterbodies.

Figure 3-2. Land Use Map for the Duck Creek Watershed.



3.3 Loading Capacity – Linking Numeric Water Quality Targets and Pollutant Sources

EPA regulations define loading, or assimilative capacity, as the greatest amount of loading that a waterbody can receive without violating water quality standards (40 CFR Part 130.2(f)).

Alabama's water quality criteria document (ADEM Admin. Code R. 335-6-10-.09-(5)(e)(4.)) states that for a diversified warm water biota, including game fish, daily dissolved oxygen concentrations shall not be less than 5 mg/l at all times; except under extreme conditions due to natural causes, it may range between 5 mg/l and 4 mg/l, provided that the water quality is favorable in all other parameters. The normal seasonal and daily fluctuations shall be maintained above these levels.

Using the D.O. water quality criterion of 5.0 mg/l as the numerical target, a TMDL model analysis was performed at critical conditions (i.e., summer) to determine the loading capacity for the watershed. This was accomplished through a series of simulations aimed at meeting the dissolved oxygen target limit by varying source contributions. The final acceptable simulation represented the TMDL (and loading capacity of the waterbody). If point sources were identified in the watershed, an additional model analysis was performed for the winter to determine the loading capacity during higher flow conditions.

In the TMDL model analysis, the pollutant concentrations from forestland were assumed to be at normal background concentrations. Specific values for background pollutant concentrations are as follows: 1.75 mg/l $CBOD_u$, 0.5 mg/l ammonia oxygen demand (NH_3-N), and 1 mg/l total organic nitrogen oxygen demand (TON). Pollutant concentrations for the other land uses in the watershed were assigned in proportion to measured concentrations and were set in the TMDL model at levels necessary to maintain dissolved oxygen concentrations greater than, or equal to, 5 mg/l. The model predictions for in-stream pollutant concentrations were then compared to actual field data. The model velocities and reaeration coefficients were adjusted in those cases where the field data indicated significant discrepancies from the model predictions.

3.4 Data Availability and Analysis

3.4.1. Watershed Characteristics

A. General Description: Duck Creek, located in Cullman County, is a tributary to the Duck River. Duck Creek is a part of the Black Warrior River basin. Duck Creek is a part of the USGS (United States Geological Survey) AL/0360109 cataloging unit and the NRCS (Natural Resources Conservation Service) 020 sub-watershed. Cataloging unit 0360109 represents the Mulberry Fork of the Black Warrior basin. NRCS sub-watershed number 020 represents the Duck River subwatershed of the Mulberry Fork of the Black Warrior basin.

Duck Creek begins approximately 2 miles north of Fairview in section 1, T. 9 S., and R 2 W. In this TMDL the model reach was from the mouth of Duck River the source of Duck Creek which has a length of 25.3 miles and a total drainage area of 63 square miles. Duck Creek has a use classification of Fish & Wildlife (F&W).

B. Geological Description: The Province is Appalachian Plateaus of the Pennsylvanian System. The main rock type in the region is sand, conglomerate, shale, siltstone, and coal.

C. Eco-region Description: Eco-region Description: The Southern Table Plateaus include Sand Mountain, Lookout Mountain, and Brindley Mountain. While it has some similarities to the Cumberland Plateau (68a) of Tennessee with its Pennsylvanian-age sandstone caprock, this ecoregion is lower in elevation, has a warmer climate, and contains more agriculture. It has higher elevation and more gentle topography with less dissection than the more forested ecoregions of 68e and 68f. Although the Georgia portion is mostly forested, elevations decrease to the southwest in Alabama and there is more cropland and pasture. It is a major poultry production region in Alabama.

D. Other Notable Characteristics: None.

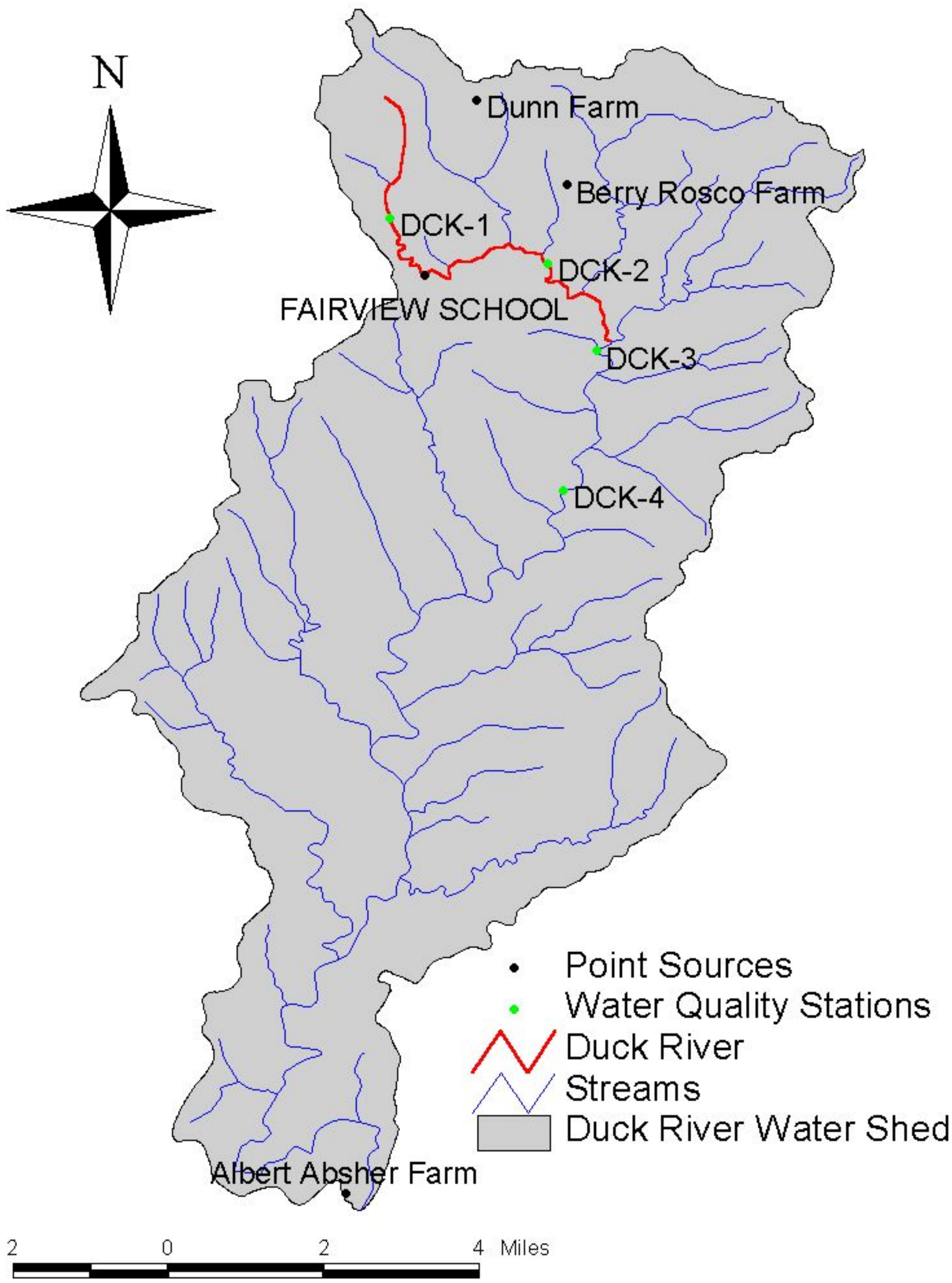
3.4.2 Available Water Quality and Biological Data

Water quality data was collected for the watershed in 1988 and 1991, indicated that dissolved oxygen impairments occurred primarily during the summer months (May through November). The percentage of the dissolved oxygen data not meeting the minimum water quality standard in 1988 and 1991 was 34%. In 1997 ADEM preformed monthly sampling on Duck Creek from May till August and an intensive survey in October. During this sampling event 40 Dissolved Oxygen samples were taken. Only one of these samples was in violation of the 5 mg/l criteria and it was taken during a period of zero flow.

A complete listing of the available data can be found in the appendix of this report.

A map indicating the location of sampling points relative to applicable point source discharges is presented in Figure 3-3.

Figure 3-3. Map of Sampling Locations and Point Source Discharges for the Duck Creek Watershed.



3.4.3. Flow data

For the purpose of this TMDL, annual $7Q_{10}$ stream flows for the summer season and annual $7Q_2$ stream flows for the winter season are employed. These flows represent worst-case scenarios for seasonal model evaluations. The use of worst-case conditions, in turn, creates a margin of safety in the final results.

The $7Q_{10}$ flow represents the minimum 7-day flow that occurs, on average, over a 10-year recurrence interval. Likewise, the $7Q_2$ is the minimum 7-day flow that occurs, on average, over a 2-year period.

Both flows (i.e., $7Q_{10}$ and $7Q_2$) can be calculated for the model using gage data from the United States Geological Survey (USGS) or by using the Bingham Equation. The Bingham Equation can be found on page 3 of a publication from the Geological Survey of Alabama entitled, **Low-Flow Characteristics of Alabama Streams, Bulletin 117**.

The equations used to calculate the $7Q_{10}$ and $7Q_2$ flows based on continuous USGS gagging records for the stream and any associated tributaries are as follows:

$$7Q_{10}\text{ (cfs)} = \frac{(7Q_{10}\text{ @ USGS Station (cfs))}}{(\text{Drainage Area @ USGS Station (mi}^2))} * (\text{Watershed Drainage Area (mi}^2))$$

$$7Q_{2}\text{ (cfs)} = \frac{(7Q_{2}\text{ @ USGS Station (cfs))}}{(\text{Drainage Area @ USGS Station (mi}^2))} * (\text{Watershed Drainage Area (mi}^2))$$

The $7Q_{10}$ and $7Q_2$ flows can also be estimated using the Bingham equation. Low flow estimates employing this equation are based on the stream's recession index (G, no units), the stream's drainage area (A, mi^2), and the mean annual precipitation (P, inches):

$$7Q_2\text{ (cfs)} = 0.24\text{x}10^{-4}(G-30)^{1.07}(A)^{0.94}(P-30)^{1.51}$$
$$7Q_{10}\text{ (cfs)} = 0.15\text{x}10^{-5}(G-30)^{1.35}(A)^{1.05}(P-30)^{1.64}$$

The method used to determine the $7Q_{10}$ and $7Q_2$ flows for the Duck Creek was the Bingham equation. The resulting $7Q_{10}$ and $7Q_2$ flows are 0.7 cfs and 4.6 cfs, respectively.

The calculated flows were distributed over Duck Creek in the form of tributary flow and incremental inflow (identified on the modeled reach schematic as IF). The IF was distributed in proportion to the length of each segment.

3.5 Critical Conditions

Summer months (May – November) are generally considered critical conditions for dissolved oxygen in streams. This can be explained by the nature of storm events in the summer versus the winter. Periods of low precipitation allow for slower in-stream velocity, which increases the organic loading residence time and decreases stream re-aeration rates. This increased time permits more decay to occur which depletes the streams dissolved oxygen supply. Reaction rates for $CBOD_u$ and NBOD (i.e., organic loading) are temperature dependent and high summertime temperatures increase the decay process, which depletes the dissolved oxygen even further.

In winter, frequent low intensity rain events are more typical and do not allow for the build-up of organic loading on the land surface, resulting in a more uniform loading rate. Higher flows and lower temperatures create less residence time and lower decay rates. This pattern is evidenced in the output data of the model where the highest allowable loading achieved was for winter stream flows.

3.6 Margin of Safety (MOS)

There are two basic methods of incorporating the MOS (USEPA, 1991): 1) implicitly, using conservative model assumptions, or 2) explicitly specify a portion of the TMDL as the MOS.

The MOS is implicit in this TMDL process through the use of conservative model input parameters (**temperature, flow and D.O. concentrations**). Conservative temperature values are employed through the use of the highest average maximum temperature that would normally occur under critical stream flow conditions. The $7Q_{10}$ and $7Q_2$ stream flows employed for summer and winter, respectively, reflect the lowest flows that would normally occur under critical conditions. All point source discharges were assumed to be continuous at current NPDES permit limits. And, finally, the D.O. concentration for incremental flow was set at 70% of the saturation concentration at the given temperature, which is 15% lower than the 85% normally assumed in a typical waste load allocation.

The following stream conditions also add to the MOS: 1) water depths are shallow, generally less than one foot, which exaggerates the effect of sediment oxygen demand (SOD); 2) water velocities are generally less than 0.5 fps or less, which intensifies the effect of SOD.

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4.0 Water Quality Model Development

4.1 Water Quality Model Selection and Setup

Since the impairment noted by the available data occurred during periods of low flows, a steady-state modeling approach was adopted as appropriate to represent the relevant conditions in the impaired waterbody. The steady state TMDL spreadsheet water quality model (SWQM) developed by the ADEM was selected for the following reasons:

- It is a simplified approach without unnecessary complexity.
- It conforms to ADEM standard practices for developing wasteload allocations.
- It lends itself to being developed with limited data, which is the present situation for this waterbody.
- It has the ability to handle tributary inputs and both point and non-point source inputs.

The TMDL spreadsheet model also provides a complete spatial view of a stream, upstream to downstream, giving differences in stream behavior at various locations along the model reach. The model computes dissolved oxygen using a modified form of the Streeter-Phelps equation. The modified Streeter-Phelps equation takes into account the oxygen demand due to carbonaceous decay plus the oxygen demand generated from the nitrification process (ammonia decay). Each stream reach is divided into twenty elements, with each element assumed to be the functional equivalent of a completely mixed reactor.

The following assumptions were used in the spreadsheet TMDL model***:***

- D.O. concentrations for incremental flow were assumed @ 70% of the saturated value at the given temperature. **(MOS)**
- Incremental and tributary loading were apportioned to correlate with the land usage of the drainage basin.
- Ratios for $CBOD_U/NH_3OD_U$ and $CBOD_U/TONOD_U$ were calculated using water quality data for the waterbody. These ratios were assigned in the estimation of loading parameters for incremental flow and tributaries for all land uses, except forest and open water.
- $CBOD_u/BOD_5$ ratios used for point sources were 1.5.
- $CBOD_u/BOD_5$ ratios used for nonpoint sources were 1.5.
- NH_3OD_u is equal to 4.57 times the ammonia nitrogen concentration.
- $TONOD_u$ is equal to 4.57 times the organic nitrogen concentration.
- Background conditions were assumed for forest incremental flow. Background conditions are typically the following ranges: 2-3 mg/l $CBOD_u$, 0.2-1 mg/l NH_3ODu, 1-2 mg/l $TONOD_u$.

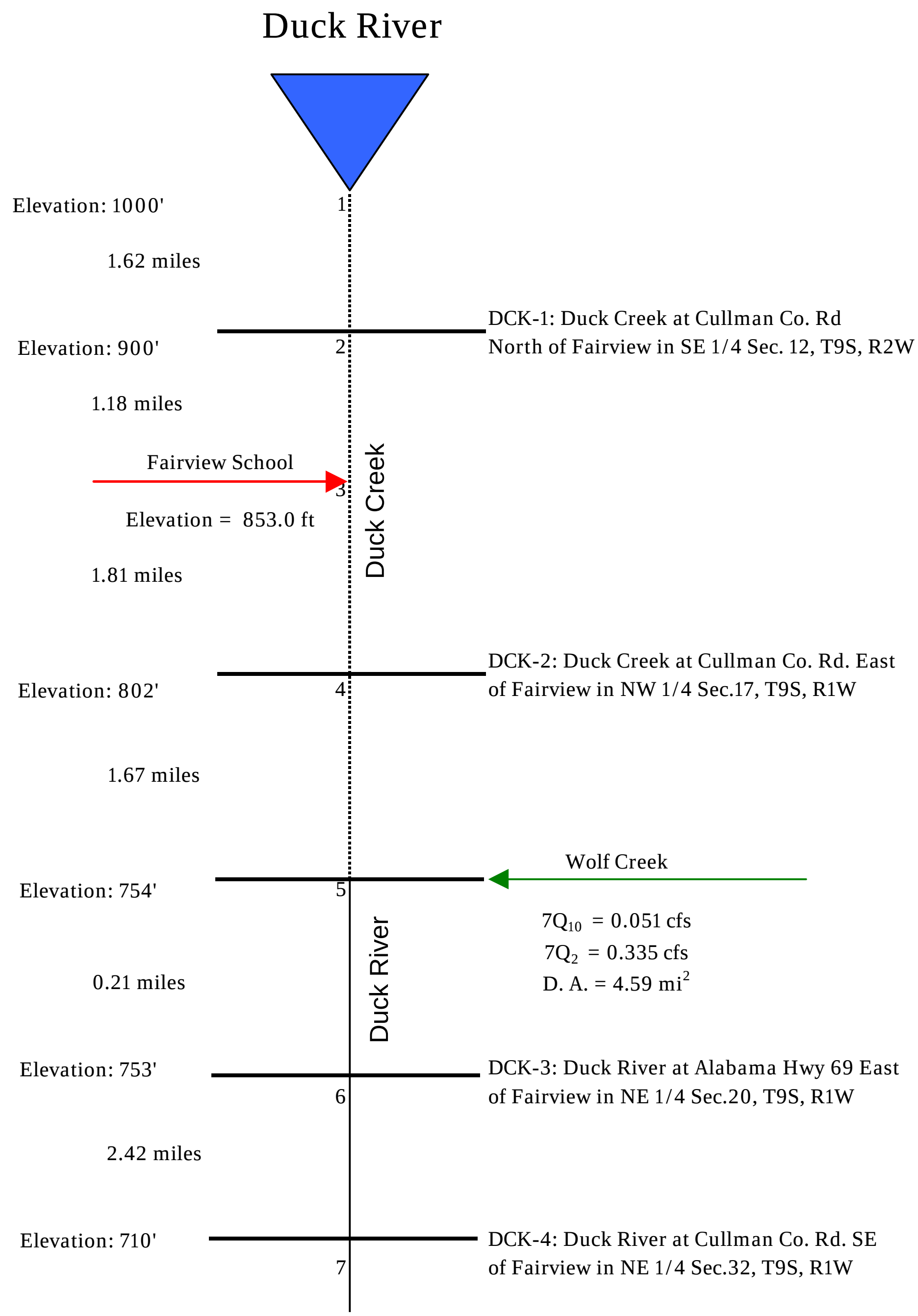
4.1.1. SOD Representation: Sediment oxygen demand (SOD) can be an important part of the oxygen demand budget in shallow streams. However, for shallow streams with steep slopes and rocky substrate, the SOD component is generally small. These hydrogeological conditions are representative of the Duck Creek. It is believed, therefore, that the SOD for this stream is minimal. In the absence of available field SOD measurements for the waterbody, SOD data was obtained from EPA Region IV's SOD database. The EPA SOD database represents mixed land uses and varying degrees of point source activity. A SOD value of 0.05 gm-O_2 ft^2/day was chosen based on similar bottom characteristics of sand, conglomerate, shale, siltstone, and coal.

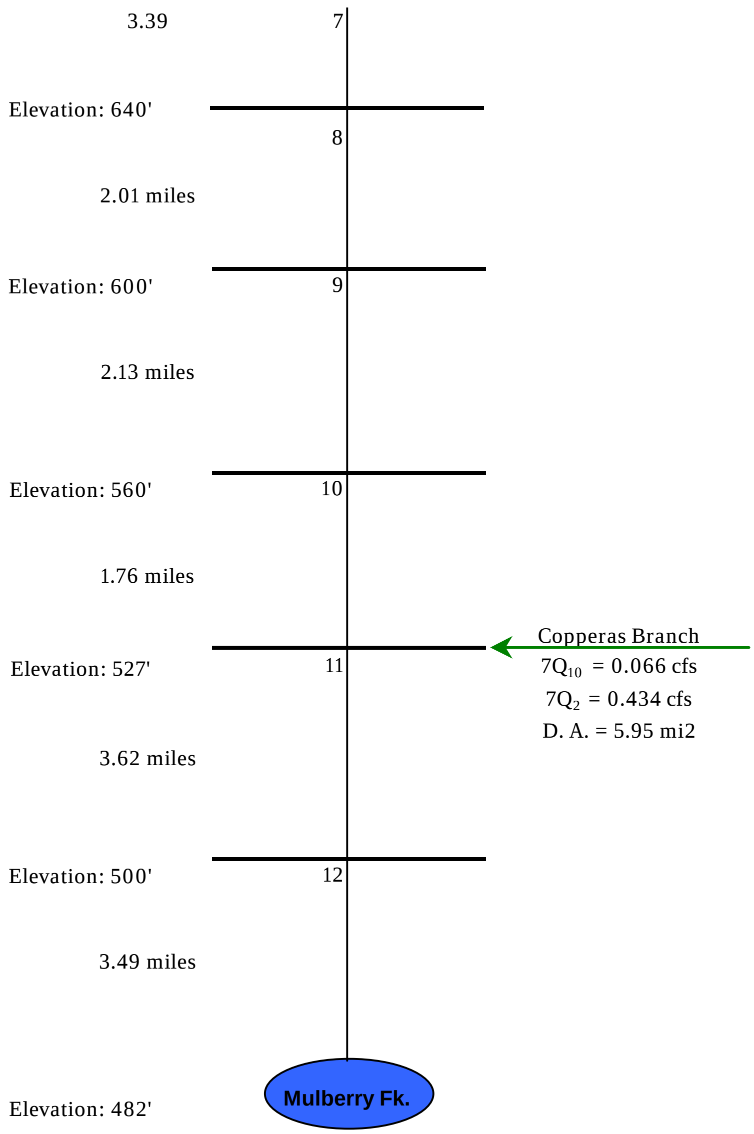
4.1.2. Calibration Data: The model calibration period was determined from an examination of the available field data (ref: Appendix). The morning of 10/09/97 was chosen due to it being a recent sampling period having the lowest D.O. values during a period when flows were recorded and DMR data was available for the Fairview School. The stream conditions (i.e., D.O., temperature, etc.) during this period were incorporated into the calibrated model TMDL spreadsheet.

4.2 Water Quality Model Summary

The model reach used for each season was longer than the impaired reach in order to ensure that predicted model pollutant concentrations were at, or near, normal background concentrations at the end of the modeled reach. The model reach consisted of 12 segments. The impaired portion of the model reach consists of segments 1-4. The length of the impaired portion is 6.28 miles. Total distance of the model reach is 25.31 miles. A schematic diagram of the model is presented in Figure 4-1. Assumed in-stream seasonal temperatures are based on historical model development. A guide for use of ADEM's TMDL water quality model can be found in the appendix. The guide also explains the theoretical basis for the physical/chemical mechanisms and principles that form the foundation of the model.

Figure 4-1. Schematic of the Modeled Reach.





Dec-April minimum 7Q2 = 4.6 cfs
May-Nov minimum 7Q10 = 0.7 cfs

4.2.1. Summer (May – November) Model

Summer Stream Flow Parameters

Description	**Flow (cfs)**	**DO (mg/l)**	**$CBOD_U$ (mg/l)**	**NH_3N (mg/l)**	**TON (mg/l)**	**Temp (^oC)**
Headwaters	0.00	6.65	1.75	0.1331	3.04	28
Fair Field school	0.046	3.00	37.5	2.9	2.9	28
Conditions @ Lowest D.O.	0.746	5.02	0.23	.05	0.26	28
Flow @ End of Model	0.746	5.02	0.23	.05	0.26	28

Summer Incremental Flow Parameters

Sections	**$CBOD_U$ (mg/l)**	**NH_3N (mg/l)**	**TON (mg/l)**	**DO (mg/l)**	**Total Flow (cfs)**	**Temp. (^oC)**
1	**1.7478**	**0.1331**	**0.3745**	**5.4800**	**0.04**	**28.0**
2	**1.7478**	**0.1331**	**0.3745**	**5.4800**	**0.03**	**28.0**
3	**1.7478**	**0.1164**	**0.3213**	**5.4800**	**0.04**	**28.0**
4	**1.7478**	**0.1164**	**0.3213**	**5.4800**	**0.04**	**28.0**
5	**1.7478**	**0.1164**	**0.3213**	**5.4800**	**0.00**	**28.0**
6	**1.7478**	**0.1122**	**0.3213**	**5.4800**	**0.06**	**28.0**
7	**1.7478**	**0.1122**	**0.3213**	**5.4800**	**0.08**	**28.0**
8	**1.7478**	**0.1122**	**0.3213**	**5.4800**	**0.05**	**28.0**
9	**1.7478**	**0.1122**	**0.3213**	**5.4800**	**0.05**	**28.0**
10	**1.7478**	**0.1122**	**0.3213**	**5.4800**	**0.04**	**28.0**
11	**1.7478**	**0.1122**	**0.3213**	**5.4800**	**0.08**	**28.0**
12	**1.7478**	**0.1122**	**0.3213**	**5.4800**	**0.08**	**28.0**

4.2.2 Winter (December – April) Model

Winter Stream Flow Parameters

Description	**Flow (cfs)**	**DO (mg/l)**	**$CBOD_U$ (mg/l)**	**NH_3N (mg/l)**	**TON (mg/l)**	**Temp (^oC)**
Headwaters	0.00	8.05	31.80	2.75	8.96	18
Fair Field school	0.05	0	37.50	20	20	18
Conditions @ Lowest D.O.	1.51	5.01	11.46	1.63	7.37	18
Flow @ End of Model	4.65	5.05	15.7	1.98	7.52	18

Winter Incremental Flow Parameters

Sections	**$CBOD_U$ (mg/l)**	**NH_3N (mg/l)**	**TON (mg/l)**	**DO (mg/l)**	**Total Flow (cfs)**	**Temp. (^oC)**
1	**31.8023**	**2.7488**	**8.9615**	**6.6300**	**0.25**	**18.0**
2	**31.8023**	**2.7488**	**8.9615**	**6.6300**	**0.18**	**18.0**
3	**31.8023**	**2.3509**	**8.9083**	**6.6300**	**0.27**	**18.0**
4	**31.8023**	**2.3509**	**8.9083**	**6.6300**	**0.25**	**18.0**
5	**31.8023**	**2.3509**	**8.9083**	**6.6300**	**0.03**	**18.0**
6	**31.8023**	**2.2169**	**8.9083**	**6.6300**	**0.37**	**18.0**
7	**31.8023**	**2.2169**	**8.9083**	**6.6300**	**0.51**	**18.0**
8	**31.8023**	**2.2169**	**8.9083**	**6.6300**	**0.30**	**18.0**
9	**31.8023**	**2.2169**	**8.9083**	**6.6300**	**0.32**	**18.0**
10	**31.8023**	**2.2169**	**8.9083**	**6.6300**	**0.27**	**18.0**
11	**31.8023**	**2.2169**	**8.9083**	**6.6300**	**0.55**	**18.0**
12	**31.8023**	**2.2169**	**8.9083**	**6.6300**	**0.53**	**18.0**

4.3 Summer and Winter Models Predictions and Graphics

Figure 4-2. Summer Model Predictions.

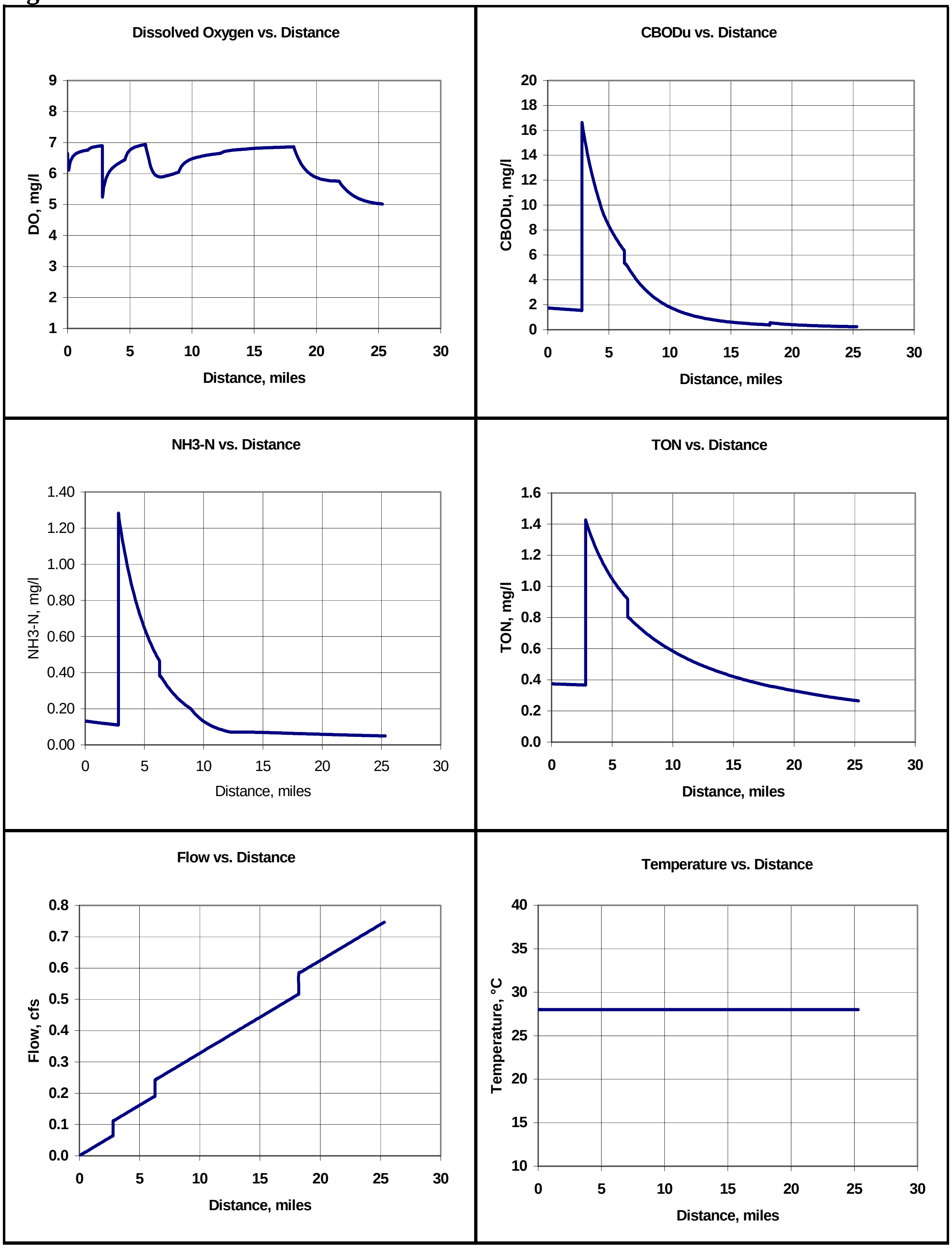
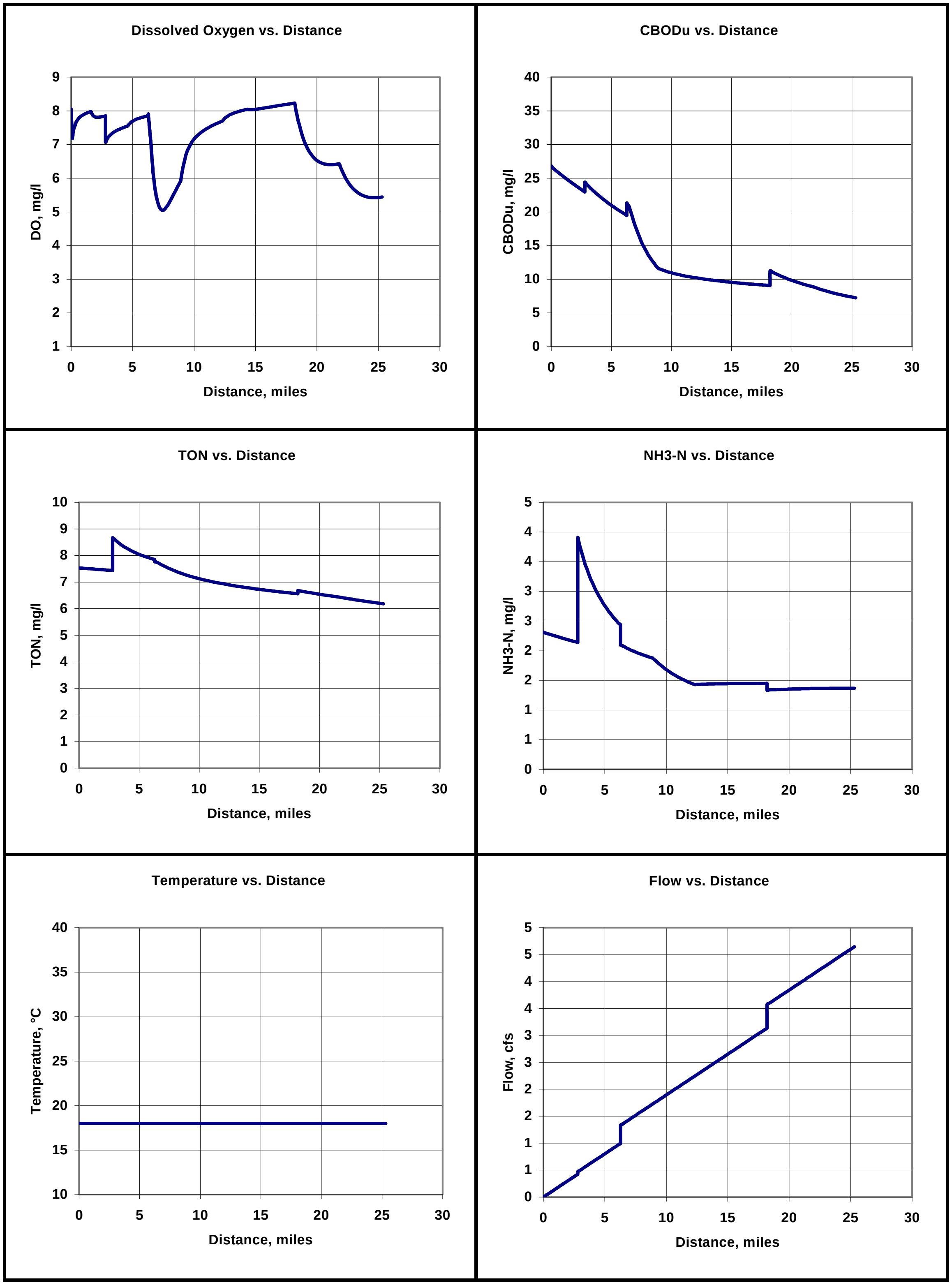


Figure 4-3. Winter Model Predictions.



4.4 Loading Reduction Analysis

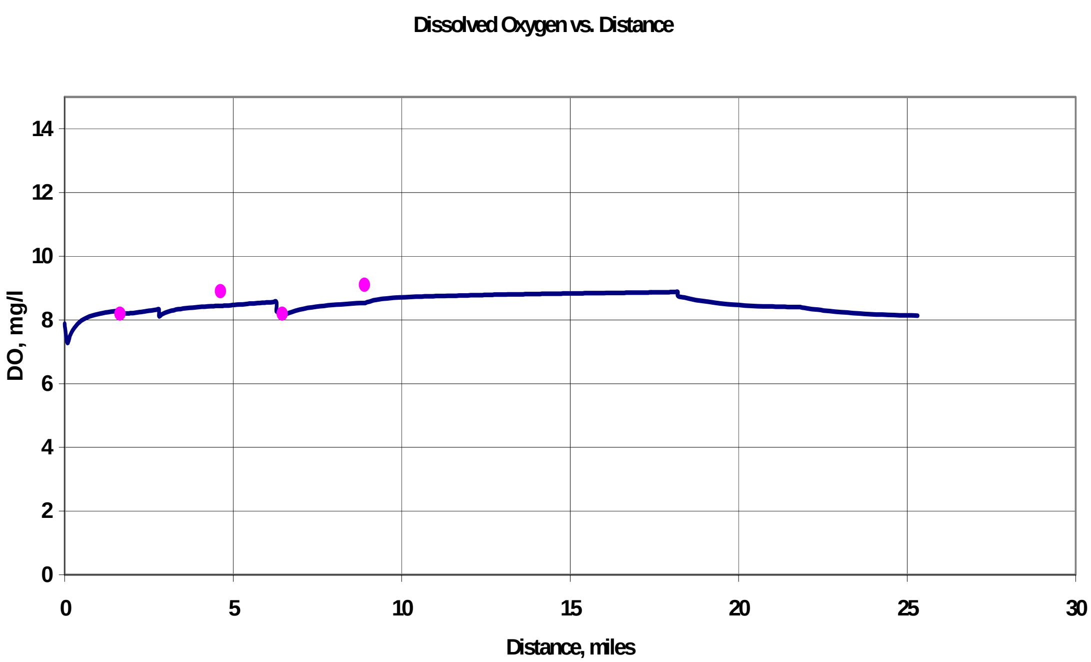
4.4.1. Calibrated Model

The model calibration period was determined from an examination of the available field data (ref: Appendix). The morning of 10/09/97 was chosen due to it being a recent sampling period having the lowest D.O. values during a period when flows were recorded and DMR data was available for the Fairview School.
The stream conditions (i.e., D.O., temperature, etc.) during this period were incorporated into the calibrated model TMDL spreadsheet.

Field data from the sampling event were used as input into the model to perform a calibrated model. Non-point source loading was adjusted so that model predictions simulated the measured D.O. values as closely as possible while still providing a reasonable representation of water quality in the stream at the time of the sampling event.

Shown in Figure 4-4, below, is a plot of D.O. calibrated model predictions vs. actual D.O. field data.

Figure 4-4. Calibrated Model D.O. Predictions vs. Actual D.O. Field Data.



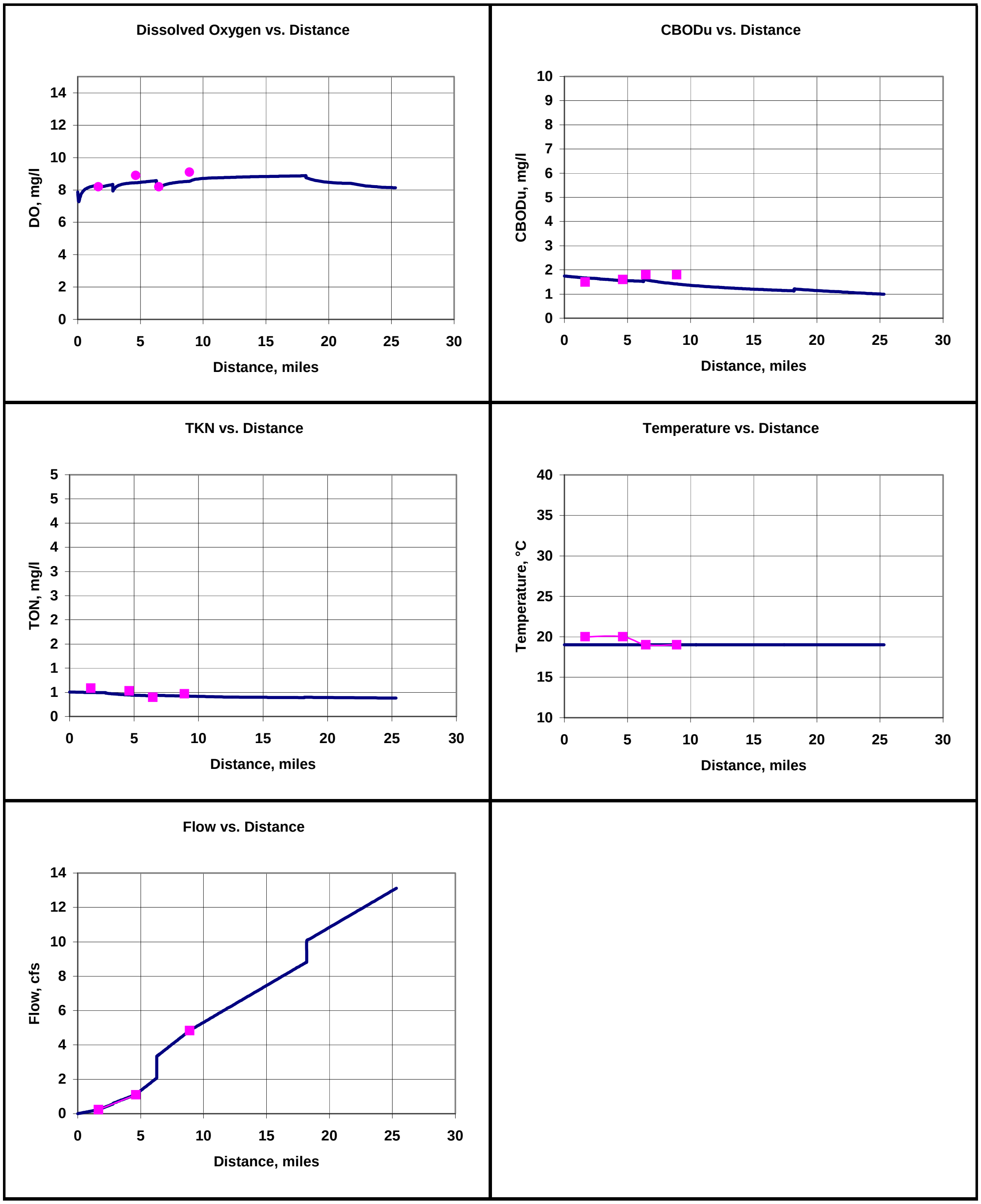
Calibrated Model Flow Parameters

Description	Flow (cfs)	DO (mg/l)	$CBOD_U$ (mg/l)	NH3N (mg/l)	TON (mg/l)	Temp (°C)
Headwaters	0.00	7.88	1.75	0.133	.375	19
Fair Field school	0.03	1.5	1.5	0.16	0.16	19
Conditions @ Low D.O.	0.12	7.28	1.74	0.13	0.37	19
Flow @ End of Model	13.12	8.14	0.99	0.08	0.30	19

Calibrated Model Incremental Flow Parameters

Sections	$CBOD_U$ (mg/l)	NH_3N (mg/l)	TON (mg/l)	DO (mg/l)	Total Flow (cfs)	Temp. (°C)
1	**1.7478**	**0.1331**	**0.3745**	**6.4900**	**0.23**	**19.0**
2	**1.7478**	**0.1331**	**0.3745**	**6.4900**	**0.34**	**19.0**
3	**1.7478**	**0.1164**	**0.3213**	**6.4900**	**0.52**	**19.0**
4	**1.7478**	**0.1164**	**0.3213**	**6.4900**	**0.96**	**19.0**
5	**1.7478**	**0.1164**	**0.3213**	**6.4900**	**0.12**	**19.0**
6	**1.7478**	**0.1122**	**0.3213**	**6.4900**	**1.39**	**19.0**
7	**1.7478**	**0.1122**	**0.3213**	**6.4900**	**1.45**	**19.0**
8	**1.7478**	**0.1122**	**0.3213**	**6.4900**	**0.86**	**19.0**
9	**1.7478**	**0.1122**	**0.3213**	**6.4900**	**0.91**	**19.0**
10	**1.7478**	**0.1122**	**0.3213**	**6.4900**	**0.75**	**19.0**
11	**1.7478**	**0.1122**	**0.3213**	**6.4900**	**1.55**	**19.0**
12	**1.7478**	**0.1122**	**0.3213**	**6.4900**	**1.50**	**19.0**

Figure 4-4. Calibrated Model Predictions and Graphics.



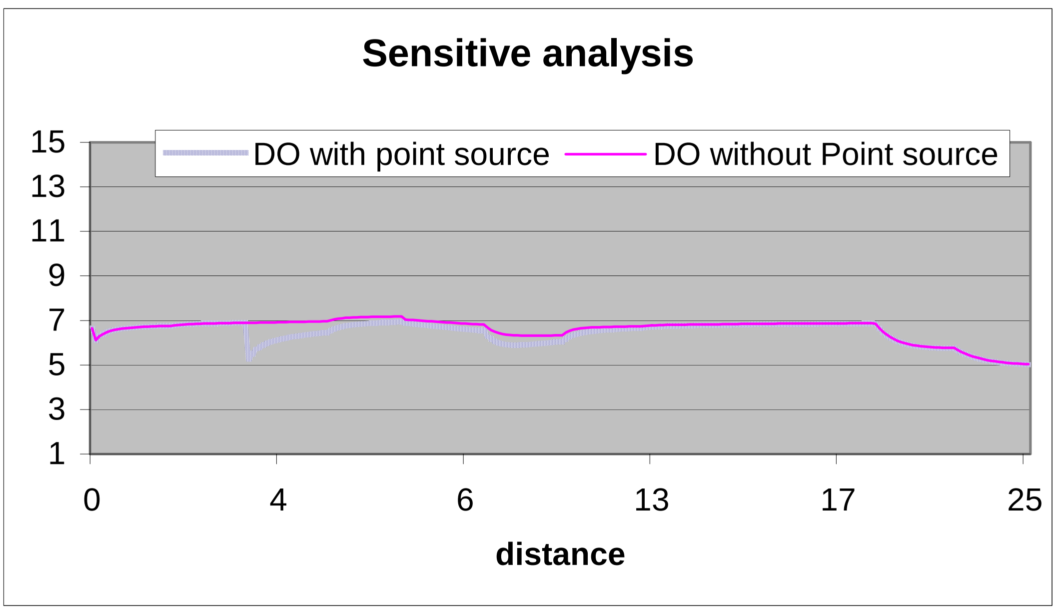
4.4.2. Load Reduction Model

No load reduction model was run due to the fact that when permit limits and critical conditions were put into the calibrated model the waterbody was already in compliance with the 5 mg/l D.O. Fish & Wildlife water quality standard. No reductions were necessary.

4.4.3 Point Source Sensitivity Analysis

Figure 4-6 below shows the influence of the point source, that is, with only nonpoint sources present. The plot includes two sets of model results: 1) with point and nonpoint sources; and 2) with nonpoint sources alone. The critical condition without point sources but including nonpoint sources (labeled without point source) shows that the point source does have an effect on the stream for a short distance after the discharge point but does not drop the DO level below the criteria.

Figure 4-6 Point Source Sensitivity Analysis



4.4.4. Required Reductions

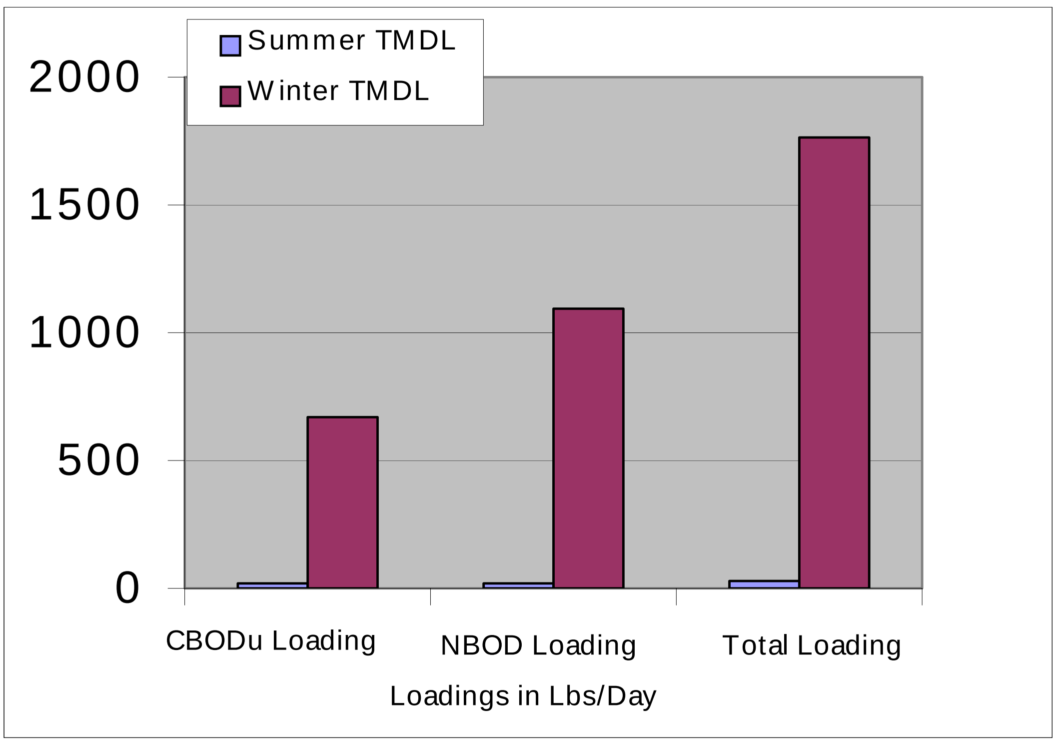
Due to the fact that when permitted limits for the point source, and critical stream flow conditions were put into the calibrated model and the DO did not drop below the criteria no reductions were required for this stream.

4.5 Seasonal Variation

The regulations require that a TMDL be established with consideration of seasonal variations. Since impairments occurred only during the summer months and not during other times of the year, a seasonal variation in the TMDL was not necessary. However, since there were point source loads identified, both summer and winter TMDLs were calculated for the purposes of determination of applicable point source permit limitations year round.

As discussed previously, TMDLs have been estimated for the summer and winter. Figure 4-7, below, illustrates the effect that seasonal temperatures and stream flows have on CBODu, NBOD and total organic loading at insert location.

Figure 4-7. Seasonal Temperature and Stream Effects on the TMDLs



5.0 Conclusions

A summary of the TMDL for both summer and winter is presented in Table 5-1.

Table 5-1. Summer and Winter TMDLs Summary

	TMDL	
	Summer	**Winter**
$CBOD_u$ Loading (lbs./day)	16	674
NBOD Loading (lbs./day)	14.3	1093
Total Loading (lbs./day)	30.3	1767

Within the impaired segment, the point source allocations used in development of the summer and winter TMDL will be addressed by the NPDES permit program during permit renewals and modifications. Based on the summer and winter TMDL analysis no reductions will be necessary.

6.0 TMDL Implementation

6.1 Non-Point Source Approach

Duck Creek is impaired primarily by nonpoint sources. For 303(d) listed waters impaired solely or primarily by nonpoint source (NPS) pollutants, necessary reductions will be sought during TMDL implementation using a phased approach. Voluntary, incentive-based mechanisms will be used to implement NPS management measures in order to assure that measurable reductions in pollutant loadings can be achieved for the targeted impaired water. Cooperation and active participation by the general public and various industry, business, and environmental groups is critical to successful implementation of TMDLs. Local citizen-led and implemented management measures offer the most efficient and comprehensive avenue for reduction of loading rates from nonpoint sources. Therefore, TMDL implementation activities will be coordinated through interaction with local entities in conjunction with Clean Water Partnership efforts.

The primary TMDL implementation mechanism used will employ concurrent education and outreach, training, technology transfer, and technical assistance with incentive-based pollutant management measures. The ADEM Office of Education and Outreach (OEO) will assist in the implementation of TMDLs in cooperation with public and private stakeholders. Planning and oversight will be provided by or coordinated with the Alabama Department of Environmental Management's (ADEM) Section 319 nonpoint source grant program in conjunction with other local, state, and federal resource management and protection programs and authorities. The CWA Section 319 grant program may provide limited funding to specifically ascertain NPS pollution sources and causes, identify and coordinate management programs and resources, present education and outreach opportunities, promote pollution prevention, and implement needed management measures to restore impaired waters.

Depending on the pollutant of concern, resources for corrective actions may be provided, as applicable, by the Alabama Cooperative Extension System (education and outreach); the USDA-Natural Resources Conservation Service (NRCS) (technical assistance) and Farm Services Agency (FSA) (federal cost-share funding); and the Alabama Soil and Water Conservation Committee (state agricultural cost share funding and management measure implementation assistance) through local Soil and Water Conservation Districts, or Resource Conservation and Development Councils (funding, project implementation, and coordination). Additional assistance from such agencies as the Alabama Department of Public Health (septic systems), Alabama Department of Agriculture and Industries (pesticides), and the Alabama Department of Industrial Relations and Dept of Interior - Office of Surface Mining (abandoned minelands), Natural Heritage Program and US Fish and Wildlife Service (threatened and endangered species), may also provide practical TMDL implementation delivery systems, programs, and information. Land use and urban sprawl issues will be addressed through the Nonpoint Source for Municipal Officials (NEMO) education and outreach program. Memorandums of Agreements (MOAs) may be used as a tool to formally define roles and responsibilities.

Additional public/private assistance is available through the Alabama Clean Water Partnership Program (CWP). The CWP program uses a local citizen-based environmental protection approach to coordinate efforts to restore and protect the state's resources in accordance with the goals of the Clean Water Act. Interaction with the state or river basin specific CWP will facilitate TMDL implementation by providing improved and timely communication and information exchange between community-based groups, units of government, industry, special interest groups, and individuals. The CWP can assist local entities to plan, develop, and coordinate restoration strategies that holistically meet multiple needs, eliminate duplication of efforts, and allow for effective and efficient use of available resources to restore the impaired waterbody or watershed.

Other mechanisms that are available and may be used during implementation of this TMDL include local regulations or ordinances related to zoning, land use, or storm water runoff controls. Local governments can provide funding assistance through general revenues, bond issuance, special taxes, utility fees, and impact fees. If applicable, reductions from point sources will be addressed by the NPDES permit program. The Alabama Water Pollution Control Act empowers ADEM to monitor water quality, issue permits, conduct inspections, and pursue enforcement of discharge activities and conditions that threaten water quality. In addition to traditional "end-of-pipe" discharges, the ADEM NPDES permit program addresses animal feeding operations and land application of animal wastes. For certain water quality improvement projects, the State Clean Water Revolving Fund (SRF) can provide low interest loans to local governments.

Long-term physical, chemical, and biological improvements in water quality will be used to measure TMDL implementation success. As may be indicated by further evaluation of stream water quality, the effectiveness of implemented management measures may necessitate revisions of this TMDL. The ADEM will continue to monitor water quality according to the rotational river basin monitoring schedule as allowed by resources. In addition, assessments may include local citizen-volunteer monitoring through the Alabama Water Watch Program and/or data collected by agencies, universities, or other entities using standardized monitoring and assessment methodologies. Core management measures will include, but not be limited to water quality improvements and designated use support, preserving and enhancing public health, enhancing ecosystems, pollution prevention and load reductions, implementation of NPS controls, and public awareness and attitude/behavior changes.

6.2 Point Source Approach

If applicable, reductions from point sources will be addressed by the NPDES permit program.

7.0 Follow Up Monitoring

ADEM has adopted a basin approach to water quality management; an approach that divides Alabama's fourteen major river basins into five groups. Each year, the ADEM water quality resources are concentrated in one of the basin groups. One goal is to continue to monitor §303(d) listed waters. This monitoring will occur in each basin according to the following schedule:

River Basin Group	Schedule
Cahaba / Black Warrior	2002
Tennessee	2003
Choctawhatchee / Chipola / Perdido-Escambia / Chattahoochee	2004
Tallapoosa / Alabama / Coosa	2005
Escatawpa / Upper Tombigbee / Lower Tombigbee / Mobile	2006

Monitoring will help further characterize water quality conditions resulting from the implementation of best management practices in the watershed. As Part of TMDL implementation Duck Creek will be monitored during 2002. If so indicated by the data collection the TMDL will be revised

8.0 Public Participation

A sixty-day public notice was provided for this TMDL. During this time, the availability of the TMDL was public noticed, a copy of the TMDL was provided as requested, and the public was invited to provide comments on the TMDL.

Appendix 9.1
References

References

Adkins, J.B., Pearman, J.L.. 1994. Low-Flow and Flow-Duration Characteristics of Alabama Streams. Water-Resources Investigations Report 93-4186.

Bingham, R.H.. 1982. Low-Flow Characteristics of Alabama Streams. Geological Survey Water-Supply Paper 2083

United States Environmental Protection Agency. 1991. Guidance for Water Quality-Based Decisions: The TMDL Process, Office of Water, EPA 440/4-91-00

United States Environmental Protection Agency Region IV Sediment Oxygen Demand (SOD) Database

Appendix 9.2
Water Quality Data

May-97

STATION	DATE	TIME	T/A °C	T/W °C	pH	DO	F. COLI.	COND.	TURB.	HARD	CBOD$_5$	TSS	TDS	ORTHO P	NH$_3$-N	NO$_2$+NO$_3$-N	TKN	PO$_4$-P	DEPTH	WIDTH	FLOW
DCK-1	5/29/97	11:45	17	16.6	7.75	7.62	>1200	60.6	15.5	32	2.4	13	60	<.005		0.882	1.001	0.086	0.6	10	normal
DCK-2	5/28/97	12:05	17	18.6	6.15	7.26	284	67.8	6.3	32	2.2	3	64	<.005	0.048	1.185	0.402	0.05	0.5	10	
DCK-3	5/28/97	10:20	15	19.2	6.63	7.17	500	68.2	6.1	32	2.1	3	67	0.019	0.055	1.528	0.874	0.059	2	15	normal
DCK-4	5/28/97	12:30	16	19.3	6.38	7.15	360	64.1	5	30	2.2	2	63	0.021	0.078	1.344	0.524	0.063	3	25	

June-97

STATION	DATE	TIME	T/A °C	T/W °C	pH	DO	F. COLI.	COND.	TURB.	HARD	CBOD$_5$	TSS	TDS	ORTHO P	NH$_3$-N	NO$_2$+NO$_3$-N	TKN	PO$_4$-P	DEPTH	WIDTH	FLOW
DCK-1	6/25/97	10:50	27	23.4	6.29	7.3	660	53.9	9	34	0.3	8	51	<.005		1.269	0.769	0.06	0.75	15	fast
DCK-2	6/26/97	11:40	26	23.4	6.45	7.65	2700	61.4	16.1	32	0.9	11	58	0.008	<.005	1.976	0.649	0.106			
DCK-3	6/26/97	10:25	28	22.9	6.82	8.13	390	61.9	8	32	0.7	5	60	0.02	0.016	2.164	0.289	0.066	4	15	
DCK-4	6/26/97	12:10	25	23.6	6.76	7.6	250	59.5	9.3	36	1	5	57	0.018	0.017	1.977	0.362	0.057			

July-97

STATION	DATE	TIME	T/A °C	T/W °C	pH	DO	F. COLI.	COND.	TURB.	HARD	CBOD$_5$	TSS	TDS	ORTHO P	NO$_2$+NO$_3$-N	TKN	PO$_4$-P	DEPTH	WIDTH	FLOW
DCK-1	7/22/97	11:00	23	24.4	6.64	5			14.6	36	2.1	8	67	0.03	0.999	1.237	0.108	1	5	
DCK-2	7/22/97	13:00	24	24.3	6.98	6.9				36	1.2	5	70	0.015	1.107	0.549	0.058	2	10	
DCK-3	7/22/97	11:30	23	24	7	6.6				38	1	2	72	0.025	1.341	0.574	0.062	>5	30	
DCK-4	7/22/97	13:30	25	25.1	6.98	6.8				34	1.5	4	70	0.023	1.17	0.559	0.066	2	15	

August-97

STATION	DATE	TIME	T/A °C	T/W °C	pH	DO	F. COLI.	COND.	TURB.	HARD	CBOD$_5$	TSS	TDS	ORTHO P	NO$_2$+NO$_3$-N	TKN	PO$_4$-P	DEPTH	WIDTH	FLOW
DCK-1	8/28/97	12:25	32	25	6.62	1.57	>1200	129	19.5	52	7.3	18	96	0.016	0.028	3.163	0.359	5"	10	slow
DCK-2	8/28/97	12:00	32.5	23.5	6.98	5.3	180	95.4	2.3	54	60	1	85	<.005	0.441	0.579	0.043	5"	10	slow
DCK-3	8/28/97	10:40	32	23	6.74	6.9	37	79.3	1.8	50	0.7	<1	69	0.013	0.35	0.321	0.054	0.5	15	slow
DCK-4	8/28/97	13:10	33	23	6.72	5.97	12	76.8	1.6	96	0.8	2	66	0.014	0.248	0.368	0.054			

DUCKCREEK01

Date	AIR TEMP CENT	BOD 5 DAY MG/L	CNDUCTVYFIELD MICROMHO	DO MG/L	DO SATUR PERCENT	NH3+NH4-N TOTAL MG/L	NO2&NO3 N-TOTAL MG/L	ORG N N MG/L	PH SU	PHOS-TOT MG/L P	RESIDUE TOT NFLT MG/L	TOT KJEL N MG/L	TURB JKSN JTU	UN-IONZD NH3-N MG/L	UN-IONZD NH3-NH3 MG/L	WATER TEMP CENT	WATER TEMP FAHN
04/20/1988		3	62.2	8.9	83.962	0.2	1.72	0.8	6	0.01	15	1	9.3	0	0	13	55.4
05/17/1988		1.5	102.8	7.1	75.532	0.1	0.95	1.1	5.9	0.03	6	1.2	3.6	0	0	19	66.2
09/28/1988	22	1	102.1	7.3	79.348	0.2	1.68	1.2	7.2	0.02	4	1.2	4.7	0.001	0.002	20	68
10/26/1988	11	1.2	93.9	9.1	84.259	0.2	0.43	0.4	7	0.02	1	0.4	2.9	0	0.001	12	53.6

DUCKCREEK02

Date	AIR TEMP CENT	BOD 5 DAY MG/L	CNDUCTVYFIELD MICROMHO	DO MG/L	DO SATUR PERCENT	NH3+NH4-N TOTAL MG/L	NO2&NO3 N-TOTAL MG/L	ORG N N MG/L	PH SU	PHOS-TOT MG/L P	RESIDUE TOT NFLT MG/L	TOT KJEL N MG/L	TURB JKSN JTU	UN-IONZD NH3-N MG/L	UN-IONZD NH3-NH3 MG/L	WATER TEMP CENT	WATER TEMP FAHN
04/20/1988		1.2	61.1	9.8	92.453	0.1	2.06	1.2	5.8	0.02	19	1.2	9.4	0	0	13	55.4
05/17/1988		1.1	94.1	6.8	73.913	0.1	1.04	1.4	5.9	0.03	5	1.4	3.1	0	0	20	68
06/29/1988		1.8	105.3	3.1	34.444	0.2	0.03	0.9	6.5	0.05	10	1.1	4.5	0	0	21	69.8
07/20/1988	27	1	114.8	3.9	45.882	0.2	0.06	0.5	7	0.01	5	0.7	4	0.001	0.001	24	75.2
09/28/1988	23	1	91.7	7.5	81.522	0.2	1.8	1.1	7	0.03	1	1.1	3.5	0.001	0.001	20	68
10/26/1988	11	1.3	94.5	9.1	81.982	0.2	0.93	0.6	7.2	0.02	1	0.6	1.4	0.001	0.001	11	51.8

DUCKCREEK03

Date	AIR TEMP CENT	BOD 5 DAY MG/L	CNDUCTVYFIELD MICROMHO	DO MG/L	DO SATUR PERCENT	NH3+NH4-N TOTAL MG/L	NO2&NO3 N-TOTAL MG/L	ORG N N MG/L	PH SU	PHOS-TOT MG/L P	RESIDUE TOT NFLT MG/L	TOT KJEL N MG/L	TURB JKSN JTU	UN-IONZD NH3-N MG/L	UN-IONZD NH3-NH3 MG/L	WATER TEMP CENT	WATER TEMP FAHN	Flow CFS
04/20/1988		1.6	55.6	9.6	90.566	1	1.64	1.4	5.8	0.02	21	1.4	10	0	0	13	55.4	
05/17/1988		1.1	78.2	7.5	81.522	0.1	0.74	0.8	6.3	0.01	3	0.8	3.5	0	0	20	68	453
06/29/1988		1.4	73.5	4.6	52.273	0.1	0.08	1	6.3	0.04	3	1.1	2	0	0	22	71.6	0
07/20/1988	27	1	74.1	3	35.714	0.1	0.04	0.6	6.3	0.02	2	0.7	5.5	0	0	25	77	1.6
08/31/1988	25	1	58	5.8	65.909	0.2	0.06	1.4	6.8	0.02	2	1.4	2	0.001	0.001	22	71.6	
09/28/1988	23.5	1	78.9	8.2	91.111	0.2	1.74	0.8	5.9	0.02	3	0.8	4	0	0	20.8	69.44	
10/26/1988	12.8	1.4	80.8	9.3	82.301	0.2	0.69	1.4	6.5	0.02	1	1.4	1.8	0	0	10.5	50.9	432

DUCKCREEK04

Date	AIR TEMP CENT	BOD 5 DAY MG/L	CNDUCTVYFIELD MICROMHO	DO MG/L	DO SATUR PERCENT	NH3+NH4-N TOTAL MG/L	NO2&NO3 N-TOTAL MG/L	ORG N N MG/L	PH SU	PHOS-TOT MG/L P	RESIDUE TOT NFLT MG/L	TOT KJEL N MG/L	TURB JKSN JTU	UN-IONZD NH3-N MG/L	UN-IONZD NH3-NH3 MG/L	WATER TEMP CENT	WATER TEMP FAHN
04/20/1988		1.9	55.5	9	84.906	0.1	1.52	1.7	6.5	0.05	26	1.8	13	0	0	13	55.4
05/17/1988		1.3	76.9	6	65.217	0.1	0.95	0.8	6.3	0.09	5	0.8	4.5	0	0	20	68
06/29/1988		2.3	85.5	2.4	28.235	0.1	1.62	1.5	5.7	0.08	10	1.6	3.9	0	0	24	75.2
07/20/1988	28	1	73.6	4.5	55.556	0.1	0.02	0.8	6.6	0.04	4	0.8	4.7	0	0	27	80.6
08/31/1988	25	2.2	52	4.3	49.425	0.2	0.04	1.2	6.5	0.05	6	1.2	8	0	0	23	73.4
09/28/1988	23	1	76.1	7.5	83.333	0.2	1.44	0.8	6.1	0.03	5	0.8	3.8	0	0	20.7	69.26
10/26/1988	10	1.2	78	9.2	82.883	0.2	0.68	1.2	7.3	0.04	3.5	1.2	2.6	0.001	0.001	11	51.8

DUCKRIVERCULL01

Date	AIR TEMP CENT	BOD 5 DAY MG/L	CNDUCTVYFIELD MICROMHO	DO MG/L	DO SATUR PERCENT	NH3+NH4-N TOTAL MG/L	NO2&NO3 N-TOTAL MG/L	ORG N N MG/L	PH SU	PHOS-TOT MG/L P	RESIDUE TOT NFLT MG/L	TOT KJEL N MG/L	TURB JKSN JTU	UN-IONZD NH3-N MG/L	UN-IONZD NH3-NH3 MG/L	WATER TEMP CENT	WATER TEMP FAHN	Flow CFS
08/13/1997	33	0.9		8.35	99.412				6.8	0.05	2					24.72	76.496	1.64

ALIAS STATION NAME	STATION	DATE FROM TO	TIME OF DAY	WATER TEMP CENT	CNDUCTVY FIELD MICROMHO	DO MG/L	DO SAT %	BOD 5 DAY MG/L	PH SU	NH3+NH4- N TOTAL MG/L	TOT KJEL N MG/L	NO2&NO3 N-TOTAL MG/L	PHOS-TOT MG/L P	FEC COLI M-FCAGAR /100ML
D9	D9	06/03/91	9:50	24.8	79	6.6	0.80	0.4	7.3	0.06	0.5	1.1	0.06	120
DCK-4	D6	06/04/91	12:45	24.5	83	8.5	1.00	1.4	7.6	0	0.24	1.1	0.12	320
DCK-4	D6	07/10/91	6:50	24	75	7.4	0.88	0.9	7.8	0.02	0.03	1.1	0.05	340
D9	D9	07/10/91	8:25	26	88	6.5	0.80	1.2	8.6	0.02	0.12	0.81	0.06	880
DCK-4	D6	08/09/91	7:20	24	92	4.1	0.49	0.7	6.1	0.02	0.5	0.12	0.02	140
D9	D9	08/09/91	8:30	27	74	2.8	0.35	8.1	8.4	0	0.48	0.05	0.03	1500
DCK-4	D6	09/10/91	7:30	21	81	3.7	0.42	0.9	6.9	0.06	0.47	0.15	0.06	450
D9	D9	09/10/91	8:45	24	62	2.6	0.31	1.5	7.4	0.09	0.56	0.04	0.06	2000
DCK-4	D6	10/08/91	6:40	9	62	5.8	0.50	1.4	5.8	0.06	0.52	0.07	0.03	90
D9	D9	10/08/91	7:45	12	62	3.6	0.33	1	7.3	0.15	0.6	0.09	0.04	600

D9 is a station down stream that does not correspond with the other stations (@Hwy 91, SW1/4 Sec.11, T11S, R2W).

Data from
Alabama Clean Water Strategy
Water Quality Assessment Report
December 1992

The samples were taken in 1991
Location: 1st sampled listed- at road crossing approximately 2 miles downstream of AL 69
Location: 2nd sampled listed- at AL91

BLACK WARRIOR RIVER BASIN SAMPLING DATA

Station	Date	Time	H_2O Temp. (deg. C)	pH (S.U.)	D.O. (mg/l)	Cond.	$CBOD_5$ (mg/l)	NH_3-N (mg/l)	TKN (mg/l)	NO_2+NO_3-N (mg/l)	PO_4-P (mg/l)	T-PO_4 (mg/l)	bacteria org/100ml
Duck Creek (F&W)	June 4	12:45	24.5	7.6	8.5	83	1.4	0.00	0.24	1.10		0.12	320
	July 10	06:50	24.0	7.8	7.4	75	0.9	0.02	0.03	1.10		0.05	340
	August 9	07:20	24.0	6.1	**4.1**	92	0.7	0.02	0.50	0.12		0.02	140
	Sept 10	07:30	21.0	6.9	**3.7**	81	0.9	0.06	0.47	0.15		0.06	450
	Oct 8	06:40	9.0	**5.8**	5.8	62	1.4	0.06	0.52	0.07		0.03	90
Duck Creek (F&W)	June 3	09:50	24.8	7.3	6.6	79	0.4	0.06	0.50	1.10		0.06	120
	July 10	08:25	26.0	**8.6**	6.5	88	1.2	0.02	0.12	0.81		0.06	880
	August 9	08:30	27.0	8.4	**2.8**	74	8.1	0.00	0.48	0.05		0.03	1500
	Sept 10	08:45	24.0	7.4	**2.6**	62	1.5	0.09	0.56	0.04		0.06	**2000**
	Oct 8	07:45	12.0	7.3	**3.6**	62	1.0	0.15	0.60	0.09		0.04	600

Appendix 9.3
Water Quality Model
Input and Output Files

SUMMER TMDL MODEL

WINTER TMDL MODEL

CALIBRATED MODEL

9.5
Spreadsheet Water Quality Model (SWQM) User Guide