Total Maximum Daily Loads (TMDLs) Analysis for Chesapeake Drainage Watersheds, Delaware: Chester River, Choptank River, and Marshyhope Creek

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EXECUTIVE SUMMARY

Section 303(d) of the Clean Water Act requires States to identify water quality impaired waterways and to develop Total Maximum Daily Loads (TMDLs) for the pollutants that impair those waterways. The Delaware Department of Natural Resources and Environmental Control (DNREC) has identified that the water quality of Chester River (segments DE100-001, DE100-002, and DE100-003), Choptank River (segments DE110-001, DE110-002, DE110-003 and DE110-L01), and Marshyhope Creek (segments DE200-001 and DE200-002) was impaired because of elevated bacteria and nutrient levels and low dissolved oxygen concentrations. These segments were placed on the State's 1996 (1), 1998 (2), 2002 (3), and 2004 (4) 303(d) lists and were targeted for development of TMDLs.

All three Chesapeake drainage basins are located on the western edge of Delaware. The Chester River Watershed lies furthest to the north and resides in both New Castle and Kent Counties, with the Sassafras River Watershed bounding the northern edge. The Delaware portion of the Chester River Watershed contains headwater tributaries (Cypress Branch, Sewell Branch, and Gravelly Run) draining to the main stem of the river in Maryland. The Choptank River Watershed in Kent County consists of Tappahanna Ditch and Culbreth Marsh Ditch, both draining to Mud Millpond, and Cow Marsh Creek, which drains directly to the river downstream of the pond before continuing into Maryland. Finally, Marshyhope Creek Watershed resides in both Kent and Sussex Counties with the Nanticoke River Watershed lying to the south. The stream flows southwestward and crosses the state line into Maryland where it eventually discharges into the Chesapeake Bay.

Of the Delaware portions of the three drainage basins, the Choptank River Watershed and the Marshyhope Creek Watershed are very similar in size at approximately 252 km^2 and 250 km^2, respectively. The Chester River Watershed is smaller at 103 km^2.

There are no active point sources discharging nutrients or bacteria into any of the three Chesapeake drainage basins, therefore, all pollutants are coming from nonpoint sources.

The "Total Maximum Daily Loads (TMDLs) Analysis for Chesapeake Drainage Watersheds, Delaware: Chester River, Choptank River, and Marshyhope Creek," documents the technical basis and development of the Chesapeake Drainage TMDLs.

The development of the Chesapeake drainage nutrient TMDLs was based on the assessment of Chester River, Choptank River, and Marshyhope Creek water quality under two different environmental conditions – average condition and summer critical condition. The average condition considers averages of water quality in the period of 2001-2003. The critical condition considers summer (July – September) water quality of the 2001-2003 period. The U.S. EPA's Enhanced Stream Water Quality Model (Qual2E) was used as the framework for the water quality assessments. Water quality data collected during the 2001-2003 period was used to calibrate the models and data collected during the summer from the same period was used to simulate the critical conditions.

The Maryland Department of the Environment (MDE) is currently in the process of conducting a water quality analysis for the development of TMDLs in the middle and upper Chester River with anticipated results in 2006 (5). In 2001, the MDE developed total maximum daily loads for phosphorous for Marshyhope Creek in Dorchester and Caroline Counties in Maryland (6). The MDE analysis indicated that there was no water quality impairment using annual average flow conditions. A low flow TMDL however was established for May 1 through

October 31, where the phosphorus load could not exceed 348 kg/month, or 12 kg/day (767 lbs/month or 26 lbs/day). In addition, under the 2000 Chesapeake Bay Agreement, nitrogen and phosphorus allocations were assigned to each major tributary in the Chesapeake Bay Basin (7). The Delaware watersheds draining to the Eastern Shore of Maryland, including Chester River, Choptank River, and Marshyhope Creek, are required to reduce nitrogen and phosphorus loads by 46.8% and 43.5%, respectively, from the baseline year of 2000 (8).

The State of Delaware has a daily average dissolved oxygen standard of 5.5 mg/l and nutrient targets of 3.0 mg/l for total nitrogen and 0.2 mg/l for total phosphorus. Additionally, the State of Maryland has a dissolved oxygen standard of 5.0 mg/l, which must be met as waters cross the state line from Delaware into Maryland. Load reduction scenarios under annual average conditions and summer critical conditions were evaluated with calibrated models. The results showed that 40% reductions of total phosphorus are required in the Chester River and Choptank River Watersheds, while in the Marshyhope Creek Watershed, total nitrogen must be reduced by 20% and total phosphorus must be reduced by 25% in order to meet the dissolved oxygen standards within Delaware and at the state line and nutrient targets in Delaware. The reductions prescribed by the Chesapeake Bay Agreement were also simulated. It was determined that these load reductions (47% for TN and 44% for TP) were greater than the reductions found necessary to meet the State of Delaware's water quality standards and nutrient targets and if implemented, would produce even greater water quality improvements.

This analysis has determined TMDLs that will require the following nutrient reductions from the 2001-2003 baseline period. Under average conditions in the three tributaries of Chester River (Cypress Branch, Sewell Branch, and Gravelly Run), total nitrogen should be capped at the baseline level of 321 kg/day (708 lb/day), and total phosphorous should be reduced from the baseline of 24.8 kg/day (54.6 lb/day) to the level of 14.7 kg/day (32.3 lb/day).

Under average conditions in Choptank River, total nitrogen should be capped at the baseline level of 616 kg/day (1,359 lb/day), and total phosphorous should be reduced from the baseline of 57.4 kg/day (127 lb/day) to the level of 34.5 kg/day (75.9 lb/day).

Under average conditions in Marshyhope Creek, total nitrogen should be reduced from the baseline of 1,219 kg/day (2,687 lb/day) to the level of 974 kg/day (2,148 lb/day), and total phosphorous should be reduced from the baseline of 49.6 kg/day (109 lb/day) to the level of 35.4 kg/day (78.1 lb/day).

Bacteria impairments were not included in the QUAL2E modeling but were evaluated at different flow conditions to determine the reductions required within the watersheds to achieve water quality standards (100 CFU enterococci/100mL geometric mean, 185 CFU enterococci/100 mL single sample maximum).

In the Chester River Watershed the nonpoint source bacteria load shall be reduced by 75.6% from the 1997 – 2005 baseline levels. This shall result in reducing a yearly-mean bacteria load from 1.9E+11 CFU per day to 4.6E+10 CFU per day.

In the Choptank River Watershed the nonpoint source bacteria load shall be reduced by 87.8% from the 1997 – 2005 baseline level. This shall result in reducing a yearly-mean bacteria load from 4.3E+11 CFU per day to 4.4E+10 CFU per day.

In the Marshyhope Creek Watershed the nonpoint source bacteria load shall be reduced by 85.7% from the 1997 – 2005 baseline levels. This shall result in reducing a yearly-mean bacteria load from 1.1E+11 CFU per day to 1.6E+10 CFU per day.

1.0 INTRODUCTION

Background

Section 303(d) of the Clean Water Act (CWA) as amended by the Water Quality Act of 1987, requires States to identify water quality limited waters to develop Total Maximum Daily Loads (TMDLs) for pollutants of concern. The Delaware Department of Natural Resources and Environmental Control has identified the waters of the Chester River (segments DE100-001, DE100-002, and DE100-003), Choptank River (segments DE110-001, DE110-002, DE110-003 and DE110-L01), and Marshyhope Creek (segments DE200-001 and DE200-002) as water quality limited waters. These segments were placed on the State's 1996 (1), 1998 (2), 2002 (3), and 2004 (4) 303(d) lists, and targeted for TMDL development. The red line showing the impaired segments listed on the 303(d) lists is presented in Figures 1 -1(a-c). Table 1-1 is the excerpt for the Chesapeake Drainage Basins from the State of Delaware's 2004 303(d) List.

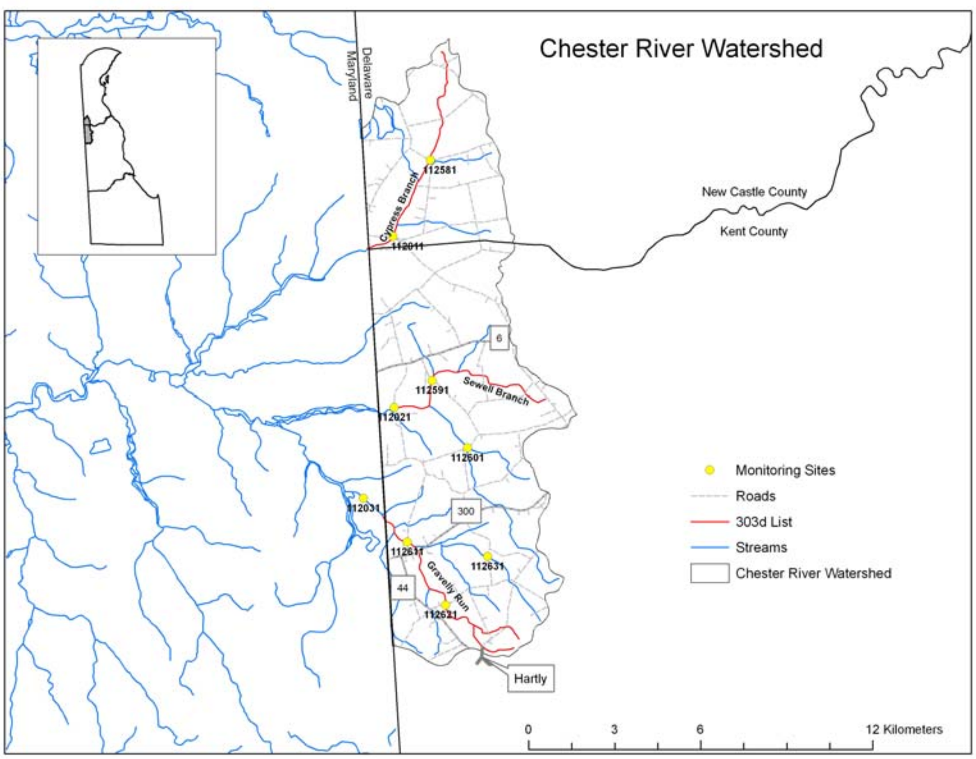

Figure 1-1a Chester River Watershed Map

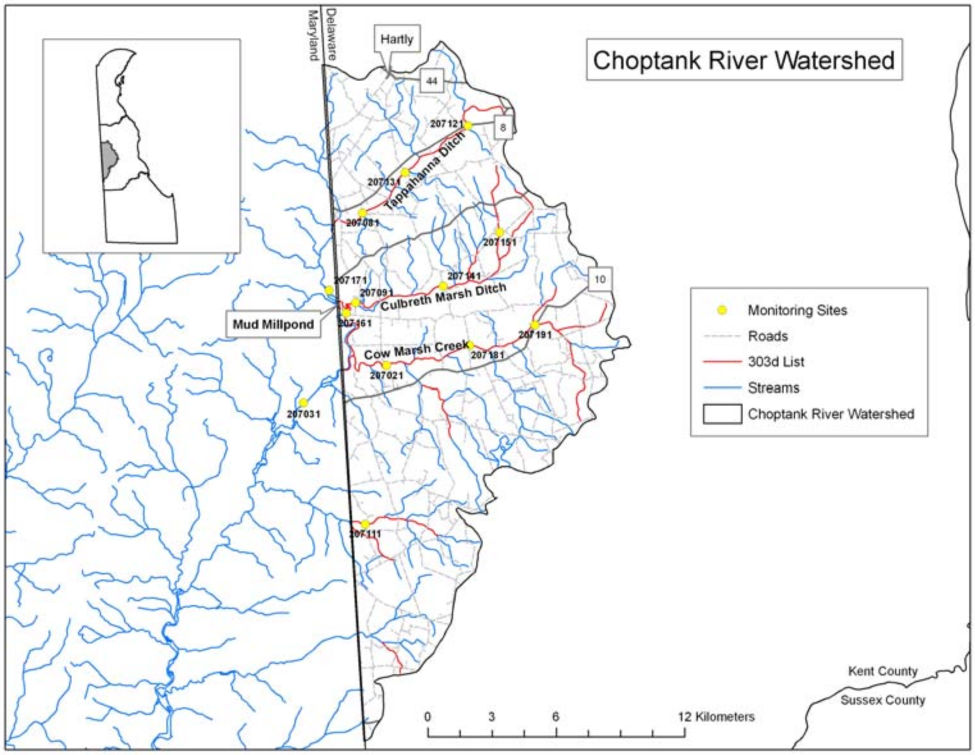

Figure 1-1b Choptank River Watershed Map

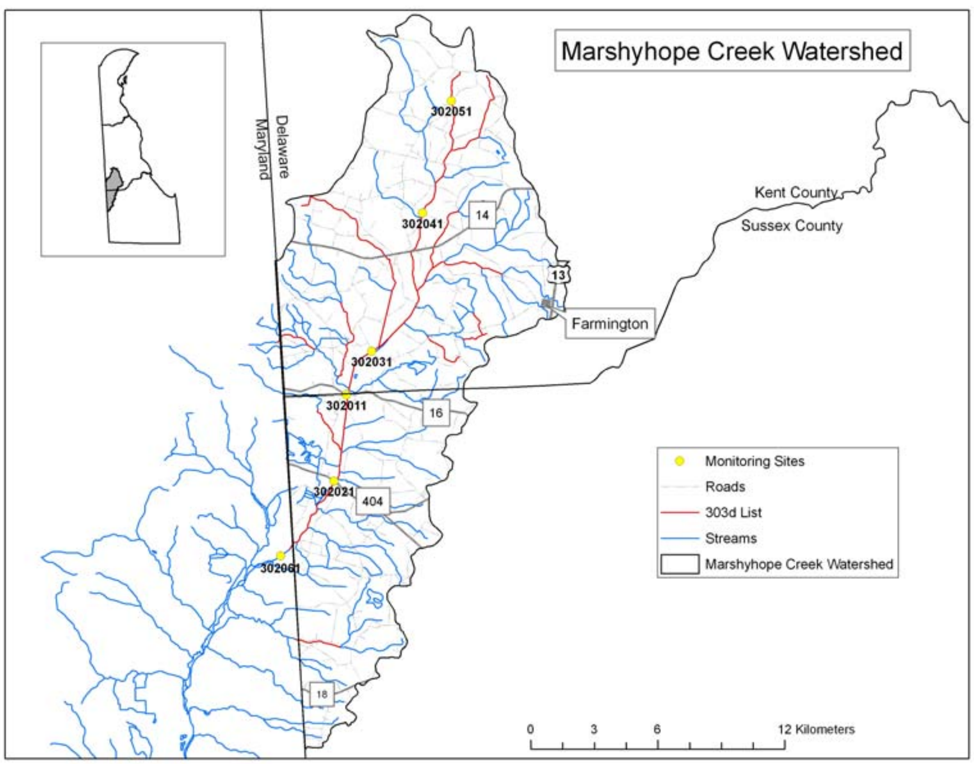

Figure 1-1c Marshyhope Creek Watershed Map

Table 1-1 Excerpt from the State of Delaware's 2004 303(d) List for Chesapeake Drainage Watersheds (4)

WATERBODY ID	WATERSHED NAME	SEGMENT	DESCRIPTION	SIZE AFFECTED	POLLUTANT(S) AND/OR STRESSOR(S)	PROBABLE SOURCE(S)	TARGET DATE FOR TMDL
DE100-001	Chester River	Cypress Branch	Mainstem	10.6 km	Bacteria, nutrients, and DO	NPS	2005
DE100-002	Chester River	Sewell Branch	Mainstem	11.6 km	Bacteria, nutrients, and DO	NPS	2005
DE100-003	Chester River	Gravelly Run	Mainstem	12.4 km	Bacteria, nutrients, and DO	NPS	2005
DE110-001	Choptank River	Tappahanna Ditch	Mainstem	12.1 km	Bacteria, nutrients, and DO	NPS	2005
DE110-002	Choptank River	Culbreth Marsh Ditch	Mainstem	16.1 km	Bacteria, nutrients, and DO	NPS	2005
DE110-003	Choptank River	Cow Marsh Creek	Mainstem	24.3 km	Bacteria, nutrients, and DO	NPS	2005
DE110-L01	Choptank River	Mud Millpond	Pond south of Marydel	0.24 km^2	Bacteria, nutrients, and DO	NPS	2005
DE200-001	Marshyhope Creek	Marshyhope Creek	From the headwaters to the MD-DE State line	31.7 km	Bacteria, nutrients, and DO	NPS	2005
DE200-002	Marshyhope Creek	Marshyhope Ditch	Headwaters of Marshyhope Creek	10.1 km	Bacteria, nutrients, and DO	NPS	2005

Chester River Watershed

Chester River Watershed is located on the western edge of Delaware and resides in both New Castle and Kent Counties. The headwaters of the Sassafras River lie to the north and the Choptank River is to the south. The Delaware portion of the Chester River Watershed contains headwater tributaries that drain to the main stem of the Chester River in Maryland. Cypress Branch, the most northerly stream, drains southwestward, while Sewell Branch directly below drains in a westerly direction. Furthest to the south in the Chester River Watershed is Gravelly Run, which drains northwestward and meets Sewell Branch several kilometers west of the Maryland-Delaware state line. The drainage area of Chester River Watershed within Delaware is approximately 103 km^2.

The streams in the northern portion of the Chester River Watershed are marsh-like due to the surrounding wetlands, while to the south, they are ditch-like, due to the agricultural influence of the area. Concerns on the watershed include low dissolved oxygen, nutrient over-enrichment, and high levels of bacteria. There are no active point sources discharging nutrients or bacteria into Chester River, therefore, all pollutants are coming from nonpoint sources.

The land use within the watershed is dominated by agriculture, wetlands, and forests. The detailed land use information for this watershed is based on 2002 Delaware Office of State Planning Coordination land cover data (9). Figure 1-2 shows the geographic distribution of different land uses in the Chester River Watershed. The land use activity in the watershed consists of 45 km^2 of agriculture (44% of the watershed), 35 km^2 of wetland (34% of the watershed), 12 km^2 of forest (12% of the watershed), 10 km^2 of residential, commercial and industrial area (9% of the watershed), and 1 km^2 of rangeland (1% of the watershed). The summary of relative distribution of land use coverage is presented in the pie chart in Figure 1-3. Hartly, which lies on the southern border of the watershed, is the only incorporated town.

Soil types in the watershed, from north to south, include grades from Mattapeake-Sassafras association (considered by the Natural Resources Conservation Service to be “well-drained, medium textured and moderately coarse textured soils on uplands”), to Keyport-Elkton and Fallsington-Mattapeake soils, to Fallsington-Pocomoke association at the border between Kent and Sussex Counties (predominantly heavier, more poorly drained), to Pocomoke-Fallsington-Sassafras association (considered by the Natural Resources Conservation Service to be “very poorly drained, poorly drained, and well drained soils that have a moderately permeable subsoil”) (10).

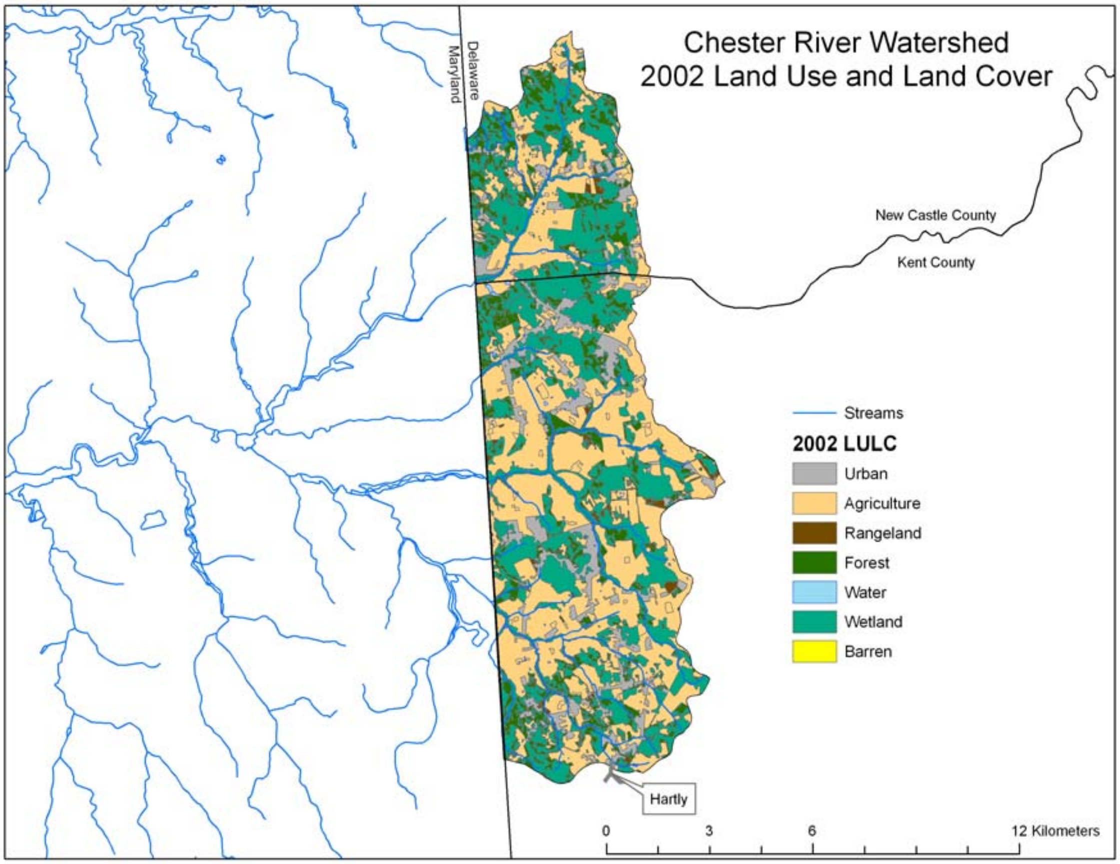

Figure 1-2 Chester River Watershed 2002 Land Use and Land Cover

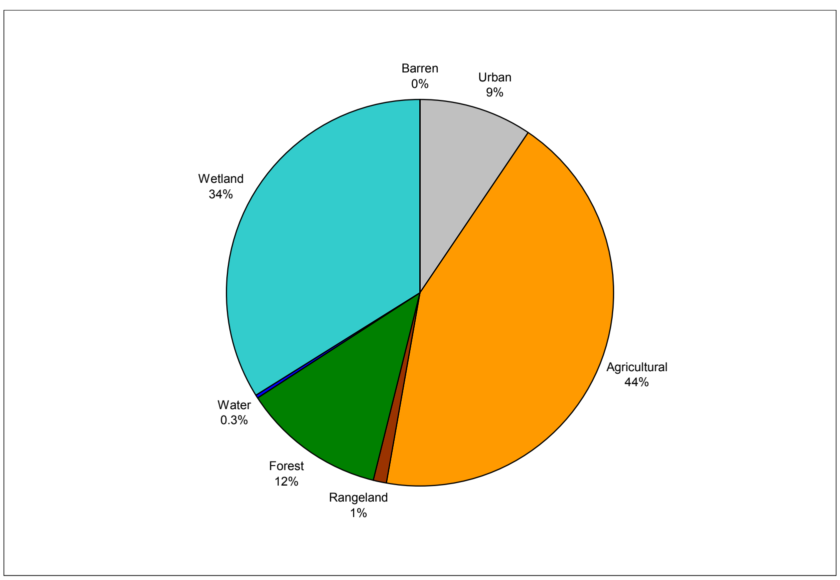

Figure 1-3 Land Use Percentages in Chester River Watershed

Choptank River Watershed

Choptank River Watershed is located on the western edge of Delaware and resides in Kent County. The headwaters of the Chester River lie to the north and Marshyhope Creek is to the south. The Choptank River Watershed consists of Tappahanna Ditch in the northern portion of the watershed, Culbreth Marsh Ditch in the center, and Cow Marsh Creek in the lower portion. Both Tappahanna Ditch and Culbreth Marsh Ditch drain to Mud Millpond, which is situated at the Maryland-Delaware state line. The pond discharges to the Choptank River in Delaware, which meanders southward, where Cow Marsh Creek connects in before continuing into Maryland. The drainage area of Choptank River Watershed within Delaware is approximately 252 km^2.

The majority of the streams within the watershed have drainage ditch characteristics due to the surrounding agricultural practices. The exceptions are found near and downstream of Mud Millpond, which is more forested. Concerns in the watershed include low dissolved oxygen, nutrient over-enrichment, and high levels of bacteria. There are no active point sources discharging nutrients or bacteria into Choptank River, therefore, all pollutants are coming from nonpoint sources.

The land use within the watershed is dominated by agriculture, wetlands, and forests. The detailed land use information for this watershed is based on 2002 Delaware Office of State Planning Coordination land cover data (9). Figure 1-4 shows the geographic distribution of different land uses in the Choptank River Watershed. The land use activity in the watershed consists of 125 km^2 of agriculture (50% of the watershed), 67 km^2 of wetland (27% of the watershed), 31 km^2 of forest (13% of the watershed), 23 km^2 of residential, commercial and industrial area (9% of the watershed), and 3 km^2 of rangeland (1% of the watershed). The summary of relative distribution of land use coverage is presented in the pie chart in Figure 1-5. Hartly, which lies on the northern border of the watershed, is the only incorporated town.

Soil types in the watershed include predominantly Pocomoke-Fallsington-Sassafras soil associations described by the Natural Resources Conservation Service as “very poorly drained, poorly drained, and well drained soils that have a moderately permeable subsoil of clay loam to sandy loam,” and Fallsington-Sassafras-Woodstown associations described as “poorly drained to well drained soils that have a moderately permeable subsoil of sandy loam to sandy clay loam” (10).

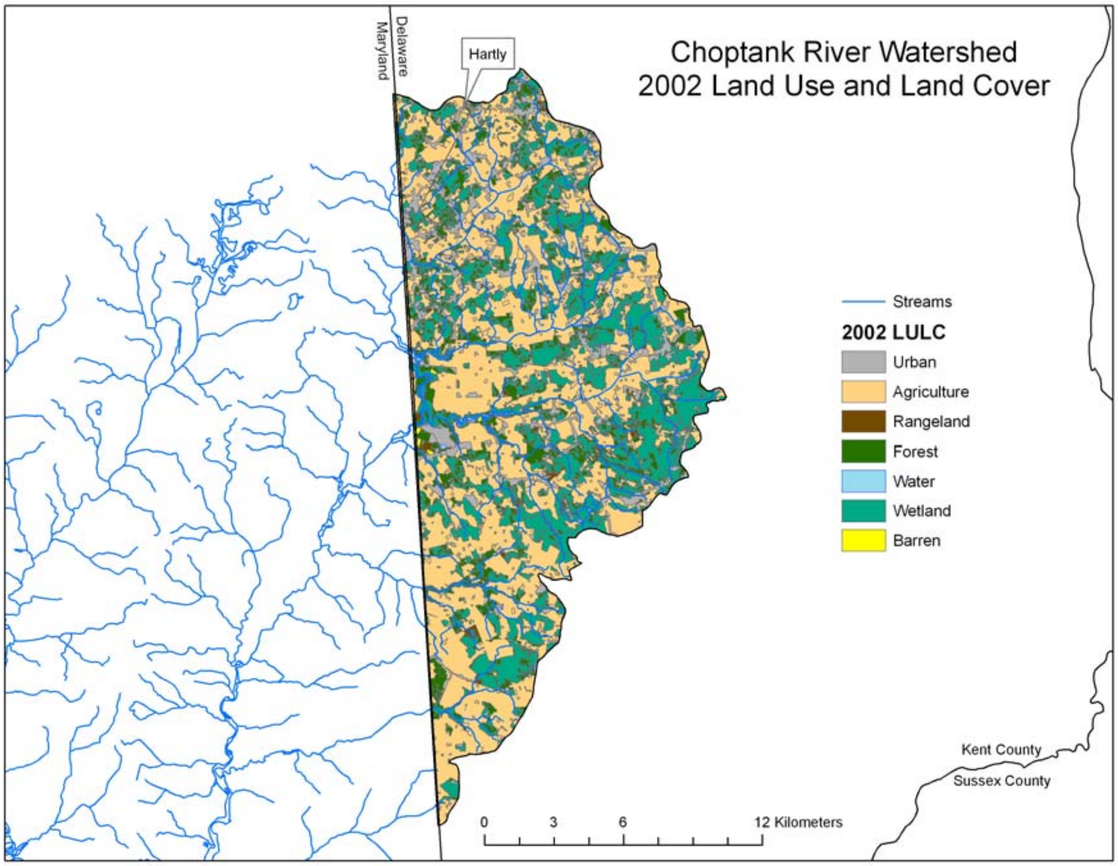

Figure 1 – 4 Choptank River Watershed 2002 Land Use and Land Cover

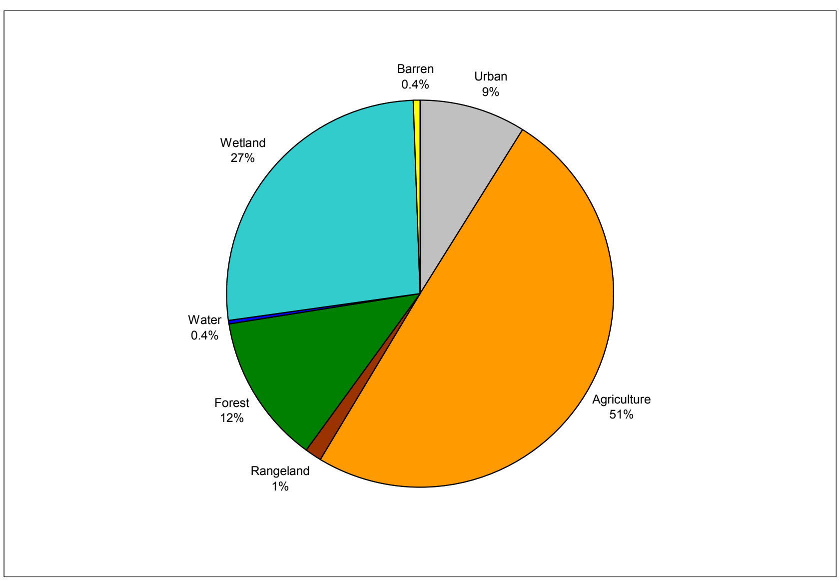

Figure 1 – 5 Land Use Percentages in Choptank River Watershed

Marshyhope Creek Watershed

Marshyhope Creek Watershed is located on the western edge of Delaware and resides in both Kent and Sussex Counties. The headwaters of the Choptank River lie to the north and the Nanticoke River is to the south of Marshyhope Creek Watershed. The stream flows southwestward and crosses the state line into Maryland where it eventually discharges into the Chesapeake Bay. The drainage area of Marshyhope Creek Watershed within Delaware is approximately 250 km^2.

Agricultural practices have lead to the headwaters and tributaries having drainage ditch characteristics. In addition, the middle stretch of the main stem of Marshyhope Creek was channelized in the past; however, in several sections, sediment and vegetation now cover the cement bottom. Concerns in the watershed include low dissolved oxygen, nutrient over-enrichment, and high levels of bacteria. There are no active point sources discharging nutrients or bacteria into Marshyhope Creek, therefore, all pollutants are coming from nonpoint sources.

The land use within the watershed is dominated by agriculture, wetlands, and forests. The detailed land use information for this watershed is based on 2002 Delaware Office of State Planning Coordination land cover data (9). Figure 1-6 shows the geographic distribution of different land uses in the Marshyhope Creek Watershed. The land use activity in the watershed consists of 138 km^2 of agriculture (55% of the watershed), 62 km^2 of wetland (25% of the watershed), 32 km^2 of forest (13% of the watershed), 10 km^2 of residential, commercial and industrial area (4% of the watershed), and 8 km^2 of rangeland (3% of the watershed). The summary of relative distribution of land use coverage is presented in the pie chart in Figure 1-7. Farmington is the only incorporated town.

Soil types in the watershed include Fallsington-Sassafras-Woodstown association described by the Natural Resources Conservation Service as “poorly drained to well drained soils that have a moderately permeable subsoil of sandy clay loam or sandy loam” (10).

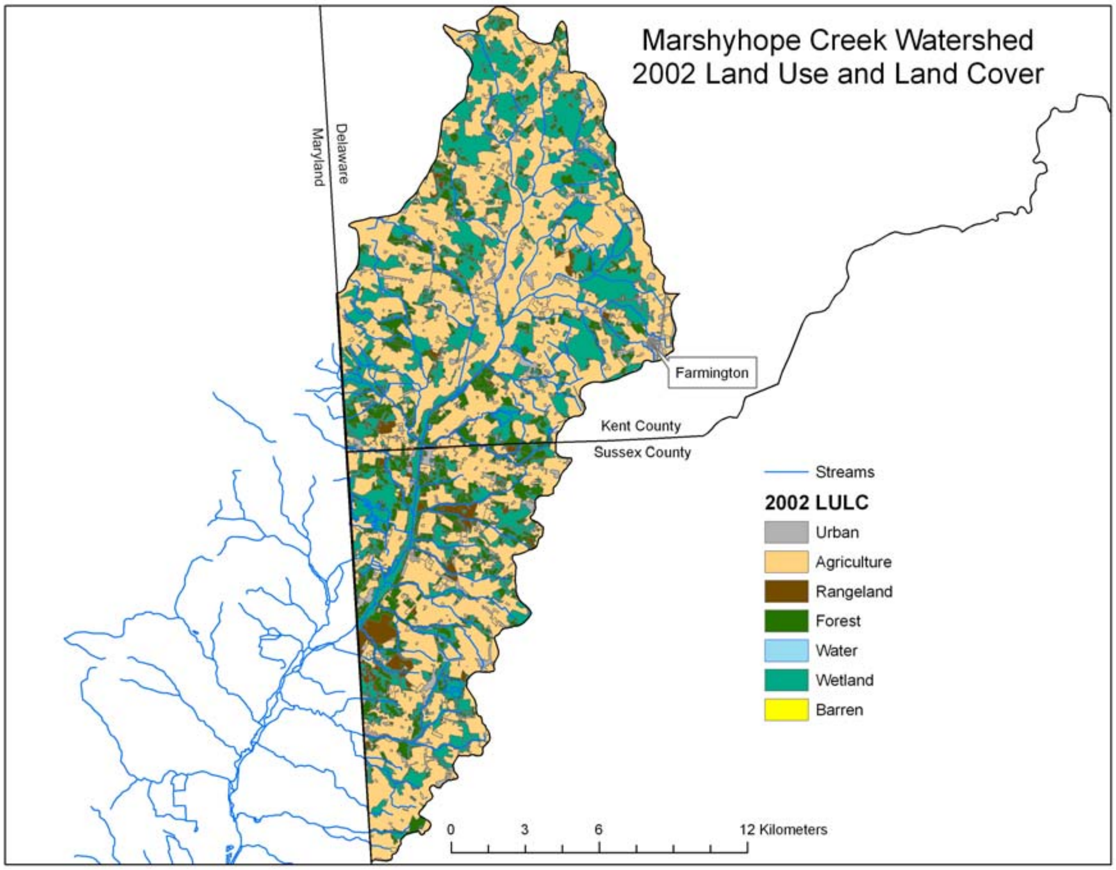

Figure 1 – 6 Marshyhope Creek Watershed 2002 Land Use and Land Cover

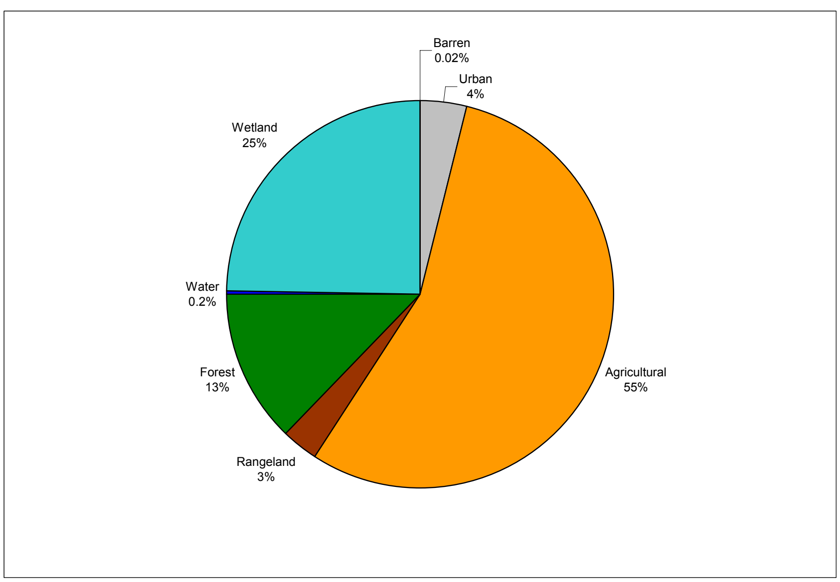

Figure 1 – 7 Land Use Percentages in Marshyhope Creek Watershed

Designated Uses

The purpose of establishing TMDLs is to reduce the pollutants to levels that result in meeting applicable water quality standards and support designated uses of the streams. Section 3 of the State of Delaware Surface Water Quality Standards, as amended, July 11, 2004 (11), specifies the following designated uses for the waters of Chester River, Choptank River, and Marshyhope Creek:

- Primary Contact Recreation
- Secondary Contact Recreation
- Fish, Aquatic Life, and Wildlife
- Agricultural Water Supply
- Industrial Water Supply

Furthermore, Marshyhope Creek is designated as a water of Exceptional Recreation or Ecological Significance (ERES).

Applicable Water Quality Standards and Nutrient Guidelines

To protect the designated uses, the following sections of the State of Delaware Surface Water Quality Standards, amended July 11, 2004 (11), provide specific narrative and numeric criteria concerning the waters in Chester River, Choptank River and Marshyhope Creek:

Section 4 Criteria to Protect Designated Uses
Section 5 Antidegradation and ERES Waters Policies

Based on the above sections, the following is a brief summary of pertinent water quality standards that are applicable to the waters of Chester River, Choptank River, and Marshyhope Creek:

a. Dissolved Oxygen (Section 4.5.2.1):
   - Daily average shall not be less than 5.5 mg/l
   - Instantaneous minimum shall not be less than 4.0 mg/l

b. Nutrients (Section 4.6.2):
   - It shall be the policy of this Department to minimize nutrient input to surface waters from point and human induced non-point sources.
   - The types of, and need for, nutrient controls shall be established on a site-specific basis.

In the absence of national numeric nutrient criteria, DNREC has used target thresholds of 3.0 mg/l for total nitrogen and 0.2 mg/l for total phosphorus as indicators of excessive nutrient levels in the streams. The above target levels have been used as the guideline for the 305(b) assessment reports and the 303(d) listing of impaired waters, and are generally accepted by the scientific community to be an indication of over-enriched waters.

c. Waters of Exceptional Recreational or Ecological Significance (ERES) (Section 5.6.1):
   - Designated ERES waters shall be accorded a level of protection and monitoring in excess of that provided most other waters of the State. These waters are recognized as special natural assets of the State, and must be protected and enhanced for the benefit of present and future generations of Delawareans.
   - ERES waters shall be restored, to the maximum extent practicable, to their natural condition. To this end, the Department shall, through adoption of a pollution control strategy for each ERES stream basin, take appropriate action to cause the systematic control, reduction, or removal of existing pollution sources, and the diversion of new pollution sources, away from ERES waters.

d. Bacteria (enterococcus):
   - 30 day geometric mean shall not exceed 100 CFU/100mL
   - Single sample maximum shall not exceed 185 CFU/100mL

Additionally, since the Chester River, Choptank River, and Marshyhope Creek drain into Maryland prior to discharging into the Chesapeake Bay, the state of Maryland's applicable water quality standards should also be noted.

a. Dissolved Oxygen (Section 26.08.02.03-3.03-3A(2))
   - The dissolved oxygen concentration may not be less than 5.0 mg/l at any time.

Stream Water Quality Conditions and Water Quality Impairment

Water quality of Chester River, Choptank River, and Marshyhope Creek varies over time.

The mainstem segments of Chester River were first listed on the State of Delaware's 303(d) list in 1996 due to their bacteria and dissolved oxygen impairments, with the exception of Cypress Branch, whose nutrient impairments were added to the list in 2002. The dissolved oxygen impairments in the headwater reaches of Cypress Branch and Sewell Branch were added to the list in 1998. Despite being listed for nutrients in 2002, intensive water quality monitoring data collected between 2001 and 2003, indicated that nitrogen levels were below the target concentration of 3 mg/l.

The bacteria, dissolved oxygen, and nutrient impairments in all mainstem segments of the Choptank River were first listed on the 1996 303(d) list and the dissolved oxygen impairments in the tributaries of Tappahanna Ditch and Culbreth Marsh Ditch were added to the list in 1998. Despite being listed for nutrients in 1996, intensive water quality monitoring data collected between 2001 and 2003, indicated that nitrogen levels were below the target concentration of 3 mg/l.

The bacteria, dissolved oxgen, and nutrient impairments in the mainstem of Marshyhope Creek were first listed on the 1996 303(d) list. The dissolved oxygen impairments in the tributaries were added to the list in 1998, while the bacteria, dissolved oxygen, and nutrient impairments in the headwater reagion, Marshyhope Ditch, were listed in 2002. Despite being listed for dissolved oxygen in 1996, intensive water quality monitoring data collected between 2001 and 2003, indicated that dissolved oxygen levels were above the standard of 5.5 mg/l.

Despite variations in water quality during different times, a watershed-wide TMDL is required for each basin to ensure that all applicable water quality standards are achieved.

To support the model development for the Chesapeake drainage watersheds, the Department has conducted extensive water quality monitoring (Table 1-2 and Figure 1-1(a-c)). Monitoring stations, usually at stream road crossings, are listed in Table 1-2 according to the watersheds in which they reside. Each station has been given a STORET identification number, which is a cataloging number for EPA's STORage and RETrieval repository. Several of the sites are part of the State's General Assessment Monitoring Network (GAMN), with samples collected on a quarterly basis over a long term to support the development of Watershed Assessment (305(b)) Reports. The majority of the sites were sampled for TMDL development between April 2001 and June 2003, which requires more intensive monitoring for a shorter period of time. Additionally, two monitoring stations were added during the modeling phase, one downstream of the state line on the Choptank River and the other downstream of the state line on Marshyhope Creek. At each station, grab samples were analyzed for a suite of 24 water quality parameters (12). Monitoring data collected during 2001-2003 and are presented in the following figures.

Table 1-2 Chesapeake Drainage Water Quality Monitoring Stations

Monitoring Location	STORET No.	TMDL (active during 2001-2003)	GAMN (long term)
***Chester River Watershed** - Cypress Branch Sub-watershed*			
1. Cypress Branch at Morris Rd. (Rd. 477)	112581	√	
2. Cypress Branch at Clayton Delaney Rd. (Rd. 40)	112011	√	√
***Chester River Watershed** - Sewell Branch Sub-watershed*			
1. Sewell Branch at Blackiston Church Rd. (Rd. 131)	112591	√	
2. Sewell Branch at Sewell Branch Rd. (Rd. 95	112021	√	√
3. Jordan Branch at Underwoods Corner Rd. (Rd. 94)	112601	√	
***Chester River Watershed** - Gravelly Run Sub-watershed*			
1. Gravelly Run at Fords Corner Rd. (Rd. 98)	112621	√	
2. Gravelly Run at Lion Hope Rd. (Rd. 143)	112611	√	
3. Gravelly Run at Stulltown Rd., MD	112031	√	√
4. Muddy Bottom Ditch at Downs Chapel Rd. (Rd. 97)	112631	√	
Choptank River Watershed			
1. Tappahanna Ditch at Route 8 bridge	207121	√	
3. Tappahanna Ditch at Tuxward Rd. (Rd. 220)	207131	√	
3. Tappahanna Ditch at Sandy Bend Rd. (Rd. 222)	207081	√	√
4. Tidy Island Creek at Westville Rd. (Rd. 206)	207171	√	
5. Culbreth Marsh Ditch at Oak Point School Rd. (Rd. 215)	207151	√	
6. Culbreth Marsh Ditch at Luck's Dr. (Rd. 223)	207141	√	
7. Culbreth Marsh Ditch at Shady Bridge Rd. (Rd. 210)	207091	√	√
8. Cow Marsh Creek at Willow Grove Rd. (Rt. 10)	207191	√	
9. Cow Marsh Creek at Hollering Hill Rd. (Rd. 213)	207181	√	
10. Cow Marsh Creek at Mahan Corner Rd. (Rd. 208)	207021	√	√
11. Mud Millpond Outflow at Mud Mill Rd. (Rd. 207)	207161	√	
12. Choptank River at Willow Grove Rd., MD (Rd 287)	207031	2005 only	
13. White Marsh Branch at Cedar Grove Church Rd. (Rd. 268)	207111	√	√
Marshyhope Creek Watershed			
1. Marshyhope Ditch at Fox Hunters Rd. (Rd. 277)	302051	√	
2. Marshyhope Creek at Hemping Rd. (Rd. 299)	302041	√	
3. Marshyhope Creek at Fishers Bridge Rd. (Rd. 308)	302031	√	√
4. Marshyhope Creek at Hickman Rd. (Rt. 16)	302011	√	
5. Marshyhope Creek at Woodenhawk Bridge (Rt. 404)	302021	√	√
6. Marshyhope Creek at Nobel Rd.	302061	2005 only	

Chester River Watershed

Table 1-3 presents the average concentrations of monitoring data collected during the 2001-2003 period.

The monitoring data showed that occasional dissolved oxygen violations occurred at all nine monitoring sites, with concentrations below 5.5 mg/l occurring most often during summer months (Figures 1-8(a-c)). Nitrogen levels in all three stream systems of the Chester River Watershed (Cypress Branch, Sewell Branch, and Gravelly Run) were below the State of Delaware's total nitrogen target threshold value of 3.0 mg/l with ranges between 0.5 mg/l and 2.9 mg/l. Phosphorus levels ranging between 0.03 mg/l and 0.7 mg/l were relatively high and exceeded the 0.2 mg/l target for total phosphorus at all stations, but one.

Based on the monitoring data, Delaware's 2004 305(b) Report (4) showed that elevated nutrient levels and low DO concentrations impaired Chester River and its designated uses were not fully supported aquatic life and primary contact recreation.

Table 1-3. Average Water Quality Conditions at Nine Monitoring Locations in Chester River Watershed during 2001-2003

Monitoring Station	Water Temp C	Field DO mg/l	BOD5 mg/l	Chlor-a ug/l	Org-N mg/l	NH3-N mg/L	NO2-N mg/l	NO3-N mg/l	TN mg/l	Org-P mg/l	Dis-P mg/l	TP mg/l
Cypress Branch												
112581	15.82	4.77	2.63	19.73	1.20	0.11	0.02	0.20	1.53	0.11	0.05	0.16
112011	14.72	5.17	2.51	6.14	0.90	0.10	0.04	0.32	1.35	0.08	0.03	0.11
Sewell Branch												
112591	13.72	6.72	2.46	8.03	0.88	0.21	0.09	0.85	2.03	0.21	0.12	0.33
112021	13.83	6.52	2.40	3.79	0.81	0.14	0.14	1.25	2.25	0.13	0.10	0.23
112601	13.91	8.48	2.42	2.61	0.63	0.06	0.12	1.08	1.89	0.11	0.08	0.18
Gravelly Run												
112621	15.16	6.34	2.73	7.80	0.65	0.12	0.04	0.35	1.15	0.13	0.04	0.16
112611	13.34	8.19	2.41	3.19	0.59	0.06	0.08	0.71	1.44	0.08	0.05	0.13
112031	14.32	7.78	2.41	2.10	0.68	0.12	0.09	0.77	1.65	0.11	0.09	0.20
112631	15.08	8.41	2.55	13.86	0.72	0.07	0.05	0.43	1.27	0.11	0.04	0.15

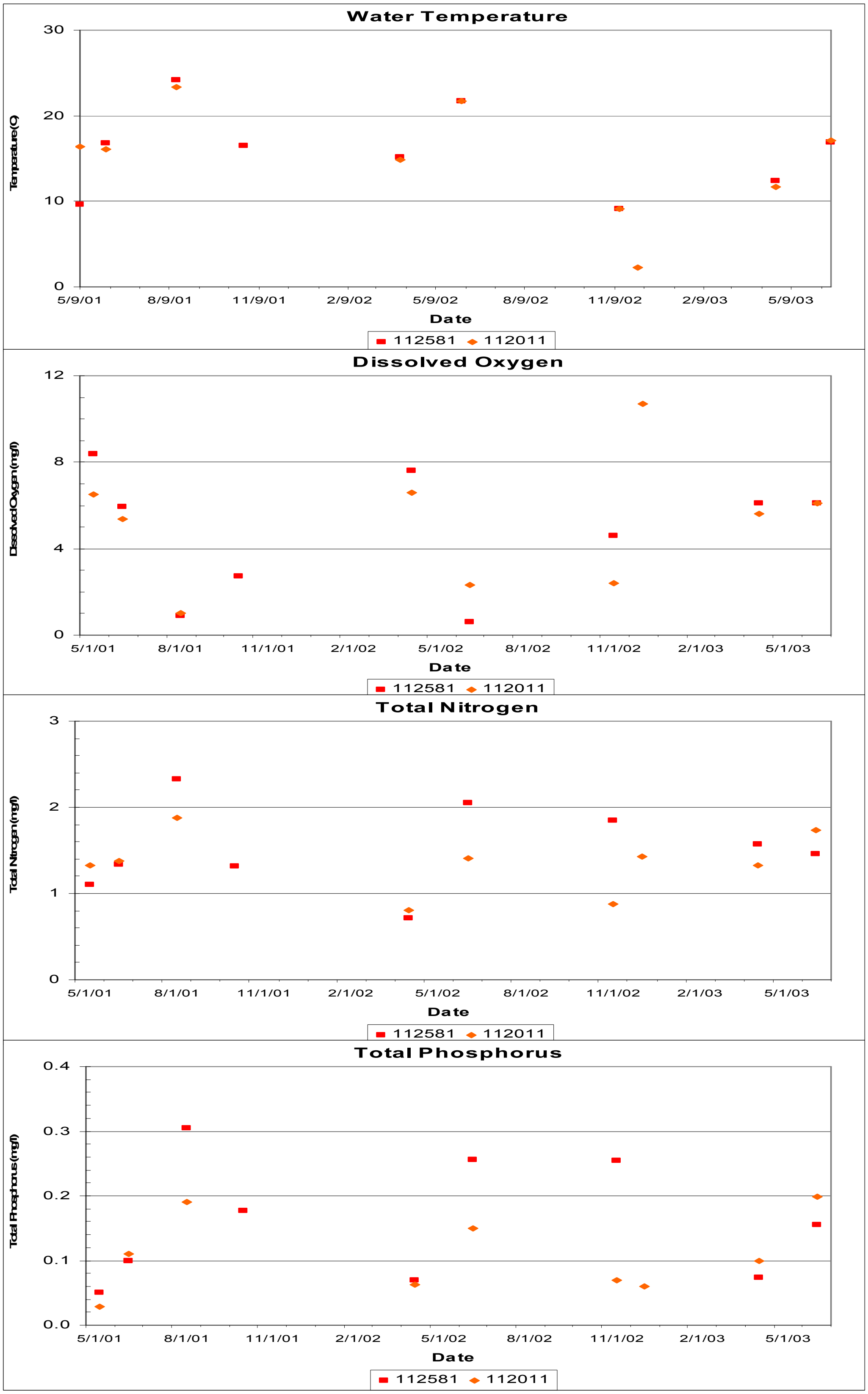

Figure 1-8a Observed Temperature, DO, TN, and TP at Monitoring Locations in Chester River Watershed-Cypress Branch Sub-watershed

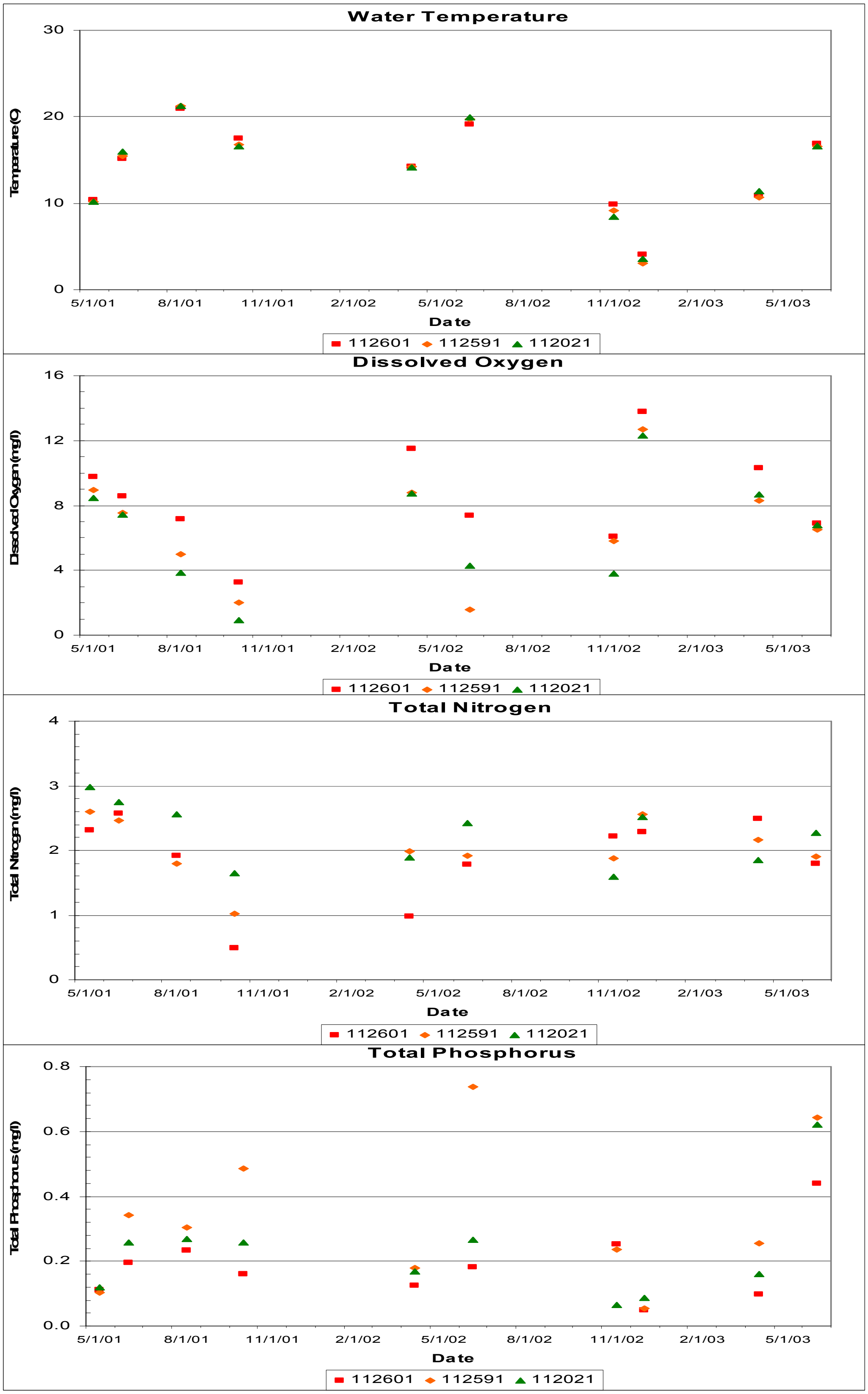

Figure 1-8b Observed Temperature, DO, TN, and TP at Monitoring Locations in Chester River Watershed-Sewell Branch Sub-watershed

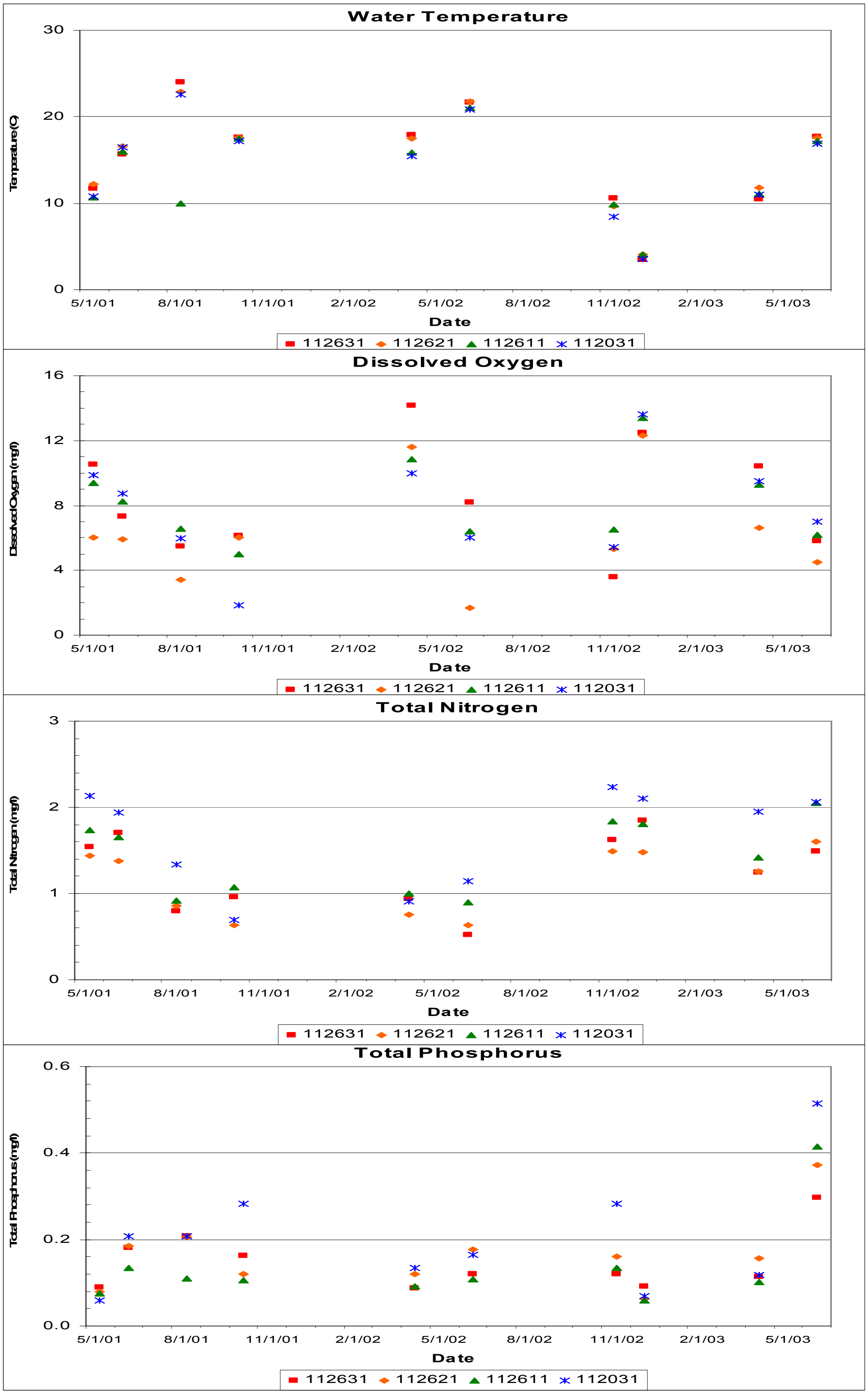

Figure 1-8c Observed Temperature, DO, TN, and TP at Monitoring Locations in Chester River Watershed-Gravelly Run Sub-watershed

The State of Delaware water quality standard for enterococcus is a geometric mean of 100 CFU/100 ml. Enterococci are present in faecal material and are used as an indicator organism with which a correlation to illness rates can be established. The level of risk associated with primary contact recreation in waters with an enterococcuus concentration of 100 CFU/100 ml has been deemed appropriate and is the basis for the current State of Delaware water quality standards for bacteria. Figure 1-9 illustrates the bacteria concentrations in the Chester River Watershed; it is clearly much greater than the bacteria standard.

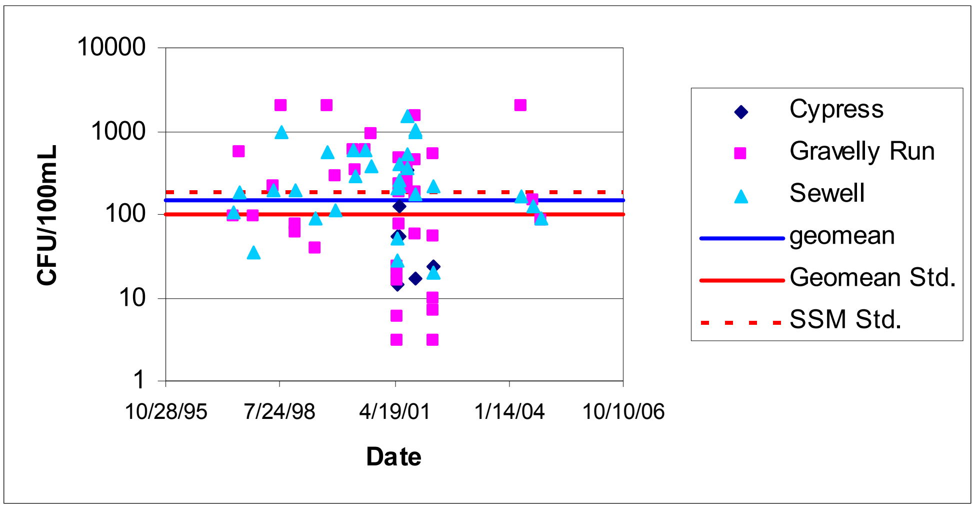

Figure 1-9 Enterococcus Concentration in Chester River Watershed

Choptank River Watershed

Table 1-4 presents the average concentrations of monitoring data collected during the 2001-2003 period, as well as the average concentration between January 2005-April 2005 at station 207031, which was sampled during the modeling phase. The observed temperature, dissolved oxygen, total nitrogen and total phosphorus on the sampling dates during the more intensive 2001 through 2003 TMDL monitoring period are presented in Figures 1-10(a-c).

The monitoring data showed that occasional dissolved oxygen violations occurred at all of the monitoring sites, with concentrations below 5.5 mg/l during summer months (Figure 1-10(a-d)). Nitrogen levels were below the State of Delaware's total nitrogen target threshold value of 3.0 mg/l at all stations but two, with ranges between 0.2 mg/l and 5.8 mg/l. Phosphorus levels ranging between 0.01 mg/l and 0.5 mg/l were relatively high and exceeded the 0.2 mg/l target for total phosphorus at all stations.

Based on the monitoring data, Delaware's 2004 305(b) Reports (4) showed that elevated nutrient levels and low DO concentrations impaired Choptank River and its designated uses were not fully supported for aquatic life or primary contact recreation.

Table 1-4. Average Water Quality Conditions at Thirteen Monitoring Locations in Choptank River Watershed during 2001-2003

Monitoring Station	Water Temp C	Field DO mg/l	BOD5 mg/l	Chlor-a ug/l	Org-N mg/l	NH3-N mg/L	NO2-N mg/l	NO3-N mg/l	TN mg/l	Org-P mg/l	Dis-P mg/l	TP mg/l
Tappahanna Ditch												
207121	16.27	5.21	2.67	16.98	0.68	0.13	0.03	0.27	1.06	0.15	0.04	0.19
207131	16.00	6.89	3.26	51.51	1.39	0.14	0.05	0.44	2.01	0.31	0.03	0.34
207081	16.28	7.29	2.40	5.04	0.72	0.09	0.07	0.64	1.53	0.08	0.03	0.11
207171	16.61	6.96	2.40	2.41	0.68	0.11	0.08	0.70	1.57	0.09	0.04	0.13
Culbreth Marsh Ditch												
207151	16.94	4.27	3.79	53.29	0.88	0.15	0.02	0.21	1.14	0.23	0.06	0.29
207141	16.65	6.38	2.40	4.24	0.61	0.11	0.07	0.61	1.40	0.12	0.03	0.15
207091	16.80	6.84	2.57	11.32	0.81	0.15	0.15	1.36	2.48	0.12	0.04	0.16
Cow Marsh Creek												
207191	16.68	5.34	2.50	5.44	0.55	0.05	0.02	0.17	0.78	0.09	0.02	0.11
207181	16.55	7.43	2.40	8.03	0.62	0.07	0.04	0.39	1.13	0.07	0.02	0.09
207021	17.06	6.75	2.40	2.88	0.59	0.11	0.09	0.79	1.58	0.07	0.02	0.09
Mainstem Choptank River												
207161	17.81	7.10	2.40	7.97	0.80	0.12	0.08	0.71	1.70	0.12	0.03	0.15
207031*	4.13	12.04	2.40	2.78	0.35	0.10	0.14	1.25	1.83	0.08	0.04	0.12
White Marsh Branch												
207111	16.32	6.67	2.40	3.50	0.87	0.11	0.30	2.73	4.02	0.07	0.04	0.12

*Station 207031 was sampled during the modeling phase of the project, therefore the averages for this station are from January 2005 through April 2005.

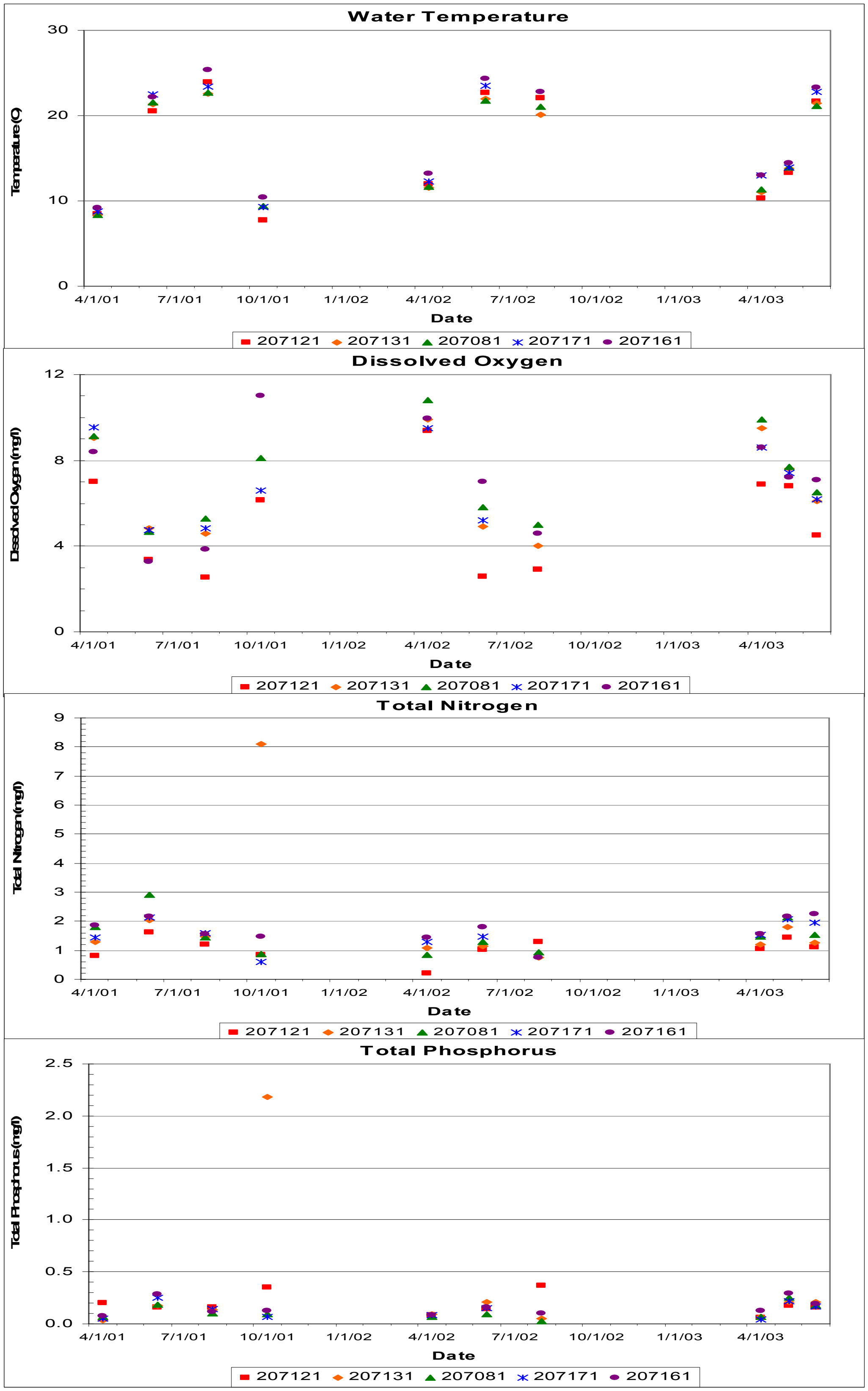

Figure 1-10a Observed Temperature, DO, TN, and TP at Monitoring Locations in Choptank River Watershed-Tappahanna Ditch Transect

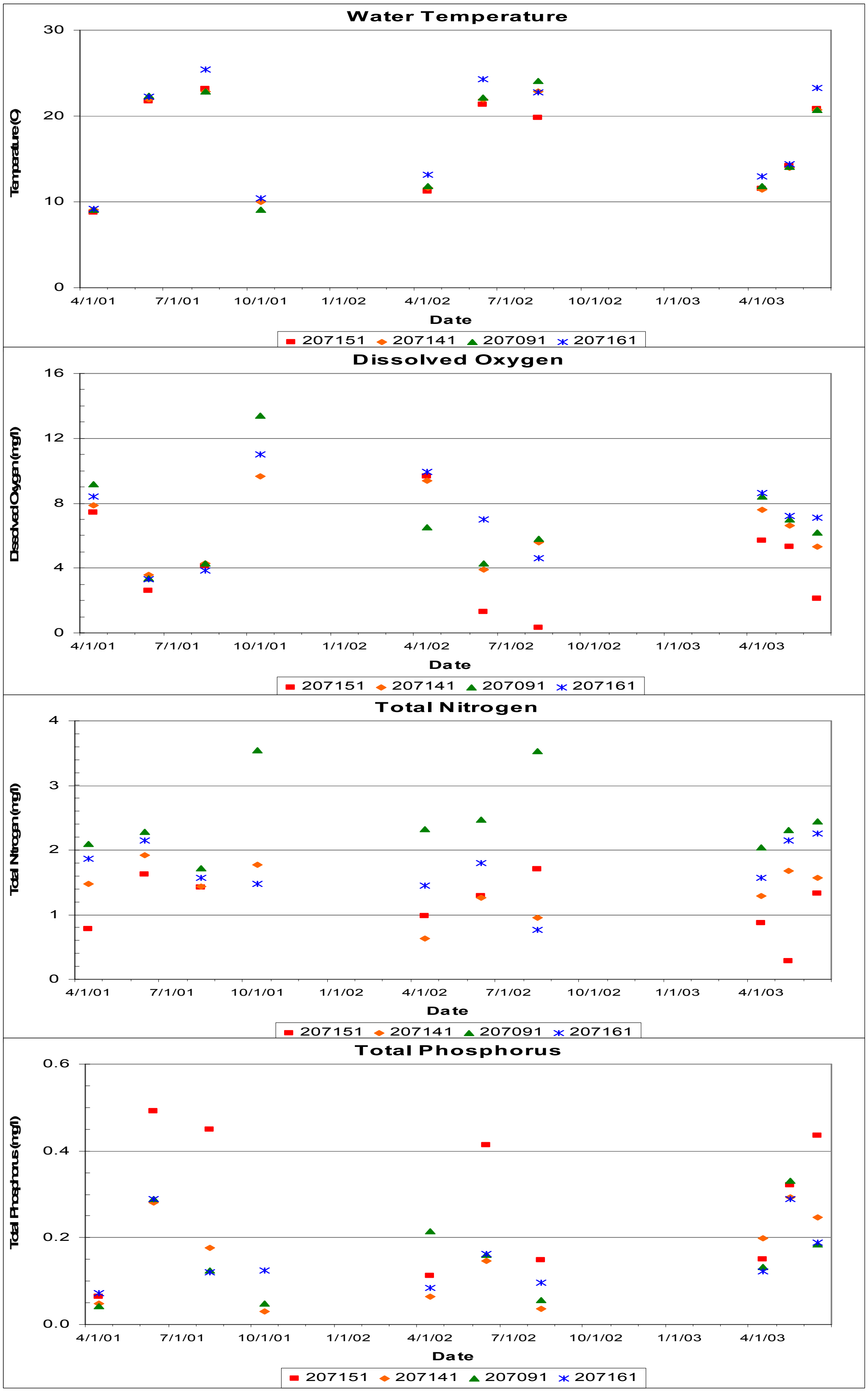

Figure 1-10b Observed Temperature, DO, TN, and TP at Monitoring Locations in Choptank River Watershed-Culbreth Marsh Ditch Transect

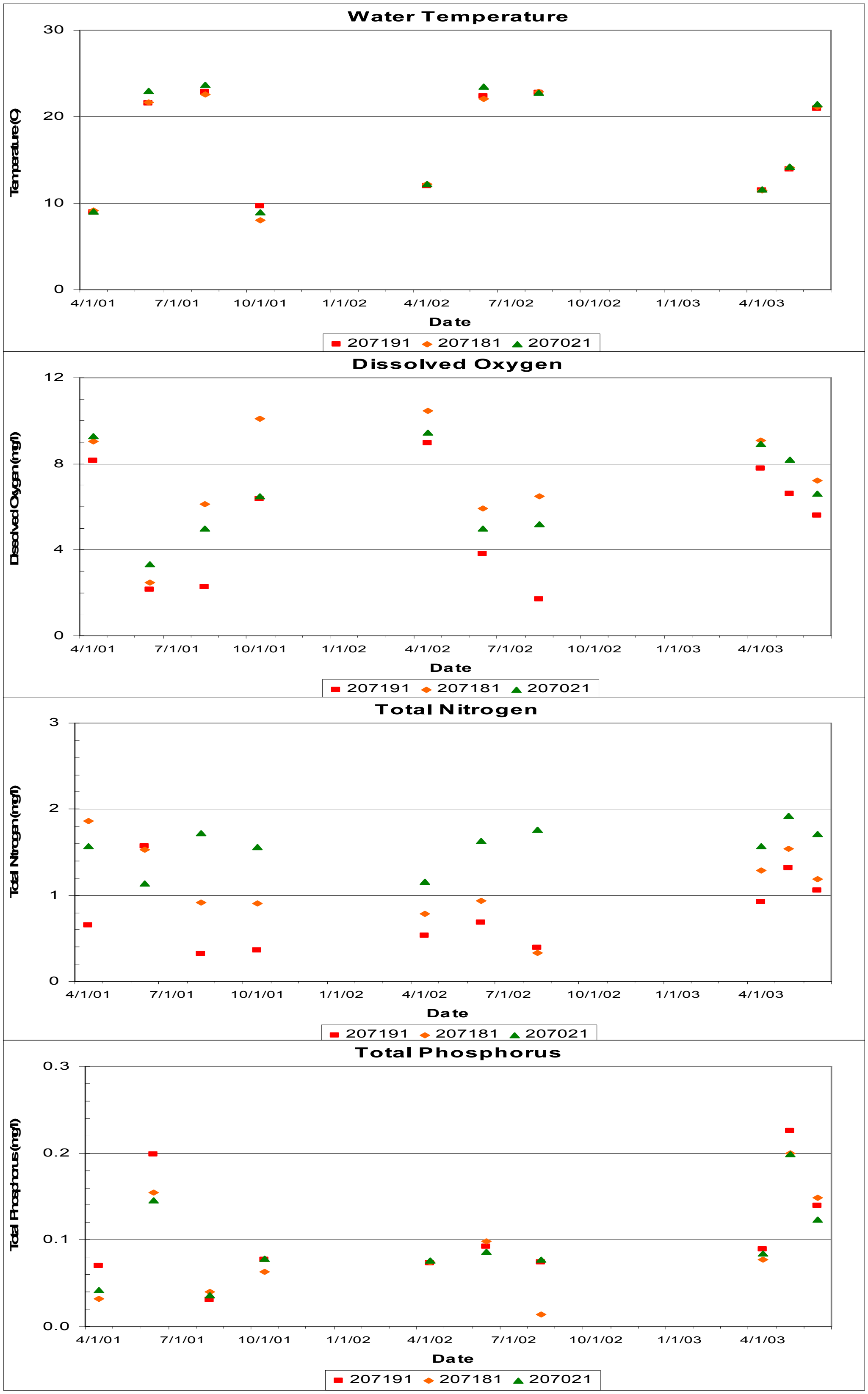

Figure 1-10c Observed Temperature, DO, TN and TP at Monitoring Locations in Choptank River Watershed-Cow Marsh Creek Transect

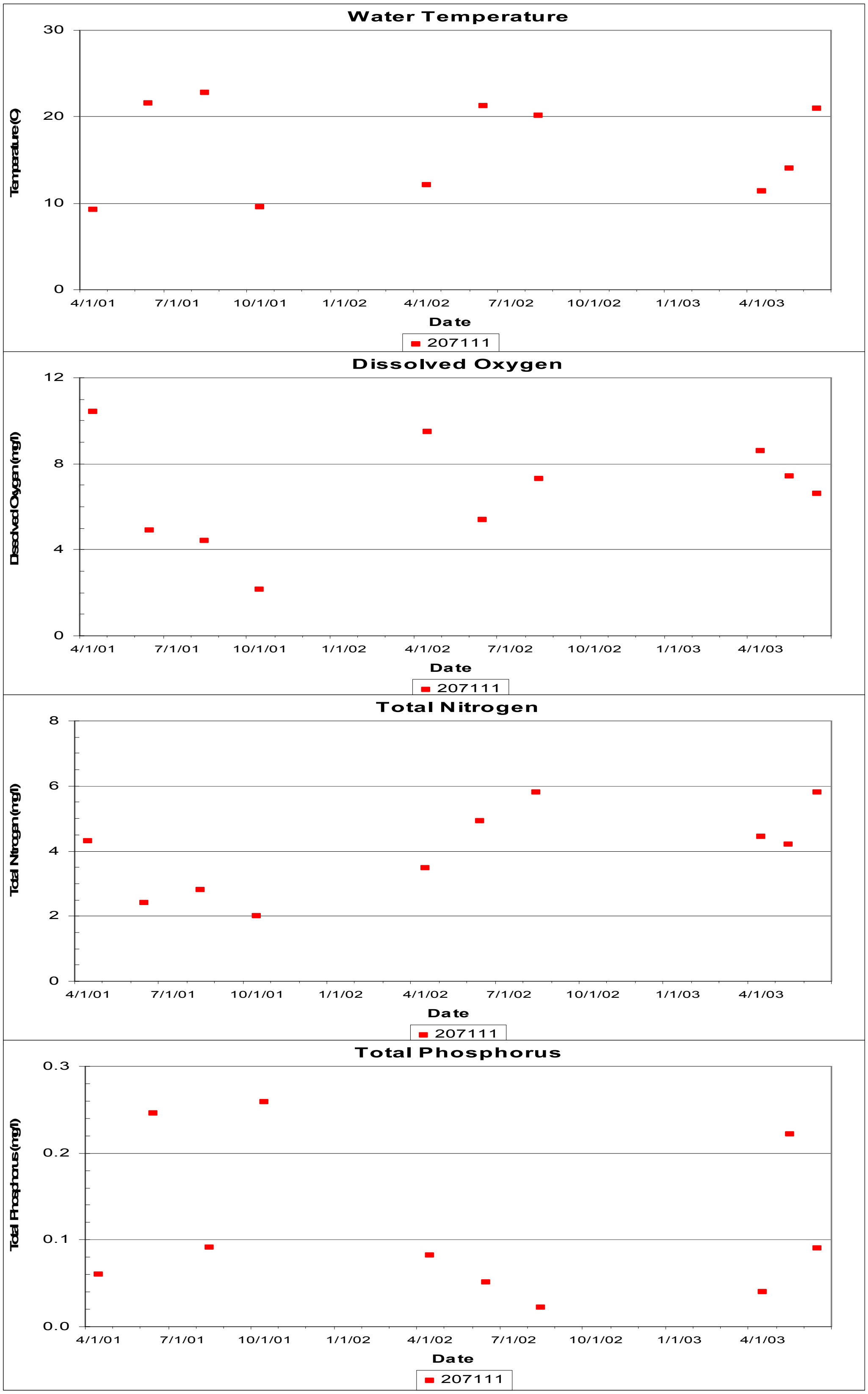

Figure 1-10d Observed Temperature, DO, TN and TP at Monitoring Location in Choptank River Watershed-White Marsh Creek

Figure 1-11 illustrates the bacteria concentrations in the Choptank River Watershed; it is clearly much greater than the bacteria standard.

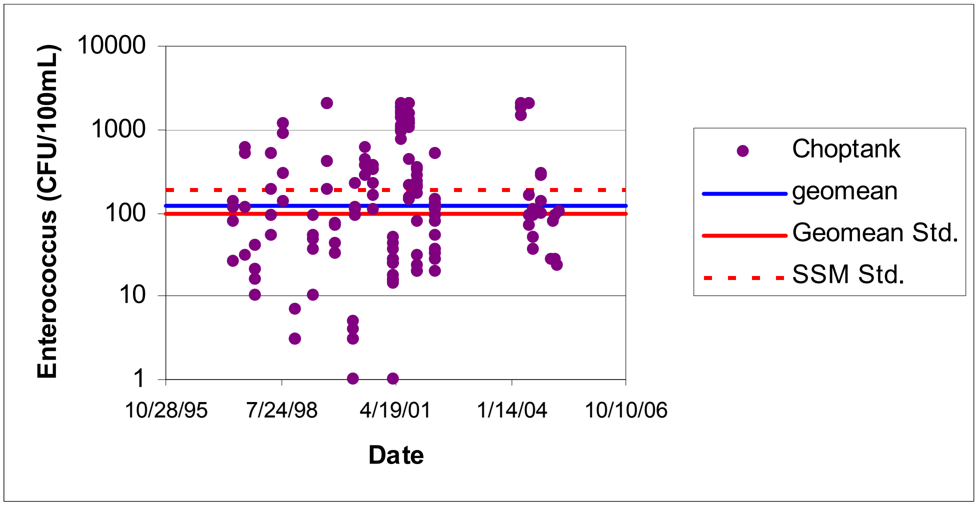

Figure 1-11 Enterococcus Concentration in Choptank River Watershed

Marshyhope Creek Watershed

Table 1-5 presents the average concentrations of monitoring data collected during the 2001 – 2003 period as well as the average concentration between December 2004-April 2005 at station 302061, which was sampled during the modeling phase. The observed temperature, dissolved oxygen, total nitrogen and total phosphorus on the sampling dates during the more intensive 2001 through 2003 TMDL monitoring period are presented in Figures 1-12.

The monitoring data showed that occasional dissolved oxygen violations occurred at all four monitoring sites, with concentrations below 5.5 mg/l occurring during summer months (Figure 1-12). Nutrient levels were relatively high in the range of 1.0 to 4.4 mg/l for total nitrogen and 0.01 to 0.47 mg/l for total phosphorous. They exceeded the State's nutrient threshold levels of 3.0 mg/l for total nitrogen and 0.2 mg/l for total phosphorous.

Based on the monitoring data, Delaware's 2004 305(b) Reports (4) showed that elevated nutrient levels and low DO concentrations impaired Marshyhope Creek and its designated uses were only partially supported for aquatic life and primary contact recreation

Table 1-5. Average Water Quality Conditions at Five Monitoring Locations in Marshyhope Creek Watershed during 2001-2003

Monitoring Station	Water Temp C	Field DO mg/l	BOD5 mg/l	Chlor-a ug/l	Org-N mg/l	NH3-N mg/L	NO2-N mg/l	NO3-N mg/l	TN mg/l	Org-P mg/l	Dis-P mg/l	TP mg/l
302051	15.99	7.23	2.64	21.63	1.19	0.19	0.09	0.79	2.26	0.34	0.06	0.40
302041	16.65	7.72	2.66	7.81	0.78	0.13	0.09	0.82	1.67	0.12	0.03	0.15
302031	16.87	8.76	2.40	5.41	0.87	0.12	0.20	1.83	3.02	0.12	0.04	0.16
302021	17.40	8.16	2.40	3.08	1.03	0.11	0.21	1.88	3.23	0.08	0.06	0.14
302061*	6.21	11.08	2.40	3.01	0.50	0.10	0.31	2.76	3.57	0.08	0.01	0.09

*Station 302061 was sampled during the modeling phase of the project, therefore the averages for this station are from December 2004 through April 2005.

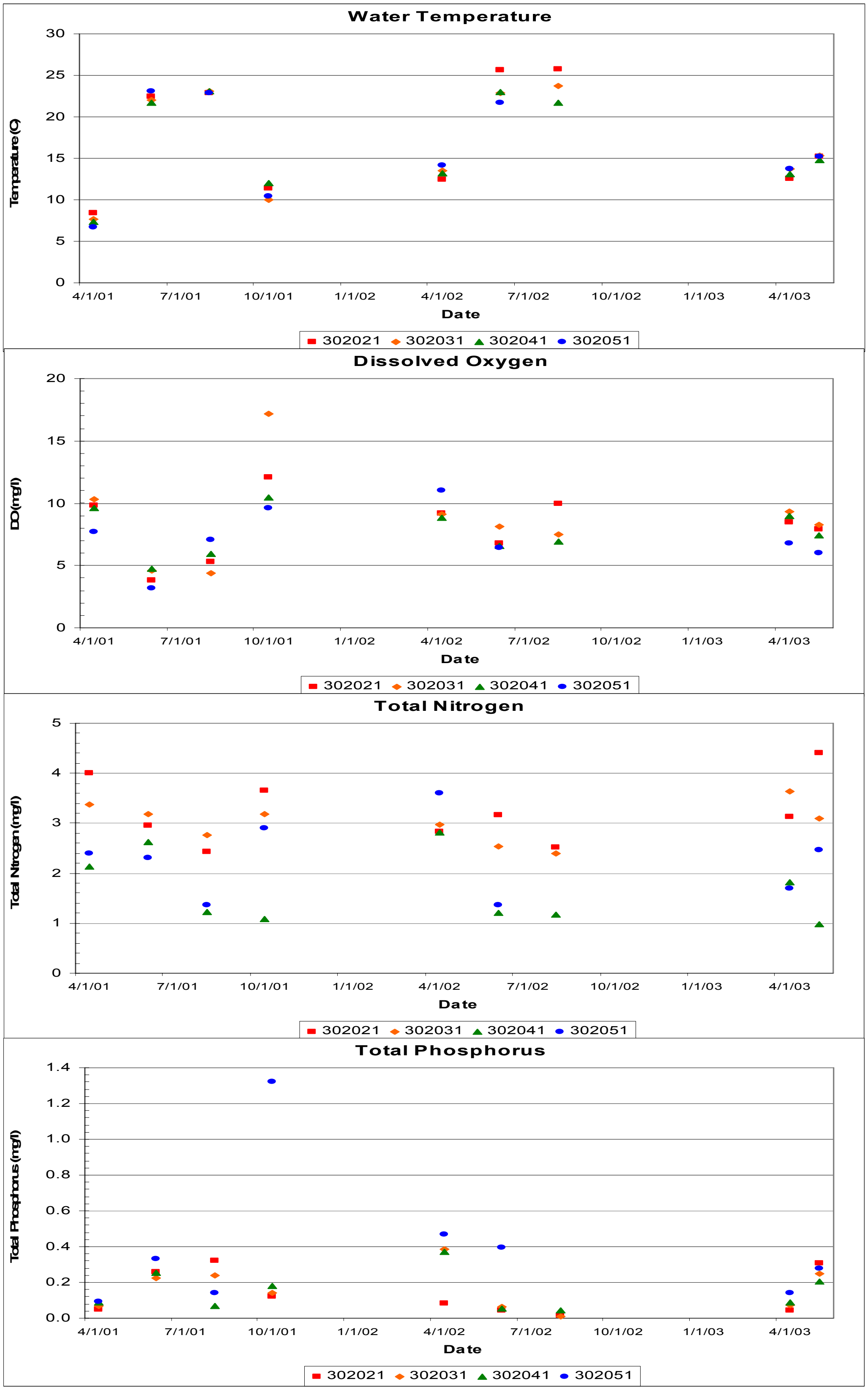

Figure 1-12 Observed Temperature, DO, TN and TP at Monitoring Locations in Marshyhope Creek Watershed

Figure 1-13 illustrates the bacteria concentrations in the Choptank River Watershed; it is clearly much greater than the bacteria standard.

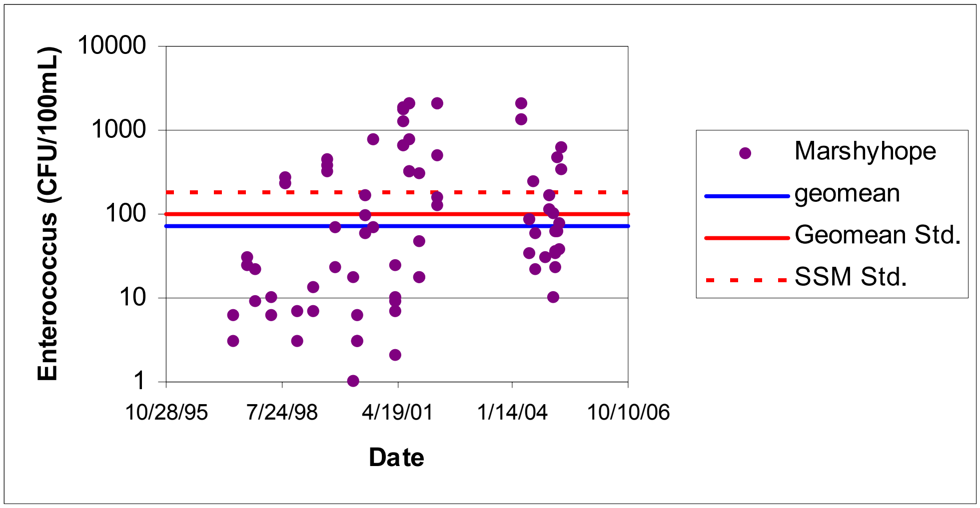

Figure 1-13 Enterococcus Concentration in Marshyhope Creek Watershed

Sources of Pollution

In general, nutrients, oxygen consuming compounds, and bacteria enter surface waters from point and nonpoint sources. Nonpoint source discharges include surface runoff from urban and other land use activities, septic tanks, and groundwater discharges. Point source discharges often include municipal and industrial wastewater treatment plants (NPDES facilities) or combined sewer overflows (CSOs). There are no active NPDES permitted point sources discharging nutrients or bacteria in the Chester River, Choptank River, or Marshyhope Creek Watersheds.

An ArcView GIS anlysis was done to determine the number of individual onsite wastewater treatment and disposal systems, or septic sytems, that exist in each watershed. There are more than 1,400 systems in the Chester River Watershed, approximately 3,700 in the Choptank River Waterhshed, and roughly 1,700 in the Marshyhope Creek Watershed. Additionally, there are 4 animal operations in the Chester River Watershed, 32 in the Choptank River Watershed, and 90 in the Marshyhope Creek Watershed. The septic systems and animal operations, as well as any other potential nonpoint nutrient and bacteria sources are estimated in the water quality models through calibration to actual site specific surface water quality data. Thus, the loads from all nonpoint sources were considered in total in the TMDL analyses.

Objective and Scope of the TMDL Analysis for Chesapeake Drainage Watersheds

The objective of the TMDL analysis for the Chesapeake drainage watersheds is to estimate the maximum amount of nutrients and bacteria that Chester River, Choptank River, and Marshyhope Creek can receive without violating water quality standards. Under such loads, the water quality standards of dissolved oxygen and bacteria will be met at all segments and targets of total nitrogen and total phosphorus will be reached at acceptable levels.

To reach the objective, DNREC:

- Established water quality models using U.S. EPA’s Qual2E as a framework for Chester River, Choptank River, and Marshyhope Creek,
- Calibrated Chester River, Choptank River, and Marshyhope Creek Qual2E models to the average conditions of water quality and flow during the 2001-2003 period,
- Applied and evaluated summer loading conditions using the calibrated models,
- Estimated current loadings under the average conditions during the 2001-2003 period.
- Estimated bacteria reductions under different flow conditions.

Chapter 2 of this report provides a brief review of the Chester River Qual2E models, the Choptank River Qual2E model, and the Marshyhope Creek Qual2E model. The results of the calibration runs and the summer loading scenario runs are presented in Chapter 3. The water quality resulting by implementing the Chesapeake Bay Agreement nutrient load reductions is shown in Chapter 4. An estimation of the Chesapeake drainage nutrient TMDLs and nutrient load allocations are discussed in Chapter 5. Chapter 6 gives a discussion of the bacteria load estimation and the bacteria reductions calculated under different flow conditions. Finally, Chapter 7 discusses the regulatory requirements for TMDLs.

2.0 CHESAPEAKE DRAINAGE WATERSHEDS WATER QUALITY MODELS

The Enhanced Stream Water Quality Model (Qual2E)

The Enhanced Stream Water Quality Model (Qual2E) was chosen as the framework for modeling Chester River, Choptank River, and Marshyhope Creek water quality and nutrient TMDL development. Qual2E is supported by the U.S. EPA and has been widely used for studying the impact of conventional pollutants on free flowing streams. DOS version 3.22 of this model was used in this study. Model code was recompiled by Linfield C. Brown to run under Windows XP operating system.

The Delaware portions of the Chester River, Choptank River, and Marshyhope Creek are small streams. At the Delaware-Maryland border, the annual mean flows of the Chester River tributaries Cypress Branch, Sewell Branch, and Gravelly Run, which will be modeled individually, are 0.6, 0.5, and 0.7 cubic meters per second (cms), respectively. The widths and depths of these three tributaries are also similar and range between 1.0 and 15 meters wide and 0.3 to 0.6 meters deep. The annual mean flow of the Choptank River is 4.4 cms at the state line. The widths of the Choptank tributaries (Tappahanna Ditch, Culbreth Marsh Ditch, and Cow Marsh Creek) range between 3 and 17 meters, while the mainstem can reach up to 20 meters wide. The depths in both the tributaries and mainstem range between 0.3 to 0.7 meters. The long-term annual mean flow of Marshyhope Creek at the state line is 4.1 cms. The width of the stream increases from about 1.5 meters at its headwater to 18 meters at its lower reaches, while its depth is more uniformly distributed from its headwater to the lower reaches at approximately 0.3 meters. Water quality concerns for each of the systems include elevated nutrient and bacteria levels and low dissolved oxygen concentrations. The bacteria modeling is discussed in Chapter 6.

The Qual2E model is suitable for simulating the hydrological and water quality components of a small stream. It is a simple one-dimensional model, but consists of the basic stream transport and mixing processes. The kinetic processes employed in Qual2E address nutrient cycles, algal growth, and dissolved oxygen dynamics. Compared to other available models, Qual2E is the best suited for the conditions of the Chester River, Choptank River, and Marshyhope Creek. Therefore, Qual2E was selected as the tool to develop the water quality models for the Chesapeake drainage systems and used to conduct the nutrient TMDL analyses.

The Qual2E consists of 13 types of input data groups. Below is a brief summary of those groups. A detailed discussion is available in the model's user manual (13). Data inputs for each of the Qual2E models are discussed in a later section of this chapter.

- Type 1, 1A, and 1B data groups define program control, global algal, nutrient, and light parameters, and temperature correction factors.
- Type 2 data identifies the stream reach system by listing reach names and lengths.
- Type 3 data gives flow augmentation information.
- Type 4 data identifies each type of computational element in each reach.
- Type 5 data describes the hydraulic characteristics of the system.
- Type 6, 6A, and 6B data provide reach varied coefficients and rates related to kinetic processes of BOD, DO, nutrients, and algae.
- Type 7 and 7A data define the initial conditions of the system.
- Type 8 and 8A data provide incremental inflow values and their concentrations.
- Type 9 data defines stream junction name and order if tributaries are simulated.
- Type 10 and 10A data define headwater conditions.
- Type 11 and 11A data define point load or tributary conditions.
- Type 12 data provides dam reaeration information.
- Type 13 data defines the downstream condition.

Input Data for the Chester River Qual2E Models

The Chester River Watershed within Delaware consists of three tributaries (Cypress Branch, Sewell Branch, and Gravelly Run), which do not join the mainstem of the Chester River until further downstream in Maryland. In an effort to simplify the model framework, each tributary will be modeled individually.

Each Chester River model (the Cypress Branch Qual2E Model, the Sewell Branch Qual2E Model, and the Gravelly Run Qual2E Model) is set up as a one dimensional, steady state model. It simulates average in-stream water quality conditions including dissolved oxygen, BOD, algae as chlorophyll-*a*, various forms of nitrogen, as well as organic and dissolved phosphorous. Water temperature and diurnal changes of algae are not simulated. The model is defined by various input data as described in the previous section. The major input data groups for the Chester River Qual2E Models are summarized below.

<u>Model Segmentation</u>

Each Chester River Qual2E Model consists of two model reaches starting from its headwater to just below the state line. Both the Cypress Branch and Sewell Branch models cover 5 km and the Gravelly Run model covers 6 km of stream length. Figures 2-1(a-c) display the reaches on the watershed maps. Due to the structure of Qual2E, each reach is further divided into a number of computational elements, which must have the same length across the entire model domain. A length of 0.5 km was assigned to all three of the Chester River Qual2E Model's computational elements. A summary of reach lengths and the number of computational elements is presented in Table 2-1.

Table 2-1 Chester River Qual2E Model Reaches

Reach Number	Description	Reach Length (km)	Number of Computational Elements
Cypress Branch Qual2E Reaches			
1	Upper reach, from headwater above Morris Road; two tributaries (Black Stallion Ditch and Dogwood Branch)	2.5	5
2	Lower reach; one tributary (Tributary 1)	2.5	5
Total Cypress Branch		5.0	10
Sewell Branch Qual2E Reaches			
1	Upper reach, from headwater above Blackiston Church Road; two tributaries (Tributary 1 and Tributary 2)	2.5	5
2	Lower reach; two tributaries (Jordan Branch and Blanco Ditch)	2.5	5
Total Sewell Branch		5.0	10
Gravelly Run Qual2E Reaches			
1	Upper reach, from headwater above Fords Corner Road; one tributary (Tributary 1)	3.0	6
2	Lower reach; four tributaries (Muddy Bottom Ditch, Tributary 2, Tributary 3, Tributary 4, Tributary 5)	3.0	6
Total Gravelly Run		6.0	12

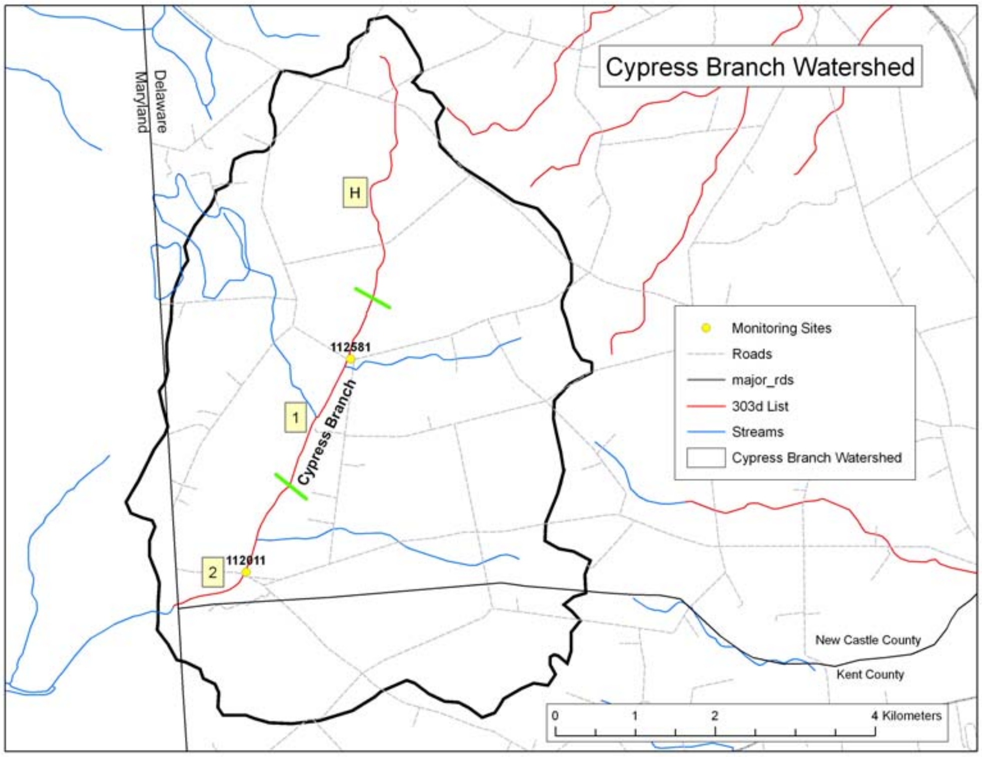

Figure 2-1a Reaches of Cypress Branch Qual2E Model

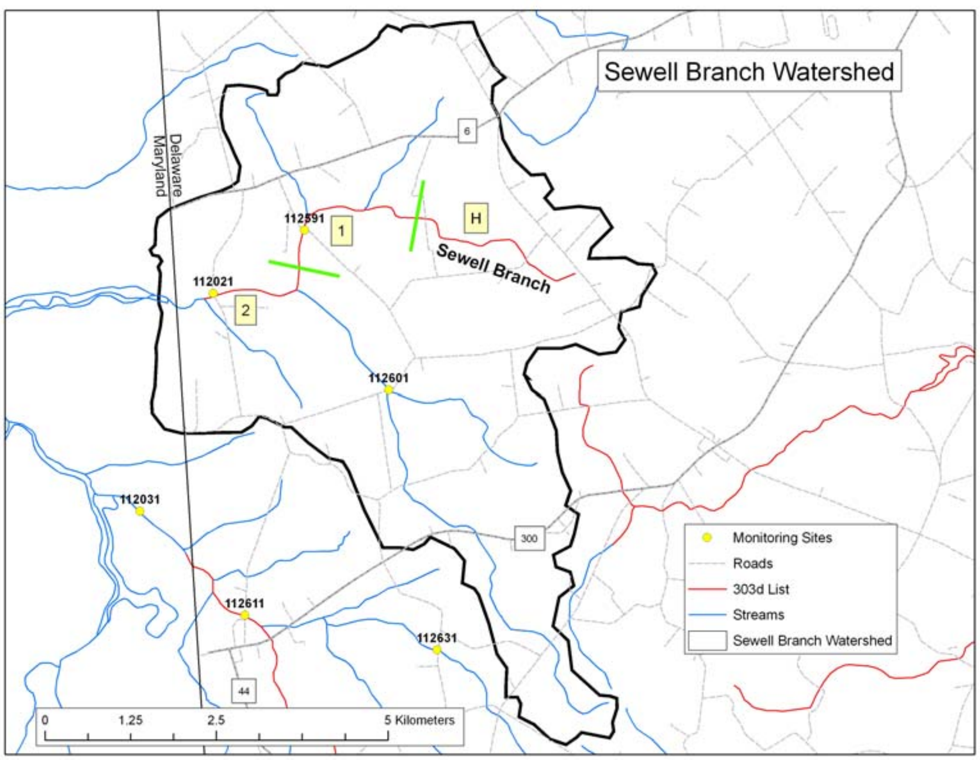

Figure 2-1b Reaches of Sewell Branch Qual2E Model

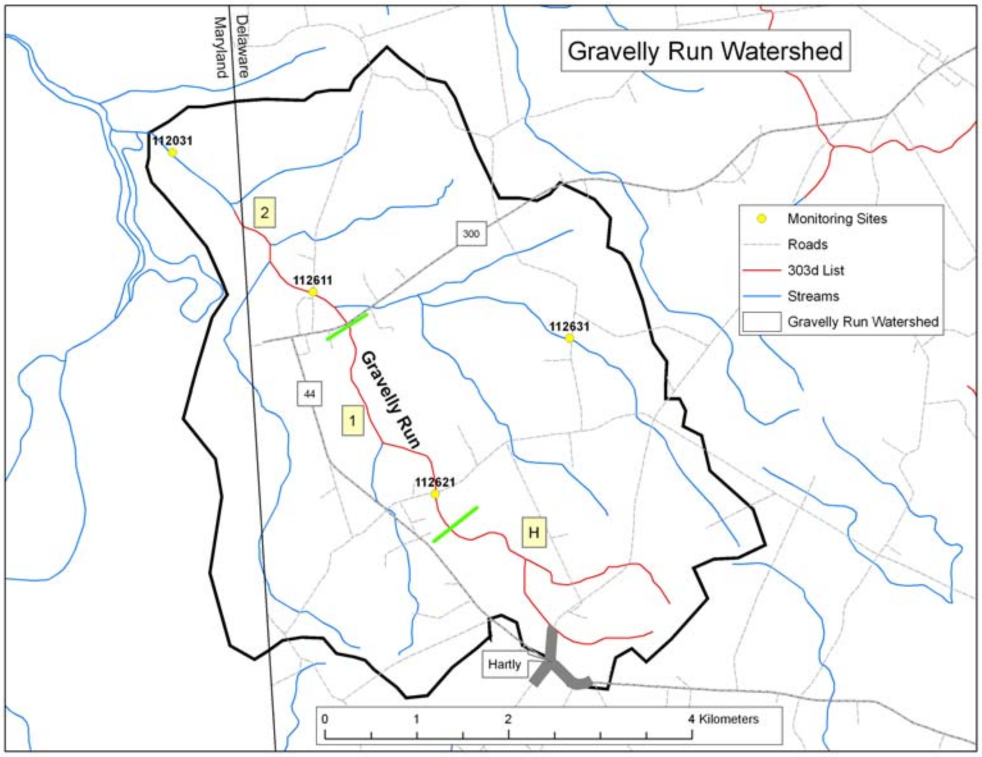

Figure 2-1c Reaches of Gravelly Run Qual2E Model

<u>Hydraulic Characteristics</u>

The Chester River Qual2E Models used functional representation, rather than geometric representation, to describe its stream hydraulic characteristics with the assumption of rectangular channel cross-section. Functional representation of hydraulic characteristics of the stream reaches were determined by using the following discharge coefficient equations:

$$\bar{u} = aQ^b$$
$$A_x = Q / \bar{u}$$
$$d = \alpha Q^\beta$$

where $\bar{u}$ - mean velocity of stream reach (m/s)
d - depth of stream reach (m)
$a, b, \alpha,$ *and* β - empirical discharge coefficient constants

Field measurements of stream channel width, depth, and velocity were conducted at the same time when water quality samples were collected at the monitoring sites during 2001-2003. Additional observations were recorded during a field reconnaissance in November 2004. The average width, depth, and velocity for each site were calculated from the field measurements, and the results are presented in Table 2–2.

Table 2-2 Average Channel Width, Depth, and Velocity of Chester River Qual2E Model Reaches

Station (from upstream down)	Stream Segment	Average Width (m)	Average Depth (m)	Average Velocity (m/s)
Cypress Branch Qual2E Reaches				
112581*	Reach 1- Upper reach	5.33	0.27	0.09
112011*	Reach 2- Lower reach	6.10	0.42	0.16
Sewell Branch Qual2E Reaches				
112591	Reach 1 - Upper reach	2.90	0.44	0.16
112021*	Reach 2 - Lower reach	11.3	0.30	0.15
112601	Jordan Branch, tributary draining to Reach 2	3.23	0.30	0.25
Gravelly Run Qual2E Reaches				
112621	Reach 1 - Upper reach	1.81	0.59	0.07
112611	Reach 2 - Lower reach	2.95	0.37	0.24
112031*	Reach 2 - Lower reach	4.54	0.42	0.26
112631	Muddy Bottom Ditch, tributary draining to Reach 2	1.32	0.35	0.06

* Data is from field reconnaissance in November 2004.

The field measurements were used to estimate discharge coefficient constants. First, channel depths and velocities, which were estimated from the data collected at each sample location, were plotted against their corresponding stream flow measurements. Next, regressions for depth versus flow and velocity versus flow were performed for stations on each stream grouped together. From the regression plots, the discharge coefficient constants a, b, α, and β were calculated and the discharge function was formed and assigned to represent the hydraulic characteristics of each stream reach. Table 2-3 summarizes the estimated discharge coefficient constants and the discharge functions for the modeled sub-watersheds of the Chester River.

Table 2-3 Discharge Coefficient Constants for Chester River Qual2E Model Reaches

Reach	Stream Segment Name	Station	Mean Velocity (m/s)	Depth (m)
			u = a Q ^b	d = α Q ^β
Cypress Branch Qual2E Reaches				
1	Upper reach	112581 112011	u = 0.2531 Q ^ 0.5074	d = 0.5868 Q ^ 0.3803
2	Lower reach			
Sewell Branch Qual2E Reaches				
1	Upper reach	112591 112601	u = 0.1365 Q ^ 0.1730	d = 0.3332 Q ^ 0.1365
2	Lower reach			
Gravelly Run Qual2E Reaches				
1	Upper reach	112621 112611 112031	u = 03160 Q ^ 0.3616	d = 0.4569 Q ^ 0.1856
2	Lower reach			

Stream Flows

The only USGS gauging station in the Delaware portions of the Chesapeake drainage watersheds is located in the Marshyhope Creek Watershed (USGS gauging station 01488500). Since all three Chesapeake drainage watersheds have similar geology, topography, and land use and are contiguous, the Marshyhope Creek discharge record will be applied to the Chester River and Choptank River watersheds.

The Marshyhope Creek discharge record runs from 1943 through December 2002 (14). In order to obtain a discharge record covering the entire period of water quality monitoring, the daily flows recorded at the Bridgeville gauging station (USGS 01487000) were used to estimate the daily flows in Marshyhope Creek for the nine-month period between January and September 2003. Figure 2-2 shows the mean daily discharge at both gauging stations beginning in October 2000 and proceeding through December 2002 at the Marshyhope guage and through September 2003 at the Bridgeville guage.

The Bridgeville gauge data was considered reasonable for estimating several months of flow for the Marshyhope Creek Watershed since it too has similar geology, topography, land use and it is located in the adjacent Nanticoke River Watershed. The drainage area to the Bridgeville station is 195 km^2 and the average discharge between October 2000 and September 2003 was 60 cms. The estimated runoff rate at Bridgeville is approximately 0.31 $m^3/km^2/sec$. This is somewhat greater then the runoff rate at Marshyhope Creek, which is only 0.18 $m^3/km^2/sec$, due to the slightly smaller drainage area (114 km^2) and slower average flow rate (2 cms). However, since only a few months of estimated data were needed to determine an overall average discharge for the 2001-2003 water years, this was considered acceptable. Additionally, the daily data from the two stations were correlated, with an R2 of 0.5289, ensuring that the Bridgeville record could adequately estimate the missing Marshyhope discharge record. A ratio of flow to drainage area was used to estimate the missing Marshyhope data.

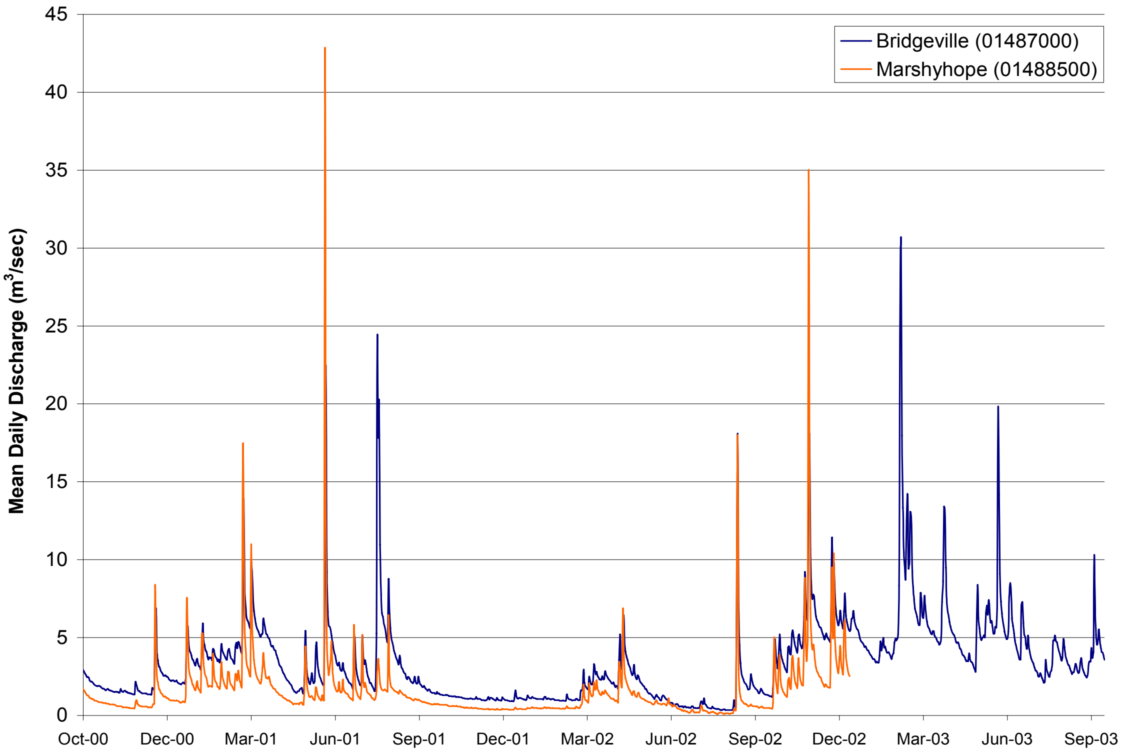

Figure 2-2 Mean Daily Discharge at the Marshyhope and Bridgeville Gauging Stations

Both annual average flow and 7Q10 flow (a low flow of 7-day duration with a recurrence interval of 10 years) conditions will be considered for development of all Chesapeake drainage watershed models and analysis of their TMDLs. Annual average flow was the result of averaging the Marshyhope Creek daily mean flows over the period of October 2000 through September 2003 (2001, 2002, and 2003 water years). The 7Q10 flow was determined using version 2.1 of DFLOW, a program to calculate design stream flows. The annual average flow is used for model calibration while the 7Q10 flow is used in model scenario runs to simulate the critical condition possibly occurring in summer low flow and warm weather situations.

The annual average and 7Q10 flows determined at the Marshyhope gauging station were used to estimate the annual average and 7Q10 stream flows in the Chester River Watershed using a ratio of discharge to drainage area. It is assumed that the runoff rate in the Chester River is similar to the Marshyhope Creek runoff rate. Table 2-4 lists the Chester River sub-watershed drainage areas as well as the estimated annual average and 7Q10 flows.

Table 2-4 Annual Average and Summer Low Flows of Chester River

Description of Drainage Area	Drainage Area	Annual average flow (10/2000-9/2003)		7Q10 Flow	
	km^2	ft^3/s	m^3/s	ft^3/s	m^3/s
Cypress Branch					
Headwater	7.31	4.43	0.125	0.18	0.005
Black Stallion Ditch, a tributary in Reach 1	3.67	2.22	0.063	0.09	0.003
Dogwood Branch, a tributary in Reach 1	3.29	1.99	0.056	0.08	0.002
Reach 1 incremental inflow	5.03	3.05	0.086	0.12	0.004
Tributary 1 in Reach 2	4.61	2.79	0.079	0.11	0.003
Reach 2 incremental inflow	11.18	6.77	0.192	0.28	0.008
Cypress Branch Sub-watershed Total	35.08	21.25	0.602	0.86	0.024
Sewell Branch					
Headwater	7.10	4.30	0.122	0.18	0.005
Tributary 1 in Reach 1	4.45	2.70	0.076	0.11	0.003
Tributary 2 in Reach 1	2.52	1.53	0.043	0.06	0.002
Reach 1 incremental inflow	2.55	1.54	0.044	0.06	0.002
Jordan Branch, a tributary in Reach 2	14.15	8.57	0.243	0.35	0.010
Blanco Ditch, a tributary in Reach 2	1.98	1.20	0.034	0.05	0.001
Reach 2 incremental inflow	5.16	3.13	0.089	0.13	0.004
Sewell Branch Sub-watershed Total	37.91	22.97	0.650	0.94	0.026
Gravelly Run					
Headwater	3.11	1.89	0.053	0.08	0.002
Tributary 1 in Reach 1	1.85	1.12	0.032	0.05	0.001
Reach 1 incremental inflow	3.01	1.83	0.052	0.07	0.002
Muddy Bottom Ditch, a tributary in Reach 2	9.76	5.91	0.167	0.24	0.007
Tributary 2 in Reach 2	5.12	3.10	0.088	0.13	0.004
Tributary 3 in Reach 2	1.73	1.05	0.030	0.04	0.001
Tributary 4 in Reach 2	2.10	1.27	0.036	0.05	0.001
Reach 2 incremental inflow	2.77	1.68	0.048	0.07	0.002
Gravelly Run Sub-watershed Total	29.46	17.84	0.505	0.73	0.021

System Parameters

The physical, chemical, and biological processes simulated by Qual2E are represented by a set of equations that contain many system parameters. Some are global constants, some are spatial variables, and some are temperature dependent. Detailed descriptions of these parameters and associated processes are available in the Qual2E user's manual. The global constants and reach variable coefficients used in the Chester River Qual2E models are listed in Table 2-5 and Table 2-6.

Table 2-5 Global Constants of the Chester River Qual2E Models

Parameter	Description	Unit	Value
α_1	Fraction of algal biomass that is Nitrogen	mg-N / mg A	0.080
α_2	Fraction of algal biomass that is Phosphorus	mg-P / mg A	0.015
α_3	O_2 production per unit of algal growth	mg-O / mg A	1.600
α_4	O_2 uptake per unit of algae respired	mg-O / mg A	2.000
α_5	O_2 uptake per unit of NH_3 oxidation	mg-O / mg A	3.500
α_6	O_2 uptake per unit of NO_2 oxidation	mg-O / mg A	1.070
μ_{max}	Maximum algal growth rate	day-1	2.000
ρ	Algal respiration rate	day-1	0.275
K_L	Light saturation coefficient (Option 2)	Langley's/min	0.025
K_N	Half-saturation constant for nitrogen	mg-N/l	0.155
K_P	Half-saturation constant for phosphorus	mg-P/l	0.026
λ_1	Linear algal self-shading coefficient	(1/m) / (µg Chl-1/l)	0.003
λ_2	Nonlinear algal self-shading coefficient	(1/m) / (µg Chl-1/l)**2/3	0.017
P_N	Algal preference factor for ammonia	-	0.900

Table 2-6 Reach Varied Coefficients of the Chester River Qual2E Models

Parameter	Description	Unit	Range
α_0	Ratio of chlorophyll-a to algal biomass	μg Chl-a / mg A	75.00
λ_0	Non-algal light extinction coefficient	1/m	0.00
σ_1	Algal settling rate	m/day	0.00-0.05
σ_2	Benthos source rate for dissolved phosphorus	mg-P /m^2-day	0.00
σ_3	Benthos source rate for ammonia nitrogen	mg-N /m^2-day	0.00
σ_4	Organic nitrogen settling rate	day-1	0.00-0.05
σ_5	Organic phosphorus settling rate	day-1	0.00-0.05
K_1	Carbonaceous deoxygeneration rate constant	day-1	0.20-0.50
K_2	Reaeration rate constant	day-1	calculated internally (option 5)
K_3	Rate of loss of BOD due to settling	day-1	0.00
K_4	Benthic oxygen uptake (SOD)	g-O / m^2-day	0.25-0.80
β_1	Rate constant for the biological oxidation of NH_3 to NO_2	day-1	0.00-0.10
β_2	Rate constant for the biological oxidation of NO_2 to NO_3	day-1	0.00-0.20
β_3	Rate constant for the hydrolysis of organic-N to ammonia	day-1	0.00-0.04
β_4	Rate constant for the decay of organic-P to dissolved-P	day-1	0.00-0.07

Boundary Conditions

Qual2E uses different data groups to define model boundary conditions. It uses the headwater data group to define most upstream boundary conditions of a model domain. Downstream boundary condition can be defined by the user, or computed internally. The point source data group defines the condition of point source discharge from facilities or small tributaries that input to the simulated stream segments.

The headwater and tributary conditions of the Cypress Branch Qual2E Model were defined by monitoring data collected at station 112581. The headwater and tributary conditions of the Sewell Branch and Gravelly Run Qual2E Models were defined by averaging monitoring data collected at stations 112591 (on Sewell Branch), 112601 (on Jordan Branch), 112621 (on Gravelly Run), and 112631 (on Muddy Bottom Ditch).

The monitoring data were averaged over the entire period of 2001 – 2003 and over the summer months (July, August and September) during 2001 – 2003. Average concentrations over the entire period of 2001 -2003 were used with average flows to calibrate the model for average conditions. To calibrate the model for critical conditions, average concentrations of the summer months were used with the 7Q10 flow. The option of internally calculating the downstream boundary conditions was selected for each of the Chester River Qual2E models.

Incremental Inflow Conditions

The incremental inflow data group defines the condition of uniformly distributed flow over the entire length of the reach. The uniformly distributed flow could be groundwater inflow and/or distributed surface runoff that can be assumed constant over time.

Incremental inflow concentrations of the Chester River Qual2E Models were estimated based on consideration of surface runoff concentrations for different land uses. The surface runoff concentrations, as listed in Table 2-7, were developed by HydroQual, Inc. considering literature values and specific studies including a land use study in Delaware (15). Land use loading rates for each parameter listed in Table 2-7 were determined and compared to the average loading rates reported in several local studies by Dr. William Ritter of the University of Delaware (16-18), which are considered a reasonable representation of land use loading rates in Delaware. The land use concentrations reported by HydroQual often underestimated nitrogen loadings, while considerably overestimated phosphorus loadings. Furthermore, in-stream water samples collected from Chester River showed nitrogen species concentrations much greater than and phosphorus species concentrations much less than the surface runoff concentrations listed in Table 2-7. Therefore, HydroQual's surface runoff concentrations were adjusted to better match Ritter's loading rates and actual water quality data. These new values are found in Table 2-8.

Table 2-7 Surface Runoff Concentrations for Each Land Use Type as Prepared by HydroQual

System	Units	Urban or Built-up Land	Agricultural Land	Rangeland	Forest Land	Water	Wetland	Barren Land
NH3-N	mg/l	0.110	0.290	0.120	0.120	0.120	0.120	0.120
NO3-N	mg/l	0.390	1.540	0.350	0.350	0.350	0.350	0.350
Dis-P	mg/l	0.150	0.310	0.130	0.130	0.130	0.130	0.130
Chlor-a	mg/l	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BOD5	mg/l	10.000	10.000	2.000	2.000	2.000	2.000	2.000
DO	mg/l	6.000	5.000	6.000	6.000	6.000	4.000	6.000
Org-N	mg/l	0.910	1.310	1.140	1.140	1.140	1.140	1.140
Org-P	mg/l	0.380	0.350	0.130	0.130	0.130	0.130	0.130

Table 2-8 Adjusted Surface Runoff Concentrations for Each Land Use Type

System	Units	Urban or Built-up Land	Agricultural Land	Rangeland	Forest Land	Water	Wetland	Barren Land
NH3-N	mg/l	0.26	0.44	0.17	0.08	0.19	0.00	0.08
NO3-N	mg/l	0.91	2.32	0.49	0.22	0.54	0.00	0.22
Dis-P	mg/l	0.03	0.07	0.05	0.03	0.08	0.00	0.03
Chlor-a	mg/l	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BOD5	mg/l	10.00	10.00	2.00	2.00	2.00	0.00	2.00
DO	mg/l	6.00	5.00	6.00	6.00	6.00	0.00	6.00
Org-N	mg/l	2.13	1.97	1.59	0.72	1.76	0.00	0.72
Org-P	mg/l	0.07	0.08	0.05	0.03	0.08	0.00	0.03

The fractions of different land uses in the Chester River drainage areas were calculated using 2002 land use and land cover data. For a sub-watershed flowing directly into a modeled reach in the distributed form, its land use data was broken down into seven major types and the fraction of each land use type was estimated. Considering the percentage of each land use type in a reach and assigning appropriate runoff concentrations for the specific land use type, a reach-wide incremental inflow concentration was summed over the seven land use types. The nitrite and nitrate concentrations were still found to be much less than actual monitoring data at several downstream stations in the Sewell Branch and Gravelly Run sub-watersheds. Those parameters were doubled to further correct for the land use estimated concentrations in Reach 2 of both sub-watersheds. The results are presented in Table 2-9.

Table 2-9 Incremental Inflow Concentrations for the Chester River Qual2E Models

Concentration of Incremental Inflow	NH3-N	NO3-N	Dis-P	Chlor-a	BOD5	DO	Org-N	Org-P
	mg/l	mg/l	mg/l	ug/l	mg/l	mg/l	mg/l	mg/l
Cypress Branch								
Reach 1	0.195	0.972	0.033	0.000	3.454	4.800	1.017	0.041
Reach 2	0.143	0.671	0.025	0.000	2.890	4.808	0.826	0.033
Sewell Branch								
Reach 1	0.317	1.618	0.054	0.000	4.816	5.092	1.574	0.063
Reach 2	0.299	3.093	0.049	0.000	4.618	4.870	1.436	0.058
Gravelly Run								
Reach 1	0.274	1.370	0.046	0.000	4.397	5.041	1.411	0.056
Reach 2	0.319	3.327	0.052	0.000	4.882	4.865	1.504	0.061

Unanalyzed Constituents

Each of these boundary data groups and incremental inflow data group consist of a set of specific constituent concentrations including dissolved oxygen, BOD, chlorophyll-*a*, organic nitrogen, ammonia nitrogen, nitrite nitrogen, nitrate nitrogen, organic phosphorous, dissolved phosphorous, and water temperature. They are required in the model input file. However, organic nitrogen, nitrite nitrogen, nitrate nitrogen, and organic phosphorous were not directly analyzed from the water quality samples. The values of the organic constituents were calculated as the difference between the respective analyzed constituents, while the nitrite and nitrate concentrations were estimated based on best professional judgment:

Organic Nitrogen	=	(TKN) - (Ammonia Nitrogen)
Nitrite Nitrogen	=	0.1* (Nitrite Nitrogen + Nitrate Nitrogen)
Nitrate Nitrogen	=	0.9* (Nitrite Nitrogen + Nitrate Nitrogen)
Organic Phosphorous	=	(Total Phos.) - (Dissolved Phos.)

Input data for the Cypress Branch Qual2E Model, the Sewell Branch Qual2E Model, and the Gravelly Run Qual2E Model calibrations are presented in Appendix A, B, and C, respectively.

Choptank River Qual2E Model Input Data

The major input data groups for the Choptank River Qual2E Model are summarized below.

Model Segmentation

The Choptank River Qual2E Model consists of nine model reaches starting from its headwater to just below the state line and covers 36 km. Figure 2-3 displays these reaches on the watershed map. Each reach is further divided into computational elements with a length of 1.0 km. A summary of reach lengths and the number of computational elements is presented in Table 2-10.

Table 2-10 Choptank River Qual2E Model Reaches

Reach Number	Description	Reach Length (km)	Number of Computational Elements
1	Upper reach on Tappahanna Ditch from headwaters above Hourglass Road; seven tributaries (all unnamed, Tributary 1-7)	6	6
2	Lower reach on Tappahanna Ditch above Mud Millpond; four tributaries (Harrington Beaverdam Ditch, Tributary 8, Tributary 9, Coolspring Branch)	5	5
3	Upper reach on Culbreth Marsh Ditch from headwaters above Fox Hole Road; three tributaries (Beachy Neidig Ditch, Luther Marvel Prong, Tributary 10)	4	4
4	Lower reach on Culbreth Marsh Ditch above Mud Millpond; three tributaries (all unnamed, Tributary 11-13)	4	4
5	Mud Millpond; one junction (Culbreth Marsh Ditch)	1	1
6	Upper reach of Choptank River from Mud Millpond to Still Road.	2	2
7	Upper reach on Cow Marsh Creek from headwaters above Henry Cowgill Road; four tributaries (Five Foot Prong, Tributary 15, Iron Mine Branch, Tributary 16)	5	5
8	Lower reach on Cow Marsh Creek above confluence with Choptank River; three tributaries (Jackson Prong, Meredith Branch, Tributary 17)	5	5
9	Lower reach of Choptank River from Still Road to just past the state line; one junction (Cow Marsh Creek); one tributary (Sandtown Branch)	4	4
Total		36	36

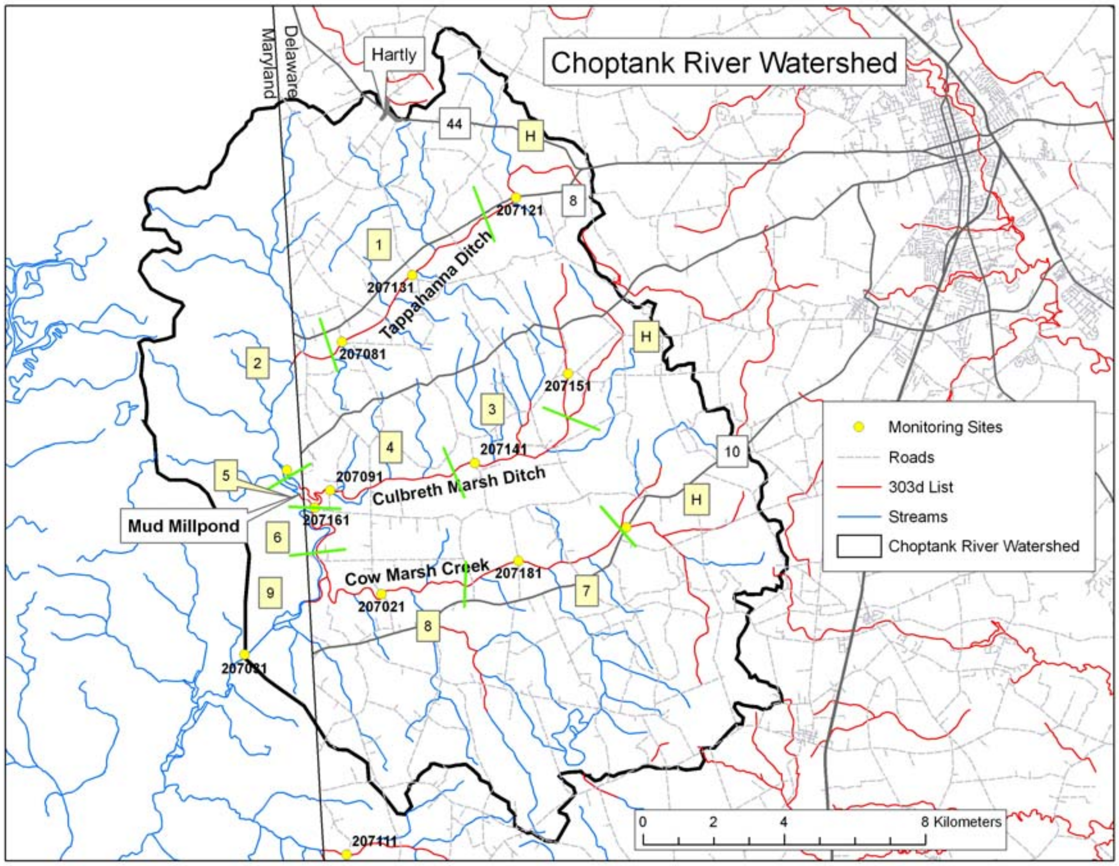

Figure 2-3 Reaches of Choptank River Qual2E Model

Hydraulic Characteristics

The average width, depth, and velocity for each site were calculated from the 2001-2003 field measurements and the results are presented in Table 2–11. The Choptank River field measurements were used to estimate discharge coefficient constants, which are summarized in Table 2-12. For further explanation on the calculation of these parameters, refer to the section on the Chester River Qual2E Models starting on page 35.

Table 2-11 Average Channel Width, Depth, and Velocity of Choptank River

Station (from upstream down)	Stream Segment	Average Width (m)	Average Depth (m)	Average Velocity (m/s)
207121	Tappahanna Ditch headwater	2.67	0.40	0.29
207131	Reach 1-upper Tappahanna Ditch, near Tributary 2	4.27	0.45	0.25
207081	Reach 1-upper Tappahanna Ditch, near Tributary 6	5.07	0.35	0.38
207171*	Reach 2-lower Tappahanna Ditch	16.8	0.57	0.15
207151	Culbreth Marsh Ditch headwater	3.15	0.37	0.19
207141*	Reach 3-upper Culbreth Marsh Ditch	5.33	0.46	0.19
207091*	Reach 4-lower Culbreth Marsh Ditch	6.10	0.53	0.23
207191*	Cow Marsh Creek headwater	6.10	0.30	0.15
207181	Reach 7-upper Cow Marsh Creek	4.91	0.24	0.25
207021*	Reach 8-lower Cow Marsh Creek	15.2	0.38	0.30
207161*	Reach 6-Mud Millpond spillway	15.2	0.53	0.30
207031*	Reach 9-lower Choptank River	19.8	0.65	0.34

*Data is from field reconnaissance in November 2004.

Table 2-12 Discharge Coefficient Constants for Choptank River Qual2E Model Reaches

Reach	Stream Segment Name	Station	Mean Velocity (m/s)	Depth (m)
			u = a Q ^b	d = α Q ^β
1	Upper Tappahanna Ditch	207121 207131 207081	u = 0.3666 Q ^ 0.1692	d = 0.4882 Q ^ 0.3474
2	Lower Tappahanna Ditch			
3	Upper Culbreth Marsh Ditch	207141 207091	u = 0.2565 Q ^ 0.3879	d = 0.5879 Q ^ 0.3280
4	Lower Culbreth Marsh Ditch			
5	Mud Millpond	none	u = 0.0045 Q ^ 0.9138	d = 1.4408 Q ^ 0.0447
6	Upper Choptank River	207161 207031	u = 0.1141 Q ^ 0.7424	d = 0.5495 Q ^ 0.1110
7	Upper Cow Marsh Creek	207181 207021	u = 0.2879 Q ^ 0.1043	d = 0.3251 Q ^ 0.1815
8	Lower Cow Marsh Creek	207191 207181 207021	u = 0.2629 Q ^ 0.0994	d = 0.3349 Q ^ 0.1831
9	Lower Choptank River	207161 207031	u = 0.1141 Q ^ 0.7424	d = 0.5495 Q ^ 0.1110

Stream Flows

Since there is also no USGS gauging station in the Delaware portion of the Choptank River Watershed, the same approach used in the Chester River Watershed to compute the annual average and critical condition stream flows using the Marshyhope Creek gauging station data was applied to the Choptank River as well. Please see the section starting on page 37 on the Chester River Qual2E Models for more details. Table 2-13 lists the Choptank River sub-watershed drainage areas as well as the estimated annual average and 7Q10 flows.

Table 2-13 Annual Average and Summer Low Flows of Choptank River

Description of Drainage Area	Drainage Area	Annual average flow (10/2000-9/2003)		7Q10 Flow	
	km^2	ft^3/s	m^3/s	ft^3/s	m^3/s
Tappahanna Ditch Headwater	15.07	9.13	0.259	0.37	0.011
Tributary 1 in Reach 1	13.10	7.94	0.225	0.32	0.009
Tributary 2 in Reach 1	2.85	1.73	0.049	0.07	0.002
Tributary 3 in Reach 1	1.25	0.76	0.021	0.03	0.001
Tributary 4 in Reach 1	1.62	0.98	0.028	0.04	0.001
Tributary 5 in Reach 1	1.29	0.78	0.022	0.03	0.001
Tributary 6 in Reach 1	1.18	0.72	0.020	0.03	0.001
Tributary 7 in Reach 1	2.46	1.49	0.042	0.06	0.002
Reach 1 incremental inflow	10.64	6.45	0.183	0.26	0.007
Harrington Beaverdam Ditch, a tributary in Reach 2	22.00	13.33	0.377	0.54	0.015
Tributary 8 in Reach 2	4.17	2.53	0.072	0.10	0.003
Tributary 9 in Reach 2	2.65	1.61	0.045	0.07	0.002
Coolspring Branch, a tributary in Reach 2	6.73	4.07	0.115	0.17	0.005
Reach 2 incremental inflow	5.10	3.09	0.088	0.13	0.004
Culbreth Marsh Ditch Headwater	10.30	6.24	0.177	0.25	0.007
Beachy Neidig Ditch, a tributary in Reach 3	5.47	3.31	0.094	0.13	0.004
Luther Marvel Prong, a tributary in Reach 3	4.27	2.58	0.073	0.11	0.003
Tributary 10 in Reach 3	5.95	3.61	0.102	0.15	0.004
Reach 3 incremental inflow	6.26	3.79	0.107	0.15	0.004
Tributary 11 in Reach 4	4.12	2.49	0.071	0.10	0.003
Tributary 12 in Reach 4	2.11	1.28	0.036	0.05	0.001
Tributary 13 in Reach 4	1.54	0.93	0.026	0.04	0.001
Reach 4 incremental inflow	6.81	4.13	0.117	0.17	0.005
Tributary 14 in Reach 5	5.24	3.18	0.090	0.13	0.004
Reach 5 incremental inflow	1.28	0.78	0.022	0.03	0.001
Reach 6 incremental inflow	3.43	2.08	0.059	0.09	0.002
Cow Marsh Creek Headwater	30.05	18.20	0.515	0.74	0.021
Fivefoot Prong, a tributary in Reach 7	2.40	1.46	0.041	0.06	0.002
Tributary 15 in Reach 7	0.98	0.59	0.017	0.02	0.001
Iron Mine Prong, a tributary in Reach 7	15.98	9.68	0.274	0.39	0.011
Tributary 16 in Reach 7	1.10	0.67	0.019	0.03	0.001
Reach 7 incremental inflow	9.64	5.84	0.165	0.24	0.007
Jackson Prong, a tributary in Reach 8	2.11	1.28	0.036	0.05	0.001
Meredith Branch, a tributary in Reach 8	23.52	14.25	0.403	0.58	0.016
Tributary 17 in Reach 8	3.50	2.12	0.060	0.09	0.002
Reach 8 incremental inflow	5.90	3.58	0.101	0.15	0.004
Sandtown Branch, a tributary in Reach 9	9.06	5.49	0.155	0.22	0.006
Reach 9 incremental inflow	6.91	4.19	0.119	0.17	0.005
Choptank River Watershed (total)	258.09	156.33	4.427	6.36	0.180

System Parameters

The same global constants used in the Chester River Qual2E Models were utilized in the Choptank River Qual2E Model (see Table 2-5 on page 40). The reach variable coefficients used in the Choptank River Qual2E Model are listed in Table 2-14. For more discussion on the use of these variables, please see the section starting on page 40 above on the Chester River Qual2E models and the Qual2E user's manual.

Table 2-14 Reach Varied Coefficients of the Choptank River Qual2E Model

Parameter	Description	Unit	Range
α_0	Ratio of chlorophyll-a to algal biomass	µg Chl-a / mg A	75.00
λ_0	Non-algal light extinction coefficient	1/m	0.00
σ_1	Algal settling rate	m/day	0.00-0.50
σ_2	Benthos source rate for dissolved phosphorus	mg-P /m^2-day	0.00
σ_3	Benthos source rate for ammonia nitrogen	mg-N /m^2-day	0.00
σ_4	Organic nitrogen settling rate	day-1	0.00-0.05
σ_5	Organic phosphorus settling rate	day-1	0.00-0.05
K_1	Carbonaceous deoxygeneration rate constant	day-1	0.00-0.20
K_2	Reaeration rate constant	day-1	calculated internally (option 5)
K_3	Rate of loss of BOD due to settling	day-1	0.00
K_4	Benthic oxygen uptake (SOD)	g-O / m^2-day	0.50
β_1	Rate constant for the biological oxidation of NH_3 to NO_2	day-1	0.00-1.00
β_2	Rate constant for the biological oxidation of NO_2 to NO_3	day-1	0.00-2.00
β_3	Rate constant for the hydrolysis of organic-N to ammonia	day-1	0.00-0.40
β_4	Rate constant for the decay of organic-P to dissolved-P	day-1	0.00-0.70

Boundary Conditions

The Choptank River Qual2E Model consists of three headwater regions. The headwater conditions were defined by the monitoring data collected at stations 207121 (Tappahanna Ditch), 207151 (Culbreth Marsh Ditch), and 207191 (Cow Marsh Creek). For several model input parameters, the data from the above three stations were averaged, while for others, the individual headwater data better represented the downstream conditions. The same inputs were used to define the tributary conditions of the respective stream branches of the Choptank River Qual2E Model.

The model was calibrated for average conditions using average concentrations between 2001 – 2003 with average flows. The average summer concentrations with 7Q10 flows were used to calibrate the model for the critical conditions. The downstream boundary conditions were calculated for the Choptank River Qual2E Model.

Incremental Inflow Conditions

The incremental inflow concentrations used in the Choptank River Qual2E Model were calculated using the same approach applied to the Chester River Qual2E Models described on page 42 above. The surface runoff concentrations in Table 2-8 were used with the 2002 land use and land cover data for the Choptank River Watershed to calculate reach-wide incremental inflow concentrations. The nitrite and nitrate concentrations were found to be much less than actual monitoring data at several downstream stations. Those parameters were doubled to further correct for the land use estimated concentrations in Reaches 2, 4, 5, 6, 8, and 9. The results are presented in Table 2-15.

Table 2-15 Incremental Inflow Concentrations for Choptank River Qual2E Model

Concentration of Incremental Inflow	NH3-N	NO3-N	Dis-P	Chlor-a	BOD5	DO	Org-N	Org-P
	mg/l	mg/l	mg/l	ug/l	mg/l	mg/l	mg/l	mg/l
Reach 1	0.280	1.393	0.047	0.000	4.517	5.119	1.461	0.058
Reach 2	0.237	2.251	0.041	0.000	4.048	5.185	1.344	0.052
Reach 3	0.232	1.180	0.040	0.000	3.825	4.870	1.161	0.047
Reach 4	0.282	2.900	0.049	0.000	4.344	4.985	1.378	0.056
Reach 5	0.202	1.738	0.046	0.000	3.110	5.430	1.332	0.054
Reach 6	0.190	1.863	0.037	0.000	3.134	5.075	1.023	0.042
Reach 7	0.267	1.355	0.044	0.000	4.299	4.907	1.335	0.053
Reach 8	0.293	2.984	0.051	0.000	4.478	5.026	1.460	0.059
Reach 9	0.186	1.686	0.038	0.000	3.025	5.343	1.149	0.045

Unanalyzed Constituents

The concentration of organic nitrogen, nitrite nitrogen, nitrate nitrogen, and organic phosphorous, all unmeasured constituents, were estimated using the same relationships outlined on page 44 on the Chester River Qual2E Models.

Input data for the Choptank River Qual2E Model calibration is presented in Appendix D.

Marshyhope Creek Qual2E Model Input Data

The major input data groups for the Marshyhope Creek Qual2E Model are summarized below.

Model Segmentation

The Marshyhope Creek Qual2E model consists of four model reaches starting from its headwater to just below the state line and covers 22 km. Figure 2-4 displays these reaches on the watershed map. Each reach is further divided into computational elements with a length of 1.0 km. A summary of reach lengths and the number of computational elements is presented in Table 2-16.

Table 2-16 Marshyhope Creek Qual2E Model Reaches

Reach Number	Description	Reach Length (km)	Number of Computational Elements
1	Most upstream reach, from headwater above Brownsville Road; two tributaries (Beaverdam Branch and Prospect Branch)	6	6
2	Upper channelized reach; three tributaries (Tributary 1, Tomahawk Branch, and Green Branch)	5	5
3	Lower channelized reach; eight tributaries (Saulsbury Creek; Quarter Branch, Tributary 2, Short and Hall Ditch, Double Fork Branch, Tributary 3, Tributary 4, Stafford Ditch)	5	5
4	Most downstream reach from Route 404 to just past the state line; five tributaries (Tributary 5, Iron Mine Branch, Jones Mill Branch, Tributary 6, Jones Branch)	6	6
Total		22	22

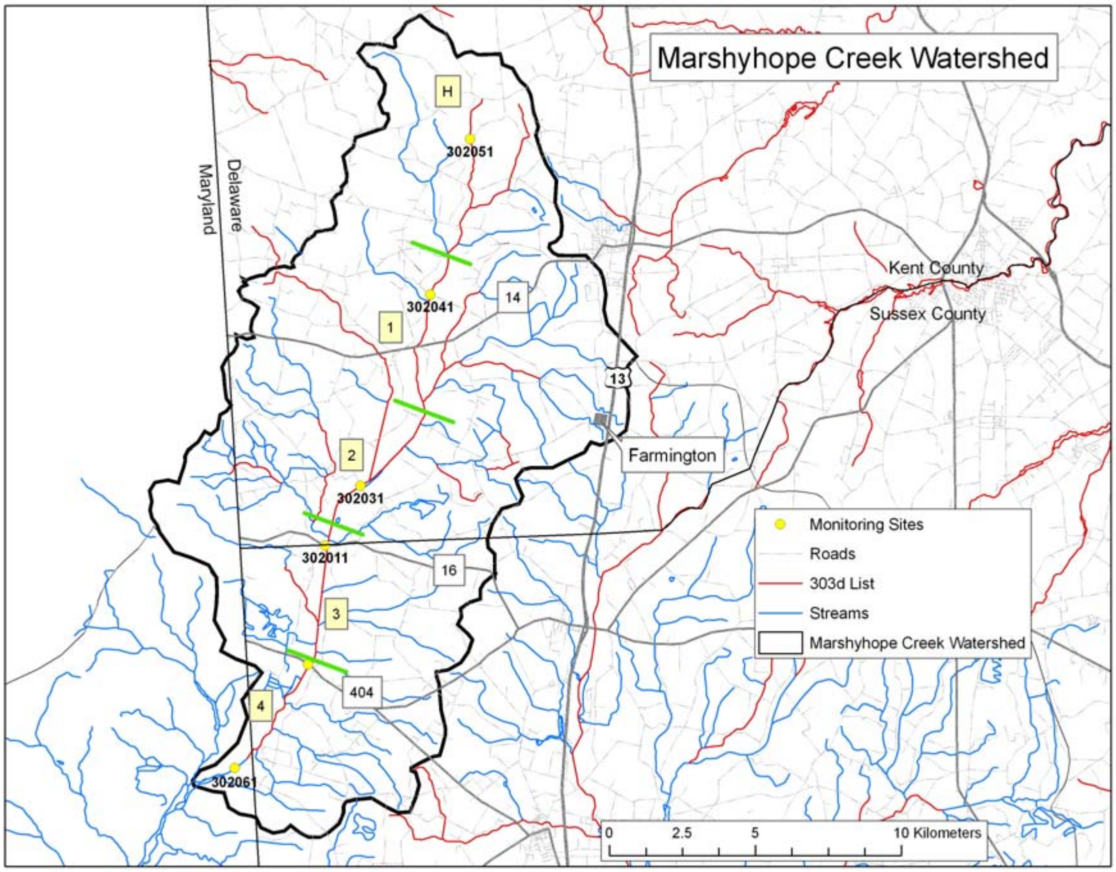

Figure 2-4 Reaches of Marshyhope Creek Qual2E Model

<u>Hydraulic Characteristics</u>

The average width, depth, and velocity for each site were calculated from the 2001-2003 field measurements and the results are presented in Table 2–17. The Marshyhope Creek field measurements were used to estimate discharge coefficient constants, which are summarized in Table 2-18. For further explanation on the calculation of these parameters, refer to the section on the Chester River Qual2E Models above on page 35.

Table 2-17 Average Channel Width, Depth, and Velocity of Marshyhope Creek

Station (from upstream down)	Stream Segment	Average Width (m)	Average Depth (m)	Average Velocity (m/s)
302051	Headwater	2.67	0.17	0.25
302041	Reach 1-most upstream reach	3.85	0.44	0.29
302031	Reach 2-upper channelized reach	10.5	0.45	0.31
302011*	Reach 3-lower channelized reach	13.7	0.61	0.34
302021*	Reach 4-most downstream reach	14.6	0.65	0.38

*Data is from field reconnaissance in November 2004.

Table 2-18 Discharge Coefficient Constants for Marshyhope Creek Qual2E Model Reaches

<table>
<tr><th rowspan="2">Reach</th><th rowspan="2">Stream Segment Name</th><th rowspan="2">Station</th><th>Mean Velocity (m/s)</th><th>Depth (m)</th></tr>
<tr><th>u = a Q ^b</th><th>d = α Q ^β</th></tr>
<tr><td>1</td><td>Most upstream reach</td><td rowspan="4">302041
302031
302011
302021</td><td rowspan="4">u = 0.2818 Q ^ 0.1952</td><td rowspan="4">d = 0.5490 Q ^ 0.1054</td></tr>
<tr><td>2</td><td>Upper reach</td></tr>
<tr><td>3</td><td>Lower reach</td></tr>
<tr><td>4</td><td>Most downstream reach</td></tr>
</table>

Stream Flows

The USGS gauging station at the Marshyhope Creek monitoring station 302031 was used for a discharge record in this watershed. Refer to the section starting on page 37 on the Chester River Qual2E models for more discussion on the use of this record and the process used to calculate annual average and 7Q10 stream flows. Table 2-19 lists Marshyhope Creek's sub-watershed drainage areas as well as the estimated annual average and 7Q10 flows.

Table 2-19 Annual Average and Summer Low Flows of Marshyhope Creek

Description of Drainage Area	Drainage Area	Annual average flow (10/2000-9/2003)		7Q10 Flow	
	km^2	ft^3/s	m^3/s	ft^3/s	m^3/s
Headwater	39.31	23.81	0.674	0.97	0.027
Beaverdam Branch, a tributary in Reach 1	6.81	4.12	0.117	0.17	0.005
Prospect Branch, a tributary in Reach 1	38.34	23.22	0.658	0.94	0.027
Reach 1 incremental inflow	8.88	5.38	0.152	0.22	0.006
Tributary 1 in Reach 2	1.37	0.83	0.023	0.03	0.001
Tomahawk Branch, a tributary in Reach 2	6.79	4.11	0.116	0.17	0.005
Green Branch, a tributary in Reach 2	18.99	11.50	0.326	0.47	0.013
Reach 2 incremental inflow	6.39	3.87	0.110	0.16	0.004
Saulsbury Creek, a tributary in Reach 3	27.93	16.92	0.479	0.69	0.019
Quarter Branch, a tributary in Reach 3	11.56	7.00	0.198	0.28	0.008
Tributary 2 in Reach 3	1.14	0.69	0.020	0.03	0.001
Short and Hall Ditch, a tributary in Reach 3	10.85	6.57	0.186	0.27	0.008
Double Fork Branch, a tributary in Reach 3	12.17	7.37	0.209	0.30	0.008
Tributary 3 in Reach 3	2.55	1.54	0.044	0.06	0.002
Tributary 4 in Reach 3	7.45	4.51	0.128	0.18	0.005
Stafford Ditch, a tributary in Reach 3	4.16	2.52	0.071	0.10	0.003
Reach 3 incremental inflow	5.71	3.46	0.098	0.14	0.004
Tributary 5 in Reach 4	0.89	0.54	0.015	0.02	0.001
Iron Mine Branch, a tributary in Reach 4	7.62	462	0.131	0.19	0.005
Jones Mill Branch, a tributary in Reach 4	6.79	4.11	0.116	0.17	0.005
Tributary 6 in Reach 4	2.93	1.78	0.050	0.07	0.002
Jones Branch, a tributary in Reach 4	4.65	2.82	0.080	0.11	0.003
Reach 4 incremental inflow	5.97	3.62	0.102	0.15	0.004
Marshyhope Creek Watershed (total)	239.25	144.92	4.104	5.89	0.167

System Parameters

The same global constants used in the Chester River Qual2E Models were utilized in the Marshyhope Creek Qual2E Model (see Table 2-5 on page 40). The reach variable coefficients used in the Marshyhope Creek Qual2E Model are listed in Table 2-20. For more discussion on the use of these variables, please see the section starting on page 40 above on the Chester River Qual2E Models and the Qual2E user's manual.

Table 2-20 Reach Varied Coefficients of the Marshyhope Creek Qual2E Model

Parameter	Description	Unit	Range
α_0	Ratio of chlorophyll-a to algal biomass	µg Chl-a / mg A	75.00
λ_0	Non-algal light extinction coefficient	1/m	0.00
σ_1	Algal settling rate	m/day	0.38
σ_2	Benthos source rate for dissolved phosphorus	mg-P /m^2-day	0.00
σ_3	Benthos source rate for ammonia nitrogen	mg-N /m^2-day	0.00
σ_4	Organic nitrogen settling rate	day-1	0.05
σ_5	Organic phosphorus settling rate	day-1	0.05
K_1	Carbonaceous deoxygeneration rate constant	day-1	0.20
K_2	Reaeration rate constant	day-1	calculated internally (option 5)
K_3	Rate of loss of BOD due to settling	day-1	0.00
K_4	Benthic oxygen uptake (SOD)	g-O / m^2-day	0.00
β_1	Rate constant for the biological oxidation of NH_3 to NO_2	day-1	0.10
β_2	Rate constant for the biological oxidation of NO_2 to NO_3	day-1	0.20
β_3	Rate constant for the hydrolysis of organic-N to ammonia	day-1	0.04
β_4	Rate constant for the decay of organic-P to dissolved-P	day-1	0.07

Boundary Conditions

The headwater conditions of the Marshyhope Creek Qual2E Model were defined by monitoring data collected at station 302051 (on Marshyhope Ditch). At this station, the nitrite/nitrate concentrations were much lower than those observed at the downstream locations, while the organic phosphorus concentrations were more than twice those observed at the downstream stations. In order to better calibrate the model, a neighboring station in the lower Choptank River Watershed (207111), which had nitrite/nitrate and organic phosphorus concentrations similar to those found at the downstream Marshyhope Creek stations, was used to define the tributary conditions of the Marshyhope Creek Qual2E Model.

The model was calibrated for average conditions using average concentrations between 2001 – 2003 with average flows. The average summer concentrations with 7Q10 flows were used to calibrate the model for the critical conditions. The downstream boundary conditions were calculated for the Marshyhope Creek Qual2E Model.

Incremental Inflow Conditions

The incremental inflow concentrations used in the Marshyhope Creek Qual2E Model were calculated using the same approach applied to the Chester River Qual2E Models described on page 42 above. The surface runoff concentrations in Table 2-8 were used with the 2002 land use and land cover data for the Marshyhope Creek Watershed to calculate reach-wide incremental inflow concentrations. The results are presented in Table 2-21.

Table 2-21 Incremental Inflow Concentrations for Marshyhope Creek Qual2E Model

Concentration of Incremental Inflow	NH3-N mg/l	NO3-N mg/l	Dis-P mg/l	Chlor-a ug/l	BOD5 mg/l	DO mg/l	Org-N mg/l	Org-P mg/l
Reach 1	0.328	1.714	0.055	0.000	4.909	4.916	1.544	0.063
Reach 2	0.270	1.363	0.049	0.000	4.033	5.127	1.365	0.055
Reach 3	0.219	1.052	0.041	0.000	3.510	5.146	1.215	0.048
Reach 4	0.197	0.940	0.037	0.000	3.298	5.109	1.121	0.044

Unanalyzed Constituents

The concentration of organic nitrogen, nitrite nitrogen, nitrate nitrogen, and organic phosphorous, all unmeasured constituents, were estimated using the same relationships outlined on page 44 above on the Chester River Qual2E Models.

Input data for the Marshyhope Creek Qual2E Model calibration is presented in Appendix E.

3.0 MODEL CALIBRATIONS AND SCENARIO ANALYSES

Chester River Qual2E Models

Model Calibration / Annual Average Baseline Condition

The Cypress Branch, Sewell Branch, and Gravelly Run Qual2E Models were calibrated to reproduce average water quality conditions observed during 2001-2003. Average annual flows and water quality concentrations were used in the models calibration. The input and output data for the Cypress Branch Qual2E Model calibration is presented in Appendix A, while the Sewell Branch and Gravelly Run Qual2E Model calibrations can be found in Appendix B and C, respectively.

Figure 3-1(a-c) displays the model calibration results for several water quality constituents including nutrient species, dissolved oxygen, biochemical oxygen demand, phytoplankton chlorophyll-*a*, and water temperature under average conditions during 2001-2003. Model calibration results are presented as lines while observed data at the monitoring sites (112581 and 112011) are shown as symbols with mean, maximum, and minimum values. These stations are 112581 and 112011 in Cypress Branch, 112591 and 112021 in Sewell Branch, and 112621, 112611, and 112031 in Gravelly Run. The most upstream point in each graph represents the water quality conditions of the headwater/tributaries. The average values from station 112581 were used as headwater/tributary inputs in Cypress Branch, and the average values of stations 112591, 112601, 112621 and 112631 were used in Sewell Branch and Gravelly Run.

The calibration results show that dissolved oxygen and temperature predictions are very close to the average observed values and that nitrogen, phosphorus, and chlorophyll-*a* have been reproduced reasonably well. The calibrated models for the average conditions during 2001 – 2003 constitute the baseline conditions for Cypress Branch, Sewell Branch, and Gravelly Run.

In Figures 3-1(a-c) the State of Delaware standard for dissolved oxygen (5.5 mg/l) and target nutrient values (3.0 mg/l for total nitrogen and 0.2 mg/l for total phosphorus) are shown as dashed green lines. These figures show that dissolved oxygen levels do not meet the standard in the upper portion of Cypress Branch, but are achieved in both Sewell Branch and Gravelly Run under average conditions. The State of Maryland dissolved oxygen standard of 5.0 mg/l is achieved at the outlet of each modeled tributary as well under these baseline conditions. Under average conditions, the total nitrogen target is achieved in all three tributaries, while the total phosphorus target is only slightly exceeded in Sewell Branch.

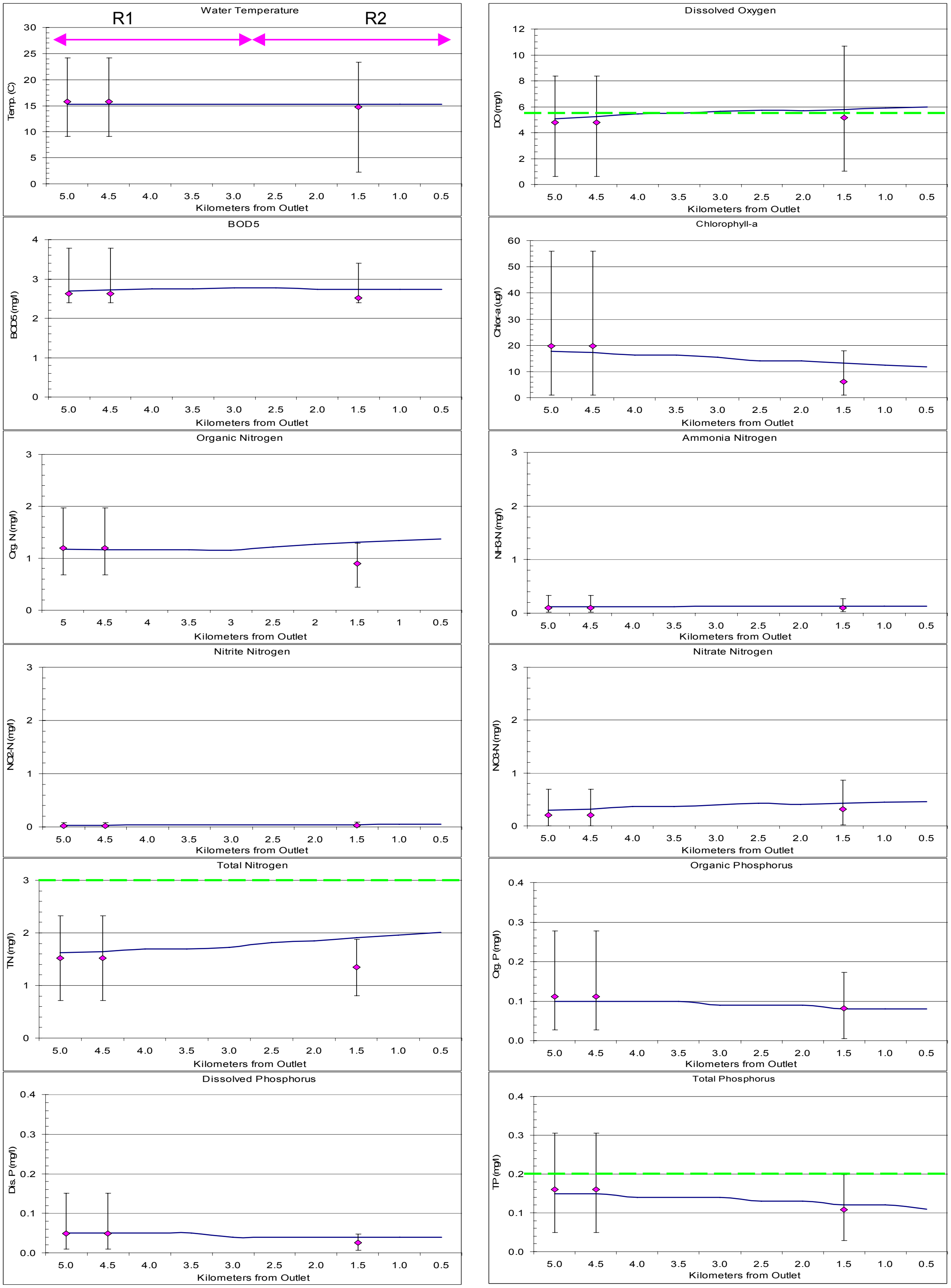

Figure 3-1a Calibration Results of Temperature, DO, BOD5, Chlor-a, Org-N, NH3-N, NO2-N, NO3-N, TN, Org-P, Dis-P, and TP in Cypress Branch

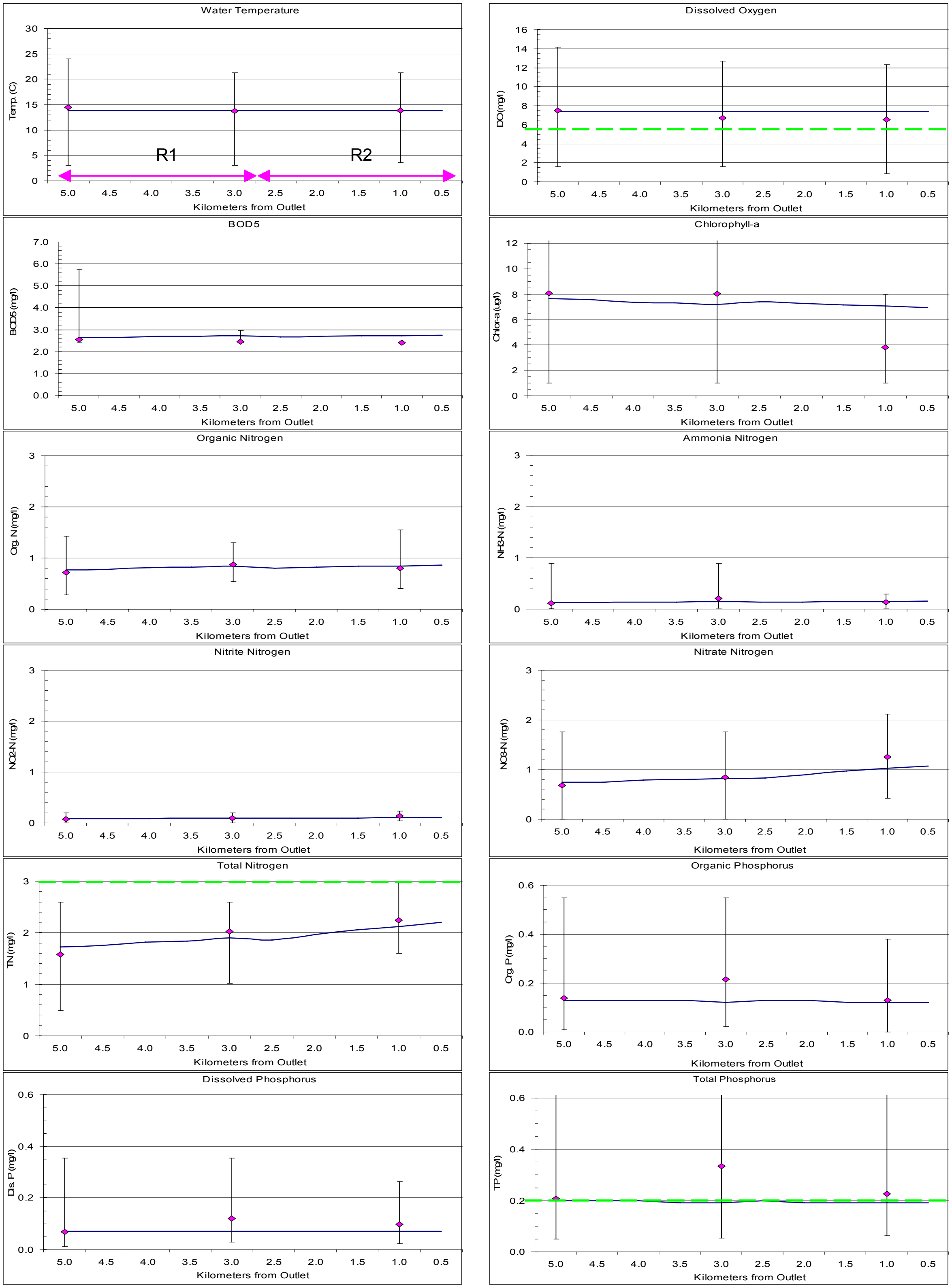

Figure 3-1b Calibration Results of Temperature, DO, BOD5, Chlor-a, Org-N, NH3-N, NO2-N, NO3-N, TN, Org-P, Dis-P, and TP in Sewell Branch

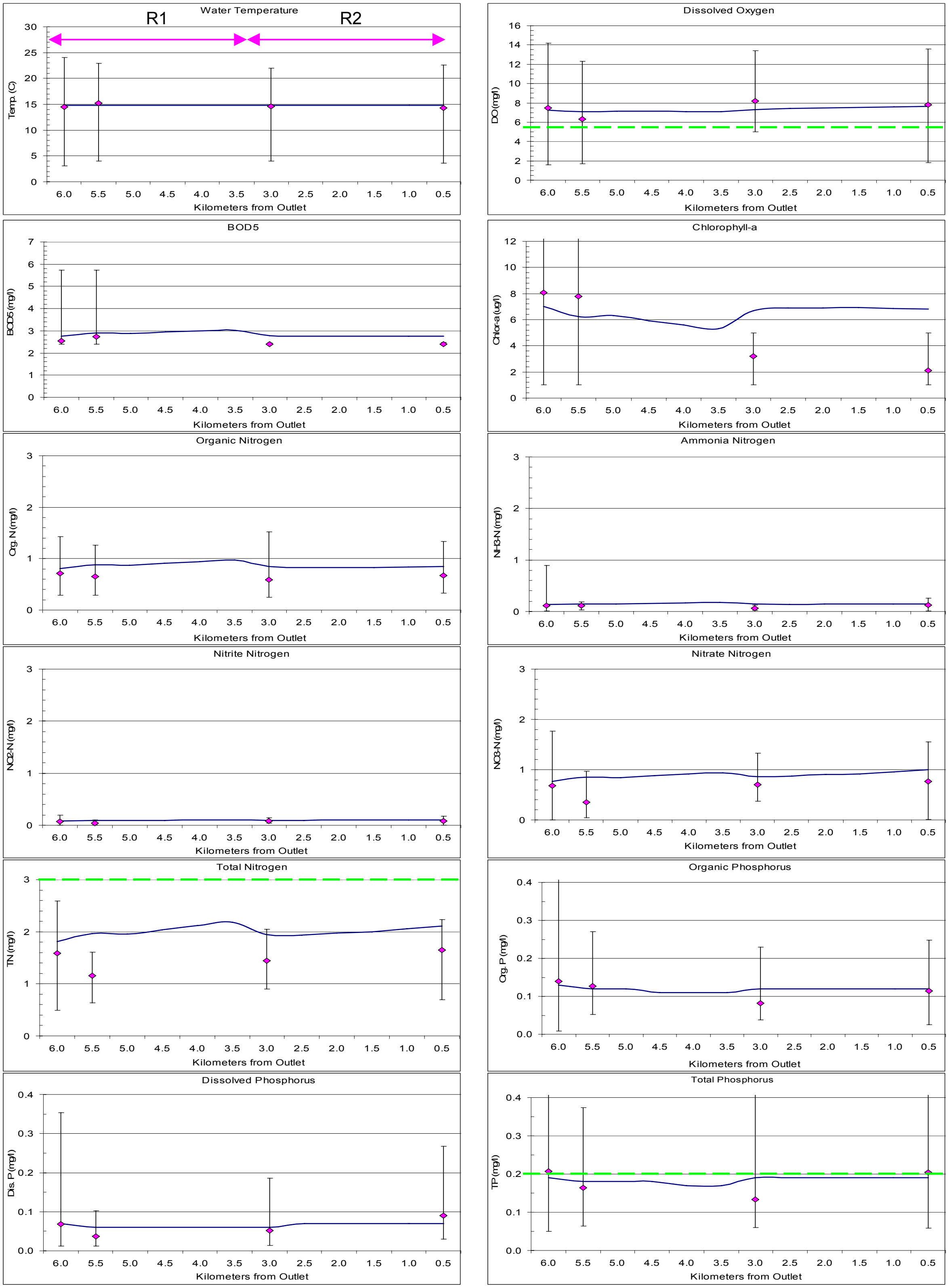

Figure 3-1c Calibration Results of Temperature, DO, BOD5, Chlor-a, Org-N, NH3-N, NO2-N, NO3-N, TN, Org-P, Dis-P, and TP in Gravelly Run

Load Reductions on the Annual Average Baseline

The nonpoint source loads are considered implicitly in the Qual2E model. They are used in the model through user-defined boundary conditions including headwater conditions, tributary inflow conditions, and incremental inflow conditions. Water quality concentrations used to define these boundary conditions for the Chester River Qual2E Models were discussed in Chapter 2 of this report.

Several load reduction scenarios, in which pollutant loads were reduced from the entire watershed, were conducted and are summarized in Tables 3-1(a-c). The mimimum dissolved oxygen concentration and maximum total nitrogen and total phosphorus concentrations observed in the modeled segments of the stream are presented for each reduction scenario under both annual average (AA) and critical conditions (CC). Cells within the table are colored green if the concentration meets the dissolved oxygen standard or nutrient target, where as if the standard or target is not met, the cell is colored orange. In the scenario that was ultimately chosen (bold font in Tables 3-1(a-c)), nitrogen concentrations were not reduced since nitrogen concentrations were less than the target of 3.0 mg/l at all times of the year. Phosphorus concentrations, which did exceed the 0.2 mg/l target during summer months (see Figure 3-3(a-c)), were reduced at a rate of 40%. Biochemical oxygen demand concentrations and sediment oxygen demand rates were also reduced by 40%. It was also assumed that these reductions will allow for the dissolved oxygen concentration of the incremental inflow waters and headwaters to meet the 5.5 mg/l standard. The results are presented in Figure 3-2(a-c) as a red line. It is apparent that this scenario could result in dissolved oxygen concentrations above the State of Delaware's 5.5 mg/l standard and produce concentrations above the State of Maryland's standard of 5.0 mg/l at the state line.

Table 3-1a Results of Load Reduction Scenarios in Cypress Branch under Annual Average (AA) and Critical Conditions (CC)

TN %	TP%		Minimum DO (mg/l)	Maximum TN (mg/l)	Maximum TP (mg/l)
Cypress Branch Baseline		AA	5.09	2.01	0.15
		CC	2.12	2.43	0.27
0%	25%	AA	5.78	2.01	0.11
		CC	5.34	2.43	0.20
25%	25%	AA	5.78	1.29	0.11
		CC	5.34	1.74	0.20
0%	**40%**	**AA**	**5.79**	**2.01**	**0.09**
		CC	**5.52**	**2.43**	**0.16**
20%	40%	AA	5.79	1.38	0.09
		CC	5.52	1.85	0.16
47%	44%	AA	5.79	0.92	0.09
		CC	5.56	1.23	0.15

Table 3-1b Results of Load Reduction Scenarios in Sewell Branch under Annual Average (AA) and Critical Conditions (CC)

TN %	TP%		Minimum DO (mg/l)	Maximum TN (mg/l)	Maximum TP (mg/l)
Sewell Branch Baseline		AA	7.36	2.20	0.20
		CC	4.75	2.05	0.23
0%	15%	AA	7.44	2.20	0.17
		CC	5.19	2.05	0.19
15%	15%	AA	7.44	1.87	0.17
		CC	5.19	1.75	0.19
0%	**40%**	**AA**	**7.48**	**2.20**	**0.12**
		CC	**5.50**	**2.05**	**0.14**
20%	40%	AA	7.49	1.76	0.12
		CC	5.50	1.64	0.14
47%	44%	AA	7.49	1.17	0.11
		CC	5.53	1.09	0.13

Table 3-1c Results of Load Reduction Scenarios in Gravelly Run under Annual Average (AA) and Critical Conditions (CC)

TN %	TP%		Minimum DO (mg/l)	Maximum TN (mg/l)	Maximum TP (mg/l)
Gravelly Run Baseline		AA	7.11	2.18	0.19
		CC	4.78	2.05	0.22
0%	10%	AA	7.23	2.18	0.17
		CC	5.13	2.05	0.20
10%	10%	AA	7.23	1.96	0.17
		CC	5.13	1.85	0.20
0%	**40%**	**AA**	**7.29**	**2.18**	**0.12**
		CC	**5.50**	**2.05**	**0.13**
20%	40%	AA	7.29	1.75	0.12
		CC	5.50	1.64	0.13
47%	44%	AA	7.29	1.16	0.11
		CC	5.52	1.09	0.12

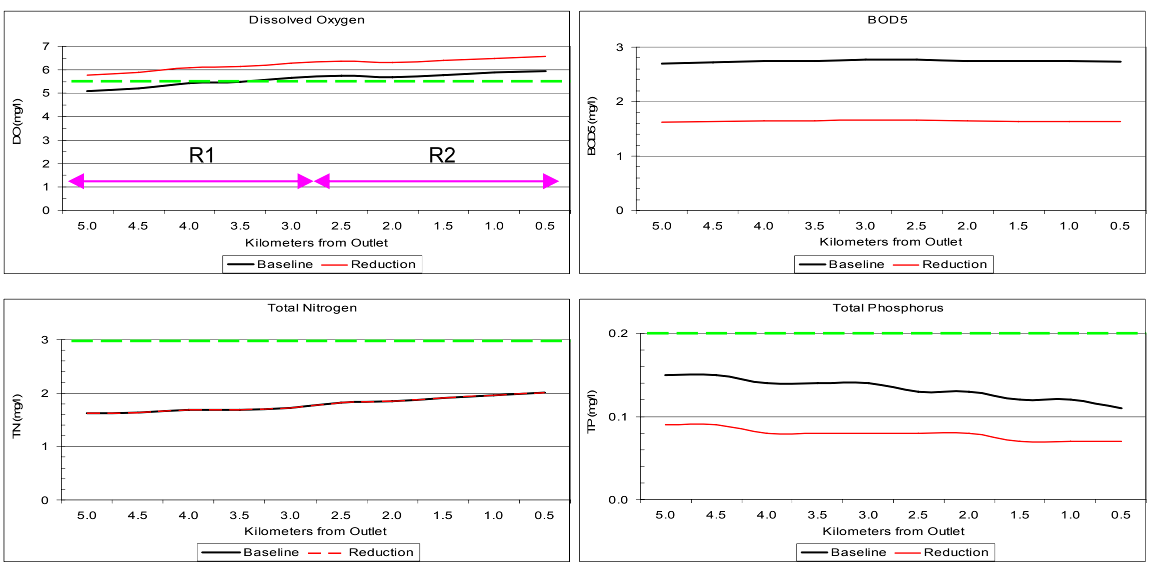

Figure 3-2a Results of Load Reductions on Baseline Scenario for DO, BOD5, TN, and TP in Cypress Branch

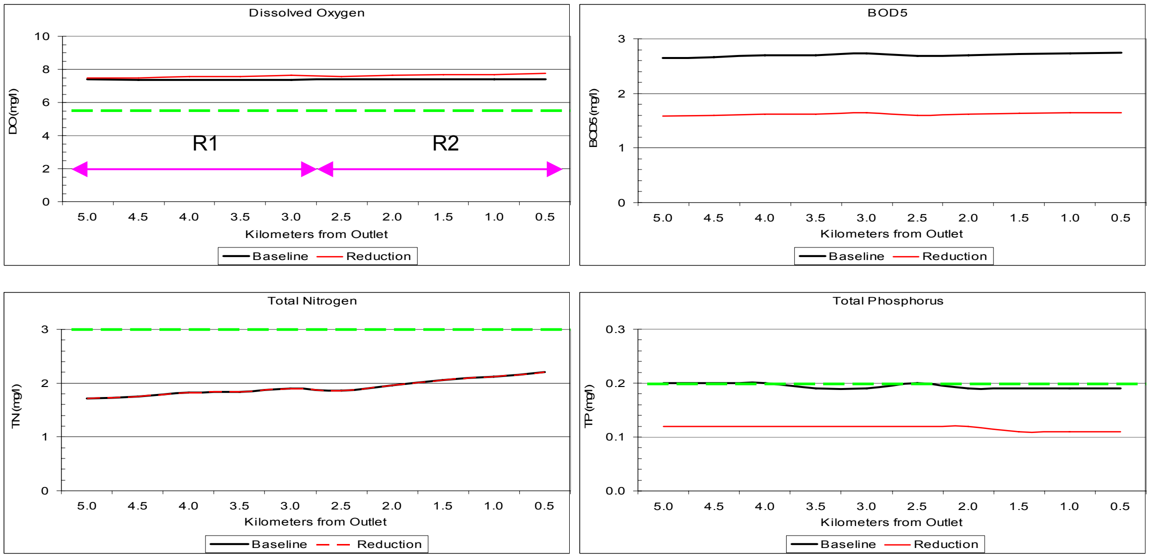

Figure 3-2b Results of Load Reductions on Baseline Scenario for DO, BOD5, TN, and TP in Sewell Branch

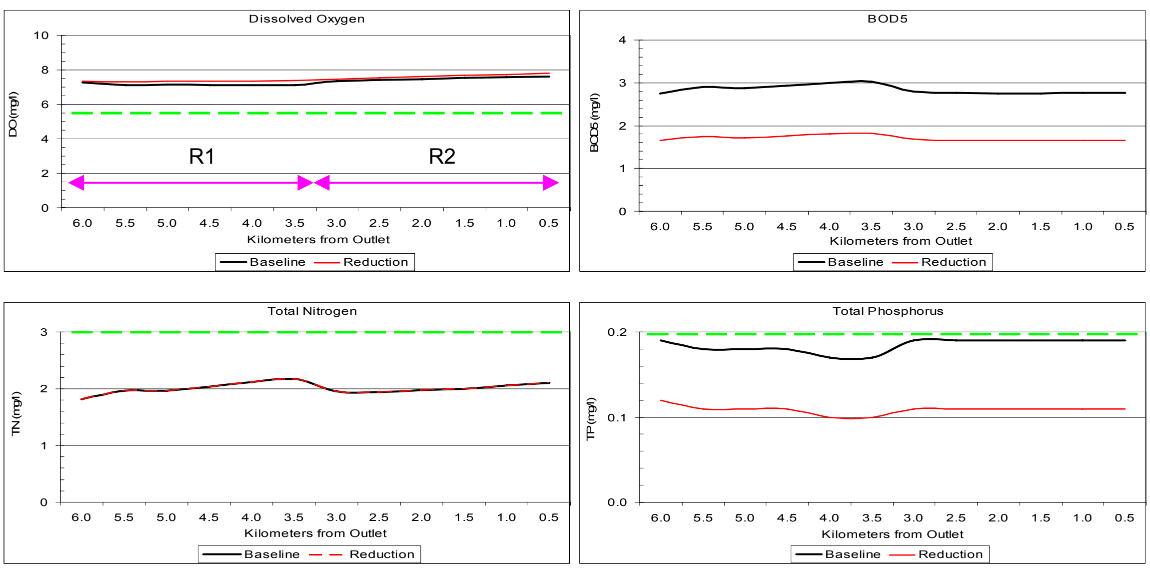

Figure 3-2c Results of Load Reductions on Baseline Scenario for DO, BOD5, TN, and TP in Gravelly Run

Baseline Critical Condition

Low flows coupled with warm temperatures are observed during the months of July, August, and September in Chester River. Monitoring data showed that violation of the dissolved oxygen standard happened more frequently during summer months than other months of the year. In addition, phosphorus concentrations were found to be greatest during the summer and exceeded the 0.2 mg/l target. The water quality conditions in the summer were simulated to form the critical baseline conditions during summer time (Tables 3-1(a-c)). Water quality data collected during July, August, and September were considered summer month samples and were averaged over the period of 2001-2003. The averaged summer concentrations were used to define the headwater conditions and tributary input conditions of the model. The average summer concentrations were coupled with the 7Q10 flows to simulate the summer critical condition. The results are presented in Figure 3-3(a-c) as a thick black line.

Load Reductions on the Baseline Critical Condition

The same load reduction rates previously discussed were applied to the summer condition (Tables 3-1(a-c)). The nitrogen concentrations were not adjusted since they were already less than the 3.0 mg/l target concentration. Phosphorus and biochemical oxygen demand concentrations at the headwater, tributary inflow, and incremental inflow were reduced at the rate of 40%, with 40% reductions of the SOD rate as well. Again, it was assumed that these reductions would allow for the dissolved oxygen concentration in the incremental inflow waters and headwaters to meet the 5.5 mg/l standard. The results of this analysis can be found in Figure 3-3(a-c) as red lines.

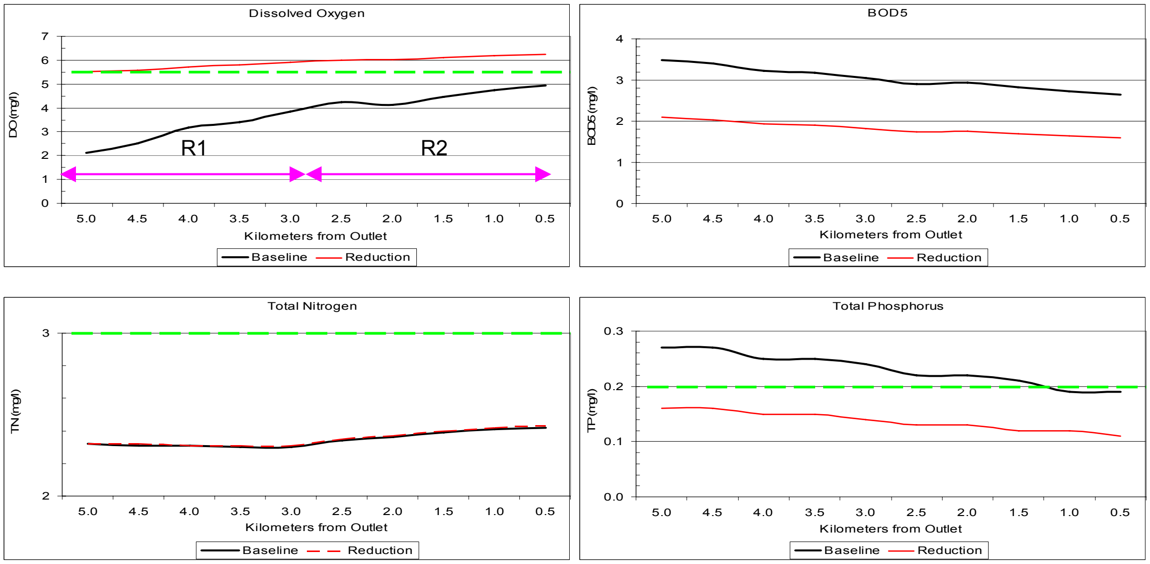

Figure 3-3a Results of Load Reductions on Critical Condition Scenario for DO, BOD5, TN, and TP in Cypress Branch

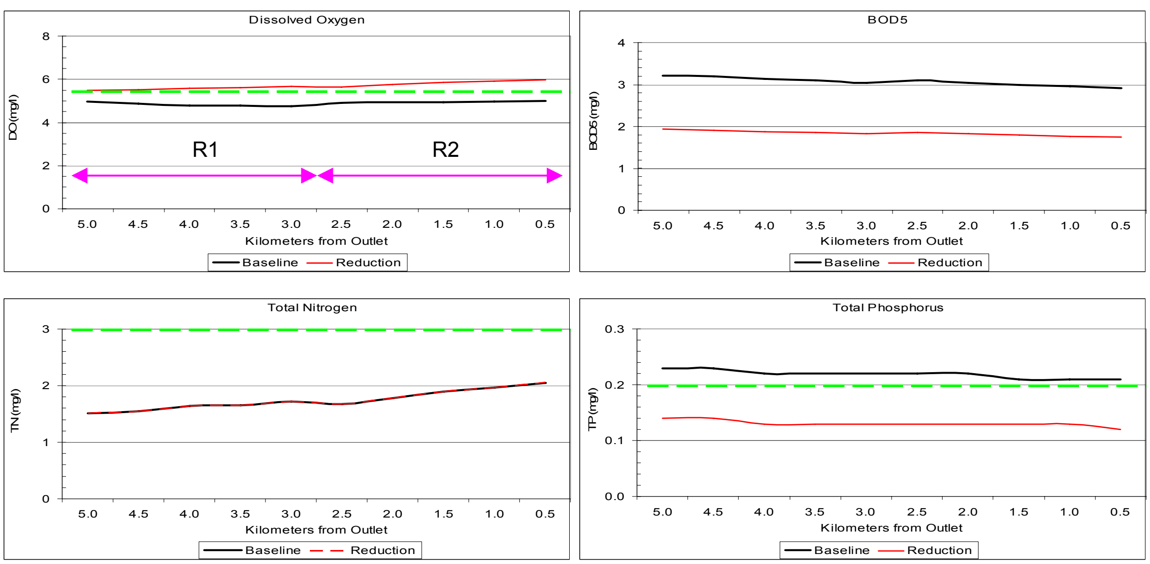

Figure 3-3b Results of Load Reductions on Critical Condition Scenario for DO, BOD5, TN, and TP in Sewell Branch

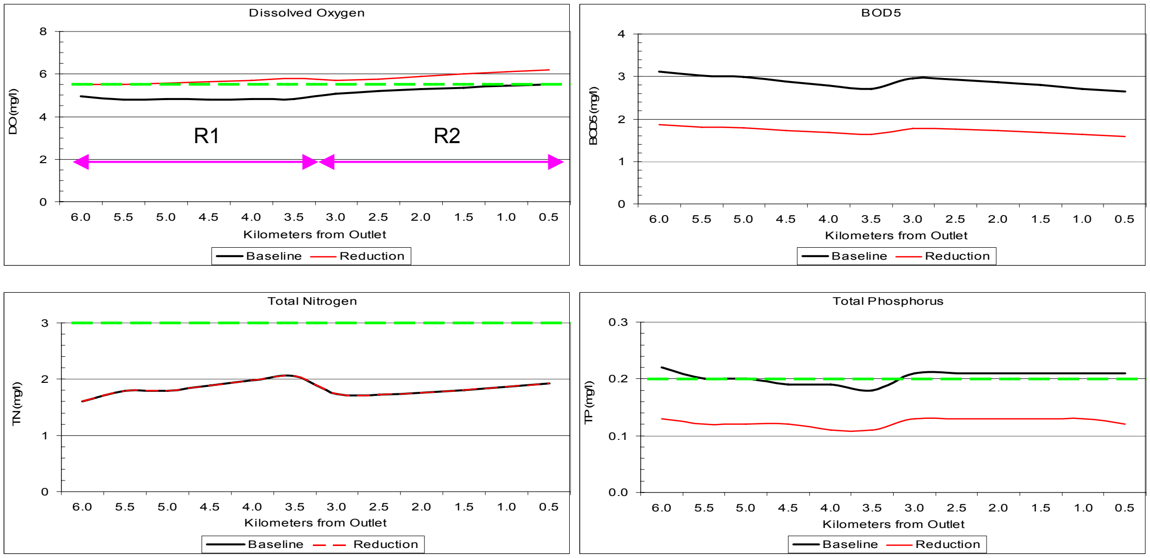

Figure 3-3c Results of Load Reductions on Critical Condition Scenario for DO, BOD5, TN, and TP in Gravelly Run

Choptank River Qual2E Model

Model Calibration / Annual Average Baseline Condition

The Choptank River Qual2E Model was calibrated to reproduce average water quality conditions observed during 2001-2003. Average annual flows and water quality concentrations were used in the models calibration. The input and output data for the Choptank River Qual2E Model calibration is presented in Appendix D.

Figure 3-4(a-c) displays the model calibration results for several water quality constituents including nutrient species, dissolved oxygen, biochemical oxygen demand, phytoplankton chlorophyll-*a*, and water temperature under average conditions during 2001-2003. Model calibration results are presented as lines while observed data at the monitoring sites (207121, 207131, 207081, 207171, 207161, and 207031 in the Tappahanna Ditch transect; 207151, 207141, 207091, 207161, and 207031 in the Culbreth Marsh Ditch transect; 207191, 207181, 207021, and 207031 in the Cow Marsh Creek transect) are shown as symbols with mean, maximum, and minimum values. The most upstream point in each graph represents the water quality conditions of the headwater/tributaries, in which the average values from stations 207021, 207151, and 207191 were used. Vertical dashed lines demark where stream junctions exist. For example, the dashed lines between kilometers seven and eight and between six and seven mark where Tappahanna Ditch and Culbreth Marsh Ditch enter Mud Millpond, while the line between kilometers four and five shows where Cow Marsh Creek joins the mainstem of the Choptank River. The transparent grey box represents Mud Millpond.

The calibration results show that dissolved oxygen and temperature predictions are very close to the average observed values and that nitrogen, phosphorous, and chlorophyll-*a* have been reproduced reasonably well. This calibrated model for average condition during 2001 – 2003 constitutes the baseline condition for Choptank River.

In Figures 3-4(a-c) the State of Delaware standard for dissolved oxygen (5.5 mg/l) and target nutrient values (3.0 mg/l for total nitrogen and 0.2 mg/l for total phosphorus) are shown as dashed green lines. These figures show that under average conditions, dissolved oxygen levels meet the standard of 5.5 mg/l at all reaches, except for the most upstream element of Reach 3 in Culbreth Marsh Ditch. The State of Maryland dissolved oxygen standard of 5.0 mg/l is achieved at the outlet of the model as well under these baseline conditions. The 3.0 mg/l total nitrogen target is achieved throughout the watershed, however, the 0.2 mg/l total phosphorus target is exceeded in Culbreth Marsh Ditch (Reach 3 and 4).

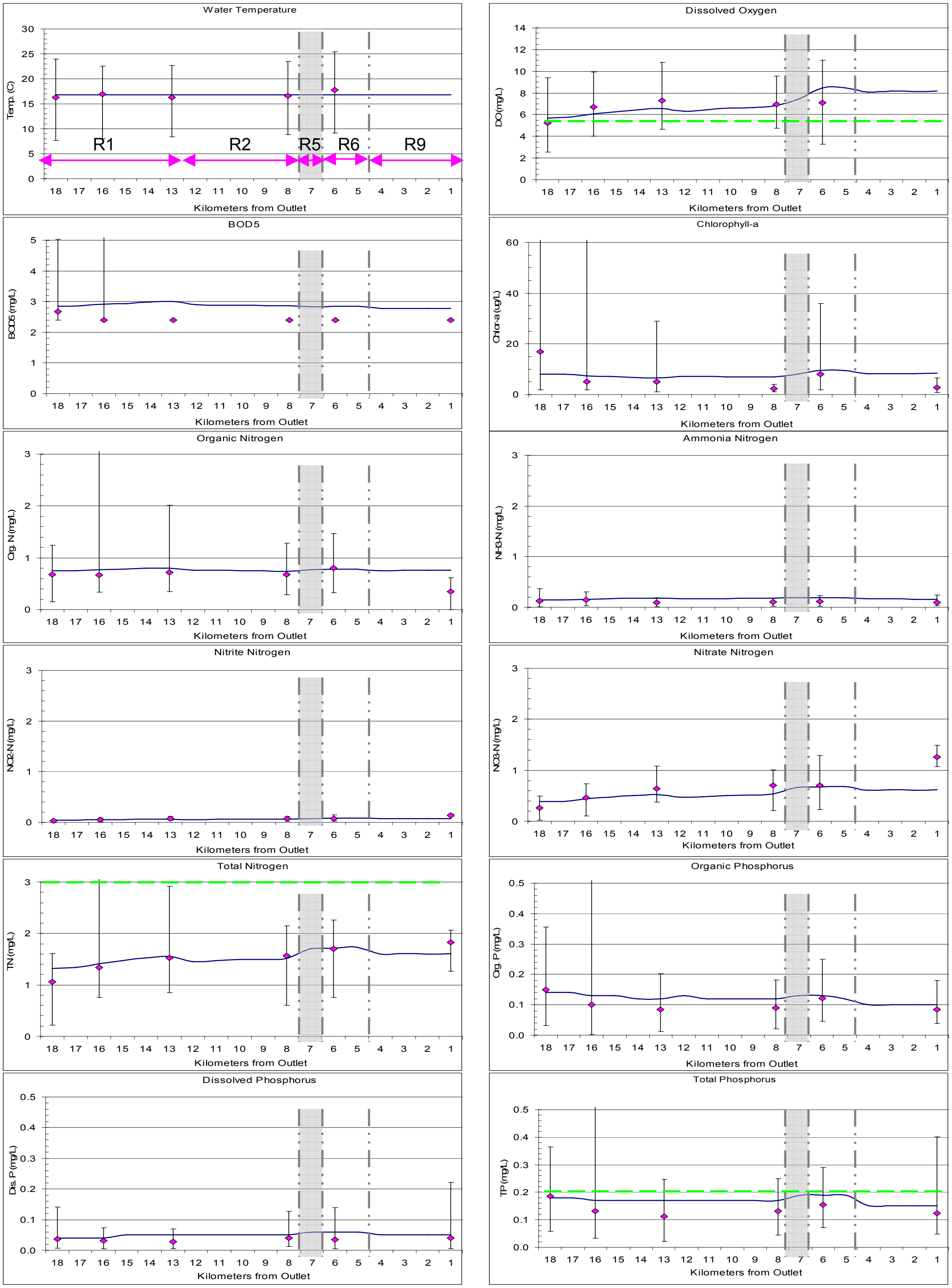

Figure 3-4a Calibration Results of Temperature, DO, BOD5, Chlor-a, Org-N, NH3-N, NO2-N, NO3-N, TN, Org-P, Dis-P, and TP in the Tappahanna Ditch Transect

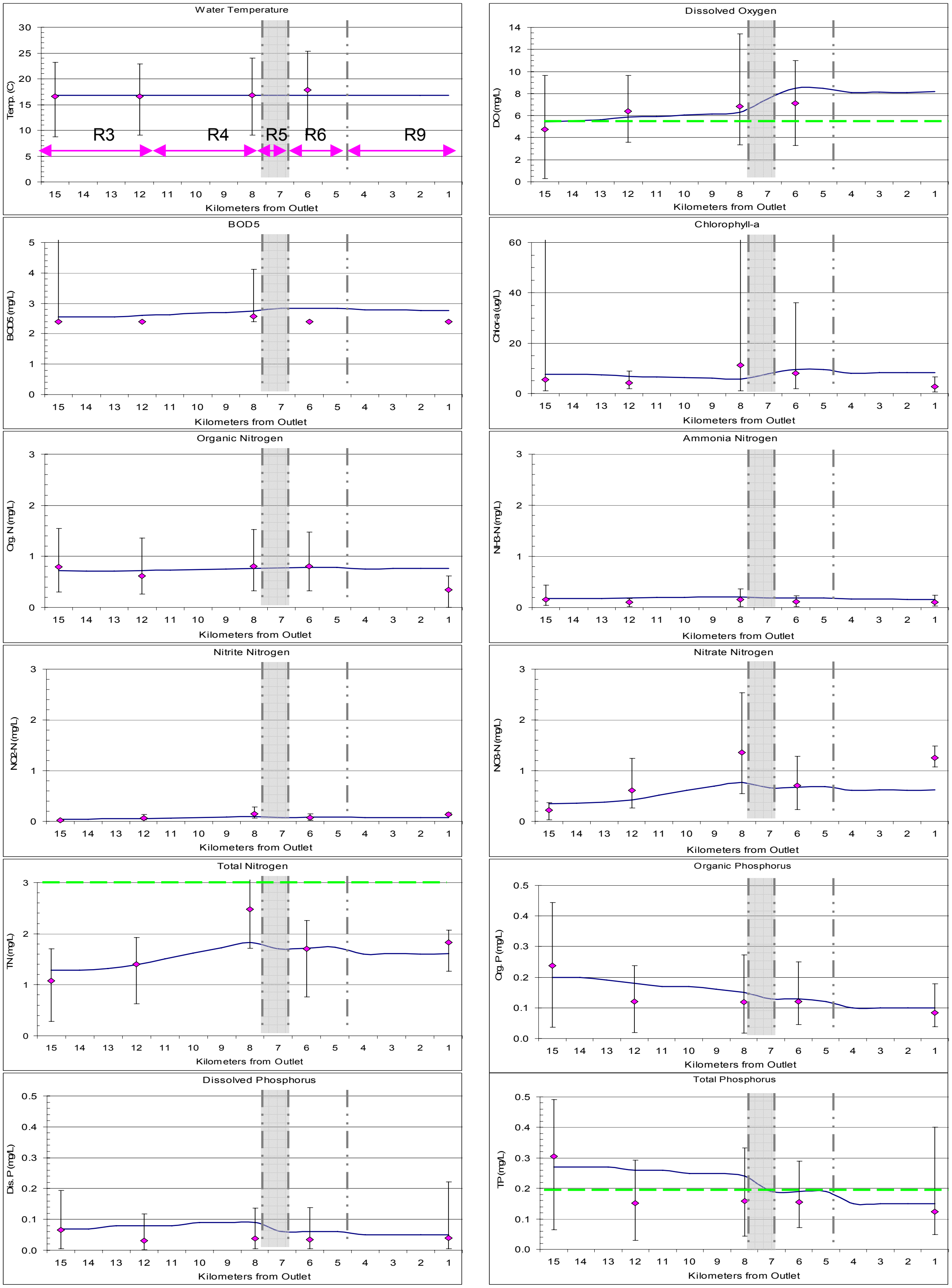

Figure 3-4b Calibration Results of Temperature, DO, BOD5, Chlor-a, Org-N, NH3-N, NO2-N, NO3-N, TN, Org-P, Dis-P, and TP in the Culbreth Marsh Ditch Transect

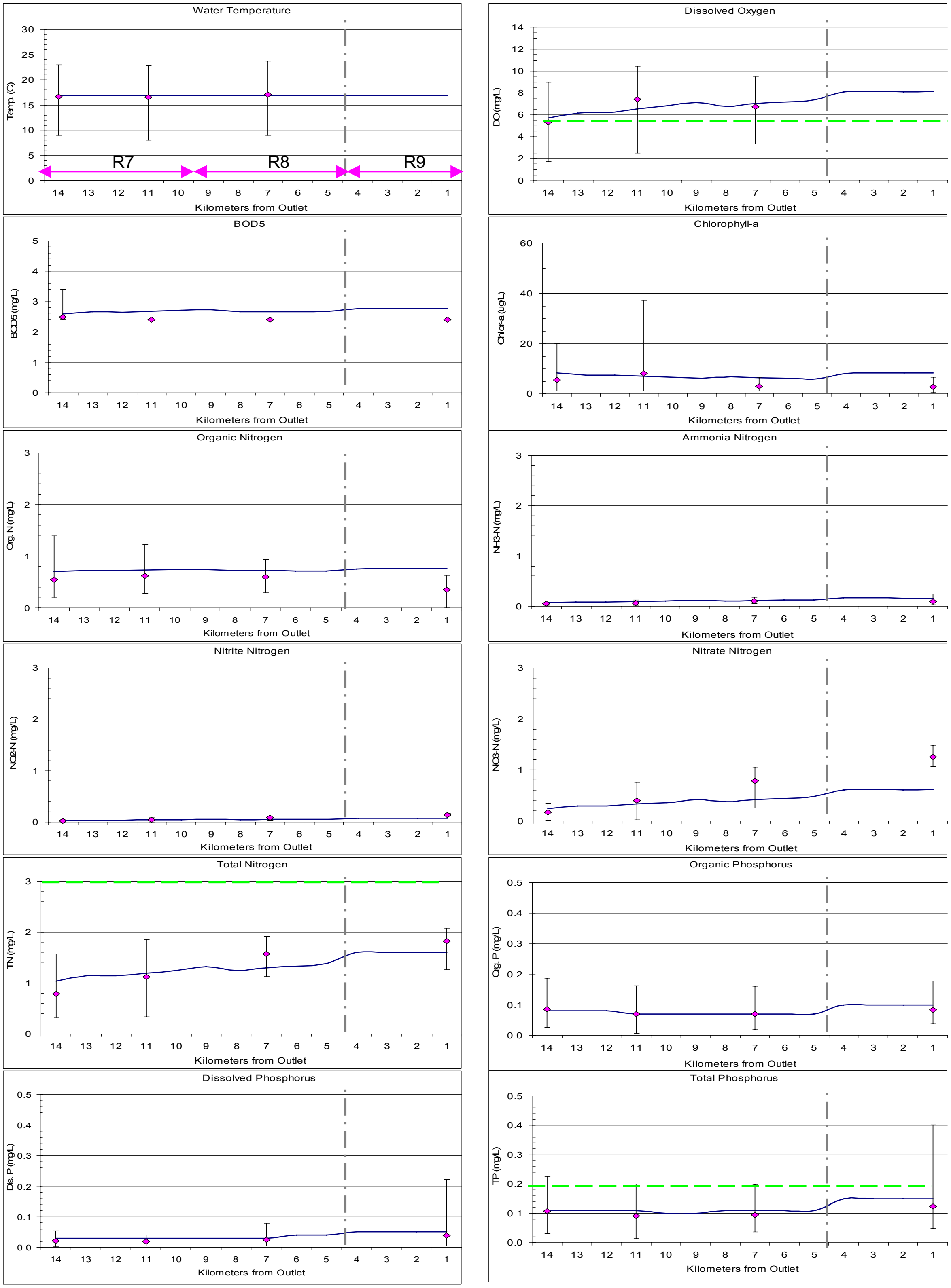

Figure 3-4c **Calibration Results of Temperature, DO, BOD5, Chlor-a, Org-N, NH3-N, NO2-N, NO3-N, TN, Org-P, Dis-P, and TP in the Cow Marsh Creek Transect**

Load Reductions on the Annual Average Baseline

The nonpoint source loads are considered implicitly in the Qual2E model. They are used in the model through user-defined boundary conditions including headwater conditions, tributary inflow conditions, and incremental inflow conditions. Water quality concentrations used to define these boundary conditions for the Choptank River Qual2E Model were discussed in Chapter 2 of this report.

Several load reduction scenarios, in which pollutant loads were reduced from the entire watershed, were conducted and are summarized in Table 3-2. The mimimum dissolved oxygen concentration and maximum total nitrogen and total phosphorus concentrations observed in the modeled segments of the stream are presented for each reduction scenario under both annual average (AA) and critical conditions (CC). Cells within the table are colored green if the concentration meets the dissolved oxygen standard or nutrient target, where as if the standard or target is not met, the cell is colored orange. In the scenario that was ultimately chosen (bold font in Table 3-2), nitrogen concentrations were not reduced since nitrogen concentrations were less than the target of 3.0 mg/l at all times of the year. Phosphorus concentrations, however, were reduced at a rate of 40%. Biochemical oxygen demand concentrations and sediment oxygen demand rates were also reduced by 40%. It was also assumed that these reductions will allow for the dissolved oxygen concentration of the incremental inflow waters to meet the 5.0 mg/l standard. The results are presented in Figure 3-5(a-c) as a red line. It is apparent that this scenario could reduce the total phosphorus concentrations so that the 0.2 mg/l target threshold could be achieved in all reaches and still maintain dissolved oxygen concentrations above the State of Delaware's 5.5 mg/l standard and produce concentrations above the State of Maryland's standard of 5.0 mg/l at the state line.

Table 3-2 Results of Load Reduction Scenarios in Choptank River under Annual Average (AA) and Critical Conditions (CC)

TN %	TP%		Minimum DO (mg/l)	Maximum TN (mg/l)	Maximum TP (mg/l)
Choptank River Baseline		AA	5.43	1.83	0.27
		CC	3.53	1.82	0.40
0%	30%	AA	5.49	1.83	0.19
		CC	5.39	1.82	0.28
30%	30%	AA	5.50	1.28	0.19
		CC	5.45	1.28	0.28
0%	**40%**	**AA**	**5.51**	**1.83**	**0.17**
		CC	**5.51**	**1.82**	**0.24**
20%	40%	AA	5.51	1.47	0.17
		CC	5.56	1.46	0.24
47%	44%	AA	5.53	0.97	0.16
		CC	5.65	0.97	0.23
0%	50%	AA	5.52	1.83	0.14
		CC	5.63	1.82	0.20

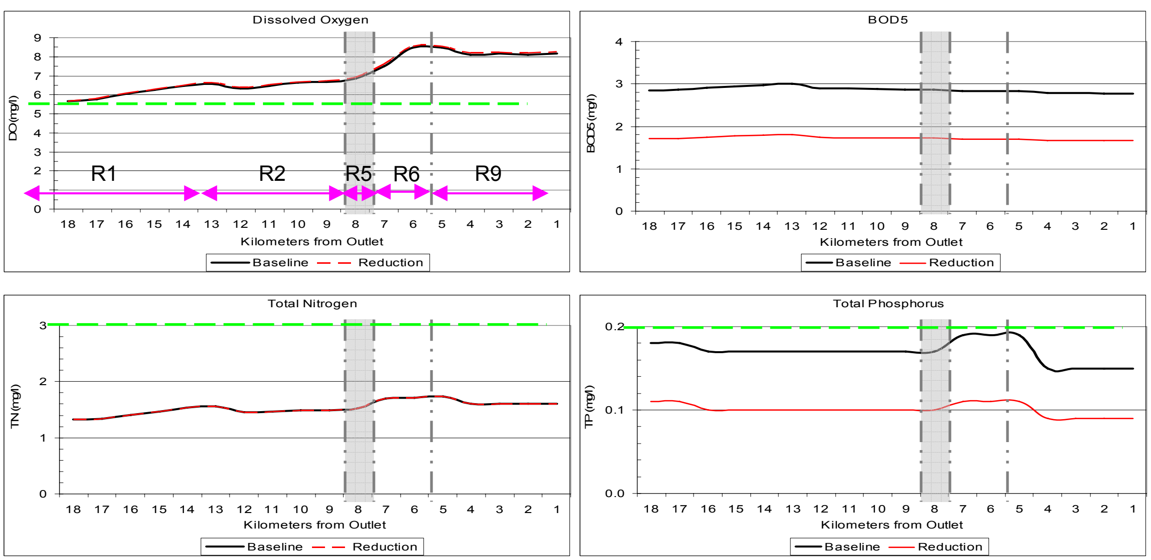

Figure 3-5a Results of Load Reductions on Baseline Scenario for DO, BOD5, TN, and TP in the Tappahanna Ditch Transect

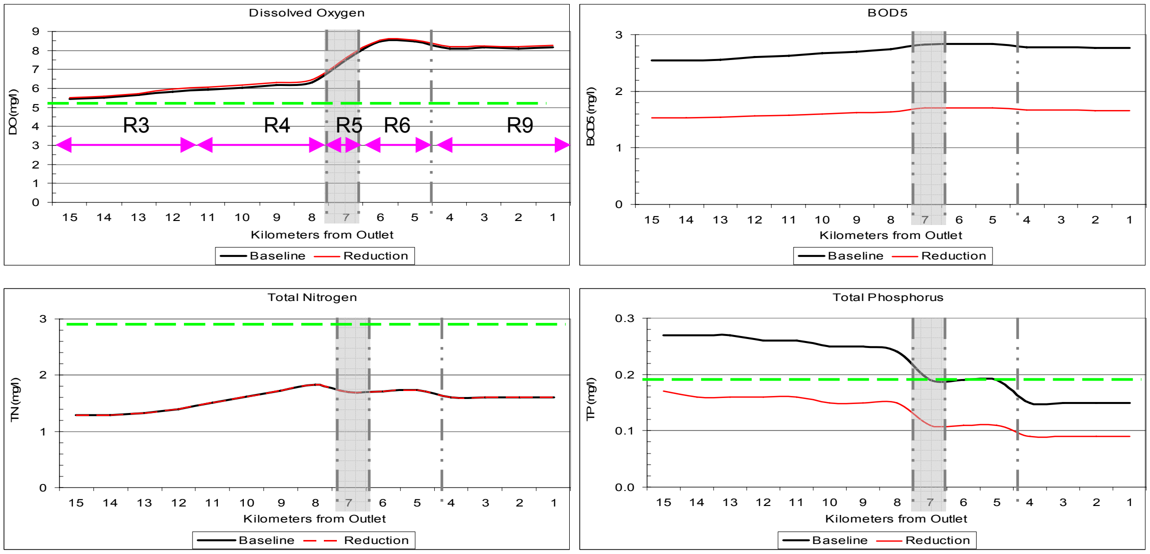

Figure 3-5b Results of Load Reductions on Baseline Scenario for DO, BOD5, TN, and TP in the Culbreth Marsh Ditch Transect

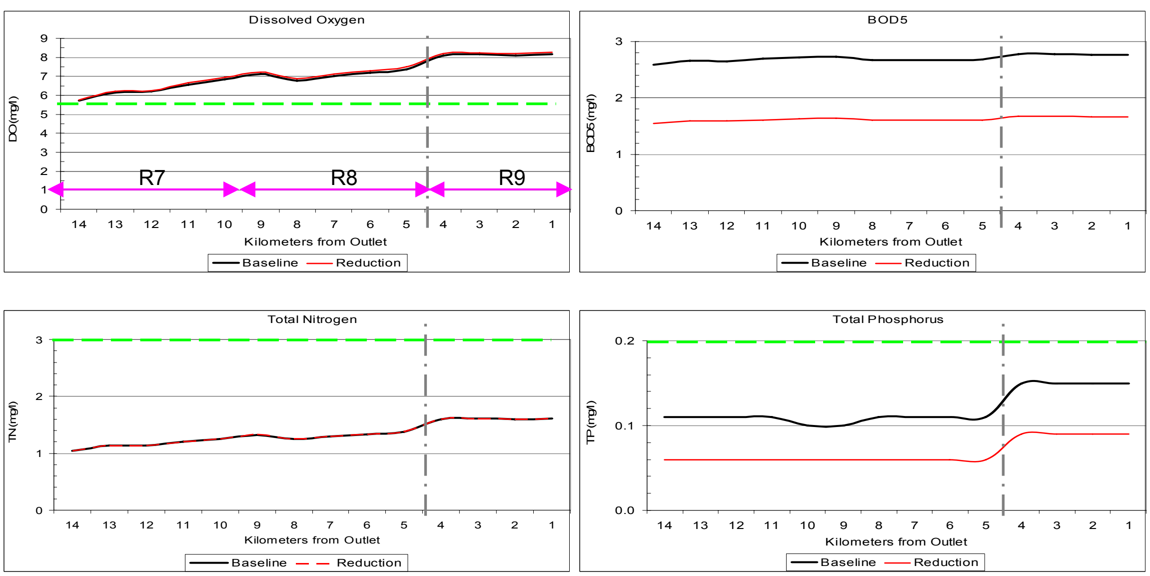

Figure 3-5c Results of Load Reductions on Baseline Scenario for DO, BOD5, TN, and TP in the Cow Marsh Creek Transect

Baseline Critical Condition

Low flows coupled with warm temperatures are observed during the months of July, August, and September in Choptank River. Monitoring data showed that violation of the dissolved oxygen standard happened more frequently during summer months than other months of the year. In addition, the phosphorus concentrations were also elevated above the 0.2 mg/l target in more segments during summer months. The water quality conditions in the summer were simulated to form the critical baseline conditions during summer time (Table 3-2). Water quality data collected during July, August, and September were considered summer month samples and were averaged over the period of 2001-2003. The averaged summer concentrations were used to define the headwater conditions and tributary input conditions of the model. The average summer concentrations were coupled with the 7Q10 flows to simulate the summer critical condition. The results are presented in Figure 3-6(a-c) as a thick black line.

Load Reductions on the Baseline Critical Condition

The same load reduction rates previously discussed were applied to the summer condition (Table 3-2). The nitrogen concentrations were not adjusted since they were already less than the 3.0 mg/l target concentration. Phosphorus and biochemical oxygen demand concentrations at the headwater, tributary inflow, and incremental inflow were reduced at the rate of 40%, with 40% reductions of the SOD rate as well. Again, it was assumed that these reductions would allow for the dissolved oxygen concentration in the incremental inflow waters to reach 5.0 mg/l. Additionally, it was also assumed that the headwater dissolved oxygen concentrations would achieve the 5.5 mg/l standard with the prescribed phosphorus, BOD, and SOD rate reductions. The results of this analysis can be found in Figure 3-6(a-c) as red lines.

It should be noted that the total phosphorus concentrations in the headwaters of Culbreth Marsh Ditch (Reaches 3 and 4 in Figure 3-6(b)) still reamin slightly elevated above the 0.2 mg/l target even after reductions during this critical condtion period. Since the 0.2 mg/l goal is a target rather than a water quality standard and since the concentration decreases below the target once the water reaches Mudmill Pond and downstream in the main channel of the Choptank River, this exceedence, which is minimal on both a spatial and temporal scale, was considered acceptable.

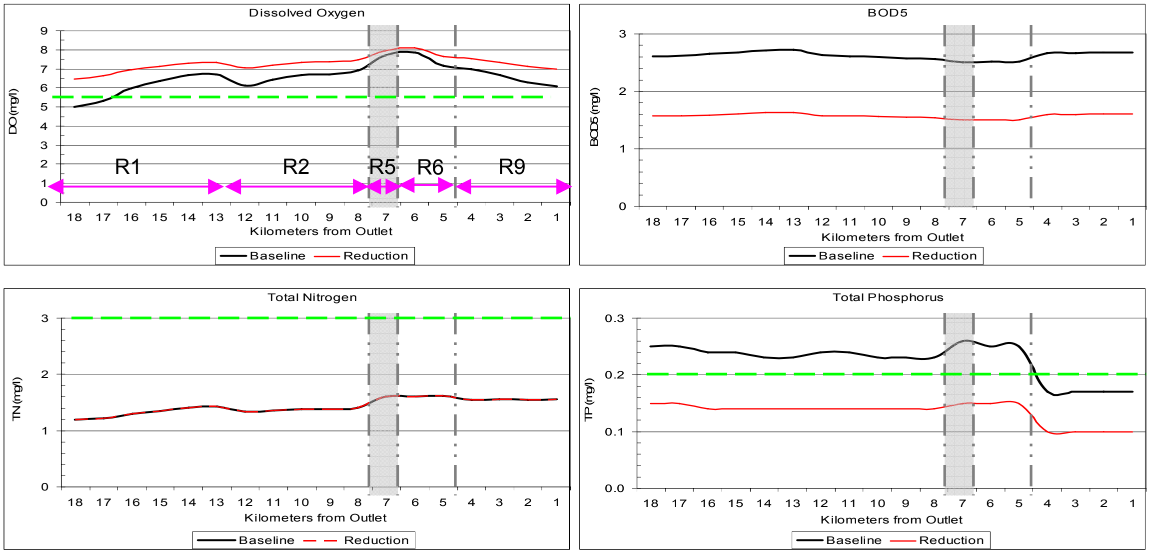

Figure 3-6a Results of Load Reductions on Critical Condition Scenario for DO, BOD5, TN, and TP in the Tappahanna Ditch Transect

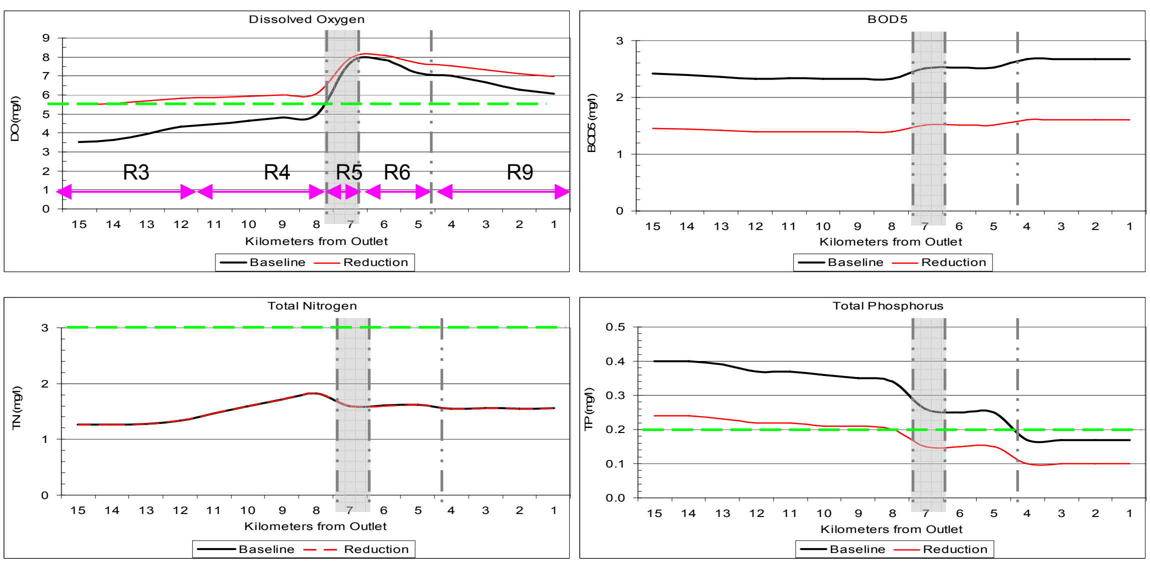

Figure 3-6b Results of Load Reductions on Critical Condition Scenario for DO, BOD5, TN, and TP in the Culbreth Marsh Ditch Transect

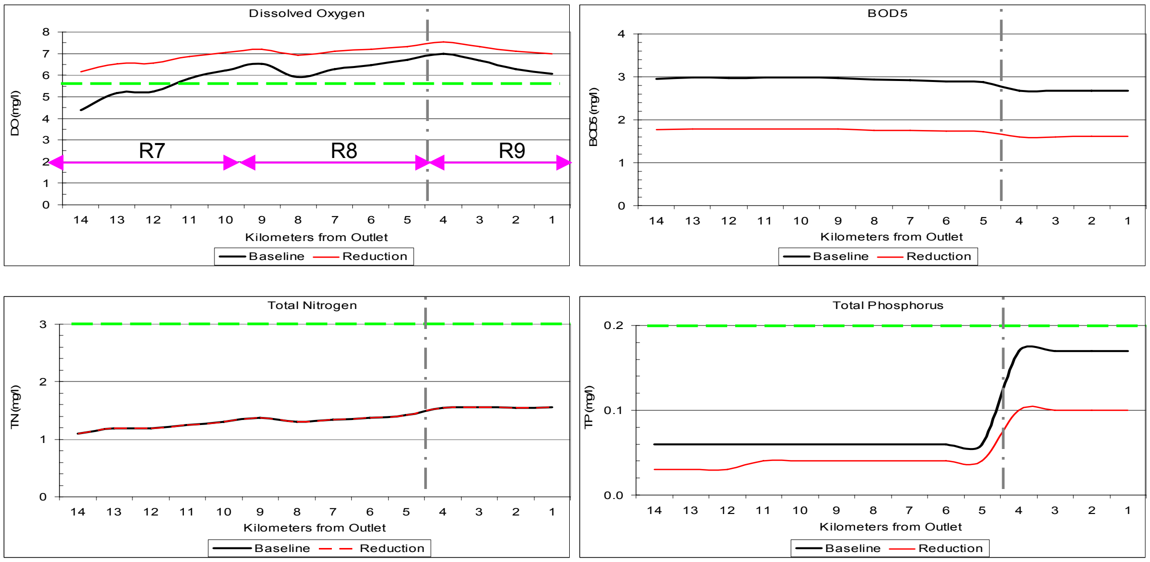

Figure 3-6c Results of Load Reductions on Critical Condition Scenario for DO, BOD5, TN, and TP in the Cow Marsh Creek Transect

Marshyhope Creek Qual2E Model

Model Calibration / Annual Average Baseline Condition

The Marshyhope Creek Qual2E Model was calibrated to reproduce average water quality conditions observed during 2001-2003. Average annual flows and water quality concentrations were used in the models calibration. The input and output data for the Marshyhope Creek Qual2E Model calibration is presented in Appendix E.

Figure 3-7 displays the model calibration results for several water quality constituents including nutrient species, dissolved oxygen, biochemical oxygen demand, phytoplankton chlorophyll-*a*, and water temperature under average conditions during 2001-2003. Model calibration results are presented as lines while observed data at the monitoring sites (302041, 302031, and 302021) are shown as symbols with mean, maximum, and minimum values. The most upstream point in each graph represents the water quality conditions of the headwater/tributaries, in which the average values from station 302051 were used.

The calibration results show that dissolved oxygen and temperature predictions are very close to the average observed values and that nitrogen, phosphorous, and chlorophyll-*a* have been reproduced reasonably well. This calibrated model for average condition during 2001 – 2003 constitutes the baseline condition for Marshyhope Creek.

In Figure 3-7, the State of Delaware standard for dissolved oxygen (5.5 mg/l) and target nutrient values (3.0 mg/l for total nitrogen and 0.2 mg/l for total phosphorus) are shown as dashed green lines. Figure 3-7 shows that under average conditions, dissolved oxygen levels meet the standard of 5.5 mg/l at all reaches. The State of Maryland dissolved oxygen standard of 5.0 mg/l is achieved at the outlet of the model as well under these baseline conditions. However, the 3.0 mg/l total nitrogen target is exceeded in the middle and lower reaches while the 0.2 mg/l total phosphorus target is exceeded in the upper reach.

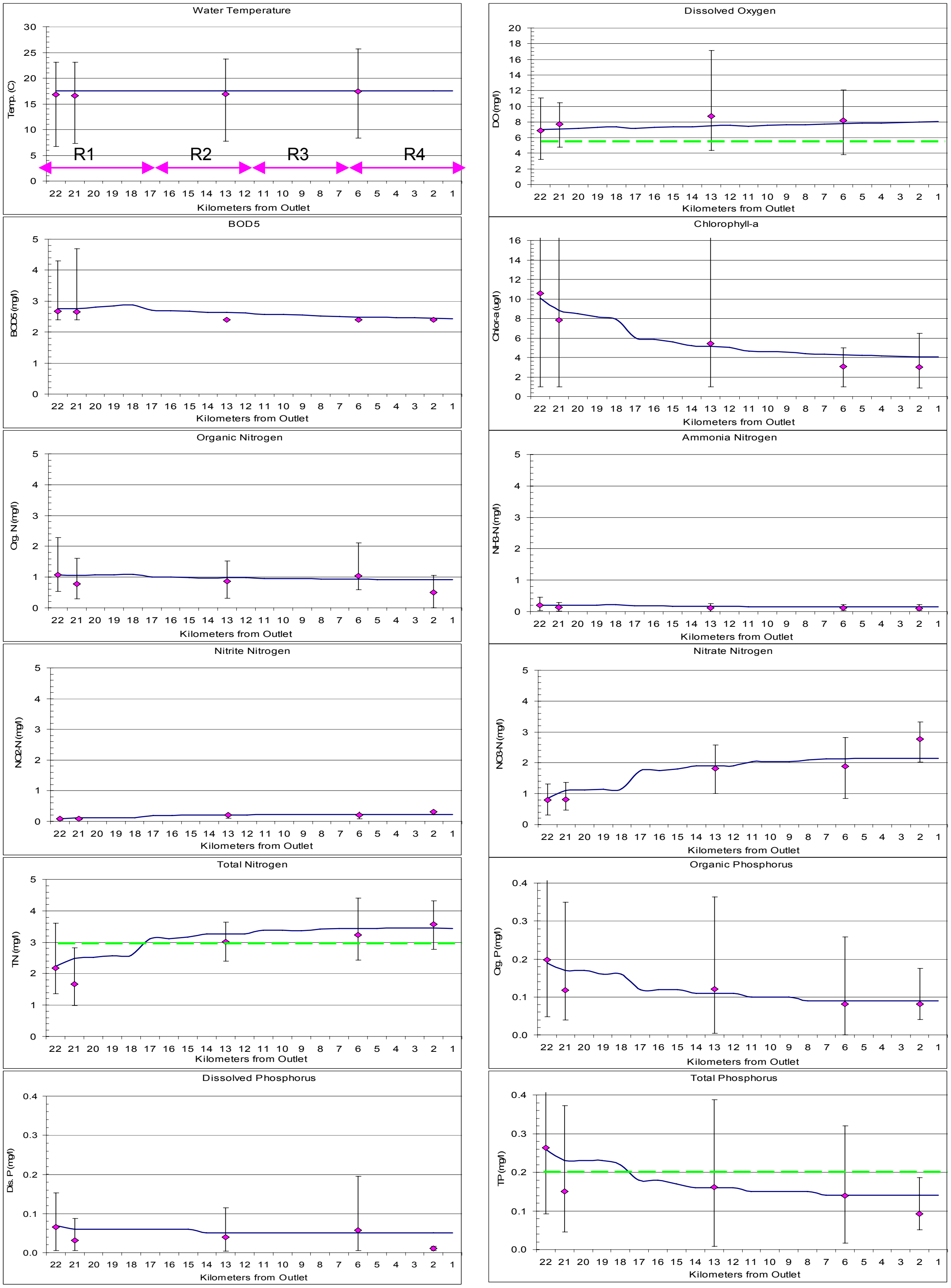

Figure 3-7 Calibration Results of Temperature, DO, BOD5, Chlor-a, Org-N, NH3-N, NO2-N, NO3-N, TN, Org-P, Dis-P, and TP in Marshyhope Creek

Load Reductions on the Annual Average Baseline

The nonpoint source loads are considered implicitly in the Qual2E model. They are used in the model through user-defined boundary conditions including headwater conditions, tributary inflow conditions, and incremental inflow conditions. Water quality concentrations used to define these boundary conditions for the Marshyhope Creek Qual2E Model were discussed in Chapter 2 of this report.

Several load reduction scenarios, in which pollutant loads were reduced from the entire watershed, were conducted and are summarized in Tables 3-3. The mimimum dissolved oxygen concentration and maximum total nitrogen and total phosphorus concentrations observed in the modeled segments of the stream are presented for each reduction scenario under both annual average (AA) and critical conditions (CC). Cells within the table are collored green if the concentration meets the dissolved oxygen standard or nutrient target, where as if the standard or target is not met, the cell is colored orange. In the scenario that was ultimately chosen (bold font in Tables 3-3), the nitrogen concentrations at the headwater, tributary inflow, and incremental inflow were reduced at a rate of 20%, while the respective phosphorus and biochemical oxygen demand concentrations were reduced at rates of 25%. The results are presented in Figure 3-8 as a red line. It is apparent that this scenario could reduce the total nitrogen and total phosphorus concentrations so that the 3.0 mg/l and 0.2 mg/l target thresholds, respectively, could be achieved in all reaches and still maintain dissolved oxygen concentrations above the State of Delaware's 5.5 mg/l standard and produce concentrations above the State of Maryland's standard of 5.0 mg/l at the state line.

Table 3-3 Results of Load Reduction Scenarios in Marshyhope Creek under Annual Average (AA) and Critical Conditions (CC)

TN %	TP%		Minimum DO (mg/l)	Maximum TN (mg/l)	Maximum TP (mg/l)
Marshyhope Creek Baseline		AA	7.01	3.45	0.26
		CC	6.83	3.73	0.14
20%	**25%**	**AA**	**7.02**	**2.76**	**0.19**
		CC	**6.75**	**2.99**	**0.11**
20%	40%	AA	7.02	7.76	0.15
		CC	6.77	2.99	0.09
47%	44%	AA	7.02	1.83	0.15
		CC	6.77	1.99	0.08

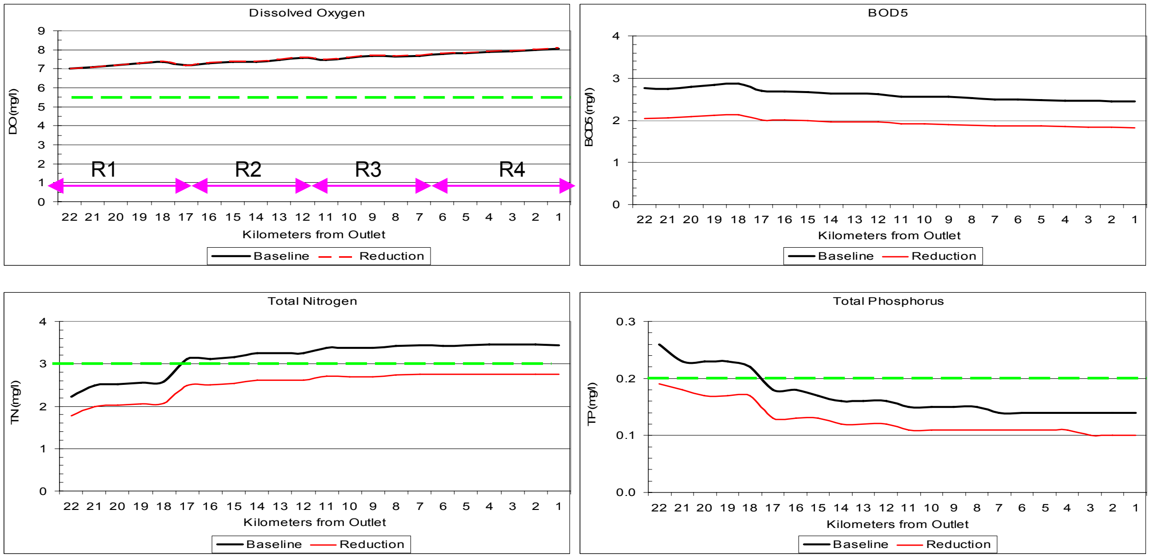

Figure 3-8 Results of Load Reductions on Baseline Scenario for DO, BOD5, TN, and TP in Marshyhope Creek

Baseline Critical Condition

Low flows coupled with warm temperatures are observed during the months of July, August, and September in Marshyhope Creek. Monitoring data showed that violation of the dissolved oxygen standard happened more frequently during summer months than other months of the year. The water quality conditions in the summer were simulated to form the critical baseline conditions during summer time (Table 3-3). Water quality data collected during July, August, and September were considered summer month samples and were averaged over the period of 2001-2003. The averaged summer concentrations were used to define the headwater conditions and tributary input conditions of the model. The average summer concentrations were coupled with the 7Q10 flows to simulate the summer critical condition. The results are presented in Figure 3-9 as a thick black line.

Load Reductions on the Baseline Critical Condition

The same load reduction rates previously discussed were applied to the summer condition (Table 3-3). The nitrogen concentrations at the headwater, tributary inflow, and incremental inflow were reduced at a rate of 20% and 25% for phosphorus and biochemical oxygen demand concentrations. The results of this analysis can be found in Figure 3-9 as red lines.

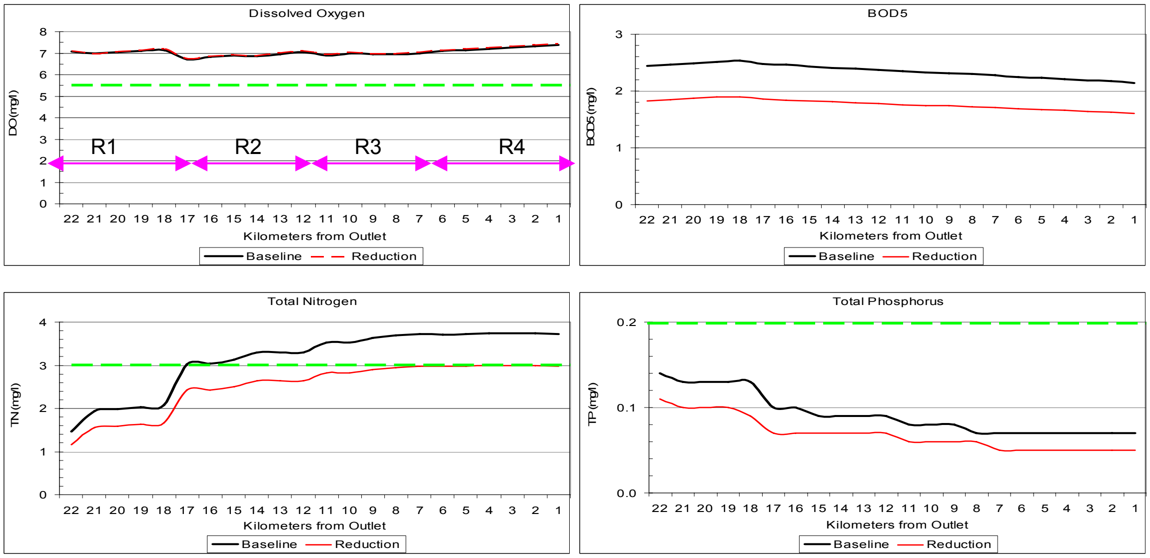

Figure 3-9 Results of Load Reductions on Critical Condition Scenario for DO, BOD5, TN, and TP in Marshyhope Creek

Sensitivity Analysis

In order to assess the sensitivity to changes in various environmental parameters used in the Chesapeake drainage basin models, a sensitivity analysis was performed for each model. For this analysis, the models were run under critical summer conditions, which is when dissolved oxygen concentrations tend to be lowest. One parameter was changed at a time and the percentage of change in dissolved oxygen concentration, as well as total nitrogen and total phosphorus concentrations, were recorded. The percent change in concentration was evaluated as the model-average change (average change in all model compuational elements) and the change at the two computation elements with the lowest dissolved oxygen concentrations. The elements with the most critical dissolved oxygen levels were in the headwaters of each model, with the exception of the Marshyhope Creek Qual2E Model, where the lowest summer dissolved oxygen concentrations were found downstream of the headwater. The sensitivity analysis results are provided in Appendices F through J.

The results of each analysis showed that the dissolved oxygen concentrations predicted by the Qual2E models are most sensitive to changes in the sediment oxygen demand rate and the carbonaceous deoxygeneration rate (BOD decay rate). The total nitrogen and total phosphorus concentrations are most sensitive to the organic nitrogen and organic phosphorus setteling rates, respectively, since the organic fractions made up the largest portions of both constituents in water quality samples.

4.0 CHESAPEAKE BAY AGREEMENT NONPOINT SOURCE REDUCTIONS

To recommit efforts and establish new and more comprehensive goals, the 2000 Chesapeake Bay Agreement was signed into effect by the states of Maryland, Pennsylvania, Virginia, the District of Columbia, the Chesapeake Bay Commission, and the US EPA. The improvement of water quality was cited as the "most critical element in the overall protection and restoration of the Chesapeake Bay and its tributaries" (7).

A 40% reduction in nutrient loads was originally agreed upon in 1987, and in 1992, the Bay Program partners further agreed to adopt tributary-specific reduction strategies. In the 2000 Agreement, additional objectives were outlined with the ultimate goal to "achieve and maintain the water quality necessary to support the aquatic living resources of the Bay and its tributaries and to protect human health" (7). One specific objective was to assign load reductions for nitrogen and phosphorus to each major tributary. As a result, in June 2003, 46.8% and 43.5% reductions in nonpoint source nitrogen and phosphorus, respectively, were allocated to the Delaware watersheds draining to the Eastern Shore of Maryland (8).

These reductions are greater than those found necessary to meet the State of Delaware's dissolved oxygen standard and nutrient targets, as reported in the previous chapter. For example, in the Chester River and Choptank River Watersheds, nitrogen reductions were not found to be necessary and the total nitrogen loads from both watersheds will be capped at baseline levels. The total phosphorus loads, however, must be reduced by 40% from both the Chester River and Choptank River Watersheds. In the Marshyhope Creek Watershed, nonpoint source total nitrogen reductions of 20% and total phosphorus reductions of 25% were found necessary to meet Delaware's water quality standards and targets. If the load reductions called for by the 2000 Chesapeake Bay Agreement were implemented, even greater nutrient reductions would be produced.

In each modeled watershed, a scenario using the load reductions prescribed by the Chesapeake Bay Agreement was run for both the annual average condition and the critical condition. This scenario is shown in the following plots for each watershed as a blue line, along with the baseline condition (black line) and the reduction found necessary to meet the State of Delaware's dissolved oxygen standard and nutrient targets (red line) (Figures 4-1 through 4-14). The figures below show that implementing the load reductions called for by the Chesapeake Bay Program in the 2003 allocations would result in additional lowering of nutrient concentrations in Delaware streams.

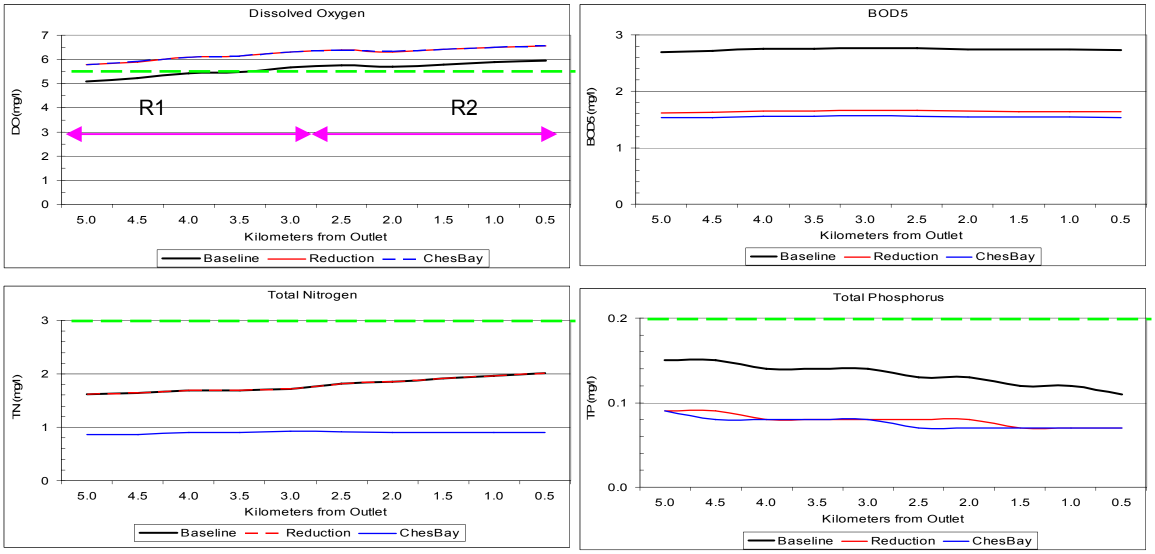

Figure 4-1 Results of Load Reductions on Baseline Scenario for DO, BOD5, TN, and TP in Cypress Branch, Chester River

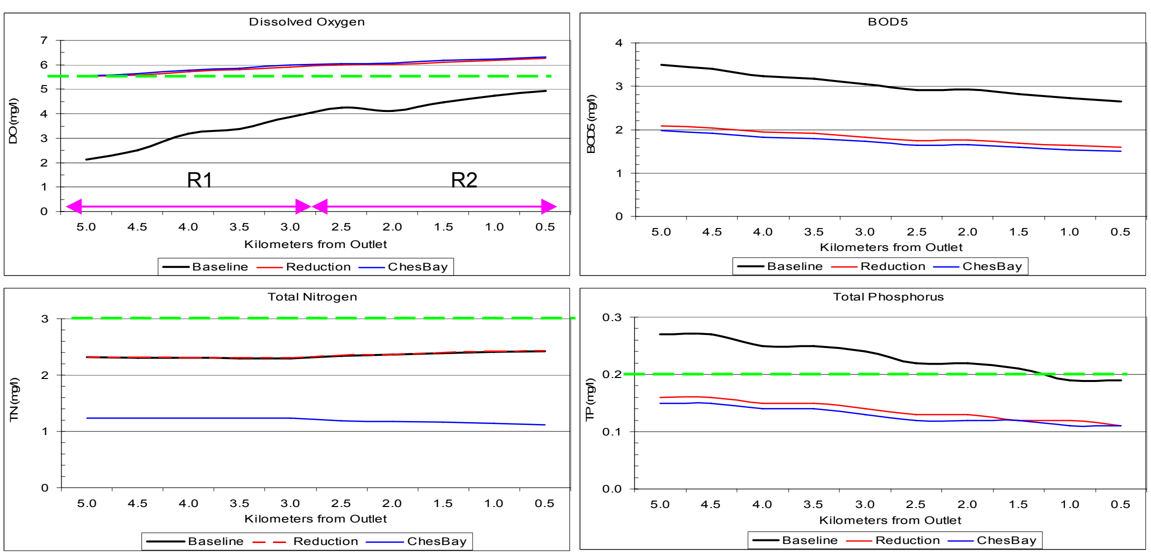

Figure 4-2 Results of Load Reductions on Critical Condition Scenario for DO, BOD5, TN, and TP in Cypress Branch, Chester River

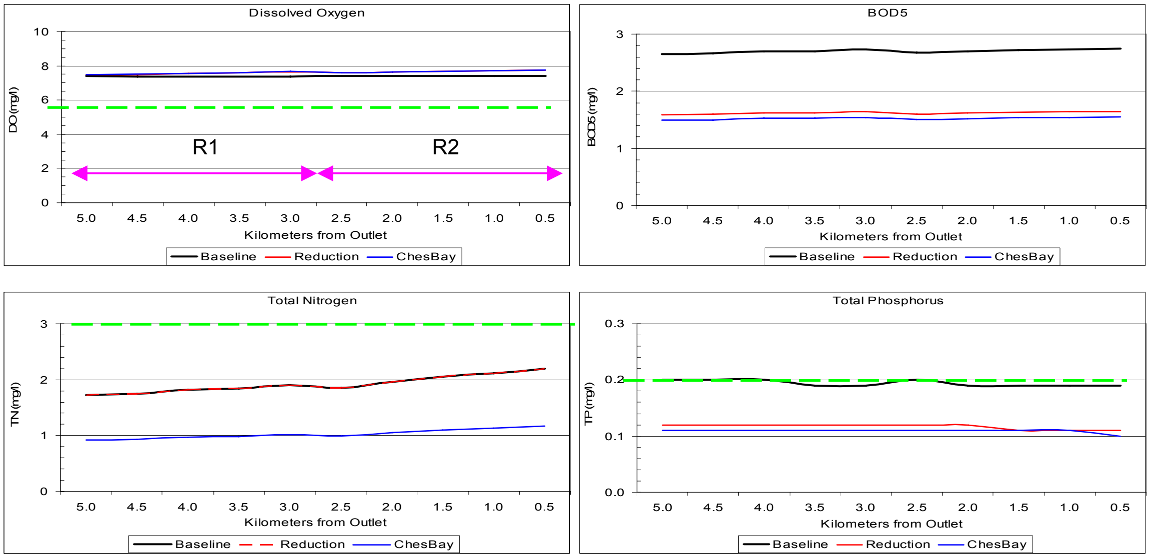

Figure 4-3 Results of Load Reductions on Baseline Scenario for DO, BOD5, TN, and TP in Sewell Branch, Chester River

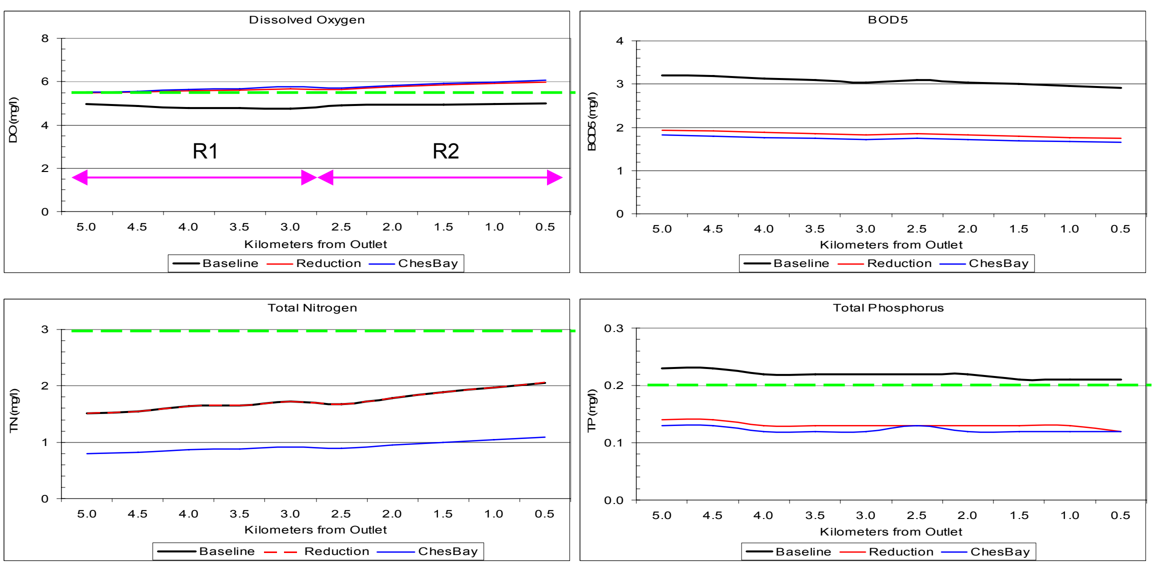

Figure 4-4 Results of Load Reductions on Critical Condition Scenario for DO, BOD5, TN, and TP in Sewell Branch, Chester River

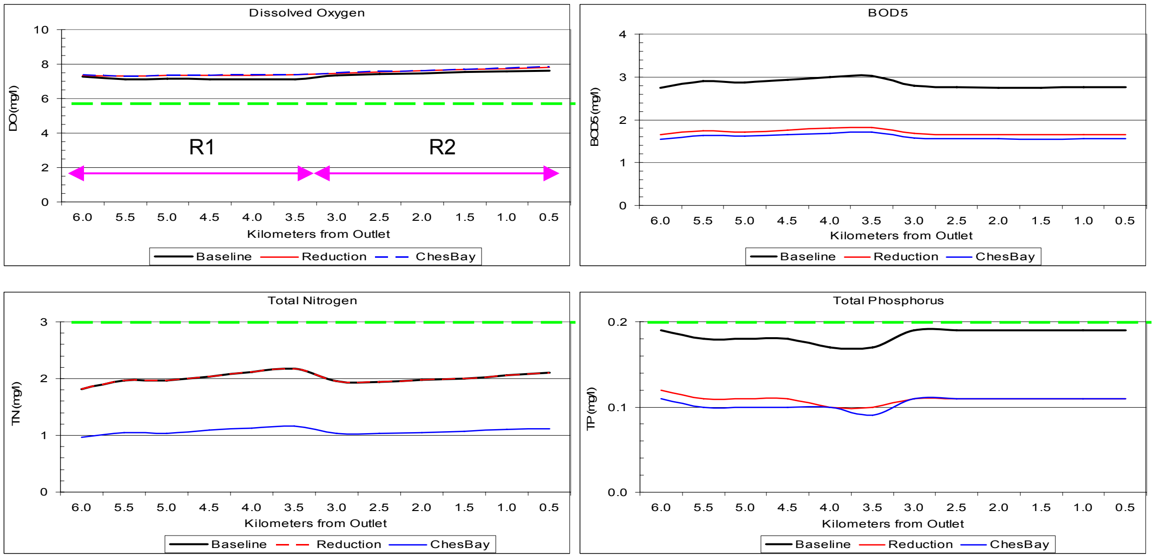

Figure 4-5 Results of Load Reductions on Baseline Scenario for DO, BOD5, TN, and TP in Gravelly Run, Chester River

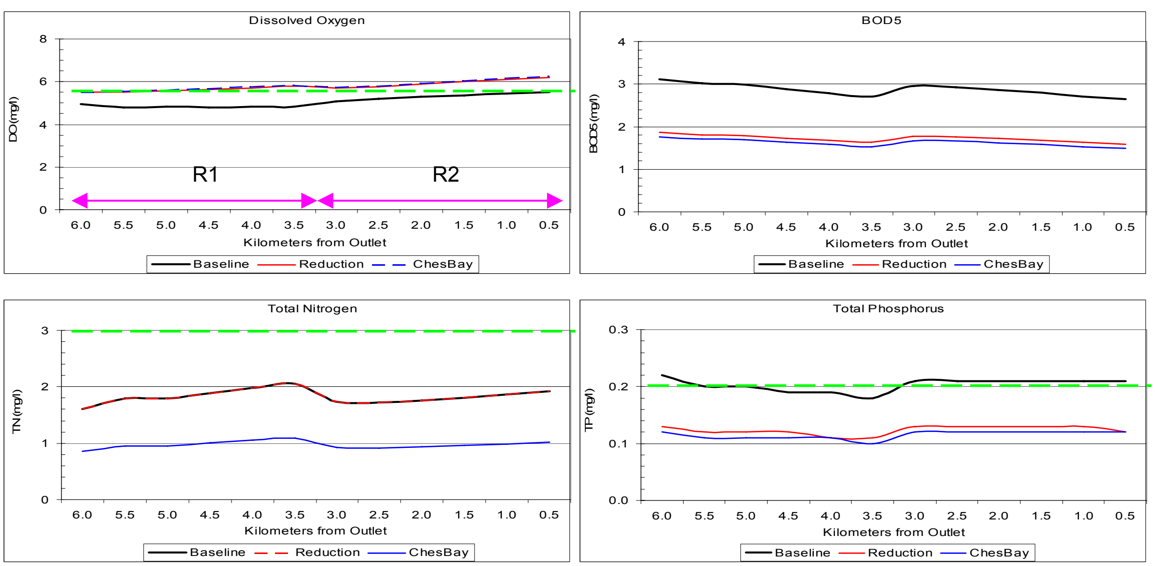

Figure 4-6 Results of Load Reductions on Critical Condition Scenario for DO, BOD5, TN, and TP in Gravelly Run, Chester River

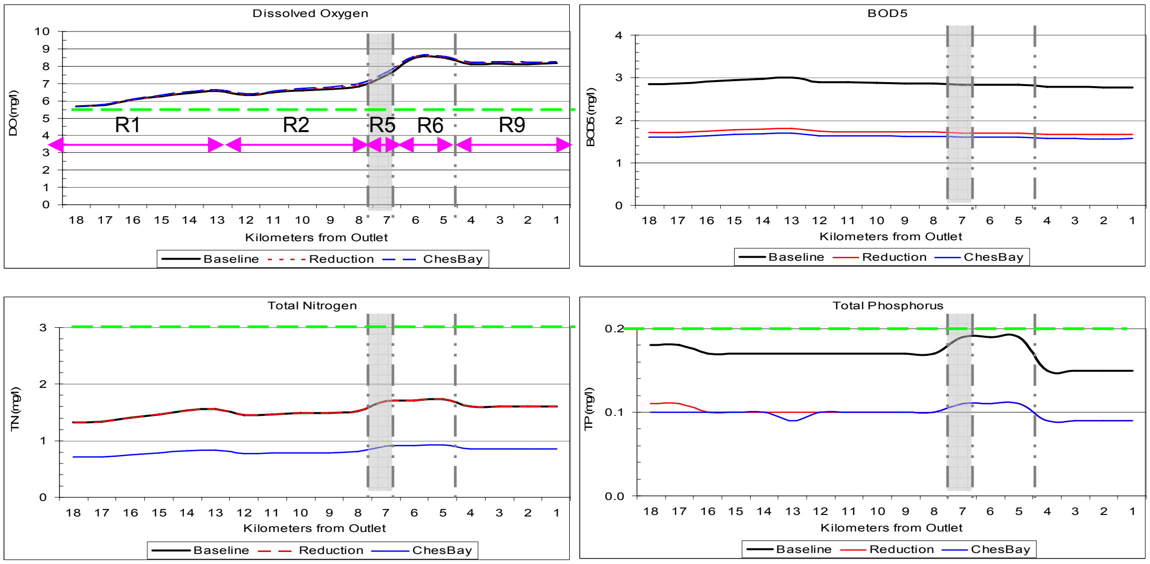

Figure 4-7 Results of Load Reductions on Baseline Scenario for DO, BOD5, TN, and TP in the Tappahanna Ditch Transect, Choptank River

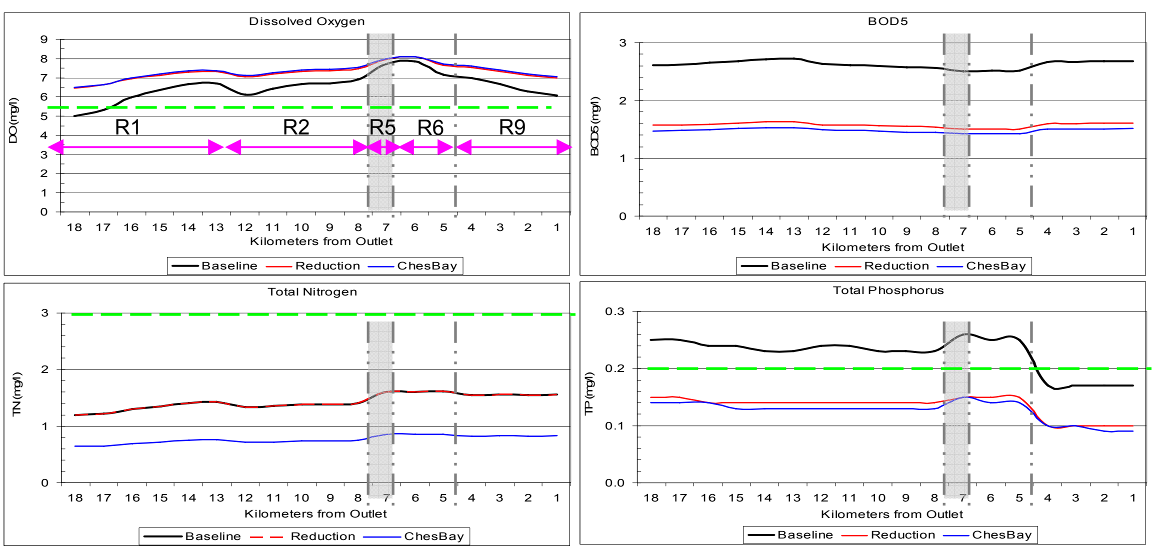

Figure 4-8 Results of Load Reductions on Critical Condition Scenario for DO, BOD5, TN, and TP in the Tappahanna Ditch Transect, Choptank River

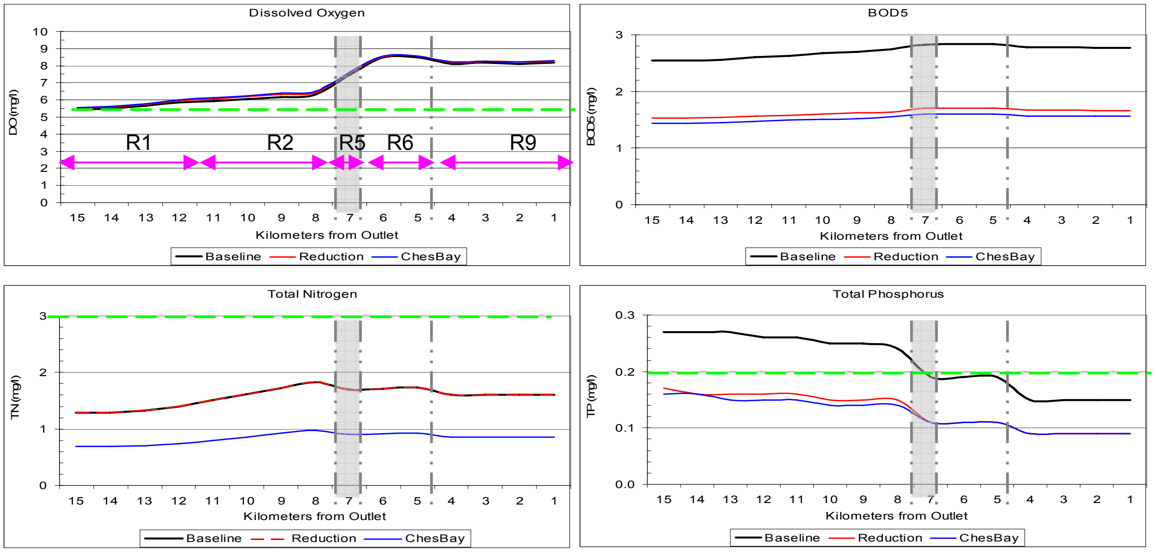

Figure 4-9 Results of Load Reductions on Baseline Scenario for DO, BOD5, TN, and TP in the Culbreth Marsh Ditch Transect, Choptank River

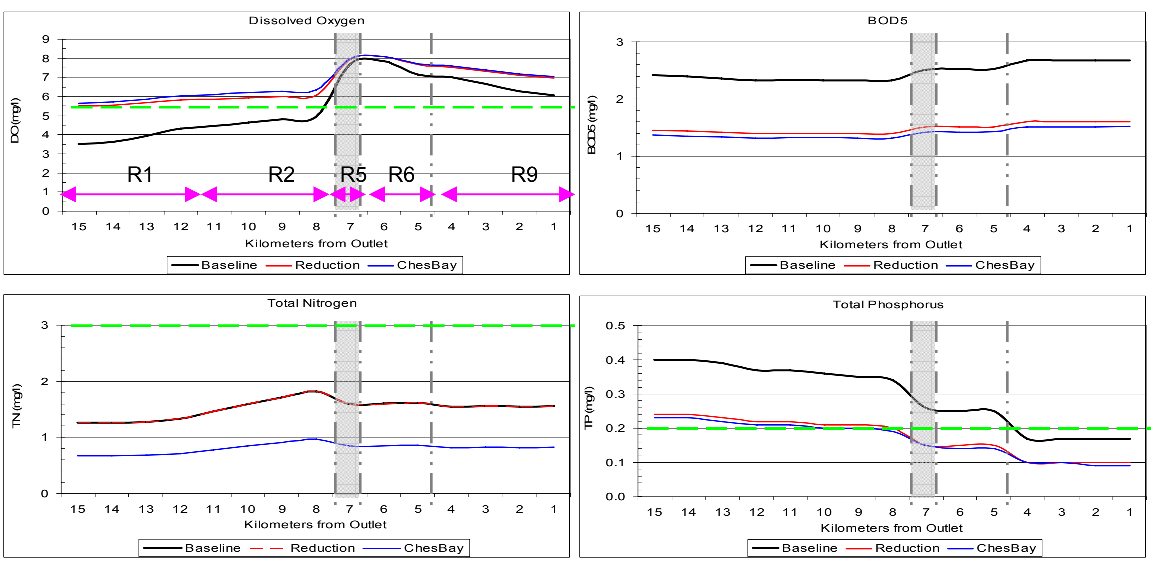

Figure 4-10 Results of Load Reductions on Critical Condition Scenario for DO, BOD5, TN, and TP in the Culbreth Marsh Ditch Transect, Choptank River

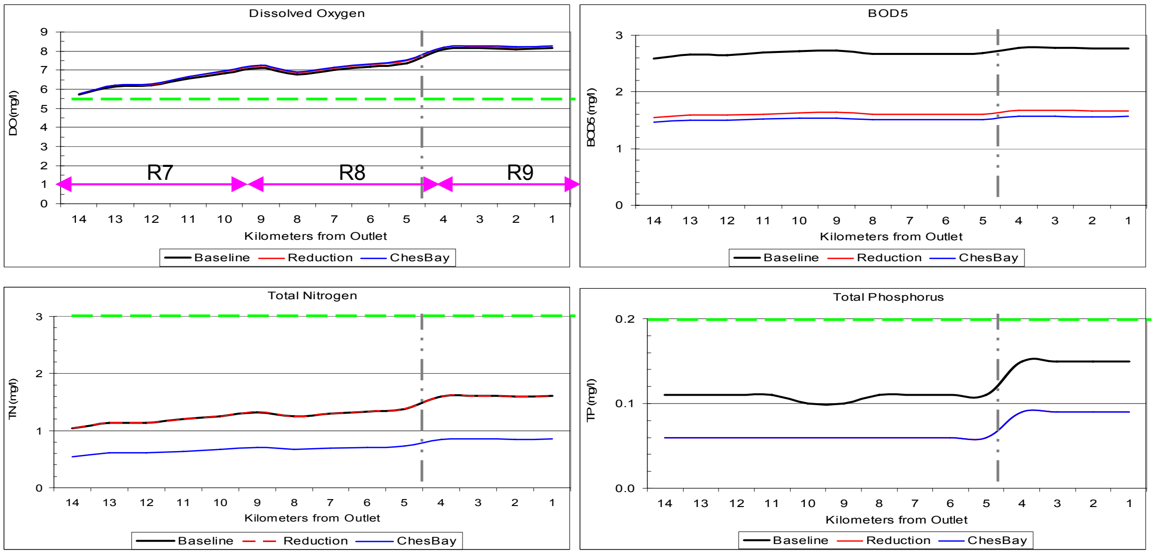

Figure 4-11 Results of Load Reductions on Baseline Scenario for DO, BOD5, TN, and TP in the Cow Marsh Creek Transect, Choptank River

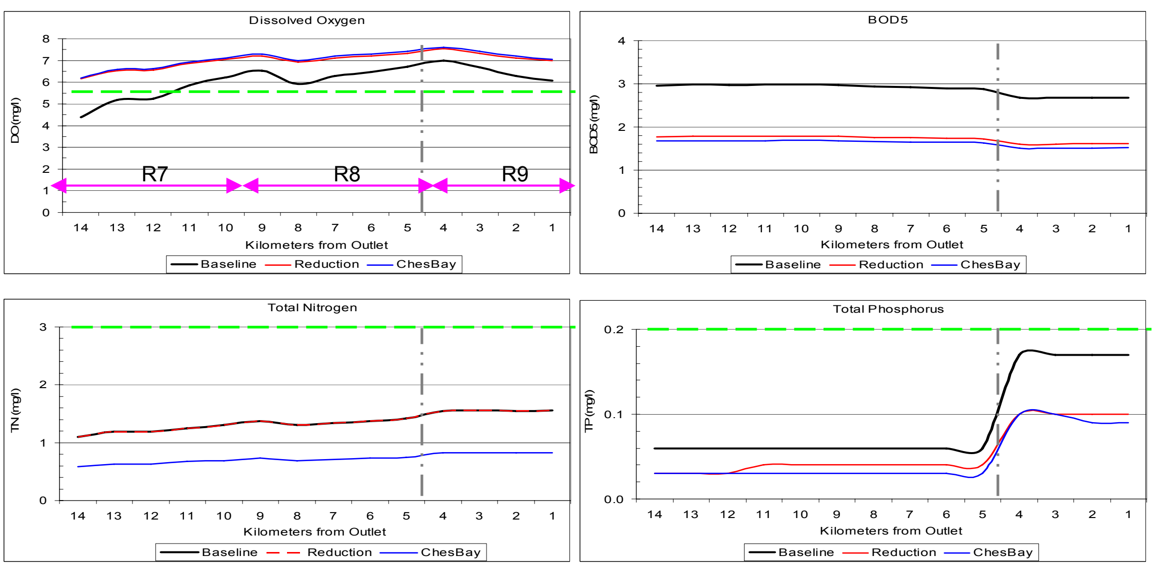

Figure 4-12 Results of Load Reductions on Critical Condition Scenario for DO, BOD5, TN, and TP in the Cow Marsh Creek Transect, Choptank River

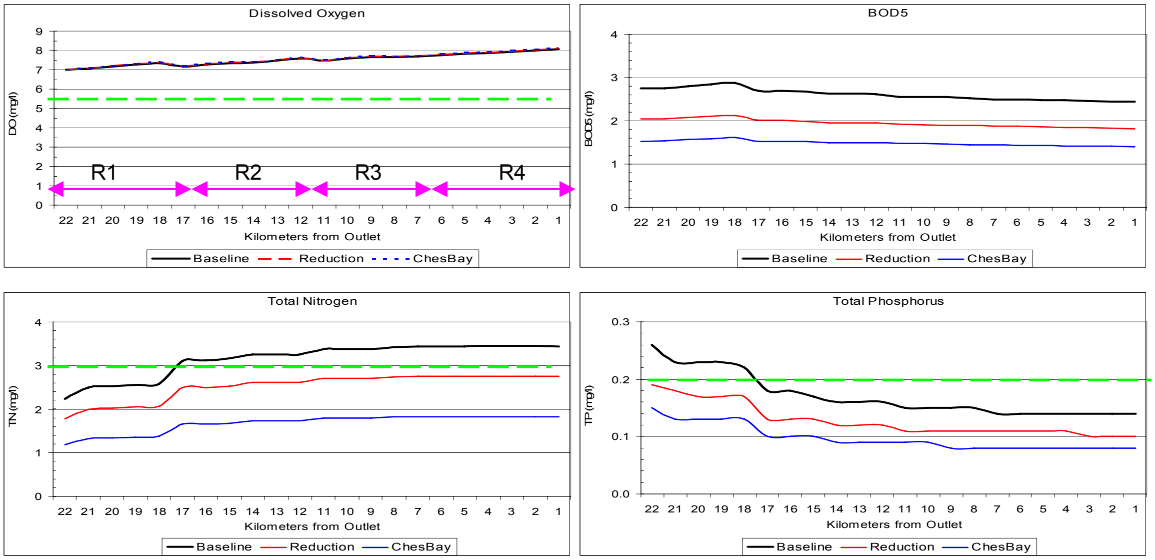

Figure 4-13 Results of Load Reductions on Baseline Scenario for DO, BOD5, TN, and TP in Marshyhope Creek

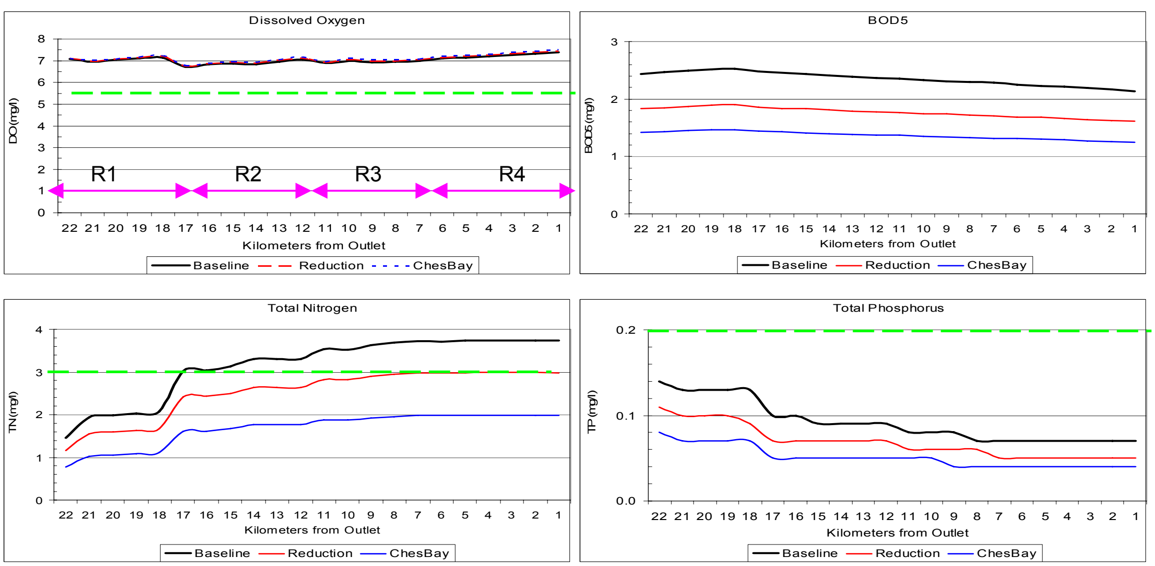

Figure 4-14 Results of Load Reductions on Critical Condition Scenario for DO, BOD5, TN, and TP in Marshyhope Creek

5.0 NUTRIENT TOTAL MAXIMUM DAILY LOADS AND ALLOCATIONS

As was stated in Chapter 1, the applicable State of Delaware water quality standard for dissolved oxygen is 5.5 mg/l for freshwater streams, and the TMDL nutrient targets are 3.0 mg/l for total nitrogen and 0.2 mg/l for total phosphorous. Additionally, the State of Maryland has a dissolved oxygen standard of 5.0 mg/l, which must be met prior to each waterbody crosses the state line from Delaware into Maryland. The results of load reduction scenarios, as discussed in Chapter 3, show that under summer critical condition as well as average condition, the dissolved oxygen standard of both states is met along all simulated reaches of Chester River, Choptank River, and Marshyhope Creek. In addition, the nutrient targets are met throughout Marshyhope Creek and the modeled tributaries of Chester River, as well as within the mainstem of Choptank River. Therefore, it can be concluded that the nonpoint source load reduction rates listed below in Table 5-1 are sufficient to achieve water quality standards in the impaired segments of the Chester River, Choptank River, and Marshyhope Creek.

Table 5-1 Nonpoint Source Nutrient Reductions Required for the Chesapeake Drainage Watersheds

	TN	TP
Chester River	0%	40%
Choptank River	0%	40%
Marshyhope Creek	20%	25%

A TMDL is defined as:

$$TMDL = WLA + LA + MOS$$

Where,

WLA = waste load allocation for point sources
LA = load allocation for nonpoint sources
MOS = margin of safety to account for uncertanites and lack of data

As discussed previously, there are no active point sources discharging nutrients within the Chester River, Choptank River, or Marshyhope Creek Watersheds. Hence, the TMDLs for Chester River, Choptank River, and Marshyhope Creek do not contain a waste load allocation for point sources and the nutrient loads considered in this study are entirely generated from nonpoint sources under average and critical low flow conditions. For these TMDLs, an implicit margin of safety has been considered through the use of conservative assumptions regarding reaction rates, pollutant loads, and simultaneous occurrence of critical environmental conditions, such as low flows and high temperatures.

The baseline loads and TMDLs for Chester River, Choptank River, and Marshyhope Creek are calculated using scenario results discussed in Chapter 3. The baseline loads were estimated from the model results of the baseline scenario. The TMDL loads were estimated from the model results of the load reduction scenarios that applied the various necessary reduction rates mentioned above. Table 5-2 presents the load allocations for total nitrogen and total phosphorous.

Under average conditions in the three tributaries of Chester River (Cypress Branch, Sewell Branch, and Gravelly Run), total nitrogen should be capped at the baseline level of 321 kg/day (708 lb/day), and total phosphorous should be reduced from the baseline of 24.8 kg/day (54.6 lb/day) to the level of 14.7 kg/day (32.3 lb/day).
Under average conditions in Choptank River, total nitrogen should be capped at the baseline level of 616 kg/day (1,359 lb/day), and total phosphorous should be reduced from the baseline of 57.4 kg/day (127 lb/day) to the level of 34.5 kg/day (75.9 lb/day).

Under average conditions in Marshyhope Creek, total nitrogen should be reduced from the baseline of 1,219 kg/day (2,687 lb/day) to the level of 974 kg/day (2,148 lb/day), and total phosphorous should be reduced from the baseline of 49.6 kg/day (109 lb/day) to the level of 35.4 kg/day (78.1 lb/day).

Table 5-2 Load Allocation of the Chesapeake Drainage TMDLs

	Flow (m3/s)	TN Load (kg/day)		TP Load (kg/day)		TN Load (lb/day)		TP Load (lb/day)	
		Baseline	TMDL	Baseline	TMDL	Baseline	TMDL	Baseline	TMDL
Chester River-Cypress Branch	*0.6*	*104*	*104*	*5.70*	*3.63*	*230*	*230*	*12.6*	*8.00*
Chester River-Sewell Branch	*0.7*	*124*	*124*	*10.7*	*6.18*	*273*	*273*	*23.5*	*13.6*
Chester River-Gravelly Run	*0.5*	*93.0*	*93.0*	*8.37*	*4.85*	*205*	*205*	*18.5*	*10.7*
Chester River	1.8	321	321	24.8	14.7	708	708	54.6	32.3
Choptank River	4.4	616	616	57.4	34.5	1,359	1,359	127	75.9
Marshyhope Creek	4.1	1,219	974	49.6	35.4	2,687	2,148	109	78.1

6.0 ESTABLISHMENT OF THE BACTERIA TMDL FOR THE CHESTER RIVER, CHOPTANK RIVER, AND MARSHYHOPE CREEK WATERSHEDS

Bacteria impairments were not included in the QUAL2E modeling but were evaluated at different flow conditions and vs. the single sample maximum to determine the reductions required in the Chester River, Choptank, and Marshyhope Watersheds to achieve water quality standards (100 CFU enterococci/100mL geometric mean, 185 CFU enterococci/100 mL single sample maximum).

The geometric means at the 1st, 2nd, 3rd and 4th flow quartiles were calculated and the 90 percentile sample values were evaluated. Within the Chester River Watershed the Cypress, Sewell, and Gravelly Run were evaluated separtately and then combined to determine an overall Chester River Watershed baseline and load allocation. Overall reductions of 75.6%, 87.8%, and 85.7% in the bacteria loading for the Chester, Choptank, and Marshyhope are required for the water quality meet the geometric mean of 100CFU/100 mL and single sample maximum (185 CFU/100mL), respectively.

Bacteria Concentrations and Loads vs. Flow Rates

The daily flow rates were divided into four ranges: the first, second, third and forth quartile with the first being the lowest 25%and the forth being the highest 25%. The geometric mean for all samples within each quartile was calculated and the baseline load was determined by multiplying the average quartile flow by the geometric mean concentration for that quartile. The TMDL load was calculated by multiplying the average quartile flow by the State water quality standard (100CFU/100mL). Required reductions were calculated by evaluating the TMDL load against the baseline. Reductions were also calculated by evaluating the 90-percentile sample value vs. single sample maximum. In this case, in order to meet both the geometric mean and single sample maximum standards, the required reductions were driven by the single sample maximum value (Tables 6-1 to 6-6).

Table 6-1 Cypress Branch Flow, Bacteria Concentrations & Loadings, and Allocations

Cypress	Flow Range (ft^3/s)	Average Flow (ft^3/s)	Geomean (CFU/100mL)	Baseline Load (CFU/day)	TMDL Load (CFU/day)	90th% Sample Value	Reduction
Minimum	0.0						
First Quartile	< 6.8	3.8	na	na	9.3E+09		na
Second Quartile	6.8 - 13.7	9.7	39	9.2E+09	2.4E+10		---
Third Quartile	13.7 - 23.4	18.0	96	4.2E+10	4.4E+10		---
Forth Quartile	> 23.4	47.8	na	na	1.2E+11		na
Maximum	796.5						
Overall		19.8	58	2.8E+10	4.9E+10		---
Single Sample Maximum					1.4E+10	366	**49.4 %***

*Reduction required to ensure 303(d) listing requirements that <10% of all samples are ≥185CFU/100mL

Table 6-2 Gravelly Run Flow, Bacteria Concentrations & Loadings, and Allocations

Gravelly Run	Flow Range (ft^3/s)	Average Flow (ft^3/s)	Geomean (CFU/100mL)	Baseline Load (CFU/day)	TMDL Load (CFU/day)	90th% Sample Value	% Reduction
Minimum	0.0						
First Quartile	< 5.7	3.2	233	1.8E+10	7.8E+09		57.2%
Second Quartile	5.7 - 11.5	8.2	95	1.9E+10	2.0E+10		---
Third Quartile	11.5 - 19.6	15.1	151	5.6E+10	3.7E+10		33.6%
Forth Quartile	> 19.6	40.2	na	na	9.8E+10		na
Maximum	669.3						
Overall		16.7	136	5.5E+10	4.1E+10		26.5%
Single Sample Maximum					1.2E+10	870	**78.7 %***

*Reduction required to ensure 303(d) listing requirements that <10% of all samples are ≥185CFU/100mL

Table 6-3 Sewell Branch Flow, Bacteria Concentrations & Loadings, and Allocations

Sewell	Flow Range (ft^3/s)	Average Flow (ft^3/s)	Geomean (CFU/100mL)	Baseline Load (CFU/day)	TMDL Load (CFU/day)	90^{th}% Sample Value	% Reduction
Minimum	0.0						
First Quartile	< 7.3	4.1	236	2.4E+10	1.0E+10		57.7%
Second Quartile	7.3 - 14.8	10.5	184	4.7E+10	2.6E+10		45.7%
Third Quartile	14.8 - 25.3	19.4	185	8.8E+10	4.8E+10		46.1%
Forth Quartile	> 25.3	51.7	na	na	1.3E+11		na
Maximum	861.3						
Overall		21.4	201	1.1E+11	5.2E+10		50.3%
Single Sample Maximum					2.0E+10	967	**80.9 %***

*Reduction required to ensure 303(d) listing requirements that <10% of all samples are ≥185CFU/100mL

Table 6-4 Overall Chester River Bacteria Concentrations & Loadings, and Allocations

Overall Chester	Baseline Load (CFU/day)	TMDL Load (CFU/day)	90^{th}% Sample Value	% Reduction
Cypress	2.8E+10	1.4E+10	336	49.4%
Gravelly Run	5.5E+10	1.2E+10	870	78.7%
Sewell Branch	1.1E+11	2.0E+10	967	80.9%
Single Sample Maximum	1.9E+11	4.6E+10		**75.6 %***

*Reduction required to ensure 303(d) listing requirements that <10% of all samples are ≥185CFU/100mL

Table 6-5 Choptank Bacteria Concentrations & Loadings, and Allocations

Choptank	Flow Range (ft^3/s)	Average Flow (ft^3/s)	Geomean (CFU/100mL)	Baseline Load (CFU/day)	TMDL Load (CFU/day)	90^{th}% Sample Value	% Reduction
Minimum	0.0						
First Quartile	< 49.8	28.1	107	7.4E+10	6.9E+10		6.8%
Second Quartile	49.8 - 100.6	71.6	94	1.6E+11	1.8E+11		---
Third Quartile	100.6 - 172.1	132.4	44	1.4E+11	3.2E+11		---
Forth Quartile	> 172.1	352.0	279	2.4E+12	8.6E+11		64.2%
Maximum	5863.6						
Overall		146.0	121	4.3E+11	3.6E+11		17.7%
Single Sample Maximum					4.4E+10	1513	**87.8 %***

*Reduction required to ensure 303(d) listing requirements that <10% of all samples are ≥185CFU/100mL

Table 6-6 Marshyhope Bacteria Concentrations & Loadings, and Allocations

Marshyhope	Flow Range (ft^3/s)	Average Flow (ft^3/s)	Geomean (CFU/100mL)	Baseline Load (CFU/day)	TMDL Load (CFU/day)	90^{th}% Sample Value	% Reduction
Minimum	0.0						
First Quartile	< 22.0	12.4	43	1.3E+10	3.0E+10		---
Second Quartile	22.0 - 44.4	31.6	28	2.2E+10	7.7E+10		---
Third Quartile	44.4 - 76.0	58.5	52	7.5E+10	1.4E+11		---
Forth Quartile	> 76.0	155.5	218	8.3E+11	3.8E+11		54.0%
Maximum	2591.0						
Overall		64.5	71	1.1E+11	1.6E+11		---
Single Sample Maximum					1.6E+10	1291	**85.7 %***

*Reduction required to ensure 303(d) listing requirements that <10% of all samples are ≥185CFU/100mL

Bacteria Reductions and TMDL Load Allocations

It is assumed that the only sources of bacteria entering the Cheasapeake Drainage Basin are non-point sources (NPS: runoff, subsurface flow, failing septic systems, resuspension from sediment, direct deposition, etc.). All NPS sources are combined and are considered as one load allocation is determined by reducing the NPS baseline loading by an appropriate level to ensure the State water quality standards are met. Both the geometric mean and the single sample maximum must be considered so the following overall reductions from the 1997-2005 baseline levels are required.

Chester River Watershed: 75.6% reduction which shall result in reducing a yearly-mean bacteria load from 1.9E+11 CFU per day to 4.6E+10 CFU per day.

Choptank River Watershed: 87.8% reduction which shall result in reducing a yearly-mean bacteria load from 4.3E+11 CFU per day to 4.4E+10 CFU per day.

Marshyhope River Watershed: 85.7% reduction which shall result in reducing a yearly-mean bacteria load from 1.1E+11 CFU per day to 1.6E+10 CFU per day.

Source Tracking Adjustment Factor

The Source Tracking Adjustment Factor (STAF) is a multiplier used to normalize human health risk associated with total fecal enterococci counts to enterococci counts derived exclusively from human sources. Bacteria source tracking (BST) data and the STAF, when available, will be used throughout the State to determine the sources of fecal contamination and in the development of pollution control strategies (PCSs).

7.0 DISCUSSION OF REGULATORY REQUIREMENTS FOR TMDLS

Federal regulations at 40 CFR Section 130 require that TMDLs must meet the following eight minimum regulatory requirements:

1. The TMDLs must be designed to achieve applicable water quality standards.
2. The TMDLs must include a total allowable load as well as individual waste load allocations for point sources and load allocations for nonpoint sources.
3. The TMDLs must consider the impact of background pollutants.
4. The TMDLs must consider critical environmental conditions.
5. The TMDLs must consider seasonal variations.
6. The TMDLs must include a margin of safety.
7. The TMDLs must have been subject to public participation.
8. There should be a reasonable assurance that the TMDLs can be met.

As will be discussed in the following, the TMDLs for the Chester River, Choptank River, and Marshyhope Creek meet the above eight minimum regulatory requirements.

1. The TMDLs must be designed to achieve applicable water quality standards.

The water quality standards for dissolved oxygen and bacteria and nutrient guidelines for total nitrogen and total phosphorus applicable to the Chesapeake drainage watersheds were described in Chapter 1. The State of Delaware dissolved oxygen criteria for fresh water streams is 5.5 mg/l; the enterococcus criteria is 100 CFU/100 ml as a 30 day geometric mean and 185 CFU/100 ml as a single sample maximum; and the TMDL nutrient target levels are 3.0 mg/l for total nitrogen and 0.2 mg/l for total phosphorus. Additionally, the State of Maryland has a dissolved oxygen standard of 5.0 mg/l, which must be met as waters cross the state line from Delaware into Maryland. The analyses show that for Chester River, the standards can be met by capping the total nitrogen load at the baseline level, reducing the total phosphorus load by 40% from the baseline level, and reducing the bacteria load by 75.6% from the baseline level. For Choptank River, the standards can be met by capping the total nitrogen load at the baseline level, reducing the total phosphorus load by 40% from the baseline level, and reducing the bacteria load by 87.8% from the baseline level. For Marshyhope Creek, the standards can be met by reducing the total nitrogen load by 20% from the baseline level, reducing the total phosphorus load by 25% from the baseline level, and reducing the bacteria load by 85.7% from the baseline level. Therefore, it can be concluded that the proposed TMDLs meets the applicable water quality criteria and target values.

2. The TMDLs must include a total allowable load as well as individual waste load allocations for point sources and load allocations for nonpoint sources.

The total allowable loads have been calculated and are presented in Table 5-2 for nutrients and Table 6-4 through 6-6 for bacteria. Since there are no active point sources discharging nutrients or bacteria within the Chester River, Choptank River, or Marshyhope Creek Watersheds, these TMDLs do not contain a waste load allocation for point sources and the nutrient loads considered in this study are entirely generated from nonpoint sources under average and critical low flow conditions. Therefore, it can be concluded that the proposed TMDLs have considered but do not warrent allocations for point sources and include alloctions for nonpoint sources.

3. The TMDLs must consider the impact of background pollutants.

The TMDL analyses for the Chester River, Choptank River, and Marshyhope Creek were based on calibrated Qual2E water quality models and/or water quality data collected in the watershed. Since background conditions are reflected in the calibrated models and the monitoring data, it can be concluded that the impact of background pollutants is accounted in these TMDL analyses.

4. The TMDLs must consider critical environmental conditions.

Low stream flow during summer months coupled with high water temperatures constitute critical conditions for Chester River, Choptank River, and Marshyhope Creek and has been recognized and simulated in these analyses. A scenario that incorporated 7Q10 flow with high water temperature was considered in each case. Headwater conditions and tributary inflow conditions were defined using data collected during summer months (July, August, and September). Details of the model inputs and results of the model runs are discussed in Chapter 3 and showed that implementing nonpoint source reductions of 40% phosphorus in Chester River, 40% phosphorus in Choptank River, and 20% nitrogen/25% phosphorus in Marshyhope Creek would result in achieving water quality standards and nutrient targets. For bacteria, concentrations and loadings were analysed over a range of flow conditions, which include any critical conditions. Therefore, the critical conditions of Chester River, Choptank River, and Marshyhope Creek were considered in this analysis.

5. The TMDLs must consider seasonal variations.

Seasonal variations are considered in the Chester River, Choptank River, and Marshyhope Creek Qual2E Models as the models were calibrated to the average flow and water quality conditions. The data used to define the model inputs were collected during 2001-2003 at different months (see Surface Water Monitoring Program FY2000), which reflected the seasonal variations in the models. In addition, the models were also run under summer critical condition of 7Q10 flow coupled with high temperature as well as summer water quality concentrations. The data used for the bacteria analyses was collected over an eight year period, with each season represented in the data set. Therefore, seasonal variations have been considered for these analyses.

6. The TMDLs must include a margin of safety.

EPA's technical guidance allows consideration of a margin of safety as implicit or as explicit. An implicit margin of safety considers the conservative assumptions for model development and TMDL establishment. An explicit margin of safety reserves a specified percentage of assimilative capacity unassigned to account for uncertainties, lack of sufficient data, or future growth.

An implicit margin of safety has been considered for the Chester River, Choptank River, and Marshyhope Creek nutrient analyses. The Qual2E models were calibrated using conservative assumptions regarding reaction rates, pollutant loads, and simultaneous occurrence of critical environmental conditions, such as low flows and high temperatures. Consideration of these conservative assumptions contributes to the implicit margin of safety and therefore an adequate margin of safety is included in the nutrient TMDLs. For the bacteria analyses, an explicit margin of safety is incorportated in the Source Tracking Adjustment Factor (STAF), a tool that will be used in the implementation and best management practice designs following the adoption of the TMDL. Therefore, an adequate margin of safety is included in the bacteria TMDLs.

7. The TMDLs must have been subject to public participation.

The proposed TMDLs for the Chester River, Choptank River, and Marshyhope Creek were presented at two public workshops. The first was held on August 30, 2005 at the Hartly Fire Hall in Hartly, Delaware and the second was held September 1, 2005 at the University of Delaware Research and Educatin Center in Georgetown, Delaware. A public hearing was also held on October 27, 2005, at the University of Delaware Research and Educatin Center in Georgetown, Delaware. Notices adversitising the public workshops and hearing were published in two local and regional newspapers. In addition, notice of the public hearing and proposed regulations were published in the October 1, 2005 issue of the Delaware Register of Regulations (Volume 9, Issue 4). The hearing record remained open for public comment until 4:30pm on October 31, 2005. Considering these opportunities, it can be concluded that the TMDLs for the Chester River, Choptank River, and Marshyhope Creek have been subject to significant public participation.

8. There should be a reasonable assurance that the TMDLs can be met.
The TMDLs for the Chester River, Choptank River, and Marshyhope Creek require reduction of nutrients and bacteria from nonpoint sources. As a result of these reductions, water quality standards with regard to dissolved oxygen and enterococcus bacteria will be met in all segments of these three waterbodies. Following adoption of these TMDLs, the Delaware DNREC in association with local citizen groups and other affected parties, will implement the requirements of these TMDLs through development of Pollution Control Strategies. Therefore, it can be concluded that there is a reasonable assurance that the TMDLs for the Chester River, Choptank River, and Marshyhope Creek will be met.

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Appendix A – Input and Output Data for Cypress Branch Qual2E Model Calibration (Run Cy127)

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                                               * * * QUAL-2E  STREAM QUALITY ROUTING MODEL * * *
                                                      Version 3.22  --  May 1996

 $$$ (PROBLEM TITLES) $$$

CARD TYPE                             QUAL-2E PROGRAM TITLES
TITLE01              Cy127, Cypress Branch, April 11, 2005
TITLE02              Based on Cy123, Annual Average Baseline Condition
TITLE03   NO         CONSERVATIVE MINERAL   I
TITLE04   NO         CONSERVATIVE MINERAL  II
TITLE05   NO         CONSERVATIVE MINERAL III
TITLE06   NO         TEMPERATURE
TITLE07  YES         5-DAY BIOCHEMICAL OXYGEN DEMAND
TITLE08  YES         ALGAE AS CHL-A IN UG/L
TITLE09  YES         PHOSPHORUS CYCLE AS P IN MG/L
TITLE10                (ORGANIC-P; DISSOLVED-P)
TITLE11  YES         NITROGEN CYCLE AS N IN MG/L
TITLE12                (ORGANIC-N; AMMONIA-N; NITRITE-N;' NITRATE-N)
TITLE13  YES         DISSOLVED OXYGEN IN MG/L
TITLE14   NO         FECAL COLIFORM IN NO./100 ML
TITLE15   NO         ARBITRARY NON-CONSERVATIVE
ENDTITLE

 $$$ DATA TYPE 1 (CONTROL DATA) $$$

CARD TYPE                                    CARD TYPE
LIST DATA INPUT             0.00000                                     0.00000
WRITE OPTIONAL SUMMARY      0.00000                                     0.00000
NO FLOW AUGMENTATION        0.00000                                     0.00000
STEADY STATE                0.00000                                     0.00000
NO TRAP CHANNELS            0.00000                                     0.00000
PRINT LCD/SOLAR DATA        0.00000                                     0.00000
PLOT DO AND BOD             0.00000                                     0.00000
FIXED DNSTM CONC (YES=1)=   0.00000         5D-ULT BOD CONV K COEF  =   0.23000
INPUT METRIC            =   1.00000         OUTPUT METRIC           =   1.00000
NUMBER OF REACHES       =   2.00000         NUMBER OF JUNCTIONS     =   0.00000
NUM OF HEADWATERS       =   1.00000         NUMBER OF POINT LOADS   =   3.00000
TIME STEP (HOURS)       =   0.00000         LNTH. COMP. ELEMENT (KM)=   0.50000
MAXIMUM ROUTE TIME (HRS)= 100.00000         TIME INC. FOR RPT2 (HRS)=   0.00000
LATITUDE OF BASIN (DEG) =  39.35000         LONGITUDE OF BASIN (DEG)=  75.75000
STANDARD MERIDIAN (DEG) =  75.00000         DAY OF YEAR START TIME  = 196.00000
EVAP. COEF.,(AE)        =   0.00001         EVAP. COEF.,(BE)        =   0.00001
ELEV. OF BASIN (METERS) =  22.00000         DUST ATTENUATION COEF.  =   0.10000
ENDATA1                     0.00000                                     0.00000

 $$$ DATA TYPE 1A (ALGAE PRODUCTION AND NITROGEN OXIDATION CONSTANTS) $$$

CARD TYPE                                           CARD TYPE
O UPTAKE BY NH3 OXID(MG O/MG N)=    3.5000          O UPTAKE BY NO2 OXID(MG O/MG N)=    1.0700
O PROD. BY ALGAE (MG O/MG A)   =    1.6000          O UPTAKE BY ALGAE (MG O/MG A)  =    2.0000
N CONTENT OF ALGAE (MG N/MG A) =    0.0800          P CONTENT OF ALGAE (MG P/MG A) =    0.0150
ALG MAX SPEC GROWTH RATE(1/DAY)=    2.0000          ALGAE RESPIRATION RATE (1/DAY) =    0.2750
N HALF SATURATION CONST. (MG/L)=    0.1550          P HALF SATURATION CONST. (MG/L)=    0.0255
LIN ALG SHADE CO (1/M-UGCHA/L) =    0.0027          NLIN SHADE (1/M-(UGCHA/L)**2/3)=    0.0165
LIGHT FUNCTION OPTION (LFNOPT) =    2.0000          LIGHT SAT'N COEF (LANGLEYS/MIN)=    0.0250
DAILY AVERAGING OPTION(LAVOPT) =    2.0000          LIGHT AVERAGING FACTOR (AFACT  =    0.9500
NUMBER OF DAYLIGHT HOURS (DLH) =   14.0000          TOTAL DAILY SOLR RAD (LANGLEYS)=  380.0000
ALGY GROWTH CALC OPTION(LGROPT)=    2.0000          ALGAL PREF FOR NH3-N (PREFN)   =    0.9000
ALG/TEMP SOLAR RAD FACT(TFACT) =    0.4500          NITRIFICATION INHIBITION COEF  =   10.0000
ENDATA1A                            0.0000                                              0.0000

 $$$ DATA TYPE 1B (TEMPERATURE CORRECTION CONSTANTS FOR RATE COEFFICIENTS) $$$

CARD TYPE     RATE CODE     THETA VALUE

THETA( 1)      BOD DECA       1.047     DFLT
THETA( 2)      BOD SETT       1.024     DFLT
THETA( 3)      OXY TRAN       1.024     DFLT
THETA( 4)      SOD RATE       1.060     DFLT
THETA( 5)      ORGN DEC       1.047     DFLT
THETA( 6)      ORGN SET       1.024     DFLT
THETA( 7)      NH3 DECA       1.083     DFLT
THETA( 8)      NH3 SRCE       1.074     DFLT
THETA( 9)      NO2 DECA       1.047     DFLT
THETA(10)      PORG DEC       1.047     DFLT
THETA(11)      PORG SET       1.024     DFLT
THETA(12)      DISP SRC       1.074     DFLT
THETA(13)      ALG GROW       1.047     DFLT
THETA(14)      ALG RESP       1.047     DFLT
THETA(15)      ALG SETT       1.024     DFLT
THETA(16)      COLI DEC       1.047     DFLT
THETA(17)      ANC DECA       1.000     DFLT
THETA(18)      ANC SETT       1.024     DFLT
THETA(19)      ANC SRCE       1.000     DFLT
ENDATA1B

 $$$ DATA TYPE 2 (REACH IDENTIFICATION) $$$

CARD TYPE           REACH ORDER AND IDENT              R. MI/KM           R. MI/KM
```

STREAM REACH	1.0	RCH= Segment 1	FROM	5.0	TO	2.5
STREAM REACH	2.0	RCH= Segment 2	FROM	2.5	TO	0.0
ENDATA2	0.0			0.0		0.0

$$$ DATA TYPE 3 (TARGET LEVEL DO AND FLOW AUGMENTATION SOURCES) $$$

CARD TYPE	REACH	AVAIL HDWS	TARGET	ORDER OF AVAIL SOURCES					
ENDATA3	0.	0.	0.0	0.	0.	0.	0.	0.	0.

$$$ DATA TYPE 4 (COMPUTATIONAL REACH FLAG FIELD) $$$

CARD TYPE	REACH	ELEMENTS/REACH	COMPUTATIONAL FLAGS
FLAG FIELD	1.	5.	1.6.2.6.2.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	2.	5.	2.6.2.2.5.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
ENDATA4	0.	0.	0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.

$$$ DATA TYPE 5 (HYDRAULIC DATA FOR DETERMINING VELOCITY AND DEPTH) $$$

CARD TYPE	REACH	COEF-DSPN	COEFQV	EXPOQV	COEFQH	EXPOQH	CMANN
HYDRAULICS	1.	100.00	0.253	0.507	0.587	0.380	0.040
HYDRAULICS	2.	100.00	0.253	0.507	0.587	0.380	0.040
ENDATA5	0.	0.00	0.000	0.000	0.000	0.000	0.000

$$$ DATA TYPE 5A (STEADY STATE TEMPERATURE AND CLIMATOLOGY DATA) $$$

CARD TYPE	REACH	ELEVATION	DUST COEF	CLOUD COVER	DRY BULB TEMP	WET BULB TEMP	ATM PRESSURE	WIND	SOLAR RAD ATTENUATION
TEMP/LCD	1.	6.71	0.10	0.10	25.00	20.00	980.00	2.50	1.00
TEMP/LCD	2.	6.71	0.10	0.10	25.00	20.00	980.00	2.50	1.00
ENDATA5A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 6 (REACTION COEFFICIENTS FOR DEOXYGENATION AND REAERATION) $$$

CARD TYPE	REACH	K1	K3	SOD RATE	K2OPT	K2	COEQK2 OR TSIV COEF OR FOR OPT 8	EXPQK2 SLOPE FOR OPT 8
REACT COEF	1.	0.20	0.00	0.300	5.	0.00	0.000	0.00000
REACT COEF	2.	0.20	0.00	0.300	5.	0.00	0.000	0.00000
ENDATA6	0.	0.00	0.00	0.000	0.	0.00	0.000	0.00000

$$$ DATA TYPE 6A (NITROGEN AND PHOSPHORUS CONSTANTS) $$$

CARD TYPE	REACH	CKNH2	SETNH2	CKNH3	SNH3	CKNO2	CKPORG	SETPORG	SPO4
N AND P COEF	1.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N AND P COEF	2.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ENDATA6A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 6B (ALGAE/OTHER COEFFICIENTS) $$$

CARD TYPE	REACH	ALPHAO	ALGSET	EXCOEF	CK5 CKCOLI	CKANC	SETANC	SRCANC
ALG/OTHER COEF	1.	75.00	0.00	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	2.	75.00	0.00	0.01	0.00	0.00	0.00	0.00
ENDATA6B	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 7 (INITIAL CONDITIONS) $$$

CARD TYPE	REACH	TEMP	D.O.	BOD	CM-1	CM-2	CM-3	ANC	COLI
INITIAL COND-1	1.	15.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-1	2.	15.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ENDATA7	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 7A (INITIAL CONDITIONS FOR CHOROPHYLL A, NITROGEN, AND PHOSPHORUS) $$$

CARD TYPE	REACH	CHL-A	ORG-N	NH3-N	NO2-N	NO3-N	ORG-P	DIS-P
INITIAL COND-2	1.	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-2	2.	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ENDATA7A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 8 (INCREMENTAL INFLOW CONDITIONS) $$$

CARD TYPE	REACH	FLOW	TEMP	D.O.	BOD	CM-1	CM-2	CM-3	ANC	COLI
INCR INFLOW-1	1.	0.086	15.27	4.80	3.45	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	2.	0.192	15.27	4.81	2.89	0.00	0.00	0.00	0.00	0.00
ENDATA8	0.	0.000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 8A (INCREMENTAL INFLOW CONDITIONS FOR CHLOROPHYLL A, NITROGEN, AND PHOSPHORUS) $$$

CARD TYPE	REACH	CHL-A	ORG-N	NH3-N	NO2-N	NO3-N	ORG-P	DIS-P
INCR INFLOW-2	1.	0.00	1.02	0.19	0.10	0.97	0.04	0.03
INCR INFLOW-2	2.	0.00	1.83	0.14	0.07	0.67	0.03	0.03
ENDATA8A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 9 (STREAM JUNCTIONS) $$$

CARD TYPE	JUNCTION ORDER AND IDENT	UPSTRM	JUNCTION	TRIB
ENDATA9	0.	0.	0.	0.

$$$ DATA TYPE 10 (HEADWATER SOURCES) $$$

CARD TYPE	HDWTR ORDER	NAME	FLOW	TEMP	D.O.	BOD	CM-1	CM-2	CM-3

HEADWTR-1	1.	Cypress Headwatr	0.12	15.27	4.77	2.63	0.00	0.00	0.00
ENDATA10	0.		0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 10A (HEADWATER CONDITIONS FOR CHLOROPHYLL, NITROGEN, PHOSPHORUS, COLIFORM AND SELECTED NON-CONSERVATIVE CONSTITUENT) $$$

CARD TYPE	HDWTR ORDER	ANC	COLI	CHL-A	ORG-N	NH3-N	NO2-N	NO3-N	ORG-P	DIS-P
HEADWTR-2	1.	0.00	0.00E+00	19.73	1.20	0.10	0.02	0.20	0.11	0.05
ENDATA10A	0.	0.00	0.00E+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 11 (POINT SOURCE / POINT SOURCE CHARACTERISTICS) $$$

CARD TYPE	POINT LOAD ORDER	NAME	EFF	FLOW	TEMP	D.O.	BOD	CM-1	CM-2	CM-3
POINTLD-1	1.	BlkStalD R1	0.00	0.06	15.27	4.77	2.63	0.00	0.00	0.00
POINTLD-1	2.	DogwoodB R1	0.00	0.06	15.27	4.77	2.63	0.00	0.00	0.00
POINTLD-1	3.	Tributar R2	0.00	0.08	15.27	4.77	2.63	0.00	0.00	0.00
ENDATA11	0.		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 11A (POINT SOURCE CHARACTERISTICS - CHLOROPHYLL A, NITROGEN, PHOSPHORUS, COLIFORMS AND SELECTED NON-CONSERVATIVE CONSTITUENT) $$$

CARD TYPE	POINT LOAD ORDER	ANC	COLI	CHL-A	ORG-N	NH3-N	NO2-N	N03-N	ORG-P	DIS-P
POINTLD-2	1.	0.00	0.00E+00	19.73	1.20	0.10	0.02	0.20	0.11	0.05
POINTLD-2	2.	0.00	0.00E+00	19.73	1.20	0.10	0.02	0.20	0.11	0.05
POINTLD-2	3.	0.00	0.00E+00	19.73	1.20	0.10	0.02	0.20	0.11	0.05
ENDATA11A	0.	0.00	0.00E+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 12 (DAM CHARACTERISTICS) $$$

	DAM	RCH	ELE	ADAM	BDAM	FDAM	HDAM
ENDATA12	0.	0.	0.	0.00	0.00	0.00	0.00

$$$ DATA TYPE 13 (DOWNSTREAM BOUNDARY CONDITIONS-1) $$$

CARD TYPE TEMP D.O. BOD CM-1 CM-2 CM-3 ANC COLI

ENDATA13 DOWNSTREAM BOUNDARY CONCENTRATIONS ARE UNCONSTRAINED

$$$ DATA TYPE 13A (DOWNSTREAM BOUNDARY CONDITIONS-2) $$$

CARD TYPE CHL-A ORG-N NH3-N NO2-N NH3-N ORG-P DIS-P

ENDATA13A DOWNSTREAM BOUNDARY CONCENTRATIONS ARE UNCONSTRAINED

STEADY STATE ALGAE/NUTRIENT/DISSOLVED OXYGEN SIMULATION; CONVERGENCE SUMMARY:

VARIABLE	ITERATION	NUMBER OF NONCONVERGENT ELEMENTS
ALGAE GROWTH RATE	1	10
ALGAE GROWTH RATE	2	10
ALGAE GROWTH RATE	3	10
ALGAE GROWTH RATE	4	10
ALGAE GROWTH RATE	5	10
ALGAE GROWTH RATE	6	10
ALGAE GROWTH RATE	7	0
ALGAE GROWTH RATE	8	0

SUMMARY OF CONDITIONS FOR ALGAL GROWTH RATE SIMULATION:

1. LIGHT AVERAGING OPTION. LAVOPT= 2

   METHOD: MEAN SOLAR RADIATION DURING DAYLIGHT HOURS

   SOURCE OF SOLAR VALUES: DATA TYPE 1A
   DAILY NET SOLAR RADIATION: 1400.300 BTU/FT-2 (380.000 LANGLEYS)
   NUMBER OF DAYLIGHT HOURS: 0.0
   PHOTOSYNTHETIC ACTIVE FRACTION OF SOLAR RADIATION (TFACT): N/A
   MEAN SOLAR RADIATION ADJUSTMENT FACTOR (AFACT): 0.950

2. LIGHT FUNCTION OPTION: LFNOPT= 2

   SMITH FUNCTION, WITH 71% IMAX = 0.025 LANGLEYS/MIN

3. GROWTH ATTENUATION OPTION FOR NUTRIENTS. LGROPT= 2

   MINIMUM OF NITROGEN, PHOSPHORUS: FL*MIN(FN,FP)

DISSOLVED OXYGEN IN MG/L ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	5.09	5.22	5.43	5.48	5.66															
2	5.75	5.69	5.79	5.88	5.96															

5-DAY BIOCHEMICAL OXYGEN DEMAND ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	2.70	2.72	2.75	2.75	2.77															
2	2.77	2.74	2.74	2.74	2.73															

ORGANIC NITROGEN AS N IN MG/L ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1.18	1.17	1.16	1.16	1.15															
2	1.22	1.27	1.31	1.34	1.37															

AMMONIA AS N IN MG/L ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.12	0.12	0.12	0.12	0.13															
2	0.13	0.13	0.13	0.13	0.13															

NITRITE AS N IN MG/L ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.03	0.03	0.04	0.04	0.04															
2	0.04	0.04	0.04	0.05	0.05															

NITRATE AS N IN MG/L ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.29	0.32	0.37	0.37	0.40															
2	0.43	0.41	0.43	0.45	0.46															

ORGANIC PHOSPHORUS AS P IN MG/L ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.10	0.10	0.10	0.10	0.09															
2	0.09	0.09	0.08	0.08	0.08															

DISSOLVED PHOSPHORUS AS P IN MG/L ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.05	0.05	0.05	0.05	0.04															
2	0.04	0.04	0.04	0.04	0.04															

ALGAE AS CHL-A IN UG/L ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	17.73	17.19	16.22	16.17	15.53															
2	14.10	14.04	13.14	12.37	11.70															

ALGAE GROWTH RATES IN PER DAY ARE ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.58	0.57	0.57	0.57	0.57															
2	0.56	0.55	0.55	0.54	0.54															

PHOTOSYNTHESIS-RESPIRATION RATIOS ARE ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	2.09	2.08	2.06	2.06	2.05															
2	2.01	2.00	1.98	1.96	1.94															

***** STEADY STATE SIMULATION *****

** HYDRAULICS SUMMARY **

ELE ORD	RCH NUM	ELE NUM	BEGIN LOC KILO	END LOC KILO	FLOW CMS	POINT SRCE CMS	INCR FLOW CMS	VEL MPS	TRVL TIME DAY	DEPTH M	WIDTH M	VOLUME K-CU-M	BOTTOM AREA K-SQ-M	X-SECT AREA SQ-M	DSPRSN COEF SQ-M/S
1	1	1	5.00	4.50	0.14	0.00	0.02	0.094	0.062	0.279	5.409	0.76	2.98	1.51	0.41
2	1	2	4.50	4.00	0.22	0.06	0.02	0.118	0.049	0.331	5.687	0.94	3.18	1.88	0.59
3	1	3	4.00	3.50	0.24	0.00	0.02	0.123	0.047	0.341	5.735	0.98	3.21	1.95	0.63
4	1	4	3.50	3.00	0.31	0.06	0.02	0.140	0.041	0.377	5.909	1.11	3.33	2.23	0.78
5	1	5	3.00	2.50	0.33	0.00	0.02	0.144	0.040	0.385	5.945	1.14	3.36	2.29	0.82
6	2	1	2.50	2.00	0.37	0.00	0.04	0.152	0.038	0.401	6.019	1.21	3.41	2.42	0.89
7	2	2	2.00	1.50	0.49	0.08	0.04	0.175	0.033	0.446	6.209	1.38	3.55	2.77	1.12
8	2	3	1.50	1.00	0.52	0.00	0.04	0.182	0.032	0.459	6.262	1.44	3.59	2.87	1.19
9	2	4	1.00	0.50	0.56	0.00	0.04	0.189	0.031	0.472	6.312	1.49	3.63	2.98	1.27
10	2	5	0.50	0.00	0.60	0.00	0.04	0.195	0.030	0.483	6.359	1.54	3.66	3.07	1.34

***** STEADY STATE SIMULATION *****

** REACTION COEFFICIENT SUMMARY **

RCH NUM	ELE NUM	DO SAT MG/L	K2 OPT	OXYGN REAIR 1/DAY	BOD DECAY 1/DAY	BOD SETT 1/DAY	SOD RATE G/M2D	ORGN DECAY 1/DAY	ORGN SETT 1/DAY	NH3 DECAY 1/DAY	NH3 SRCE MG/M2D	NO2 DECAY 1/DAY	ORGP DECAY 1/DAY	ORGP SETT 1/DAY	DISP SRCE MG/M2D	COLI DECAY 1/DAY	ANC DECAY 1/DAY	ANC SETT 1/DAY	ANC SRCE MG/M2D
1	1	9.82	5	1.43	0.16	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	2	9.82	5	1.46	0.16	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	3	9.82	5	1.50	0.16	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	4	9.82	5	1.53	0.16	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	5	9.82	5	1.55	0.16	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	1	9.82	5	1.56	0.16	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	2	9.82	5	1.59	0.16	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	3	9.82	5	1.62	0.16	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	4	9.82	5	1.63	0.16	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	5	9.82	5	1.64	0.16	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

***** STEADY STATE SIMULATION *****

** WATER QUALITY VARIABLES **

RCH NUM	ELE NUM	TEMP DEG-C	CM-1	CM-2	CM-3	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM-N MG/L	ORGP MG/L	DIS-P MG/L	SUM-P MG/L	COLI #/100ML	ANC	CHLA UG/L
1	1	15.27	0.00	0.00	0.00	5.09	2.70	1.18	0.12	0.03	0.29	1.62	0.10	0.05	0.15	.00E+00	0.00	17.73
1	2	15.27	0.00	0.00	0.00	5.22	2.72	1.17	0.12	0.03	0.32	1.64	0.10	0.05	0.15	.00E+00	0.00	17.19
1	3	15.27	0.00	0.00	0.00	5.43	2.75	1.16	0.12	0.04	0.37	1.69	0.10	0.05	0.14	.00E+00	0.00	16.22
1	4	15.27	0.00	0.00	0.00	5.48	2.75	1.16	0.12	0.04	0.37	1.69	0.10	0.05	0.14	.00E+00	0.00	16.17
1	5	15.27	0.00	0.00	0.00	5.66	2.77	1.15	0.13	0.04	0.40	1.72	0.09	0.04	0.14	.00E+00	0.00	15.53
2	1	15.27	0.00	0.00	0.00	5.75	2.77	1.22	0.13	0.04	0.43	1.82	0.09	0.04	0.13	.00E+00	0.00	14.10
2	2	15.27	0.00	0.00	0.00	5.69	2.74	1.27	0.13	0.04	0.41	1.85	0.09	0.04	0.13	.00E+00	0.00	14.04
2	3	15.27	0.00	0.00	0.00	5.79	2.74	1.31	0.13	0.04	0.43	1.91	0.08	0.04	0.12	.00E+00	0.00	13.14
2	4	15.27	0.00	0.00	0.00	5.88	2.74	1.34	0.13	0.05	0.45	1.96	0.08	0.04	0.12	.00E+00	0.00	12.37
2	5	15.27	0.00	0.00	0.00	5.96	2.73	1.37	0.13	0.05	0.46	2.01	0.08	0.04	0.11	.00E+00	0.00	11.70

***** STEADY STATE SIMULATION *****

** ALGAE DATA **

ELE ORD	RCH NUM	ELE NUM	CHLA UG/L	ALGY GRWTH 1/DAY	ALGY RESP 1/DAY	ALGY SETT M/DAY	A P/R RATIO *	NET P-R MG/L-D	NH3 PREF *	NH3-N FRACT N-UPTKE *	LIGHT EXTCO 1/M	ALGAE GROWTH RATE ATTEN FACTORS LIGHT *	NITRGN *	PHSPRS *
1	1	1	17.73	0.58	0.22	0.00	2.09	0.11	0.90	0.78	0.17	0.55	0.72	0.65
2	1	2	17.19	0.57	0.22	0.00	2.08	0.11	0.90	0.77	0.17	0.55	0.74	0.65
3	1	3	16.22	0.57	0.22	0.00	2.06	0.10	0.90	0.75	0.16	0.55	0.76	0.64
4	1	4	16.17	0.57	0.22	0.00	2.06	0.10	0.90	0.75	0.16	0.55	0.76	0.64
5	1	5	15.53	0.57	0.22	0.00	2.05	0.10	0.90	0.74	0.15	0.55	0.77	0.64
6	2	1	14.10	0.56	0.22	0.00	2.01	0.08	0.90	0.73	0.14	0.55	0.78	0.62
7	2	2	14.04	0.55	0.22	0.00	2.00	0.08	0.90	0.73	0.14	0.55	0.78	0.62
8	2	3	13.14	0.55	0.22	0.00	1.98	0.08	0.90	0.73	0.14	0.55	0.78	0.62
9	2	4	12.37	0.54	0.22	0.00	1.96	0.07	0.90	0.72	0.13	0.55	0.79	0.61
10	2	5	11.70	0.54	0.22	0.00	1.94	0.06	0.90	0.72	0.13	0.55	0.79	0.60

***** STEADY STATE SIMULATION *****

** DISSOLVED OXYGEN DATA **

ELE ORD	RCH NUM	ELE NUM	TEMP DEG-C	DO SAT MG/L	DO MG/L	DO DEF MG/L	DAM INPUT MG/L	NIT INHIB FACT	COMPONENTS OF DISSOLVED OXYGEN MASS BALANCE (MG/L-DAY) F-FNCTN INPUT	OXYGN REAIR	C-BOD	SOD	NET P-R	NH3-N	NO2-N
1	1	1	15.27	9.82	5.09	4.73	0.00	1.00	77.60	6.78	-0.44	-0.81	0.11	0.00	0.00
2	1	2	15.27	9.82	5.22	4.61	0.00	1.00	35.13	6.74	-0.44	-0.69	0.11	0.00	0.00
3	1	3	15.27	9.82	5.43	4.39	0.00	1.00	7.30	6.59	-0.44	-0.67	0.10	0.00	0.00
4	1	4	15.27	9.82	5.48	4.34	0.00	1.00	27.11	6.61	-0.44	-0.60	0.10	0.00	0.00
5	1	5	15.27	9.82	5.66	4.17	0.00	1.00	6.23	6.45	-0.45	-0.59	0.10	0.00	0.00
6	2	1	15.27	9.82	5.75	4.07	0.00	1.00	13.20	6.35	-0.45	-0.57	0.08	0.00	0.00
7	2	2	15.27	9.82	5.69	4.13	0.00	1.00	35.04	6.58	-0.44	-0.51	0.08	0.00	0.00
8	2	3	15.27	9.82	5.79	4.03	0.00	1.00	11.10	6.53	-0.44	-0.50	0.08	0.00	0.00
9	2	4	15.27	9.82	5.88	3.94	0.00	1.00	10.72	6.42	-0.44	-0.48	0.07	0.00	0.00
10	2	5	15.27	9.82	5.96	3.86	0.00	1.00	10.37	6.34	-0.44	-0.47	0.06	0.00	0.00

```
                                   D I S S O L V E D  O X Y G E N  ( M G / L )
         0.0       1.0       2.0       3.0       4.0       5.0       6.0       7.0       8.0       9.0      10.0
R    5.0 ++++.+++++++++++++++++++++++++++++++++++++++++++++*++++++++++++++++++++++++++++++++++++++++++++++++++
          +    .    +         +         +         +         +*        +         +         +         +         +
I         +    .    +         +         +         +         +   *     +         +         +         +         +
          +    .    +         +         +         +         +   *     +         +         +         +         +
V         +    .                                                  *                                             +
          +    .                                                   *                                            +
E         +    .    +         +         +         +         +     *   +         +         +         +         +
          +    .    +         +         +         +         +      *  +         +         +         +         +
R         +    .    +         +         +         +         +        *+         +         +         +         +
     0.5 ++++.++++++++++++++++++++++++++++++++++++++++++++++++++++++*+++++++++++++++++++++++++++++++++++++++++
         0.0       5.0      10.0      15.0      20.0      25.0      30.0      35.0      40.0      45.0      50.0
                         B I O C H E M I C A L  O X Y G E N  D E M A N D  ( M G / L )
```

DISSOLVED OXYGEN = * * * *

BIOCHEMICAL OXYGEN DEMAND = ...

Appendix B – Input and Output Data for Sewell Branch Qual2E Model Calibration (Run Se050)

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                                                * * * QUAL-2E  STREAM QUALITY ROUTING MODEL * * *
                                                         Version 3.22  --  May 1996

 $$$ (PROBLEM TITLES) $$$

CARD TYPE                             QUAL-2E PROGRAM TITLES
TITLE01             Se050, Sewell Branch, April 27, 2005
TITLE02             Based on Se032, Annual Average Baseline Condition
TITLE03   NO        CONSERVATIVE MINERAL   I
TITLE04   NO        CONSERVATIVE MINERAL  II
TITLE05   NO        CONSERVATIVE MINERAL III
TITLE06   NO        TEMPERATURE
TITLE07  YES        5-DAY BIOCHEMICAL OXYGEN DEMAND
TITLE08  YES        ALGAE AS CHL-A IN UG/L
TITLE09  YES        PHOSPHORUS CYCLE AS P IN MG/L
TITLE10               (ORGANIC-P; DISSOLVED-P)
TITLE11  YES        NITROGEN CYCLE AS N IN MG/L
TITLE12               (ORGANIC-N; AMMONIA-N; NITRITE-N;' NITRATE-N)
TITLE13  YES        DISSOLVED OXYGEN IN MG/L
TITLE14   NO        FECAL COLIFORM IN NO./100 ML
TITLE15   NO        ARBITRARY NON-CONSERVATIVE
ENDTITLE

 $$$ DATA TYPE 1 (CONTROL DATA) $$$

CARD TYPE                                            CARD TYPE
LIST DATA INPUT             0.00000                                            0.00000
WRITE OPTIONAL SUMMARY      0.00000                                            0.00000
NO FLOW AUGMENTATION        0.00000                                            0.00000
STEADY STATE                0.00000                                            0.00000
NO TRAP CHANNELS            0.00000                                            0.00000
PRINT LCD/SOLAR DATA        0.00000                                            0.00000
PLOT DO AND BOD             0.00000                                            0.00000
FIXED DNSTM CONC (YES=1)=   0.00000          5D-ULT BOD CONV K COEF  =   0.23000
INPUT METRIC            =   1.00000          OUTPUT METRIC           =   1.00000
NUMBER OF REACHES       =   2.00000          NUMBER OF JUNCTIONS     =   0.00000
NUM OF HEADWATERS       =   1.00000          NUMBER OF POINT LOADS   =   4.00000
TIME STEP (HOURS)       =   0.00000          LNTH. COMP. ELEMENT (KM)=   0.50000
MAXIMUM ROUTE TIME (HRS)= 100.00000          TIME INC. FOR RPT2 (HRS)=   0.00000
LATITUDE OF BASIN (DEG) =  39.25000          LONGITUDE OF BASIN (DEG)=  75.75000
STANDARD MERIDIAN (DEG) =  75.00000          DAY OF YEAR START TIME  = 196.00000
EVAP. COEF.,(AE)        =   0.00001          EVAP. COEF.,(BE)        =   0.00001
ELEV. OF BASIN (METERS) =  20.00000          DUST ATTENUATION COEF.  =   0.10000
ENDATA1                     0.00000                                      0.00000

 $$$ DATA TYPE 1A (ALGAE PRODUCTION AND NITROGEN OXIDATION CONSTANTS) $$$

CARD TYPE                                           CARD TYPE
O UPTAKE BY NH3 OXID(MG O/MG N)=    3.5000          O UPTAKE BY NO2 OXID(MG O/MG N)=    1.0700
O PROD. BY ALGAE (MG O/MG A)   =    1.6000          O UPTAKE BY ALGAE (MG O/MG A)  =    2.0000
N CONTENT OF ALGAE (MG N/MG A) =    0.0800          P CONTENT OF ALGAE (MG P/MG A) =    0.0150
ALG MAX SPEC GROWTH RATE(1/DAY)=    2.0000          ALGAE RESPIRATION RATE (1/DAY) =    0.2750
N HALF SATURATION CONST. (MG/L)=    0.1550          P HALF SATURATION CONST. (MG/L)=    0.0255
LIN ALG SHADE CO (1/M-UGCHA/L) =    0.0027          NLIN SHADE (1/M-(UGCHA/L)**2/3)=    0.0165
LIGHT FUNCTION OPTION (LFNOPT) =    2.0000          LIGHT SAT'N COEF (LANGLEYS/MIN)=    0.0250
DAILY AVERAGING OPTION(LAVOPT) =    2.0000          LIGHT AVERAGING FACTOR (AFACT  =    0.9500
NUMBER OF DAYLIGHT HOURS (DLH) =   14.0000          TOTAL DAILY SOLR RAD (LANGLEYS)=  380.0000
ALGY GROWTH CALC OPTION(LGROPT)=    2.0000          ALGAL PREF FOR NH3-N (PREFN)   =    0.9000
ALG/TEMP SOLAR RAD FACT(TFACT) =    0.4500          NITRIFICATION INHIBITION COEF  =   10.0000
ENDATA1A                            0.0000                                              0.0000

 $$$ DATA TYPE 1B (TEMPERATURE CORRECTION CONSTANTS FOR RATE COEFFICIENTS) $$$

CARD TYPE     RATE CODE     THETA VALUE

THETA( 1)      BOD DECA        1.047     DFLT
THETA( 2)      BOD SETT        1.024     DFLT
THETA( 3)      OXY TRAN        1.024     DFLT
THETA( 4)      SOD RATE        1.060     DFLT
THETA( 5)      ORGN DEC        1.047     DFLT
THETA( 6)      ORGN SET        1.024     DFLT
THETA( 7)      NH3 DECA        1.083     DFLT
THETA( 8)      NH3 SRCE        1.074     DFLT
THETA( 9)      NO2 DECA        1.047     DFLT
THETA(10)      PORG DEC        1.047     DFLT
THETA(11)      PORG SET        1.024     DFLT
THETA(12)      DISP SRC        1.074     DFLT
THETA(13)      ALG GROW        1.047     DFLT
THETA(14)      ALG RESP        1.047     DFLT
THETA(15)      ALG SETT        1.024     DFLT
THETA(16)      COLI DEC        1.047     DFLT
THETA(17)      ANC DECA        1.000     DFLT
THETA(18)      ANC SETT        1.024     DFLT
THETA(19)      ANC SRCE        1.000     DFLT
ENDATA1B

 $$$ DATA TYPE 2 (REACH IDENTIFICATION) $$$

CARD TYPE           REACH ORDER AND IDENT              R. MI/KM           R. MI/KM
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STREAM REACH     1.0  RCH= Segment 1         FROM          5.0    TO            2.5
STREAM REACH     2.0  RCH= Segment 2         FROM          2.5    TO            0.0
ENDATA2          0.0                                       0.0                  0.0

 $$$ DATA TYPE 3 (TARGET LEVEL DO AND FLOW AUGMENTATION SOURCES) $$$

CARD TYPE                  REACH  AVAIL HDWS TARGET     ORDER OF AVAIL SOURCES
ENDATA3                     0.       0.       0.0  0.  0.  0.  0.  0.  0.

 $$$ DATA TYPE 4 (COMPUTATIONAL REACH FLAG FIELD) $$$

CARD TYPE        REACH ELEMENTS/REACH             COMPUTATIONAL FLAGS
FLAG FIELD        1.        5.          1.6.2.6.2.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD        2.        5.          6.2.2.6.5.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
ENDATA4           0.        0.          0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.

 $$$ DATA TYPE 5 (HYDRAULIC DATA FOR DETERMINING VELOCITY AND DEPTH) $$$

CARD TYPE        REACH  COEF-DSPN  COEFQV    EXPOQV    COEFQH   EXPOQH     CMANN
HYDRAULICS        1.    100.00     0.137     0.173     0.333     0.137     0.040
HYDRAULICS        2.    100.00     0.137     0.173     0.333     0.137     0.040
ENDATA5           0.      0.00     0.000     0.000     0.000     0.000     0.000

 $$$ DATA TYPE 5A (STEADY STATE TEMPERATURE AND CLIMATOLOGY DATA) $$$

CARD TYPE                              DUST      CLOUD    DRY BULB  WET BULB     ATM                   SOLAR RAD
                REACH   ELEVATION      COEF      COVER      TEMP      TEMP    PRESSURE      WIND    ATTENUATION
TEMP/LCD          1.        6.10       0.10       0.10     25.00     20.00    980.00        2.50       1.00
TEMP/LCD          2.        6.10       0.10       0.10     25.00     20.00    980.00        2.50       1.00
ENDATA5A          0.        0.00       0.00       0.00      0.00      0.00      0.00        0.00       0.00

 $$$ DATA TYPE 6 (REACTION COEFFICIENTS FOR DEOXYGENATION AND REAERATION) $$$

CARD TYPE        REACH      K1         K3         SOD         K2OPT       K2       COEQK2    OR   EXPQK2
                                                  RATE                             TSIV COEF  OR    SLOPE
                                                                                   FOR OPT 8      FOR OPT 8
REACT COEF        1.       0.40       0.00       0.700         5.       0.00       0.000         0.00000
REACT COEF        2.       0.40       0.00       0.700         5.       0.00       0.000         0.00000
ENDATA6           0.       0.00       0.00       0.000         0.       0.00       0.000         0.00000

  $$$ DATA TYPE 6A (NITROGEN AND PHOSPHORUS CONSTANTS) $$$

CARD TYPE           REACH     CKNH2     SETNH2     CKNH3       SNH3      CKNO2      CKPORG    SETPORG      SPO4
N AND P COEF          1.       0.04      0.05       0.10       0.00       0.20       0.07       0.05       0.00
N AND P COEF          2.       0.04      0.05       0.10       0.00       0.20       0.07       0.05       0.00
ENDATA6A              0.       0.00      0.00       0.00       0.00       0.00       0.00       0.00       0.00

 $$$ DATA TYPE 6B (ALGAE/OTHER COEFFICIENTS) $$$

CARD TYPE           REACH     ALPHAO    ALGSET     EXCOEF      CK5       CKANC     SETANC     SRCANC
                                                             CKCOLI
ALG/OTHER COEF        1.      75.00      0.05       0.01       0.00       0.00       0.00       0.00
ALG/OTHER COEF        2.      75.00      0.05       0.01       0.00       0.00       0.00       0.00
ENDATA6B              0.       0.00      0.00       0.00       0.00       0.00       0.00       0.00

 $$$ DATA TYPE 7 (INITIAL CONDITIONS) $$$

CARD TYPE           REACH     TEMP       D.O.       BOD        CM-1       CM-2       CM-3        ANC       COLI
INITIAL COND-1        1.      13.82      0.00       0.00       0.00       0.00       0.00       0.00       0.00
INITIAL COND-1        2.      13.82      0.00       0.00       0.00       0.00       0.00       0.00       0.00
ENDATA7               0.       0.00      0.00       0.00       0.00       0.00       0.00       0.00       0.00

 $$$ DATA TYPE 7A (INITIAL CONDITIONS FOR CHOROPHYLL A, NITROGEN, AND PHOSPHORUS) $$$

CARD TYPE           REACH     CHL-A      ORG-N      NH3-N      NO2-N      NO3-N      ORG-P      DIS-P
INITIAL COND-2        1.       0.00       0.00       0.00       0.00       0.00       0.00       0.00
INITIAL COND-2        2.       0.00       0.00       0.00       0.00       0.00       0.00       0.00
ENDATA7A              0.       0.00       0.00       0.00       0.00       0.00       0.00       0.00

 $$$ DATA TYPE 8 (INCREMENTAL INFLOW CONDITIONS) $$$

CARD TYPE           REACH      FLOW       TEMP       D.O.        BOD       CM-1       CM-2       CM-3        ANC       COLI
INCR INFLOW-1         1.      0.044      13.82       5.09       4.82       0.00       0.00       0.00       0.00       0.00
INCR INFLOW-1         2.      0.089      13.82       4.87       4.62       0.00       0.00       0.00       0.00       0.00
ENDATA8               0.      0.000       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00

 $$$ DATA TYPE 8A (INCREMENTAL INFLOW CONDITIONS FOR CHLOROPHYLL A, NITROGEN, AND PHOSPHORUS) $$$

CARD TYPE           REACH     CHL-A      ORG-N      NH3-N      NO2-N      NO3-N      ORG-P      DIS-P
INCR INFLOW-2         1.       0.00       1.57       0.32       0.16       1.62       0.06       0.05
INCR INFLOW-2         2.       0.00       1.44       0.30       0.31       3.09       0.06       0.05
ENDATA8A              0.       0.00       0.00       0.00       0.00       0.00       0.00       0.00

 $$$ DATA TYPE 9 (STREAM JUNCTIONS) $$$

CARD TYPE                 JUNCTION ORDER AND IDENT         UPSTRM   JUNCTION     TRIB
ENDATA9                   0.                                  0.       0.          0.

 $$$ DATA TYPE 10 (HEADWATER SOURCES) $$$

CARD TYPE    HDWTR     NAME              FLOW       TEMP       D.O.       BOD       CM-1       CM-2       CM-3
             ORDER
```

HEADWTR-1	1.	Cypress Headwatr	0.12	13.82	7.49	2.54	0.00	0.00	0.00
ENDATA10	0.		0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 10A (HEADWATER CONDITIONS FOR CHLOROPHYLL, NITROGEN, PHOSPHORUS, COLIFORM AND SELECTED NON-CONSERVATIVE CONSTITUENT) $$$

CARD TYPE	HDWTR ORDER	ANC	COLI	CHL-A	ORG-N	NH3-N	NO2-N	NO3-N	ORG-P	DIS-P
HEADWTR-2	1.	0.00	0.00E+00	8.07	0.72	0.11	0.08	0.68	0.14	0.07
ENDATA10A	0.	0.00	0.00E+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 11 (POINT SOURCE / POINT SOURCE CHARACTERISTICS) $$$

CARD TYPE	POINT LOAD ORDER	NAME	EFF	FLOW	TEMP	D.O.	BOD	CM-1	CM-2	CM-3
POINTLD-1	1.	Tributa1 R1	0.00	0.08	13.82	7.49	2.54	0.00	0.00	0.00
POINTLD-1	2.	Tributa2 R1	0.00	0.04	13.82	7.49	2.54	0.00	0.00	0.00
POINTLD-1	3.	JordanBr R2	0.00	0.24	13.82	7.49	2.54	0.00	0.00	0.00
POINTLD-1	4.	BlancoDi R2	0.00	0.03	13.82	7.49	2.54	0.00	0.00	0.00
ENDATA11	0.		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 11A (POINT SOURCE CHARACTERISTICS - CHLOROPHYLL A, NITROGEN, PHOSPHORUS, COLIFORMS AND SELECTED NON-CONSERVATIVE CONSTITUENT) $$$

CARD TYPE	POINT LOAD ORDER	ANC	COLI	CHL-A	ORG-N	NH3-N	NO2-N	N03-N	ORG-P	DIS-P
POINTLD-2	1.	0.00	0.00E+00	8.07	0.72	0.11	0.08	0.68	0.14	0.07
POINTLD-2	2.	0.00	0.00E+00	8.07	0.72	0.11	0.08	0.68	0.14	0.07
POINTLD-2	3.	0.00	0.00E+00	8.07	0.72	0.11	0.08	0.68	0.14	0.07
POINTLD-2	4.	0.00	0.00E+00	8.07	0.72	0.11	0.08	0.68	0.14	0.07
ENDATA11A	0.	0.00	0.00E+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 12 (DAM CHARACTERISTICS) $$$

	DAM	RCH	ELE	ADAM	BDAM	FDAM	HDAM
ENDATA12	0.	0.	0.	0.00	0.00	0.00	0.00

$$$ DATA TYPE 13 (DOWNSTREAM BOUNDARY CONDITIONS-1) $$$

CARD TYPE	TEMP	D.O.	BOD	CM-1	CM-2	CM-3	ANC	COLI
ENDATA13	DOWNSTREAM BOUNDARY CONCENTRATIONS ARE UNCONSTRAINED							

$$$ DATA TYPE 13A (DOWNSTREAM BOUNDARY CONDITIONS-2) $$$

CARD TYPE	CHL-A	ORG-N	NH3-N	NO2-N	NH3-N	ORG-P	DIS-P
ENDATA13A	DOWNSTREAM BOUNDARY CONCENTRATIONS ARE UNCONSTRAINED						

STEADY STATE ALGAE/NUTRIENT/DISSOLVED OXYGEN SIMULATION; CONVERGENCE SUMMARY:

VARIABLE	ITERATION	NUMBER OF NONCONVERGENT ELEMENTS
ALGAE GROWTH RATE	1	10
ALGAE GROWTH RATE	2	10
ALGAE GROWTH RATE	3	10
ALGAE GROWTH RATE	4	10
ALGAE GROWTH RATE	5	10
ALGAE GROWTH RATE	6	10
ALGAE GROWTH RATE	7	0
ALGAE GROWTH RATE	8	0

SUMMARY OF CONDITIONS FOR ALGAL GROWTH RATE SIMULATION:

1. LIGHT AVERAGING OPTION.   LAVOPT= 2

   METHOD: MEAN SOLAR RADIATION DURING DAYLIGHT HOURS

   SOURCE OF SOLAR VALUES: DATA TYPE 1A
   DAILY NET SOLAR RADIATION: 1400.300 BTU/FT-2 (380.000 LANGLEYS)
   NUMBER OF DAYLIGHT HOURS: 0.0
   PHOTOSYNTHETIC ACTIVE FRACTION OF SOLAR RADIATION (TFACT): N/A
   MEAN SOLAR RADIATION ADJUSTMENT FACTOR (AFACT): 0.950

2. LIGHT FUNCTION OPTION: LFNOPT= 2

   SMITH FUNCTION, WITH 71% IMAX = 0.025 LANGLEYS/MIN

3. GROWTH ATTENUATION OPTION FOR NUTRIENTS.   LGROPT= 2

   MINIMUM OF NITROGEN, PHOSPHORUS: FL*MIN(FN,FP)

DISSOLVED OXYGEN IN MG/L ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	7.39	7.37	7.36	7.37	7.38															
2	7.39	7.39	7.39	7.40	7.41															

5-DAY BIOCHEMICAL OXYGEN DEMAND ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	2.65	2.66	2.70	2.70	2.73															
2	2.68	2.70	2.72	2.73	2.74															

ORGANIC NITROGEN AS N IN MG/L ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.77	0.78	0.81	0.82	0.84															
2	0.80	0.82	0.84	0.84	0.86															

AMMONIA AS N IN MG/L ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.13	0.13	0.14	0.14	0.15															
2	0.14	0.14	0.15	0.15	0.16															

NITRITE AS N IN MG/L ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.08	0.08	0.08	0.09	0.09															
2	0.09	0.10	0.10	0.11	0.11															

NITRATE AS N IN MG/L ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.74	0.75	0.79	0.80	0.82															
2	0.83	0.90	0.97	1.02	1.07															

ORGANIC PHOSPHORUS AS P IN MG/L ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.13	0.13	0.13	0.13	0.12															
2	0.13	0.13	0.12	0.12	0.12															

DISSOLVED PHOSPHORUS AS P IN MG/L ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.07	0.07	0.07	0.07	0.07															
2	0.07	0.07	0.07	0.07	0.07															

ALGAE AS CHL-A IN UG/L ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	7.64	7.56	7.36	7.32	7.19															
2	7.42	7.27	7.13	7.06	6.95															

ALGAE GROWTH RATES IN PER DAY ARE ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.60	0.60	0.60	0.60	0.60															
2	0.60	0.60	0.60	0.60	0.60															

PHOTOSYNTHESIS-RESPIRATION RATIOS ARE ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	2.34	2.33	2.33	2.33	2.33															
2	2.33	2.33	2.33	2.33	2.32															

***** STEADY STATE SIMULATION *****

** HYDRAULICS SUMMARY **

ELE ORD	RCH NUM	ELE NUM	BEGIN LOC KILO	END LOC KILO	FLOW CMS	POINT SRCE CMS	INCR FLOW CMS	VEL MPS	TRVL TIME DAY	DEPTH M	WIDTH M	VOLUME K-CU-M	BOTTOM AREA K-SQ-M	X-SECT AREA SQ-M	DSPRSN COEF SQ-M/S
1	1	1	5.00	4.50	0.13	0.00	0.01	0.096	0.060	0.252	5.397	0.68	2.95	1.36	0.38
2	1	2	4.50	4.00	0.22	0.08	0.01	0.105	0.055	0.270	7.622	1.03	4.08	2.06	0.44
3	1	3	4.00	3.50	0.22	0.00	0.01	0.105	0.055	0.272	7.835	1.06	4.19	2.13	0.45
4	1	4	3.50	3.00	0.28	0.04	0.01	0.109	0.053	0.280	9.043	1.26	4.80	2.53	0.47
5	1	5	3.00	2.50	0.28	0.00	0.01	0.110	0.053	0.281	9.241	1.30	4.90	2.59	0.48
6	2	1	2.50	2.00	0.55	0.24	0.02	0.123	0.047	0.307	14.474	2.22	7.55	4.44	0.58
7	2	2	2.00	1.50	0.56	0.00	0.02	0.124	0.047	0.308	14.798	2.28	7.71	4.56	0.58
8	2	3	1.50	1.00	0.58	0.00	0.02	0.124	0.047	0.309	15.119	2.34	7.87	4.68	0.59
9	2	4	1.00	0.50	0.63	0.03	0.02	0.126	0.046	0.313	16.037	2.51	8.33	5.02	0.60
10	2	5	0.50	0.00	0.65	0.00	0.02	0.127	0.046	0.314	16.347	2.57	8.49	5.14	0.61

***** STEADY STATE SIMULATION *****

** REACTION COEFFICIENT SUMMARY **

RCH NUM	ELE NUM	DO SAT MG/L	K2 OPT	OXYGN REAIR 1/DAY	BOD DECAY 1/DAY	BOD SETT 1/DAY	SOD RATE G/M2D	ORGN DECAY 1/DAY	ORGN SETT 1/DAY	NH3 DECAY 1/DAY	NH3 SRCE MG/M2D	NO2 DECAY 1/DAY	ORGP DECAY 1/DAY	ORGP SETT 1/DAY	DISP SRCE MG/M2D	COLI DECAY 1/DAY	ANC DECAY 1/DAY	ANC SETT 1/DAY	ANC SRCE MG/M2D
1	1	10.14	5	1.60	0.30	0.00	0.49	0.03	0.04	0.06	0.00	0.15	0.05	0.04	0.00	0.00	0.00	0.00	0.00
1	2	10.14	5	1.61	0.30	0.00	0.49	0.03	0.04	0.06	0.00	0.15	0.05	0.04	0.00	0.00	0.00	0.00	0.00
1	3	10.14	5	1.62	0.30	0.00	0.49	0.03	0.04	0.06	0.00	0.15	0.05	0.04	0.00	0.00	0.00	0.00	0.00
1	4	10.14	5	1.63	0.30	0.00	0.49	0.03	0.04	0.06	0.00	0.15	0.05	0.04	0.00	0.00	0.00	0.00	0.00
1	5	10.14	5	1.63	0.30	0.00	0.49	0.03	0.04	0.06	0.00	0.15	0.05	0.04	0.00	0.00	0.00	0.00	0.00
2	1	10.14	5	1.65	0.30	0.00	0.49	0.03	0.04	0.06	0.00	0.15	0.05	0.04	0.00	0.00	0.00	0.00	0.00
2	2	10.14	5	1.66	0.30	0.00	0.49	0.03	0.04	0.06	0.00	0.15	0.05	0.04	0.00	0.00	0.00	0.00	0.00
2	3	10.14	5	1.66	0.30	0.00	0.49	0.03	0.04	0.06	0.00	0.15	0.05	0.04	0.00	0.00	0.00	0.00	0.00
2	4	10.14	5	1.66	0.30	0.00	0.49	0.03	0.04	0.06	0.00	0.15	0.05	0.04	0.00	0.00	0.00	0.00	0.00
2	5	10.14	5	1.67	0.30	0.00	0.49	0.03	0.04	0.06	0.00	0.15	0.05	0.04	0.00	0.00	0.00	0.00	0.00

***** STEADY STATE SIMULATION *****

** WATER QUALITY VARIABLES **

RCH NUM	ELE NUM	TEMP DEG-C	CM-1	CM-2	CM-3	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM-N MG/L	ORGP MG/L	DIS-P MG/L	SUM-P MG/L	COLI #/100ML	ANC	CHLA UG/L
1	1	13.82	0.00	0.00	0.00	7.39	2.65	0.77	0.13	0.08	0.74	1.72	0.13	0.07	0.20	.00E+00	0.00	7.64
1	2	13.82	0.00	0.00	0.00	7.37	2.66	0.78	0.13	0.08	0.75	1.75	0.13	0.07	0.20	.00E+00	0.00	7.56
1	3	13.82	0.00	0.00	0.00	7.36	2.70	0.81	0.14	0.08	0.79	1.82	0.13	0.07	0.20	.00E+00	0.00	7.36
1	4	13.82	0.00	0.00	0.00	7.37	2.70	0.82	0.14	0.09	0.80	1.84	0.13	0.07	0.19	.00E+00	0.00	7.32
1	5	13.82	0.00	0.00	0.00	7.38	2.73	0.84	0.15	0.09	0.82	1.90	0.12	0.07	0.19	.00E+00	0.00	7.19
2	1	13.82	0.00	0.00	0.00	7.39	2.68	0.80	0.14	0.09	0.83	1.86	0.13	0.07	0.20	.00E+00	0.00	7.42
2	2	13.82	0.00	0.00	0.00	7.39	2.70	0.82	0.14	0.10	0.90	1.96	0.13	0.07	0.19	.00E+00	0.00	7.27
2	3	13.82	0.00	0.00	0.00	7.39	2.72	0.84	0.15	0.10	0.97	2.06	0.12	0.07	0.19	.00E+00	0.00	7.13
2	4	13.82	0.00	0.00	0.00	7.40	2.73	0.84	0.15	0.11	1.02	2.12	0.12	0.07	0.19	.00E+00	0.00	7.06
2	5	13.82	0.00	0.00	0.00	7.41	2.74	0.86	0.16	0.11	1.07	2.20	0.12	0.07	0.19	.00E+00	0.00	6.95

***** STEADY STATE SIMULATION *****

** ALGAE DATA **

ELE ORD	RCH NUM	ELE NUM	CHLA UG/L	ALGY GRWTH 1/DAY	ALGY RESP 1/DAY	ALGY SETT M/DAY	A P/R RATIO *	NET P-R MG/L-D	NH3 PREF *	NH3-N FRACT N-UPTKE *	LIGHT EXTCO 1/M	ALGAE GROWTH RATE ATTEN FACTORS LIGHT *	NITRGN *	PHSPRS *
1	1	1	7.64	0.60	0.21	0.04	2.34	0.06	0.90	0.61	0.09	0.55	0.85	0.73
2	1	2	7.56	0.60	0.21	0.04	2.33	0.06	0.90	0.61	0.09	0.55	0.85	0.73
3	1	3	7.36	0.60	0.21	0.04	2.33	0.05	0.90	0.61	0.09	0.55	0.86	0.72
4	1	4	7.32	0.60	0.21	0.04	2.33	0.05	0.90	0.62	0.09	0.55	0.86	0.72
5	1	5	7.19	0.60	0.21	0.04	2.33	0.05	0.90	0.62	0.09	0.55	0.86	0.72
6	2	1	7.42	0.60	0.21	0.04	2.33	0.05	0.90	0.60	0.09	0.55	0.86	0.72
7	2	2	7.27	0.60	0.21	0.04	2.33	0.05	0.90	0.59	0.09	0.55	0.87	0.72
8	2	3	7.13	0.60	0.21	0.04	2.33	0.05	0.90	0.58	0.09	0.55	0.88	0.72
9	2	4	7.06	0.60	0.21	0.04	2.33	0.05	0.90	0.57	0.09	0.55	0.88	0.72
10	2	5	6.95	0.60	0.21	0.04	2.32	0.05	0.90	0.57	0.09	0.55	0.89	0.72

***** STEADY STATE SIMULATION *****

** DISSOLVED OXYGEN DATA **

ELE ORD	RCH NUM	ELE NUM	TEMP DEG-C	DO SAT MG/L	DO MG/L	DO DEF MG/L	DAM INPUT MG/L	NIT INHIB FACT	COMPONENTS OF DISSOLVED OXYGEN MASS BALANCE (MG/L-DAY) F-FNCTN INPUT	OXYGN REAIR	C-BOD	SOD	NET P-R	NH3-N	NO2-N
1	1	1	13.82	10.14	7.39	2.75	0.00	1.00	121.51	4.40	-0.80	-1.93	0.06	-0.03	-0.01
2	1	2	13.82	10.14	7.37	2.76	0.00	1.00	51.49	4.45	-0.80	-1.81	0.06	-0.03	-0.01
3	1	3	13.82	10.14	7.36	2.78	0.00	1.00	3.64	4.51	-0.81	-1.80	0.05	-0.03	-0.01
4	1	4	13.82	10.14	7.37	2.77	0.00	1.00	25.06	4.50	-0.81	-1.75	0.05	-0.03	-0.01
5	1	5	13.82	10.14	7.38	2.76	0.00	1.00	2.98	4.51	-0.82	-1.74	0.05	-0.03	-0.01
6	2	1	13.82	10.14	7.39	2.75	0.00	1.00	74.16	4.52	-0.81	-1.59	0.05	-0.03	-0.01
7	2	2	13.82	10.14	7.39	2.75	0.00	1.00	3.28	4.56	-0.81	-1.58	0.05	-0.03	-0.02
8	2	3	13.82	10.14	7.39	2.75	0.00	1.00	3.20	4.56	-0.82	-1.58	0.05	-0.03	-0.02
9	2	4	13.82	10.14	7.40	2.74	0.00	1.00	11.74	4.55	-0.82	-1.56	0.05	-0.03	-0.02
10	2	5	13.82	10.14	7.41	2.73	0.00	1.00	2.92	4.55	-0.83	-1.55	0.05	-0.03	-0.02

```
                                  D I S S O L V E D   O X Y G E N   ( M G / L )
       0.0       1.0       2.0       3.0       4.0       5.0       6.0       7.0       8.0       9.0      10.0
R   5.0 ++++.++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++*+++++++++++++++++++++++++++
        +   .     +         +         +         +         +         +         + *       +         +         +
I       +   .     +         +         +         +         +         +         + *       +         +         +
        +   .     +         +         +         +         +         +         + *       +         +         +
V       +   .                                                                    *                          +
        +   .                                                                    *                          +
E       +   .     +         +         +         +         +         +         +  *      +         +         +
        +   .     +         +         +         +         +         +         +  *      +         +         +
R       +   .     +         +         +         +         +         +         +  *      +         +         +
    0.5 ++++.++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++*+++++++++++++++++++++++++++
       0.0       5.0      10.0      15.0      20.0      25.0      30.0      35.0      40.0      45.0      50.0
                        B I O C H E M I C A L   O X Y G E N   D E M A N D   ( M G / L )


               DISSOLVED OXYGEN          = * * * *

                BIOCHEMICAL OXYGEN DEMAND = . . . .
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Appendix C – Input and Output Data for Gravelly Run Qual2E Model Calibration (Run Gr049)

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                                       * * * QUAL-2E  STREAM QUALITY ROUTING MODEL * * *
                                               Version 3.22  --  May 1996

 $$$ (PROBLEM TITLES) $$$

CARD TYPE                             QUAL-2E PROGRAM TITLES
TITLE01             Gr049, Gravelly Run, April 25, 2005
TITLE02             Based on Gr047, Annual Average Baseline Condition
TITLE03   NO        CONSERVATIVE MINERAL   I
TITLE04   NO        CONSERVATIVE MINERAL  II
TITLE05   NO        CONSERVATIVE MINERAL III
TITLE06   NO        TEMPERATURE
TITLE07  YES        5-DAY BIOCHEMICAL OXYGEN DEMAND
TITLE08  YES        ALGAE AS CHL-A IN UG/L
TITLE09  YES        PHOSPHORUS CYCLE AS P IN MG/L
TITLE10               (ORGANIC-P; DISSOLVED-P)
TITLE11  YES        NITROGEN CYCLE AS N IN MG/L
TITLE12               (ORGANIC-N; AMMONIA-N; NITRITE-N;' NITRATE-N)
TITLE13  YES        DISSOLVED OXYGEN IN MG/L
TITLE14   NO        FECAL COLIFORM IN NO./100 ML
TITLE15   NO        ARBITRARY NON-CONSERVATIVE
ENDTITLE

 $$$ DATA TYPE 1 (CONTROL DATA) $$$

CARD TYPE                                             CARD TYPE
LIST DATA INPUT             0.00000                                                 0.00000
WRITE OPTIONAL SUMMARY      0.00000                                                 0.00000
NO FLOW AUGMENTATION        0.00000                                                 0.00000
STEADY STATE                0.00000                                                 0.00000
NO TRAP CHANNELS            0.00000                                                 0.00000
PRINT LCD/SOLAR DATA        0.00000                                                 0.00000
PLOT DO AND BOD             0.00000                                                 0.00000
FIXED DNSTM CONC (YES=1)=   0.00000           5D-ULT BOD CONV K COEF  =   0.23000
INPUT METRIC           =   1.00000           OUTPUT METRIC           =   1.00000
NUMBER OF REACHES      =   2.00000           NUMBER OF JUNCTIONS     =   0.00000
NUM OF HEADWATERS      =   1.00000           NUMBER OF POINT LOADS   =   5.00000
TIME STEP (HOURS)      =   0.00000           LNTH. COMP. ELEMENT (KM)=   0.50000
MAXIMUM ROUTE TIME (HRS)= 100.00000          TIME INC. FOR RPT2 (HRS)=   0.00000
LATITUDE OF BASIN (DEG) =  39.20000          LONGITUDE OF BASIN (DEG)=  75.75000
STANDARD MERIDIAN (DEG) =  75.00000          DAY OF YEAR START TIME  = 196.00000
EVAP. COEF.,(AE)       =   0.00001           EVAP. COEF.,(BE)        =   0.00001
ELEV. OF BASIN (METERS) =  21.00000          DUST ATTENUATION COEF.  =   0.10000
ENDATA1                     0.00000                                                 0.00000

 $$$ DATA TYPE 1A (ALGAE PRODUCTION AND NITROGEN OXIDATION CONSTANTS) $$$

CARD TYPE                                              CARD TYPE
O UPTAKE BY NH3 OXID(MG O/MG N)=    3.5000             O UPTAKE BY NO2 OXID(MG O/MG N)=    1.0700
O PROD. BY ALGAE (MG O/MG A)   =    1.6000             O UPTAKE BY ALGAE (MG O/MG A)  =    2.0000
N CONTENT OF ALGAE (MG N/MG A) =    0.0800             P CONTENT OF ALGAE (MG P/MG A) =    0.0150
ALG MAX SPEC GROWTH RATE(1/DAY)=    2.0000             ALGAE RESPIRATION RATE (1/DAY) =    0.2750
N HALF SATURATION CONST. (MG/L)=    0.1550             P HALF SATURATION CONST. (MG/L)=    0.0255
LIN ALG SHADE CO (1/M-UGCHA/L) =    0.0027             NLIN SHADE (1/M-(UGCHA/L)**2/3)=    0.0165
LIGHT FUNCTION OPTION (LFNOPT) =    2.0000             LIGHT SAT'N COEF (LANGLEYS/MIN)=    0.0250
DAILY AVERAGING OPTION(LAVOPT) =    2.0000             LIGHT AVERAGING FACTOR (AFACT  =    0.9500
NUMBER OF DAYLIGHT HOURS (DLH) =   14.0000             TOTAL DAILY SOLR RAD (LANGLEYS)=  380.0000
ALGY GROWTH CALC OPTION(LGROPT)=    2.0000             ALGAL PREF FOR NH3-N (PREFN)   =    0.9000
ALG/TEMP SOLAR RAD FACT(TFACT) =    0.4500             NITRIFICATION INHIBITION COEF  =   10.0000
ENDATA1A                            0.0000                                                 0.0000

 $$$ DATA TYPE 1B (TEMPERATURE CORRECTION CONSTANTS FOR RATE COEFFICIENTS) $$$

CARD TYPE     RATE CODE     THETA VALUE

THETA( 1)      BOD DECA       1.047     DFLT
THETA( 2)      BOD SETT       1.024     DFLT
THETA( 3)      OXY TRAN       1.024     DFLT
THETA( 4)      SOD RATE       1.060     DFLT
THETA( 5)      ORGN DEC       1.047     DFLT
THETA( 6)      ORGN SET       1.024     DFLT
THETA( 7)      NH3 DECA       1.083     DFLT
THETA( 8)      NH3 SRCE       1.074     DFLT
THETA( 9)      NO2 DECA       1.047     DFLT
THETA(10)      PORG DEC       1.047     DFLT
THETA(11)      PORG SET       1.024     DFLT
THETA(12)      DISP SRC       1.074     DFLT
THETA(13)      ALG GROW       1.047     DFLT
THETA(14)      ALG RESP       1.047     DFLT
THETA(15)      ALG SETT       1.024     DFLT
THETA(16)      COLI DEC       1.047     DFLT
THETA(17)      ANC DECA       1.000     DFLT
THETA(18)      ANC SETT       1.024     DFLT
THETA(19)      ANC SRCE       1.000     DFLT
ENDATA1B

 $$$ DATA TYPE 2 (REACH IDENTIFICATION) $$$

CARD TYPE           REACH ORDER AND IDENT               R. MI/KM            R. MI/KM
```

STREAM REACH	1.0	RCH= Segment 1	FROM	6.0	TO	3.0
STREAM REACH	2.0	RCH= Segment 2	FROM	3.0	TO	0.0
ENDATA2	0.0			0.0		0.0

$$$ DATA TYPE 3 (TARGET LEVEL DO AND FLOW AUGMENTATION SOURCES) $$$

CARD TYPE	REACH	AVAIL HDWS	TARGET	ORDER OF AVAIL SOURCES					
ENDATA3	0.	0.	0.0	0.	0.	0.	0.	0.	0.

$$$ DATA TYPE 4 (COMPUTATIONAL REACH FLAG FIELD) $$$

CARD TYPE	REACH	ELEMENTS/REACH	COMPUTATIONAL FLAGS
FLAG FIELD	1.	6.	1.2.6.2.2.2.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	2.	6.	6.6.6.6.2.5.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
ENDATA4	0.	0.	0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.

$$$ DATA TYPE 5 (HYDRAULIC DATA FOR DETERMINING VELOCITY AND DEPTH) $$$

CARD TYPE	REACH	COEF-DSPN	COEFQV	EXPOQV	COEFQH	EXPOQH	CMANN
HYDRAULICS	1.	100.00	0.316	0.362	0.457	0.186	0.040
HYDRAULICS	2.	100.00	0.316	0.362	0.457	0.186	0.040
ENDATA5	0.	0.00	0.000	0.000	0.000	0.000	0.000

$$$ DATA TYPE 5A (STEADY STATE TEMPERATURE AND CLIMATOLOGY DATA) $$$

CARD TYPE			DUST	CLOUD	DRY BULB	WET BULB	ATM		SOLAR RAD
	REACH	ELEVATION	COEF	COVER	TEMP	TEMP	PRESSURE	WIND	ATTENUATION
TEMP/LCD	1.	6.40	0.10	0.10	25.00	20.00	980.00	2.50	1.00
TEMP/LCD	2.	6.40	0.10	0.10	25.00	20.00	980.00	2.50	1.00
ENDATA5A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 6 (REACTION COEFFICIENTS FOR DEOXYGENATION AND REAERATION) $$$

CARD TYPE	REACH	K1	K3	SOD	K2OPT	K2	COEQK2	OR	EXPQK2
				RATE			TSIV COEF	OR	SLOPE
							FOR OPT 8		FOR OPT 8
REACT COEF	1.	0.50	0.00	0.250	5.	0.00	0.000		0.00000
REACT COEF	2.	0.50	0.00	0.250	5.	0.00	0.000		0.00000
ENDATA6	0.	0.00	0.00	0.000	0.	0.00	0.000		0.00000

$$$ DATA TYPE 6A (NITROGEN AND PHOSPHORUS CONSTANTS) $$$

CARD TYPE	REACH	CKNH2	SETNH2	CKNH3	SNH3	CKNO2	CKPORG	SETPORG	SPO4
N AND P COEF	1.	0.04	0.05	0.10	0.00	0.20	0.07	0.05	0.00
N AND P COEF	2.	0.04	0.05	0.10	0.00	0.20	0.07	0.05	0.00
ENDATA6A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 6B (ALGAE/OTHER COEFFICIENTS) $$$

CARD TYPE	REACH	ALPHAO	ALGSET	EXCOEF	CK5 CKCOLI	CKANC	SETANC	SRCANC
ALG/OTHER COEF	1.	75.00	0.05	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	2.	75.00	0.05	0.01	0.00	0.00	0.00	0.00
ENDATA6B	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 7 (INITIAL CONDITIONS) $$$

CARD TYPE	REACH	TEMP	D.O.	BOD	CM-1	CM-2	CM-3	ANC	COLI
INITIAL COND-1	1.	14.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-1	2.	14.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ENDATA7	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 7A (INITIAL CONDITIONS FOR CHOROPHYLL A, NITROGEN, AND PHOSPHORUS) $$$

CARD TYPE	REACH	CHL-A	ORG-N	NH3-N	NO2-N	NO3-N	ORG-P	DIS-P
INITIAL COND-2	1.	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-2	2.	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ENDATA7A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 8 (INCREMENTAL INFLOW CONDITIONS) $$$

CARD TYPE	REACH	FLOW	TEMP	D.O.	BOD	CM-1	CM-2	CM-3	ANC	COLI
INCR INFLOW-1	1.	0.052	14.77	5.04	4.40	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	2.	0.048	14.77	4.86	4.88	0.00	0.00	0.00	0.00	0.00
ENDATA8	0.	0.000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 8A (INCREMENTAL INFLOW CONDITIONS FOR CHLOROPHYLL A, NITROGEN, AND PHOSPHORUS) $$$

CARD TYPE	REACH	CHL-A	ORG-N	NH3-N	NO2-N	NO3-N	ORG-P	DIS-P
INCR INFLOW-2	1.	0.00	1.41	0.27	0.14	1.37	0.06	0.05
INCR INFLOW-2	2.	0.00	1.50	0.32	0.33	3.33	0.06	0.05
ENDATA8A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 9 (STREAM JUNCTIONS) $$$

CARD TYPE	JUNCTION ORDER AND IDENT	UPSTRM	JUNCTION	TRIB
ENDATA9	0.	0.	0.	0.

$$$ DATA TYPE 10 (HEADWATER SOURCES) $$$

CARD TYPE	HDWTR ORDER	NAME	FLOW	TEMP	D.O.	BOD	CM-1	CM-2	CM-3

HEADWTR-1	1.	Cypress Headwatr	0.05	14.77	7.49	2.54	0.00	0.00	0.00
ENDATA10	0.		0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 10A (HEADWATER CONDITIONS FOR CHLOROPHYLL, NITROGEN, PHOSPHORUS, COLIFORM AND SELECTED NON-CONSERVATIVE CONSTITUENT) $$$

CARD TYPE	HDWTR ORDER	ANC	COLI	CHL-A	ORG-N	NH3-N	NO2-N	NO3-N	ORG-P	DIS-P
HEADWTR-2	1.	0.00	0.00E+00	8.07	0.72	0.11	0.08	0.68	0.14	0.07
ENDATA10A	0.	0.00	0.00E+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 11 (POINT SOURCE / POINT SOURCE CHARACTERISTICS) $$$

CARD TYPE	POINT LOAD ORDER	NAME	EFF	FLOW	TEMP	D.O.	BOD	CM-1	CM-2	CM-3
POINTLD-1	1.	Tributa1 R1	0.00	0.03	14.77	7.49	2.54	0.00	0.00	0.00
POINTLD-1	2.	JamisonB R2	0.00	0.17	14.77	7.49	2.54	0.00	0.00	0.00
POINTLD-1	3.	Tributa2 R2	0.00	0.09	14.77	7.49	2.54	0.00	0.00	0.00
POINTLD-1	4.	Tributa3 R2	0.00	0.03	14.77	7.49	2.54	0.00	0.00	0.00
POINTLD-1	5.	Tributa4 R2	0.00	0.04	14.77	7.49	2.54	0.00	0.00	0.00
ENDATA11	0.		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 11A (POINT SOURCE CHARACTERISTICS - CHLOROPHYLL A, NITROGEN, PHOSPHORUS, COLIFORMS AND SELECTED NON-CONSERVATIVE CONSTITUENT) $$$

CARD TYPE	POINT LOAD ORDER	ANC	COLI	CHL-A	ORG-N	NH3-N	NO2-N	N03-N	ORG-P	DIS-P
POINTLD-2	1.	0.00	0.00E+00	8.07	0.72	0.11	0.08	0.68	0.14	0.07
POINTLD-2	2.	0.00	0.00E+00	8.07	0.72	0.11	0.08	0.68	0.14	0.07
POINTLD-2	3.	0.00	0.00E+00	8.07	0.72	0.11	0.08	0.68	0.14	0.07
POINTLD-2	4.	0.00	0.00E+00	8.07	0.72	0.11	0.08	0.68	0.14	0.07
POINTLD-2	5.	0.00	0.00E+00	8.07	0.72	0.11	0.08	0.68	0.14	0.07
ENDATA11A	0.	0.00	0.00E+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 12 (DAM CHARACTERISTICS) $$$

	DAM	RCH	ELE	ADAM	BDAM	FDAM	HDAM
ENDATA12	0.	0.	0.	0.00	0.00	0.00	0.00

$$$ DATA TYPE 13 (DOWNSTREAM BOUNDARY CONDITIONS-1) $$$

CARD TYPE	TEMP	D.O.	BOD	CM-1	CM-2	CM-3	ANC	COLI

ENDATA13 DOWNSTREAM BOUNDARY CONCENTRATIONS ARE UNCONSTRAINED

$$$ DATA TYPE 13A (DOWNSTREAM BOUNDARY CONDITIONS-2) $$$

CARD TYPE	CHL-A	ORG-N	NH3-N	NO2-N	NH3-N	ORG-P	DIS-P

ENDATA13A DOWNSTREAM BOUNDARY CONCENTRATIONS ARE UNCONSTRAINED

STEADY STATE ALGAE/NUTRIENT/DISSOLVED OXYGEN SIMULATION; CONVERGENCE SUMMARY:

VARIABLE	ITERATION	NUMBER OF NONCONVERGENT ELEMENTS
ALGAE GROWTH RATE	1	12
ALGAE GROWTH RATE	2	12
ALGAE GROWTH RATE	3	12
ALGAE GROWTH RATE	4	12
ALGAE GROWTH RATE	5	12
ALGAE GROWTH RATE	6	12
ALGAE GROWTH RATE	7	0
ALGAE GROWTH RATE	8	0

SUMMARY OF CONDITIONS FOR ALGAL GROWTH RATE SIMULATION:

1. LIGHT AVERAGING OPTION. LAVOPT= 2

   METHOD: MEAN SOLAR RADIATION DURING DAYLIGHT HOURS

   SOURCE OF SOLAR VALUES: DATA TYPE 1A
   DAILY NET SOLAR RADIATION: 1400.300 BTU/FT-2 (380.000 LANGLEYS)
   NUMBER OF DAYLIGHT HOURS: 0.0
   PHOTOSYNTHETIC ACTIVE FRACTION OF SOLAR RADIATION (TFACT): N/A
   MEAN SOLAR RADIATION ADJUSTMENT FACTOR (AFACT): 0.950

2. LIGHT FUNCTION OPTION: LFNOPT= 2

   SMITH FUNCTION, WITH 71% IMAX = 0.025 LANGLEYS/MIN

3. GROWTH ATTENUATION OPTION FOR NUTRIENTS. LGROPT= 2

   MINIMUM OF NITROGEN, PHOSPHORUS: FL*MIN(FN,FP)

DISSOLVED OXYGEN IN MG/L — ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	7.26	7.11	7.16	7.13	7.11	7.11														
2	7.33	7.41	7.47	7.53	7.58	7.63														

5-DAY BIOCHEMICAL OXYGEN DEMAND — ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	2.75	2.90	2.87	2.94	2.99	3.03														
2	2.79	2.76	2.75	2.75	2.76	2.76														

ORGANIC NITROGEN AS N IN MG/L — ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.81	0.88	0.87	0.91	0.94	0.97														
2	0.85	0.83	0.83	0.83	0.84	0.85														

AMMONIA AS N IN MG/L — ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.14	0.15	0.15	0.16	0.17	0.18														
2	0.15	0.14	0.15	0.15	0.15	0.15														

NITRITE AS N IN MG/L — ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.08	0.09	0.09	0.09	0.10	0.10														
2	0.09	0.09	0.10	0.10	0.10	0.10														

NITRATE AS N IN MG/L — ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.77	0.85	0.84	0.88	0.91	0.94														
2	0.86	0.87	0.90	0.92	0.96	1.00														

ORGANIC PHOSPHORUS AS P IN MG/L — ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.13	0.12	0.12	0.11	0.11	0.11														
2	0.12	0.12	0.12	0.12	0.12	0.12														

DISSOLVED PHOSPHORUS AS P IN MG/L — ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.07	0.06	0.06	0.06	0.06	0.06														
2	0.06	0.07	0.07	0.07	0.07	0.07														

ALGAE AS CHL-A IN UG/L — ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	7.02	6.24	6.33	5.93	5.59	5.30														
2	6.69	6.90	6.90	6.92	6.86	6.80														

ALGAE GROWTH RATES IN PER DAY ARE — ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.63	0.62	0.62	0.62	0.61	0.61														
2	0.62	0.63	0.63	0.63	0.63	0.63														

PHOTOSYNTHESIS-RESPIRATION RATIOS ARE — ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	2.31	2.29	2.30	2.28	2.27	2.27														
2	2.31	2.31	2.31	2.32	2.31	2.31														

***** STEADY STATE SIMULATION *****

** HYDRAULICS SUMMARY **

ELE ORD	RCH NUM	ELE NUM	BEGIN LOC KILO	END LOC KILO	FLOW CMS	POINT SRCE CMS	INCR FLOW CMS	VEL MPS	TRVL TIME DAY	DEPTH M	WIDTH M	VOLUME K-CU-M	BOTTOM AREA K-SQ-M	X-SECT AREA SQ-M	DSPRSN COEF SQ-M/S
1	1	1	6.00	5.50	0.06	0.00	0.01	0.115	0.050	0.272	1.962	0.27	1.25	0.53	0.49
2	1	2	5.50	5.00	0.07	0.00	0.01	0.121	0.048	0.279	2.082	0.29	1.32	0.58	0.52
3	1	3	5.00	4.50	0.11	0.03	0.01	0.143	0.041	0.304	2.560	0.39	1.58	0.78	0.66
4	1	4	4.50	4.00	0.12	0.00	0.01	0.147	0.039	0.308	2.648	0.41	1.63	0.82	0.69
5	1	5	4.00	3.50	0.13	0.00	0.01	0.150	0.038	0.312	2.734	0.43	1.68	0.85	0.71
6	1	6	3.50	3.00	0.14	0.00	0.01	0.154	0.038	0.316	2.816	0.44	1.72	0.89	0.74
7	2	1	3.00	2.50	0.31	0.17	0.01	0.207	0.028	0.368	4.087	0.75	2.41	1.50	1.13
8	2	2	2.50	2.00	0.41	0.09	0.01	0.229	0.025	0.387	4.615	0.89	2.70	1.79	1.30
9	2	3	2.00	1.50	0.45	0.03	0.01	0.236	0.025	0.393	4.805	0.95	2.80	1.89	1.36
10	2	4	1.50	1.00	0.49	0.04	0.01	0.244	0.024	0.400	5.014	1.00	2.91	2.01	1.43
11	2	5	1.00	0.50	0.50	0.00	0.01	0.246	0.024	0.401	5.051	1.01	2.93	2.03	1.44
12	2	6	0.50	0.00	0.51	0.00	0.01	0.247	0.023	0.403	5.088	1.02	2.95	2.05	1.45

***** STEADY STATE SIMULATION *****

** REACTION COEFFICIENT SUMMARY **

RCH NUM	ELE NUM	DO SAT MG/L	K2 OPT	OXYGN REAIR 1/DAY	BOD DECAY 1/DAY	BOD SETT 1/DAY	SOD RATE G/M2D	ORGN DECAY 1/DAY	ORGN SETT 1/DAY	NH3 DECAY 1/DAY	NH3 SRCE MG/M2D	NO2 DECAY 1/DAY	ORGP DECAY 1/DAY	ORGP SETT 1/DAY	DISP SRCE MG/M2D	COLI DECAY 1/DAY	ANC DECAY 1/DAY	ANC SETT 1/DAY	ANC SRCE MG/M2D
1	1	9.93	5	1.83	0.39	0.00	0.18	0.03	0.04	0.07	0.00	0.16	0.06	0.04	0.00	0.00	0.00	0.00	0.00
1	2	9.93	5	1.85	0.39	0.00	0.18	0.03	0.04	0.07	0.00	0.16	0.06	0.04	0.00	0.00	0.00	0.00	0.00
1	3	9.93	5	1.95	0.39	0.00	0.18	0.03	0.04	0.07	0.00	0.16	0.06	0.04	0.00	0.00	0.00	0.00	0.00
1	4	9.93	5	2.04	0.39	0.00	0.18	0.03	0.04	0.07	0.00	0.16	0.06	0.04	0.00	0.00	0.00	0.00	0.00
1	5	9.93	5	2.06	0.39	0.00	0.18	0.03	0.04	0.07	0.00	0.16	0.06	0.04	0.00	0.00	0.00	0.00	0.00
1	6	9.93	5	2.09	0.39	0.00	0.18	0.03	0.04	0.07	0.00	0.16	0.06	0.04	0.00	0.00	0.00	0.00	0.00
2	1	9.93	5	2.27	0.39	0.00	0.18	0.03	0.04	0.07	0.00	0.16	0.06	0.04	0.00	0.00	0.00	0.00	0.00
2	2	9.93	5	2.49	0.39	0.00	0.18	0.03	0.04	0.07	0.00	0.16	0.06	0.04	0.00	0.00	0.00	0.00	0.00
2	3	9.93	5	2.57	0.39	0.00	0.18	0.03	0.04	0.07	0.00	0.16	0.06	0.04	0.00	0.00	0.00	0.00	0.00
2	4	9.93	5	2.61	0.39	0.00	0.18	0.03	0.04	0.07	0.00	0.16	0.06	0.04	0.00	0.00	0.00	0.00	0.00
2	5	9.93	5	2.64	0.39	0.00	0.18	0.03	0.04	0.07	0.00	0.16	0.06	0.04	0.00	0.00	0.00	0.00	0.00
2	6	9.93	5	2.65	0.39	0.00	0.18	0.03	0.04	0.07	0.00	0.16	0.06	0.04	0.00	0.00	0.00	0.00	0.00

***** STEADY STATE SIMULATION *****

** WATER QUALITY VARIABLES **

RCH NUM	ELE NUM	TEMP DEG-C	CM-1	CM-2	CM-3	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM-N MG/L	ORGP MG/L	DIS-P MG/L	SUM-P MG/L	COLI #/100ML	ANC	CHLA UG/L
1	1	14.77	0.00	0.00	0.00	7.26	2.75	0.81	0.14	0.08	0.77	1.81	0.13	0.07	0.19	.00E+00	0.00	7.02
1	2	14.77	0.00	0.00	0.00	7.11	2.90	0.88	0.15	0.09	0.85	1.97	0.12	0.06	0.18	.00E+00	0.00	6.24
1	3	14.77	0.00	0.00	0.00	7.16	2.87	0.87	0.15	0.09	0.84	1.96	0.12	0.06	0.18	.00E+00	0.00	6.33
1	4	14.77	0.00	0.00	0.00	7.13	2.94	0.91	0.16	0.09	0.88	2.04	0.11	0.06	0.18	.00E+00	0.00	5.93
1	5	14.77	0.00	0.00	0.00	7.11	2.99	0.94	0.17	0.10	0.91	2.12	0.11	0.06	0.17	.00E+00	0.00	5.59
1	6	14.77	0.00	0.00	0.00	7.11	3.03	0.97	0.18	0.10	0.94	2.18	0.11	0.06	0.17	.00E+00	0.00	5.30
2	1	14.77	0.00	0.00	0.00	7.33	2.79	0.85	0.15	0.09	0.86	1.95	0.12	0.06	0.19	.00E+00	0.00	6.69
2	2	14.77	0.00	0.00	0.00	7.41	2.76	0.83	0.14	0.09	0.87	1.94	0.12	0.07	0.19	.00E+00	0.00	6.90
2	3	14.77	0.00	0.00	0.00	7.47	2.75	0.83	0.15	0.10	0.90	1.98	0.12	0.07	0.19	.00E+00	0.00	6.90
2	4	14.77	0.00	0.00	0.00	7.53	2.75	0.83	0.15	0.10	0.92	2.00	0.12	0.07	0.19	.00E+00	0.00	6.92
2	5	14.77	0.00	0.00	0.00	7.58	2.76	0.84	0.15	0.10	0.96	2.06	0.12	0.07	0.19	.00E+00	0.00	6.86
2	6	14.77	0.00	0.00	0.00	7.63	2.76	0.85	0.15	0.10	1.00	2.11	0.12	0.07	0.19	.00E+00	0.00	6.80

***** STEADY STATE SIMULATION *****

** ALGAE DATA **

ELE ORD	RCH NUM	ELE NUM	CHLA UG/L	ALGY GRWTH 1/DAY	ALGY RESP 1/DAY	ALGY SETT M/DAY	A P/R RATIO *	NET P-R MG/L-D	NH3 PREF *	NH3-N FRACT N-UPTKE *	LIGHT EXTCO 1/M	ALGAE GROWTH RATE ATTEN FACTORS LIGHT *	NITRGN *	PHSPRS *
1	1	1	7.02	0.63	0.22	0.04	2.31	0.05	0.90	0.61	0.09	0.55	0.85	0.72
2	1	2	6.24	0.62	0.22	0.04	2.29	0.05	0.90	0.62	0.08	0.55	0.87	0.71
3	1	3	6.33	0.62	0.22	0.04	2.30	0.05	0.90	0.62	0.08	0.55	0.86	0.71
4	1	4	5.93	0.62	0.22	0.04	2.28	0.04	0.90	0.62	0.08	0.55	0.87	0.71
5	1	5	5.59	0.61	0.22	0.04	2.27	0.04	0.90	0.63	0.08	0.55	0.87	0.71
6	1	6	5.30	0.61	0.22	0.04	2.27	0.04	0.90	0.63	0.07	0.55	0.88	0.70
7	2	1	6.69	0.62	0.22	0.04	2.31	0.05	0.90	0.61	0.09	0.55	0.87	0.72
8	2	2	6.90	0.63	0.22	0.04	2.31	0.05	0.90	0.60	0.09	0.55	0.87	0.72
9	2	3	6.90	0.63	0.22	0.04	2.31	0.05	0.90	0.59	0.09	0.55	0.87	0.72
10	2	4	6.92	0.63	0.22	0.04	2.32	0.05	0.90	0.59	0.09	0.55	0.87	0.72
11	2	5	6.86	0.63	0.22	0.04	2.31	0.05	0.90	0.58	0.09	0.55	0.88	0.72
12	2	6	6.80	0.63	0.22	0.04	2.31	0.05	0.90	0.58	0.09	0.55	0.88	0.72

***** STEADY STATE SIMULATION *****

** DISSOLVED OXYGEN DATA **

ELE ORD	RCH NUM	ELE NUM	TEMP DEG-C	DO SAT MG/L	DO MG/L	DO DEF MG/L	DAM INPUT MG/L	NIT INHIB FACT	F-FNCTN INPUT	OXYGN REAIR	C-BOD	SOD	NET P-R	NH3-N	NO2-N
									COMPONENTS OF DISSOLVED OXYGEN MASS BALANCE (MG/L-DAY)						
1	1	1	14.77	9.93	7.26	2.67	0.00	1.00	142.40	4.88	-1.08	-0.68	0.05	-0.03	-0.01
2	1	2	14.77	9.93	7.11	2.82	0.00	1.00	12.99	5.21	-1.14	-0.66	0.05	-0.04	-0.02
3	1	3	14.77	9.93	7.16	2.77	0.00	1.00	62.92	5.40	-1.13	-0.61	0.05	-0.04	-0.02
4	1	4	14.77	9.93	7.13	2.80	0.00	1.00	9.25	5.70	-1.16	-0.60	0.04	-0.04	-0.02
5	1	5	14.77	9.93	7.11	2.81	0.00	1.00	8.85	5.81	-1.18	-0.59	0.04	-0.04	-0.02
6	1	6	14.77	9.93	7.11	2.82	0.00	1.00	8.48	5.89	-1.19	-0.58	0.04	-0.04	-0.02
7	2	1	14.77	9.93	7.33	2.60	0.00	1.00	148.05	5.88	-1.10	-0.50	0.05	-0.03	-0.02
8	2	2	14.77	9.93	7.41	2.52	0.00	1.00	67.52	6.27	-1.08	-0.48	0.05	-0.03	-0.02
9	2	3	14.77	9.93	7.47	2.46	0.00	1.00	24.09	6.32	-1.08	-0.47	0.05	-0.03	-0.02
10	2	4	14.77	9.93	7.53	2.40	0.00	1.00	26.55	6.28	-1.08	-0.46	0.05	-0.03	-0.02
11	2	5	14.77	9.93	7.58	2.35	0.00	1.00	3.32	6.20	-1.08	-0.46	0.05	-0.03	-0.02
12	2	6	14.77	9.93	7.63	2.30	0.00	1.00	3.28	6.09	-1.09	-0.46	0.05	-0.04	-0.02

```
                            D I S S O L V E D   O X Y G E N   ( M G / L )
       0.0     1.0     2.0     3.0     4.0     5.0     6.0     7.0     8.0     9.0    10.0
R   6.0 ++++.+++++++++++++++++++++++++++++++++++++++++++++++++++++*++++++++++++++++++++++
        +   .   +       +       +       +       +       +       *       +       +       +
I       +   .   +       +       +       +       +       +       +*      +       +       +
        +   .   +       +       +       +       +       +       +*      +       +       +
V       +   .                                                   *                       +
        +   .                                                   *                       +
E       +   .                                                     *                     +
        +   .                                                      *                    +
R       +   .   +       +       +       +       +       +       +  *    +       +       +
        +   .   +       +       +       +       +       +       +   *   +       +       +
        +   .   +       +       +       +       +       +       +   *   +       +       +
    0.5 ++++.++++++++++++++++++++++++++++++++++++++++++++++++++++++++*+++++++++++++++++++
       0.0     5.0    10.0    15.0    20.0    25.0    30.0    35.0    40.0    45.0    50.0
                    B I O C H E M I C A L   O X Y G E N   D E M A N D   ( M G / L )
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DISSOLVED OXYGEN          = * * * *

BIOCHEMICAL OXYGEN DEMAND = . . . .
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Appendix D – Input and Output Data for Choptank River Qual2E Model Calibration (Run Ch275)

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                                             * * * QUAL-2E  STREAM QUALITY ROUTING MODEL * * *
                                                      Version 3.22  --  May 1996

 $$$ (PROBLEM TITLES) $$$

CARD TYPE                             QUAL-2E PROGRAM TITLES
TITLE01              Ch275, Choptank River, March 17, 2005
TITLE02              Based on Ch270, Annual Average Baseline Condition
TITLE03   NO         CONSERVATIVE MINERAL   I
TITLE04   NO         CONSERVATIVE MINERAL  II
TITLE05   NO         CONSERVATIVE MINERAL III
TITLE06   NO         TEMPERATURE
TITLE07  YES         5-DAY BIOCHEMICAL OXYGEN DEMAND
TITLE08  YES         ALGAE AS CHL-A IN UG/L
TITLE09  YES         PHOSPHORUS CYCLE AS P IN MG/L
TITLE10                (ORGANIC-P; DISSOLVED-P)
TITLE11  YES         NITROGEN CYCLE AS N IN MG/L
TITLE12                (ORGANIC-N; AMMONIA-N; NITRITE-N;' NITRATE-N)
TITLE13  YES         DISSOLVED OXYGEN IN MG/L
TITLE14   NO         FECAL COLIFORM IN NO./100 ML
TITLE15   NO         ARBITRARY NON-CONSERVATIVE
ENDTITLE

 $$$ DATA TYPE 1 (CONTROL DATA) $$$

CARD TYPE                                    CARD TYPE
LIST DATA INPUT             0.00000                                     0.00000
WRITE OPTIONAL SUMMARY      0.00000                                     0.00000
NO FLOW AUGMENTATION        0.00000                                     0.00000
STEADY STATE                0.00000                                     0.00000
NO TRAP CHANNELS            0.00000                                     0.00000
PRINT LCD/SOLAR DATA        0.00000                                     0.00000
PLOT DO AND BOD             0.00000                                     0.00000
FIXED DNSTM CONC (YES=1)=   0.00000        5D-ULT BOD CONV K COEF  =   0.23000
INPUT METRIC            =   1.00000        OUTPUT METRIC           =   1.00000
NUMBER OF REACHES       =   9.00000        NUMBER OF JUNCTIONS     =   2.00000
NUM OF HEADWATERS       =   3.00000        NUMBER OF POINT LOADS   =  20.00000
TIME STEP (HOURS)       =   0.00000        LNTH. COMP. ELEMENT (KM)=   1.00000
MAXIMUM ROUTE TIME (HRS)= 100.00000        TIME INC. FOR RPT2 (HRS)=   0.00000
LATITUDE OF BASIN (DEG) =  39.10000        LONGITUDE OF BASIN (DEG)=  75.70000
STANDARD MERIDIAN (DEG) =  75.00000        DAY OF YEAR START TIME  = 196.00000
EVAP. COEF.,(AE)        =   0.00001        EVAP. COEF.,(BE)        =   0.00001
ELEV. OF BASIN (METERS) =  16.00000        DUST ATTENUATION COEF.  =   0.10000
ENDATA1                     0.00000                                     0.00000

 $$$ DATA TYPE 1A (ALGAE PRODUCTION AND NITROGEN OXIDATION CONSTANTS) $$$

CARD TYPE                                           CARD TYPE
O UPTAKE BY NH3 OXID(MG O/MG N)=    3.5000          O UPTAKE BY NO2 OXID(MG O/MG N)=    1.0700
O PROD. BY ALGAE (MG O/MG A)   =    1.6000          O UPTAKE BY ALGAE (MG O/MG A)  =    2.0000
N CONTENT OF ALGAE (MG N/MG A) =    0.0800          P CONTENT OF ALGAE (MG P/MG A) =    0.0150
ALG MAX SPEC GROWTH RATE(1/DAY)=    2.0000          ALGAE RESPIRATION RATE (1/DAY) =    0.2750
N HALF SATURATION CONST. (MG/L)=    0.1550          P HALF SATURATION CONST. (MG/L)=    0.0255
LIN ALG SHADE CO (1/M-UGCHA/L) =    0.0027          NLIN SHADE (1/M-(UGCHA/L)**2/3)=    0.0165
LIGHT FUNCTION OPTION (LFNOPT) =    2.0000          LIGHT SAT'N COEF (LANGLEYS/MIN)=    0.0250
DAILY AVERAGING OPTION(LAVOPT) =    2.0000          LIGHT AVERAGING FACTOR (AFACT  =    0.9500
NUMBER OF DAYLIGHT HOURS (DLH) =   14.0000          TOTAL DAILY SOLR RAD (LANGLEYS)=  380.0000
ALGY GROWTH CALC OPTION(LGROPT)=    2.0000          ALGAL PREF FOR NH3-N (PREFN)   =    0.9000
ALG/TEMP SOLAR RAD FACT(TFACT) =    0.4500          NITRIFICATION INHIBITION COEF  =   10.0000
ENDATA1A                            0.0000                                              0.0000

 $$$ DATA TYPE 1B (TEMPERATURE CORRECTION CONSTANTS FOR RATE COEFFICIENTS) $$$

CARD TYPE     RATE CODE     THETA VALUE

THETA( 1)      BOD DECA        1.047     DFLT
THETA( 2)      BOD SETT        1.024     DFLT
THETA( 3)      OXY TRAN        1.024     DFLT
THETA( 4)      SOD RATE        1.060     DFLT
THETA( 5)      ORGN DEC        1.047     DFLT
THETA( 6)      ORGN SET        1.024     DFLT
THETA( 7)      NH3 DECA        1.083     DFLT
THETA( 8)      NH3 SRCE        1.074     DFLT
THETA( 9)      NO2 DECA        1.047     DFLT
THETA(10)      PORG DEC        1.047     DFLT
THETA(11)      PORG SET        1.024     DFLT
THETA(12)      DISP SRC        1.074     DFLT
THETA(13)      ALG GROW        1.047     DFLT
THETA(14)      ALG RESP        1.047     DFLT
THETA(15)      ALG SETT        1.024     DFLT
THETA(16)      COLI DEC        1.047     DFLT
THETA(17)      ANC DECA        1.000     DFLT
THETA(18)      ANC SETT        1.024     DFLT
THETA(19)      ANC SRCE        1.000     DFLT
ENDATA1B

 $$$ DATA TYPE 2 (REACH IDENTIFICATION) $$$

CARD TYPE           REACH ORDER AND IDENT              R. MI/KM           R. MI/KM
```

STREAM REACH	1.0	RCH= Segment 1	FROM	18.0	TO	12.0
STREAM REACH	2.0	RCH= Segment 2	FROM	12.0	TO	7.0
STREAM REACH	3.0	RCH= Segment 3	FROM	8.0	TO	4.0
STREAM REACH	4.0	RCH= Segment 4	FROM	4.0	TO	0.0
STREAM REACH	5.0	RCH= Segment 5	FROM	7.0	TO	6.0
STREAM REACH	6.0	RCH= Segment 6	FROM	6.0	TO	4.0
STREAM REACH	7.0	RCH= Segment 7	FROM	10.0	TO	5.0
STREAM REACH	8.0	RCH= Segment 8	FROM	5.0	TO	0.0
STREAM REACH	9.0	RCH= Segment 9	FROM	4.0	TO	0.0
ENDATA2	0.0			0.0		0.0

$$$ DATA TYPE 3 (TARGET LEVEL DO AND FLOW AUGMENTATION SOURCES) $$$

CARD TYPE	REACH	AVAIL HDWS	TARGET	ORDER OF AVAIL SOURCES					
ENDATA3	0.	0.	0.0	0.	0.	0.	0.	0.	0.

$$$ DATA TYPE 4 (COMPUTATIONAL REACH FLAG FIELD) $$$

CARD TYPE	REACH	ELEMENTS/REACH	COMPUTATIONAL FLAGS
FLAG FIELD	1.	6.	1.6.6.6.6.6.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	2.	5.	6.6.6.6.3.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	3.	4.	1.6.6.2.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	4.	4.	6.6.6.2.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	5.	1.	4.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	6.	2.	2.3.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	7.	5.	1.6.6.2.6.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	8.	5.	2.6.2.6.2.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	9.	4.	4.2.6.5.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
ENDATA4	0.	0.	0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.

$$$ DATA TYPE 5 (HYDRAULIC DATA FOR DETERMINING VELOCITY AND DEPTH) $$$

CARD TYPE	REACH	COEF-DSPN	COEFQV	EXPOQV	COEFQH	EXPOQH	CMANN
HYDRAULICS	1.	100.00	0.367	0.169	0.488	0.347	0.040
HYDRAULICS	2.	100.00	0.367	0.169	0.488	0.347	0.040
HYDRAULICS	3.	100.00	0.257	0.388	0.588	0.328	0.040
HYDRAULICS	4.	100.00	0.257	0.388	0.588	0.328	0.040
HYDRAULICS	5.	6000.00	0.004	0.914	1.441	0.045	0.040
HYDRAULICS	6.	100.00	0.114	0.742	0.549	0.111	0.040
HYDRAULICS	7.	100.00	0.288	0.104	0.325	0.182	0.040
HYDRAULICS	8.	100.00	0.263	0.099	0.335	0.183	0.040
HYDRAULICS	9.	100.00	0.114	0.742	0.549	0.111	0.040
ENDATA5	0.	0.00	0.000	0.000	0.000	0.000	0.000

$$$ DATA TYPE 5A (STEADY STATE TEMPERATURE AND CLIMATOLOGY DATA) $$$

CARD TYPE	REACH	ELEVATION	DUST COEF	CLOUD COVER	DRY BULB TEMP	WET BULB TEMP	ATM PRESSURE	WIND	SOLAR RAD ATTENUATION
TEMP/LCD	1.	4.88	0.10	0.10	25.00	20.00	980.00	2.50	1.00
TEMP/LCD	2.	4.88	0.10	0.10	25.00	20.00	980.00	2.50	1.00
TEMP/LCD	3.	4.88	0.10	0.10	25.00	20.00	980.00	2.50	1.00
TEMP/LCD	4.	4.88	0.10	0.10	25.00	20.00	980.00	2.50	1.00
TEMP/LCD	5.	4.88	0.10	0.10	25.00	20.00	980.00	2.50	1.00
TEMP/LCD	6.	4.88	0.10	0.10	25.00	20.00	980.00	2.50	1.00
TEMP/LCD	7.	4.88	0.10	0.10	25.00	20.00	980.00	2.50	1.00
TEMP/LCD	8.	4.88	0.10	0.10	25.00	20.00	980.00	2.50	1.00
TEMP/LCD	9.	4.88	0.10	0.10	25.00	20.00	980.00	2.50	1.00
ENDATA5A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 6 (REACTION COEFFICIENTS FOR DEOXYGENATION AND REAERATION) $$$

CARD TYPE	REACH	K1	K3	SOD RATE	K2OPT	K2	COEQK2 OR TSIV COEF FOR OPT 8	OR OR	EXPQK2 SLOPE FOR OPT 8
REACT COEF	1.	0.20	0.00	0.500	5.	0.00	0.000		0.00000
REACT COEF	2.	0.20	0.00	0.500	5.	0.00	0.000		0.00000
REACT COEF	3.	0.20	0.00	0.500	5.	0.00	0.000		0.00000
REACT COEF	4.	0.20	0.00	0.500	5.	0.00	0.000		0.00000
REACT COEF	5.	0.00	0.00	0.500	5.	0.00	0.000		0.00000
REACT COEF	6.	0.00	0.00	0.500	5.	0.00	0.000		0.00000
REACT COEF	7.	0.20	0.00	0.500	5.	0.00	0.000		0.00000
REACT COEF	8.	0.20	0.00	0.500	5.	0.00	0.000		0.00000
REACT COEF	9.	0.00	0.00	0.500	5.	0.00	0.000		0.00000
ENDATA6	0.	0.00	0.00	0.000	0.	0.00	0.000		0.00000

$$$ DATA TYPE 6A (NITROGEN AND PHOSPHORUS CONSTANTS) $$$

CARD TYPE	REACH	CKNH2	SETNH2	CKNH3	SNH3	CKNO2	CKPORG	SETPORG	SPO4
N AND P COEF	1.	0.40	0.05	1.00	0.00	2.00	0.70	0.05	0.00
N AND P COEF	2.	0.40	0.05	1.00	0.00	2.00	0.70	0.05	0.00
N AND P COEF	3.	0.40	0.05	1.00	0.00	2.00	0.70	0.05	0.00
N AND P COEF	4.	0.40	0.05	1.00	0.00	2.00	0.70	0.05	0.00
N AND P COEF	5.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N AND P COEF	6.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N AND P COEF	7.	0.40	0.05	1.00	0.00	2.00	0.70	0.05	0.00
N AND P COEF	8.	0.40	0.05	1.00	0.00	2.00	0.70	0.05	0.00
N AND P COEF	9.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ENDATA6A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 6B (ALGAE/OTHER COEFFICIENTS) $$$

CARD TYPE	REACH	ALPHAO	ALGSET	EXCOEF	CK5	CKANC	SETANC	SRCANC

					CKCOLI			
ALG/OTHER COEF	1.	75.00	0.50	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	2.	75.00	0.50	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	3.	75.00	0.50	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	4.	75.00	0.50	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	5.	75.00	0.00	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	6.	75.00	0.00	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	7.	75.00	0.50	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	8.	75.00	0.50	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	9.	75.00	0.00	0.01	0.00	0.00	0.00	0.00
ENDATA6B	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 7 (INITIAL CONDITIONS) $$$

CARD TYPE	REACH	TEMP	D.O.	BOD	CM-1	CM-2	CM-3	ANC	COLI
INITIAL COND-1	1.	16.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-1	2.	16.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-1	3.	16.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-1	4.	16.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-1	5.	16.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-1	6.	16.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-1	7.	16.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-1	8.	16.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-1	9.	16.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ENDATA7	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 7A (INITIAL CONDITIONS FOR CHOROPHYLL A, NITROGEN, AND PHOSPHORUS) $$$

CARD TYPE	REACH	CHL-A	ORG-N	NH3-N	NO2-N	NO3-N	ORG-P	DIS-P
INITIAL COND-2	1.	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-2	2.	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-2	3.	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-2	4.	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-2	5.	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-2	6.	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-2	7.	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-2	8.	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-2	9.	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ENDATA7A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 8 (INCREMENTAL INFLOW CONDITIONS) $$$

CARD TYPE	REACH	FLOW	TEMP	D.O.	BOD	CM-1	CM-2	CM-3	ANC	COLI
INCR INFLOW-1	1.	0.183	16.84	5.12	4.52	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	2.	0.088	16.84	5.18	4.05	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	3.	0.107	16.84	4.87	3.83	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	4.	0.117	16.84	4.99	4.34	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	5.	0.112	16.84	5.43	3.11	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	6.	0.059	16.84	5.07	3.13	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	7.	0.165	16.84	4.91	4.30	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	8.	0.101	16.84	5.03	4.48	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	9.	0.119	16.84	5.34	3.03	0.00	0.00	0.00	0.00	0.00
ENDATA8	0.	0.000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 8A (INCREMENTAL INFLOW CONDITIONS FOR CHLOROPHYLL A, NITROGEN, AND PHOSPHORUS) $$$

CARD TYPE	REACH	CHL-A	ORG-N	NH3-N	NO2-N	NO3-N	ORG-P	DIS-P
INCR INFLOW-2	1.	0.00	1.46	0.28	0.14	1.39	0.06	0.05
INCR INFLOW-2	2.	0.00	1.34	0.24	0.22	2.25	0.05	0.04
INCR INFLOW-2	3.	0.00	1.16	0.23	0.12	1.18	0.05	0.04
INCR INFLOW-2	4.	0.00	1.38	0.28	0.29	2.90	0.06	0.05
INCR INFLOW-2	5.	0.00	1.33	0.20	0.17	1.74	0.05	0.05
INCR INFLOW-2	6.	0.00	1.02	0.19	0.19	1.86	0.04	0.04
INCR INFLOW-2	7.	0.00	1.34	0.27	0.14	1.36	0.05	0.04
INCR INFLOW-2	8.	0.00	1.46	0.29	0.30	2.98	0.06	0.05
INCR INFLOW-2	9.	0.00	1.15	0.19	0.17	1.69	0.05	0.04
ENDATA8A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 9 (STREAM JUNCTIONS) $$$

CARD TYPE	JUNCTION ORDER AND IDENT		UPSTRM	JUNCTION	TRIB
STREAM JUNCTION	1.	JNC= CULBRETH MARSH	11.	20.	19.
STREAM JUNCTION	2.	JNC= COW MARSH CRK	22.	33.	32.
ENDATA9	0.		0.	0.	0.

$$$ DATA TYPE 10 (HEADWATER SOURCES) $$$

CARD TYPE	HDWTR ORDER	NAME	FLOW	TEMP	D.O.	BOD	CM-1	CM-2	CM-3
HEADWTR-1	1.	Tappaha Headwtr	0.26	16.51	5.11	2.67	0.00	0.00	0.00
HEADWTR-1	2.	Culbret Headwtr	0.18	16.51	5.11	2.40	0.00	0.00	0.00
HEADWTR-1	3.	CowMars Headwtr	0.51	16.51	5.11	2.50	0.00	0.00	0.00
ENDATA10	0.		0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 10A (HEADWATER CONDITIONS FOR CHLOROPHYLL, NITROGEN, PHOSPHORUS,
COLIFORM AND SELECTED NON-CONSERVATIVE CONSTITUENT) $$$

CARD TYPE	HDWTR ORDER	ANC	COLI	CHL-A	ORG-N	NH3-N	NO2-N	NO3-N	ORG-P	DIS-P
HEADWTR-2	1.	0.00	0.00E+00	9.33	0.67	0.13	0.03	0.26	0.15	0.04
HEADWTR-2	2.	0.00	0.00E+00	9.33	0.67	0.16	0.03	0.22	0.24	0.07
HEADWTR-2	3.	0.00	0.00E+00	9.33	0.67	0.05	0.02	0.17	0.09	0.02

ENDATA10A	0.	0.00	0.00E+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 11 (POINT SOURCE / POINT SOURCE CHARACTERISTICS) $$$

CARD TYPE	POINT LOAD ORDER	NAME		EFF	FLOW	TEMP	D.O.	BOD	CM-1	CM-2	CM-3
POINTLD-1	1.	T1	R1	0.00	0.22	16.51	5.11	2.67	0.00	0.00	0.00
POINTLD-1	2.	T2	R1	0.00	0.05	16.51	5.11	2.67	0.00	0.00	0.00
POINTLD-1	3.	T3 n T4	R1	0.00	0.05	16.51	5.11	2.67	0.00	0.00	0.00
POINTLD-1	4.	T5	R1	0.00	0.02	16.51	5.11	2.67	0.00	0.00	0.00
POINTLD-1	5.	T6 N T7	R1	0.00	0.06	16.51	5.11	2.67	0.00	0.00	0.00
POINTLD-1	6.	HarBe Di	R2	0.00	0.38	16.51	5.11	2.67	0.00	0.00	0.00
POINTLD-1	7.	T8	R2	0.00	0.07	16.51	5.11	2.67	0.00	0.00	0.00
POINTLD-1	8.	T9	R2	0.00	0.05	16.51	5.11	2.67	0.00	0.00	0.00
POINTLD-1	9.	CoSpr Br	R2	0.00	0.12	16.51	5.11	2.67	0.00	0.00	0.00
POINTLD-1	10.	BNDinLMP	R3	0.00	0.17	16.51	5.11	2.40	0.00	0.00	0.00
POINTLD-1	11.	T10	R3	0.00	0.10	16.51	5.11	2.40	0.00	0.00	0.00
POINTLD-1	12.	T11	R4	0.00	0.07	16.51	5.11	2.40	0.00	0.00	0.00
POINTLD-1	13.	T12	R4	0.00	0.04	16.51	5.11	2.40	0.00	0.00	0.00
POINTLD-1	14.	T13	R4	0.00	0.03	16.51	5.11	2.40	0.00	0.00	0.00
POINTLD-1	15.	FiveF Pr	R7	0.00	0.04	16.51	5.11	2.50	0.00	0.00	0.00
POINTLD-1	16.	T15nIMPr	R7	0.00	0.29	16.51	5.11	2.50	0.00	0.00	0.00
POINTLD-1	17.	T16	R7	0.00	0.02	16.51	5.11	2.50	0.00	0.00	0.00
POINTLD-1	18.	JPrnMeBr	R8	0.00	0.44	16.51	5.11	2.50	0.00	0.00	0.00
POINTLD-1	19.	T17	R8	0.00	0.06	16.51	5.11	2.50	0.00	0.00	0.00
POINTLD-1	20.	Sandt Br	R9	0.00	0.16	16.51	5.11	2.50	0.00	0.00	0.00
ENDATA11	0.			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 11A (POINT SOURCE CHARACTERISTICS - CHLOROPHYLL A, NITROGEN, PHOSPHORUS, COLIFORMS AND SELECTED NON-CONSERVATIVE CONSTITUENT) $$$

CARD TYPE	POINT LOAD ORDER	ANC	COLI	CHL-A	ORG-N	NH3-N	NO2-N	N03-N	ORG-P	DIS-P
POINTLD-2	1.	0.00	0.00E+00	9.33	0.67	0.13	0.03	0.26	0.15	0.04
POINTLD-2	2.	0.00	0.00E+00	9.33	0.67	0.13	0.03	0.26	0.15	0.04
POINTLD-2	3.	0.00	0.00E+00	9.33	0.67	0.13	0.03	0.26	0.15	0.04
POINTLD-2	4.	0.00	0.00E+00	9.33	0.67	0.13	0.03	0.26	0.15	0.04
POINTLD-2	5.	0.00	0.00E+00	9.33	0.67	0.13	0.03	0.26	0.15	0.04
POINTLD-2	6.	0.00	0.00E+00	9.33	0.67	0.13	0.03	0.26	0.15	0.04
POINTLD-2	7.	0.00	0.00E+00	9.33	0.67	0.13	0.03	0.26	0.15	0.04
POINTLD-2	8.	0.00	0.00E+00	9.33	0.67	0.13	0.03	0.26	0.15	0.04
POINTLD-2	9.	0.00	0.00E+00	9.33	0.67	0.13	0.03	0.26	0.15	0.04
POINTLD-2	10.	0.00	0.00E+00	9.33	0.67	0.16	0.03	0.22	0.24	0.07
POINTLD-2	11.	0.00	0.00E+00	9.33	0.67	0.16	0.03	0.22	0.24	0.07
POINTLD-2	12.	0.00	0.00E+00	9.33	0.67	0.16	0.03	0.22	0.24	0.07
POINTLD-2	13.	0.00	0.00E+00	9.33	0.67	0.16	0.03	0.22	0.24	0.07
POINTLD-2	14.	0.00	0.00E+00	9.33	0.67	0.16	0.03	0.22	0.24	0.07
POINTLD-2	15.	0.00	0.00E+00	9.33	0.67	0.05	0.02	0.17	0.09	0.02
POINTLD-2	16.	0.00	0.00E+00	9.33	0.67	0.05	0.02	0.17	0.09	0.02
POINTLD-2	17.	0.00	0.00E+00	9.33	0.67	0.05	0.02	0.17	0.09	0.02
POINTLD-2	18.	0.00	0.00E+00	9.33	0.67	0.05	0.02	0.17	0.09	0.02
POINTLD-2	19.	0.00	0.00E+00	9.33	0.67	0.05	0.02	0.17	0.09	0.02
POINTLD-2	20.	0.00	0.00E+00	9.33	0.67	0.05	0.02	0.17	0.09	0.02
ENDATA11A	0.	0.00	0.00E+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 12 (DAM CHARACTERISTICS) $$$

	DAM	RCH	ELE	ADAM	BDAM	FDAM	HDAM
DAM DATA	1.	6.	1.	1.60	0.80	1.00	1.83
ENDATA12	0.	0.	0.	0.00	0.00	0.00	0.00

$$$ DATA TYPE 13 (DOWNSTREAM BOUNDARY CONDITIONS-1) $$$

CARD TYPE	TEMP	D.O.	BOD	CM-1	CM-2	CM-3	ANC	COLI

ENDATA13 DOWNSTREAM BOUNDARY CONCENTRATIONS ARE UNCONSTRAINED

$$$ DATA TYPE 13A (DOWNSTREAM BOUNDARY CONDITIONS-2) $$$

CARD TYPE	CHL-A	ORG-N	NH3-N	NO2-N	NH3-N	ORG-P	DIS-P

ENDATA13A DOWNSTREAM BOUNDARY CONCENTRATIONS ARE UNCONSTRAINED

STEADY STATE ALGAE/NUTRIENT/DISSOLVED OXYGEN SIMULATION; CONVERGENCE SUMMARY:

VARIABLE	ITERATION	NUMBER OF NONCONVERGENT ELEMENTS
ALGAE GROWTH RATE	1	36
ALGAE GROWTH RATE	2	36
ALGAE GROWTH RATE	3	36
ALGAE GROWTH RATE	4	36
ALGAE GROWTH RATE	5	36
ALGAE GROWTH RATE	6	36
ALGAE GROWTH RATE	7	0
DISSOLVED OXYGEN (DAMS)	1	0
ALGAE GROWTH RATE	8	0
DISSOLVED OXYGEN (DAMS)	2	0

SUMMARY OF CONDITIONS FOR ALGAL GROWTH RATE SIMULATION:

1. LIGHT AVERAGING OPTION. LAVOPT= 2

   METHOD: MEAN SOLAR RADIATION DURING DAYLIGHT HOURS

   SOURCE OF SOLAR VALUES: DATA TYPE 1A
   DAILY NET SOLAR RADIATION: 1400.300 BTU/FT-2 (380.000 LANGLEYS)
   NUMBER OF DAYLIGHT HOURS: 0.0
   PHOTOSYNTHETIC ACTIVE FRACTION OF SOLAR RADIATION (TFACT): N/A
   MEAN SOLAR RADIATION ADJUSTMENT FACTOR (AFACT): 0.950

2. LIGHT FUNCTION OPTION: LFNOPT= 2

   SMITH FUNCTION, WITH 71% IMAX = 0.025 LANGLEYS/MIN

3. GROWTH ATTENUATION OPTION FOR NUTRIENTS. LGROPT= 2

   MINIMUM OF NITROGEN, PHOSPHORUS: FL*MIN(FN,FP)

DISSOLVED OXYGEN IN MG/L ITERATION 10

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	5.66	5.77	6.05	6.25	6.46	6.56														
2	6.33	6.47	6.62	6.68	6.84															
3	5.43	5.50	5.64	5.84																
4	5.93	6.05	6.16	6.30																
5	7.49																			
6	8.49	8.49																		
7	5.72	6.14	6.20	6.56	6.84															
8	7.10	6.77	7.02	7.17	7.37															
9	8.10	8.16	8.11	8.17																

5-DAY BIOCHEMICAL OXYGEN DEMAND ITERATION 10

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	2.85	2.86	2.91	2.94	2.98	3.00														
2	2.90	2.89	2.88	2.87	2.87															
3	2.55	2.55	2.56	2.60																
4	2.63	2.67	2.70	2.74																
5	2.83																			
6	2.84	2.84																		
7	2.59	2.66	2.65	2.69	2.72															
8	2.73	2.67	2.67	2.67	2.68															
9	2.78	2.78	2.77	2.77																

ORGANIC NITROGEN AS N IN MG/L ITERATION 10

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.75	0.75	0.77	0.78	0.80	0.80														
2	0.76	0.76	0.75	0.75	0.74															
3	0.72	0.71	0.71	0.72																
4	0.73	0.74	0.75	0.76																
5	0.77																			
6	0.78	0.78																		
7	0.70	0.72	0.72	0.73	0.74															
8	0.74	0.72	0.72	0.71	0.71															
9	0.75	0.76	0.76	0.76																

AMMONIA AS N IN MG/L ITERATION 10

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.15	0.15	0.16	0.17	0.18	0.18														
2	0.17	0.17	0.17	0.18	0.18															
3	0.18	0.18	0.18	0.19																
4	0.20	0.20	0.21	0.21																
5	0.19																			
6	0.19	0.19																		
7	0.07	0.09	0.09	0.10	0.11															
8	0.12	0.11	0.12	0.13	0.13															
9	0.17	0.17	0.16	0.16																

NITRITE AS N IN MG/L ITERATION 10

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.04	0.04	0.05	0.05	0.06	0.06														
2	0.05	0.06	0.06	0.06	0.06															
3	0.04	0.04	0.05	0.05																
4	0.06	0.07	0.08	0.09																
5	0.07																			
6	0.08	0.08																		
7	0.03	0.03	0.03	0.04	0.04															
8	0.05	0.04	0.05	0.05	0.05															
9	0.07	0.07	0.07	0.07																

NITRATE AS N IN MG/L ITERATION 10

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.39	0.39	0.44	0.47	0.50	0.52														
2	0.47	0.48	0.50	0.51	0.53															
3	0.35	0.36	0.38	0.42																
4	0.52	0.61	0.69	0.77																
5	0.66																			
6	0.67	0.68																		
7	0.24	0.29	0.29	0.33	0.36															
8	0.42	0.38	0.42	0.44	0.48															
9	0.61	0.62	0.61	0.62																

ORGANIC PHOSPHORUS AS P IN MG/L ITERATION 10

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.14	0.14	0.13	0.13	0.12	0.12														
2	0.13	0.12	0.12	0.12	0.12															
3	0.20	0.20	0.19	0.18																
4	0.17	0.17	0.16	0.15																
5	0.13																			
6	0.13	0.12																		
7	0.08	0.08	0.08	0.07	0.07															
8	0.07	0.07	0.07	0.07	0.07															
9	0.10	0.10	0.10	0.10																

DISSOLVED PHOSPHORUS AS P IN MG/L ITERATION 10

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.04	0.04	0.04	0.05	0.05	0.05														
2	0.05	0.05	0.05	0.05	0.05															
3	0.07	0.07	0.08	0.08																
4	0.08	0.09	0.09	0.09																
5	0.06																			
6	0.06	0.06																		
7	0.03	0.03	0.03	0.03	0.03															
8	0.03	0.03	0.03	0.04	0.04															
9	0.05	0.05	0.05	0.05																

ALGAE AS CHL-A IN UG/L ITERATION 10

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	8.02	7.93	7.47	7.12	6.75	6.58														
2	7.22	7.14	7.03	7.04	6.89															
3	7.59	7.57	7.33	6.80																
4	6.63	6.38	6.13	5.83																
5	7.93																			
6	9.48	9.57																		
7	8.30	7.54	7.53	6.96	6.49															
8	6.10	6.72	6.37	6.16	5.87															
9	8.15	8.21	8.31	8.36																

ALGAE GROWTH RATES IN PER DAY ARE ITERATION 10

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.59	0.59	0.60	0.61	0.62	0.63														
2	0.62	0.63	0.63	0.64	0.65															
3	0.71	0.71	0.72	0.73																
4	0.73	0.74	0.74	0.75																
5	0.69																			
6	0.68	0.68																		
7	0.48	0.50	0.50	0.52	0.54															
8	0.55	0.54	0.55	0.56	0.57															
9	0.65	0.65	0.64	0.64																

PHOTOSYNTHESIS-RESPIRATION RATIOS ARE ITERATION 10

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1.97	1.99	2.03	2.06	2.10	2.12														
2	2.09	2.11	2.13	2.14	2.17															
3	2.38	2.39	2.42	2.45																
4	2.46	2.48	2.50	2.52																
5	2.31																			
6	2.30	2.30																		
7	1.60	1.68	1.69	1.75	1.80															
8	1.85	1.81	1.86	1.89	1.93															
9	2.18	2.18	2.16	2.16																

***** STEADY STATE SIMULATION *****

** HYDRAULICS SUMMARY **

ELE ORD	RCH NUM	ELE NUM	BEGIN LOC KILO	END LOC KILO	FLOW CMS	POINT SRCE CMS	INCR FLOW CMS	VEL MPS	TRVL TIME DAY	DEPTH M	WIDTH M	VOLUME K-CU-M	BOTTOM AREA K-SQ-M	X-SECT AREA SQ-M	DSPRSN COEF SQ-M/S
1	1	1	18.00	17.00	0.29	0.00	0.03	0.297	0.039	0.317	3.069	0.97	3.70	0.97	1.43
2	1	2	17.00	16.00	0.54	0.22	0.03	0.331	0.035	0.395	4.167	1.65	4.96	1.65	1.91
3	1	3	16.00	15.00	0.62	0.05	0.03	0.339	0.034	0.415	4.450	1.85	5.28	1.84	2.04
4	1	4	15.00	14.00	0.70	0.05	0.03	0.345	0.034	0.432	4.715	2.04	5.58	2.04	2.15
5	1	5	14.00	13.00	0.76	0.02	0.03	0.350	0.033	0.443	4.882	2.16	5.77	2.16	2.22
6	1	6	13.00	12.00	0.85	0.06	0.03	0.357	0.032	0.461	5.165	2.38	6.09	2.38	2.35
7	2	1	12.00	11.00	1.24	0.38	0.02	0.380	0.030	0.527	6.211	3.27	7.27	3.27	2.79
8	2	2	11.00	10.00	1.33	0.07	0.02	0.385	0.030	0.540	6.423	3.47	7.50	3.47	2.89
9	2	3	10.00	9.00	1.40	0.05	0.02	0.388	0.030	0.548	6.567	3.60	7.67	3.60	2.95
10	2	4	9.00	8.00	1.53	0.12	0.02	0.394	0.029	0.566	6.861	3.88	7.99	3.88	3.07
11	2	5	8.00	7.00	1.55	0.00	0.02	0.395	0.029	0.568	6.899	3.92	8.04	3.92	3.09
12	3	1	8.00	7.00	0.20	0.00	0.03	0.138	0.084	0.349	4.220	1.47	4.92	1.47	0.72
13	3	2	7.00	6.00	0.40	0.17	0.03	0.179	0.065	0.434	5.102	2.22	5.97	2.22	1.12
14	3	3	6.00	5.00	0.53	0.10	0.03	0.200	0.058	0.476	5.526	2.63	6.48	2.63	1.35
15	3	4	5.00	4.00	0.55	0.00	0.03	0.204	0.057	0.484	5.604	2.71	6.57	2.71	1.40
16	4	1	4.00	3.00	0.65	0.07	0.03	0.217	0.053	0.511	5.876	3.00	6.90	3.00	1.56
17	4	2	3.00	2.00	0.72	0.04	0.03	0.226	0.051	0.527	6.037	3.19	7.09	3.18	1.66
18	4	3	2.00	1.00	0.77	0.03	0.03	0.232	0.050	0.540	6.165	3.33	7.25	3.33	1.74
19	4	4	1.00	0.00	0.80	0.00	0.03	0.236	0.049	0.547	6.231	3.41	7.33	3.41	1.79
20	5	1	7.00	6.00	2.46	0.00	0.11	0.010	1.129	1.500	160.111	240.22	163.15	240.17	10.80
21	6	1	6.00	5.00	2.49	0.00	0.03	0.225	0.052	0.608	18.233	11.09	19.45	11.09	1.86
22	6	2	5.00	4.00	2.52	0.00	0.03	0.227	0.051	0.609	18.265	11.12	19.49	11.12	1.88
23	7	1	10.00	9.00	0.55	0.00	0.03	0.270	0.043	0.291	6.953	2.03	7.54	2.03	1.21
24	7	2	9.00	8.00	0.62	0.04	0.03	0.274	0.042	0.298	7.611	2.27	8.21	2.27	1.25
25	7	3	8.00	7.00	0.95	0.29	0.03	0.286	0.040	0.322	10.269	3.31	10.92	3.30	1.39
26	7	4	7.00	6.00	0.98	0.00	0.03	0.287	0.040	0.324	10.523	3.41	11.17	3.41	1.41
27	7	5	6.00	5.00	1.03	0.02	0.03	0.289	0.040	0.327	10.920	3.57	11.58	3.57	1.43
28	8	1	5.00	4.00	1.05	0.00	0.02	0.264	0.044	0.338	11.772	3.98	12.45	3.98	1.34
29	8	2	4.00	3.00	1.51	0.44	0.02	0.274	0.042	0.361	15.276	5.52	16.00	5.52	1.47
30	8	3	3.00	2.00	1.53	0.00	0.02	0.274	0.042	0.362	15.422	5.59	16.15	5.58	1.47
31	8	4	2.00	1.00	1.61	0.06	0.02	0.276	0.042	0.365	15.997	5.85	16.73	5.85	1.49
32	8	5	1.00	0.00	1.63	0.00	0.02	0.276	0.042	0.366	16.141	5.91	16.88	5.91	1.50

***** STEADY STATE SIMULATION *****

** HYDRAULICS SUMMARY **

ELE ORD	RCH NUM	ELE NUM	BEGIN LOC KILO	END LOC KILO	FLOW CMS	POINT SRCE CMS	INCR FLOW CMS	VEL MPS	TRVL TIME DAY	DEPTH M	WIDTH M	VOLUME K-CU-M	BOTTOM AREA K-SQ-M	X-SECT AREA SQ-M	DSPRSN COEF SQ-M/S
33	9	1	4.00	3.00	4.18	0.00	0.03	0.330	0.035	0.644	19.672	12.67	20.97	12.67	2.87
34	9	2	3.00	2.00	4.21	0.00	0.03	0.332	0.035	0.645	19.693	12.70	20.99	12.69	2.88
35	9	3	2.00	1.00	4.40	0.16	0.03	0.343	0.034	0.648	19.817	12.84	21.12	12.84	2.99
36	9	4	1.00	0.00	4.43	0.00	0.03	0.344	0.034	0.648	19.837	12.86	21.14	12.86	3.01

***** STEADY STATE SIMULATION *****

** REACTION COEFFICIENT SUMMARY **

RCH NUM	ELE NUM	DO SAT MG/L	K2 OPT	OXYGN REAIR 1/DAY	BOD DECAY 1/DAY	BOD SETT 1/DAY	SOD RATE G/M2D	ORGN DECAY 1/DAY	ORGN SETT 1/DAY	NH3 DECAY 1/DAY	NH3 SRCE MG/M2D	NO2 DECAY 1/DAY	ORGP DECAY 1/DAY	ORGP SETT 1/DAY	DISP SRCE MG/M2D	COLI DECAY 1/DAY	ANC DECAY 1/DAY	ANC SETT 1/DAY	ANC SRCE MG/M2D
1	1	9.50	5	4.61	0.17	0.00	0.42	0.35	0.05	0.78	0.00	1.73	0.61	0.05	0.00	0.00	0.00	0.00	0.00
1	2	9.50	5	4.29	0.17	0.00	0.42	0.35	0.05	0.78	0.00	1.73	0.61	0.05	0.00	0.00	0.00	0.00	0.00
1	3	9.50	5	3.91	0.17	0.00	0.42	0.35	0.05	0.78	0.00	1.73	0.61	0.05	0.00	0.00	0.00	0.00	0.00
1	4	9.50	5	3.79	0.17	0.00	0.42	0.35	0.05	0.78	0.00	1.73	0.61	0.05	0.00	0.00	0.00	0.00	0.00
1	5	9.50	5	3.71	0.17	0.00	0.42	0.35	0.05	0.78	0.00	1.73	0.61	0.05	0.00	0.00	0.00	0.00	0.00
1	6	9.50	5	3.62	0.17	0.00	0.42	0.35	0.05	0.78	0.00	1.73	0.61	0.05	0.00	0.00	0.00	0.00	0.00
2	1	9.50	5	3.42	0.17	0.00	0.42	0.35	0.05	0.78	0.00	1.73	0.61	0.05	0.00	0.00	0.00	0.00	0.00
2	2	9.50	5	3.24	0.17	0.00	0.42	0.35	0.05	0.78	0.00	1.73	0.61	0.05	0.00	0.00	0.00	0.00	0.00
2	3	9.50	5	3.19	0.17	0.00	0.42	0.35	0.05	0.78	0.00	1.73	0.61	0.05	0.00	0.00	0.00	0.00	0.00
2	4	9.50	5	3.14	0.17	0.00	0.42	0.35	0.05	0.78	0.00	1.73	0.61	0.05	0.00	0.00	0.00	0.00	0.00
2	5	9.50	5	3.11	0.17	0.00	0.42	0.35	0.05	0.78	0.00	1.73	0.61	0.05	0.00	0.00	0.00	0.00	0.00
3	1	9.50	5	1.74	0.17	0.00	0.42	0.35	0.05	0.78	0.00	1.73	0.61	0.05	0.00	0.00	0.00	0.00	0.00
3	2	9.50	5	1.75	0.17	0.00	0.42	0.35	0.05	0.78	0.00	1.73	0.61	0.05	0.00	0.00	0.00	0.00	0.00
3	3	9.50	5	1.78	0.17	0.00	0.42	0.35	0.05	0.78	0.00	1.73	0.61	0.05	0.00	0.00	0.00	0.00	0.00
3	4	9.50	5	1.79	0.17	0.00	0.42	0.35	0.05	0.78	0.00	1.73	0.61	0.05	0.00	0.00	0.00	0.00	0.00
4	1	9.50	5	1.79	0.17	0.00	0.42	0.35	0.05	0.78	0.00	1.73	0.61	0.05	0.00	0.00	0.00	0.00	0.00
4	2	9.50	5	1.80	0.17	0.00	0.42	0.35	0.05	0.78	0.00	1.73	0.61	0.05	0.00	0.00	0.00	0.00	0.00
4	3	9.50	5	1.81	0.17	0.00	0.42	0.35	0.05	0.78	0.00	1.73	0.61	0.05	0.00	0.00	0.00	0.00	0.00
4	4	9.50	5	1.81	0.17	0.00	0.42	0.35	0.05	0.78	0.00	1.73	0.61	0.05	0.00	0.00	0.00	0.00	0.00
5	1	9.50	5	1.24	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	1	9.50	5	0.76	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	2	9.50	5	1.52	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	1	9.50	5	4.60	0.17	0.00	0.42	0.35	0.05	0.78	0.00	1.73	0.61	0.05	0.00	0.00	0.00	0.00	0.00
7	2	9.50	5	4.57	0.17	0.00	0.42	0.35	0.05	0.78	0.00	1.73	0.61	0.05	0.00	0.00	0.00	0.00	0.00
7	3	9.50	5	4.44	0.17	0.00	0.42	0.35	0.05	0.78	0.00	1.73	0.61	0.05	0.00	0.00	0.00	0.00	0.00
7	4	9.50	5	4.33	0.17	0.00	0.42	0.35	0.05	0.78	0.00	1.73	0.61	0.05	0.00	0.00	0.00	0.00	0.00
7	5	9.50	5	4.31	0.17	0.00	0.42	0.35	0.05	0.78	0.00	1.73	0.61	0.05	0.00	0.00	0.00	0.00	0.00
8	1	9.50	5	4.02	0.17	0.00	0.42	0.35	0.05	0.78	0.00	1.73	0.61	0.05	0.00	0.00	0.00	0.00	0.00
8	2	9.50	5	3.66	0.17	0.00	0.42	0.35	0.05	0.78	0.00	1.73	0.61	0.05	0.00	0.00	0.00	0.00	0.00
8	3	9.50	5	3.58	0.17	0.00	0.42	0.35	0.05	0.78	0.00	1.73	0.61	0.05	0.00	0.00	0.00	0.00	0.00
8	4	9.50	5	3.56	0.17	0.00	0.42	0.35	0.05	0.78	0.00	1.73	0.61	0.05	0.00	0.00	0.00	0.00	0.00
8	5	9.50	5	3.55	0.17	0.00	0.42	0.35	0.05	0.78	0.00	1.73	0.61	0.05	0.00	0.00	0.00	0.00	0.00

***** STEADY STATE SIMULATION *****

** REACTION COEFFICIENT SUMMARY **

RCH NUM	ELE NUM	DO SAT MG/L	K2 OPT	OXYGN REAIR 1/DAY	BOD DECAY 1/DAY	BOD SETT 1/DAY	SOD RATE G/M2D	ORGN DECAY 1/DAY	ORGN SETT 1/DAY	NH3 DECAY 1/DAY	NH3 SRCE MG/M2D	NO2 DECAY 1/DAY	ORGP DECAY 1/DAY	ORGP SETT 1/DAY	DISP SRCE MG/M2D	COLI DECAY 1/DAY	ANC DECAY 1/DAY	ANC SETT 1/DAY	ANC SRCE MG/M2D
9	1	9.50	5	2.35	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	2	9.50	5	2.17	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	3	9.50	5	2.21	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	4	9.50	5	2.25	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

STREAM QUALITY SIMULATION OUTPUT PAGE NUMBER 5
QUAL-2E STREAM QUALITY ROUTING MODEL Version 3.22 -- May 1996

***** STEADY STATE SIMULATION *****

** WATER QUALITY VARIABLES **

RCH NUM	ELE NUM	TEMP DEG-C	CM-1	CM-2	CM-3	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM-N MG/L	ORGP MG/L	DIS-P MG/L	SUM-P MG/L	COLI #/100ML	ANC	CHLA UG/L
1	1	16.84	0.00	0.00	0.00	5.66	2.85	0.75	0.15	0.04	0.39	1.32	0.14	0.04	0.18	.00E+00	0.00	8.02
1	2	16.84	0.00	0.00	0.00	5.77	2.86	0.75	0.15	0.04	0.39	1.34	0.14	0.04	0.18	.00E+00	0.00	7.93
1	3	16.84	0.00	0.00	0.00	6.05	2.91	0.77	0.16	0.05	0.44	1.41	0.13	0.04	0.17	.00E+00	0.00	7.47
1	4	16.84	0.00	0.00	0.00	6.25	2.94	0.78	0.17	0.05	0.47	1.47	0.13	0.05	0.17	.00E+00	0.00	7.12
1	5	16.84	0.00	0.00	0.00	6.46	2.98	0.80	0.18	0.06	0.50	1.53	0.12	0.05	0.17	.00E+00	0.00	6.75
1	6	16.84	0.00	0.00	0.00	6.56	3.00	0.80	0.18	0.06	0.52	1.56	0.12	0.05	0.17	.00E+00	0.00	6.58
2	1	16.84	0.00	0.00	0.00	6.33	2.90	0.76	0.17	0.05	0.47	1.45	0.13	0.05	0.17	.00E+00	0.00	7.22
2	2	16.84	0.00	0.00	0.00	6.47	2.89	0.76	0.17	0.06	0.48	1.47	0.12	0.05	0.17	.00E+00	0.00	7.14
2	3	16.84	0.00	0.00	0.00	6.62	2.88	0.75	0.17	0.06	0.50	1.49	0.12	0.05	0.17	.00E+00	0.00	7.03
2	4	16.84	0.00	0.00	0.00	6.68	2.87	0.75	0.18	0.06	0.51	1.49	0.12	0.05	0.17	.00E+00	0.00	7.04
2	5	16.84	0.00	0.00	0.00	6.84	2.87	0.74	0.18	0.06	0.53	1.52	0.12	0.05	0.17	.00E+00	0.00	6.89
3	1	16.84	0.00	0.00	0.00	5.43	2.55	0.72	0.18	0.04	0.35	1.29	0.20	0.07	0.27	.00E+00	0.00	7.59
3	2	16.84	0.00	0.00	0.00	5.50	2.55	0.71	0.18	0.04	0.36	1.29	0.20	0.07	0.27	.00E+00	0.00	7.57
3	3	16.84	0.00	0.00	0.00	5.64	2.56	0.71	0.18	0.05	0.38	1.32	0.19	0.08	0.27	.00E+00	0.00	7.33
3	4	16.84	0.00	0.00	0.00	5.84	2.60	0.72	0.19	0.05	0.42	1.39	0.18	0.08	0.26	.00E+00	0.00	6.80
4	1	16.84	0.00	0.00	0.00	5.93	2.63	0.73	0.20	0.06	0.52	1.51	0.17	0.08	0.26	.00E+00	0.00	6.63
4	2	16.84	0.00	0.00	0.00	6.05	2.67	0.74	0.20	0.07	0.61	1.62	0.17	0.09	0.25	.00E+00	0.00	6.38
4	3	16.84	0.00	0.00	0.00	6.16	2.70	0.75	0.21	0.08	0.69	1.72	0.16	0.09	0.25	.00E+00	0.00	6.13
4	4	16.84	0.00	0.00	0.00	6.30	2.74	0.76	0.21	0.09	0.77	1.83	0.15	0.09	0.24	.00E+00	0.00	5.83
5	1	16.84	0.00	0.00	0.00	7.49	2.83	0.77	0.19	0.07	0.66	1.70	0.13	0.06	0.19	.00E+00	0.00	7.93
6	1	16.84	0.00	0.00	0.00	8.49	2.84	0.78	0.19	0.08	0.67	1.71	0.13	0.06	0.19	.00E+00	0.00	9.48
6	2	16.84	0.00	0.00	0.00	8.49	2.84	0.78	0.19	0.08	0.68	1.73	0.12	0.06	0.19	.00E+00	0.00	9.57
7	1	16.84	0.00	0.00	0.00	5.72	2.59	0.70	0.07	0.03	0.24	1.04	0.08	0.03	0.11	.00E+00	0.00	8.30
7	2	16.84	0.00	0.00	0.00	6.14	2.66	0.72	0.09	0.03	0.29	1.14	0.08	0.03	0.11	.00E+00	0.00	7.54
7	3	16.84	0.00	0.00	0.00	6.20	2.65	0.72	0.09	0.03	0.29	1.14	0.08	0.03	0.11	.00E+00	0.00	7.53
7	4	16.84	0.00	0.00	0.00	6.56	2.69	0.73	0.10	0.04	0.33	1.20	0.07	0.03	0.11	.00E+00	0.00	6.96
7	5	16.84	0.00	0.00	0.00	6.84	2.72	0.74	0.11	0.04	0.36	1.25	0.07	0.03	0.10	.00E+00	0.00	6.49
8	1	16.84	0.00	0.00	0.00	7.10	2.73	0.74	0.12	0.05	0.42	1.32	0.07	0.03	0.10	.00E+00	0.00	6.10
8	2	16.84	0.00	0.00	0.00	6.77	2.67	0.72	0.11	0.04	0.38	1.25	0.07	0.03	0.11	.00E+00	0.00	6.72
8	3	16.84	0.00	0.00	0.00	7.02	2.67	0.72	0.12	0.05	0.42	1.30	0.07	0.03	0.11	.00E+00	0.00	6.37
8	4	16.84	0.00	0.00	0.00	7.17	2.67	0.71	0.13	0.05	0.44	1.33	0.07	0.04	0.11	.00E+00	0.00	6.16
8	5	16.84	0.00	0.00	0.00	7.37	2.68	0.71	0.13	0.05	0.48	1.38	0.07	0.04	0.11	.00E+00	0.00	5.87

***** STEADY STATE SIMULATION *****

** WATER QUALITY VARIABLES **

RCH NUM	ELE NUM	TEMP DEG-C	CM-1	CM-2	CM-3	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM-N MG/L	ORGP MG/L	DIS-P MG/L	SUM-P MG/L	COLI #/100ML	ANC	CHLA UG/L
9	1	16.84	0.00	0.00	0.00	8.10	2.78	0.75	0.17	0.07	0.61	1.60	0.10	0.05	0.15	.00E+00	0.00	8.15
9	2	16.84	0.00	0.00	0.00	8.16	2.78	0.76	0.17	0.07	0.62	1.61	0.10	0.05	0.15	.00E+00	0.00	8.21
9	3	16.84	0.00	0.00	0.00	8.11	2.77	0.76	0.16	0.07	0.61	1.60	0.10	0.05	0.15	.00E+00	0.00	8.31
9	4	16.84	0.00	0.00	0.00	8.17	2.77	0.76	0.16	0.07	0.62	1.61	0.10	0.05	0.15	.00E+00	0.00	8.36

***** STEADY STATE SIMULATION *****

** ALGAE DATA **

ELE ORD	RCH NUM	ELE NUM	CHLA UG/L	ALGY GRWTH 1/DAY	ALGY RESP 1/DAY	ALGY SETT M/DAY	A P/R RATIO *	NET P-R MG/L-D	NH3 PREF *	NH3-N FRACT N-UPTKE *	LIGHT EXTCO 1/M	ALGAE GROWTH RATE ATTEN FACTORS LIGHT *	NITRGN *	PHSPRS *
1	1	1	8.02	0.59	0.24	0.46	1.97	0.05	0.90	0.78	0.10	0.55	0.78	0.61
2	1	2	7.93	0.59	0.24	0.46	1.99	0.05	0.90	0.78	0.10	0.55	0.78	0.62
3	1	3	7.47	0.60	0.24	0.46	2.03	0.05	0.90	0.77	0.09	0.55	0.79	0.63
4	1	4	7.12	0.61	0.24	0.46	2.06	0.05	0.90	0.76	0.09	0.55	0.80	0.64
5	1	5	6.75	0.62	0.24	0.46	2.10	0.05	0.90	0.76	0.09	0.55	0.81	0.65
6	1	6	6.58	0.63	0.24	0.46	2.12	0.05	0.90	0.76	0.09	0.55	0.82	0.66
7	2	1	7.22	0.62	0.24	0.46	2.09	0.05	0.90	0.76	0.09	0.55	0.80	0.65
8	2	2	7.14	0.63	0.24	0.46	2.11	0.05	0.90	0.76	0.09	0.55	0.81	0.65
9	2	3	7.03	0.63	0.24	0.46	2.13	0.05	0.90	0.76	0.09	0.55	0.81	0.66
10	2	4	7.04	0.64	0.24	0.46	2.14	0.05	0.90	0.76	0.09	0.55	0.82	0.67
11	2	5	6.89	0.65	0.24	0.46	2.17	0.05	0.90	0.75	0.09	0.55	0.82	0.67
12	3	1	7.59	0.71	0.24	0.46	2.38	0.07	0.90	0.82	0.09	0.55	0.77	0.74
13	3	2	7.57	0.71	0.24	0.46	2.39	0.07	0.90	0.82	0.09	0.55	0.78	0.74
14	3	3	7.33	0.72	0.24	0.46	2.42	0.07	0.90	0.81	0.09	0.55	0.78	0.75
15	3	4	6.80	0.73	0.24	0.46	2.45	0.06	0.90	0.80	0.09	0.55	0.80	0.76
16	4	1	6.63	0.73	0.24	0.46	2.46	0.06	0.90	0.77	0.09	0.55	0.82	0.77
17	4	2	6.38	0.74	0.24	0.46	2.48	0.06	0.90	0.75	0.08	0.55	0.84	0.77
18	4	3	6.13	0.74	0.24	0.46	2.50	0.06	0.90	0.73	0.08	0.55	0.85	0.78
19	4	4	5.83	0.75	0.24	0.46	2.52	0.06	0.90	0.71	0.08	0.55	0.86	0.78
20	5	1	7.93	0.69	0.24	0.00	2.31	0.07	0.90	0.72	0.10	0.55	0.85	0.72
21	6	1	9.48	0.68	0.24	0.00	2.30	0.08	0.90	0.72	0.11	0.55	0.85	0.72
22	6	2	9.57	0.68	0.24	0.00	2.30	0.08	0.90	0.71	0.11	0.55	0.85	0.71
23	7	1	8.30	0.48	0.24	0.46	1.60	0.03	0.90	0.74	0.10	0.55	0.67	0.50
24	7	2	7.54	0.50	0.24	0.46	1.68	0.03	0.90	0.73	0.09	0.55	0.71	0.52
25	7	3	7.53	0.50	0.24	0.46	1.69	0.03	0.90	0.74	0.09	0.55	0.71	0.53
26	7	4	6.96	0.52	0.24	0.46	1.75	0.03	0.90	0.74	0.09	0.55	0.74	0.55
27	7	5	6.49	0.54	0.24	0.46	1.80	0.03	0.90	0.74	0.08	0.55	0.76	0.56
28	8	1	6.10	0.55	0.24	0.46	1.85	0.03	0.90	0.73	0.08	0.55	0.78	0.58
29	8	2	6.72	0.54	0.24	0.46	1.81	0.03	0.90	0.73	0.09	0.55	0.76	0.56
30	8	3	6.37	0.55	0.24	0.46	1.86	0.03	0.90	0.72	0.08	0.55	0.78	0.58
31	8	4	6.16	0.56	0.24	0.46	1.89	0.03	0.90	0.72	0.08	0.55	0.79	0.59
32	8	5	5.87	0.57	0.24	0.46	1.93	0.03	0.90	0.72	0.08	0.55	0.80	0.60

***** STEADY STATE SIMULATION *****

** ALGAE DATA **

ELE ORD	RCH NUM	ELE NUM	CHLA UG/L	ALGY GRWTH 1/DAY	ALGY RESP 1/DAY	ALGY SETT M/DAY	A P/R RATIO *	NET P-R MG/L-D	NH3 PREF *	NH3-N FRACT N-UPTKE *	LIGHT EXTCO 1/M	ALGAE GROWTH RATE ATTEN FACTORS LIGHT *	NITRGN *	PHSPRS *
33	9	1	8.15	0.65	0.24	0.00	2.18	0.06	0.90	0.71	0.10	0.55	0.83	0.68
34	9	2	8.21	0.65	0.24	0.00	2.18	0.06	0.90	0.71	0.10	0.55	0.84	0.68
35	9	3	8.31	0.64	0.24	0.00	2.16	0.06	0.90	0.71	0.10	0.55	0.83	0.67
36	9	4	8.36	0.64	0.24	0.00	2.16	0.06	0.90	0.70	0.10	0.55	0.83	0.67

***** STEADY STATE SIMULATION *****

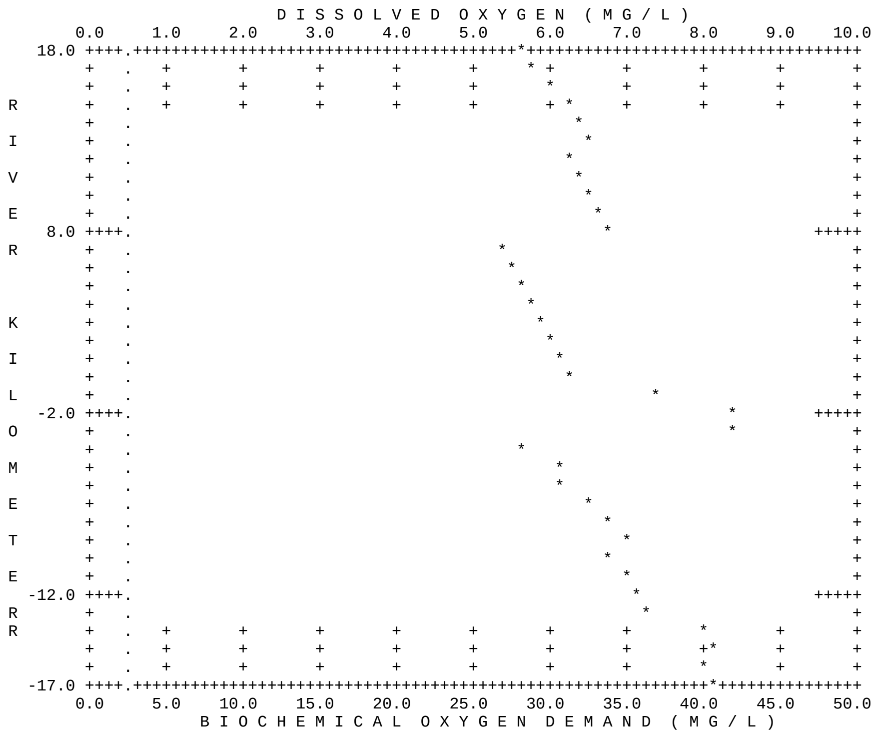
** DISSOLVED OXYGEN DATA **

ELE ORD	RCH NUM	ELE NUM	TEMP DEG-C	DO SAT MG/L	DO MG/L	DO DEF MG/L	DAM INPUT MG/L	NIT INHIB FACT	F-FNCTN INPUT	OXYGN REAIR	C-BOD	SOD	NET P-R	NH3-N	NO2-N
									COMPONENTS OF DISSOLVED OXYGEN MASS BALANCE (MG/L-DAY)						
1	1	1	16.84	9.50	5.66	3.84	0.00	1.00	131.18	17.70	-0.49	-1.31	0.05	-0.41	-0.08
2	1	2	16.84	9.50	5.77	3.73	0.00	1.00	68.45	16.00	-0.49	-1.05	0.05	-0.41	-0.08
3	1	3	16.84	9.50	6.05	3.45	0.00	1.00	19.03	13.50	-0.50	-1.00	0.05	-0.44	-0.09
4	1	4	16.84	9.50	6.25	3.25	0.00	1.00	17.23	12.30	-0.51	-0.96	0.05	-0.46	-0.10
5	1	5	16.84	9.50	6.46	3.04	0.00	1.00	10.72	11.27	-0.52	-0.94	0.05	-0.48	-0.10
6	1	6	16.84	9.50	6.56	2.94	0.00	1.00	17.32	10.64	-0.52	-0.90	0.05	-0.49	-0.11
7	2	1	16.84	9.50	6.33	3.17	0.00	1.00	53.25	10.84	-0.50	-0.79	0.05	-0.46	-0.10
8	2	2	16.84	9.50	6.47	3.03	0.00	1.00	11.44	9.81	-0.50	-0.77	0.05	-0.47	-0.10
9	2	3	16.84	9.50	6.62	2.88	0.00	1.00	7.70	9.21	-0.50	-0.76	0.05	-0.47	-0.11
10	2	4	16.84	9.50	6.68	2.82	0.00	1.00	15.10	8.87	-0.50	-0.73	0.05	-0.48	-0.11
11	2	5	16.84	9.50	6.84	2.66	0.00	1.00	2.01	8.25	-0.50	-0.73	0.05	-0.49	-0.11
12	3	1	16.84	9.50	5.43	4.07	0.00	1.00	60.69	7.06	-0.44	-1.19	0.07	-0.48	-0.08
13	3	2	16.84	9.50	5.50	4.00	0.00	1.00	38.32	7.01	-0.44	-0.96	0.07	-0.48	-0.08
14	3	3	16.84	9.50	5.64	3.86	0.00	1.00	21.38	6.87	-0.44	-0.87	0.07	-0.50	-0.09
15	3	4	16.84	9.50	5.84	3.66	0.00	1.00	4.15	6.54	-0.45	-0.86	0.06	-0.52	-0.10
16	4	1	16.84	9.50	5.93	3.57	0.00	1.00	14.62	6.40	-0.46	-0.81	0.06	-0.53	-0.12
17	4	2	16.84	9.50	6.05	3.45	0.00	1.00	8.94	6.21	-0.46	-0.79	0.06	-0.55	-0.13
18	4	3	16.84	9.50	6.16	3.34	0.00	1.00	7.22	6.03	-0.47	-0.77	0.06	-0.57	-0.15
19	4	4	16.84	9.50	6.30	3.20	0.00	1.00	3.70	5.79	-0.47	-0.76	0.06	-0.58	-0.16
20	5	1	16.84	9.50	7.49	2.01	0.00	1.00	0.22	2.48	0.00	-0.28	0.07	0.00	0.00
21	6	1	16.84	9.50	8.49	1.01	1.12	1.00	1.17	0.77	0.00	-0.68	0.08	0.00	0.00
22	6	2	16.84	9.50	8.49	1.01	0.00	1.00	1.16	1.53	0.00	-0.68	0.08	0.00	0.00
23	7	1	16.84	9.50	5.72	3.78	0.00	1.00	119.02	17.40	-0.45	-1.43	0.03	-0.20	-0.05
24	7	2	16.84	9.50	6.14	3.36	0.00	1.00	14.13	15.33	-0.46	-1.39	0.03	-0.25	-0.06
25	7	3	16.84	9.50	6.20	3.30	0.00	1.00	43.08	14.67	-0.46	-1.29	0.03	-0.25	-0.06
26	7	4	16.84	9.50	6.56	2.94	0.00	1.00	4.10	12.73	-0.46	-1.28	0.03	-0.28	-0.07
27	7	5	16.84	9.50	6.84	2.66	0.00	1.00	6.27	11.48	-0.47	-1.27	0.03	-0.31	-0.07
28	8	1	16.84	9.50	7.10	2.40	0.00	1.00	2.20	9.64	-0.47	-1.23	0.03	-0.34	-0.08
29	8	2	16.84	9.50	6.77	2.73	0.00	1.00	36.77	9.98	-0.46	-1.15	0.03	-0.30	-0.08
30	8	3	16.84	9.50	7.02	2.48	0.00	1.00	1.57	8.86	-0.46	-1.15	0.03	-0.33	-0.08
31	8	4	16.84	9.50	7.17	2.33	0.00	1.00	6.03	8.29	-0.46	-1.14	0.03	-0.34	-0.09
32	8	5	16.84	9.50	7.37	2.13	0.00	1.00	1.48	7.57	-0.46	-1.14	0.03	-0.37	-0.10

***** STEADY STATE SIMULATION *****

** DISSOLVED OXYGEN DATA **

ELE ORD	RCH NUM	ELE NUM	TEMP DEG-C	DO SAT MG/L	DO MG/L	DO DEF MG/L	DAM INPUT MG/L	NIT INHIB FACT	COMPONENTS OF DISSOLVED OXYGEN MASS BALANCE (MG/L-DAY) F-FNCTN INPUT	OXYGN REAIR	C-BOD	SOD	NET P-R	NH3-N	NO2-N
33	9	1	16.84	9.50	8.10	1.40	0.00	1.00	1.08	3.30	0.00	-0.65	0.06	0.00	0.00
34	9	2	16.84	9.50	8.16	1.34	0.00	1.00	1.08	2.92	0.00	-0.65	0.06	0.00	0.00
35	9	3	16.84	9.50	8.11	1.39	0.00	1.00	6.40	3.07	0.00	-0.64	0.06	0.00	0.00
36	9	4	16.84	9.50	8.17	1.33	0.00	1.00	1.07	2.99	0.00	-0.64	0.06	0.00	0.00



DISSOLVED OXYGEN = * * * *

BIOCHEMICAL OXYGEN DEMAND = ...

Appendix E – Input and Output Data for Marshyhope Creek Qual2E Model Calibration (Run Ma079)

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                                        * * * QUAL-2E  STREAM QUALITY ROUTING MODEL * * *
                                                     Version 3.22  --  May 1996

 $$$ (PROBLEM TITLES) $$$

CARD TYPE                             QUAL-2E PROGRAM TITLES
TITLE01              Ma079, Marshyhope Creek, May 1, 2005
TITLE02              Based on Ma077, Annual Average Baseline Condition
TITLE03   NO         CONSERVATIVE MINERAL   I
TITLE04   NO         CONSERVATIVE MINERAL  II
TITLE05   NO         CONSERVATIVE MINERAL III
TITLE06   NO         TEMPERATURE
TITLE07  YES         5-DAY BIOCHEMICAL OXYGEN DEMAND
TITLE08  YES         ALGAE AS CHL-A IN UG/L
TITLE09  YES         PHOSPHORUS CYCLE AS P IN MG/L
TITLE10                (ORGANIC-P; DISSOLVED-P)
TITLE11  YES         NITROGEN CYCLE AS N IN MG/L
TITLE12                (ORGANIC-N; AMMONIA-N; NITRITE-N;' NITRATE-N)
TITLE13  YES         DISSOLVED OXYGEN IN MG/L
TITLE14   NO         FECAL COLIFORM IN NO./100 ML
TITLE15   NO         ARBITRARY NON-CONSERVATIVE
ENDTITLE

 $$$ DATA TYPE 1 (CONTROL DATA) $$$

CARD TYPE                                    CARD TYPE
LIST DATA INPUT            0.00000                                      0.00000
WRITE OPTIONAL SUMMARY     0.00000                                      0.00000
NO FLOW AUGMENTATION       0.00000                                      0.00000
STEADY STATE               0.00000                                      0.00000
NO TRAP CHANNELS           0.00000                                      0.00000
PRINT LCD/SOLAR DATA       0.00000                                      0.00000
PLOT DO AND BOD            0.00000                                      0.00000
FIXED DNSTM CONC (YES=1)=  0.00000           5D-ULT BOD CONV K COEF  =  0.23000
INPUT METRIC            =  1.00000           OUTPUT METRIC           =  1.00000
NUMBER OF REACHES       =  4.00000           NUMBER OF JUNCTIONS     =  0.00000
NUM OF HEADWATERS       =  1.00000           NUMBER OF POINT LOADS   = 13.00000
TIME STEP (HOURS)       =  0.00000           LNTH. COMP. ELEMENT (KM)=  1.00000
MAXIMUM ROUTE TIME (HRS)= 100.00000          TIME INC. FOR RPT2 (HRS)=  0.00000
LATITUDE OF BASIN (DEG) =  38.90000          LONGITUDE OF BASIN (DEG)=  75.70000
STANDARD MERIDIAN (DEG) =  75.00000          DAY OF YEAR START TIME  = 196.00000
EVAP. COEF.,(AE)        =  0.00001           EVAP. COEF.,(BE)        =  0.00001
ELEV. OF BASIN (METERS) =  15.00000          DUST ATTENUATION COEF.  =  0.10000
ENDATA1                    0.00000                                      0.00000

 $$$ DATA TYPE 1A (ALGAE PRODUCTION AND NITROGEN OXIDATION CONSTANTS) $$$

CARD TYPE                                           CARD TYPE
O UPTAKE BY NH3 OXID(MG O/MG N)=    3.5000          O UPTAKE BY NO2 OXID(MG O/MG N)=    1.0700
O PROD. BY ALGAE (MG O/MG A)   =    1.6000          O UPTAKE BY ALGAE (MG O/MG A)  =    2.0000
N CONTENT OF ALGAE (MG N/MG A) =    0.0800          P CONTENT OF ALGAE (MG P/MG A) =    0.0150
ALG MAX SPEC GROWTH RATE(1/DAY)=    2.0000          ALGAE RESPIRATION RATE (1/DAY) =    0.2750
N HALF SATURATION CONST. (MG/L)=    0.1550          P HALF SATURATION CONST. (MG/L)=    0.0255
LIN ALG SHADE CO (1/M-UGCHA/L) =    0.0027          NLIN SHADE (1/M-(UGCHA/L)**2/3)=    0.0165
LIGHT FUNCTION OPTION (LFNOPT) =    2.0000          LIGHT SAT'N COEF (LANGLEYS/MIN)=    0.0250
DAILY AVERAGING OPTION(LAVOPT) =    2.0000          LIGHT AVERAGING FACTOR (AFACT  =    0.9500
NUMBER OF DAYLIGHT HOURS (DLH) =   14.0000          TOTAL DAILY SOLR RAD (LANGLEYS)=  380.0000
ALGY GROWTH CALC OPTION(LGROPT)=    2.0000          ALGAL PREF FOR NH3-N (PREFN)   =    0.9000
ALG/TEMP SOLAR RAD FACT(TFACT) =    0.4500          NITRIFICATION INHIBITION COEF  =   10.0000
ENDATA1A                            0.0000                                              0.0000

 $$$ DATA TYPE 1B (TEMPERATURE CORRECTION CONSTANTS FOR RATE COEFFICIENTS) $$$

CARD TYPE     RATE CODE     THETA VALUE

THETA( 1)      BOD DECA        1.047     DFLT
THETA( 2)      BOD SETT        1.024     DFLT
THETA( 3)      OXY TRAN        1.024     DFLT
THETA( 4)      SOD RATE        1.060     DFLT
THETA( 5)      ORGN DEC        1.047     DFLT
THETA( 6)      ORGN SET        1.024     DFLT
THETA( 7)      NH3 DECA        1.083     DFLT
THETA( 8)      NH3 SRCE        1.074     DFLT
THETA( 9)      NO2 DECA        1.047     DFLT
THETA(10)      PORG DEC        1.047     DFLT
THETA(11)      PORG SET        1.024     DFLT
THETA(12)      DISP SRC        1.074     DFLT
THETA(13)      ALG GROW        1.047     DFLT
THETA(14)      ALG RESP        1.047     DFLT
THETA(15)      ALG SETT        1.024     DFLT
THETA(16)      COLI DEC        1.047     DFLT
THETA(17)      ANC DECA        1.000     DFLT
THETA(18)      ANC SETT        1.024     DFLT
THETA(19)      ANC SRCE        1.000     DFLT
ENDATA1B

 $$$ DATA TYPE 2 (REACH IDENTIFICATION) $$$

CARD TYPE           REACH ORDER AND IDENT              R. MI/KM           R. MI/KM
```

STREAM REACH	1.0	RCH= Segment 1	FROM	22.0	TO	16.0
STREAM REACH	2.0	RCH= Segment 2	FROM	16.0	TO	11.0
STREAM REACH	3.0	RCH= Segment 3	FROM	11.0	TO	6.0
STREAM REACH	4.0	RCH= Segment 4	FROM	6.0	TO	0.0
ENDATA2	0.0			0.0		0.0

$$$ DATA TYPE 3 (TARGET LEVEL DO AND FLOW AUGMENTATION SOURCES) $$$

CARD TYPE	REACH	AVAIL HDWS	TARGET	ORDER OF AVAIL SOURCES					
ENDATA3	0.	0.	0.0	0.	0.	0.	0.	0.	0.

$$$ DATA TYPE 4 (COMPUTATIONAL REACH FLAG FIELD) $$$

CARD TYPE	REACH	ELEMENTS/REACH	COMPUTATIONAL FLAGS
FLAG FIELD	1.	6.	1.6.2.2.2.6.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	2.	5.	6.6.6.2.2.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	3.	5.	6.2.6.6.6.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	4.	6.	2.6.6.6.6.5.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
ENDATA4	0.	0.	0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.

$$$ DATA TYPE 5 (HYDRAULIC DATA FOR DETERMINING VELOCITY AND DEPTH) $$$

CARD TYPE	REACH	COEF-DSPN	COEFQV	EXPOQV	COEFQH	EXPOQH	CMANN
HYDRAULICS	1.	100.00	0.282	0.195	0.549	0.105	0.040
HYDRAULICS	2.	100.00	0.282	0.195	0.549	0.105	0.040
HYDRAULICS	3.	100.00	0.282	0.195	0.549	0.105	0.040
HYDRAULICS	4.	100.00	0.282	0.195	0.549	0.105	0.040
ENDATA5	0.	0.00	0.000	0.000	0.000	0.000	0.000

$$$ DATA TYPE 5A (STEADY STATE TEMPERATURE AND CLIMATOLOGY DATA) $$$

CARD TYPE	REACH	ELEVATION	DUST COEF	CLOUD COVER	DRY BULB TEMP	WET BULB TEMP	ATM PRESSURE	WIND	SOLAR RAD ATTENUATION
TEMP/LCD	1.	4.57	0.10	0.10	25.00	20.00	980.00	2.50	1.00
TEMP/LCD	2.	4.57	0.10	0.10	25.00	20.00	980.00	2.50	1.00
TEMP/LCD	3.	4.57	0.10	0.10	25.00	20.00	980.00	2.50	1.00
TEMP/LCD	4.	4.57	0.10	0.10	25.00	20.00	980.00	2.50	1.00
ENDATA5A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 6 (REACTION COEFFICIENTS FOR DEOXYGENATION AND REAERATION) $$$

CARD TYPE	REACH	K1	K3	SOD RATE	K2OPT	K2	COEQK2 OR TSIV COEF FOR OPT 8	OR EXPQK2 OR SLOPE FOR OPT 8
REACT COEF	1.	0.20	0.00	0.000	5.	0.00	0.000	0.00000
REACT COEF	2.	0.20	0.00	0.000	5.	0.00	0.000	0.00000
REACT COEF	3.	0.20	0.00	0.000	5.	0.00	0.000	0.00000
REACT COEF	4.	0.20	0.00	0.000	5.	0.00	0.000	0.00000
ENDATA6	0.	0.00	0.00	0.000	0.	0.00	0.000	0.00000

$$$ DATA TYPE 6A (NITROGEN AND PHOSPHORUS CONSTANTS) $$$

CARD TYPE	REACH	CKNH2	SETNH2	CKNH3	SNH3	CKNO2	CKPORG	SETPORG	SPO4
N AND P COEF	1.	0.04	0.05	0.10	0.00	0.20	0.07	0.05	0.00
N AND P COEF	2.	0.04	0.05	0.10	0.00	0.20	0.07	0.05	0.00
N AND P COEF	3.	0.04	0.05	0.10	0.00	0.20	0.07	0.05	0.00
N AND P COEF	4.	0.04	0.05	0.10	0.00	0.20	0.07	0.05	0.00
ENDATA6A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 6B (ALGAE/OTHER COEFFICIENTS) $$$

CARD TYPE	REACH	ALPHAO	ALGSET	EXCOEF	CK5 CKCOLI	CKANC	SETANC	SRCANC
ALG/OTHER COEF	1.	75.00	0.38	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	2.	75.00	0.38	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	3.	75.00	0.38	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	4.	75.00	0.38	0.01	0.00	0.00	0.00	0.00
ENDATA6B	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 7 (INITIAL CONDITIONS) $$$

CARD TYPE	REACH	TEMP	D.O.	BOD	CM-1	CM-2	CM-3	ANC	COLI
INITIAL COND-1	1.	17.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-1	2.	17.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-1	3.	17.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-1	4.	17.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ENDATA7	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 7A (INITIAL CONDITIONS FOR CHOROPHYLL A, NITROGEN, AND PHOSPHORUS) $$$

CARD TYPE	REACH	CHL-A	ORG-N	NH3-N	NO2-N	NO3-N	ORG-P	DIS-P
INITIAL COND-2	1.	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-2	2.	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-2	3.	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-2	4.	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ENDATA7A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 8 (INCREMENTAL INFLOW CONDITIONS) $$$

CARD TYPE	REACH	FLOW	TEMP	D.O.	BOD	CM-1	CM-2	CM-3	ANC	COLI
INCR INFLOW-1	1.	0.152	17.48	4.92	4.91	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	2.	0.110	17.48	5.13	4.03	0.00	0.00	0.00	0.00	0.00

INCR INFLOW-1	3.	0.098	17.48	5.15	3.51	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	4.	0.102	17.48	5.11	3.30	0.00	0.00	0.00	0.00	0.00
ENDATA8	0.	0.000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 8A (INCREMENTAL INFLOW CONDITIONS FOR CHLOROPHYLL A, NITROGEN, AND PHOSPHORUS) $$$

CARD TYPE	REACH	CHL-A	ORG-N	NH3-N	NO2-N	NO3-N	ORG-P	DIS-P
INCR INFLOW-2	1.	0.00	1.54	0.33	0.17	1.71	0.06	0.06
INCR INFLOW-2	2.	0.00	1.37	0.27	0.14	1.36	0.06	0.05
INCR INFLOW-2	3.	0.00	1.22	0.22	0.10	1.05	0.05	0.04
INCR INFLOW-2	4.	0.00	1.12	0.20	0.10	0.94	0.04	0.04
ENDATA8A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 9 (STREAM JUNCTIONS) $$$

CARD TYPE	JUNCTION ORDER AND IDENT	UPSTRM	JUNCTION	TRIB
ENDATA9	0.	0.	0.	0.

$$$ DATA TYPE 10 (HEADWATER SOURCES) $$$

CARD TYPE	HDWTR ORDER	NAME	FLOW	TEMP	D.O.	BOD	CM-1	CM-2	CM-3
HEADWTR-1	1.	Marshys Headwtr	0.67	16.79	6.89	2.70	0.00	0.00	0.00
ENDATA10	0.		0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 10A (HEADWATER CONDITIONS FOR CHLOROPHYLL, NITROGEN, PHOSPHORUS,
COLIFORM AND SELECTED NON-CONSERVATIVE CONSTITUENT) $$$

CARD TYPE	HDWTR ORDER	ANC	COLI	CHL-A	ORG-N	NH3-N	NO2-N	NO3-N	ORG-P	DIS-P
HEADWTR-2	1.	0.00	0.00E+00	10.57	1.07	0.21	0.09	0.80	0.20	0.07
ENDATA10A	0.	0.00	0.00E+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 11 (POINT SOURCE / POINT SOURCE CHARACTERISTICS) $$$

CARD TYPE	POINT LOAD ORDER	NAME	EFF	FLOW	TEMP	D.O.	BOD	CM-1	CM-2	CM-3
POINTLD-1	1.	Beave Br R1	0.00	0.12	15.81	6.67	2.40	0.00	0.00	0.00
POINTLD-1	2.	Prosp Br R1	0.00	0.66	15.81	6.67	2.40	0.00	0.00	0.00
POINTLD-1	3.	Tributar R2	0.00	0.02	15.81	6.67	2.40	0.00	0.00	0.00
POINTLD-1	4.	Tomah Br R2	0.00	0.12	15.81	6.67	2.40	0.00	0.00	0.00
POINTLD-1	5.	Green Br R2	0.00	0.33	15.81	6.67	2.40	0.00	0.00	0.00
POINTLD-1	6.	SaulQuar R3	0.00	0.68	15.81	6.67	2.40	0.00	0.00	0.00
POINTLD-1	7.	Tributa1 R3	0.00	0.02	15.81	6.67	2.40	0.00	0.00	0.00
POINTLD-1	8.	ShNHaDFB R3	0.00	0.40	15.81	6.67	2.40	0.00	0.00	0.00
POINTLD-1	9.	T2T3Staf R3	0.00	0.24	15.81	6.67	2.40	0.00	0.00	0.00
POINTLD-1	10.	T1IrMiBr R4	0.00	0.15	15.81	6.67	2.40	0.00	0.00	0.00
POINTLD-1	11.	JoMil Br R4	0.00	0.12	15.81	6.67	2.40	0.00	0.00	0.00
POINTLD-1	12.	Tributa2 R4	0.00	0.05	15.81	6.67	2.40	0.00	0.00	0.00
POINTLD-1	13.	Jones Br R4	0.00	0.08	15.81	6.67	2.40	0.00	0.00	0.00
ENDATA11	0.		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 11A (POINT SOURCE CHARACTERISTICS - CHLOROPHYLL A, NITROGEN, PHOSPHORUS,
COLIFORMS AND SELECTED NON-CONSERVATIVE CONSTITUENT) $$$

CARD TYPE	POINT LOAD ORDER	ANC	COLI	CHL-A	ORG-N	NH3-N	NO2-N	N03-N	ORG-P	DIS-P
POINTLD-2	1.	0.00	0.00E+00	3.68	0.86	0.11	0.28	2.56	0.07	0.05
POINTLD-2	2.	0.00	0.00E+00	3.68	0.86	0.11	0.28	2.56	0.07	0.05
POINTLD-2	3.	0.00	0.00E+00	3.68	0.86	0.11	0.28	2.56	0.07	0.05
POINTLD-2	4.	0.00	0.00E+00	3.68	0.86	0.11	0.28	2.56	0.07	0.05
POINTLD-2	5.	0.00	0.00E+00	3.68	0.86	0.11	0.28	2.56	0.07	0.05
POINTLD-2	6.	0.00	0.00E+00	3.68	0.86	0.11	0.28	2.56	0.07	0.05
POINTLD-2	7.	0.00	0.00E+00	3.68	0.86	0.11	0.28	2.56	0.07	0.05
POINTLD-2	8.	0.00	0.00E+00	3.68	0.86	0.11	0.28	2.56	0.07	0.05
POINTLD-2	9.	0.00	0.00E+00	3.68	0.86	0.11	0.28	2.56	0.07	0.05
POINTLD-2	10.	0.00	0.00E+00	3.68	0.86	0.11	0.28	2.56	0.07	0.05
POINTLD-2	11.	0.00	0.00E+00	3.68	0.86	0.11	0.28	2.56	0.07	0.05
POINTLD-2	12.	0.00	0.00E+00	3.68	0.86	0.11	0.28	2.56	0.07	0.05
POINTLD-2	13.	0.00	0.00E+00	3.68	0.86	0.11	0.28	2.56	0.07	0.05
ENDATA11A	0.	0.00	0.00E+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 12 (DAM CHARACTERISTICS) $$$

	DAM	RCH	ELE	ADAM	BDAM	FDAM	HDAM
ENDATA12	0.	0.	0.	0.00	0.00	0.00	0.00

$$$ DATA TYPE 13 (DOWNSTREAM BOUNDARY CONDITIONS-1) $$$

CARD TYPE	TEMP	D.O.	BOD	CM-1	CM-2	CM-3	ANC	COLI
ENDATA13	DOWNSTREAM BOUNDARY CONCENTRATIONS ARE UNCONSTRAINED							

$$$ DATA TYPE 13A (DOWNSTREAM BOUNDARY CONDITIONS-2) $$$

CARD TYPE	CHL-A	ORG-N	NH3-N	NO2-N	NH3-N	ORG-P	DIS-P
ENDATA13A	DOWNSTREAM BOUNDARY CONCENTRATIONS ARE UNCONSTRAINED						

STEADY STATE ALGAE/NUTRIENT/DISSOLVED OXYGEN SIMULATION; CONVERGENCE SUMMARY:

VARIABLE	ITERATION	NUMBER OF NONCONVERGENT ELEMENTS
ALGAE GROWTH RATE	1	22
ALGAE GROWTH RATE	2	22
ALGAE GROWTH RATE	3	22
ALGAE GROWTH RATE	4	22
ALGAE GROWTH RATE	5	22
ALGAE GROWTH RATE	6	22
ALGAE GROWTH RATE	7	0
ALGAE GROWTH RATE	8	0

SUMMARY OF CONDITIONS FOR ALGAL GROWTH RATE SIMULATION:
----

1. LIGHT AVERAGING OPTION. LAVOPT= 2

    METHOD: MEAN SOLAR RADIATION DURING DAYLIGHT HOURS

    SOURCE OF SOLAR VALUES: DATA TYPE 1A
        DAILY NET SOLAR RADIATION: 1400.300 BTU/FT-2 (380.000 LANGLEYS)
        NUMBER OF DAYLIGHT HOURS: 0.0
        PHOTOSYNTHETIC ACTIVE FRACTION OF SOLAR RADIATION (TFACT): N/A
        MEAN SOLAR RADIATION ADJUSTMENT FACTOR (AFACT): 0.950

2. LIGHT FUNCTION OPTION: LFNOPT= 2

    SMITH FUNCTION, WITH 71% IMAX = 0.025 LANGLEYS/MIN

3. GROWTH ATTENUATION OPTION FOR NUTRIENTS. LGROPT= 2

    MINIMUM OF NITROGEN, PHOSPHORUS: FL*MIN(FN,FP)

DISSOLVED OXYGEN IN MG/L ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	7.01	7.07	7.18	7.28	7.36	7.17														
2	7.29	7.36	7.37	7.48	7.58															
3	7.47	7.58	7.67	7.65	7.68															
4	7.77	7.82	7.87	7.93	7.99	8.06														

5-DAY BIOCHEMICAL OXYGEN DEMAND ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	2.76	2.75	2.80	2.84	2.87	2.70														
2	2.69	2.67	2.63	2.63	2.62															
3	2.56	2.56	2.55	2.52	2.50															
4	2.49	2.48	2.47	2.46	2.45	2.44														

ORGANIC NITROGEN AS N IN MG/L ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1.08	1.06	1.07	1.08	1.09	1.00														
2	1.00	0.99	0.97	0.98	0.98															
3	0.95	0.95	0.95	0.93	0.93															
4	0.93	0.92	0.92	0.92	0.92	0.91														

AMMONIA AS N IN MG/L ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.21	0.20	0.21	0.21	0.22	0.18														
2	0.18	0.17	0.17	0.17	0.17															
3	0.16	0.16	0.16	0.16	0.15															
4	0.15	0.15	0.15	0.15	0.15	0.15														

NITRITE AS N IN MG/L ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.09	0.12	0.12	0.12	0.13	0.19														
2	0.19	0.20	0.21	0.21	0.20															
3	0.22	0.22	0.22	0.23	0.23															
4	0.23	0.23	0.23	0.23	0.23	0.23														

NITRATE AS N IN MG/L ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.84	1.10	1.12	1.14	1.16	1.74														
2	1.75	1.80	1.91	1.91	1.90															
3	2.05	2.05	2.05	2.10	2.13															
4	2.13	2.14	2.15	2.15	2.15	2.15														

ORGANIC PHOSPHORUS AS P IN MG/L ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.19	0.17	0.17	0.16	0.16	0.12														
2	0.12	0.12	0.11	0.11	0.11															
3	0.10	0.10	0.10	0.09	0.09															
4	0.09	0.09	0.09	0.09	0.09	0.09														

DISSOLVED PHOSPHORUS AS P IN MG/L ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.07	0.06	0.06	0.06	0.06	0.06														
2	0.06	0.06	0.05	0.05	0.05															
3	0.05	0.05	0.05	0.05	0.05															
4	0.05	0.05	0.05	0.05	0.05	0.05														

ALGAE AS CHL-A IN UG/L ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	10.09	8.83	8.50	8.19	7.89	6.01														
2	5.85	5.60	5.22	5.14	5.05															
3	4.67	4.62	4.55	4.40	4.31															
4	4.27	4.21	4.15	4.11	4.06	4.03														

ALGAE GROWTH RATES IN PER DAY ARE ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.71	0.70	0.70	0.70	0.70	0.68														
2	0.68	0.68	0.67	0.67	0.67															
3	0.66	0.66	0.66	0.66	0.66															
4	0.66	0.66	0.66	0.66	0.66	0.66														

PHOTOSYNTHESIS-RESPIRATION RATIOS ARE ITERATION 8

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	2.32	2.29	2.29	2.30	2.30	2.21														
2	2.21	2.20	2.19	2.19	2.19															
3	2.16	2.16	2.16	2.15	2.15															
4	2.15	2.15	2.15	2.15	2.15	2.15														

***** STEADY STATE SIMULATION *****

** HYDRAULICS SUMMARY **

ELE ORD	RCH NUM	ELE NUM	BEGIN LOC KILO	END LOC KILO	FLOW CMS	POINT SRCE CMS	INCR FLOW CMS	VEL MPS	TRVL TIME DAY	DEPTH M	WIDTH M	VOLUME K-CU-M	BOTTOM AREA K-SQ-M	X-SECT AREA SQ-M	DSPRSN COEF SQ-M/S
1	1	1	22.00	21.00	0.70	0.00	0.03	0.263	0.044	0.529	5.033	2.66	6.09	2.66	1.94
2	1	2	21.00	20.00	0.84	0.12	0.03	0.272	0.042	0.539	5.730	3.09	6.81	3.09	2.04
3	1	3	20.00	19.00	0.87	0.00	0.03	0.274	0.042	0.541	5.850	3.16	6.93	3.16	2.06
4	1	4	19.00	18.00	0.89	0.00	0.03	0.276	0.042	0.542	5.969	3.24	7.06	3.24	2.07
5	1	5	18.00	17.00	0.92	0.00	0.03	0.277	0.042	0.544	6.087	3.31	7.18	3.31	2.09
6	1	6	17.00	16.00	1.60	0.66	0.03	0.309	0.037	0.577	8.983	5.18	10.14	5.18	2.45
7	2	1	16.00	15.00	1.65	0.02	0.02	0.311	0.037	0.579	9.159	5.30	10.32	5.30	2.47
8	2	2	15.00	14.00	1.78	0.12	0.02	0.316	0.037	0.584	9.690	5.66	10.86	5.65	2.52
9	2	3	14.00	13.00	2.13	0.33	0.02	0.327	0.035	0.595	10.976	6.53	12.17	6.53	2.65
10	2	4	13.00	12.00	2.15	0.00	0.02	0.327	0.035	0.595	11.055	6.58	12.25	6.58	2.66
11	2	5	12.00	11.00	2.18	0.00	0.02	0.328	0.035	0.596	11.134	6.64	12.33	6.63	2.67
12	3	1	11.00	10.00	2.87	0.68	0.02	0.346	0.033	0.614	13.521	8.30	14.75	8.30	2.89
13	3	2	10.00	9.00	2.89	0.00	0.02	0.347	0.033	0.614	13.585	8.34	14.82	8.34	2.89
14	3	3	9.00	8.00	2.93	0.02	0.02	0.348	0.033	0.615	13.715	8.44	14.95	8.43	2.91
15	3	4	8.00	7.00	3.35	0.40	0.02	0.357	0.032	0.624	15.044	9.38	16.30	9.38	3.02
16	3	5	7.00	6.00	3.61	0.24	0.02	0.362	0.032	0.629	15.861	9.97	17.12	9.97	3.08
17	4	1	6.00	5.00	3.63	0.00	0.02	0.362	0.032	0.629	15.913	10.01	17.17	10.01	3.09
18	4	2	5.00	4.00	3.79	0.15	0.02	0.365	0.032	0.632	16.410	10.37	17.68	10.37	3.12
19	4	3	4.00	3.00	3.92	0.12	0.02	0.368	0.031	0.634	16.811	10.66	18.08	10.66	3.15
20	4	4	3.00	2.00	3.99	0.05	0.02	0.369	0.031	0.635	17.011	10.81	18.29	10.81	3.17
21	4	5	2.00	1.00	4.09	0.08	0.02	0.371	0.031	0.637	17.299	11.02	18.58	11.02	3.19
22	4	6	1.00	0.00	4.10	0.00	0.02	0.371	0.031	0.637	17.350	11.06	18.63	11.05	3.19

***** STEADY STATE SIMULATION *****

** REACTION COEFFICIENT SUMMARY **

RCH NUM	ELE NUM	DO SAT MG/L	K2 OPT	OXYGN REAIR 1/DAY	BOD DECAY 1/DAY	BOD SETT 1/DAY	SOD RATE G/M2D	ORGN DECAY 1/DAY	ORGN SETT 1/DAY	NH3 DECAY 1/DAY	NH3 SRCE MG/M2D	NO2 DECAY 1/DAY	ORGP DECAY 1/DAY	ORGP SETT 1/DAY	DISP SRCE MG/M2D	COLI DECAY 1/DAY	ANC DECAY 1/DAY	ANC SETT 1/DAY	ANC SRCE MG/M2D
1	1	9.37	5	2.17	0.18	0.00	0.00	0.04	0.05	0.08	0.00	0.18	0.06	0.05	0.00	0.00	0.00	0.00	0.00
1	2	9.37	5	2.19	0.18	0.00	0.00	0.04	0.05	0.08	0.00	0.18	0.06	0.05	0.00	0.00	0.00	0.00	0.00
1	3	9.37	5	2.21	0.18	0.00	0.00	0.04	0.05	0.08	0.00	0.18	0.06	0.05	0.00	0.00	0.00	0.00	0.00
1	4	9.37	5	2.21	0.18	0.00	0.00	0.04	0.05	0.08	0.00	0.18	0.06	0.05	0.00	0.00	0.00	0.00	0.00
1	5	9.37	5	2.22	0.18	0.00	0.00	0.04	0.05	0.08	0.00	0.18	0.06	0.05	0.00	0.00	0.00	0.00	0.00
1	6	9.37	5	2.28	0.18	0.00	0.00	0.04	0.05	0.08	0.00	0.18	0.06	0.05	0.00	0.00	0.00	0.00	0.00
2	1	9.37	5	2.34	0.18	0.00	0.00	0.04	0.05	0.08	0.00	0.18	0.06	0.05	0.00	0.00	0.00	0.00	0.00
2	2	9.37	5	2.35	0.18	0.00	0.00	0.04	0.05	0.08	0.00	0.18	0.06	0.05	0.00	0.00	0.00	0.00	0.00
2	3	9.37	5	2.38	0.18	0.00	0.00	0.04	0.05	0.08	0.00	0.18	0.06	0.05	0.00	0.00	0.00	0.00	0.00
2	4	9.37	5	2.40	0.18	0.00	0.00	0.04	0.05	0.08	0.00	0.18	0.06	0.05	0.00	0.00	0.00	0.00	0.00
2	5	9.37	5	2.40	0.18	0.00	0.00	0.04	0.05	0.08	0.00	0.18	0.06	0.05	0.00	0.00	0.00	0.00	0.00
3	1	9.37	5	2.43	0.18	0.00	0.00	0.04	0.05	0.08	0.00	0.18	0.06	0.05	0.00	0.00	0.00	0.00	0.00
3	2	9.37	5	2.47	0.18	0.00	0.00	0.04	0.05	0.08	0.00	0.18	0.06	0.05	0.00	0.00	0.00	0.00	0.00
3	3	9.37	5	2.47	0.18	0.00	0.00	0.04	0.05	0.08	0.00	0.18	0.06	0.05	0.00	0.00	0.00	0.00	0.00
3	4	9.37	5	2.49	0.18	0.00	0.00	0.04	0.05	0.08	0.00	0.18	0.06	0.05	0.00	0.00	0.00	0.00	0.00
3	5	9.37	5	2.51	0.18	0.00	0.00	0.04	0.05	0.08	0.00	0.18	0.06	0.05	0.00	0.00	0.00	0.00	0.00
4	1	9.37	5	2.52	0.18	0.00	0.00	0.04	0.05	0.08	0.00	0.18	0.06	0.05	0.00	0.00	0.00	0.00	0.00
4	2	9.37	5	2.52	0.18	0.00	0.00	0.04	0.05	0.08	0.00	0.18	0.06	0.05	0.00	0.00	0.00	0.00	0.00
4	3	9.37	5	2.53	0.18	0.00	0.00	0.04	0.05	0.08	0.00	0.18	0.06	0.05	0.00	0.00	0.00	0.00	0.00
4	4	9.37	5	2.54	0.18	0.00	0.00	0.04	0.05	0.08	0.00	0.18	0.06	0.05	0.00	0.00	0.00	0.00	0.00
4	5	9.37	5	2.54	0.18	0.00	0.00	0.04	0.05	0.08	0.00	0.18	0.06	0.05	0.00	0.00	0.00	0.00	0.00
4	6	9.37	5	2.55	0.18	0.00	0.00	0.04	0.05	0.08	0.00	0.18	0.06	0.05	0.00	0.00	0.00	0.00	0.00

***** STEADY STATE SIMULATION *****

** WATER QUALITY VARIABLES **

RCH NUM	ELE NUM	TEMP DEG-C	CM-1	CM-2	CM-3	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM-N MG/L	ORGP MG/L	DIS-P MG/L	SUM-P COLI MG/L #/100ML	ANC	CHLA UG/L
1	1	17.48	0.00	0.00	0.00	7.01	2.76	1.08	0.21	0.09	0.84	2.23	0.19	0.07	0.26.00E+00	0.00	10.09
1	2	17.48	0.00	0.00	0.00	7.07	2.75	1.06	0.20	0.12	1.10	2.49	0.17	0.06	0.23.00E+00	0.00	8.83
1	3	17.48	0.00	0.00	0.00	7.18	2.80	1.07	0.21	0.12	1.12	2.52	0.17	0.06	0.23.00E+00	0.00	8.50
1	4	17.48	0.00	0.00	0.00	7.28	2.84	1.08	0.21	0.12	1.14	2.56	0.16	0.06	0.23.00E+00	0.00	8.19
1	5	17.48	0.00	0.00	0.00	7.36	2.87	1.09	0.22	0.13	1.16	2.59	0.16	0.06	0.22.00E+00	0.00	7.89
1	6	17.48	0.00	0.00	0.00	7.17	2.70	1.00	0.18	0.19	1.74	3.11	0.12	0.06	0.18.00E+00	0.00	6.01
2	1	17.48	0.00	0.00	0.00	7.29	2.69	1.00	0.18	0.19	1.75	3.12	0.12	0.06	0.18.00E+00	0.00	5.85
2	2	17.48	0.00	0.00	0.00	7.36	2.67	0.99	0.17	0.20	1.80	3.16	0.12	0.06	0.17.00E+00	0.00	5.60
2	3	17.48	0.00	0.00	0.00	7.37	2.63	0.97	0.17	0.21	1.91	3.26	0.11	0.05	0.16.00E+00	0.00	5.22
2	4	17.48	0.00	0.00	0.00	7.48	2.63	0.98	0.17	0.21	1.91	3.26	0.11	0.05	0.16.00E+00	0.00	5.14
2	5	17.48	0.00	0.00	0.00	7.58	2.62	0.98	0.17	0.20	1.90	3.26	0.11	0.05	0.16.00E+00	0.00	5.05
3	1	17.48	0.00	0.00	0.00	7.47	2.56	0.95	0.16	0.22	2.05	3.38	0.10	0.05	0.15.00E+00	0.00	4.67
3	2	17.48	0.00	0.00	0.00	7.58	2.56	0.95	0.16	0.22	2.05	3.38	0.10	0.05	0.15.00E+00	0.00	4.62
3	3	17.48	0.00	0.00	0.00	7.67	2.55	0.95	0.16	0.22	2.05	3.37	0.10	0.05	0.15.00E+00	0.00	4.55
3	4	17.48	0.00	0.00	0.00	7.65	2.52	0.93	0.16	0.23	2.10	3.42	0.09	0.05	0.15.00E+00	0.00	4.40
3	5	17.48	0.00	0.00	0.00	7.68	2.50	0.93	0.15	0.23	2.13	3.44	0.09	0.05	0.14.00E+00	0.00	4.31
4	1	17.48	0.00	0.00	0.00	7.77	2.49	0.93	0.15	0.23	2.13	3.43	0.09	0.05	0.14.00E+00	0.00	4.27
4	2	17.48	0.00	0.00	0.00	7.82	2.48	0.92	0.15	0.23	2.14	3.44	0.09	0.05	0.14.00E+00	0.00	4.21
4	3	17.48	0.00	0.00	0.00	7.87	2.47	0.92	0.15	0.23	2.15	3.45	0.09	0.05	0.14.00E+00	0.00	4.15
4	4	17.48	0.00	0.00	0.00	7.93	2.46	0.92	0.15	0.23	2.15	3.45	0.09	0.05	0.14.00E+00	0.00	4.11
4	5	17.48	0.00	0.00	0.00	7.99	2.45	0.92	0.15	0.23	2.15	3.45	0.09	0.05	0.14.00E+00	0.00	4.06
4	6	17.48	0.00	0.00	0.00	8.06	2.44	0.91	0.15	0.23	2.15	3.44	0.09	0.05	0.14.00E+00	0.00	4.03

***** STEADY STATE SIMULATION *****

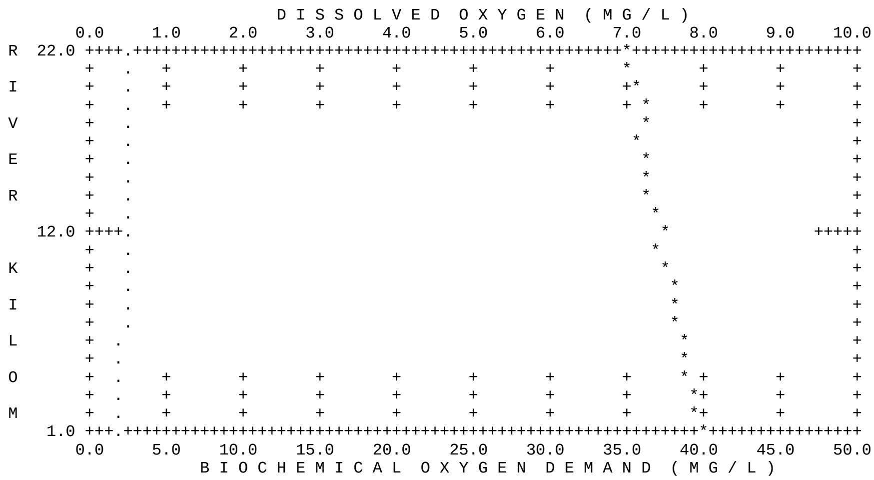
** ALGAE DATA **

ELE ORD	RCH NUM	ELE NUM	CHLA UG/L	ALGY GRWTH 1/DAY	ALGY RESP 1/DAY	ALGY SETT M/DAY	A P/R RATIO *	NET P-R MG/L-D	NH3 PREF *	NH3-N FRACT N-UPTKE *	LIGHT EXTCO 1/M	ALGAE GROWTH RATE ATTEN FACTORS LIGHT *	NITRGN *	PHSPRS *
1	1	1	10.09	0.71	0.24	0.36	2.32	0.09	0.90	0.70	0.11	0.55	0.87	0.72
2	1	2	8.83	0.70	0.24	0.36	2.29	0.07	0.90	0.63	0.10	0.55	0.89	0.71
3	1	3	8.50	0.70	0.24	0.36	2.29	0.07	0.90	0.63	0.10	0.55	0.90	0.71
4	1	4	8.19	0.70	0.24	0.36	2.30	0.07	0.90	0.63	0.10	0.55	0.90	0.71
5	1	5	7.89	0.70	0.24	0.36	2.30	0.07	0.90	0.63	0.10	0.55	0.90	0.71
6	1	6	6.01	0.68	0.24	0.36	2.21	0.05	0.90	0.48	0.08	0.55	0.93	0.69
7	2	1	5.85	0.68	0.24	0.36	2.21	0.05	0.90	0.48	0.08	0.55	0.93	0.69
8	2	2	5.60	0.68	0.24	0.36	2.20	0.04	0.90	0.47	0.08	0.55	0.93	0.68
9	2	3	5.22	0.67	0.24	0.36	2.19	0.04	0.90	0.44	0.07	0.55	0.93	0.68
10	2	4	5.14	0.67	0.24	0.36	2.19	0.04	0.90	0.44	0.07	0.55	0.93	0.68
11	2	5	5.05	0.67	0.24	0.36	2.19	0.04	0.90	0.45	0.07	0.55	0.93	0.68
12	3	1	4.67	0.66	0.24	0.36	2.16	0.04	0.90	0.41	0.07	0.55	0.93	0.67
13	3	2	4.62	0.66	0.24	0.36	2.16	0.04	0.90	0.41	0.07	0.55	0.93	0.67
14	3	3	4.55	0.66	0.24	0.36	2.16	0.03	0.90	0.41	0.07	0.55	0.93	0.67
15	3	4	4.40	0.66	0.24	0.36	2.15	0.03	0.90	0.40	0.07	0.55	0.94	0.67
16	3	5	4.31	0.66	0.24	0.36	2.15	0.03	0.90	0.39	0.07	0.55	0.94	0.67
17	4	1	4.27	0.66	0.24	0.36	2.15	0.03	0.90	0.39	0.06	0.55	0.94	0.67
18	4	2	4.21	0.66	0.24	0.36	2.15	0.03	0.90	0.39	0.06	0.55	0.94	0.67
19	4	3	4.15	0.66	0.24	0.36	2.15	0.03	0.90	0.39	0.06	0.55	0.94	0.67
20	4	4	4.11	0.66	0.24	0.36	2.15	0.03	0.90	0.39	0.06	0.55	0.94	0.67
21	4	5	4.06	0.66	0.24	0.36	2.15	0.03	0.90	0.39	0.06	0.55	0.94	0.67
22	4	6	4.03	0.66	0.24	0.36	2.15	0.03	0.90	0.39	0.06	0.55	0.94	0.67

***** STEADY STATE SIMULATION *****

** DISSOLVED OXYGEN DATA **

ELE ORD	RCH NUM	ELE NUM	TEMP DEG-C	DO SAT MG/L	DO MG/L	DO DEF MG/L	DAM INPUT MG/L	NIT INHIB FACT	F-FNCTN INPUT	OXYGN REAIR	C-BOD	SOD	NET P-R	NH3-N	NO2-N
									COMPONENTS OF DISSOLVED OXYGEN MASS BALANCE (MG/L-DAY)						
1	1	1	17.48	9.37	7.01	2.36	0.00	1.00	154.78	5.13	-0.49	0.00	0.09	-0.06	-0.02
2	1	2	17.48	9.37	7.07	2.30	0.00	1.00	25.31	5.04	-0.49	0.00	0.07	-0.06	-0.02
3	1	3	17.48	9.37	7.18	2.19	0.00	1.00	3.40	4.85	-0.50	0.00	0.07	-0.06	-0.02
4	1	4	17.48	9.37	7.28	2.10	0.00	1.00	3.32	4.64	-0.51	0.00	0.07	-0.06	-0.02
5	1	5	17.48	9.37	7.36	2.01	0.00	1.00	3.25	4.47	-0.51	0.00	0.07	-0.06	-0.02
6	1	6	17.48	9.37	7.17	2.20	0.00	1.00	75.23	5.02	-0.48	0.00	0.05	-0.05	-0.04
7	2	1	17.48	9.37	7.29	2.08	0.00	1.00	4.34	4.88	-0.48	0.00	0.05	-0.05	-0.04
8	2	2	17.48	9.37	7.36	2.01	0.00	1.00	13.54	4.73	-0.48	0.00	0.04	-0.05	-0.04
9	2	3	17.48	9.37	7.37	2.00	0.00	1.00	30.27	4.77	-0.47	0.00	0.04	-0.05	-0.04
10	2	4	17.48	9.37	7.48	1.89	0.00	1.00	1.48	4.54	-0.47	0.00	0.04	-0.05	-0.04
11	2	5	17.48	9.37	7.58	1.79	0.00	1.00	1.47	4.31	-0.47	0.00	0.04	-0.05	-0.04
12	3	1	17.48	9.37	7.47	1.90	0.00	1.00	48.07	4.64	-0.46	0.00	0.04	-0.05	-0.04
13	3	2	17.48	9.37	7.58	1.80	0.00	1.00	1.04	4.43	-0.46	0.00	0.04	-0.05	-0.04
14	3	3	17.48	9.37	7.67	1.70	0.00	1.00	2.40	4.21	-0.45	0.00	0.03	-0.05	-0.04
15	3	4	17.48	9.37	7.65	1.73	0.00	1.00	25.19	4.29	-0.45	0.00	0.03	-0.04	-0.04
16	3	5	17.48	9.37	7.68	1.70	0.00	1.00	14.92	4.25	-0.45	0.00	0.03	-0.04	-0.04
17	4	1	17.48	9.37	7.77	1.60	0.00	1.00	0.75	4.03	-0.44	0.00	0.03	-0.04	-0.04
18	4	2	17.48	9.37	7.82	1.56	0.00	1.00	8.84	3.93	-0.44	0.00	0.03	-0.04	-0.04
19	4	3	17.48	9.37	7.87	1.50	0.00	1.00	6.97	3.81	-0.44	0.00	0.03	-0.04	-0.04
20	4	4	17.48	9.37	7.93	1.44	0.00	1.00	3.36	3.66	-0.44	0.00	0.03	-0.04	-0.04
21	4	5	17.48	9.37	7.99	1.39	0.00	1.00	4.87	3.53	-0.44	0.00	0.03	-0.04	-0.04
22	4	6	17.48	9.37	8.06	1.32	0.00	1.00	0.68	3.36	-0.43	0.00	0.03	-0.04	-0.04



DISSOLVED OXYGEN = * * * *

BIOCHEMICAL OXYGEN DEMAND = ...

Appendix F - Summary of Sensitity Analysis for Cypress Branch Qual2e Model

Parameter	Description	Unit	Value	Input Change	Response %								
					Model Average			Reach 1, Computational Element 1			Reach 1, Computational Element 2		
					DO	TN	TP	DO	TN	TP	DO	TN	TP
α_1	Fraction of algal biomass that is Nitrogen	mg-N / mg A	0.080	50%	0.0	-0.3	0.0	0.0	-0.4	0.0	0.0	0.0	0.0
				-50%	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.4	0.0
α_2	Fraction of algal biomass that is Phosphorus	mg-P / mg A	0.015	50%	-0.2	0.1	-1.3	0.0	0.0	0.0	-0.4	0.0	-3.8
				-50%	0.4	-0.1	0.4	0.5	-0.4	0.0	0.0	0.0	0.0
α_3	O_2 production per unit of algal growth	mg-O / mg A	1.600	50%	3.4	0.0	0.0	3.6	0.0	0.0	3.5	0.0	0.0
				-50%	-3.5	0.0	0.0	-3.4	0.0	0.0	-4.2	0.0	0.0
α_4	O_2 uptake per unit of algae respired	mg-O / mg A	2.000	50%	-2.2	0.0	0.0	-1.9	0.0	0.0	-2.5	0.0	0.0
				-50%	2.2	0.0	0.0	2.3	0.0	0.0	2.3	0.0	0.0
α_5	O_2 uptake per unit of NH_3 oxidation	mg-O / mg A	3.500	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
α_6	O_2 uptake per unit of NO_2 oxidation	mg-O / mg A	1.070	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
μ_{max}	Maximum algal growth rate	day-1	2.000	50%	3.9	-0.7	-3.1	4.1	-0.4	0.0	4.2	-0.4	-3.8
				-50%	-3.1	0.5	0.4	-3.4	0.0	0.0	-3.7	0.4	0.0
ρ	Algal respiration rate	day-1	0.275	50%	-2.2	0.3	0.4	-2.4	0.0	0.0	-2.5	0.4	0.0
				-50%	2.8	-0.4	-1.8	2.8	-0.4	0.0	2.7	0.0	-3.8
K_L	Light saturation coefficient (Option 2)	Langley's/min	0.025	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K_N	Half-saturation constant for nitrogen	mg-N/l	0.155	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K_P	Half-saturation constant for phosphorus	mg-P/l	0.026	50%	-1.3	0.3	0.4	-1.4	0.0	0.0	-1.6	0.4	0.0
				-50%	2.8	-0.5	-2.2	2.8	-0.4	0.0	2.7	0.0	-3.8
λ_1	Linear algal self-shading coefficient	(1/m) / (µg Chl-1/l)	0.003	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
λ_2	Nonlinear algal self-shading coefficient	(1/m) / (µg Chl-1/l)**2/3	0.017	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
P_N	Algal preference factor for ammonia	-	0.900	1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

α_0	Ratio of chlorophyll-a to algal biomass	μg Chl-a / mg A	75.000	100.000	-0.5	0.1	0.4	-0.5	0.0	0.0	-0.8	0.0	0.0
				-50%	1.2	-0.3	-1.8	2.3	-0.4	0.0	2.0	0.0	-3.8
λ_0	Non-algal light extinction coefficient	1/m	0.000	1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				NA									
σ_1	Algal settling rate	m/day	0.000	1.000	-2.2	0.5	0.4	-1.9	0.0	0.0	-2.5	0.4	0.0
				NA									
σ_2	Benthos source rate for dissolved phosphorus	mg-P /m^2-day	0.000	1.000	1.5	-0.3	4.1	0.9	-0.4	3.6	0.8	0.0	0.0
				NA									
σ_3	Benthos source rate for ammonia nitrogen	mg-N /m^2-day	0.000	1.000	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.4	0.0
				NA									
σ_4	Organic nitrogen settling rate	day-1	0.000	1.000	0.0	-56.1	0.0	0.0	-24.7	0.0	0.0	-32.0	0.0
				NA									
σ_5	Organic phosphorus settling rate	day-1	0.000	1.000	0.0	0.0	-83.3	0.0	0.0	-28.6	0.0	0.0	-42.1
				NA									
K_1	Carbonaceous deoxygeneration rate constant	day-1	0.200	50%	-4.6	0.0	0.0	-5.5	0.0	0.0	-5.9	0.0	0.0
				-50%	5.0	0.0	0.0	5.8	0.0	0.0	5.7	0.0	0.0
K_3	Rate of loss of BOD due to settling	day-1	0.000	1.000	4.5	0.0	0.0	2.8	0.0	0.0	3.5	0.0	0.0
				NA									
K_4	Benthic oxygen uptake (SOD)	g-O / m^2-day	0.300	50%	-23.7	0.0	0.0	-32.5	0.0	0.0	-32.3	0.0	0.0
				-50%	16.2	0.0	0.0	20.0	0.0	0.0	19.6	0.0	0.0
β_1	Rate constant for the biological oxidation of NH_3 to NO_2	day-1	0.000	1.000	-6.9	0.0	0.0	-11.6	0.0	0.0	-11.6	0.0	0.0
				NA									
β_2	Rate constant for the biological oxidation of NO_2 to NO_3	day-1	0.000	1.000	-0.2	0.0	0.0	0.0	0.0	0.0	-0.4	0.0	0.0
				NA									
β_3	Rate constant for the hydrolysis of organic-N to ammonia	day-1	0.000	1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				NA									
β_4	Rate constant for the decay of organic-P to dissolved-P	day-1	0.000	1.000	6.5	-1.1	-3.1	4.5	-0.4	0.0	4.6	-0.4	-3.8
				NA									

Appendix G - Summary of Sensitity Analysis for Sewell Branch Qual2e Model

Parameter	Description	Unit	Value	Input Change	Response %								
					Model Average			Reach 1, Computational Element 4			Reach 1, Computational Element 5		
					DO	TN	TP	DO	TN	TP	DO	TN	TP
α_1	Fraction of algal biomass that is Nitrogen	mg-N / mg A	0.080	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
α_2	Fraction of algal biomass that is Phosphorus	mg-P / mg A	0.015	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
α_3	O_2 production per unit of algal growth	mg-O / mg A	1.600	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	-0.1	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	0.0
α_4	O_2 uptake per unit of algae respired	mg-O / mg A	2.000	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
α_5	O_2 uptake per unit of NH_3 oxidation	mg-O / mg A	3.500	50%	-0.2	0.0	0.0	-0.2	0.0	0.0	-0.2	0.0	0.0
				-50%	0.1	0.0	0.0	0.2	0.0	0.0	0.2	0.0	0.0
α_6	O_2 uptake per unit of NO_2 oxidation	mg-O / mg A	1.070	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
μ_{max}	Maximum algal growth rate	day-1	2.000	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	-0.1	0.1	0.0	0.0	0.0	0.0	-0.2	0.0	0.0
ρ	Algal respiration rate	day-1	0.275	50%	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K_L	Light saturation coefficient (Option 2)	Langley's/min	0.025	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K_N	Half-saturation constant for nitrogen	mg-N/l	0.155	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K_P	Half-saturation constant for phosphorus	mg-P/l	0.026	50%	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
λ_1	Linear algal self-shading coefficient	(1/m) / (µg Chl-1/l)	0.003	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
λ_2	Nonlinear algal self-shading coefficient	(1/m) / (µg Chl-1/l)**2/3	0.017	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
P_N	Algal preference factor for ammonia	-	0.900	1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	-0.2	-2.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0

α_0	Ratio of chlorophyll-a to algal biomass	µg Chl-a / mg A	75.000	100.000	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
λ_0	Non-algal light extinction coefficient	1/m	0.000	1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				NA									
σ_1	Algal settling rate	m/day	0.050	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
σ_2	Benthos source rate for dissolved phosphorus	mg-P /m^2-day	0.000	1.000	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
				NA									
σ_3	Benthos source rate for ammonia nitrogen	mg-N /m^2-day	0.000	1.000	0.0	0.2	0.0	0.0	0.6	0.0	0.0	0.0	0.0
				NA									
σ_4	Organic nitrogen settling rate	day-1	0.050	50%	0.0	-0.3	0.0	0.0	0.0	0.0	0.0	-0.6	0.0
				-50%	0.0	0.3	0.0	0.0	0.6	0.0	0.0	0.0	0.0
σ_5	Organic phosphorus settling rate	day-1	0.050	50%	0.0	0.0	-0.9	0.0	0.0	0.0	0.0	0.0	-4.8
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K_1	Carbonaceous deoxygeneration rate constant	day-1	0.400	50%	-3.5	0.0	0.0	-3.7	0.0	0.0	-4.4	0.0	0.0
				-50%	3.5	0.0	0.0	3.6	0.0	0.0	4.4	0.0	0.0
K_3	Rate of loss of BOD due to settling	day-1	0.000	1.000	1.5	0.0	0.0	1.2	0.0	0.0	1.9	0.0	0.0
				NA									
K_4	Benthic oxygen uptake (SOD)	g-O / m^2-day	0.700	50%	-14.0	0.0	0.0	-15.2	0.0	0.0	-18.8	0.0	0.0
				-50%	10.9	0.0	0.0	11.6	0.0	0.0	13.5	0.0	0.0
β_1	Rate constant for the biological oxidation of NH_3 to NO_2	day-1	0.100	50%	-0.2	0.0	0.0	-0.2	0.0	0.0	-0.2	0.0	0.0
				-50%	0.1	0.0	0.0	0.2	0.0	0.0	0.2	0.0	0.0
β_2	Rate constant for the biological oxidation of NO_2 to NO_3	day-1	0.200	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
β_3	Rate constant for the hydrolysis of organic-N to ammonia	day-1	0.040	50%	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
β_4	Rate constant for the decay of organic-P to dissolved-P	day-1	0.070	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Appendix H - Summary of Sensitity Analysis for Gravelly Run Qual2e Model

Parameter	Description	Unit	Value	Input Change	Response %								
					Model Average			Reach 1, Computational Element 2			Reach 1, Computational Element 4		
					DO	TN	TP	DO	TN	TP	DO	TN	TP
α_1	Fraction of algal biomass that is Nitrogen	mg-N / mg A	0.080	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
α_2	Fraction of algal biomass that is Phosphorus	mg-P / mg A	0.015	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
α_3	O_2 production per unit of algal growth	mg-O / mg A	1.600	50%	0.1	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
				-50%	-0.1	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	0.0
α_4	O_2 uptake per unit of algae respired	mg-O / mg A	2.000	50%	-0.1	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
α_5	O_2 uptake per unit of NH_3 oxidation	mg-O / mg A	3.500	50%	-0.2	0.0	0.0	-0.2	0.0	0.0	-0.2	0.0	0.0
				-50%	0.1	0.0	0.0	0.2	0.0	0.0	0.2	0.0	0.0
α_6	O_2 uptake per unit of NO_2 oxidation	mg-O / mg A	1.070	50%	-0.1	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
μ_{max}	Maximum algal growth rate	day-1	2.000	50%	0.1	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
				-50%	-0.1	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	0.0
ρ	Algal respiration rate	day-1	0.275	50%	-0.1	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K_L	Light saturation coefficient (Option 2)	Langley's/min	0.025	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K_N	Half-saturation constant for nitrogen	mg-N/l	0.155	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K_P	Half-saturation constant for phosphorus	mg-P/l	0.026	50%	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
λ_1	Linear algal self-shading coefficient	(1/m) / (µg Chl-1/l)	0.003	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
λ_2	Nonlinear algal self-shading coefficient	(1/m) / (µg Chl-1/l)**2/3	0.017	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
P_N	Algal preference factor for ammonia	-	0.900	1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

α_0	Ratio of chlorophyll-a to algal biomass	µg Chl-a / mg A	75.000	100.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.1	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
λ_0	Non-algal light extinction coefficient	1/m	0.000	1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				NA									
σ_1	Algal settling rate	m/day	0.050	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
σ_2	Benthos source rate for dissolved phosphorus	mg-P /m^2-day	0.000	1.000	0.0	0.0	2.8	0.0	0.0	4.8	0.0	0.0	5.0
				NA									
σ_3	Benthos source rate for ammonia nitrogen	mg-N /m^2-day	0.000	1.000	0.0	0.4	0.0	0.0	0.6	0.0	0.0	0.5	0.0
				NA									
σ_4	Organic nitrogen settling rate	day-1	0.050	50%	0.0	-0.5	0.0	0.0	-0.6	0.0	0.0	-0.5	0.0
				-50%	0.0	0.5	0.0	0.0	0.6	0.0	0.0	0.5	0.0
σ_5	Organic phosphorus settling rate	day-1	0.050	50%	0.0	0.0	-0.4	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	5.0
K_1	Carbonaceous deoxygeneration rate constant	day-1	0.500	50%	-4.8	0.0	0.0	-5.1	0.0	0.0	-6.2	0.0	0.0
				-50%	5.2	0.0	0.0	5.3	0.0	0.0	6.3	0.0	0.0
K_3	Rate of loss of BOD due to settling	day-1	0.000	1.000	2.9	0.0	0.0	2.2	0.0	0.0	3.4	0.0	0.0
				NA									
K_4	Benthic oxygen uptake (SOD)	g-O / m^2-day	0.250	50%	-7.5	0.0	0.0	-8.4	0.0	0.0	-10.6	0.0	0.0
				-50%	6.5	0.0	0.0	7.4	0.0	0.0	8.6	0.0	0.0
β_1	Rate constant for the biological oxidation of NH_3 to NO_2	day-1	0.100	50%	-0.2	0.0	0.0	-0.2	0.0	0.0	-0.2	0.0	0.0
				-50%	0.1	0.0	0.0	0.2	0.0	0.0	0.2	0.0	0.0
β_2	Rate constant for the biological oxidation of NO_2 to NO_3	day-1	0.200	50%	-0.1	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
β_3	Rate constant for the hydrolysis of organic-N to ammonia	day-1	0.040	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
β_4	Rate constant for the decay of organic-P to dissolved-P	day-1	0.070	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Appendix I - Summary of Sensitity Analysis for Choptank River Qual2e Model

Parameter	Description	Unit	Value	Input Change	Response %								
					Model Average			Reach 1, Computational Element 6			Reach 2, Computational Element 1		
					DO	TN	TP	DO	TN	TP	DO	TN	TP
α_1	Fraction of algal biomass that is Nitrogen	mg-N / mg A	0.080	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
α_2	Fraction of algal biomass that is Phosphorus	mg-P / mg A	0.015	50%	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
α_3	O_2 production per unit of algal growth	mg-O / mg A	1.600	50%	0.3	0.0	0.0	0.6	0.0	0.0	0.5	0.0	0.0
				-50%	-0.3	0.0	0.0	-0.3	0.0	0.0	-0.3	0.0	0.0
α_4	O_2 uptake per unit of algae respired	mg-O / mg A	2.000	50%	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.1	0.0	0.0	0.3	0.0	0.0	0.3	0.0	0.0
α_5	O_2 uptake per unit of NH_3 oxidation	mg-O / mg A	3.500	50%	-1.1	0.0	0.0	-2.6	0.0	0.0	-2.8	0.0	0.0
				-50%	1.0	0.0	0.0	2.8	0.0	0.0	2.9	0.0	0.0
α_6	O_2 uptake per unit of NO_2 oxidation	mg-O / mg A	1.070	50%	-0.2	0.0	0.0	-0.3	0.0	0.0	-0.3	0.0	0.0
				-50%	0.2	0.0	0.0	0.6	0.0	0.0	0.5	0.0	0.0
μ_{max}	Maximum algal growth rate	day-1	2.000	50%	0.3	-0.1	-0.1	0.6	0.0	0.0	0.8	0.0	0.0
				-50%	-0.3	0.0	-0.1	-0.3	0.0	0.0	-0.6	0.0	0.0
ρ	Algal respiration rate	day-1	0.275	50%	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.1	0.0	-0.1	0.3	0.0	0.0	0.3	0.0	0.0
K_L	Light saturation coefficient (Option 2)	Langley's/min	0.025	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K_N	Half-saturation constant for nitrogen	mg-N/l	0.155	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K_P	Half-saturation constant for phosphorus	mg-P/l	0.026	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.1	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0
λ_1	Linear algal self-shading coefficient	(1/m) / (µg Chl-1/l)	0.003	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
λ_2	Nonlinear algal self-shading coefficient	(1/m) / (µg Chl-1/l)**2/3	0.017	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
P_N	Algal preference factor for ammonia	-	0.900	1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

α_0	Ratio of chlorophyll-a to algal biomass	µg Chl-a / mg A	75.000	100.000	-0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.3	-0.2	-0.1	0.8	0.0	0.0	0.8	0.0	0.0
λ_0	Non-algal light extinction coefficient	1/m	0.000	1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				NA									
σ_1	Algal settling rate	m/day	0.000-0.500	1.000 / 50%	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				NA / -50%	0.2	-0.1	-0.1	0.3	0.0	0.0	0.5	0.0	0.0
σ_2	Benthos source rate for dissolved phosphorus	mg-P /m^2-day	0.000	1.000	0.0	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0
				NA									
σ_3	Benthos source rate for ammonia nitrogen	mg-N /m^2-day	0.000	1.000	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				NA									
σ_4	Organic nitrogen settling rate	day-1	0.000-0.0500	1.000 / 50%	0.0	-9.1	0.0	0.0	-0.8	0.0	0.3	-0.8	0.0
				NA / -50%	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
σ_5	Organic phosphorus settling rate	day-1	0.000-0.050	1.000 / 50%	0.0	0.0	-12.9	0.0	0.0	0.0	0.0	0.0	0.0
				NA / -50%	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0
K_1	Carbonaceous deoxygeneration rate constant	day-1	0.000-0.200	1.000 / 50%	-2.8	0.0	0.0	-1.7	0.0	0.0	-2.0	0.0	0.0
				NA / -50%	0.9	0.0	0.0	2.2	0.0	0.0	2.4	0.0	0.0
K_3	Rate of loss of BOD due to settling	day-1	0.000	1.000	0.5	0.0	0.0	1.1	0.0	0.0	1.1	0.0	0.0
				NA									
K_4	Benthic oxygen uptake (SOD)	g-O / m^2-day	0.500	50%	-7.2	0.0	0.0	-18.1	0.0	0.0	-18.6	0.0	0.0
				-50%	6.3	0.0	0.0	13.5	0.0	0.0	13.7	0.0	0.0
β_1	Rate constant for the biological oxidation of NH_3 to NO_2	day-1	0.000-1.000	1.000 / 50%	-1.0	0.0	0.0	-1.7	0.0	0.0	-2.0	0.0	0.0
				NA / -50%	0.9	0.0	0.0	2.5	0.0	0.0	2.7	0.0	0.0
β_2	Rate constant for the biological oxidation of NO_2 to NO_3	day-1	0.000-2.000	1.000 / 50%	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				NA / -50%	0.1	0.0	0.0	0.3	0.0	0.0	0.5	0.0	0.0
β_3	Rate constant for the hydrolysis of organic-N to ammonia	day-1	0.000-0.400	1.000 / 50%	-0.3	0.0	0.0	-0.6	0.0	0.0	-0.6	0.0	0.0
				NA / -50%	0.4	-0.1	0.0	0.8	0.0	0.0	1.1	0.0	0.0
β_4	Rate constant for the decay of organic-P to dissolved-P	day-1	0.000-0.700	1.000 / 50%	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
				NA / -50%	0.0	0.0	-0.4	0.0	0.0	0.0	0.0	0.0	0.0

Appendix J - Summary of Sensitity Analysis for Marshyhope Creek Qual2e Model

Parameter	Description	Unit	Value	Input Change	Response %								
					Model Average			Reach 1, Computational Element 6			Reach 2, Computational Element 1		
					DO	TN	TP	DO	TN	TP	DO	TN	TP
α_1	Fraction of algal biomass that is Nitrogen	mg-N / mg A	0.080	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
α_2	Fraction of algal biomass that is Phosphorus	mg-P / mg A	0.015	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
α_3	O_2 production per unit of algal growth	mg-O / mg A	1.600	50%	0.1	0.0	0.0	0.3	0.0	0.0	0.1	0.0	0.0
				-50%	-0.1	0.0	0.0	-0.1	0.0	0.0	-0.1	0.0	0.0
α_4	O_2 uptake per unit of algae respired	mg-O / mg A	2.000	50%	-0.1	0.0	0.0	-0.1	0.0	0.0	-0.1	0.0	0.0
				-50%	0.1	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0
α_5	O_2 uptake per unit of NH_3 oxidation	mg-O / mg A	3.500	50%	-0.1	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0
				-50%	0.1	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0
α_6	O_2 uptake per unit of NO_2 oxidation	mg-O / mg A	1.070	50%	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
μ_{max}	Maximum algal growth rate	day-1	2.000	50%	0.2	0.0	0.0	0.3	-0.3	0.0	0.3	0.0	0.0
				-50%	-0.1	0.1	0.0	-0.1	0.0	0.0	-0.1	0.3	0.0
ρ	Algal respiration rate	day-1	0.275	50%	-0.1	0.0	0.0	-0.1	0.0	0.0	-0.1	0.0	0.0
				-50%	0.1	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0
K_L	Light saturation coefficient (Option 2)	Langley's/min	0.025	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K_N	Half-saturation constant for nitrogen	mg-N/l	0.155	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K_P	Half-saturation constant for phosphorus	mg-P/l	0.026	50%	-0.1	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0
				-50%	0.1	0.0	0.0	0.1	-0.3	0.0	0.1	0.0	0.0
λ_1	Linear algal self-shading coefficient	(1/m) / (µg Chl-1/l)	0.003	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
λ_2	Nonlinear algal self-shading coefficient	(1/m) / (µg Chl-1/l)**2/3	0.017	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
P_N	Algal preference factor for ammonia	-	0.900	1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

α_0	Ratio of chlorophyll-a to algal biomass	µg Chl-a / mg A	75.000	100.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.1	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0
λ_0	Non-algal light extinction coefficient	1/m	0.000	1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				NA									
σ_1	Algal settling rate	m/day	0.380	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
σ_2	Benthos source rate for dissolved phosphorus	mg-P /m^2-day	0.000	1.000	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0
				NA									
σ_3	Benthos source rate for ammonia nitrogen	mg-N /m^2-day	0.000	1.000	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.3	0.0
				NA									
σ_4	Organic nitrogen settling rate	day-1	0.050	50%	0.0	-0.2	0.0	0.0	-0.3	0.0	0.0	0.0	0.0
				-50%	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.3	0.0
σ_5	Organic phosphorus settling rate	day-1	0.050	50%	0.0	0.0	-0.5	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
K_1	Carbonaceous deoxygeneration rate constant	day-1	0.200	50%	-1.2	0.0	0.0	-1.1	0.0	0.0	-1.2	0.0	0.0
				-50%	1.3	0.0	0.0	1.2	0.0	0.0	1.3	0.0	0.0
K_3	Rate of loss of BOD due to settling	day-1	0.000	1.000	0.8	0.0	0.0	0.4	0.0	0.0	0.6	0.0	0.0
				NA									
K_4	Benthic oxygen uptake (SOD)	g-O / m^2-day	0.000	1.000	-23.1	0.0	0.0	-22.7	0.0	0.0	-25.8	0.0	0.0
				NA									
β_1	Rate constant for the biological oxidation of NH_3 to NO_2	day-1	0.100	50%	-0.1	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0
				-50%	0.1	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0
β_2	Rate constant for the biological oxidation of NO_2 to NO_3	day-1	0.200	50%	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
β_3	Rate constant for the hydrolysis of organic-N to ammonia	day-1	0.040	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
β_4	Rate constant for the decay of organic-P to dissolved-P	day-1	0.070	50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0