Total Maximum Daily Loads (TMDLs) Analysis for Naamans Creek, Delaware

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EXECUTIVE SUMMARY

Section 303(d) of the Clean Water Act requires States to identify water quality impaired waterways and 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 approximately 8 miles of Naamans Creek and its North Branch and South Branch (segments DE230-001-01 and DE230-001-02) are impaired because of elevated nutrient and bacteria levels (1) (2) (3). Those impaired segments were placed on the State's biennial 303 (d) lists and targeted for development of TMDLs.

Naamans Creek is located in the northeast corner of New Castle County, Delaware. It has two main branches (North Branch and South Branch), each about 6 miles in length. The South Branch drains about 4000 acres of residential and commercial areas in northern New Castle County and the North Branch drains a similar area in west of Marcus Hook of Pennsylvania. The two branches meet just west of Route 13 crossing and form the Naamans Creek that discharges into the Delaware River at Claymont, Delaware. Within the watershed, three NPDES facilities are identified. They are located in the area east of Rt. 13. However, their process waters and other type of discharges go into Delaware River, Only storm water outfalls from CitiSteel discharge to Naamans Creek.

Development of the Naamans Creek nutrient TMDLs is based on water quality analysis of Naamans Creek under two different environmental conditions: 1) average condition, and 2) summer critical condition. Average condition considers average flow and averages of water quality during the period of 2000 – 2004. Summer critical condition considers 7Q10 flow and water quality during summer season (July – September) of 2000 – 2004.

The U.S. EPA's Enhanced Stream Water Quality Model (Qual2E) was used as the framework for the nutrient TMDL analysis. Water quality data collected during 2000-2004 was used to calibrate the model, and data collected during summer season from the same period was used to simulate the summer critical conditions.

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

The results of water quality modeling and analysis for nutrient showed that, under both average and summer conditions, water quality standard of 5.5 mg/l for dissolved oxygen was achieved in all segments of the Naamans Creek. At the same time, total nitrogen concentration in all segments was below its TMDL target of 3 mg/l and total phosphorous concentration was below its TMDL target of 0.2 mg/l. The above results indicate that current nutrient loading of 228 lb/day total nitrogen and 13 lb/day total phosphorous would not result in violation of water quality standards under average and summer low-flow conditions, hence no load reduction is necessary for this watershed. However, bacteria loads need to be reduced by 78% to achieve State water quality standards.

Of 228 lb/day of total nitrogen load under average condition, 100 lb/day is coming from the drainage area within Pennsylvania and 128 lb/day from Delaware. Similarly, of the total phosphorous load of 13 lb/day, 4 lb/day is coming from Pennsylvania and 9 lb/day from Delaware. Therefore, under average condition, total nitrogen and total phosphorous loads shall be capped at 100 lb/day and 4 lb/day, respectively, at the state lines. Total nitrogen and total phosphorous loads generated from the drainage areas within Delaware are from the nonpoint sources and should be capped at 128 lb/day and 9 lb/day, respectively.

1.0 INTRODUCTION

Section 303(d) of the Clean Water Act (CWA) as amended by the Water Quality Act of 1987, requires States to identify impaired waters and develop Total Maximum Daily Loads (TMDLs) for pollutants of concern. The Delaware Department of Natural Resources and Environmental Control (DNREC) has identified 8.1 miles of Naamans Creek (including portions of South Branch, North Branch, and Lower Naamans Creek) as impaired because of its high nutrient and bacteria levels. These segments of the stream have been placed on the State's biennial 303(d) lists, and targeted for TMDL development. Figure 1-1 shows Delaware portion of the watershed. The red lines on the map illustrate impaired stream segments that are on the 303 (d) Lists. Table 1-1 is the excerpt from the 2002 303 (d) List for Naamans Creek.

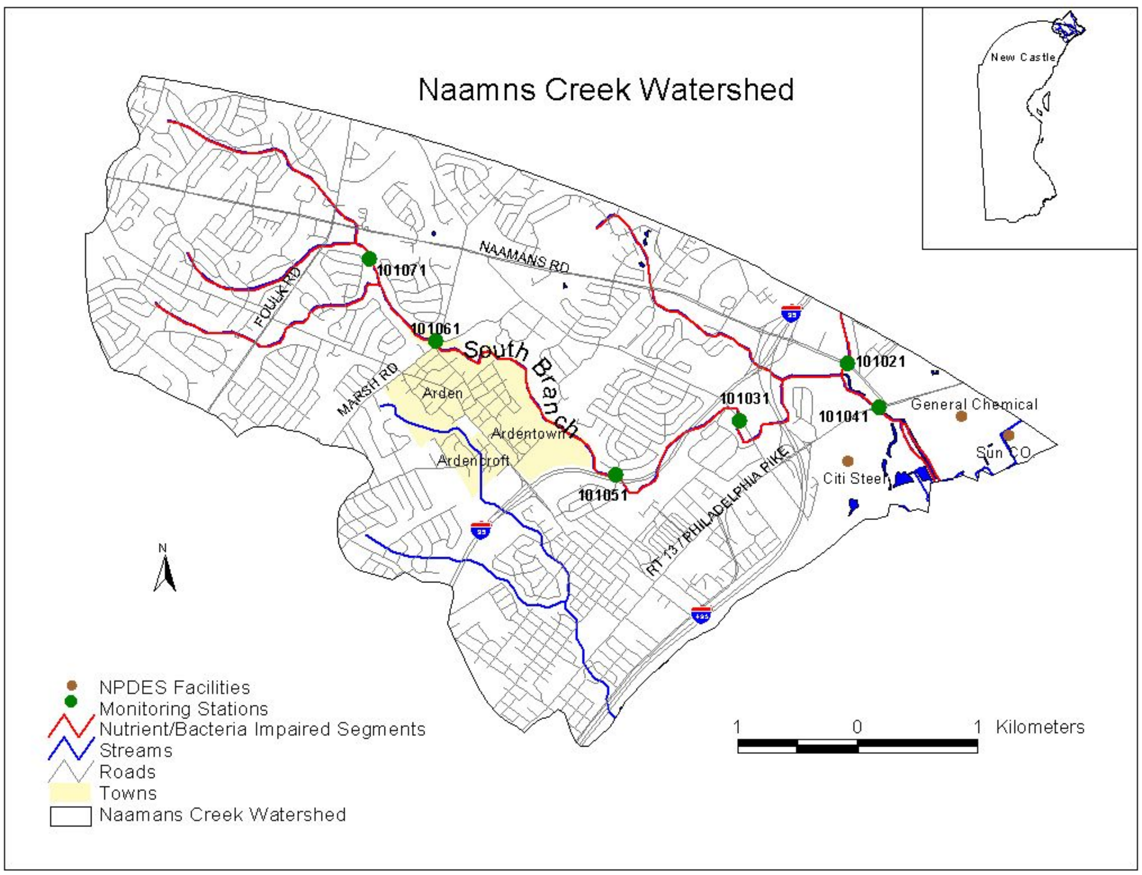

Figure 1 – 1 Naamans Creek Watershed Map

Table 1-1 Excerpt from 303(d) List of 2002 for Naamans Creek (3)

WATERBODY ID (TOTAL SIZE)	WATERSHED NAME	SEGMENT	DESCRIPTION	SIZE AFFECTED	POLLUTANT(S) AND/OR STRESSOR(S)	PROBABLE SOURCE(S)	TARGET DATE FOR TMDL
DE230-001-01 (0.30 miles)	Naamans Creek	Lower Naamans Creek	From the mouth at the Delaware River, upstream to the first railroad bridge crossing	0.30 miles	Bacteria / Nutrients	NPS	2004
DE230-001-02 (11.0 miles)	Naamans Creek	North Branch and South Branch	Upper Naamans Creek, including all tributaries on the North Branch and South Branch	7.8 miles	Bacteria and nutrients	NPS	2004

1.1 Naamans Creek Watershed

Naamans Creek Watershed is located in the northeast corner of New Castle County, Delaware. It has two branches (North Branch and South Branch), each about 6 miles in length. The South Branch drains about 4000 acres of residential and commercial areas in northern New Castle County of Delaware. The North Branch drains a similar area in west of Marcus Hook of Pennsylvania. The two branches meet just west of Route 13 crossing and form the Naamans Creek that discharges into the Delaware River at Claymont, Delaware. The stream is mostly free flowing. A tidal dam is located on lower Naamans Creek near the property of CitiSteel USA, Inc., about 0.5 miles upstream from its mouth (9).

This study focused on the area drains to the South Branch and lower Naamans Creek within Delaware's boundary. Upper reaches of the South Branch has rocky bottom with relatively steep slope. The middle stretch of the stream (in vicinity of I-95) is channelized with concrete bed and banks. The lower Naamans Creek forms below the confluence of North Branch and South Branch is less than 2 miles long (see Figure 1-1). Concerns in the watershed include nutrient overenrichment and high bacteria counts. Three point sources are identified in the watershed. They are NPDES facilities and located in the area east of Rt. 13.

The land use within the watershed is dominated by commercial, residential, and industrial areas. It is a highly urbanized watershed. The detailed land use information for this watershed based on 2002 Delaware Office of Planning land cover data is shown in Figure 1-2. As it can be seen from Figure 1-2 and pie chart in Figure 1-3, the land use activity within the watershed consists of 3712 acres of residential, commercial and industrial area (85% of the watershed), 578 acres of forest (13% of the watershed), and 92 acres of other land uses (2% of the watershed).

Soil types within the watershed include Neshaminy-Aldino- Wachung association described by the Natural Conservation Service as "well drained, moderately well drained and poorly drained, medium textured soils" with moderately fine or fine subsoils. Neshaminy- Tallyville-Urban association is considered "well drained, medium textured soils, relatively undisturbed to severely disturbed" also with moderately fine or fine subsoils.

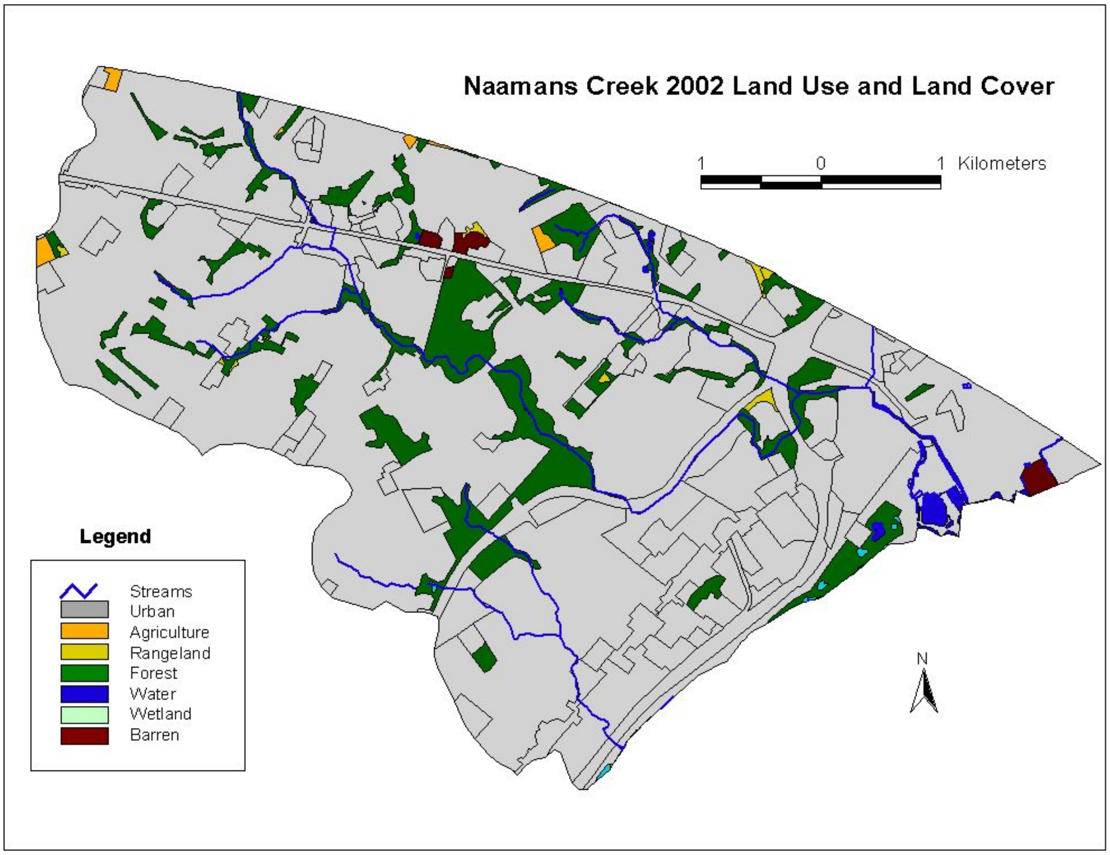

Figure 1-2 Naamans Creek Watershed 2002 Land Use and Land Cover

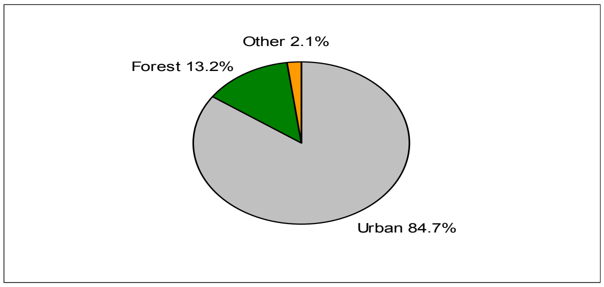

Figure 1-3 Landuse Percentages in Naamans Creek Watershed

1.2 Designated Uses

The purpose of establishing TMDLs is to reduce 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, specifies the following designated uses for the waters of Naamans Creek (4):

- Primary Contact Recreation

- Secondary Contact Recreation
- Fish, Aquatic Life, and Wildlife
- Agricultural Water Supply for freshwater segments
- Industrial Water Supply

1.3 Applicable Water Quality Standards and Nutrient Guidelines

To protect the designated uses, the following sections of the State of Delaware Surface Water Quality Standards, as amended July 11, 2004, provide specific narrative and numeric criteria concerning the waters in Naamans Creek (4):

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 Naamans Creek Watershed:

a. Dissolved Oxygen (D.O.):
   - Daily average shall not be less than 5.5 mg/l (for fresh waters)
   - 4.0 mg/l instantaneous minimum

b. Nutrients:
   - 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.

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

The standards are a State regulation and the basis for preparing 305(b) Reports, compiling 303(d) Lists, and developing TMDLs.

In the absence of 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 threshold values have been used as a guideline for 305(b) assessment reports and 303(d) listing of impaired waters, and are generally accepted by the scientific community to be an indication of over-enriched waters.

1.4 Stream Water Quality Condition

Water quality of Naamans Creek varies over time. Main stem segments of Naamans Creek (8.1 mi) were first listed in 1996 due to their bacteria impairment. In 1998, nutrient impairment for the same 8.1-mile segments was added to the list, and remained on the list even subsequent years water quality data showed that nutrient targets were met. Based on the data collected during 1995-1997 period, the 1998 State of Delaware 305 (b) Report showed that total phosphorous concentration was high at some segments and in result, the designated uses were not fully supported. However, evaluating data collected during 1996 – 2001, the 2002 305(b) Report showed that nutrient levels at all segments of Naamans Creek were under their thresholds and in result, designated uses of Naamans Creek were reported to be fully supported except for primary contact recreation use which was impaired by high bacteria levels (2). Dissolved oxygen was never reported as a problem for Naamans Creek and therefore was never appeared on 303(d) list.

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

To support this modeling and analysis effort, water quality data was collected at several locations in the watershed during 2000 – 2004. Sampling sites are listed in Table 1-2 and are shown in Figure 1-1. At each monitoring site, grab surface water samples were collected several times during 2000 - 2004 period and were analyzed for a suite of 24 water quality parameters (5). Figure 1-5 shows the water quality data collected at six locations along Naamans Creek and its North and South Branches for water temperature, dissolved oxygen, total nitrogen, and total phosphorous. The average values of the same parameters are presented in Figure 1-6. More water quality monitoring data collected during the period are attached into Appendix B.

Table 1-2 Naamans Creek Water Quality Monitoring Sites

Station	Site Description	Type of Site
From Downstream Up		
Lower Naamans Creek		
101041	Naamans Creek at Rt. 13A	Long-term
North Branch (drains PA)		
101021	Naamans Creek at Naamans Rd	Long-term
South Branch (drains DE)		
101031	South Branch at Darley Rd	Long-term
101051	South Branch, at Glenrock Rd bridge	special request
101061	South Branch, at Rt. 3 (or Marsh Rd) bridge	special request
101071	South Branch, at Decatur Road	special request

The monitoring data collected during the period of 2000 – 2004 showed that dissolved oxygen concentration met the standard of 5.5 mg/l in most samples. Only two samples collected from lower portion of the stream showed that dissolved oxygen levels were below the standard, one sample was collected at station 101041 (at RT. 13A) on 8/7/2002 and another sample was at station 101021 (at Naamans Road) on 11/13/2002. Nonetheless, average concentration of dissolved oxygen at each station over the monitoring period was well above the standard, in a range of 8 – 10 mg/l. Similarly, one sample from each station of 101021 and 101041 had total nitrogen exceeded its threshold of 3 mg/l and total phosphorous exceeded its threshold of 0.2 mg/l; however, average concentrations of total nitrogen and total phosphorous at each station were below their respective threshold values.

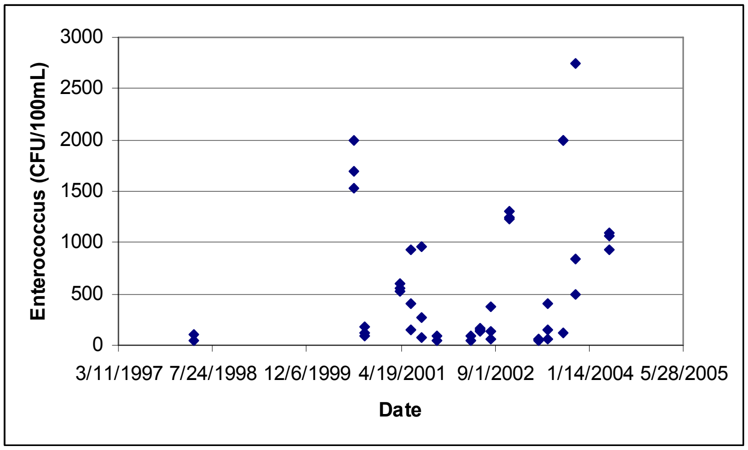

Figure 1-4 Bacteria Concentrations in Naamans Creek Watershed

The State Water Quality Standard for enterococcus is a geometric mean of 100CFU/100mL. 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 enterococcus concentration of 100CFU/100mL has been deemed appropriate and is the basis for the current State Water Quality Standards for bacteria. Figure 1-4 illustrates the bacteria concentrations in the Naamans Creek Watershed; it is clearly much greater than the State Water Quality Standards for bacteria.

1.5 Sources of Pollution

In general, nutrients, oxygen consuming compounds, and bacteria enter surface waters from point and nonpoint sources. Nonpoint source discharges include surface runoffs from urban and other land use activities, septic tanks, and groundwater discharges. Point source discharges include discharges from municipal and industrial wastewater treatment plants (NPDES facilities), Combined Sewer Overflows, etc.

Within the Naamans Creek, three NPDES facilities (see Figure 1-1 and Table1-3 below) are located in the area east of Rt. 13. However, most their discharges go into Delaware River. The only possible discharge to Naamans Creek is from CitiSteel's storm water outfalls. Since discharges from storm water outfalls are expected to occur only during storm events and high flow conditions, they are considered as a source only during bacteria TMDL analysis. This is because during nutrient and DO TMDL analysis (which is established to protect water quality during low flow critical conditions) stormwater discharge does not occur.

With regard to septic tank systems within the watershed, a Geographic Information

System (GIS) database search revealed that a total of 9 septic tank systems exist within the Naamans Creek watershed. However, they are located near the DE and PA state line, far from modeled reaches, their direct impact to water quality of the Naamans Creek is considered to be minimal.

Table 1-3 Point Source Facilities in the Naamans Creek Watershed

PERMIT ID	FACILITY NAME	RECEIVING WATER	DISCHARGE DISCRIPTION
DE 0051021	CitiSteel	Delaware River	contact, noncontact cooling water, and storm water
		Naamans Creek	storm water
DE 0000655	General Chemical Corp.	Delaware River	storm water, groundwater infiltration, and water of blowdown from boilers, cooling towers, and steam traps.
DE 0050288	Sun Co.	Delaware River, Middle Creek	storm water

1.6 Objective and Scope of the TMDL Analysis for Naamans Creek

The objective of the TMDL analysis for Naamans Creek is to estimate the total maximum amount of bacteria and nutrients that Naamans Creek can receive without violating water quality standards. Under TMDL loading condition, the water quality standards for dissolved oxygen and bacteria will be met at all segments and threshold values for total nitrogen and total phosphorous will be met.

To achieve the above objective, DNREC has:

- Developed a water quality model for Naamans Creek using the U.S. EPA's Qual2E as a framework.
- Calibrated the Naamans Creek Qual2E model to the average water quality and flow conditions of 2000-2004.
- Applied and evaluated summer loading conditions using the above calibrated model.
- Estimated annual-average loading of nutrients under average condition during the period of 2000 – 2004.
- Estimated bacteria reduction under different flow conditions.

Chapter 2 of this report provides a brief review of the Naamans Creek Qual2E model. The results of calibration run and summer loading scenario run are presented in Chapter 3. An estimation of Naamans Creek's TMDLs and the rational for acceptance of the loads as Naamans Creek TMDLs are discussed in Chapter 4. Chapter 5 gives a discussion of bacteria load estimation and its reduction calculation under different flow conditions.

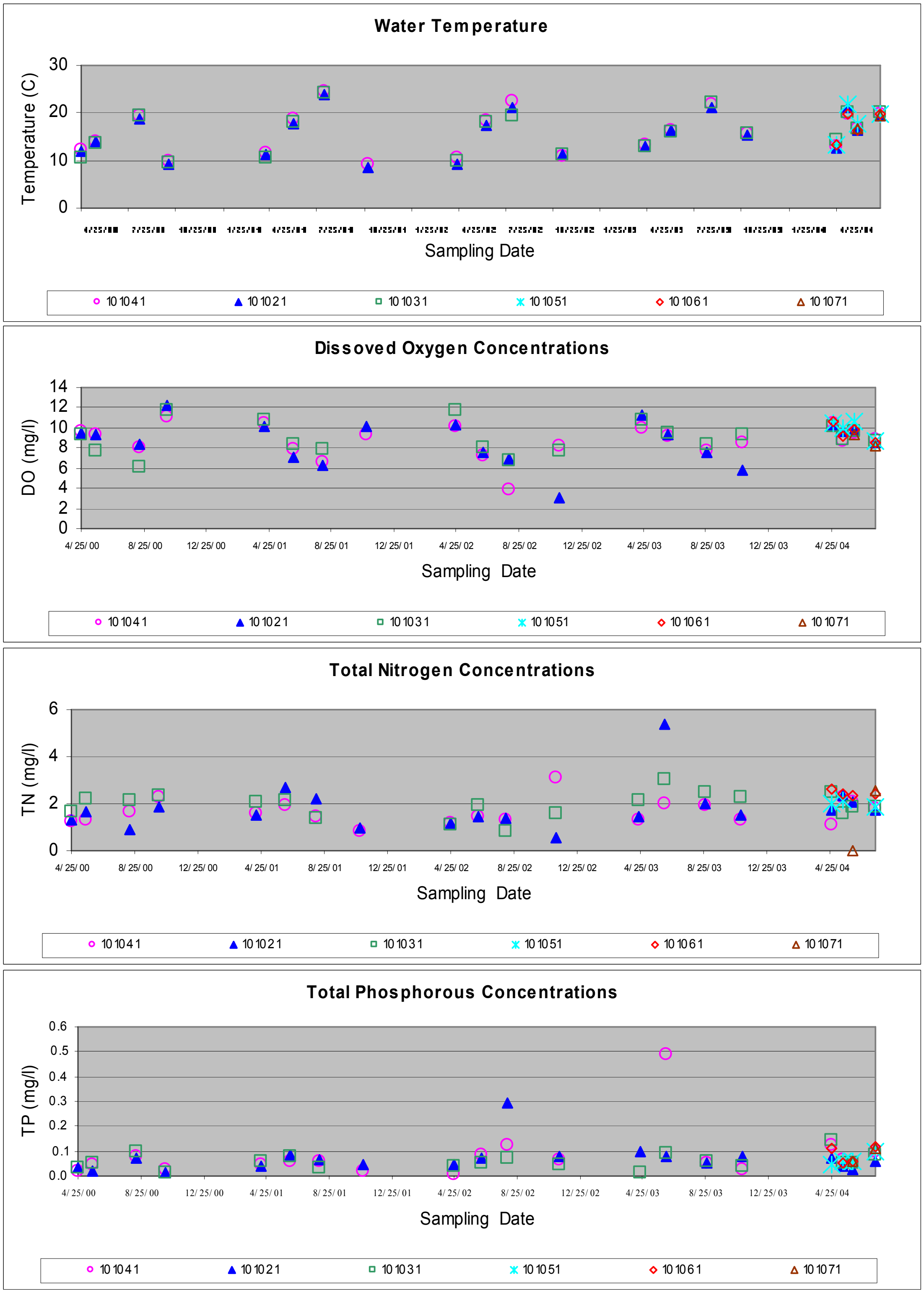

Figure 1-5 Observed Water Temperature, Dissolved Oxygen, Total Nitrogen, and Total Phosphorous at Six Monitoring Locations along the Naamans Creek

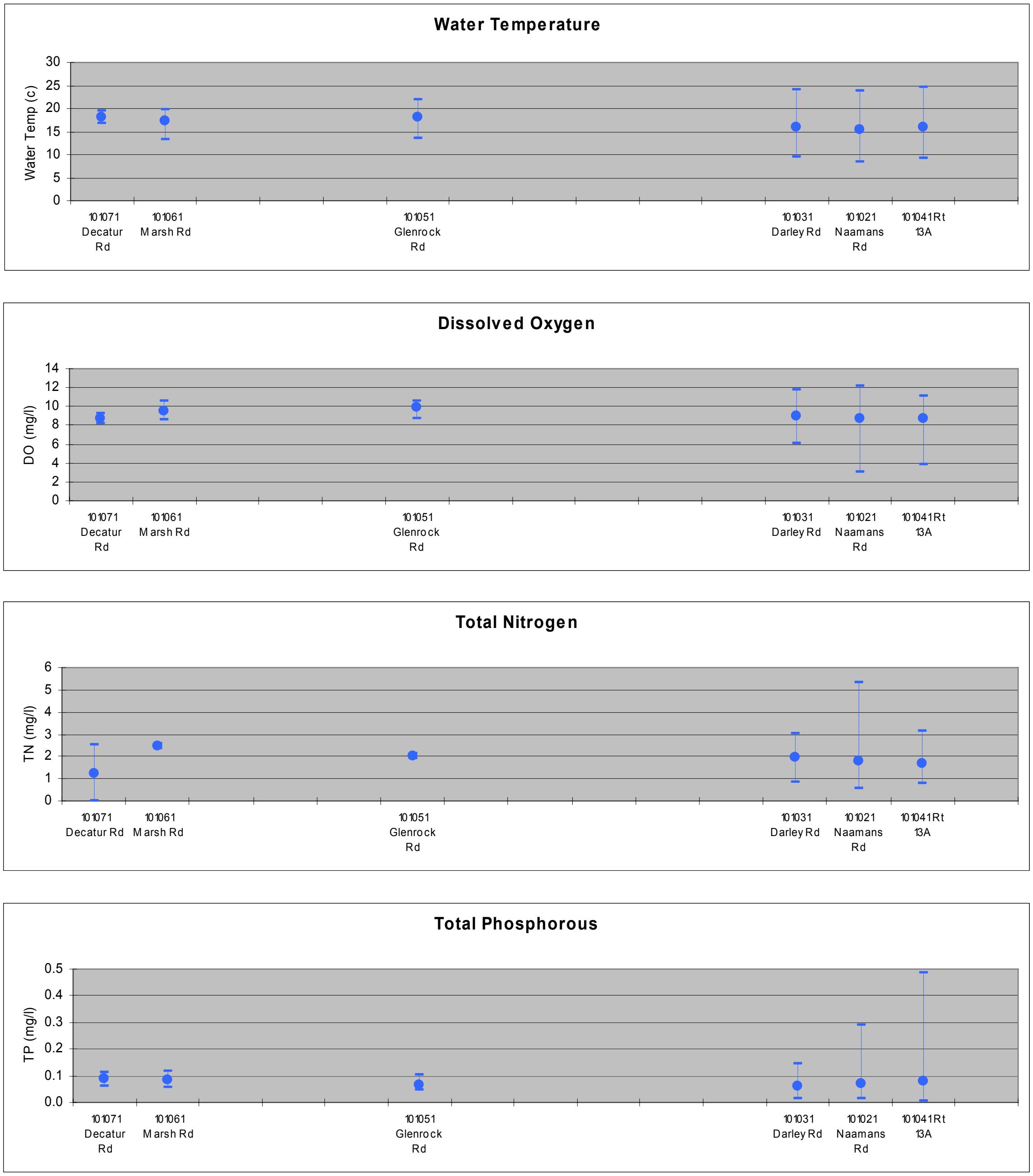

Figure 1-6 Summary of Water Quality Monitoring Data for Water Temperature, Dissolved Oxygen, Total Nitrogen and Total Phosphorous at Six Monitoring Locations in Naamans Creek Watershed

2.0 NAAMANS CREEK WATER QUALITY MODEL

2.1 The Enhanced Stream Water Quality Model (Qual2E)

The Enhanced Stream Water Quality Model (Qual2E) is chosen as a framework for Naamans Creek model development. Qual2E is supported by the U.S. EPA and has been widely used for studying the impact of conventional pollutants on streams. DOS version 3.22 of this model is used for the study. Model code was recompiled by Linfield C. Brown to run under Windows XP operating system (6).

Naamans Creek is a small and fresh water stream except the most down stream stretch, less than 0.5 miles is tide influenced. Salinity data collected at all stations in Naamans Creek during 2000 – 2004 showed that the salinity level was less than 0.2 parts per thousand. The long-term annual mean flow of Naamans Creek is less than 18 cubic feet per second (cfs). The width of the stream is generally less than 25 ft and its depth is less than 1 ft except for the most down stream one-mile segment of the creek. Water quality concern for Naamans Creek is elevated nutrient and bacteria levels.

The Qual2E model is suitable for simulating the hydrological and water quality conditions of a small stream. It is a simple one-dimensional model that simulates basic stream transport and mixing processes. The kinetic processes employed in Qual2E address nutrient cycle, algal growth, and dissolved oxygen dynamics. Comparing to other available models, Qual2E is the one best suited for Naamans Creek's condition. Therefore, Qual2E was selected as the tool to develop the Naamans Creek water quality model and conduct TMDL analysis.

Qual2E consists of thirteen input data groups. Below is a brief summary of the input data groups. A detailed discussion of the model is available in the model's user manual (6). Data inputs for the Naamans Creek Qual2E model are grouped according to Qual2E's data input requirements, and discussed in the next 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 stream reach system by listing reach names and lengths.
- Type 3 data gives flow augmentation information.
- Type 4 data identifies computational elements for each reach.
- Type 5 data describes hydraulic characteristics of the system.
- Type 6, 6A, and 6B data provide reach varied coefficients and rates related to kinetic processes of BOD, DO, nutrient and algae.
- Type 7 and 7A data define 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 downstream conditions.

2.2 Naamans Creek Qual2E Model Input Data

The Naamans Creek Qual2E Model is set up as a one-dimensional, steady-state model. It simulates average instream water quality condition including dissolved oxygen, BOD, algae as chlorophyll-*a*, as well as various forms of nitrogen and 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 Naamans Creek Qual2E Model are summarized below.

Model Segmentation

The Naamans Creek Qual2E model consists of four reaches and covers South Branch and Lower Naamans Creek for a length of 7.5 kilometers (4.7 miles). The model starts from headwaters above Marsh Road on the South Branch to the mouth of Naamans Creek at Delaware River. Figure 2-1 displays stream reaches on a watershed map. Due to the structure of Qual2E, each model reach is further divided into a number of model computational elements (CE) which must have the same length across the entire model domain. A length of 0.5 kilometer was selected for Naamans Creek Qual2E model computational element. A summary of reach length and the number of computational element is presented in Table 2-1.

Table 2-1 Naamans Creek Qual2E Reaches

Reach Number	Description	Reach Length (km)	Number of Computational Elements
1	The most upstream reach, from headwater above Marsh Road	2.5	5
2	Channelized segment of the stream (along I-95)	2.0	4
3	Lower reaches of South Branch	1.5	3
4	The most downstream segment of Naamans Creek	1.5	3
Total		7.5	15

Hydraulic Characteristics

The Naamans Creek Qual2E model uses functional representation, rather than geometric representation, to describe stream hydraulic characteristics and assumes that stream has a rectangular channel cross-section. Functional representation of hydraulic characteristics of the stream reaches are 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 segment (m/s)
d – depth of stream segment (m)
a, b, α, and β - empirical discharge coefficient constants

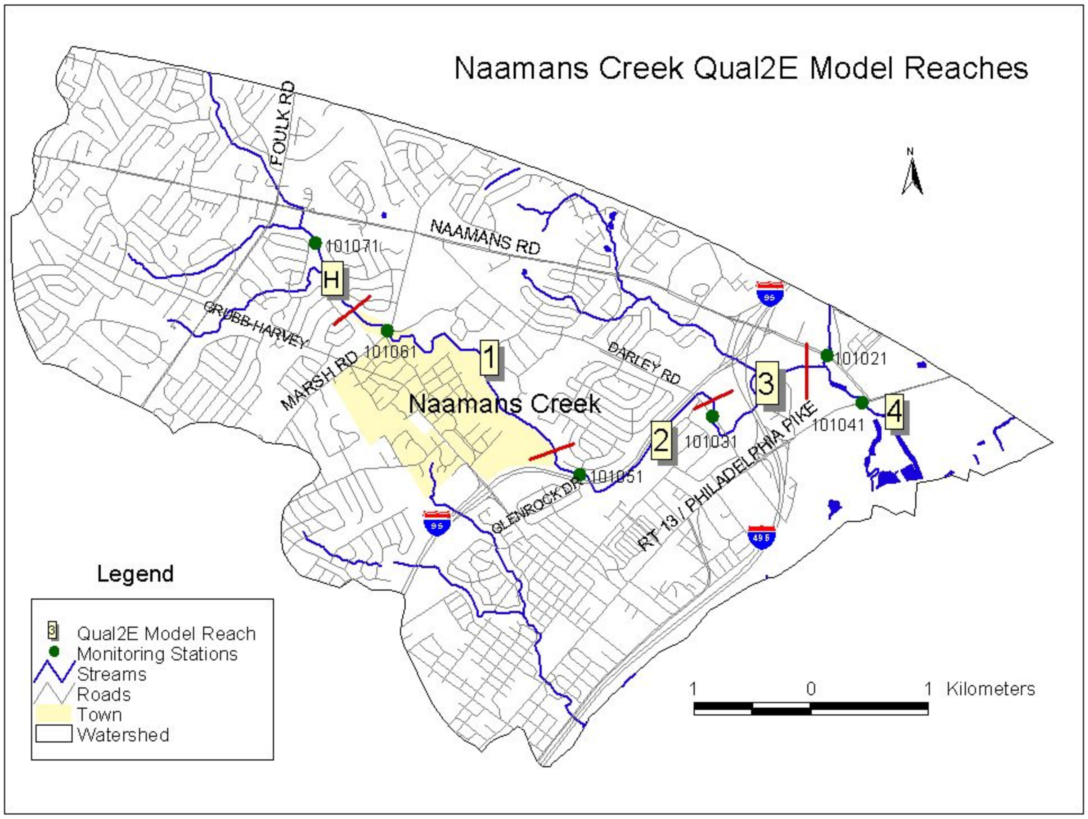

Figure 2-1 Reaches of Naamans Creek Qual2E Model

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 the period of 2000-2004. The average width, depth, and velocity are calculated based on the measurements and the results are presented in Table 2–2.

These field measurements were used to estimate the discharge coefficient constants and to form discharge coefficient equations. First, measures of channel depth and velocity were plotted against their corresponding stream-flow measurements for each monitoring site. Next, regressions of depth vs. flow and velocity vs. flow were performed and the discharge coefficient constants *a, b, α,* and *β* were calculated. Then the discharge function at each monitoring site was prepared and assigned to represent hydraulic characteristics of the stream reach. Table 2-3 summarizes the estimated discharge coefficient constants and discharge functions.

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

Station (from down stream up)	Stream Segment	Average Width (ft)	Average Depth (ft)	Average Velocity (ft/s)
101021	On North Branch	14	0.5	0.7
101041*	Reach 4, Lower Naamans Creek	30	0.8	1.3
101031	Reach 3, lower reach of South Branch	11	0.6	0.7
101051	Reach 2, mid reach of South Br, channelized	25	0.2	0.7
101071	Reach 1, upper reach of South Branch	4	0.6	1.2

* Data is from field reconnaissance in April 2004.

Table 2-3 Discharge Coefficient Constants for Naamans Creek Qual2E Model Reaches

Reach	Stream Reach Name	Station	Mean Velocity (m/s)	Depth (m)
			u = a Q ^b	d = α Q ^β
1	Most upstream reach	101071	u = 2.1332 Q ^ 0.8159	d = 0.3845 Q ^0.1841
2	Channelized reach	101051	u = 1.3363 Q ^ 0.5848	d = 0.0716 Q ^ 0.2886
3	Lower South Branch	101031	u = 0.4054 Q ^ 0.3056	d = 0.5155 Q ^ 0.5104
4	Most Downstream reach	101021	u = 0.4516 Q ^ 0.3634	d = 0.3602 Q ^ 0.5

Stream Flow

Both annual-average flow and 7Q10 flow were considered for development of the Naamans Creek Qual2E model and the TMDL analysis. Annual-average flow was calculated by averaging daily mean flow over the period of 2000 - 2004. 7Q10 flow is a low flow of 7-day duration with recurrence interval of 10 years and has been calculated using the flow record during period of 1946 – 2004. The annual-average flow was used for model calibration while the 7Q10 flow was used to simulate the critical condition of summer low flow and warm temperature.

There is no USGS gauging station in the Naamans Creek Watershed. Daily flows recorded at the Shellpot Creek gauging station (USGS 01477800) were used to estimate daily flows in Naamans Creek using a similar run-off rate (the ratio of flow to drainage area). The Shellpot Creek gauging station flow data was considered to be a reasonable source for estimating the flow of the Naamans Creek due to the fact that both watersheds have similar geology and topography, and are in close proximity. The gauging station at Shellpot Creek has a drainage area of 7.46 square miles with an annual-average daily flow of 12 cfs during 2000 -2004. The 7Q10 flow at this station during the period of 1946-2004 is calculated to be 0.25 cfs (7). Naamans Creek's sub-watersheds drainage area as well as their annual-average flows and 7Q10 flows were estimated and presented in Table 2-4.

Table 2-4. Annual-average Flow and 7Q10 Flow of Naamans Creek's Sub-watersheds

Sub-watershed	Area	Annual-average Flow (4/1/00 - 7/31/04)		7Q10 Flow during 1945-2003	
	km2	cfs	cms	cfs	cms
Headwater	9.1	5.643	0.160	0.118	0.0033
Reach 1 (distributed flow)	3.2	1.974	0.056	0.041	0.0012
Reach 2 (distributed flow)	1.4	0.879	0.025	0.018	0.0005
A tributary to reach 3	2.2	1.367	0.039	0.029	0.0008
Reach 3 remainder (distributed)	0.7	0.408	0.012	0.009	0.0002
North Branch	16.8	10.383	0.294	0.217	0.0061
Reach 4 remainder (distributed)	1.3	0.798	0.023	0.017	0.0005
Total	34.7	21.452	0.607	0.449	0.0127

System Parameters

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

Table 2-5 Global Constants of Naamans Creek Qual2E Model

Parameter	Description	Unit	Value
α_1	Fraction of algal biomass that is Nitrogen	mg-N / mg A	0.08
α_2	Fraction of algal biomass that is Phosphorus	mg-p / mg A	0.014
α_3	O_2 production per unit of algal growth	mg-O / mg A	1.6
α_4	O_2 uptake per unit of algae respired	mg-O / mg A	2
α_5	O_2 uptake per unit of NH_3 oxidation	mg-O / mg N	3.43
α_6	O_2 uptake per unit of NO_2 oxidation	mg-O / mg N	1.1
μ_{max}	maximum algal growth rate	day-l	3

ρ	Algal respiration rate	day-l	0.05
K_L	Light saturation coefficient (Option 2)	langleys/min	0.025
K_N	Half- saturation constant for nitrogen	mg-N/L	0.05
K_p	Half- saturation constant for phosphorus	mg-P/L	0.001
λ1	Linear algal self-shading coefficient	(1/m) / (ug Chl-a/L)	0.0008
λ2	Nonlinear algal self- shading coefficient	(1/m) / (ug Chl-a/L)**2/3	0
P_N	Algal preference factor for ammonia	-	0.9

Table 2-6 Reach Variable Coefficients of Naamans Creek Qual2E Model

Parameter	Description	Unit	Range
α0	Ratio of chlorophyll -a to algal biomass	ug Chl-*a*/ mg A	50
λ0	Non-algal light extinction coefficient	1/m	0
σ_1	Algal settling rate	m/day	0
σ_2	Benthos source rate for dissolved phosphorous	mg-p / m2-day	0
σ_3	Benthos source rate for ammonia nitrogen	mg-N / m2-day	0
σ_4	Organic nitrogen settling rate	day-l	0
σ_5	Organic phosphorus settling rate	day-l	0
K_1	Carbonaceous deoxygeneration rate constant	day-l	0.2
K_2	Reaeration rate constant	day-l	calculated internally (option 5)
K_3	Rate of loss of BOD due to settling	day-l	0
K_4	Benthic oxygen uptake (SOD)	mg-O / m2-day	0 – 0.5
β1	Rate constant for the biological oxidation of NH3 to NO2	day -1	0.3
β2	Rate constant for the biological oxidation of NO2 to NO3	day-l	1
β3	Rate constant for the hydrolysis of organic- N to ammonia	day-l	0.3
β4	Rate constant for the decay of organic-P to dissolved-P	day-l	0.5

Boundary Conditions

Qual2E model uses various data groups to define model boundary conditions. It uses headwater data group to define upstream boundary condition of 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 enter simulated stream segments.

The headwater condition of the Naamans Creek Qual2E Model was characterized by using monitoring data collected at station 101071 (at Decatur Road), and the tributary condition was characterized by data collected at station 101021 (at Naamans Road). The monitoring data were averaged over the entire period of 2000 – 2004 and over the summer months (July, August and September) during 2000 – 2004. The Average concentrations over the entire period of 2000 -2004 were used along with annual-average flows to calibrate the model for the average conditions. The average concentrations during summer months were used along with 7Q10 flows to simulate the critical summer conditions.

Option of internally calculating downstream boundary conditions was selected for development of the Naamans Creek Qual2E Model.

Incremental Inflow

The incremental inflow data group in Qual2E defines the condition of uniformly distributed flow over the entire length of the model reach. The uniformly distributed flow could be groundwater inflow and/or distributed surface runoff that is assumed to be constant over time.

Water quality characteristics of the incremental inflow for the Naamans Creek Qual2E Model were estimated based on assigning surface runoff concentrations to various land uses. The surface runoff concentrations as listed in Table 2-7, were originally used by HydroQual, Inc in developing a water quality model for the Murderkill River Watershed, Delaware. HydroQual considered literature values as well as land use studies in Delaware to arrive at the runoff concentrations (8). To apply runoff concentrations to the Naamans Creek, the assigned phosphorous concentration of surface runoffs was reduced based on observed concentrations at monitoring sites. Table 2-7 lists the assigned surface runoff concentrations for the Naamans Creek.

The fractions of different land uses in Naamans Creek Watershed are calculated using 2002 land use and land cover data. For a sub-watershed flowing directly into a modeled reach in a distributed form, its land use data was broken down into seven major types as listed in Table 2-7, and the fraction of each type of land use area to the total sub-watershed area was calculated. Considering the fraction of each land use type in a reach and assigning appropriate runoff concentrations for the land use type, a reach-wide incremental inflow concentration was calculated for the seven land use types and are presented in Table 2-8.

Table 2-7 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	mg/l	0.110	0.290	0.120	0.120	0.120	0.120	0.120
NO3	mg/l	0.390	1.540	0.350	0.350	0.350	0.350	0.350
PO4	mg/l	0.120	0.248	0.104	0.104	0.104	0.104	0.104
Phyto	mg/l	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CBOD	mg/l	5.000	5.000	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
OrgN	mg/l	0.910	1.310	1.140	1.140	1.140	1.140	1.140
OrgP	mg/l	0.152	0.140	0.052	0.052	0.052	0.052	0.052

Table 2-8 Incremental Inflow Concentrations for Naamans Qual2E Model

Concentrations from Incremental Inflow	NH3	NO3	PO4	Phyto	CBOD	DO	OrgN	OrgP	BOD5
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Reach 1	0.113	0.377	0.115	0.000	4.054	5.999	0.983	0.120	2.486
Reach 2	0.110	0.389	0.120	0.000	4.934	6.000	0.915	0.150	3.026
Reach 3	0.113	0.380	0.116	0.000	4.210	6.000	0.971	0.126	2.582
Reach 4	0.111	0.385	0.118	0.000	4.632	6.000	0.938	0.140	2.841

Unanalyzed Constituents

Each of boundary data groups and incremental inflow data groups require water quality concentration for a set of constituents including dissolved oxygen, BOD, chlorophyll-*a*, organic nitrogen, ammonia nitrogen, nitrite nitrogen, nitrate nitrogen, organic phosphorous, dissolved phosphorous, and water temperature. The above constituents are required for the model input file. However, since organic nitrogen, nitrite nitrogen, nitrate nitrogen, and organic phosphorous were not directly analyzed as part of Department's routine water quality monitoring, their concentrations were estimated according to the following relationships:

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

Input data for Naamans Creek Qual2E model calibration is presented in Appendix A.

3.0 MODEL CALIBRATION AND SCENARIO ANALYSIS

3.1 Model Calibration

Naamans Creek Qual2E model was calibrated based on average water quality conditions observed during 2000-2004 and annual-average flow condition of the same period. The input and output data for the Naamans Creek Qual2E Model calibration is presented in Appendix A.

Figure 3-1 displays the model calibration results for several water quality constituents including various forms of nutrient, dissolved oxygen, biochemical oxygen demand, phytoplankton chlorophyll-*a*, and water temperature. Model calibration results are presented as lines while observed data at four monitoring sites (101061, 101051, 101031, and 101041 from upstream to downstream) are summarized and shown as symbols representing mean, maximum, and minimum values.

The calibration results show that dissolved oxygen is calibrated reasonably well. Nitrogen and phosphorous simulations show a slight over estimation of those parameters, however the results are within acceptable range.

Model calibration condition represents the average condition of Naamans Creek during 2000 – 2004. Therefore, the calibration results also reveal that stream water quality at all modeled reaches meet dissolved oxygen standard of 5.5 mg/l and nutrient target values of 3 mg/l for total nitrogen and 0.2 mg/l for total phosphorous under average condition.

3.2 Critical Condition Analysis

The above calibrated model was used to simulate water quality condition of the Naamans Creek during critical, summer month period. Water quality data collected during the months of July, August, and September in 2000-2004 was used for this analysis. It was assumed that stream flow was at 7Q10 levels and water temperature at 24 ^{0}C. The results of this analysis are presented in Figure 3-2 which shows that, under summer, low-flow condition, water quality of Naamans Creek meet dissolved oxygen standard of 5.5 mg/l and nutrient target values of 3 mg/l for total nitrogen and of 0.2 mg/l for total phosphorous.

3.3 Sensitivity Analysis

In order to assess the Naamans Creek Qual2E Model's sensitivity to changes of various environmental parameters used in the model, a sensitivity analysis was performed. For this analysis, the Naamans Creek Qual2E Model was run while model parameters were changed one at a time at 50% rate. Then, the percentage changes of dissolved oxygen concentration, total nitrogen and total phosphorous at the last computational element of the model were projected and recorded.

The results of the sensitivity analysis showed that dissolved oxygen is most sensitive to changes in water temperature, reaeration rate, and sediment oxygen demand. A complete list of the results of the sensitivity analysis is provided in Appendix C.

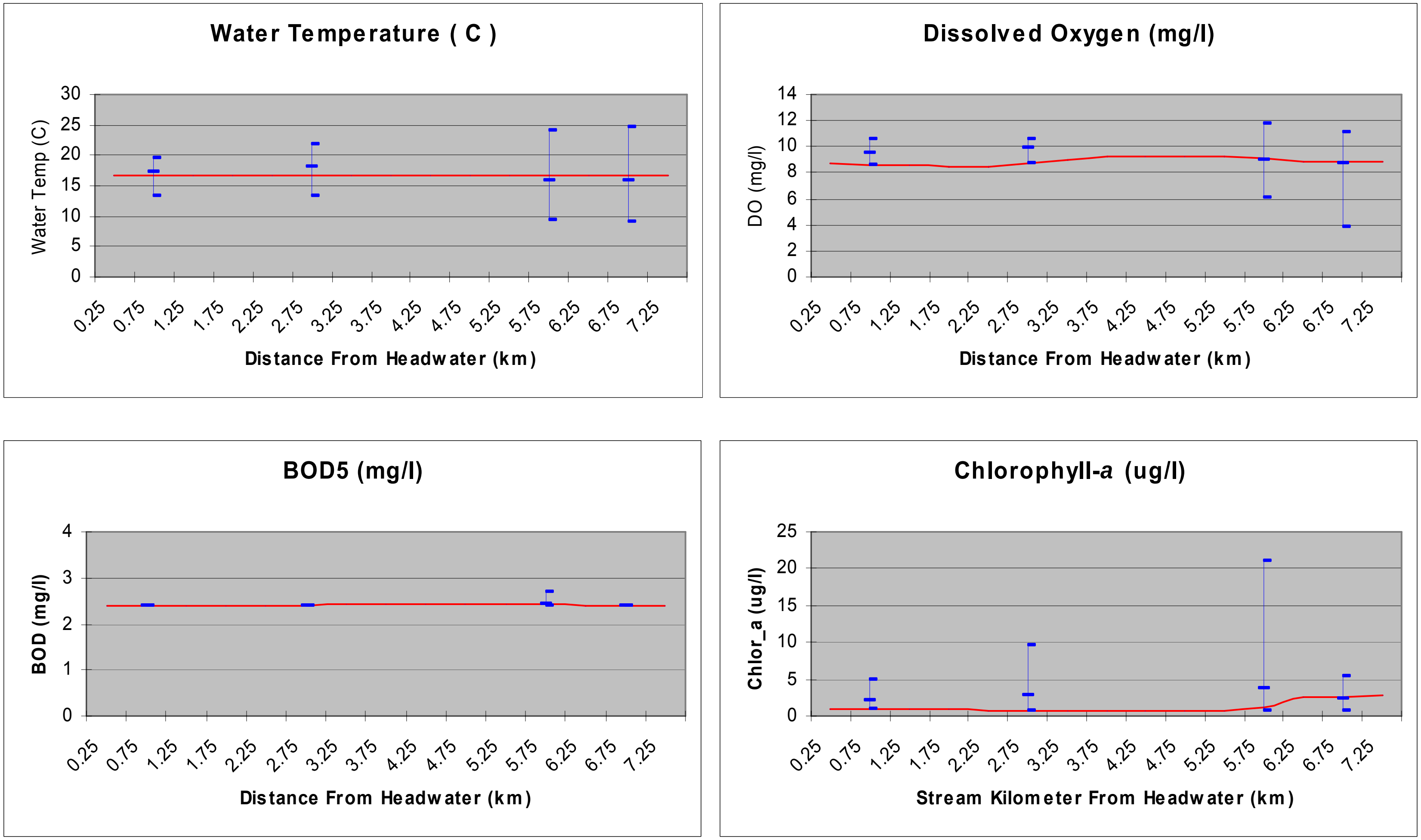

Figure 3-1 Calibration Results of the Naamans Creek Qual2E Model

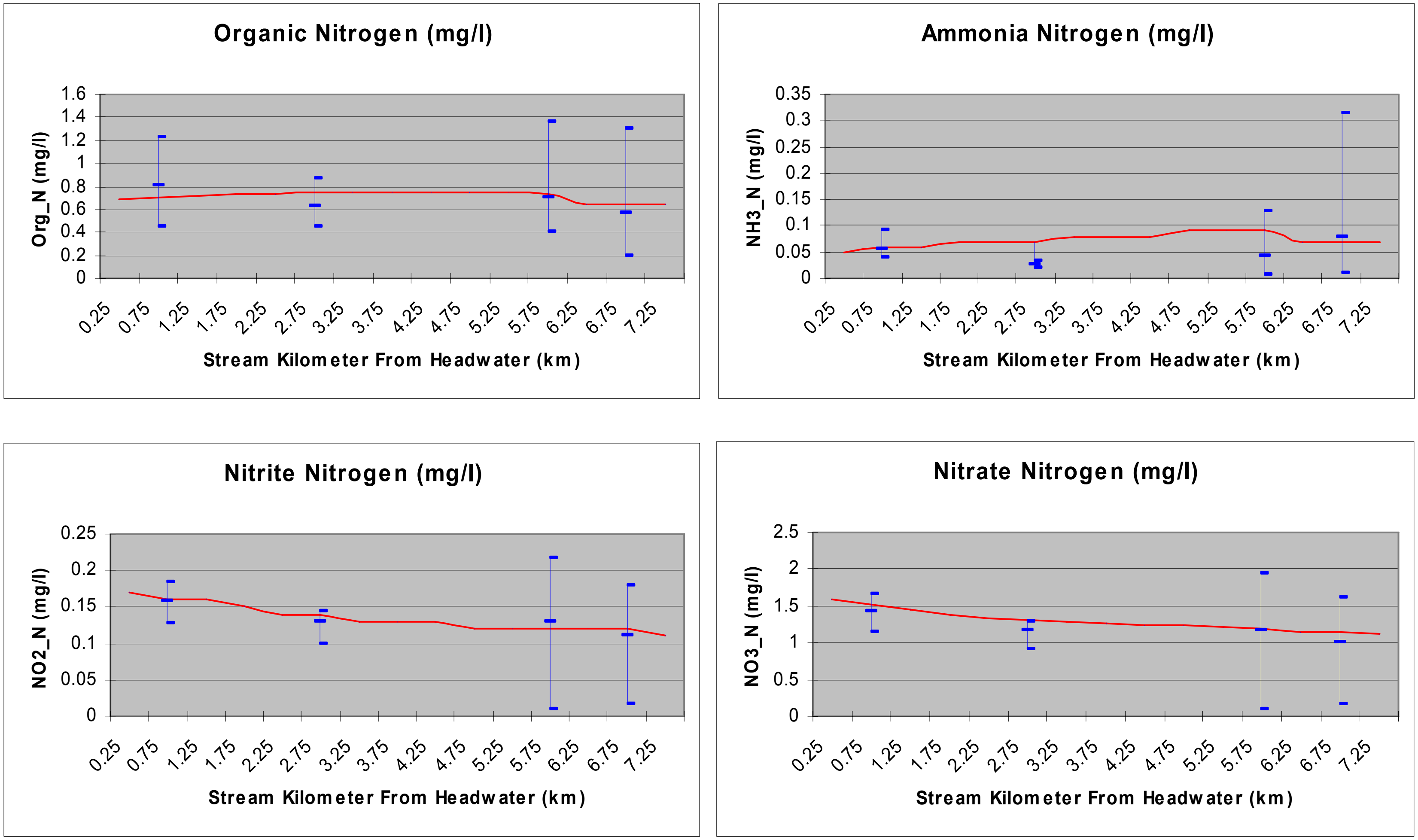

Figure 3-1 Calibration Results of the Naamans Creek Qual2E Model – Conti.

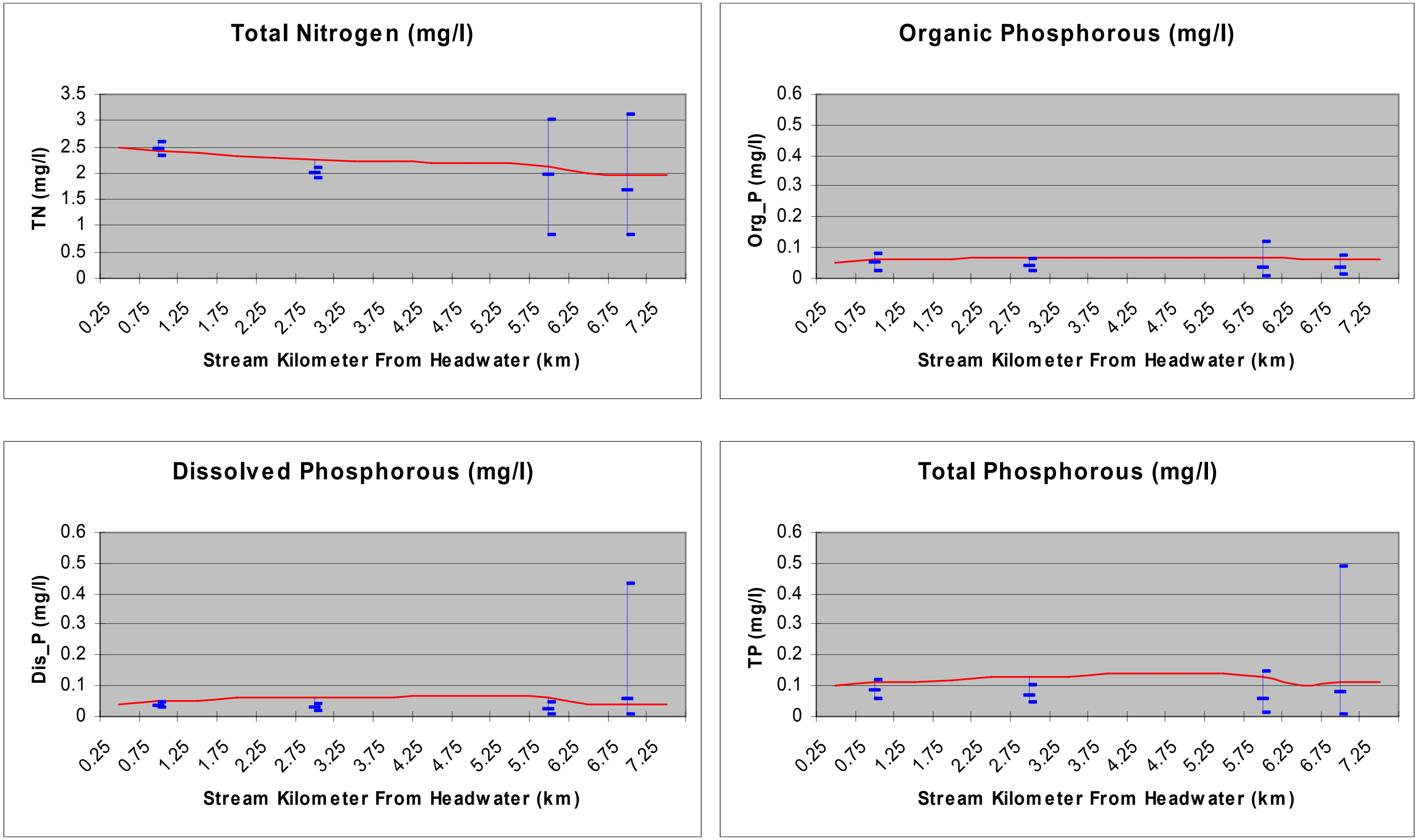

Figure 3-1 Calibration Results of the Naamans Creek Qual2E Model – Conti.

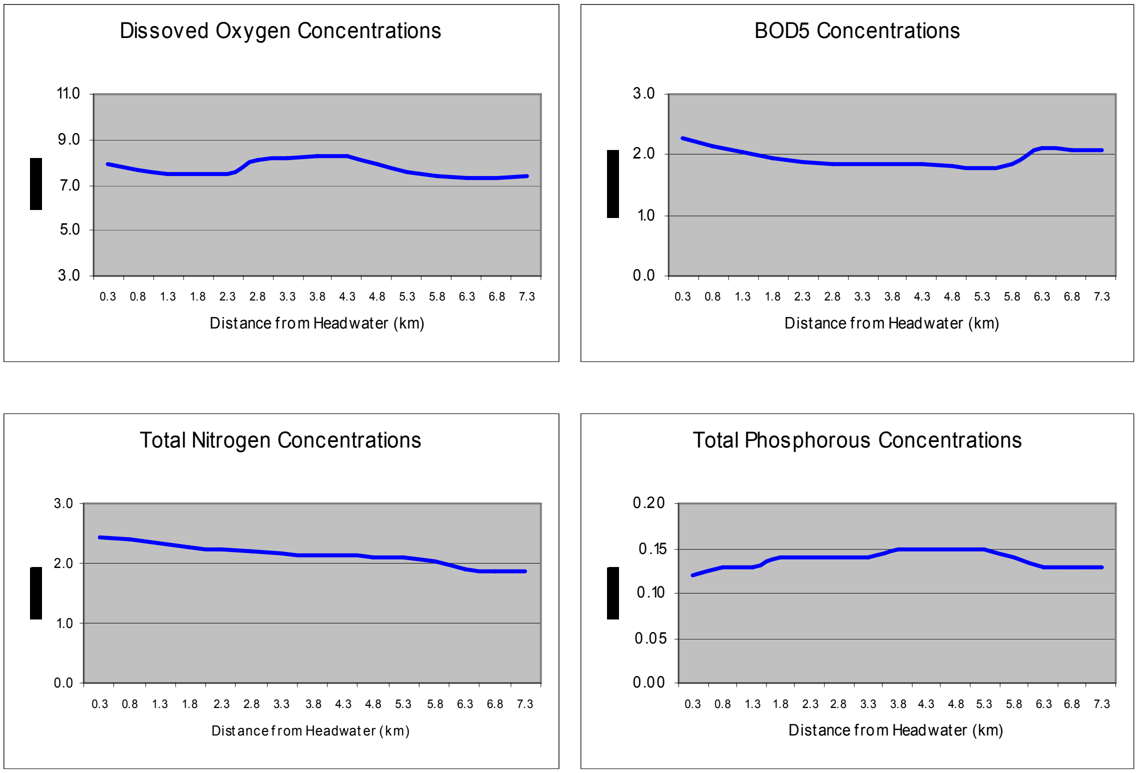

Figure 3-2 The Results of Naamans Creek Qual2E Model Considering Summer, Low-flow Conditions

4.0 ESTABLISHMENT OF THE NUTRIENT TMDL FOR THE NAAMANS CREEK

As it was stated in Chapter 1 of this report, the applicable State of Delaware water quality standard for dissolved oxygen in freshwater streams is 5.5 mg/l, and the TMDL nutrient target levels are 3.0 mg/l for total nitrogen and 0.2 mg/l for total phosphorous. The results of modeling analyses, as discussed in Chapter 3, show that under annual-average as well as during critical summer, low-flow conditions, the dissolved oxygen standard and nutrient targets are met along all simulated reaches of Naamans Creek. Therefore, it can be concluded that the current loading conditions do not exceed the assimilative capacity of the Naamans Creek. And the current loading condition is considered as the TMDL for the watershed. Table 4-1 shows nutrient loads under TMDL condition or baseline condition.

About 4100 acre of the entire Naamans Creek watershed (8600 acres) is within the State of Pennsylvania. Under TMDL scenario, the nutrient loads from Pennsylvania portion of the watershed are capped at the state lines at the amount as showed in Table 4-1. For the loads from the Delaware portion, they are capped at the level after Pennsylvania's contribution was substracted from the total, as showed in Table 4-1.

Table 4 -1 Naamans Creek Nutrient TMDL/Baseline Loads

Naamans Creek Condition	Watershed/sub-watershed	TMDL/Baseline Loads (lb/day)	
		TN	TP
Annual Average	Entire Naamans Creek (including DE & PA)	228	13
	North Branch (PA portion of the watershed)	100	4
	South Branch (DE portion of the watershed)	128	9

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 uncertainties and lack of data

As discussed in Chapter 3, the nutrient loads considered in this study are entirely generated from nonpoint sources under average and critical low flow condition. However, the entire New Castle County in Delaware is covered by Municipal Separate Storm Sewer System (MS4) permitting system. The US EPA guidelines require that nonpoint source loads for MS4 municipalities be considered as Waste Load Allocation (WLA) instead of Load Allocation (LA). Therefore, all nonpoint source nutrient loads generated from Delaware portion of the watershed are allocated to MS4 municipality (as a WLA) and zero load to nonpoint sources (as a LA), as it can be seen from Table 4-2. For this

TMDL, an implicit margin of safety has been considered through using conservative assumptions regarding reaction rates, pollutant loads, and simultaneous occurrence of critical environmental conditions (low flow and high temperature).

Table 4-2 Shellpot Creek Nutrient TMDL WLA and LA

Source		TN (lb/day)	TP (lb/day)
TMDL for Pennsylvania Portion of the watershed		100	4
TMDL for Delaware Portion of the watershed	WLA (MS4 Municipality)	128	9
	LA	0	0
TMDL		228	13

5.0 ESTABLISHMENT OF THE BACTERIA TMDL FOR THE NAAMANS CREEK

As it was stated in Chapter 1 of this report, the applicable State of Delaware water quality standard for enterococcus in a fresh water stream is a geometric mean not to 100CFU/100mL and a single sample maximum not to exceed 185 CFU/100 mL. The geometric mean at the 1st, 2nd, 3rd and 4th flow quartile are 172 CFU/100 mL, 1,030 CFU/100 mL, 216 CFU/100 mL, and 445 CFU/100 mL, respectively. An overall reduction of 78% in the bacteria loading is required for the water quality in Naamans Creek to meet the State water quality standards.

5.1 BACTERIA CONCENTRATIONS VERSUS FLOW RATES

The daily flow rates in the Shellpot Creek (from USGS station 01477800) were adjusted based on land area (Shellpot:Naamans = 1:1.79) to estimate the flow rates in the Naamans Creek and 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 average flow and bacteria concentrations in the stream for each quartile were calculated and are shown in Table 5-1 and Figure 5-1.

Table 5-1 Naamans Creek Flow Ranges vs. Bacteria Concentrations

	Shellpot flow range (ft^3/sec)	Naamans est. ave. flow rate (ft^3/sec)	Geometric mean enterococcus concentration (CFU/100mL)
1st quartile	≤ 1.6	1.69	172
2nd quartile	1.6 – 2.2	3.21	1030
3rd quartile	2.2 – 4.8	5.94	216
4th quartile	≥ 4.8	57.82	445

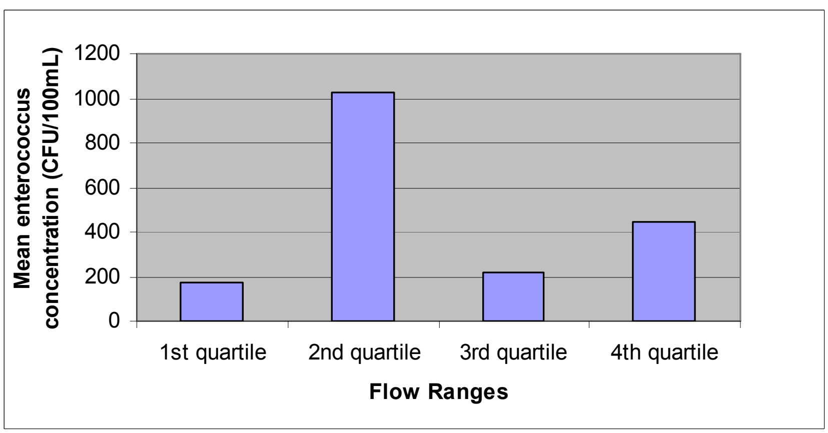

Figure 5-1 **Naamans Creek Flow Ranges vs. Bacteria Concentrations**

5.2 BACTERIA LOADING VERSUS FLOW RATES

The daily baseline load was determined by multiplying the average quartile flow by the geometric mean concentration for that quartile (Table 5-2 and Figure 5-2).

Table 5-2 Naamans Creek Flow Ranges vs. Baseline Bacteria Loadings

	Flow (L/day)	Total NPS Baseline Load (CFU/day)
1st quartile	4,126,252	7.1E+09
2nd quartile	7,857,438	8.1E+10
3rd quartile	14,529,676	3.1E+10
4th quartile	141,433,888	6.3E+11

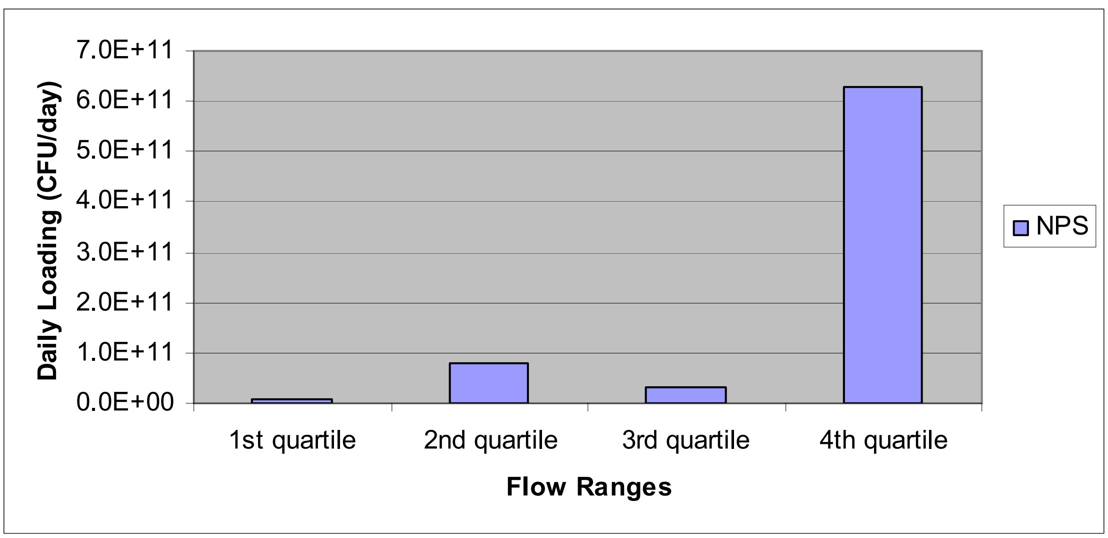

Figure 5-2 **Naamans Creek Flow Ranges vs. Baseline Bacteria Loading**

5.3 BACTERIA REDUCTIONS AND TMDL WASTE LOAD ALLOCATIONS

It is assumed that the only sources of bacteria entering the Naamans Creek 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 and a MS4 WLA is determined by reducing the NPS baseline loading by an appropriate level to ensure the State water quality standards are met. An overall reduction of 78% is required; reductions in the 1st, 2nd, 3rd and 4th flow quartile are 42%, 90%, 54%, and 78%, respectively; see Table 5-3 and Figure 5-3.

Table 5-3 Naamans Creek Baseline and TMDL Waste Load Allocations

Flow	**Total Baseline Load (CFU/day)**	**Total TMDL Load Allocations (MS4 WLA, CFU/day)**	**% Reductions**
1st quartile	7.1E+09	4.1E+09	42%
2nd quartile	8.1E+10	7.9E+09	90%
3rd quartile	3.1E+10	1.5E+10	54%
4th quartile	6.3E+11	1.4E+11	78%

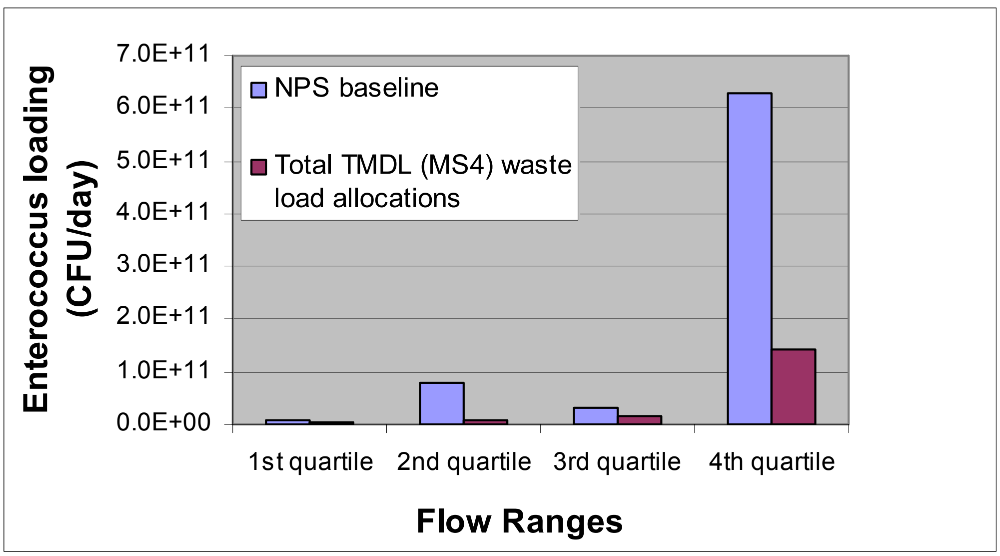

Figure 5-3 **Naamans Creek Baseline and TMDL Waste Load Allocations**

5.4 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).

6.0 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 Naamans Creek TMDL meets the above eight minimum regulatory requirements.

1. The TMDLs must be designed to achieve applicable water quality standards.
Section 1.3 describes the water quality standards for dissolved oxygen and bacteria and nutrient guidelines for total nitrogen and total phosphorous in the Naamans Creek. The dissolved oxygen criteria for fresh water stream is 5.5 mg/l; the enterococcus criteria is 100 CFU/100ml as 30 day geometric mean and 185 as single sample maximum; and the TMDL nutrient target levels are 3.0 mg/l for total nitrogen and 0.2 mg/l for total phosphorous. The results of the TMDL scenario (annual average condition) for nutrients indicate that dissolved oxygen criteria and nutrient target values were met in all segments of Naamans Creek. For bacteria, the analysis shows that 78% reduction resulted in achieving bacteria water quality standards. Therefore, it can be concluded that the proposed TMDL 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, as presented in Table 4-1 for nutrients and Table 5-3 for bacteria. The proposed TMDLs allocate entire nutrient loads generated from Delaware portion of the watershed to MS4 municipality and part of the bacteria baseline loads to MS4 according to flow ranges. Therefore, it can be concluded that the proposed TMDLs include allocations for point and nonpoint sources.

3. The TMDLs must consider the impact of background pollutants.
The Naamans Creek TMDL analysis was based on a calibrated Qual2E water quality model and/or water quality data collected in the watershed. Since background conditions are reflected in the calibrated model and the monitoring data, it can be concluded that the impact of background pollutants is accounted in this TMDL analysis.

4. The TMDLs must consider critical environmental conditions.

Low stream flow during summer months coupled with high water temperature is a critical condition for Naamans Creek and has been considered in this TMDL analysis. A modeling scenario that considered the low 7Q10 flow along with a high water temperature during summer months was run. In this scenario, the headwater condition and tributary inflow condition were defined using the data collected during the summer months (July, August, and September) in 2002-2004. Details of model inputs and results of the model run are discussed in Chapter 3, which showed that water quality standards and nutrient targets were met under existing summer loading condition. Therefore, the critical condition of Naamans Creek was considered in this analysis.

5. The TMDLs must consider seasonal variations.

Seasonal variations are considered in development of the Naamans Creek Qual2E Model. The data used to define model inputs was collected during 2000-2004 period at different months and seasons, reflecting seasonal variations. In addition, the model was run under summer low flow (7Q10 flow) condition.

The data used for the bacteria analyses was collected over approximately 6 years with data points at each season being represented. Therefore, seasonal variations were considered for this analysis.

6. The TMDLs must consider a margin of safety.

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

An implicit margin of safety has been considered for this analysis. The Naamans Creek Qual2E model was calibrated using conservative assumptions regarding reaction rates, pollutant loads, and simultaneous occurrence of critical environmental conditions (low flow and high temperature). Consideration of these conservative assumptions contributed to an implicit margin of safety.

An explicit margin of safety is incorporated in the Source Tracking Adjustment Factor (STAF), a tool that will be used in the implementation and BMP design following adoption of the TMDL, therefore an adequate margin of safety is included in the bacteria TMDL (waste) load allocations.

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

The Proposed Naamans Creek TMDLs were presented during a public workshop on June 15, 2005. A public hearing was also held on September 7, 2005. Notices advertising the public workshop and hearing were published in two local and regional newspapers. In addition, notice of the public hearing and proposed regulations were published in the August 1, 2005 issue of the Delaware Register of Regulations (Volume 9, Issue 2).

Considering this, it can be concluded that the Naamans Creek TMDLs have been subject to significant public participation.

8. There should be a reasonable assurance that the TMDLs can be met.

The Naamans Creek TMDL considers reduction of nutrients and bacteria loads from point and nonpoint sources. As the result of these reductions, water quality standards with regard to dissolved oxygen and enterococcus bacteria will be met in all segments of the Naamans Creek.

Following adoption of the Naamans Creek TMDL, the DNREC, in association with local citizen groups and other affected parties, will develop a Pollution Control Strategy to implement the requirements of the proposed Naamans Creek TMDL Regulation. Therefore, it can be concluded that there is a reasonable assurance that the Naamans Creek TMDLs will be met.

REFERENCES

1. “State of Delaware 1998 Watershed Assessment Report (305(b))”, Department of Natural Resources and Environmental Control, April 1, 1998.

2. “State of Delaware 2002 Watershed Assessment Report (305(b))”, Department of Natural Resources and Environmental Control, April 1, 2002.

3. “Revised Final Determination for the State of Delaware 2002 Clean Water Act Section 303(d) List of Waters Needing TMDLs”, Department of Natural Resources and Environmental Control, December 19, 2003.

4. “State of Delaware Surface Water Quality Standards, as amended July 11, 2004,” Department of Natural Resources and Environmental Control, Division of Water Resources.

5. “State of Delaware Surface Water Quality Monitoring Program FY2000", Department of Natural Resources and Environmental Control, May 3, 1999.

6. “Linfield C. Brown and Thomas O. Barnwell, Jr., The Enhanced Stream Water Quality Models Qual2E and Qual2E-UNCAS: Documentation and User Manual, EPA/600/3-87/007, May 1987, Environmental Research laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Athens, Georgia, 30613.

7. “Water Resource Data, Maryland, Delaware, and Washington, D.C., Water Year 2002, Volume 1. Surface-Water Data”, U.S. Geological Survey.

8. “A model for the Murderkill River Watershed”, HydroQual Inc., February 2001

9. “Tidegate Study for New Castle County, Delaware” New Castle Conservation District, December 1986.

Appendix A – Input and Output Data for Naamans Creek Qual2E Model Calibration

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

 $$$ (PROBLEM TITLES) $$$

CARD TYPE                             QUAL-2E PROGRAM TITLES
TITLE01               Na035, based on Na034
TITLE02               decrease org-P settling rate from 2 to 0
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   =      2.00000
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) =    39.50000            LONGITUDE OF BASIN (DEG)=     75.30000
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) = 100.00000              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)=    3.4300              O UPTAKE BY NO2 OXID(MG O/MG N)=    1.1000
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) =    0.0140
ALG MAX SPEC GROWTH RATE(1/DAY)=    3.0000              ALGAE RESPIRATION RATE (1/DAY) =    0.0500
N HALF SATURATION CONST. (MG/L)=    0.0500              P HALF SATURATION CONST. (MG/L)=    0.0010
LIN ALG SHADE CO (1/M-UGCHA/L) =    0.0008              NLIN SHADE (1/M-(UGCHA/L)**2/3)=    0.0000
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        1.080     USER
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         7.5    TO           5.0
STREAM REACH     2.0  RCH= Segment 2        FROM         5.0    TO           3.0
STREAM REACH     3.0  RCH= Segment 3        FROM         3.0    TO           1.5
```

STREAM REACH	4.0	RCH= Segment 4	FROM	1.5	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.	1.2.2.2.2.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	2.	4.	2.2.2.2.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	3.	3.	2.2.6.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	4.	3.	6.2.5.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
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	2.133	0.816	0.384	0.184	0.040
HYDRAULICS	2.	100.00	0.828	0.453	0.094	0.371	0.040
HYDRAULICS	3.	100.00	0.405	0.306	0.516	0.510	0.040
HYDRAULICS	4.	100.00	0.452	0.363	0.360	0.500	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.	30.48	0.10	0.10	25.00	20.00	980.00	2.50	1.00
TEMP/LCD	2.	30.48	0.10	0.10	25.00	20.00	980.00	2.50	1.00
TEMP/LCD	3.	30.48	0.10	0.10	25.00	20.00	980.00	2.50	1.00
TEMP/LCD	4.	30.48	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	0.500	5.	0.00	0.000	0.00000
REACT COEF	4.	0.20	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.	0.30	0.00	0.30	0.00	1.00	0.50	0.00	0.00
N AND P COEF	2.	0.30	0.00	0.30	0.00	1.00	0.50	0.00	0.00
N AND P COEF	3.	0.30	0.00	0.30	0.00	1.00	0.50	0.00	0.00
N AND P COEF	4.	0.30	0.00	0.30	0.00	1.00	0.50	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.	50.00	0.00	0.00	0.00	0.00	0.00	0.00
ALG/OTHER COEF	2.	50.00	0.00	0.00	0.00	0.00	0.00	0.00
ALG/OTHER COEF	3.	50.00	0.00	0.00	0.00	0.00	0.00	0.00
ALG/OTHER COEF	4.	50.00	0.00	0.00	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.	16.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-1	2.	16.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-1	3.	16.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-1	4.	16.82	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
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.	0.056	16.82	5.90	2.48	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	2.	0.025	16.82	5.90	3.02	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	3.	0.012	16.82	5.90	2.58	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	4.	0.023	16.82	6.00	2.84	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	0.98	0.11	0.04	0.38	0.12	0.12
INCR INFLOW-2	2.	0.00	0.92	0.11	0.04	0.39	0.15	0.12
INCR INFLOW-2	3.	0.00	0.97	0.11	0.04	0.38	0.13	0.12
INCR INFLOW-2	4.	0.00	0.94	0.11	0.04	0.38	0.14	0.12
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.	Naamans Headwtr	0.16	18.15	8.76	2.40	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	1.00	0.67	0.05	0.19	1.66	0.05	0.04
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.	Reach3 Trib	0.00	0.04	15.48	8.66	2.40	0.00	0.00	0.00
POINTLD-1	2.	North Br R4	0.00	0.29	15.48	8.66	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	4.04	0.55	0.05	0.12	1.12	0.05	0.02
POINTLD-2	2.	0.00	0.00E+00	4.04	0.55	0.05	0.12	1.12	0.05	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
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	15
ALGAE GROWTH RATE	2	15
ALGAE GROWTH RATE	3	15
ALGAE GROWTH RATE	4	15
ALGAE GROWTH RATE	5	15
ALGAE GROWTH RATE	6	15
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	8.66	8.59	8.53	8.49	8.47															
2	8.73	9.04	9.21	9.29																
3	9.30	9.22	9.09																	
4	8.86	8.86	8.85																	

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	2.40	2.40	2.40	2.40	2.40															
2	2.41	2.43	2.44	2.44																
3	2.44	2.43	2.42																	
4	2.41	2.41	2.41																	

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	0.69	0.71	0.72	0.73	0.74															
2	0.75	0.75	0.75	0.75																
3	0.75	0.75	0.73																	
4	0.64	0.64	0.64																	

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	0.05	0.06	0.06	0.07	0.07															
2	0.07	0.08	0.08	0.08																
3	0.09	0.09	0.09																	
4	0.07	0.07	0.07																	

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	0.17	0.16	0.16	0.15	0.14															
2	0.14	0.13	0.13	0.13																
3	0.12	0.12	0.12																	
4	0.12	0.12	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	1.58	1.51	1.44	1.39	1.33															
2	1.31	1.29	1.26	1.24																
3	1.23	1.22	1.20																	
4	1.15	1.14	1.13																	

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	0.05	0.06	0.06	0.06	0.07															
2	0.07	0.07	0.07	0.07																
3	0.07	0.07	0.07																	
4	0.06	0.06	0.06																	

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	0.04	0.05	0.05	0.06	0.06															
2	0.06	0.06	0.06	0.07																
3	0.07	0.07	0.06																	
4	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	0.95	0.90	0.86	0.83	0.79															
2	0.78	0.78	0.77	0.76																
3	0.77	0.78	1.25																	
4	2.65	2.67	2.70																	

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	1.39	1.39	1.39	1.39	1.38															
2	1.39	1.38	1.38	1.38																
3	1.38	1.38	1.38																	
4	1.38	1.38	1.38																	

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	25.77	25.74	25.70	25.67	25.64															
2	25.65	25.61	25.60	25.59																
3	25.59	25.58	25.56																	
4	25.51	25.51	25.50																	

***** 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
1	1	1	7.50	7.00	0.17	0.00	0.01	0.505	0.011	0.278	1.219	0.17	0.89	0.34	2.18
2	1	2	7.00	6.50	0.18	0.00	0.01	0.532	0.011	0.281	1.219	0.17	0.89	0.34	2.32
3	1	3	6.50	6.00	0.19	0.00	0.01	0.559	0.010	0.284	1.219	0.17	0.89	0.35	2.45
4	1	4	6.00	5.50	0.20	0.00	0.01	0.585	0.010	0.287	1.219	0.18	0.90	0.35	2.59
5	1	5	5.50	5.00	0.22	0.00	0.01	0.611	0.009	0.290	1.219	0.18	0.90	0.35	2.73
6	2	1	5.00	4.50	0.22	0.00	0.01	0.419	0.014	0.054	9.877	0.27	4.99	0.53	0.46
7	2	2	4.50	4.00	0.23	0.00	0.01	0.424	0.014	0.054	9.925	0.27	5.02	0.54	0.47
8	2	3	4.00	3.50	0.23	0.00	0.01	0.430	0.013	0.055	9.972	0.27	5.04	0.55	0.48
9	2	4	3.50	3.00	0.24	0.00	0.01	0.435	0.013	0.055	10.018	0.28	5.07	0.55	0.49
10	3	1	3.00	2.50	0.24	0.00	0.00	0.264	0.022	0.251	3.694	0.46	2.10	0.93	1.05
11	3	2	2.50	2.00	0.25	0.00	0.00	0.265	0.022	0.254	3.705	0.47	2.11	0.94	1.06
12	3	3	2.00	1.50	0.29	0.04	0.00	0.278	0.021	0.275	3.815	0.52	2.18	1.05	1.19
13	4	1	1.50	1.00	0.59	0.29	0.01	0.374	0.015	0.278	5.725	0.79	3.14	1.59	1.61
14	4	2	1.00	0.50	0.60	0.00	0.01	0.375	0.015	0.279	5.735	0.80	3.15	1.60	1.63
15	4	3	0.50	0.00	0.61	0.00	0.01	0.377	0.015	0.281	5.745	0.81	3.15	1.61	1.64

***** 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	10.08	0.17	0.00	0.00	0.23	0.00	0.23	0.00	0.86	0.43	0.00	0.00	0.00	0.00	0.00	0.00
1	2	9.50	5	10.32	0.17	0.00	0.00	0.23	0.00	0.23	0.00	0.86	0.43	0.00	0.00	0.00	0.00	0.00	0.00
1	3	9.50	5	10.80	0.17	0.00	0.00	0.23	0.00	0.23	0.00	0.86	0.43	0.00	0.00	0.00	0.00	0.00	0.00
1	4	9.50	5	11.27	0.17	0.00	0.00	0.23	0.00	0.23	0.00	0.86	0.43	0.00	0.00	0.00	0.00	0.00	0.00
1	5	9.50	5	11.73	0.17	0.00	0.00	0.23	0.00	0.23	0.00	0.86	0.43	0.00	0.00	0.00	0.00	0.00	0.00
2	1	9.50	5	38.24	0.17	0.00	0.00	0.23	0.00	0.23	0.00	0.86	0.43	0.00	0.00	0.00	0.00	0.00	0.00
2	2	9.50	5	64.59	0.17	0.00	0.00	0.23	0.00	0.23	0.00	0.86	0.43	0.00	0.00	0.00	0.00	0.00	0.00
2	3	9.50	5	64.72	0.17	0.00	0.00	0.23	0.00	0.23	0.00	0.86	0.43	0.00	0.00	0.00	0.00	0.00	0.00
2	4	9.50	5	64.86	0.17	0.00	0.00	0.23	0.00	0.23	0.00	0.86	0.43	0.00	0.00	0.00	0.00	0.00	0.00
3	1	9.50	5	35.15	0.17	0.00	0.42	0.23	0.00	0.23	0.00	0.86	0.43	0.00	0.00	0.00	0.00	0.00	0.00
3	2	9.50	5	5.35	0.17	0.00	0.42	0.23	0.00	0.23	0.00	0.86	0.43	0.00	0.00	0.00	0.00	0.00	0.00
3	3	9.50	5	5.22	0.17	0.00	0.42	0.23	0.00	0.23	0.00	0.86	0.43	0.00	0.00	0.00	0.00	0.00	0.00
4	1	9.50	5	6.10	0.17	0.00	0.42	0.23	0.00	0.23	0.00	0.86	0.43	0.00	0.00	0.00	0.00	0.00	0.00
4	2	9.50	5	7.08	0.17	0.00	0.42	0.23	0.00	0.23	0.00	0.86	0.43	0.00	0.00	0.00	0.00	0.00	0.00
4	3	9.50	5	7.06	0.17	0.00	0.42	0.23	0.00	0.23	0.00	0.86	0.43	0.00	0.00	0.00	0.00	0.00	0.00

STREAM QUALITY SIMULATION
OUTPUT PAGE NUMBER 3

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 COLI MG/L #/100ML	ANC	CHLA UG/L
1	1	16.82	0.00	0.00	0.00	8.66	2.40	0.69	0.05	0.17	1.58	2.49	0.05	0.04	0.10.00E+00	0.00	0.95
1	2	16.82	0.00	0.00	0.00	8.59	2.40	0.71	0.06	0.16	1.51	2.43	0.06	0.05	0.11.00E+00	0.00	0.90
1	3	16.82	0.00	0.00	0.00	8.53	2.40	0.72	0.06	0.16	1.44	2.38	0.06	0.05	0.11.00E+00	0.00	0.86
1	4	16.82	0.00	0.00	0.00	8.49	2.40	0.73	0.07	0.15	1.39	2.33	0.06	0.06	0.12.00E+00	0.00	0.83
1	5	16.82	0.00	0.00	0.00	8.47	2.40	0.74	0.07	0.14	1.33	2.29	0.07	0.06	0.13.00E+00	0.00	0.79
2	1	16.82	0.00	0.00	0.00	8.73	2.41	0.75	0.07	0.14	1.31	2.27	0.07	0.06	0.13.00E+00	0.00	0.78
2	2	16.82	0.00	0.00	0.00	9.04	2.43	0.75	0.08	0.13	1.29	2.24	0.07	0.06	0.13.00E+00	0.00	0.78
2	3	16.82	0.00	0.00	0.00	9.21	2.44	0.75	0.08	0.13	1.26	2.22	0.07	0.06	0.14.00E+00	0.00	0.77
2	4	16.82	0.00	0.00	0.00	9.29	2.44	0.75	0.08	0.13	1.24	2.20	0.07	0.07	0.14.00E+00	0.00	0.76
3	1	16.82	0.00	0.00	0.00	9.30	2.44	0.75	0.09	0.12	1.23	2.19	0.07	0.07	0.14.00E+00	0.00	0.77
3	2	16.82	0.00	0.00	0.00	9.22	2.43	0.75	0.09	0.12	1.22	2.18	0.07	0.07	0.14.00E+00	0.00	0.78
3	3	16.82	0.00	0.00	0.00	9.09	2.42	0.73	0.09	0.12	1.20	2.13	0.07	0.06	0.13.00E+00	0.00	1.25
4	1	16.82	0.00	0.00	0.00	8.86	2.41	0.64	0.07	0.12	1.15	1.98	0.06	0.04	0.10.00E+00	0.00	2.65
4	2	16.82	0.00	0.00	0.00	8.86	2.41	0.64	0.07	0.12	1.14	1.97	0.06	0.04	0.11.00E+00	0.00	2.67
4	3	16.82	0.00	0.00	0.00	8.85	2.41	0.64	0.07	0.11	1.13	1.97	0.06	0.04	0.11.00E+00	0.00	2.70

***** 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	0.95	1.39	0.04	0.00	25.77	0.04	0.90	0.23	0.00	0.55	0.97	0.98
2	1	2	0.90	1.39	0.04	0.00	25.74	0.04	0.90	0.26	0.00	0.55	0.97	0.98
3	1	3	0.86	1.39	0.04	0.00	25.70	0.04	0.90	0.28	0.00	0.55	0.97	0.98
4	1	4	0.83	1.39	0.04	0.00	25.67	0.04	0.90	0.30	0.00	0.55	0.97	0.98
5	1	5	0.79	1.38	0.04	0.00	25.64	0.03	0.90	0.32	0.00	0.55	0.97	0.98
6	2	1	0.78	1.39	0.04	0.00	25.65	0.03	0.90	0.34	0.00	0.55	0.97	0.98
7	2	2	0.78	1.38	0.04	0.00	25.61	0.03	0.90	0.35	0.00	0.55	0.96	0.98
8	2	3	0.77	1.38	0.04	0.00	25.60	0.03	0.90	0.36	0.00	0.55	0.96	0.98
9	2	4	0.76	1.38	0.04	0.00	25.59	0.03	0.90	0.37	0.00	0.55	0.96	0.99
10	3	1	0.77	1.38	0.04	0.00	25.59	0.03	0.90	0.39	0.00	0.55	0.96	0.99
11	3	2	0.78	1.38	0.04	0.00	25.58	0.03	0.90	0.40	0.00	0.55	0.96	0.99
12	3	3	1.25	1.38	0.04	0.00	25.56	0.05	0.90	0.40	0.00	0.55	0.96	0.98
13	4	1	2.65	1.38	0.04	0.00	25.51	0.11	0.90	0.35	0.00	0.55	0.96	0.98
14	4	2	2.67	1.38	0.04	0.00	25.51	0.11	0.90	0.36	0.00	0.55	0.96	0.98
15	4	3	2.70	1.38	0.04	0.00	25.50	0.11	0.90	0.37	0.00	0.55	0.96	0.98

***** 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	16.82	9.50	8.66	0.84	0.00	1.00	748.55	8.50	-0.41	0.00	0.04	-0.04	-0.17
2	1	2	16.82	9.50	8.59	0.92	0.00	1.00	33.31	9.47	-0.41	0.00	0.04	-0.05	-0.16
3	1	3	16.82	9.50	8.53	0.97	0.00	1.00	32.95	10.50	-0.41	0.00	0.04	-0.05	-0.15
4	1	4	16.82	9.50	8.49	1.01	0.00	1.00	32.61	11.40	-0.41	0.00	0.04	-0.05	-0.14
5	1	5	16.82	9.50	8.47	1.04	0.00	1.00	32.29	12.15	-0.42	0.00	0.03	-0.06	-0.13
6	2	1	16.82	9.50	8.73	0.78	0.00	1.00	12.01	29.73	-0.42	0.00	0.03	-0.06	-0.13
7	2	2	16.82	9.50	9.04	0.46	0.00	1.00	11.83	29.82	-0.42	0.00	0.03	-0.06	-0.13
8	2	3	16.82	9.50	9.21	0.30	0.00	1.00	11.66	19.29	-0.42	0.00	0.03	-0.06	-0.12
9	2	4	16.82	9.50	9.29	0.21	0.00	1.00	11.49	13.76	-0.42	0.00	0.03	-0.07	-0.12
10	3	1	16.82	9.50	9.30	0.20	0.00	1.00	4.39	7.02	-0.42	-1.65	0.03	-0.07	-0.12
11	3	2	16.82	9.50	9.22	0.28	0.00	1.00	4.34	1.50	-0.42	-1.64	0.03	-0.07	-0.11
12	3	3	16.82	9.50	9.09	0.41	0.00	1.00	59.50	2.14	-0.42	-1.51	0.05	-0.07	-0.11
13	4	1	16.82	9.50	8.86	0.65	0.00	1.00	281.84	3.94	-0.42	-1.50	0.11	-0.06	-0.11
14	4	2	16.82	9.50	8.86	0.65	0.00	1.00	4.96	4.59	-0.42	-1.49	0.11	-0.06	-0.11
15	4	3	16.82	9.50	8.85	0.65	0.00	1.00	4.92	4.58	-0.42	-1.48	0.11	-0.06	-0.11

```
                            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   7.5 +++.+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++*+++++++++++
        +  .    +       +       +       +       +       +       +       +   *   +       +
I       +  .    +       +       +       +       +       +       +       +   *   +       +
        +  .    +       +       +       +       +       +       +       +  *    +       +
V       +  .                                                               *            +
        +  .                                                                 *          +
E       +  .                                                                    *       +
        +  .                                                                     *      +
R       +  .                                                                      *     +
        +  .                                                                      *     +
    2.5 +++.+                                                                    *  +++++
        +  .    +       +       +       +       +       +       +       +       *       +
K       +  .    +       +       +       +       +       +       +       +     * +       +
        +  .    +       +       +       +       +       +       +       +     * +       +
I   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 = ...

Appendix B: Naamans Creek Water Quality Monitoring Data

101021 Naamans STORET No. 101021 (Naamans Creek at Naamans Rd)

Date Month/Day/Year	Water TempC 00010	Air TempC 00020	pH 00400	Flow CFS 00061	Salinity ppt 00096	Secchi IN 00077	SpecC uS/cm field 00094	DO Field 00299	DO MG/L 00300	CBOD5 MG/L 80082	CBOD20 MG/L 80087	THard MG/L 00900	TOC MG/L 00680	DOC MG/L 00681
4 / 25 / 2000	11.9	12	7.5		0.2		315.3	9.46	10.38	2.4	2.4	107	5	4
5 / 23 / 2000	13.9	18	8	6.63	0.1		301.5	9.32	8.96	2.4	2.4	98	4	3
8 / 15 / 2000	18.9	21	7.6	5.9	0.1		235.2	8.39	7.77	2.4	2.58	77	7	5
10 / 10 / 2000	9.2	11	7.9	NA	0.2		3491	12.17	10.06	2.4	2.47	143	3	2
4 / 16 / 2001	11.1	10	6.4	2.88	0.1		275.1	10.14	11.12	2.4	2.4	80	6	5
6 / 11 / 2001	17.7	30	6.5	FQ	0.1		194.6	7.02	6.49	2.4	3.97	74	4	4
8 / 7 / 2001	23.9	33	7.3	NA	0.2		414.8	6.32	6.24	2.4	2.4	141	4	3
10 / 31 / 2001	8.5	13	IF	0.89	0.2		376	10.19	8.23	2.4	2.4	138	5	3
4 / 24 / 2002	9.29	8	7.3	1.15	0.16	NC	323	10.25	7.21	2.4	2.4	118	4	3
6 / 17 / 2002	17.42	20	6.8	0.79	0.1		303	7.6	5.8	2.4	2.4	113	4.6	3.8
8 / 7 / 2002	21.12	22	7.6	0.34	0.2		401	7	5.8	2.4	2.6	138	3.6	3.2
11 / 13 / 2002	11.22	6	7.1	2.7	0.4		884	3.1	3.1	2.4	2.78	323	7.2	6.7
4 / 22 / 2003	12.86	13	7.6	IM	0.2		331	11.3		2.4	2.4	120	E 2.2	E 3.0
6 / 10 / 2003	16.38	16	7.2	IM	0.2		398	9.4		2.4	2.53	119	6.5	6.2
8 / 27 / 2003	21.29	26	7.9	IM	0.2		342	7.5		2.4	2.63	111	E 3.5	E 4.3
11 / 5 / 2003	15.32	16	6.9	IM	0.1		277	5.8		2.77	4.1	91.9	6.8	6.5
4 / 27 / 2004	12.76	18	7.41	STD	0.1		220	10.24		< 2.40	< 2.40	71.3	E 5.5	E 5.7
5 / 18 / 2004	20.99	30	7.36	7.1	0.17		347	9.59		< 2.40	3.08	118	J 2.8	J 2.6
6 / 7 / 2004	16.29	30	7.52	7.43	0.15		312	9.85		< 2.40	< 2.40	115	17.2	J 2.3
7 / 19 / 2004	19.59	26	6.9	29.4	0.12		259	8.58		< 2.40	< 2.40	87.8	5.2	4.9

Date Month/Day/Year	Alkal MG/L 00410	TKjel MG/L 00625	AmoN MG/L 00610	Chloride MG/L 00940	NOXN MG/L 00630	TotalN MG/L ****	DOrthP MG/L 00671	TPhos MG/L 00665	TSS MG/L 00530	Chlor-a UG/L 32211	Pheo-a UG/L 32218	Turb FTU 00076	SpecC uS/cm lab 00095	Enterco #/100ml 31639
4 / 25 / 2000	57	NV#	0.026	38	1.32	1.32	0.005	0.032	4	1	4	1		70
5 / 23 / 2000	58	0.295	0.09	37	1.33	1.625	0.016	0.021	2	3	2	5		530
8 / 15 / 2000	52	* 0.675	0.068	36	0.885	0.885	0.022	0.071	8	1	6	13		1700
10 / 10 / 2000	67	0.279	0.018	45	1.59	1.869	0.012	0.016	1	5.34	2	2		87
4 / 16 / 2001	50	0.509	0.041	39	1.01	1.519	0.007	0.036	4	5	8	6		520
6 / 11 / 2001	53	1.15	0.114	33	1.53	2.68	0.026	0.086	19	1	6	9		143
8 / 7 / 2001	73	1.23	0.058	52	0.958	2.188	0.017	0.067	3	1	7	3		967
10 / 31 / 2001	85	0.324	0.016	50	0.63	0.954	0.005	0.044	24	1	4	5		87
4 / 24 / 2002	64	0.296	0.042	46	0.842	1.138	0.005	0.045	2	2	2	2		90
6 / 17 / 2002	63.1	0.395	0.035	40	1.02	1.415	0.026	0.075	5	1	2	5		147
8 / 7 / 2002	86.9	1.03	0.044	59	0.317	1.347	0.018	0.292	135	25	14	2		380
11 / 13 / 2002	234	0.44	J 0.015	98	0.103	0.543	J 0.010	0.077	4	1	2	6		1230
4 / 22 / 2003	58.5	0.322	J 0.017	52	1.11	1.432	J 0.009	0.097	4	2	2	1		60
6 / 10 / 2003	59.4	0.97	0.028	63	4.38	5.35	0.03	0.081	16	J 0.9	2	2		400
8 / 27 / 2003	65.7	0.365	0.021	46	1.61	1.975	0.015	0.054	2	J 2.2	2	5		2000
11 / 5 / 2003	65.3	0.709	J 0.012	38	0.833	1.542	0.014	0.08	29	20.2	2	7		833
4 / 27 / 2004	45.4	0.759	0.157	28	0.985	1.744	J 0.008	0.075	11	J 4.5	< 3.0	20		933
5 / 18 / 2004	64.6	0.742	0.055	45	1.57	2.312	0.012	0.042	11	J 1.2	< 2.0	2		370
6 / 7 / 2004	55.1	0.248	0.026	46	1.84	2.088	0.019	J 0.023	J 2	J 0.6	< 2.0	4		267
7 / 19 / 2004	51.7	0.685	0.063	31	1.07	1.755	0.017	JH 0.061	14	J 1.8	< 2.0	14		> 2000

101031 Naamans STORET No. 101031 (Naamans Creek South Branch)

Date Month/Day/Year		Water TempC 00010	Air TempC 00020	pH 00400	Flow CFS 00061	Salinity ppt 00096	Secchi IN 00077	SpecC uS/cm field 00094	DO Field 00299	DO MG/L 00300	CBOD5 MG/L 80082	CBOD20 MG/L 80087	THard MG/L 00900	TOC MG/L 00680	DOC MG/L 00681
4 / 25 / 2000		10.7	14	7.4		0.1		304.8	9.27	9.94	2.4	2.4	82	7	5
5 / 23 / 2000		13.8	18	7.4	FQ	0.1		226.2	7.67	7.02	2.4	2.69	61	8	6
8 / 15 / 2000		19.3	21	7.2	FQ	0.1		252	6.11	5.29	2.4	3.23	73	9	7
10 / 10 / 2000		9.4	10.5	7.4	NA	0.1		2797	11.68	10.85	2.4	2.4	90	3	3
4 / 16 / 2001		10.7	10	6.3	12.48	0.1		270.3	10.71	11.13	2.4	2.87	68	8	8
6 / 11 / 2001		17.9	30	7.1	2.48	0.2		360.2	8.36	7.82	2.4	2.84	123	7	3
8 / 7 / 2001		24.1	33	7.8	NA	0.2		312.6	7.85	7.68	2.4	2.4	103	18	2
4 / 24 / 2002		10	8	7.4	0.5	0.11	NC	231	11.73	8.33	2.4	3.11	88	6	5
6 / 17 / 2002		18.15	20	7.1	0.23	0.1		243	8.1	6	2.4	3.2	84.5	7.2	6.1
6 / 17 / 2002	D	18.16	20	7.1	0.23	0.1		243	8.1	5.1	2.4	2.9	82.5	7.3	6.4
8 / 7 / 2002		19.46	22	7.4	SNF	0.2		351	6.8	6	2.4	3.3	114	5.7	4.6
8 / 7 / 2002	D	19.46	22	7.4	SNF	0.2		352	6.8	6.1	2.4	2.8	110	5.6	4.4
11 / 13 / 2002		11.21	6	7.2	SNF	0.1		250	7.7	8.8	2.4	2.44	87.8	8.8	7.6
11 / 13 / 2002	D	11.21	6	7.2	SNF	0.1		250	7.7	8.7	2.4	2.4	86.4	9.1	8.4
4 / 22 / 2003		12.89	13	7.9	IM	0.1		287	10.8		2.4	3.31	87.9	E 3.5	E 3.5
4 / 22 / 2003	D	12.9	13	7.9	IM	0.1		286	10.8		2.4	2.62	90.6	3.7	3.7
6 / 10 / 2003		16.11	19	7.5	IM	0.1		294	9.5		2.4	2.4	94	7.3	7.1
6 / 10 / 2003	D	16.11	19	7.5	IM	0.1		294	9.5		2.4	2.51	94.2	E 7.4	E 7.4
8 / 27 / 2003		22.06	26	7.7	IM	0.1		303	8.4		2.71	4.2	93.3	E 3.5	E 3.7
8 / 27 / 2003	D	22.07	26	7.7	IM	0.1		303	8.4		2.4	3.62	91.8	3.9	3.4
11 / 5 / 2003		15.55	17	6.8	IM	0.1		284	9.4		2.4	2.65	95.1	7.4	7.4
11 / 5 / 2003	D	15.55	17	6.8	IM	0.1		284	9.4		2.4	2.86	94.4	7.6	7.2
4 / 27 / 2004		14.26	19	7.55	STD	0.1		211	10.11		< 2.40	4.34	59.7	10.1	9.8
4 / 27 / 2004	D	14.03	19	7.55	STD	0.1		212	10.21		< 2.40	2.93	61.1	E 10	E 10.1
5 / 18 / 2004		20.1	28	7.58	2.71	0.17		359	8.88		< 2.40	2.86	108	3.5	3.5
6 / 7 / 2004		16.65	19	7.68	4.75	0.13		268	9.62		< 2.40	< 2.40	81.8	17.2	4.2
7 / 19 / 2004		20.09	25	6.88	9.22	0.11		226	8.61		< 2.40	< 2.40	68.8	E 7.7	E 7.9

Date Month/Day/Year		Alkal MG/L 00410	TKjel MG/L 00625	AmoN MG/L 00610	Chloride MG/L 00940	NOXN MG/L 00630	TotalN MG/L ****	DOrthP MG/L 00671	TPhos MG/L 00665	TSS MG/L 00530	Chlor-a UG/L 32211	Pheo-a UG/L 32218	Turb FTU 00076	SpecC uS/cm lab 00095	Enterco #/100ml 31639
4 / 25 / 2000		49	NV#	0.059	51	1.68	1.68	0.005	0.034	15	1	4	7		600
5 / 23 / 2000		51	0.758	0.127	28	1.43	2.188	0.029	0.049	5	1	4	7		600
8 / 15 / 2000		56	1.13	0.129	33	1.02	2.15	0.026	0.098	36	11	2	15		1533
10 / 10 / 2000		69	0.431	0.014	33	1.94	2.371	0.01	0.014	1	1	5.61	1		127
4 / 16 / 2001		46	1.07	0.063	43	0.986	2.056	0.01	0.059	6	21	2	14		600
6 / 11 / 2001		67	0.455	0.05	48	1.66	2.115	0.022	0.08	7	1	6	3		933
8 / 7 / 2001		76	0.496	0.019	36	0.899	1.395	0.018	0.034	2	5	2	2		270
4 / 24 / 2002		66	0.446	0.022	27	0.623	1.069	0.01	0.039	1	3	2	3		50
6 / 17 / 2002		59.2	0.865	0.026	26	1.1	1.965	0.047	0.053	2	1	2	2		133
6 / 17 / 2002	D	59.3	0.956	0.025	26	1.16	2.116	0.049	0.062	2	1	2	2		183
8 / 7 / 2002		90.8	0.723	0.034	50	0.1	0.823	0.034	0.07	12	3	2	6		130
8 / 7 / 2002	D	88.6	0.702	0.043	49	0.317	1.019	0.033	0.066	23	3	2	3		127
11 / 13 / 2002		47.3	0.59	J 0.013	25	0.981	1.571	0.012	0.047	4	1	2	10		1330
11 / 13 / 2002	D	44.4	0.648	J 0.013	24	0.924	1.572	0.012	0.052	4	1	2	10		1170
4 / 22 / 2003		56.4	0.543	J 0.007	44	1.59	2.133	0.01	0.016	2	5	2	1		27
4 / 22 / 2003	D	57.2	0.395	J 0.009	43	1.57	1.965	0.011	JL 0.039	2	6	2	1		63

Date Month/Day/Year		Alkal MG/L 00410	TKjel MG/L 00625	AmoN MG/L 00610	Chloride MG/L 00940	NOXN MG/L 00630	TotalN MG/L ****	DOrthP MG/L 00671	TPhos MG/L 00665	TSS MG/L 00530	Chlor-a UG/L 32211	Pheo-a UG/L 32218	Turb FTU 00076	Enterco #/100ml 31639
6 / 10 / 2003		61.9	0.844	0.022	38	2.16	3.004	0.031	0.09	J 4	J 0.8	2	3	33
6 / 10 / 2003	D	54.7	0.977	0.029	37	3.63	4.607	0.031	0.076	J 3	J 1.3	2	3	73
8 / 27 / 2003		70.2	0.742	0.025	40	1.75	2.492	0.023	0.057	J 4	J 2.2	2	2	110
8 / 27 / 2003	D	69.8	0.601	0.024	40	1.77	2.371	0.023	0.057	J 3	J 2.4	2	2	140
11 / 5 / 2003		68.2	0.748	J 0.012	38	1.51	2.258	0.018	J 0.038	2	J 1.0	2	1	3030
11 / 5 / 2003	D	67.7	0.711	J 0.014	38	1.52	2.231	0.018	0.045	2	J 1.2	2	1	2470
4 / 27 / 2004		43.4	1.46	0.1	28	1.03	2.49	0.026	0.143	22	J 8.5	J 3.4	26	1000
4 / 27 / 2004	D	42.3	1.45	0.103	30	1.02	2.47	0.026	0.123	18	J 8.2	J 3.3	27	1130
5 / 18 / 2004		65.6	JH 0.793	0.044	57	1.56	1.56	0.028	0.055	6	J 1.3	< 2.0	1	300
6 / 7 / 2004		53.1	0.432	0.032	40	1.46	1.892	0.03	0.051	J 3	J 0.7	< 2.0	3	533
7 / 19 / 2004		46.5	0.861	0.036	25	0.987	1.848	JL 0.038	0.088	6	J 0.9	< 2.0	8	> 2000

101041 Naamans STORET No. 101041 (Rt 13 A)

Date Month/Day/Year		Water TempC 00010	Air TempC 00020	pH 00400	Flow CFS 00061	Salinity ppt 00096	Secchi IN 00077	SpecC uS/cm field 00094	DO Field 00299	DO MG/L 00300	CBOD5 MG/L 80082	CBOD20 MG/L 80087	THard MG/L 00900	TOC MG/L 00680	DOC MG/L 00681
8 / 2 / 2099		25		8.7		0.2		515	5.96	5.7	2.4	2.4	145	3	3
11 / 16 / 2099		8	8	7.7		0.2		362.9	10.66	10.86	2.4	2.4	128	5	4
4 / 25 / 2000		12.4	13	7.3		0.2		347.6	9.67	10.62	2.4	2.4	113	5	4
5 / 23 / 2000		14.1	18	8		0.2		318.2	9.37	8.78	2.4	2.4	88	20	4
8 / 15 / 2000		19.4	21	7.8		0.1		204.5	8.07	8.04	2.4	2.68	63	5	5
10 / 10 / 2000		9.9	10.5	8		0.2		3955	11.14	9.7	2.4	4.32	126	4	4
10 / 10 / 2000	D	9.9	10.5	8		0.2		3955	11.14	10.01	2.4	4.15	125	4	4
4 / 16 / 2001		11.6	10	6.9		0.1		302	10.51	11.94	2.4	2.4	82	6	5
6 / 11 / 2001		18.8	30	6.8		0.2		373.2	7.83	8.46	2.4	2.77	127	5	2
8 / 7 / 2001		24.5	33	7.7		0.2		447.6	6.55	5.71	2.4	2.4	136	3	2
10 / 31 / 2001		9.1	13	6.1		0.2		437.9	9.41	6.79	2.4	2.4	155	6	4
4 / 24 / 2002		10.7	8	7.9	NC	0.17	NC	362	10.12	8.78	2.4	2.4	112	4	4
8 / 7 / 2002		22.65	22	8.5	SNF	0.3		719	3.8	3.7	2.4	2.4	147	6.1	5.8
6 / 17 / 2002		18.26	19	6.6		0.2		452	7.2	6.6	2.4	2.4	107	6	4.7
11 / 13 / 2002		11	6	7.2		0.1		264	8.2	9	2.4	5.41	88.8	E 13.9	E 14.4
4 / 22 / 2003		13.17	13	7.6		0.2		376	10		2.4	2.4	120	2.8	2.6
6 / 10 / 2003		16.2	16	7		0.2		455	9.2		2.4	2.4	112	E 3.8	E 4.1
8 / 27 / 2003		21.98	26	7.6		0.2		378	7.8		2.4	2.68	118	4.3	4.2
11 / 5 / 2003		15.56	16	7.2		0.2		329	8.6		2.4	2.4	125	E 4.6	E 5.0
4 / 27 / 2004		13.1	17	7.93		0.12		243	10.52		< 2.40	4.14	68.8	8.7	8.5
5 / 18 / 2004		19.81	30	7.48		0.18		378	8.66		< 2.40	2.48	129	E 3.3	E 3.7
5 / 18 / 2004	D	19.84	30	7.48		0.18		378	8.64		< 2.40	< 2.40	128	E 3.3	E 3.4
6 / 7 / 2004		16.76	30	7.65		0.15		310	9.43		< 2.40	< 2.40	103	19.4	4
6 / 7 / 2004	D	16.76	30	7.64		0.15		310	9.42		< 2.40	< 2.40	102	3.9	3.5
7 / 19 / 2004		19.89	26	7		0.12		253	8.82		< 2.40	< 2.40	80.4	6.6	6.6
7 / 19 / 2004	D	19.91	26	7.01		0.12		250	8.78	8.7	< 2.40	< 2.40	78.5	6.4	6.4

Date Month/Day/Year		Alkal MG/L 00410	TKjel MG/L 00625	AmoN MG/L 00610	Chloride MG/L 00940	NOXN MG/L 00630	TotalN MG/L ****	DOrthP MG/L 00671	TPhos MG/L 00665	TSS MG/L 00530	Chlor-a UG/L 32211	Pheo-a UG/L 32218	Turb FTU 00076	Enterco #/100ml 31639
8 / 2 / 2099		93	0.088	0.068	74	0.483	0.571	0.018	0.044	5	8	2	1	103
11 / 16 / 2099		78	0.463	0.051	48	1.23	1.693	0.005	0.054	2	5	2	1	73
4 / 25 / 2000		62	NV#	0.045	47	1.27	1.27	0.005	0.017	9	3	2	2	80

5 / 23 / 2000		60	* 0.416	0.11	42	1.3	1.3	0.021	0.046	2	1	4	6	600
8 / 15 / 2000		45	0.769	0.079	25	0.881	1.65	0.028	0.076	7	5	2	15	2000
10 / 10 / 2000		74	0.957	0.081	56	1.34	2.297	0.017	0.027	2	2.67	2.94	2	153
10 / 10 / 2000	D	72	0.893	0.081	53	1.42	2.313	0.017	0.02	1	2.67	2.94	2	210
4 / 16 / 2001		54	0.512	0.044	46	1.04	1.552	0.012	0.048	5	5	6	5	550
6 / 11 / 2001		75	0.545	0.079	54	1.41	1.955	0.021	0.056	4	1	10	4	400
8 / 7 / 2001		81	0.652	0.103	60	0.769	1.421	0.02	0.057	2	3	3	3	73
10 / 31 / 2001		99	0.317	0.07	64	0.488	0.805	0.005	0.022	5	1	1	2	47
4 / 24 / 2002		70	0.52	0.065	52	0.663	1.183	0.012	0.005	4	2	2	3	NF
8 / 7 / 2002		90.1	1.17	0.314	150	0.172	1.342	0.064	0.122	5	4	2	3	57
6 / 17 / 2002		68.4	0.564	0.069	48	0.891	1.455	0.036	0.084	6	1	2	8	137
11 / 13 / 2002		48.5	1.33	0.023	20	1.79	3.12	0.036	0.065	5	2	2	8	1300
4 / 22 / 2003		64.2	0.238	0.037	61	1.06	1.298	J 0.006	J 0.005	3	2	2	1	63
6 / 10 / 2003		60.8	0.518	0.028	44	1.49	2.008	0.431	JH 0.487	J 3	J 0.9	2	4	157
8 / 27 / 2003		72	0.489	J 0.019	52	1.47	1.959	0.012	0.054	J 2	J 1.5	2	5	2000
11 / 5 / 2003		70.3	0.262	J 0.009	44	1.06	1.322	0.015	J 0.028	2	J 0.7	2	1	500
4 / 27 / 2004		42	1.08	0.094	32	JH 0.929	1.08	0.232	0.125	19	J 5.3	< 3.6	26	1100
5 / 18 / 2004		74.5	0.754	0.127	57	1.53	2.284	0.018	0.063	J 4	J 2.4	J 2.0	3	330
5 / 18 / 2004	D	67.6	0.869	0.102	56	1.44	2.309	0.017	0.053	5	J 2.2	< 2.0	3	340
6 / 7 / 2004		64.7	0.48	0.077	50	1.56	2.04	0.021	0.051	J 3	J 1.3	< 2.0	4	600
6 / 7 / 2004	D	64.7	0.436	0.073	47	1.51	1.946	0.023	0.042	6	J 1.5	< 2.0	4	300
7 / 19 / 2004		46.7	0.79	0.074	32	1.02	1.81	0.028	0.099	10	J 1.3	< 2.0	14	> 2000
7 / 19 / 2004	D	48.5	0.783	0.059	30	0.981	1.764	0.028	0.088	9	J 1.5	< 2.0	14	> 2000

101051 Naamans STORET No 101051 (Naamans Creek at Glenrock Road Bridge)

Date Month/Day/Year	Water TempC 00010	Air TempC 00020	pH 00400	Flow CFS 00061	Salinity ppt 00096	SpecC uS/cm field 00094	DO Field 00299	DO MG/L 00300	CBOD5 MG/L 80082	CBOD20 MG/L 80087	THard MG/L 00900	TOC MG/L 00680	DOC MG/L 00681	Alkal MG/L 00410
4 / 27 / 2004	13.4	19	7.63	3.37	0.15	320	10.41		< 2.40	< 2.40	95	6.2	6.1	60.1
5 / 18 / 2004	21.92	30	7.66	3.01	0.15	325	9.96		< 2.40	< 2.40	91.7	3.8	3.5	61.9
6 / 7 / 2004	17.62	28	7.85	3.06	0.12	249	10.59		< 2.40	< 2.40	74.4	E 4.6	E 4.7	53.9
7 / 19 / 2004	19.81	25	6.91	9.2	0.1	213	8.77	9	< 2.40	< 2.40	64.6	E 8.0	E 8.3	41.1

Date Month/Day/Year	TKjel MG/L 00625	AmoN MG/L 00610	Chloride MG/L 00940	NOXN MG/L 00630	TotalN MG/L ****	DOrthP MG/L 00671	TPhos MG/L 00665	TSS MG/L 00530	Chlor-a UG/L 32211	Pheo-a UG/L 32218	Turb FTU 00076	Enterco #/100ml 31639
4 / 27 / 2004	0.604	0.034	45	1.37	1.974	0.015	0.047	< 2	9.5	< 2.0	5	270
5 / 18 / 2004	0.667	0.025	50	1.44	2.107	0.028	0.058	9	J 0.6	< 2.0	3	83
6 / 7 / 2004	0.463	0.02	35	1.34		0.034	0.056	J 4	J 0.7	< 2.0	2	533
7 / 19 / 2004	0.892	0.026	21	1	1.892	0.039	0.101	6	J 0.7	< 2.0	8	> 2000

101061 Naamans STORET No. 101061 (Naamans Creek at Rt 3 (Marsh Road))

Date Month/Day/Year	Water TempC 00010	Air TempC 00020	pH 00400	Flow CFS 00061	Salinity ppt 00096	SpecC uS/cm field 00094	DO Field 00299	DO MG/L 00300	CBOD5 MG/L 80082	CBOD20 MG/L 80087	THard MG/L 00900	TOC MG/L 00680	DOC MG/L 00681	Alkal MG/L 00410
4 / 27 / 2004	13.18	20	7.5	5.41	0.1	207	10.55		< 2.40	< 2.40	64.7	10	10	48.9
5 / 18 / 2004	19.65	30	7.52	STS	0.14	291	9.14		< 2.40	< 2.40	92.1	E 3.5	E 3.7	66.4
6 / 7 / 2004	16.52	30	7.69		0.12	258	9.76		< 2.40	< 2.40	81.6	E 4.5	E 4.8	61.6
7 / 19 / 2004	19.62	25	6.78		0.11	237	8.54		< 2.40	< 2.40	76.1	8.4	8.3	49.3

Date Month/Day/Year	TKjel MG/L 00625	AmoN MG/L 00610	Chloride MG/L 00940	NOXN MG/L 00630	TotalN MG/L ****	DOrthP MG/L 00671	TPhos MG/L 00665	TSS MG/L 00530	Chlor-a UG/L 32211	Pheo-a UG/L 32218	Turb FTU 00076	Enterco #/100ml 31639
4 / 27 / 2004	1.32	0.09	23	1.27	2.59	0.032	0.111	8	J 4.8	< 2.0	17	1270
5 / 18 / 2004	0.595	0.04	42	1.81	2.405	0.028	0.055	6	J 1.0	< 2.0	1	360
6 / 7 / 2004	0.491	0.04	34	1.84	2.331	0.035	0.058	J 2	J 1.2	< 2.0	3	400
7 / 19 / 2004	1.03	0.049	22	1.41	2.44	0.045	0.118	6	J 1.0	< 2.0	7	> 2000

101071 Naamans STORET No. 101071 (Naamans Creek Decatur Rd)

Date Month/Day/Year	Water TempC 00010	Air TempC 00020	pH 00400	Flow CFS 00061	Salinity ppt 00096	SpecC uS/cm field 00094	DO Field 00299	DO MG/L 00300	CBOD5 MG/L 80082	CBOD20 MG/L 80087	THard MG/L 00900	TOC MG/L 00680	DOC MG/L 00681	Alkal MG/L 00410
6 / 7 / 2004	16.87	30	7.44	1.63	0.13	268	9.28		< 2.40	< 2.40	84	4.4	3.9	57.6
7 / 19 / 2004	19.43	25	6.77	10	0.12	256	8.24	8.5	< 2.40	< 2.40	79.3	8.4	8.4	53.6

Date Month/Day/Year	TKjel MG/L 00625	AmoN MG/L 00610	Chloride MG/L 00940	NOXN MG/L 00630	TotalN MG/L ****	DOrthP MG/L 00671	TPhos MG/L 00665	TSS MG/L 00530	Chlor-a UG/L 32211	Pheo-a UG/L 32218	Turb FTU 00076	Enterco #/100ml 31639
6 / 7 / 2004	0.495	0.044	38	2.11	0	0.03	0.061	6	J 1.0	< 2.0	3	767
7 / 19 / 2004	0.938	0.048	25	1.58	2.518	0.043	0.112	5	J 1.0	< 2.0	7	> 2000

E=Value exceeds a theoretical equivalent or greater value, however, the difference isn't significant.
FQ=No Flow
IF=Field instrument malfunctioned; no measurement taken
IM=Instrument malfunctioned, no measurement taken.
J=Analyte present, reported value is estimated
JH=Result is likely overestimated due to matrix effect.
JL=Result is likely underestimated due to matrix effect.
NA=Not analyzed but required by workplan. Sample collected but not analyzed due to lab error.
NC=Sample not collected but required by work plan.
NF=Sample collected but not analyzed due to field error.
NV# = Analytical result not valid
SNF=Site has no flow
STD=Stream too deep.
STS=Site is too shallow.
<=Sample value is below the method detection limit.
>=Sample value is above the upper quantitation limit
*Result is likely underestimated due to matrix effect
*Total Nitrogen - Result is likely overestimated due to matrix effect

APPENDIX C SUMMARY OF SENSITIVITY ANALYSIS

Parameter** (Notation in Qual2E)	Parameter Description	Unit	Value used at Last Reach (rch5) of Shellpot Model	Input Change (%)	Response (%) at the Last Element (Ele3) of the Last Reach (Rch4)		
					DO	TN	TP
α0	Ratio of chlorophyll -a to algal biomass	ug Chl-*a*/ mg A	50	50	0.00	0.00	0.00
				-50	0.11	0.00	0.00
λ0	Non-algal light extinction coefficient	1/m	0.001	50	0.00	0.00	0.00
				-50	0.00	0.00	0.00
σ_1	Algal settling rate	m/day	0	mid of recommended value	0.00	0.00	0.00
σ_2	Benthos source rate for dissolved phosphorous	mg-p / m2-day	0		0.00	0.00	0.00
					0.00	0.00	0.00
σ_3	Benthos source rate for ammonia nitrogen	mg-N / m2-day	0	50	0.00	0.00	0.00
				-50	0.00	0.00	0.00
σ_4	Organic nitrogen settling rate	day-I	0	mid of recommended value	0.00	0.00	0.00
σ_5	Organic phosphorus settling rate	day-I	0	mid of recommended value	0.00	0.00	0.00
K_1	Carbonaceous deoxygeneration rate constant	day-I	0.2	50	-0.11	0.00	0.00
				-50	0.23	0.00	0.00
K_2	Reaeration rate constant	day-I	7.06	50	0.68	0.00	0.00
				-50	-0.90	0.00	0.00
K_3	Rate of loss of BOD due to settling	day-I	0		0.00	0.00	0.00
					0.00	0.00	0.00
K_4	Benthic oxygen uptake (SOD)	mg-O / m2-day	0.5	50	-0.34	0.00	0.00
				-50	0.45	0.00	0.00
β1	Rate constant for the biological oxidation of NH3 to NO2	day -1	0.3	50	0.00	0.00	0.00
				-50	0.11	0.00	0.00
β2	Rate constant for the biological oxidation of NO2 to NO3	day-I	1	50	0.00	0.00	0.00
				-50	0.11	0.00	0.00
β3	Rate constant for the hydrolysis of organic- N to ammonia	day-I	0.3	50	0.00	0.00	0.00
				-50	0.00	0.00	0.00
β4	Rate constant for the decay of organic-P to dissolved-P	day-I	0.5	50	0.00	0.00	0.00
				-50	0.00	0.00	-9.09
T	Initial water temperature	C	16.82	50	-4.75	0.00	0.00
				-50	4.63	0.00	0.00