Total Maximum Daily Load (TMDL) Analysis
for
Tributaries and Ponds of the Nanticoke River and Broad Creek, Delaware

Prepared by:

Watershed Assessment Section
Division of Water Resources
Delaware Department of Natural Resources and Environmental Control
820 Silver Lake Blvd, Suite 220
Dover, DE 19904

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EXECUTIVE SUMMARY

Several tributaries and ponds of the Nanticoke River and Broad Creek are listed in the State of Delaware's 1996 and 1998 Section 303(d) Lists of impaired waters requiring establishment of the Total Maximum Daily Load (TMDL) (see Table A). The causes of impairment are high nutrient concentrations and/or low dissolved oxygen levels. A court approved Consent Decree (C.A. No. 96-591, D. Del 1996) required Delaware Department of Natural Resources and Environmental Control (DNREC) to establish a TMDL for the above tributaries and ponds by December 2000.

In 1998, Delaware DNREC established a TMDL for the main stems of the Nanticoke River and Broad Creek. Among other requirements, Articles 3 and 4 of the TMDL regulation called for nonpoint source nutrient load reductions for the entire basin. The reduction levels are 30% for nitrogen and 50% for phosphorous and were established to meet the state water quality standards and targets for the main stems of the Nanticoke River and Broad Creek.

This technical report addresses wether the already established load reduction targets (30% for nitrogen and 50% for phosphorous) in 1998 are sufficient to meet water quality standards and targets in all tributaries and ponds which are listed for nutrients and dissolved oxygen within the basin. The sources of pollutants for all these tributaries and ponds are nonpoint sources. To conduct this analysis, water quality models are developed for the listed tributaries and ponds. The USEPA's Qual2E Enhanced Stream Water Quality Model is used as the framework for this analysis. The water quality models are calibrated using intensive water quality and hydrological data collected during 1998 - 1999.

As shown in this document, the results of the analysis using the calibrated Qual2E models demonstrate that the already established load reduction levels (30% for nitrogen and 50% for phosphorous) are sufficient to meet water quality standards at all

tributaries and ponds which were listed for nutrients and/or dissolved oxygen. In addition, the results of the analyses show that implementing the above nutrient load reduction levels will result in meeting the total nitrogen and total phosphorous concentration targets in the main stems of the Nanticoke River and Broad Creek, with consideration of 20% confidence interval.

Based on the above analysis, it is concluded that the 1998 TMDL regulation for the Nanticoke River and Broad Creek is sufficient to protect designated uses for the tributaries and ponds listed for nutrients and/or dissolved oxygen. Therefore, the existing regulation will remain intact without any modifications.

Table A. Waterbody Segments on 1998 303(d) List for Nutrients and DO (1)

WATERBOD ID (TOTAL SIZE)	WATERSHED NAME	SEGMENT
DE240-003 (22.9 miles)	Nanticoke River	Clear Brook Branch
DE240-004 (99.2 miles)	Nanticoke River	Deep Creek Branch
DE240-005 (61.2 miles)	Nanticoke River	Gravelly Branch
DE240-006 (9.6 miles)	Nanticoke River	Bridgeville Branch
DE240-007 (12.1 miles)	Nanticoke River	Gum Branch
DE240-008 (25.8 miles)	Nanticoke River	Lewes Creek
DE240-L01 (11.9 acres)	Nanticoke River	Craigs Pond
DE240-L02 (87.4 acres)	Nanticoke River	Concord Pond
DE240-L04 (100.o acres)	Nanticoke River	Williams Pond
DE240-L05 (67.0 acres)	Nanticoke River	Hearns Pond
DE050-002 (13.0 miles)	Broad Creek	Tussocky Branch
DE050-004 (21.7 miles)	Broad Creek	Chipman Pond Branch
DE050-005-01 (31.7 miles)	Broad Creek	James Branch
DE050-005-02 (18.8 miles)	Broad Creek	Trussum Pond Branch
DE050-006-01 (21.5 miles)	Broad Creek	Trap Pond Branch
DE050-L01 (14.5 acres)	Broad Creek	Portsville Pond
DE050-L03 (46.3 miles)	Broad Creek	Horseys Pond
DE050-L04 (91.9 acres)	Broad Creek	Records Pond
DE050-L05 (47.0 acres)	Broad Creek	Chipman Pond
DE050-L06 (58.7 acres)	Broad Creek	Trussum Pond
DE050-L07 (88.0 acres)	Broad Creek	Trap Pond
DE050-L08 (13.5 acres)	Broad Creek	Raccoon Pond

1. Introduction

1.1. Background

Several tributaries and ponds of the Nanticoke River and Broad Creek are listed for nutrients and/or dissolved oxygen in the State of Delaware's 1996 and 1998 Section 303(d) List of impaired waters requiring establishment of the Total Maximum Daily Load (TMDL). A court approved Consent Decree (C.A. No. 96-591, D. Del 1996) required Delaware Department of Natural Resources and Environmental Control (DNREC) to establish a TMDL for the above tributaries and ponds by December 2000.

In 1998, Delaware Department of Natural Resources and Environmental Control (DNREC) established a Total Maximum Daily Loads (TMDLs) for the Nanticoke River and Broad Creek. Among other things, Articles 3 and 4 of the TMDL regulation required non-point source nutrient load reductions from the entire basin. The reduction levels are 30% for nitrogen and 50% for phosphorous and were established to meet the state water quality standards and targets for the main stems of the Nanticoke River and Broad Creek.

To ensure implementing the existing TMDL regulation will result in meeting state water quality standards for the listed tributaries and ponds listed for nutrients and/or dissolved oxygen, DNREC has conducted the current investigation. For this investigation, water quality models are developed for all listed tributaries and ponds impaired by nutrients and/or dissolved oxygen. The USEPA's Qual2E Enhanced Stream Water Quality Model is used as the framework for this analysis. The tributary pollutant loading generated from the Qual2E models output were entered into the receiving stream hydrodynamic and water quality model- WASP to evaluate water quality conditions of the main stems of the Nanticoke River and Broad Creek.

1.2 303(d) List

State of Delaware 1996 and 1998 303(d) Lists (1) have listed 22 waterbody segments (11 stream segments and 11 ponds) as impaired because of low dissolved oxygen and/or high nutrients (see Table 1-1). The sources of the pollutants are non-point sources. A court approved Consent Decree (C.A. No. 96-591, D. Del 1996) required DNREC to establish a TMDL for DO and nutrients for the above segments by December 2000.

The listed segments in Table 1 -1 are grouped into 12 stream systems. These stream systems and their corresponding drainage areas are displayed in Figure 1-1.

Table 1-1 Tributaries and Ponds on 303(d) List of 1998 for Nutrients and DO (1)

SEGMENT	DESCRIPTION	SIZE AFFECTED	POLLUTANT(S) AND / OR STRESSOR(S)	PROBABLE SOURCE(S)	YEAR LISTED	TARGET DATE FOR TMDL
Clear Brook Branch	From the headwaters of Clear Brook, Friedel Prong, and Bucks Branch to the confluence with Williams Pond	12.9 miles	Nutrients and DO	NPS	1996	2000
Deep Creek Branch	From the headwaters above Concord Pond to the confluence with the Nanticoke River, excluding Concord Pond	5.5 miles	Nutrients	NPS	1996	2000
Gravelly Branch	From the headwaters of Gravelly Branch above Collins Pond to the confluence with the Nanticoke River, excluding Collins Pond	6.5 miles	Nutrients	NPS	1996	2000
Bridgeville Branch	From the headwaters of Bridgeville Branch to the confluence with Nanticoke River	7.2 miles	Nutrients and DO	NPS	1996	2000
Gum Branch	From the headwaters located northeast of Woodland Ferry to the confluence with Nanticoke River	6.0 miles	Nutrients	NPS	1996	2000
Lewes Creek	Lewes Creek, including Butler Mill Branch and Chapel Branch	10.3 miles	Nutrients	NPS	1996	2000
Craigs Pond	Pond southwest of Seaford and below Butler Mill Branch	11.9 acres	Nutrients	NPS	1996	2000
Concord Pond	Pond east of Seaford on Deep Creek Branch	87.4 acres	Nutrients	NPS	1996	2000
Williams Pond	Pond located in Seaford and below Middleford	100.0 acres	Nutrients	NPS	1996	2000
Hearns Pond	Pond located north of Seaford on Clear Brook Branch	67.0 acres	Nutrients	NPS	1996	2000
Tussocky Branch	Tributary west of Laurel, excluding Portsville and Tussock Ponds	7.9 miles	Nutrients	NPS	1996	2000
Chipman Pond Branch	Tributary northeast of Laurel, excluding Chipman Pond	6.7 miles	Nutrients	NPS	1996	2000
James Branch	James Branch, including Pepper Pond Branch, Hitch Pond Branch, and Grays Branch	11.1 miles	Nutrients	NPS	1996	2000
Trussum Pond Branch	Wards Branch--from the confluence of the headwaters to the confluence with James Branch	3.18 miles	DO	NPS	1998	2000
Trap Pond Branch	From the headwaters of Trap Pond including Saunders and Thompson Branches	2.9 miles	Nutrients	NPS	1996	2000
Portsville Pond	Pond west of Laurel on Tussocky Branch	14.5 acres	Nutrients	NPS	1996	2000
Horseys Pond	Pond south of Laurel on Little Creek tributary	46.3 acres	Nutrients	NPS	1996	2000
Records Pond	Pond adjacent to Laurel	91.9 acres	Nutrients and DO	NPS	1996	2000

SEGMENT	DESCRIPTION	SIZE AFFECTED	POLLUTANT(S) AND / OR STRESSOR(S)	PROBABLE SOURCE(S)	YEAR LISTED	TARGET DATE FOR TMDL
Chipman Pond	Pond located north of Laurel on Chipman Branch	47.0 acres	Nutrients	NPS	1996	2000
Trussum Pond	Pond southeast of Laurel on James Branch	58.7 acres	DO	NPS	1996	2000
Trap Pond	Pond east of Laurel on Hitch Pond Branch	88.0 acres	Nutrients	NPS	1996	2000
Raccoon Pond	Pond east of Laurel on Hitch Pond Branch	13.5 acres	Nutrients	NPS	1996	2000

1.3 Water Quality Condition

Water quality of the Nanticoke River Basin has been monitored for more than 25 years. However, to support this study, an intensive water quality monitoring program was conducted during 1998-99. During this period, quarterly water quality samples were collected and analyzed.

A comprehensive water quality assessment of the Nanticoke River (2) and the 1996, 1998, and 2000 305(b) Reports (3)(4)(5) have shown that nutrient over enrichment and low DO concentration have impaired several tributaries as well as main stems of Nanticoke River and Broad Creek. 1996, 1998, and 2000 305(b) Reports have identified following designated uses as not being fully supported because of low DO and high nutrient concentrations:

- fish and aquatic life use, and
- Exceptional Recreational and Ecological Significance use.

Major sources of pollution in the tributaries, are nonpoint sources like surface runoffs from agricultural, urban, and other land use activities in the basin.

Based on intensive water quality monitoring data collected during 1998-99, the State of Delaware 2000 305(b) Report (5) has summarized the relevant water quality data for each of the above 22 impaired segments. Figures 1-2 and 1-3 show the average concentrations of several pertinent water quality parameters including DO, total nitrogen (TN), total phosphorous (TP), and chlorophyll a for each of the 22 segments listed on the 303 (d) List.

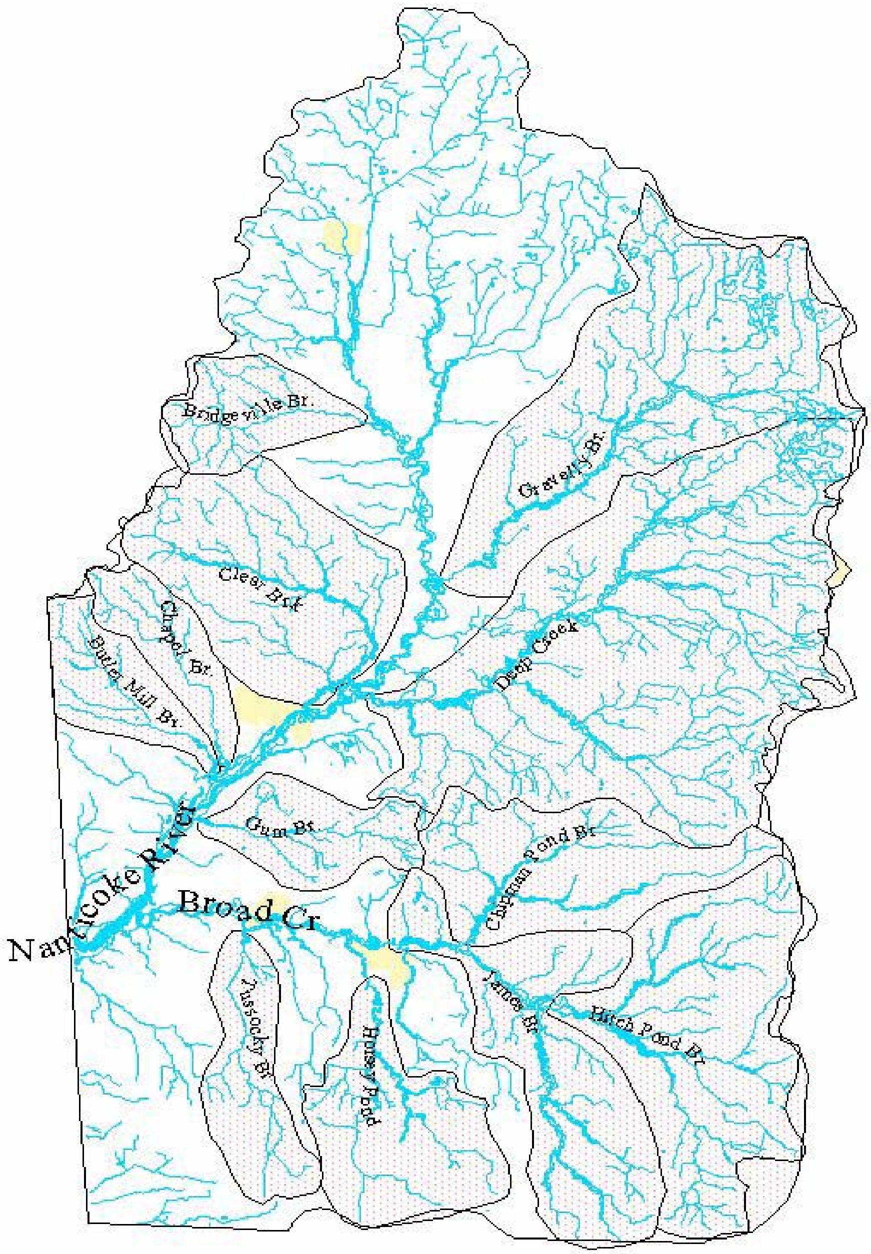
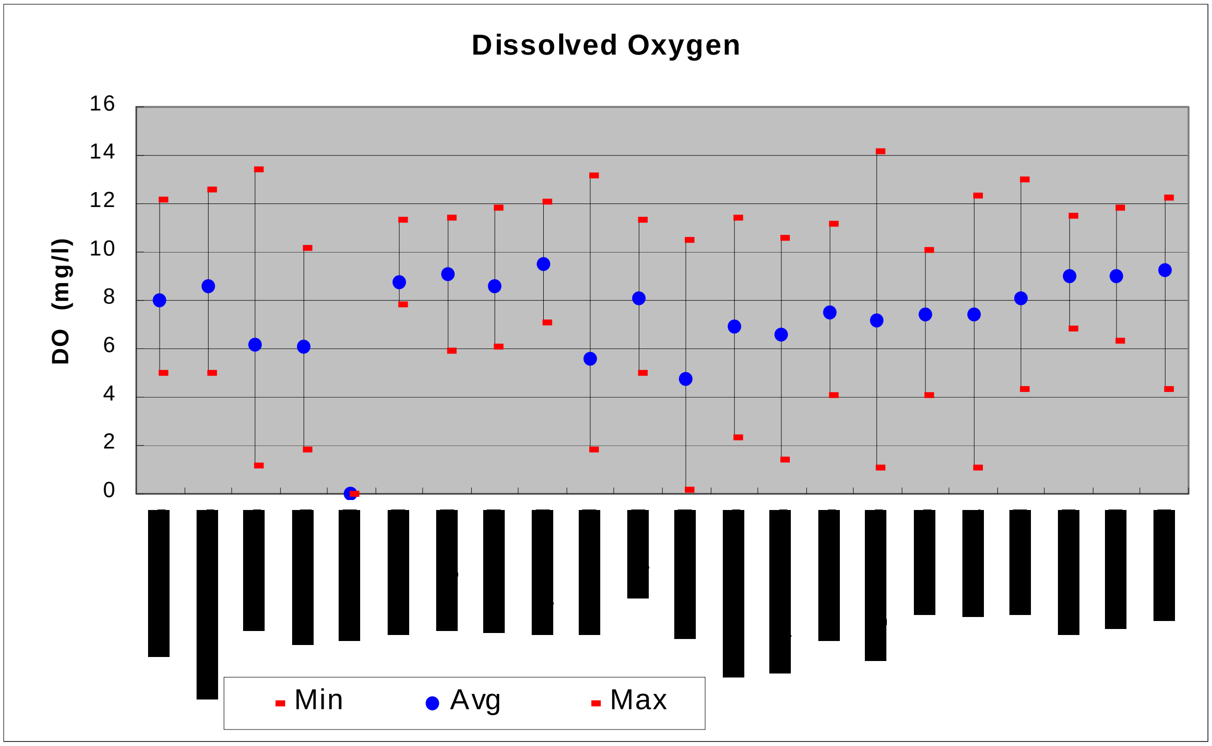


Figure 1 - 1 Nanticoke Basin and Tributary Watersheds



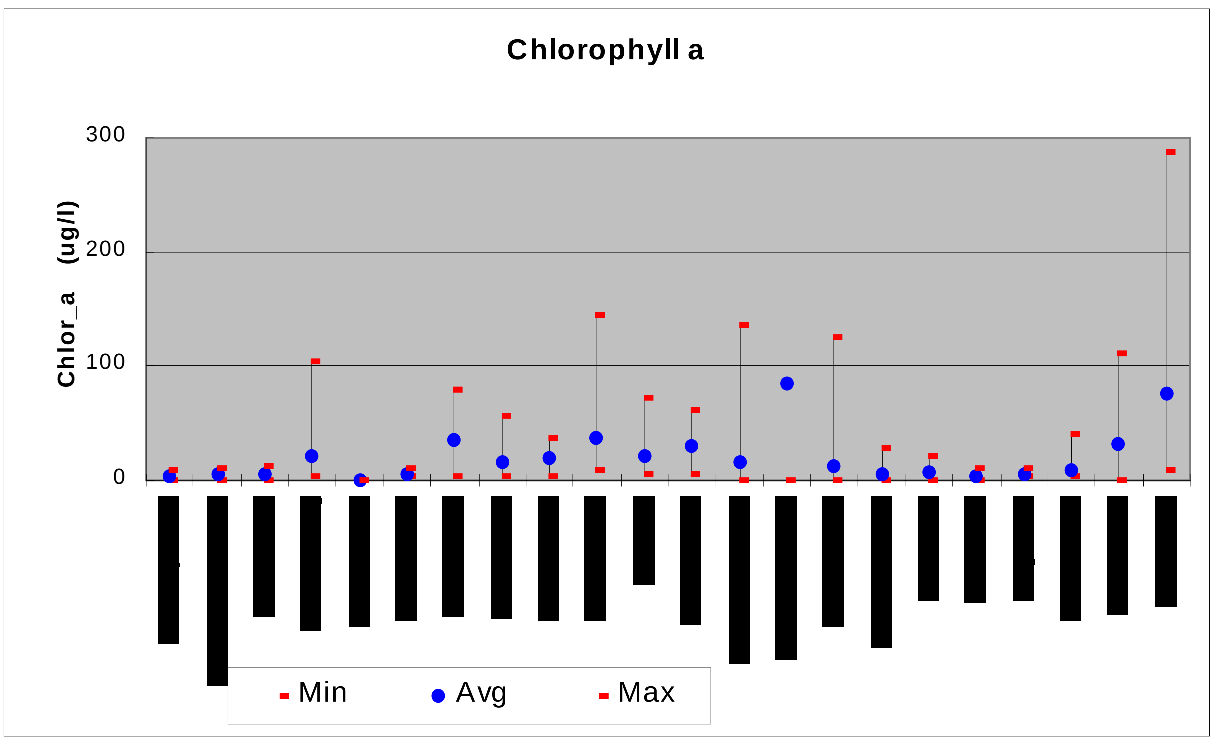
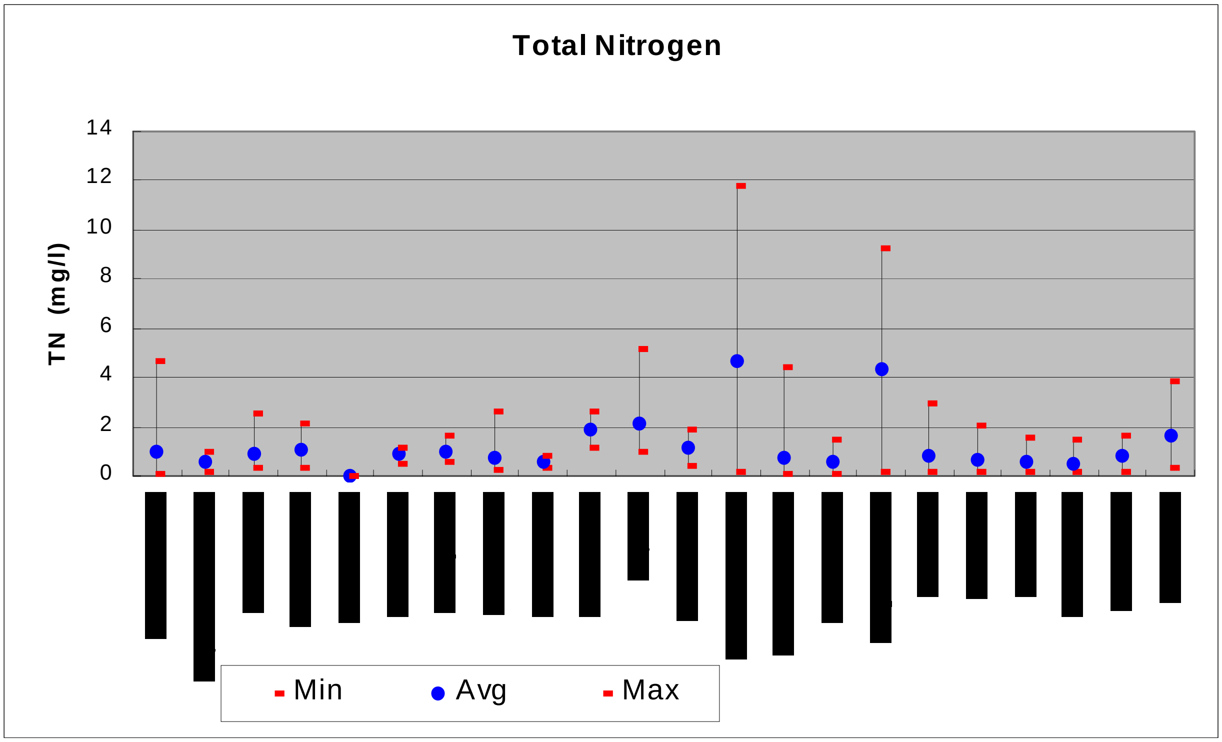


Figure 1 - 2. Concentrations of DO and Chorophyll a at 303(d) Listed Tributary Segments



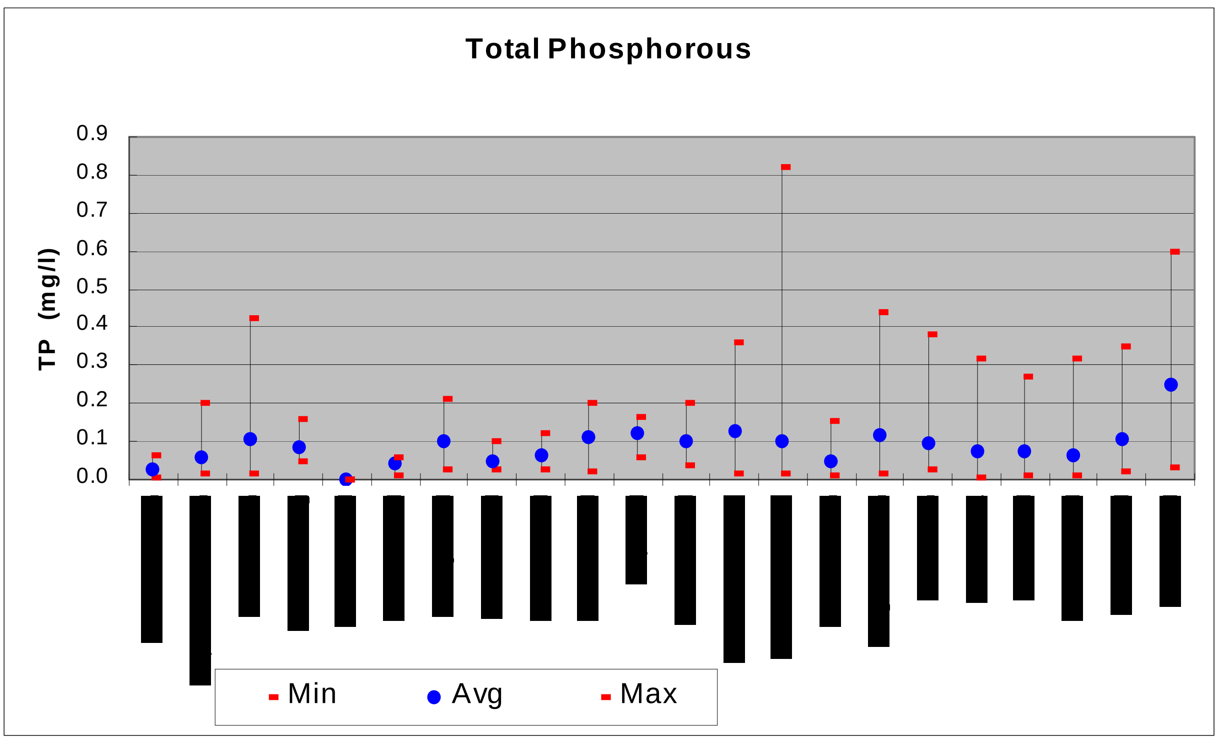


Figure 1 - 3. Concentrations of Total N and Total P at 303(d) Listed Segments

1.4 Characteristics of Nanticoke River Basin

Nanticoke River basin of Delaware is located in southwestern part of the State, with major portion of the watershed in Sussex County and only a small parcel of upper Nanticoke is located in Kent County. The basin consists of Nanticoke River and its major tributary Broad Creek, as well as many other small tributaries and ponds. The majority of small tributaries are free flowing, while parts of main stems of the Nanticoke River and Broad Creek are tidal (see Figure 1- 1).

The topography of the basin is characterized by extremely flat lands with slight localized relief, most of which is along the middle sections of the basin and next to the River. The basin's upper most reaches are about 60 feet above sea level, while the area close to Maryland border is only 10 ft above sea level (6).

The basin drains an area of 397 square miles (253,906 acres). Major land use activity in this basin is agriculture which takes 51 percent of the total land in the basin. After agriculture, wooded area takes 39%, brushland 5%, and urban areas 2.4% (6) (see pie chart in Figure 1- 4).

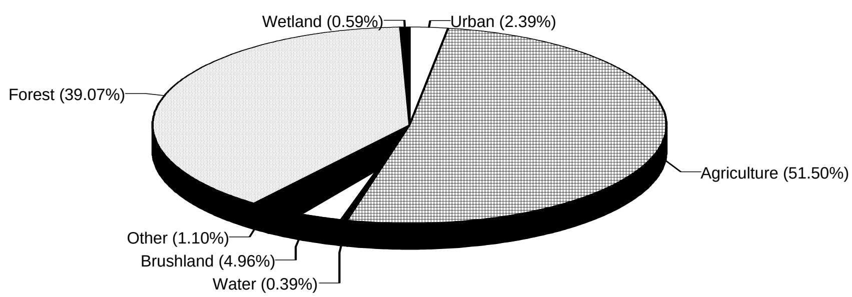


Figure 1-4. Land Use/Land Cover in the Nanticoke River Basin

Geologically, the basin lies within the Atlantic Coastal Plain which consists of a seaward dipping wedge of unconsolidated and semi-consolidated sediments. There is no bedrock near the surface or the soil in this Basin. Also, there are no mineral extraction or oil and gas drilling sites in the area (6).

The soils are generally sandy and porous and consist of the following major associations: *Tidal Marsh, Fresh, Association; Sassafras-Fallsington association; Evesboro-Rumford association*; *Fallsington- Sassafras-Woodstown association*; and *Fallsington-Pocomoke-Woodstown association.* The *Fallsington-Sassafras-Woodstown* and *Fallsington-Pocomoke-Woodstown* occur in the upper most reaches of the Nanticoke River and cover about one-third of the Basin (6).

There are seven point source NPDES facilities in the Nanticoke River basin (see Table 1-2), however, none of them are impacting the tributaries and ponds which are subject of this, hence are not included in the analysis. Therefore, nonpoint source is the only pollutant source concerned in these tributaries TMDL analysis.

Table 1-2. NPDES Facilities and Their Status

Facility Name	ID	Size	Type	Receiving Stream	Reason for not addressed in tributary TMDL study
Seaford STP	DE0020265	Major	Municipal	Nanicoke R.	Addressed in the main stem TMDL study
Bridgeville STP	DE0020249	Major	Municipal	Nanicoke R	Addressed in the main stem TMDL study
Laurel STP	DE0020125	Major	Municipal	Broad Cr.	Addressed in the main stem TMDL study
DuPont Seaford	DE0000035	Major	Industrial	DuPont Gut	Not listed for high nutrient and low DO, therefore not included.
DelAgra Corp.	DE0050938	Minor	Industrial	Bridgeville Br.	Eliminated since September 30, 1999
S. C. Johnson	DE0050971	Minor	Industrial	Herring Run	Herring Run was not listed for nutrients and/or DO
Mobile Garden Trailer Park	DE0050725	Minor	Municipal	unnamed tributary	The receiving tributary was not listed, because the point of discharge of the facility is less than 1/3 mile from the main stem of Nanticoke River and the impact on the tributary was minimal. The impact of this discharge on the main stem Nanticoke River was addessed in the main stem TMDL study.

1.5 Applicable Water Quality Standards and Nutrient Guidelines

The State of Delaware Surface Water Quality Standards has two major components. One is “designated use”, such as fish and aquatic life use. Another one is “criterion”, the in-stream condition necessary to protect the designated use. The criterion can be a numeric value (chemical concentration or physical measure) or a narrative statement. The Standard is a State regulation and the basis for preparing 305(b) Reports, 303(d) Lists, and TMDL Regulations.

The following sections of the Standards provide specific narrative and numeric criteria concerning the waters of the Nanticoke River (7):

1. Section 3. This Section of the State Water Quality Standards provides general guidelines regarding the Department's Antidegradation policies.
2. Section 7. This Section of the Standards provides specific narrative and numeric criteria for controlling nutrient over enrichment in waters of the State.
3. Section 9. This Section provides specific narrative and numeric criteria for toxic substances.
4. Section 11. This Section of the Standards provides specific water quality criteria for surface waters of the State.

Based on the above Sections, the following is a summary of some pertinent water quality standards which are applicable to the waters of Nanticoke River and Broad Creek and their tributaries and ponds:

a. *Dissolved Oxygen (D.O.):*
   - 5.5 mg/l daily average (from June through September)
   - 4.0 mg/l 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.
   - For lakes and ponds, controls shall be designed to eliminate over enrichment.

In addition to the above narrative and numeric criteria, Section 11.5 of the State Water Quality Standards provides general policies and criteria for Waters of Exceptional Recreational or Ecological Significance (ERES Waters). The Section requires that ERES Waters, which are considered as special natural assets of the State, shall be accorded a level of protection in excess of that provided for most other waters of the State. Furthermore, it calls for restoring ERES Waters, to the maximum extent practicable, to their natural condition by adopting pollution control strategies which will take appropriate action to cause systematic control, reduction, or elimination of existing pollution sources.

With the above standards in mind, DNREC has been using a target value of 3.0 mg/l for total nitrogen (TN) and 0.1 mg/l for total phosphorus (TP) as indication of excessive nutrient levels in the main stems of the Nanticoke River and Broad Creek. Furthermore, the above target values are used in the assessment for 305(b) Reports, 303(d) Lists, and TMDL Regulations.

2. Available Data

2.1 Water Quality Data

To support the tributary TMDL modeling development, the Department has conducted intensive tributary water quality monitoring to collect data during 1998 - 1999. Table 2-1 lists those monitoring stations (total 50) and Figure 2-1 shows their locations on the basin map. At each station, grab samples were collected 4 times a year and were analyzed for the 24 water quality parameters listed in Table 2-2. A summary of the monitoring data is presented in Table 2-3.

Furthermore, continuous YSI Data Sonde Monitors were deployed at the following nine sites: 1) Portsville Pond, 2) Chipman Pond, 3) Trap Pond, 4) Horsey Pond, 5) Records Pond, 6) Hearns Pond, 7) Williams Pond, 8) Concord Pond, and 9) Craig Pond. One week long continuous DO, water temperature, and other chemical parameters were collected twice at each site during July and August of 1999.

These water quality data and additional data have been used to develop and calibrate the tributary and pond models and to establish TMDL.

Table 2-1. Tributary Water Quality Monitoring Station* (8)

Monitoring Location	**Storet No.**
Tussocky Branch / Portsville Pond	
1. Portsville Pond on Tussocky Branch of Broad Creek, at county road 496 (lat:38 33 50.0, long: 075 37 55.0)	307061
2. Tussocky Branch at County Road 494, southwest of laurel (lat:38 32 30.0, long: 075 38 15.0)	307101
3. Tussocky Branch at Route 24 Bridge (lat: 38 31 18.0, long: 075 37 58.8)	307291
4. Turkey Branch at Rt. 495 Bridge (lat:38 46 34, long: 75 32 11)	307331
Chipman Pond Branch / Chipman Pond	
1. Chipman Pond Branch at Road 467 Bridge (below confluence of Mirey Branch and Elliot Pond Br)	307121
2. Chipman Pond, 2/3 distance from Spillway to inflow stream confluence (lat:38 34 10.8, long: 075 32 03.3)	307131
3. Chipman Pond Branch at Rt. 465 Bridge, down stream of Chipman Pond Spillway (lat:38 33 28, long: 075 31 51)	307341
4. Beaver Dam Branch at Rd. 447 Bridge (below Wileys Pond) (lat: 38 34 27.6, long: 075 31 11.9)	307111
Pepper Pond Branch	
1. Pepper Pond Branch at Rt. 24 Bridge (lat: 38 32 27.0, long: 075 28 25.2)	307281
2. Grays Branch at Rt. 62 Bridge (lat: 38 33 28, long: 75 31 51)	307351
3. Pepper Branch at Rt 62 Bridge (lat: 38 33 28, long: 75 31 51)	307361

Monitoring Location	Storet No.
Trap Pond Branch	
1. Thomson Branch at Rd. 72 Bridge (lat: 38 31 01.7, long.: 075 27 08.7)	307221
2. Racoon Prong at Racoon Pond Spillway (Road 72 Bridge) (lat:38 30 55.7, long: 075 27 39.8)	307201
3. Trap Pond, 200 yard above Spillway (lat:38 31 41.2, long: 075 28 49.4)	307181
4. Trap Pond on Hitch Pond Branch at County Road 449 (lat: 38 31 45.0, long: 075 28 55.0)	307081
5. Raccoon Prong at Rd 62 Bridge (lat: 38 29 49.18, long: 75 27 06.44)	307371
Horsey Pond	
1. Horseys Pond, 50 yards above Spillway (lat: 38 31 54.3, long: 075 34 41.6)	307171
2. Meadow Branch at Road 501 Bridge (lat: 38 34 07.0, long: 075 37 11.7)	307151
3. Horsey Pond Overflow	307171
Record Pond / Trussum Pond	
1. James Branch, outflow of Trussum Pond at Rd. 72 Bridge (lat: 38 31 33.03, 75 30 40.84)	307091
2. James Branch at Rd 451 Bridge (lat: 38 30 27.80, long: 75 30 24.20)	307381
3. James Branch on Rt 24 Bridge (lat: 38 33 16.23, long: 75 32 19.94)	307391
4. Records Pond Spillway (lat: 38 33 31.47, long: 75 34 02.36)	307401
5. Record Pond Overflow	307011
Clear Brook / Hearns Pond / Williams Pond	
1. Herring Run at Rt. 20 Bridge before entering Williams Pond (lat: 38 39 08.82, long: 75 35 49.75)	304621
2. William H. Newton Ditch at Rt. 46 Bridge (lat: 38 40 32.06, long: 75 34 36.91)	304631
3. Clear Brook at US Rt. 13 (downstream of Hearns Pond)	304571
4. Clear Brook above DE Rt. 18 Bridge	304371
5. Clear Brooks, Bucks Branch at Rd. 546	304381
6. Hearns Pond, 100 yrd above spillway	304411
7. Williams Pond, middle of the pond at US Rt. 13	304581
8. William Pond Overflow	304321
Deep Creek / Concord Pond	
1. Baker Mill Branch at Rt. 483 Bridge (lat: 38 38 21.28, long: 75 32 18.67)	304641
2. Tyndall Branch at Rt. 484 Bridge at spillway of Fleetwood Pond (lat: 38 38 40.26, long: 75 30 31.70)	304651
3. Deep Creek above Concord Pond, near Old Furnace at Rd. 46	304591
4. Deep Creek above Concord Pond, near Cokesbury Church at DE Rt. 18	304601
5. Concord Pond Overflow	304311
Gravelly Branch	
1. Gravelly Branch downstream of the outlet of Collins Pond at Rt. 404 Bridge	316021

Monitoring Location	Storet No.
2. Gravelly Branch at west edge of Redden State Park, Rd. 565 Bridge	316031
3. Gravelly Branch at Rd 525	316011
Bridgeville Branch	
1. Bridgeville Branch at US Rt. 13 Bridge	304051
2. Bridgeville Branch at DE Rt. 404 Bridge	304271
3. Bridgeville Branch at Rd. 564 Bridge	304611
Gum Branch	
1. Gum Branch at Rd. 487 Bridge (the western intersect)	304441
2. Gum Branch at Rd. 485 Bridge	304531
Lewes Creek / Craig Pond	
1. Lewes Creek, Chapel Branch at Rt. 20	304451
2. Lewes Creek, Chapel Branch at Rd. 547	304541
3. Lewes Creek, Butler Mill Branch at Rd. 80 Bridge	304551
4. Lewes Creek, Butler Mill Branch, Horse Pen Branch at Rd. 20	304561
5. Lewes Creek, Butler Mill Branch, downstream of Craig Pond at Rd. 542A	304301

* Flow measurements also to be taken at free flowing stations

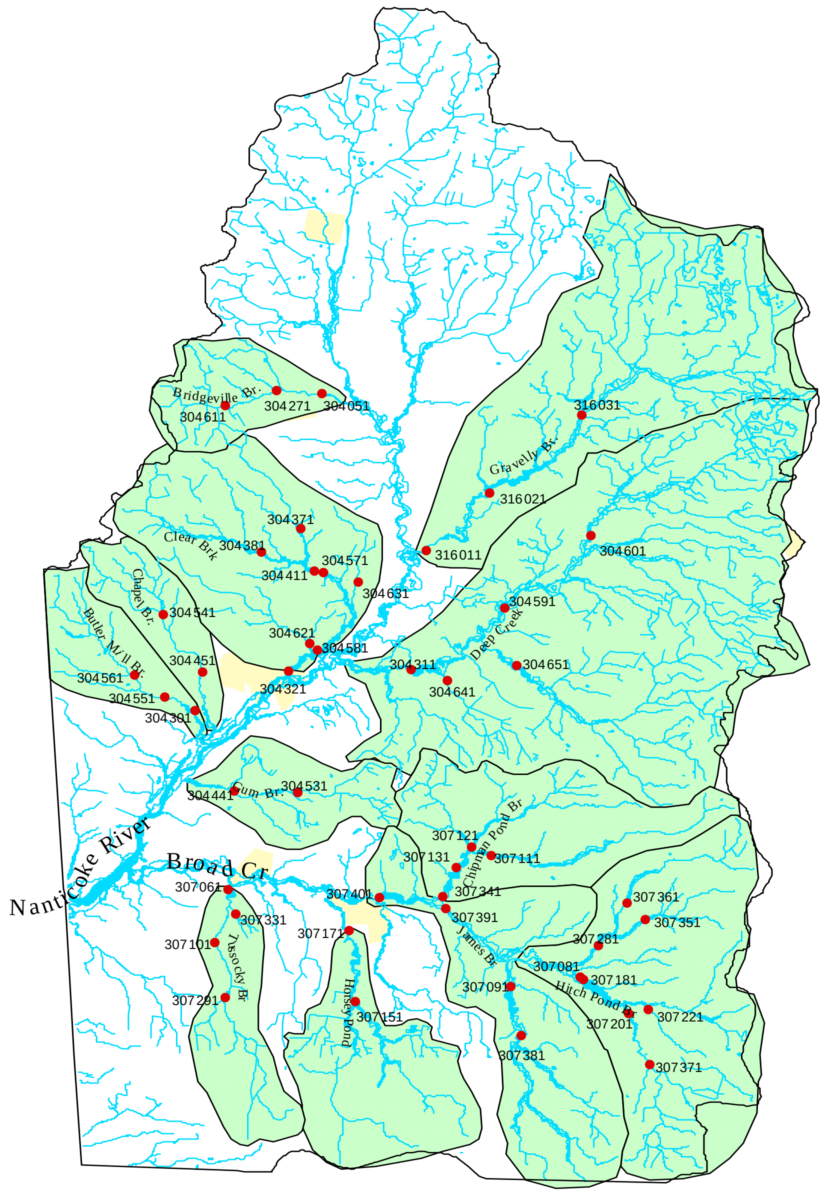


Figure 2 - 1. Water Quality Monitoring Stations

Table 2-2 Water Quality Parameters Analyzed for Tributary Samples (8)

Parameter	Storet Code	Method Reference (EPA)	Reporting Level
Water Column Nutrients			
Total Phosphorus	00665	EPA365.1	0.005 mg/l P
Soluble Ortho-phosphorus	00671	EPA365.1	0.005 mg/l P
Total Kjeldahl Nitrogen	00625	EPA351.2	0.05 mg/l N
Ammonia Nitrogen	00610	EPA350.1	0.005 mg/l N
Nitrite+Nitrate N	00630	EPA353.2	0.005 mg/l N
Carbon and Organics			
Total Organic Carbon	00680	EPA415.1	1 mg/l
Dissolved Organic Carbon	00681	EPA415.1	1 mg/l
Chlorophyll-a (Corr)	32211	10200H	0.001 mg/l
Pheophytin	32218	10200H	0.002 mg/l
Biochemical Oxygen Demand			
BOD_5, N-Inhib (CBOD)	80082	Stdmtd 18th ed.5210B	2.4 mg/l
BOD_{20}, N-Inhib (CBOD)	80087	Stdmtd 18th ed.5210B	2.4 mg/l
General			
Dissolved oxygen	00300	EPA360.2	0.25 mg/l
Total Suspended Solids	00530	EPA160.2	1 mg/l
Alkalinity	00410	EPA310.1	1 mg/l
Hardness	00900	EPA130.2	5 mg/l
Field pH	00400	EPA150.1	0.1 unit
Conductivity			1 umho/cm
Salinity	00096		1 ppt
Temperature	00010	EPA170.1	0.5°C
Secchi Depth	00077		in
Light Attenuation			%
Turbidity	00076	EPA180.1	0.5 FTU
Chloride	00940	EPA325.2	1 mg/l
Bacteria			
Enterococcus	31639	EPA111.Dc	1/100ml

Table 2-3. Average of Water Quality Monitoring Data

Tributary	Location	Station	Flow	w. Temp	DO	CBOD5	Chlor-a	TKN	NH3	NOXN	OrthoP	TP
			cfs	C	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Tussocky Br.	Head Water	307291	0.573	17.000	7.672	2.400	4.200	0.390	0.045	4.022	0.006	0.030
	Tusscky Pd &	307101	1.020	21.020	8.748	2.400	6.000	0.820	0.060	2.285	0.008	0.041
	Portsville Pd	307061		21.100	8.724	3.040	5.400	0.653	0.058	4.904	0.006	0.026
	Tributary	307331		21.900	5.800	2.400	1.000	2.820	1.820	11.700	0.004	0.016
Horsey Pond	Head Water	307151	6.760	16.475	7.943	2.400	9.250	0.638	0.061	2.960	0.022	0.099
	Horsey Pd	307171	3.473	20.900	10.144	2.980	35.800	0.830	0.046	1.811	0.014	0.075
James Br.	Record Pd	307011	23.080	20.300	8.770	2.452	12.600	0.755	0.156	3.004	0.010	0.061
	Record Pd	307401	44.710	18.750	9.350	3.578	24.000	0.815	0.043	3.243	0.012	0.035
	Mid James Br.	307391	0.000	16.940	6.964	2.400	3.400	0.710	0.050	4.238	0.020	0.048
	Trussum Pd	307091	5.250	19.420	5.584	3.884	37.800	1.853	0.070	0.699	0.012	0.110
	Head Water	307381	0.000	16.500	6.314	2.400	7.600	0.733	0.076	2.692	0.042	0.096
Hitch Pd Br.	Pepper Pd Br	307351	1.423	15.280	5.702	2.400	5.600	0.808	0.080	1.163	0.040	0.105
	Pepper Pd Br	307361	0.960	15.620	4.788	2.400	4.400	0.919	0.191	0.562	0.079	0.165
	Pepper Pd Br.	307281	3.097	16.020	6.098	2.400	4.400	0.899	0.057	3.414	0.020	0.055
	TrapPdOutfall	307081	5.087	20.250	7.145	2.400	7.500	0.990	0.091	0.521	0.092	0.182
	TrapPd	307181	0.000	21.280	8.124	2.684	20.800	2.093	0.057	0.379	0.023	0.124
	Raccoon Pd	307201	0.505	17.900	4.753	2.723	30.000	1.034	0.091	0.425	0.009	0.101
	Trib.frm	307221	0.240	15.125	7.140	2.400	6.000	0.616	0.061	3.070	0.017	0.063
	HdWater	307371	0.000	20.300	4.025	3.100	53.500	2.030	0.063	1.407	0.008	0.160
Chipman P Br.	Chipman Pd	307341	8.697	19.050	9.648	2.400	6.000	0.655	0.055	3.675	0.007	0.033
	Chipman Pd	307131	0.000	20.760	9.490	3.162	20.000	0.544	0.068	4.440	0.012	0.063
	Head Water	307111	0.483	15.060	7.498	2.424	5.000	0.514	0.056	5.062	0.015	0.087
	Trib to	307121	0.000	16.440	8.712	2.400	6.600	0.511	0.074	8.258	0.018	0.051
Gum Br.	Lower Strm R3	304441	0.700	16.240	7.184	2.400	5.600	0.998	0.105	5.960	0.011	0.123
	Head Water	304531	0.813	17.040	6.792	2.420	10.600	0.664	0.169	3.008	0.010	0.081
Deep Cr.	Trib. to Concord	304641	1.283	15.080	8.000	3.032	3.000	0.408	0.030	5.110	0.009	0.029
	Trib frm Tyndall	304651	6.815	17.800	8.925	2.400	6.250	0.321	0.052	3.493	0.019	0.051
	Concord PD	304311	22.067	19.980	9.214	2.832	7.600	0.490	0.042	1.270	0.012	0.021
	MidStrm btwn	304591	0.000	16.160	5.692	5.024	312.600	1.428	0.091	0.589	0.013	0.263
	Head Water	304601	4.710	17.200	7.016	2.400	6.200	0.638	0.040	0.607	0.018	0.050
Gravelly Br.	End of Gravelly	316011	0.000	16.660	8.182	2.400	7.600	0.571	0.052	2.386	0.007	0.026
	Outfall of Collins	316021	9.420	19.620	7.028	2.470	33.800	0.800	0.055	1.256	0.015	0.034
	Head Water to	316031	0.000	18.760	6.154	2.400	7.200	0.538	0.076	0.896	0.025	0.046
Bridgeville Br.	Lower seg	304051	5.030	18.820	9.322	3.330	9.000	0.975	0.088	4.722	0.021	0.066
	Mid & Upper	304271	4.843	18.340	7.084	2.400	3.400	0.820	0.117	3.984	0.017	0.044
	HeadWater	304611	0.667	17.380	7.102	2.400	5.600	0.701	0.054	3.980	0.011	0.050
Clear Brook	Outfall	304321		21.240	9.054	2.840	43.600	0.695	0.066	1.361	0.009	0.067
	William Pd	304581	0.000	21.160	8.968	3.340	46.400	0.826	0.040	1.426	0.007	0.067
	Herring Run	304621	0.000	17.660	5.666	2.814	10.200	1.060	0.141	4.064	0.019	0.089
	Newton Ditch	304631		15.800	2.400	2.400	3.000		0.017	2.890	0.048	
	Outfall of Hearn	304571	0.000	19.820	5.114	3.860	55.400	1.452	0.225	1.640	0.017	0.161
	Outfall of Hearn	304411	0.000	20.860	9.410	4.582	102.000	1.919	0.112	1.630	0.068	0.228
	Bucks Br.	304381	2.460	16.400	7.360	2.683	5.500	0.734	0.111	5.543	0.040	0.141
	Head water	304371	0.000	15.625	5.100	2.400	7.250	0.866	0.214	2.006	0.109	0.217
Chapel Br.	Mid & Lower seg	304451	2.030	15.720	7.008	2.410	2.600	0.543	0.045	8.762	0.015	0.032
	Head Water	304541	0.000	16.220	4.874	2.400	4.400	0.805	0.210	2.975	0.049	0.110
Butler M Br.	Crag Pd Outfall	304301	4.173	18.800	7.354	2.400	4.000	0.606	0.096	4.352	0.011	0.027
	Mid Seg	304551	2.140	14.625	8.268	2.400	5.000	0.865	0.042	6.940	0.020	0.045
	Head Water	304561	2.493	17.983	7.415	2.400	3.833	0.694	0.079	6.731	0.039	0.069

2.2 Stream Flow Data

Annual average flow and 7Q10 flow regimes are two flow conditions which are considered for these tributaries TMDL developments. Water quality data collected during 1998 to 1999 as well as the mean flow of water year 1999 are selected for model setup and calibration. 7Q10 flow is used in model scenario runs.

USGS station 01487000 at upstream of Nanticoke River near Bridgeville is the only one stream gaging station within the Nanicoke basin. It has a drainage area of 75.4 square miles. The annual mean flow of water year 1999 is 70.22 cfs (9), and 7Q10 flow is 14.92 cfs. Tributaries' annual mean flows and 7Q10 flows were calculated based on ratios of tributary drainage area to the drainage area at the USGS gaging station. Table 2-4 lists tributary drainage areas and their estimated annual mean flows during 1999 and 7Q10 flows.

Table 2-4. Tributary Annual Mean Flow during Y99 and 7Q10 Flow

Name of Stream	Watershed Area (mi2)	Estimated 7Q10 Flow (cfs)	Estimated 7Q10 Flow (m3/s)	Estimated Mean Y99 Flow (cfs)	Estimated Mean Y99 Flow (m3/s)
1. Tussocky Branch	11.53	2.28	0.065	10.73	0.30
2. Horsey Pond	14.80	2.93	0.083	13.78	0.39
3. Records Pond	73.93	14.63	0.414	68.85	1.95
4. Hitch Pd Br.	28.81	5.70	0.161	26.83	0.76
5. Chipman Pd Br.	18.09	3.58	0.101	16.84	0.48
6. Gum Branch	9.52	1.88	0.053	8.87	0.25
7. Deep Creek	65.22	12.91	0.365	60.74	1.72
8. Gravelly Br.	39.28	7.77	0.220	36.58	1.04
9. Bridgeville Br	7.61	1.51	0.043	7.09	0.20
10. Clear Brook	24.02	4.75	0.135	22.37	0.63
11. Chapel Br	7.72	1.53	0.043	7.19	0.20
12. Butler Mill Br	8.33	1.65	0.047	7.76	0.22

In addition to above estimations, stream flows were measured in the field as part of routine monitoring at free flowing water quality monitoring sites. A comparison of estimated flows and field measurements at several monitoring locations is shown in Figure 2 -2.

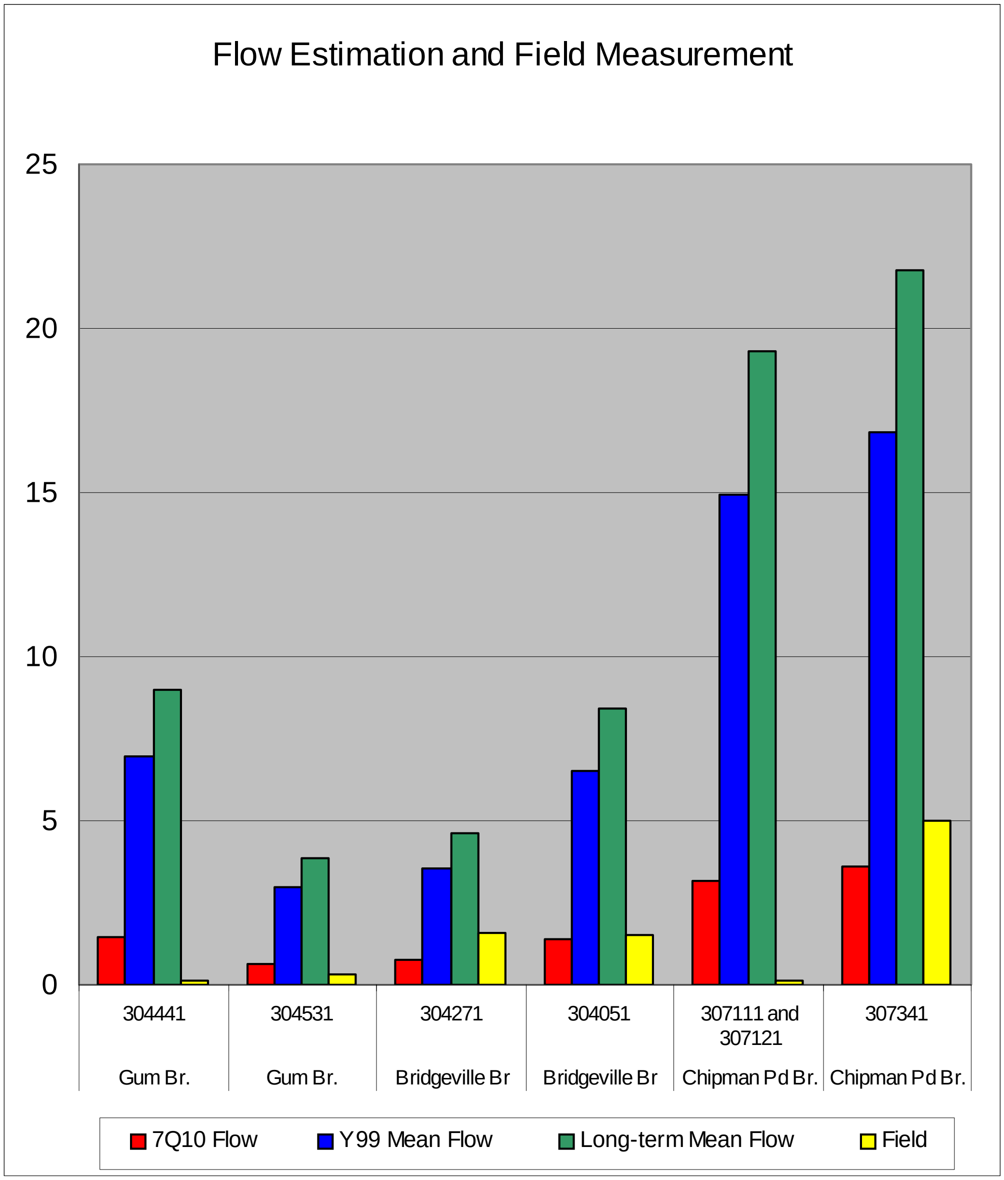


Figure 2 - 2. Comparison of Estimated Flows and Field Measurements

2.3 Physical Dimension Data

Tributaries in the Nanticoke basin are relatively small streams. Their widths range from 2.5 to 30.0 ft, while their depths vary from 0.5 to 2.0 ft. Field survey for obtaining stream dimension and other data were conducted in mid January of 2000. The stream width and depth were estimated using field survey data as well as 1:24000 USGS quadrangles. These results are presented in Table 2 - 5.

Table 2 - 5   Estimated Tributary Width and Depth

Tributary	Stream Reach	Width	Depth
		(ft)	(ft)
Gum Br.	Upper Br. (upstream frm Gum Br Rd at east side above)	8.0	1.0
	Mid. Br. (btwn two Gum Br Rds)	8.0	0.5
	Lower Br. (downstrm frm Gum Br Rd at west side down)	2.5	0.5
Deep Creek	Reach 1 (most upper stream)	10.0	0.5
	Reach 2	12.5	0.5
	Reach 3	6.0	0.6
	Reach 4 (upstrm of Concord Pd)	25.0	2.0
Gravelly Br.	Reach 1 (dwnstrm of Colins Pd)		
	Reach 2 (frm its mouth at Nanticoke R. up to Reach 1)		
Bridgeville Br.	Upper Br.	10.0	1.0
	Mid Br.	10.0	1.2
	Lower Br	15.0	1.2
Clear Brook	Reach btwn Hearns Pd and William Pd	20.0	1.3
Chapel Br.	Upper Br.	7.0	1.0
	Lower Br.	10.0	1.2
Butler Mill Br.	Upstrm of Craig Pd	10.0	1.2
Tussucky Br.	Upper Br. (upstrm of Tussuck Pd)	20.0	0.7
	Lower Br. (dwnstrm of Tussuck Pd)	15.0	1.0
Chipman Pd Br.	Upper Br. (upstm of Chipman Pd)	20.0	1.0
	Lower Br. (dwnstrm of Chipman Pd)	20.0	1.0
Hitch Pd Br.	Upper Br (upstrm of Trap Pd)	20.0	1.0
	Lower Br (dwnstrm of Trap Pd)	10.0	1.0
James Br.	Upper Br (frm dwnstrm of Trussum Pd to confl. with Hitch Pd Br)	20.0	1.0
	Lower Br (frm confl. with Hitch Pd Br. to head of Record Pd)	30.0	1.5

Pond information, presented in Table 2 - 6, is mainly obtained from two sources. One is from Delaware Department of Transportation (DelDOT) and another from Division of Fish and Wildlife (DFW), DNREC. In a few cases, when different values were reported for a pond in these two sources, then, DFW's data were chosen and used for the study.

Table 2 - 6 Physical Dimensions of Pond (10)(11)

Name of Pond	Waterway	Water Release Type****(12)	Dam Height	Surface Area	Volume	Max. Depth	Mean Depth
			(ft)	(acre)	(acre-ft)	(ft)	(ft)
Nanticoke River:							
1. Craigs Pond	Butler Mill Branch	pb	8**	11.9	45.50	7.0	3.8
2. Concord Pond	Deep Creek	s	13	67.6	236.60	6.0	3.5
3. William's Pond	Clear Brook	s	19	83.9	377.55	9.5	4.5
4. Hearns Pond	Clear Brook	s	18	53.4***	235.12	9.0	4.4
5. Collins Pond *	Gravelly Branch		12	102.8			4.0
Broad Creek:							
6. Portsville Mill Pond	Tussocky Branch	pb	12	14.5	56.46	8.0	3.9
7. Tussock Pond *	Tussock Branch	pb	10**	8.6	20.36	6.0	2.4
8. Horseys Pond	Little Creek	s	18	46.3	225.19	12.0	5.0
9. Records Pond	Broad Creek	p	11	91.9	364.30	10.0	4.0
10. Chipman Pond	Chipman Branch	s	16	52.4	220.84	8.0	4.2
11. Trussum Pond	James Branch	s	11	58.7***	228.80	8.0	3.9
12. Trap Pond	Hitch Pond Branch	s, pb	15	88.0	360.80	8.0	4.1
13. Raccoon Pond	Raccoon Prong	s	6	13.5	28.12	6.0	2.1
Average			**12**				**3.7**

* pond is not listed in 303(d) list
** estimated from field survey
*** from Delaware Public Ponds, Div. Of Fish and Wild Life, DNREC, 1993.
**** s - sluice boards; p - pipe with gate valve; pb - pipe with boards

3. Water Quality Model Structure

3.1 Model Selection

Stream water quality model Qual2E has been chosen as the framework for Nanticoke tributary TMDL development. This model is supported by U.S. EPA and has been widely used for studying the impact of conventional pollutants on streams and lakes.

The majority of the tributaries considered for this study are small free flowing streams with annual mean flow ranging from 0.26 to 2.22 cubic meter per second, width around 3 - 4 meter, and depth less than 0.5 meter. Therefore, basic stream transport and mixing processes should be considered by the selected model. As the streams are small and free flowing, one dimensional model will be adequate to represent the streams.

Water quality concerns for these tributaries and ponds include high nutrient concentrations, low DO, and possible algae bloom in sluggish segments during warm weather. The selected model should have the kinetic processes which describe nutrient (N and P) cycles, algal growth, temperature, nutrients, and dissolved oxygen.

Qual2E has the capacity for simulating the behavior of the hydrological and water quality components of a stream system. It has the basic stream transport and mixing processes and is a one dimensional model. Its chemical kinetic processes address nutrient cycles, algal growth, and DO reactions. Therefore, Qual2E was selected as the tool to set up the tributary TMDL model framework.

3.2 Model Framework

3.2.1 Introduction

Considering the principle of mass conservation, Qual2E uses one dimensional advection - dispersion mass transport equation, which is numerically integrated over space and time for each water quality constituent. This equation includes the effects of advection, dispersion, dilution, constituent reactions and interactions, and sources and sinks (13). Under steady-state conditions, the mass conservation equation for a computational element is written as:

$$\frac{\partial\left[A_X D_L (\partial C/\partial X)\right]}{A_X \partial X} - \frac{\partial\left(A_X \bar{u} C\right)}{A_X \partial X} + \frac{dC}{dt} + \frac{s}{V} = 0$$

where

X	=	distance (km)
C	=	concentration (mg/l)
A_X	=	cross-sectional area (m^2)
D_L	=	dispersion coefficient (m^2/s)

$\bar{u}$ = mean velocity (m/s)
s = external sources or sinks (mg/s)

and the hydrological balance is written:

$$\left(\frac{\partial Q}{\partial X}\right)_i = \left(Q_X\right)_i$$

where
$(Q_X)_i$ = sum of the external inflow and/or withdrawals to the element (13).

3.2.2 Spacial Coverages and Model Segmentation

As the twelve tributary streams are not physically connected with each other, each stream has to have its own model setup. Therefore, twelve tributary Qual2E models were set up. Each model consists of two or more reaches depending on stream physical dimensions. A reach is further divided into several computational elements which dictate the modeling computations and are required to be of equal length within each model setup. Therefore, for the convenience, a computational length of 0.5 km has been chosen for all 12 model setups. Table 3 - 1 lists the 12 tributaries with their Qual2E model coverages and number of reaches. Figure 3 - 1 shows model segments (or reaches).

Table 3 - 1 Spacial Coverages of Tributary Models

Tributary	Model Upstream Location	Model Downstream Location	Stream Length (km)	Number of Reach	Number of Computational Element
Gum Br.	Rd 485 (Oneals Rd)	Gum Br. Rd of west	3.5	3	7
Deep Creek	DE Rt. 18	Outfall of Concord Pd	10.0	5	20
Gravelly Br.	Outfall of Collins Pd	Confl. with Nanticoke R.	4.5	2	9
Bridgeville Br.	Rd. 564	Confl. with Nanticoke R.	5.5	3	11
Clear Brook	Inputs of Hearns Pd	Outfall of William Pd	8.5	5	17
Chapel Branch	Rd 547	Woodland Rd.	5.5	2	11
Butler Mill Br.	DE Rt. 20	Outfall of Craigs Pd	3.0	2	6
Tussucky Br.	DE Rt. 24	Portsville Pd outfall	5.5	3	11
Horsey Pond	Input of the pond	Outfall of the pond	2.0	2	4
Chipman Pd Br.	Confl. of Mirey Br. & Elliott Pd Br.	Confl. with James Br.	3.0	3	6
Hitch Pd Br.	Input of Raccoon Pd	Confl. with James Br.	6.5	4	13
James Pd Br (Incl Record Pd)	Input of Trussum Pd	Input to Record Pd	8.5	4	17
TOTAL			**66**		

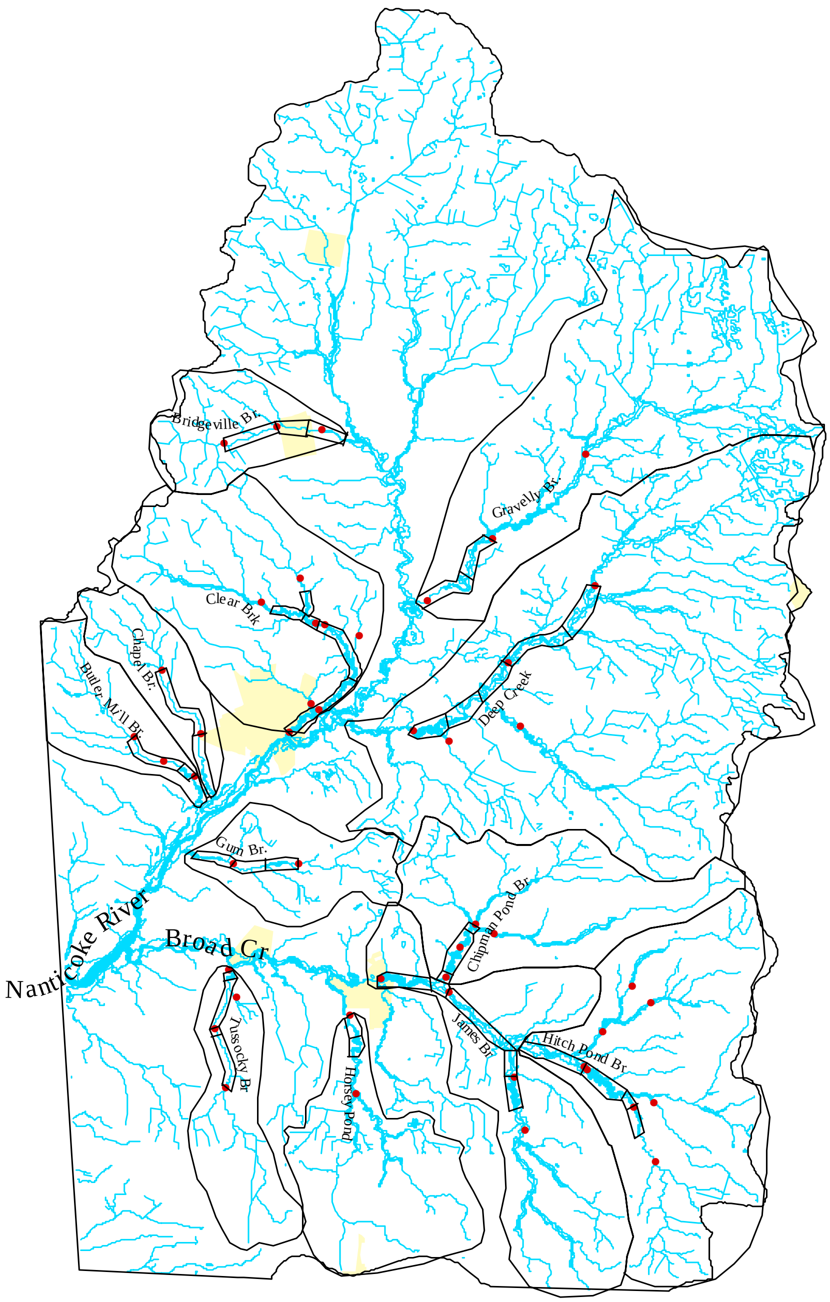


Figure 3 - 1 Tributary Model Segments

3.2.3 Simulated Constituents and Their Reactions

Tributary model simulates the following 9 constituents:

- Dissolved oxygen (DO)
- Biochemical oxygen demand (BOD)
- Algae as chlorophyll a
- Organic nitrogen as N
- Ammonia as N
- Nitrite as N
- Nitrate as N
- Organic phosphorus as P
- Dissolved phosphorus as P

The mathematical relationships that describe the individual reactions and interactions are presented as followings.

Chlorophyll a (13)

Chlorophylla be calculated using the following equation:

$$Chl\underline{a} = \alpha_0 A$$

where

Chl<u>a</u>	=	chlorophyll a concentration, ug/l
A	=	algal biomass concentration, mg/l
α_0	=	a conversion factor, ug Chl<u>a</u> / mg A

And

$$\frac{dA}{dt} = \mu A - \rho A - \frac{\sigma_1}{d} A$$

where

A	=	algal biomass concentration, mg/l
t	=	time, day
μ	=	local specific growth rate of algae as defined below, which is temperature dependent, 1/day
ρ	=	local respiration rate of algae, which is temperature dependent, 1/day
σ1	=	local settling rate for algae, temperature dependent, m/day
d	=	average depth, m

Algae specific growth rate can be calculated using the following equation:

$$\mu = \mu_{max} (FL) \, Min(FN, FP)$$

where

μ_{max}	=	maximum specific algal growth rate, 1/day
FL	=	algal growth limitation factor for light
FN	=	algal growth limitation factor for nitrogen
FP	=	algal growth limitation factor for phosphorous

The algal growth limitation factor for light can be estimated using:

$$FL = AFACT * f * FL_1$$

where

$$FL_1 = \frac{1}{\lambda d} \ln \left[\frac{K_L + \bar{I}_{alg}}{K_L + \bar{I}_{alg} e^{-\lambda d}} \right]$$

and

$$\bar{I}_{alg} = \frac{I_{tot}}{N}$$

In the above three equations:

FL	=	algae growth attenuation factor for light, adjusted for daylight hours and averaging method
AFACT	=	light averaging factor
f	=	fraction of daylight hours
FL_1	=	depth-averaged algal growth attenuation factor for light
K_L	=	half saturation coefficient for light, light intensity at which growth rate is 50% of maximum growth rate
d	=	depth of flow, m
λ	=	light extinction coefficient, 1/m
$\bar{I}_{alg}$	=	daylight average, photo synthetically active, light intensity, But/ft^2-hr
I_{tot}	=	total daily photo synthetically active solar radiation, But/ft^2
N	=	number of daylight hours per day, hr

Algal growth limitation for nitrogen and phosphorous can be calculated by:

$$FN = \frac{N_e}{N_e + K_N}$$

and

$$FP = \frac{P_2}{P_2 + K_P}$$

where

Ne	=	effective local concentration of available inorganic nitrogen $(NH_3 + NO_3)^{-N}$, mg/l
K_N	=	Michaelis-Menton half-saturation constant for nitrogen, mg/l
P_2	=	local concentration of dissolved phosphorous, mg/l
K_P	=	Michaelis-Menton half-saturation constant for phosphorous, mg/l.

Nitrogen Cycle (13)

Concentrations of various nitrogen compounds can be estimated by following equations:

Organic Nitrogen $dN_4 / dt = \alpha_1 \rho A - \beta_3 N_4 - \sigma_4 N_4$

Ammonia Nitrogen $dN_1 / dt = \beta_3 N_4 - \beta_1 N_1 + \sigma_3/d - F \alpha_1 \mu A$
and

$$F = P_N N_1 / (P_N N_1 + (1 - P_N)N_3)$$

Nitrite Nitrogen $dN_2/dt = \beta_1 N_1 - \beta_2 N_2$

Nitrate Nitrogen $dN_3/dt = \beta_2 N_2 - (1- F) \alpha_1 \mu A$

where

N_4	=	concentration of organic nitrogen, mg/l
N_1	=	concentration of ammonia nitrogen, mg/l
N_2	=	concentration of nitrite nitrogen, mg/l
N_3	=	concentration of nitrate nitrogen, mg/l
α_1	=	fraction of algal biomass that is nitrogen, mg-N/mg-A
ρ	=	algal respiration rate, 1/day
μ	=	algal growth rate, 1/day, 1/day
A	=	algal biomass concentration, mg/l
F	=	fraction of algal nitrogen uptake from ammonia pool
P_N	=	preference factor for ammonia nitrogen (0 to 1.0)
β_3	=	rate constant for hydrolysis of organic nitrogen to ammonia nitrogen, temperature dependent, 1/day
β_1	=	rate constant for biological oxidation of ammonia nitrogen, temperature dependent, 1/day
β_2	=	rate constant for oxidation of nitrite nitrogen, temperature dependent, 1/day
σ_4	=	rate coefficient for organic nitrogen setting, temperature dependent, 1/day
σ_3	=	benthos source rate for ammonia nitrogen, mg/m^2-day
d	=	mean stream depth, m

Phosphorus Cycle (13)

Concentrations of phosphorous species can be calculated using the following equations:

Organic Phosphorous $dP_1 / dt = \alpha_2 \rho A - \beta_4 P_1 - \sigma_5 P_1$

Dissolved Phosphorous $dP_2 / dt = \beta_4 P_1 + \sigma_2 /d - \alpha_2 \mu A$

where

P_1	=	concentration of organic phosphorous, mg/l
P_2	=	concentration of dissolved phosphorous, mg/l
α_2	=	phosphorous content of algae, mg-P/mg-A
ρ	=	algal respiration rate, 1/day
μ	=	algal growth rate, 1/day
A	=	algal biomass concentration, mg/l
β_4	=	organic phosphorous decay rate, temperature dependent, 1/day
σ_5	=	organic phosphorous settling rate, temperature dependent, 1/day
σ_2	=	benthos source rate for dissolved phosphorous, temperature dependent, mg/m^2-day
d	=	mean stream depth, m

<u>Carbonaceous BOD</u> (13)

Concentration of carbonaceous BOD can be estimated by:

$$dL / dt = - K_1 L - K_3 L$$

where

L	=	concentration of ultimate carbonaceous BOD, mg/l
K_1	=	BOD decay rate, temperature dependent, 1/day
K_3	=	BOD settling rate, temperature dependent, 1/day

Nanticoke tributary models use 5-day BOD values for input and output. The Qual2E model internally converts the BOD_5 to ultimate CBOD using the following equation:

$$BOD_5 = L (1 - e^{5*(-KBOD)})$$

where

KBOD = BOD conversion rate coefficient, 1/day

<u>Dissolved Oxygen</u> (13)

Dissolved oxygen concentration of water column can be estimated by:

$$dO / dt = K_2 (O^* - O) + (\alpha_3 \mu - \alpha_4 \rho) A - K_1 L - K_4/d - \alpha_5 \beta_1 N1 - \alpha_6 \beta_2 N_2$$

and saturation concentration of DO can be calculated by:

$$\ln O^* = -139.34410 + (1.575701 * 10^5/T) - (6.642308 * 10^7/T^2) + (1.243800 * 10^{10}/T^3) - (8.621949 * 10^{11}/T^4)$$

where

O	=	concentration of dissolved oxygen, mg/l
O*	=	saturation concentration of DO and local temperature and pressure, mg/l
K_1	=	BOD decay rate, temperature dependent, 1/day
K_2	=	reaeration rate, temperature dependent, 1/day
K_4	=	sediment oxygen demand rate, temperature dependent, g/m^2-day
α_3	=	rate of oxygen production per unit of algal photosynthesis, mg-O/mg-A
α_4	=	rate of oxygen uptake per unit of algal respired, mg-O/mg-A
α_5	=	rate of oxygen uptake per unit of ammonia nitrogen oxidation, mg-O/mg-N
α_6	=	rate of oxygen uptake per unit of nitrite nitrogen oxidation, mg-O/mg-N
ρ	=	algal respiration rate, 1/day
μ	=	algal growth rate, 1/day
A	=	algal biomass concentration, mg/l
L	=	concentration of ultimate carbonaceous BOD, mg/l
d	=	mean stream depth, m
β_1	=	rate constant for biological oxidation of ammonia nitrogen, temperature dependent, 1/day
β_2	=	rate constant for oxidation of nitrite nitrogen, temperature dependent, 1/day
N_1	=	concentration of ammonia nitrogen, mg/l
N_2	=	concentration of nitrite nitrogen, mg/l
T	=	temperature, ^{0}K (T ^{0}K = ^{0}C + 273.150), and ^{0}C is within 0 to 40 ^{0}C

Temperature Effect on Reaction Rates (13)

Temperature effect on reaction rates can be calculated by:

$$X_T = X_{20}\, \Theta^{(T-20)}$$

where

X_T	=	value of the coefficient at the local temperature (T)
X_{20}	=	value of the coefficient at the standard temperature (20 ^{0}C)
Θ	=	an empirical constant for each reaction coefficient

3.2.4 System Parameters

The chemical and biological reactions that are simulated by Qual2E are represented by a complex set of equations that contain many system parameters; some are global constant, some are spacial variables, and some are temperature dependent. Table 3 - 2 lists these system parameters with their units and the range of values used in the Nanticoke tributary models calibrations.

Table 3 - 2 Qual2E Model System Parameters

Parameter	Description	Unit	Range of Values
α_0	Ratio of chlorophyll-a to algal biomass	ug-Chl a / mg A	10-100
α_1	Fraction of algal biomass that is Nitrogen	mg-N / mg A	0.07-0.09
α_2	Fraction of algal biomass that is Phosphorus	mg-p / mg A	0.01-0.02
α_3	O_2 production per unit of algal growth	mg-O / mg A	1.4-1.8
α_4	O_2 uptake per unit of algae respired	mg-O / mg A	1.6-2.3
α_5	O_2 uptake per unit of NH_3 oxidation	mg-O / mg N	3.0-4.0
α_6	O_2 uptake per unit of $N0_2$ oxidation	mg-O / mg N	1.0-1.14
μ_{max}	maximum algal growth rate	day-I	1.0-3.0
ρ	Algal respiration rate	day-I	0.05-0.5
K_L	Michaelis-Menton half- saturation constant for light (Option 1)	Btu/ft2-min	0.02-0.10
K_N	Michaelis-Mention half- saturation constant for nitrogen	mg-N/L	0.01-0.30
K_p	Michaelis-Menton half- saturation constant for phosphorus	mg-P/L	.(01-0.05
λ_0	Non-algal light extinction coefficient	ft-I	Variable
λ_1	Linear algal self-shading coefficient	(1/ft) / (ug Chl-a/L)	0.002-0.02
λ_2	Nonlinear algal self- shading coefficient	(1/ft) / (λg Chl-a/L)2/3	0.0165 (RiIey)
P_N	Algal preference factor for ammonia	-	0.0-1.0
σ_1	Algal settling rate	ft/day	0.5-6.0
σ_2	Benthos source rate for phosphorous	mg-p / ft2-day	Variable
σ_3	Benthos source rate for ammonia nitrogen	mg-O / ft2-day	Variable
σ_4	Organic nitrogen settling rate	day-I	0.001-0.1
σ_5	Organic phosphorus settling rate	day-I	0.001-0.1
σ_6	Arbitrary non-conservative settling rate	day-I	Variable
σ_7	Benthal source rate for arbitrary non-conservative settling rate	mg-ANC / ft2-day	Variable
K_1	Carbonaceous deoxygeneration rate constant	day-I	0.02-3.4
K_2	Reaeration rate constant	day-I	0.0-100
K_3	Rate of loss of BOD due to settling	day-I	-0.72
K_4	Benthic oxygen uptake	mg-O / ft2-day	Variable
K_5	Coliform die-off rate	day-I	0.05-4.0
K_6	Arbitrary non-conservative decay coefficient	day-I	Variable
β_1	Rate constant for the biological oxidation of NH3 to tIO2	day -1	0.10 - 1.00
β_2	Rate constant for the biological oxidation of N02 to N03	day-I	0.20-2.0
β_3	Rate constant for the hydrolysis of organic- N to ammonia	day-I	0.02-0.4
β_4	Rate constant for the decay of organic-P to dissolved-P	day-I	0.01-0.7

3.2.5 Input Data

Hydraulic Characteristics

The option of functional representation, rather than geometric representation, has been chosen for all the tributary models to describe the stream hydraulic characteristics, since the channel dimension data collected isn't sufficient for using geometric representation. Therefore, hydraulic characteristics of the stream segments are determined by equations of the form:

$$\bar{u} = aQ^b$$

$$A_X = Q / \bar{u}$$

$$d = \alpha Q^\beta$$

where a, b, α, and β are empirical constants, $\bar{u}$ is stream mean velocity (m/s), and d is the stream depth.

Constants a, b, α, and β were calculated for each stream segment using field survey data and are listed in Table 3 - 3.

Table 3 - 3 Empirical Constants for Tributary Models

Stream	Reach	*a***	*b***	*α***	*β***
1. Gum Branch	Reach 1	0.306	0.250	1.326	0.750
	Reach 2	0.347	0.415	1.141	0.578
	Reach 3	0.453	0.510	0.888	0.490
2. Deep Creek	Reach 1	0.191	0.144	0.508	0.405
	Reach 2	0.175	0.149	0.468	0.419
	Reach 3	0.890	0.101	0.374	0.899
	Reach 4	0.114	0.157	0.383	0.706
	Concord pd	0.008	0.260	0.726	0.710
3. Gravelly Br.	Reach 1	0.506	0.334	0.363	0.330
	Reach 2	0.506	0.334	0.363	0.330
4. Bridgeville Br	Reach 1	0.173	0.125	0.585	0.785
	Reach 2	0.253	0.169	0.642	0.371
	Reach 3	0.336	0.586	0.507	0.233
5. Clear Brook	Hearn Pd - Main	0.005	0.284	1.826	0.434
	Hearn Pd - Trib	0.004	0.301	2.209	0.415
	Hearn Pd	0.005	0.284	1.826	0.434
	Reach 4	0.267	0.154	0.524	0.511
	William Pd	0.006	0.306	1.555	0.601
6. Chapel Br	Reach 1	0.468	0.250	0.641	0.472
	Reach 2	0.426	0.457	0.492	0.212
7. Butler Mill Br	Reach 1	0.476	0.540	0.490	0.202
	Craig Pd	0.004	0.444	2.237	0.516
8. Tussocky Br.	Reach 1	0.469	0.631	0.276	0.202
	Tussocky Pd	0.012	0.426	1.229	0.462
	Reach 3	0.419	0.479	0.397	0.261
	Portsville Mill Pd	0.004	0.238	2.309	0.695

Stream	Reach	*a***	*b***	*α***	*β***
9. Horsey Pd	Reach 1	0.005	0.361	2.351	0.629
	Reach 2	0.005	0.361	2.351	0.629
10. Chipman Pd Br.	Reach 1	0.408	0.286	0.389	0.601
	Chipman Pd	0.004	0.361	1.710	0.601
	Reach 3	0.408	0.286	0.389	0.601
11. Hitch Pd Br.	Raccoon Pd	0.011	0.387	1.527	0.557
	Reach 2	0.198	0.320	0.954	0.670
	Trap Pd	0.004	0.710	1.383	0.159
	Reach 4	0.716	0.296	0.435	0.621
12. Records Pond	Trussum Pd	0.004	0.645	1.529	0.350
	Reach 2	0.346	0.225	0.437	0.594
	Reach 3	0.277	0.492	0.401	0.345
	Records Pd	0.009	0.213	0.622	0.711

Initial Conditions

Prior to the start of a model simulation, initial conditions were assigned to each segment of these tributary models. Initial condition for a segment consists of a set of concentration values including DO, BOD_5, Chl-a, organic nitrogen, ammonia nitrogen, nitrite nitrogen, nitrate nitrogen, organic phosphorous, dissolved phosphorous, and a water temperature value (in centigrade). Water quality monitoring stations located within a tributary model domain were assigned to corresponding model segments. These station assignments are listed in the third column of Table 3-4.

Concentrations of input constituents are average values of monitoring results during a period of July 1998 through October 1999. Because organic nitrogen (orgN), nitrite nitrogen (NO_2_N), nitrate nitrogen (NO_3_N), and organic phosphorous (orgP) were not directly measured, they were calculated from measured values as follows:

$$\begin{aligned} \text{orgN} &= \text{TKN} - NH_3\text{\_N} \\ NO_2\text{\_N} &= 0.1 * \text{NOXN} \\ NO_3\text{\_N} &= 0.9 * \text{NOXN} \\ \text{orgP} &= \text{TP} - \text{disP} \end{aligned}$$

where

TKN	=	total Kjedhal nitrogen, mg/l
NOXN	=	combination of nitrite nitrogen and nitrate nitrogen, mg/l
TP	=	total phosphorous, mg/l
disP	=	dissolved phosphorous, which assumed equal to ortho phosphorous

Initial temperature values were used to calculate the temperature dependent coefficient parameters, since stream temperatures are considered constant in the model.

Boundary Conditions

Upper boundary condition, which Qual2E refers to headwater, defines the most upstream condition of a model domain. Data from the nearest water quality monitoring stations were assigned to each tributary stream model to define the headwater condition. These station assignments are listed in column 4 of Table 3-4.

Same as the initial condition, concentrations of input constituents are average values of monitoring results during July 1998 - October 1999. Organic nitrogen (orgN), nitrite nitrogen (NO_2_N), nitrate nitrogen (NO_3_N), and organic phosphorous (orgP) were calculated from measured values.

Lower boundary condition is open condition, which Qual2E calculates their concentration values without the need for input data.

Tributary Inflows

Tributary inflow, or point source as called by Qual2E, defines the water quality condition of small tributaries which input to the simulated stream segments. Data from the nearest water quality monitoring stations were assigned to each tributary stream model to define the tributary condition. These station assignments are listed in fifth column of Tables 3-4 (tributary column).

Same as the initial condition, concentrations of input constituents are average values of monitoring results during July 1998 - October 1999. Organic nitrogen (orgN), nitrite nitrogen (NO_2_N), nitrate nitrogen (NO_3_N), and organic phosphorous (orgP) were calculated from measured values.

Incremental (Distributed) Inflows

Incremental Inflow, or distributed source, defines the water quality condition of the flow, other than from point source, which enter the simulated stream segments. Data from the nearest water quality monitoring stations were assigned to each tributary stream model to define the incremental flow condition. These station assignments are listed in sixth column of Table 3-4 (incremental column).

Same as the initial condition, concentration of input constituents are average values of monitoring results during July 1998 - October 1999. Organic nitrogen (orgN), nitrite nitrogen (NO_2_N), nitrate nitrogen (NO_3_N), and organic phosphorous (orgP) were calculated from measured values.

Table 3 - 4 Input Conditions for Tributary Models

Stream	Reach	Initial	Headwater	Tributary	Incremental
Gum Br.	1	304531	304531		304531
	2	304441		304531	304531
	3	304441		304531	304531
Deep Cr	1	304601	304601	304601	304601
	2	304591		304601	304601
	3	304591		304641/304651	304641
	4	304591		304641	304641
	5	304311		304641	304641
Gravelly Br.	1	316021	306021		316031
	2	316011			316031
Bridgeville Br.	1	304611	304611		304611
	2	304271		304611	304611
	3	304051			304611
Clear Bro.	1	304411	304371		304371
	2	304411	304381	304371	
	3	304411			304371
	4	304571		304371	304371
	5	304581		304621	304621
Chapel Br.	1	304451	304541	304541	304541
	2	304451			304541
Butler Mill Br.	1	304551	304561	304561	304561
	2	304301			304561
Tussucky Br.	1	307291	307291		307291
	2	307101			307291
	3	307101		307331	307331
	4	307061			307291
Chipman Pond Br.	1	307121	avg(307111&307121)		
	2	307131			avg(307111&307121)
	3	307341			avg(307111&307121)
Hitch Pond Br.	1	307201	307371		307361
	2	307201			307361
	3	307181		307221	307361
	4	307081		307281	307361
James Br.	1	307091	307381		307381

Stream	Reach	Initial	Headwater	Tributary	Incremental
	2	307391		307381	307381
	3	307391		307381	307381
	4	307401		307381	307381

Qual2E input data structure as well as parameter values constitute the first part of the model output file. An example of input data for Bridgeville Branch Qual2E model is shown in Appendix B of this report..

4. Model Development and Calibration

As the tributaries and ponds studied in this report are not physically connected with each other, separate Qual2E models have been constructed. Each tributary stream has its own model setup.

In developing and calibrating Qual2E models for tributaries and ponds of the Nanticoke River and Broad Creek, a greater emphasis is placed on achieving reasonable agreements between model predictions and observed field data at most downstream segments. This is because downstream segments provide tributary (nonpoint source) loads to the mainstems, hence, have greater impact on water quality of the Nanticoke River and Broad Creek.

Qual2E model development and calibration for tributaries and ponds of the Nanticoke River and Broad Creek are described under each tributary heading.

4.1 Tributary Models

Bridgeville Branch was divided into three reaches (see Figure 3 -1 for the model segmentation). The Qual2E model starts from headwaters at 0.0 km and ends at 5.5 km, the confluence with the Nanticoke River. A tributary enters Bridgeville Branch at 2.5 km.

Organic nitrogen, nitrate nitrogen, and nitrite nitrogen values of some upstream tributary stations were manually adjusted to agree with the observed data of downstream stations. Figures 4-1 to 4-3 present the calibration results for this tributary. Qual2E model output file for Bridgeville Branch is included in Appendix B of this report.

Butler Mill Branch Craig Pond was included in this tributary model. The branch was divided into two reaches (see Figure 3-1 for the model segmentation). The Qual2E model starts from Butler Branch headwaters at 0.0 km and ends at the outflow of Craig Pond at 3.0 km. Craig Pond is located at the most downstream segment from 2.5 to 3.0 km. A small tributary enters Butler Mill Branch at 1.0 km.

Dissolved and total phosphorous predictions were slightly higher than the observed field data, however, total phosphorous concentration was less than the target value of 0.1 mg/l, hence, no further adjustment was performed for phosphorous. Regarding nitrogen species, nitrate nitrogen values of headwater, tributary, and incremental flows were manually adjusted to meet the downstream observation data. Figures 4-4 to 4-6 present the calibration results for Butler Mill Branch.

Chapel Branch was divided into two reaches (see Figure 3-1 for model segmentation). The model starts from Chapel Branch headwaters at 0.0 km and ends at the confluence with Butler Mill Branch at 5.5 km. A tributary enters Chapel Branch at upstream portion at 1.0 km.

Dissolved phosphorous concentrations of tributary flow and incremental flow were manually adjusted to agree with the observed field data at downstream stations. In addition, nitrate and nitrite nitrogen were manually adjusted to agree with the observed data. Other parameter predictions agreed well with the observed data. Figures 4-7 to 4-9 present the calibration results for Chapel Branch.

Chipman Pond Branch Chipman Pond was included in the tributary model for Chipman Pond Branch. The branch was divided into three reaches (see Figure 3-1 for the model segmentation). The Qual2E model starts from the headwaters at 0.0 km and ends at 3.0 km, with Chipman Pond located between 0.5 to 2.0 km.

Concentrations of nitrate and nitrite nitrogen from headwater and incremental flows were manually adjusted to agree with the down stream observations. Other parameters agreed well with the observed data. Figures 4-10 to 4-12 present the calibration results for Chipman Pond Branch.

Clear Brook Hearns Pond and Williams Pond were included in the Clear Brook Qual2E model. The tributary was divided into five reaches (see Figure 3-1 for the model segmentation). Model starts from inflow of Hearns Pond at 0.0 km and ends with outflow of Williams Pond at 8.5 km. Upper portions of Hearns Pond has two branches, one receives water from Clear Brook and another from Bucks Branch. The branch receiving water from Clear Brook has the stream kilometer from 0.0 to 1.0, while another branch has the stream kilometer from 1.0 to 2.0. Lower portions of the pond runs from 2.0 to 2.5 km. A tributary enters Bucks Branch at 2.0 km. Williams Pond locates between 5.5 km and 8.5 km and receives flow from Herring Run at 7.5 km. William Newton Ditch enters Clear brook at 5.0 km.

Nitrate and total nitrogen were over estimated at Williams Pond. Figures 4-13 to 4-15 present the calibration results. For the rest of the parameters, model predictions agreed well with the field data.

Deep Creek Concord Pond was included in the Deep Creek Qual2E model. The creek was divided into five reaches (see Figure 3-1 for the model segmentation). Model starts from the headwaters at 0.0 km and ends at 10.0 km. Concord Pond is located at 8.5 km to 10 km. Nine small tributaries enter Deep Creek at various locations along the stream and one of them enters Concord Pond.

Nitrate nitrogen and total nitrogen were over estimated at most down stream segments including Concord Pond. However, the concentrations of both parameters were well less than the targeted value of 3.0 mg/l, hence no further adjustment was performed. Figures 4-16 to 4-18 present the calibration results for Deep Creek.

Gravelly Branch was divided into two reaches (see Figure 3-1 for the model segmentation). The Qual2E model for Gravelly Branch starts from outflow of Collins Pond at 0.0 km and ends at 4.5 km confluence with the Nanticoke River.

Nitrite and nitrate nitrogen values of headwater and incremental flows were manually adjusted to agree with the downstream field observations. For the rest of parameters, model predictions agreed well with the observed data. Figures 4-19 to 4-21 present the calibration results for Gravelly Branch.

Gum Branch was divided into three reaches (see Figure 3-1 for the model segmentation). The Qual2E model for Gum Branch starts from headwater at 0.0 km and ends at 3.5 km. Three tributaries enter the Gum Branch at 1.5 km, 2.0 km, and 3.0 km, respectively.

Organic nitrogen, nitrite nitrogen and nitrate nitrogen values of the 3 tributaries and incremental flows were manually adjusted to agree with the downstream field observations. For other parameters, model predictions agreed well with the observed data. Figures 4-22 to 4-24 present the calibration results for Gum Branch.

Hitch Pond Branch Trap Pond and Raccoon Pond were included in the Qual2E model for Hitch Pond Branch. The branch was divided into four reaches (see Figure 3-1 for the model segmentation). The model starts from the headwaters at 0.0 km and ends at 6.5 km. Raccoon Pond is located between 0.0 and 1.0 km, and Trap Pond between 1.5 and 3.5 km. Two tributaries enter Trap Pond and one tributary enters downstream segment of Trap Pond at 4.0 km.

Nitrate and nitrite nitrogen of headwaters and incremental flows were manually adjusted to agree with the down stream field observations. For other parameters, model predictions agreed well with the observed data. Figures 4-25 to 4-27 present the calibration results for Hitch Pond Branch.

Horsey Pond was divided into 2 reaches from pond inflow to pond spillway (see Figure 3-1 for the model segmentation). Nitrate nitrogen was over estimated, so did total nitrogen. The rest of the parameter predictions agreed with the observed data well. Figures 4-28 to 4-30 present the calibration results for Horsey Pond.

James Branch Records Pond and Trussum Pond were included in the Qual2E model for James Branch. The branch was divided into 4 reaches (see Figure 3-1). The Qual2E model starts from the headwaters at 0.0 km to the ends at 8.5 km. Trussum Pond is located between 0.0 and 1.5 km, and Record Pond between 6.5 and 8.5 km. One tributary enters Record Pond and 6 other tributaries enter the branch at various locations along the stream between the two ponds.

Figures 4-31 to 4-33 present the calibration results for James Branch.

Tussocky Branch Tussock Pond and Portsville Mill Pond were included in the Qual2E model for Tussocky Branch. The branch was divided into four reaches (see Figure 3-1 for the model segmentation). The model starts from the headwaters at 0.0 km and ends at 5.5 km. Tussock Pond is located between 2.0 and 2.5 km, and Portsville Mill Pond between 5.0 and 5.5 km. A small tributary enter the branch at 4.0 km which is between the two ponds.

Organic nitrogen and organic phosphorous were under estimated for the two ponds, while nitrate nitrogen and dissolved phosphorous were over estimated. These discrepancies could be attributed to model's inability to simulate benthic processes. Ammonia nitrogen has a hump around 4.5 km, which is the result of high ammonia input from the small tributary entered at this location. Figures 4-34 to 4-36 present the calibration results for the Tussocky Branch.

4.2 Statistical Summary

In order to quantify developed models' ability of predicting field observations, tributary model predictions are compared to observed data at the monitoring locations. Statistical relative difference for each modeled pollutant for each tributary model is calculated and listed in Table 4-1 and shown in Figures 4-37 and 4-38.

The relative difference between model predictions and observations for each pollutant of the model is defined by equation below which is the ratio of the absolute difference between model predictions and observations to the average of the observations and is expressed in a percent.

$$D\% = \frac{\sum |M - O_{avg}|}{\sum O_{avg}} * 100$$

where

D%	=	relative difference in percent
M	=	model output, concentrations at the monitoring locations
O_{avg}	=	average of field observations at the monitoring locations

Table 4 - 1. Summary of Tributary Models Relative Differences for Modeled Parameters

Tributary	DO	BOD	Org-N	NH3N	NO2N	NO3N	TN	Org-P	Dis-P	TP	Chl-a
Bridgeville Br.	8.66	10.95	2.82	15.83	5.85	1.16	1.03	17.65	38.78	14.11	29.94
Butler Mill Br.	3.03	0.00	11.20	20.11	3.43	19.65	17.00	12.49	71.84	48.87	8.70
Chapel Br.	6.04	0.21	2.38	37.42	16.07	11.33	9.74	18.57	26.18	27.34	13.86
Chipman Br.	6.10	9.46	10.40	14.62	32.32	25.81	23.63	13.79	39.47	21.64	43.87
Clear Brook	15.50	21.34	29.06	24.95	22.59	47.99	29.84	14.25	22.97	10.57	22.04
Deep Cr.	3.44	28.12	33.84	7.85	27.03	30.51	27.60	39.52	40.85	24.70	51.38
Gravelly Br.	1.34	0.21	13.08	21.50	33.79	30.89	25.89	4.17	35.19	12.50	59.42
Gum Br.	2.60	0.41	2.77	20.26	1.87	2.96	2.10	23.01	6.54	21.28	21.11
Hitch Pd Br.	7.65	3.28	42.02	38.50	53.38	72.28	53.51	33.52	53.01	44.14	64.32
Horsey Pond	8.80	0.37	7.84	13.39	9.88	22.49	14.21	2.32	17.01	3.95	21.18
James Br.	13.92	7.68	31.73	61.74	42.29	45.29	21.62	40.44	21.17	28.94	51.54
Tussocky Pd Br.	2.69	0.13	34.65	28.61	7.50	21.31	11.70	21.65	48.51	16.23	6.15

To compare the magnitude of relative differences among various water quality modeling exercises, the Hydrodynamic and Water Quality Model of Christina River Basin (14) has summarized relative differences for DO, chlorophyll a, TN and TP from 15 to 20 modeling studies. The results are summarized in Table 4 - 2 below and are used as a benchmark for comparison with the calibration results of Qual2E models for tributaries and ponds of Nanticoke River and Broad Creek.

Table 4 - 2. Range of Relative Differences From Other Models

	DO	Chlorophyll a	TN	TP
Range of Relative Difference	5% - 58%	6% - 76%	6% - 33%	6% - 48%

As it can be seen, DO predictions for Qual2E models of tributaries and ponds of the Nanticoke River and Broad Creek are well calibrated, as majority of the statistic relative differences are less than 10 percent, only James Branch and Clear Brook exceed 10% and have 14% and 16% relative difference respectively.

For chlorophyll a simulation, the relative differences range from 6% to 64% and are within the reference ranges as listed in Table 4 - 2.

Total nitrogen simulations are within the reference range, except for Hitch Pond Branch which has relative difference of 53.51%. This is mainly related to the over estimation of nitrate nitrogen for upstream at Raccoon Pond. Manual adjustment of headwater nitrate nitrogen to agree with the downstream field observations was the main factor for this relative difference.

Total phosphorous simulation are generally within the reference range of 6% - 48%. Similarly, dissolved phosphorous calibration are in the reasonable ranges as indicated by Tables 4-1 and 4-2.

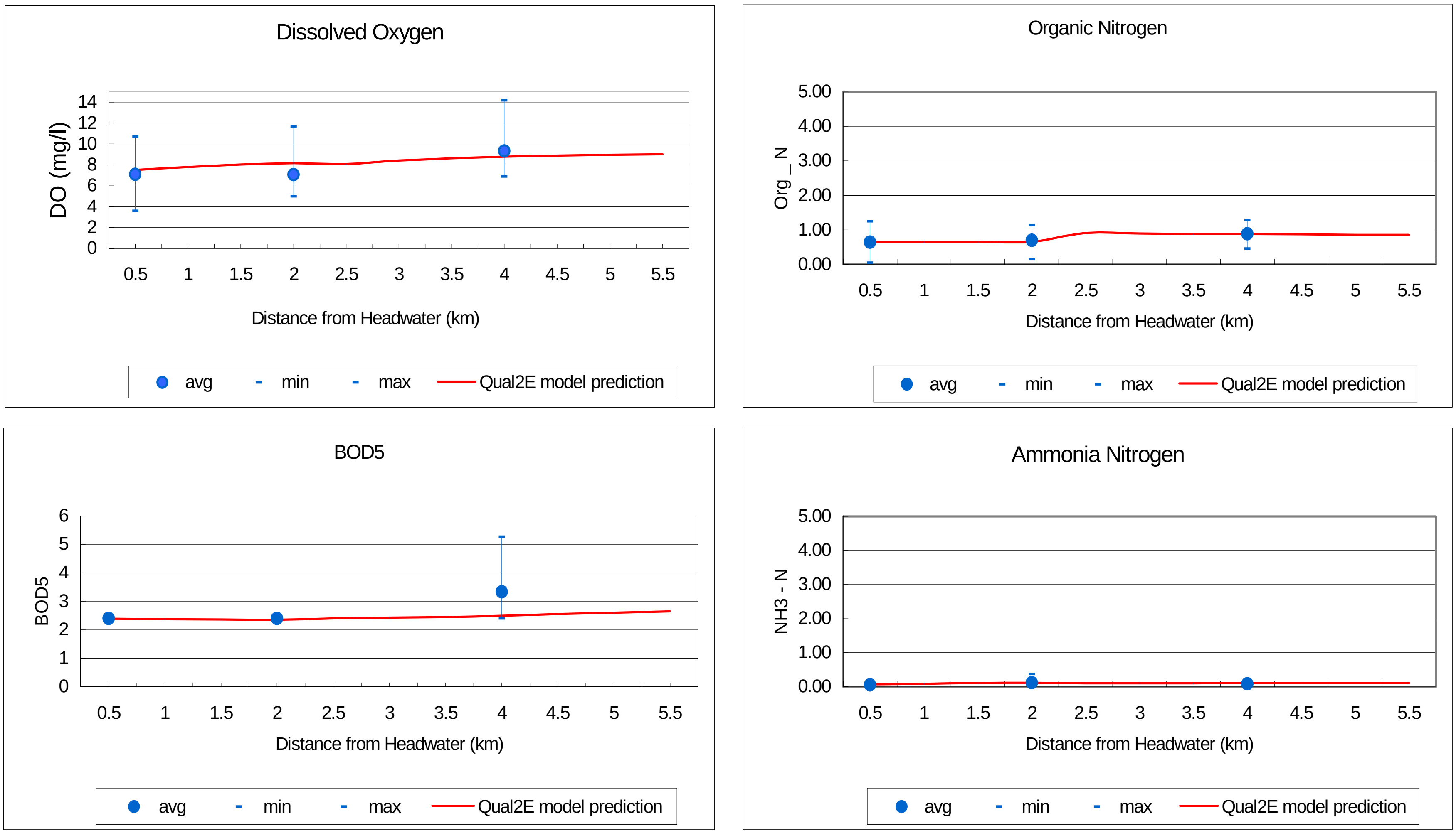


Figure 4 - 1 Bridgeville Branch DO, BOD5, Org_N, and NH3_N Calibration

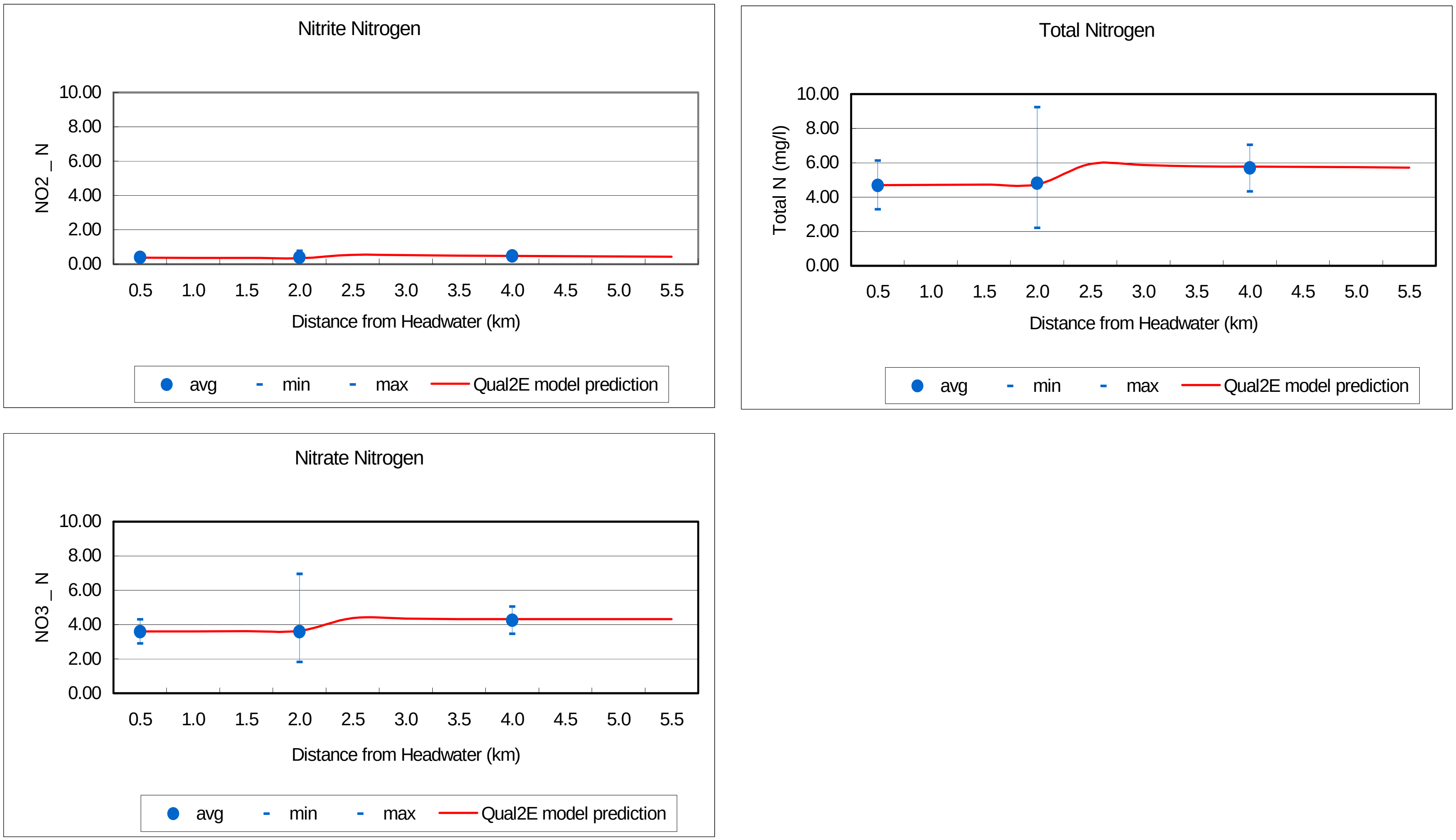


Figure 4 - 2 Bridgeville Branch Nitrite, Nitrate and Total Nitrogen Calibration

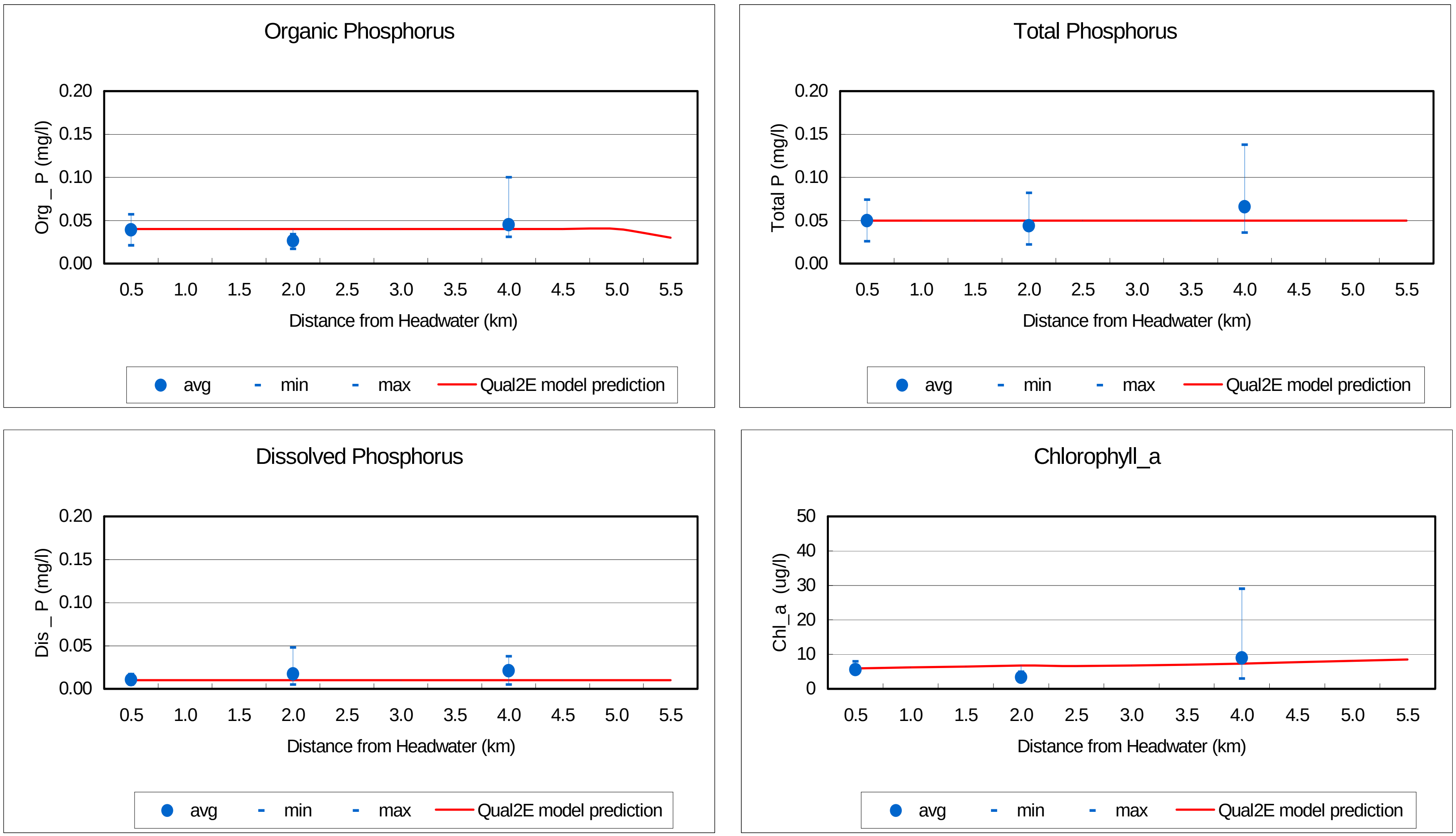


Figure 4 - 3 Bridgeville Branch Org_P, Dis_P, Total P, and Chlorophyll_a Calibration

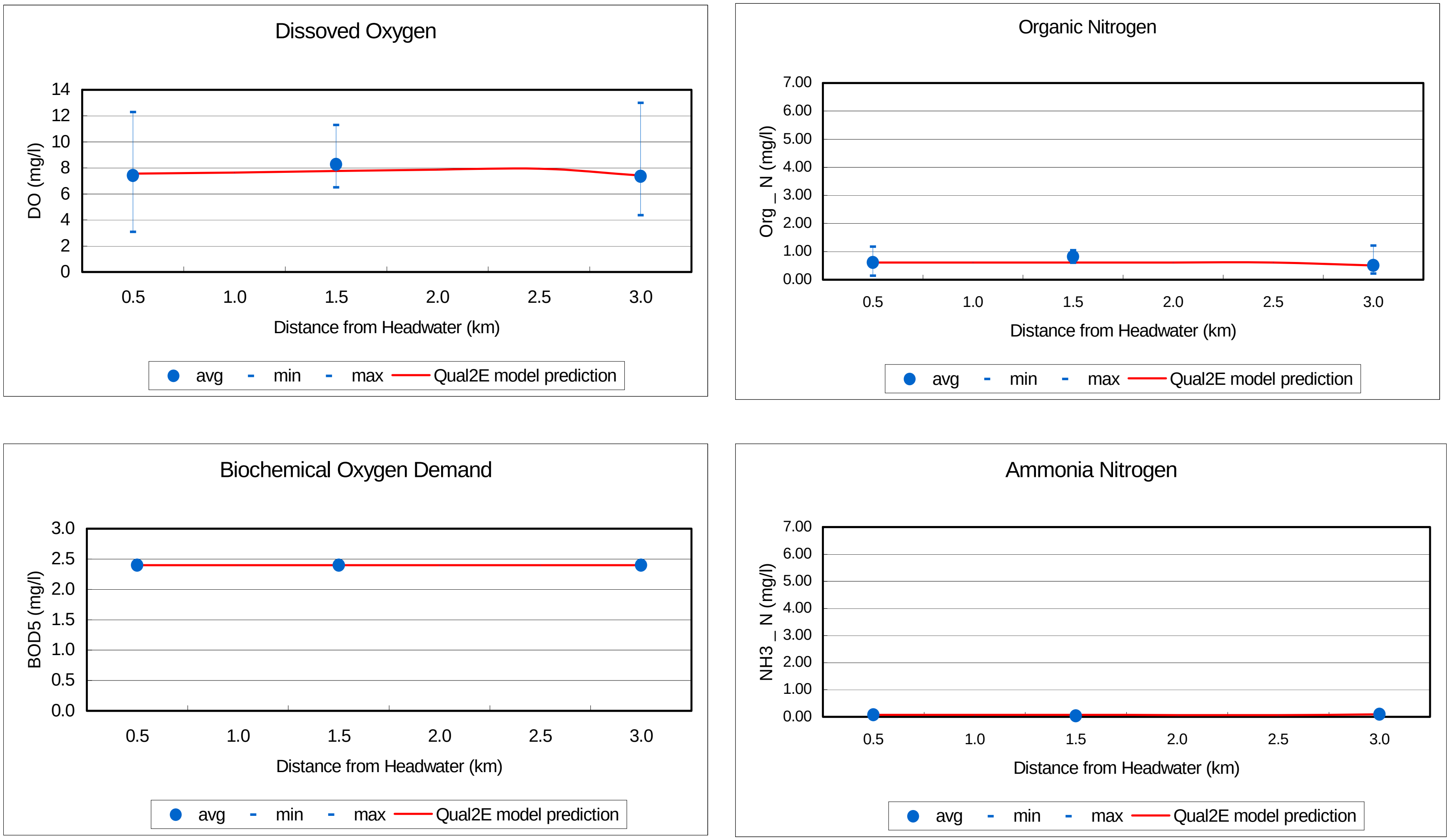


Figure 4 - 4 Butler Mill Branch DO, BOD5, Org_N, and NH3_N Calibration

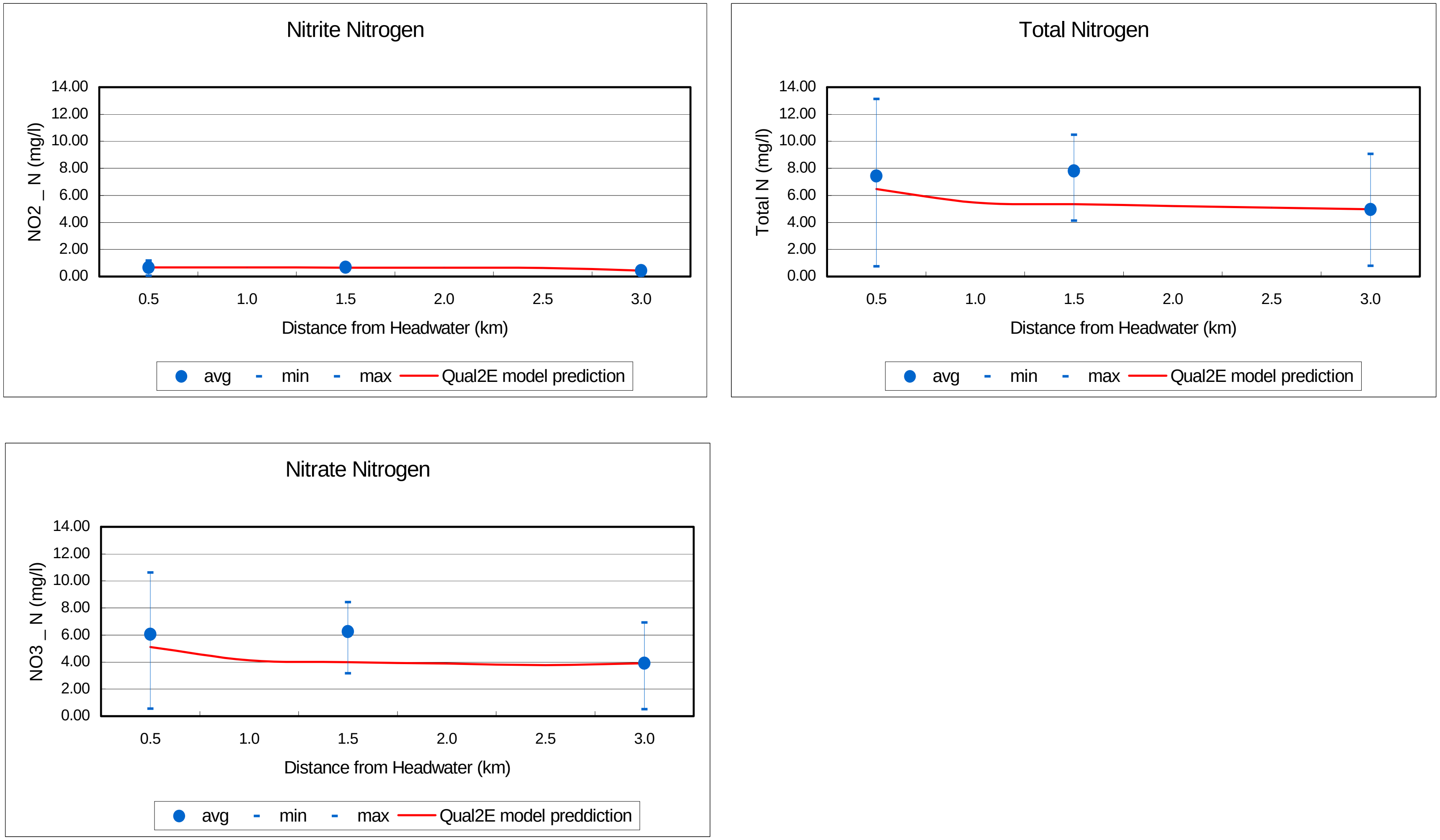


Figure 4 - 5 Butler Mill Branch Nitrite, Nitrate and Total Nitrogen Calibration

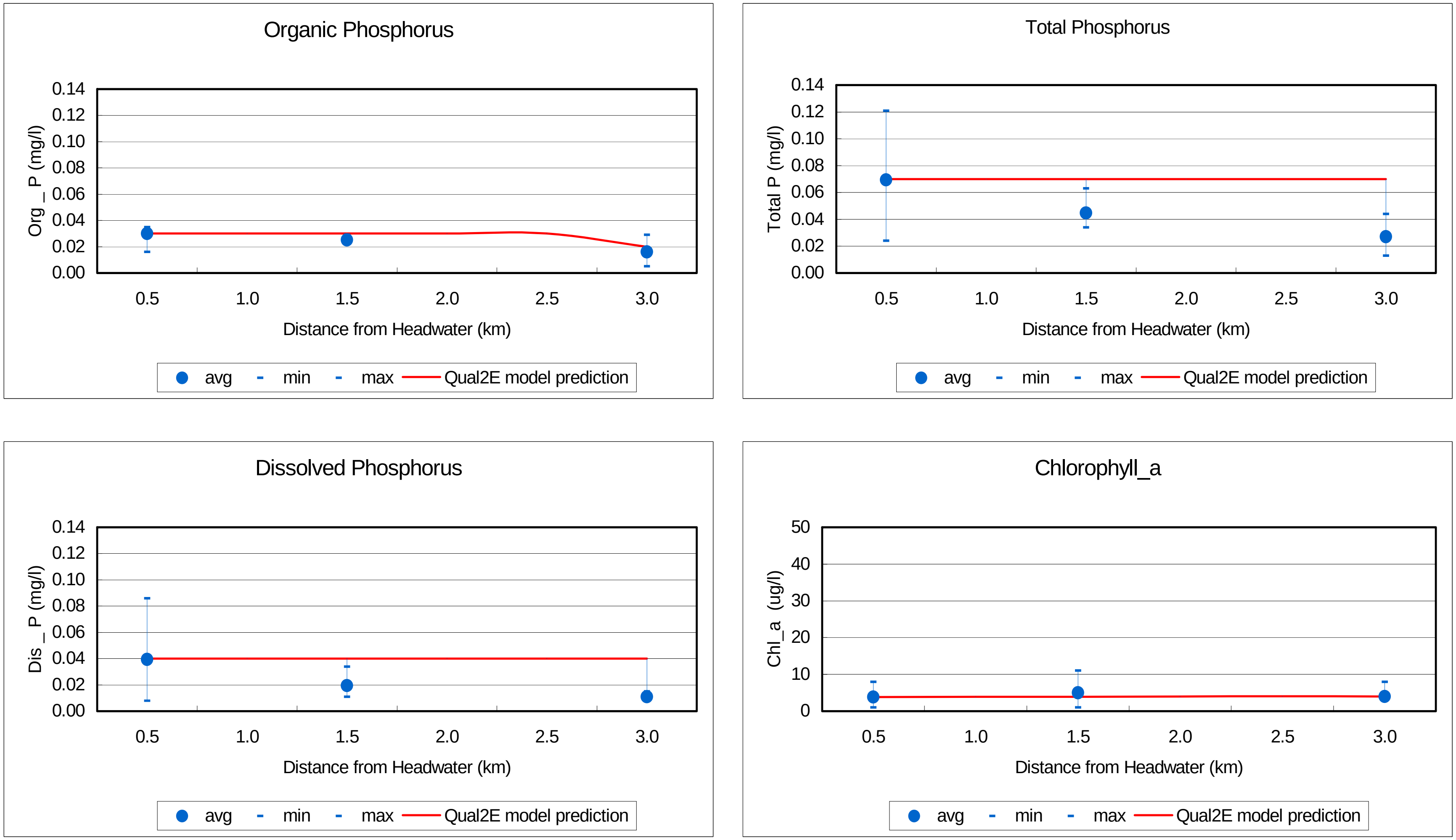


Figure 4 - 6 Butler Mill Branch Org_P, Dis_P, Total P, and Chlorophyll_a Calibration

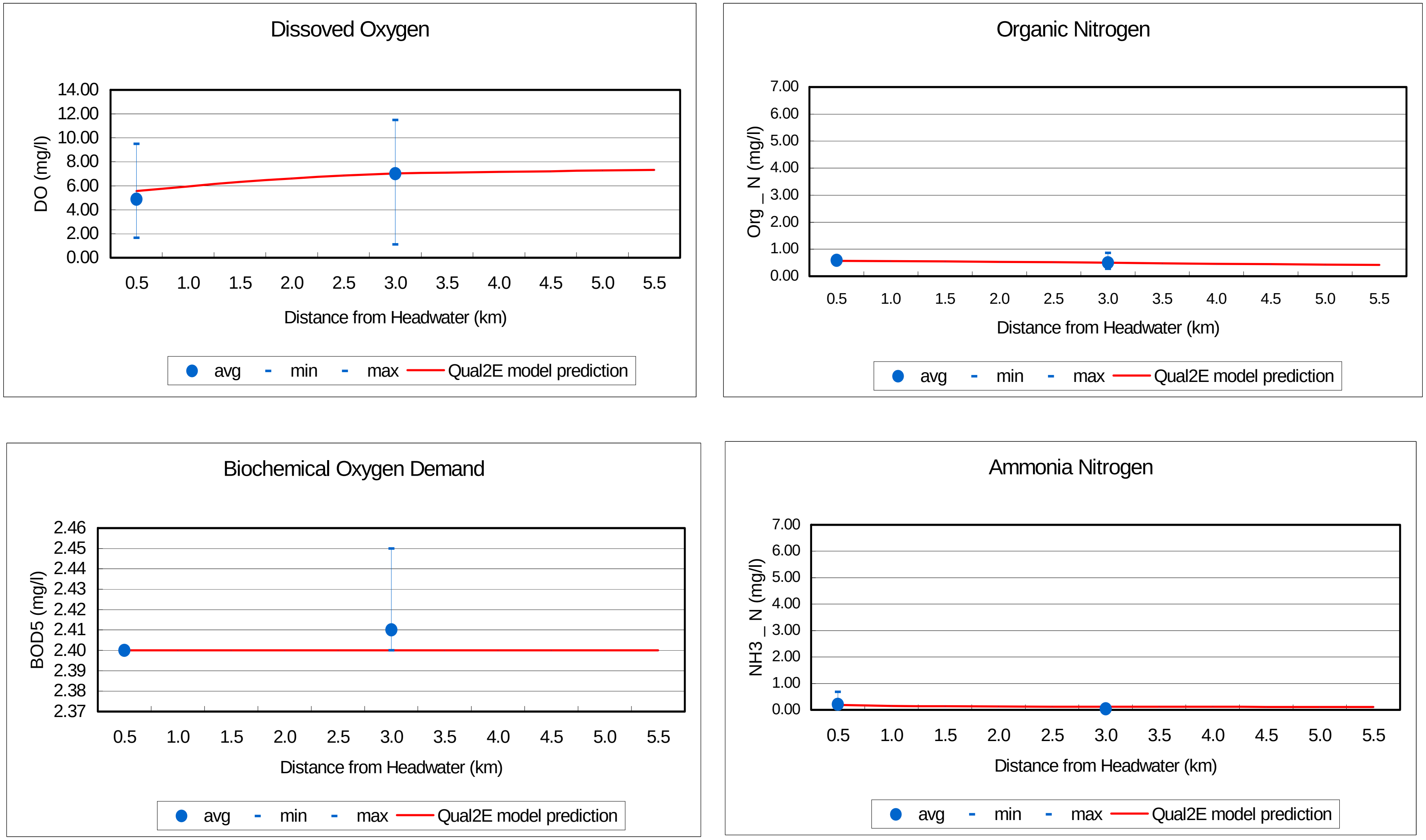


Figure 4 - 7 Chapel Branch DO, BOD5, Org_N, and NH3_N Calibration

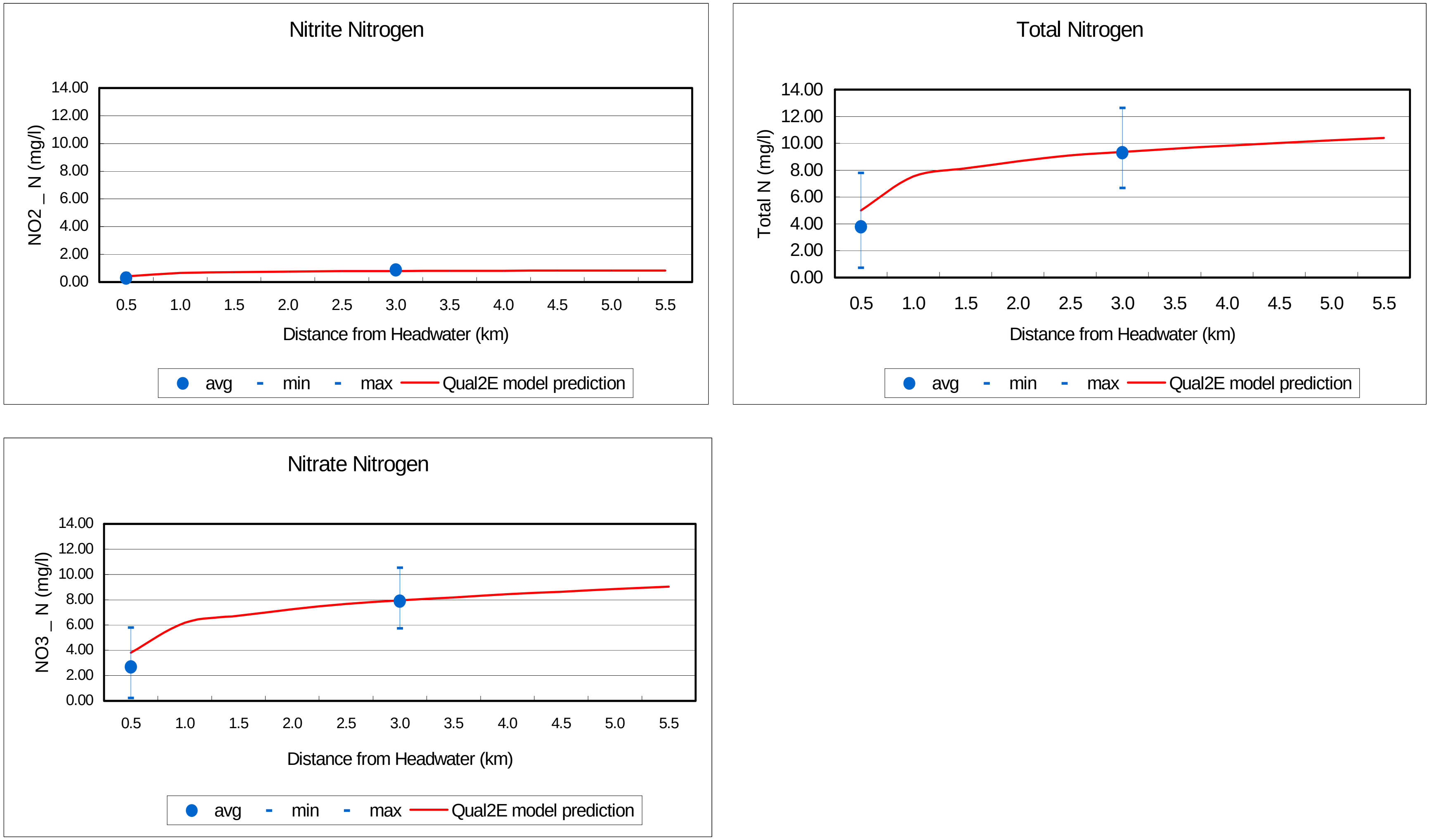


Figure 4 - 8 Chapel Branch Nitrite, Nitrate and Total Nitrogen Calibration

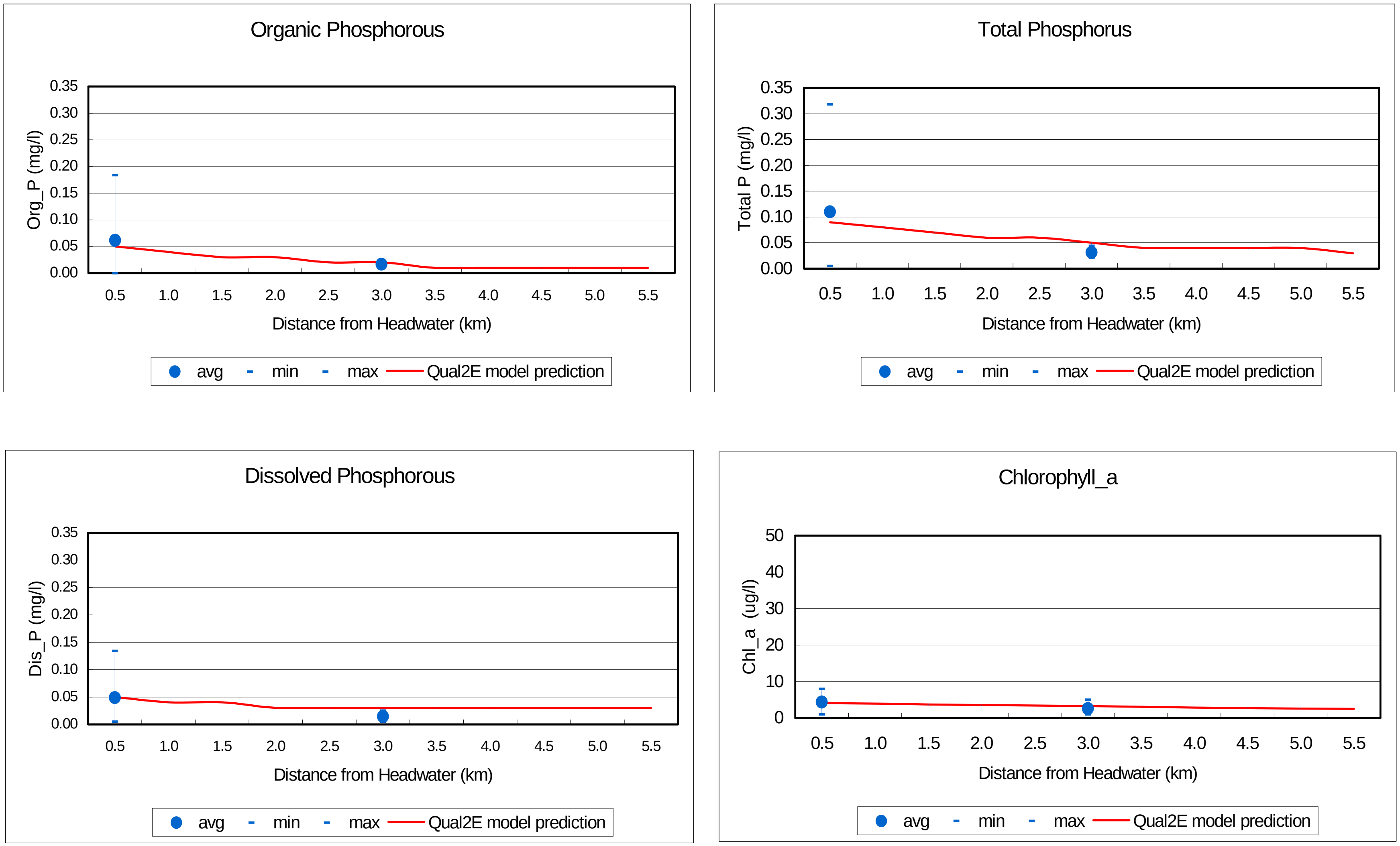


Figure 4 - 9 Chapel Branch Org_P, Dis_P, Total P, and Chlorophyll_a Calibration

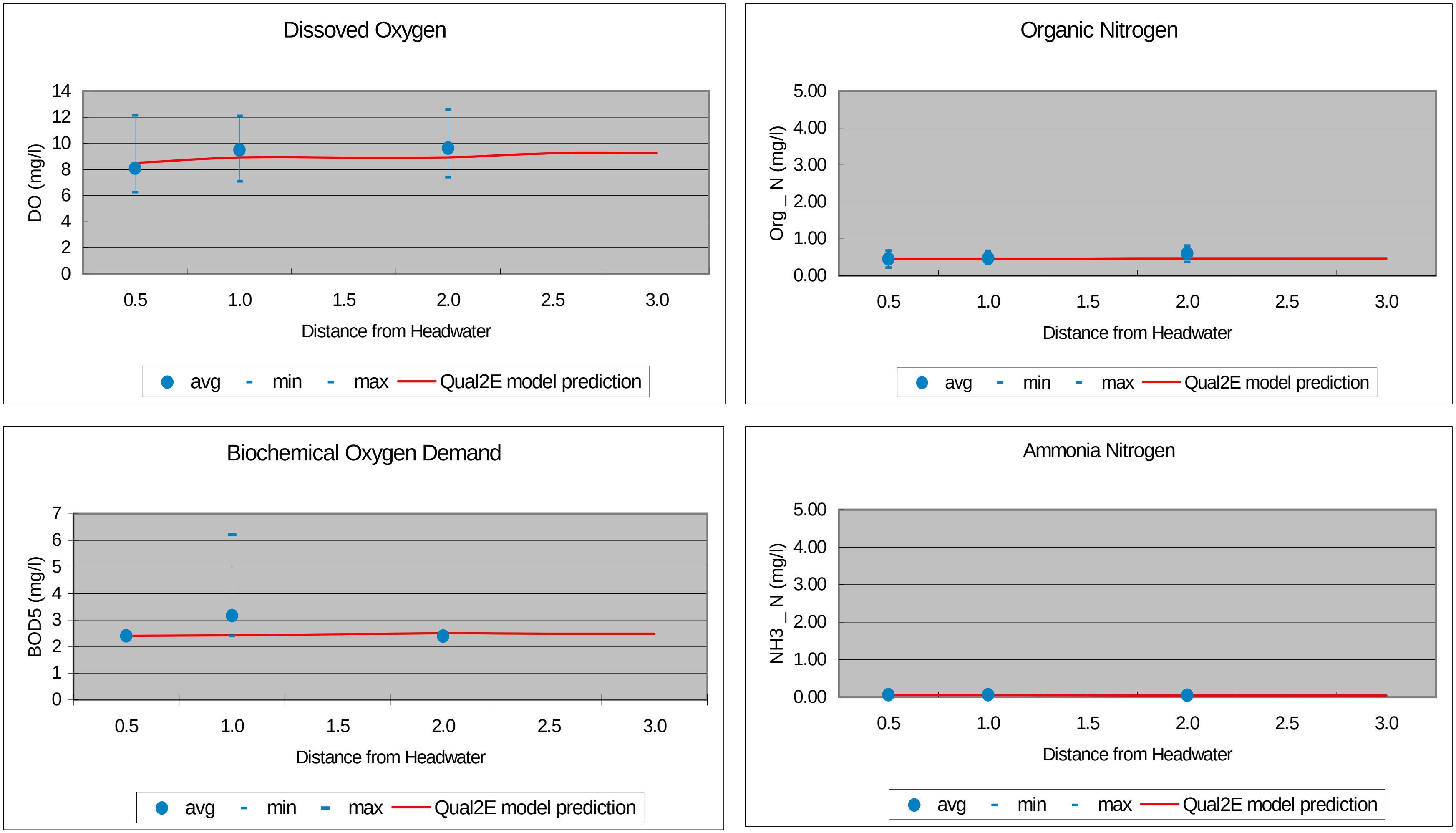


Figure 4 - 10 Chipman Pond Branch DO, BOD5, Org_N, and NH3_N Calibration

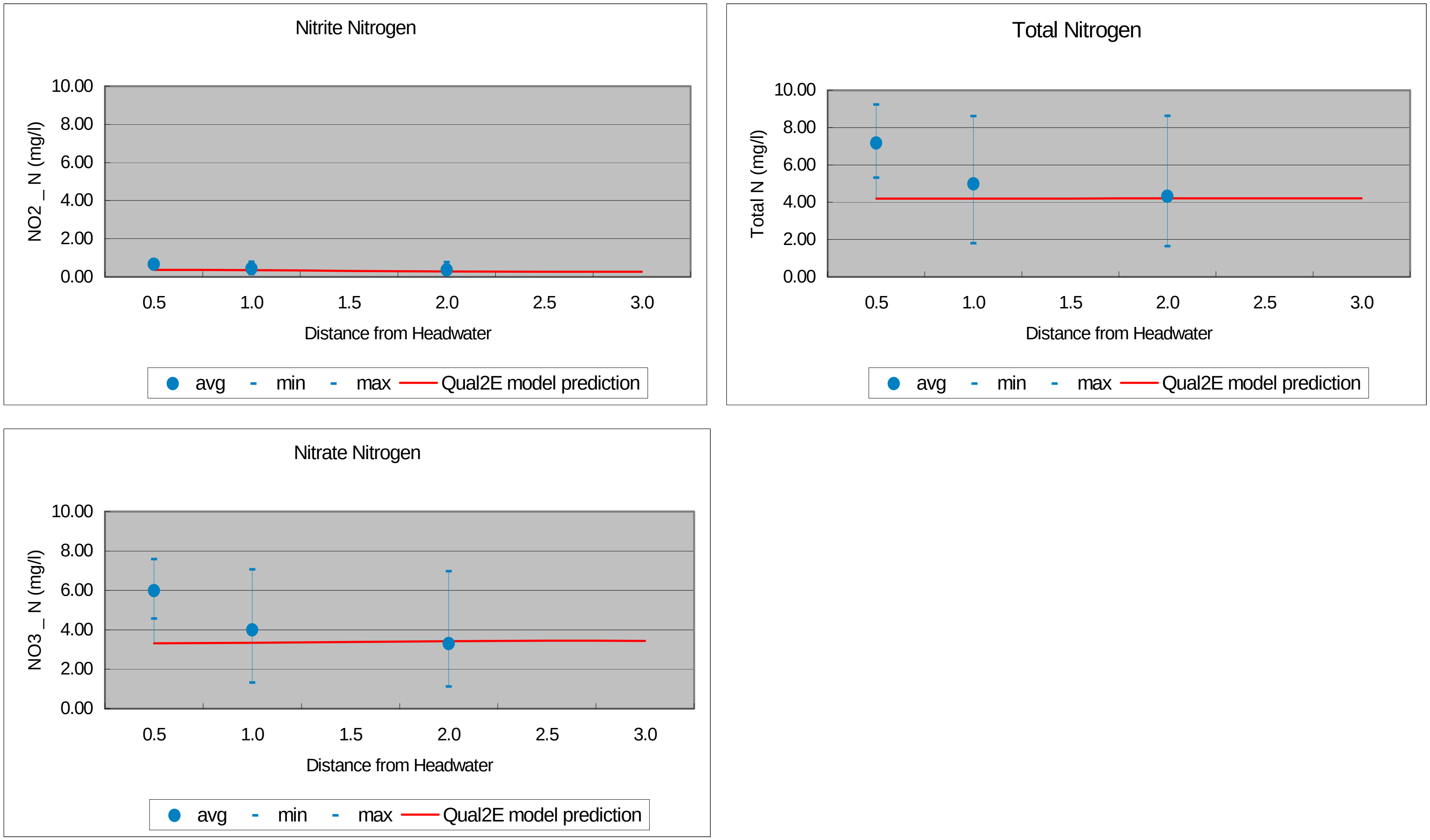


Figure 4 - 11 Chipman Pond Branch Nitrite, Nitrate and Total Nitrogen Calibration

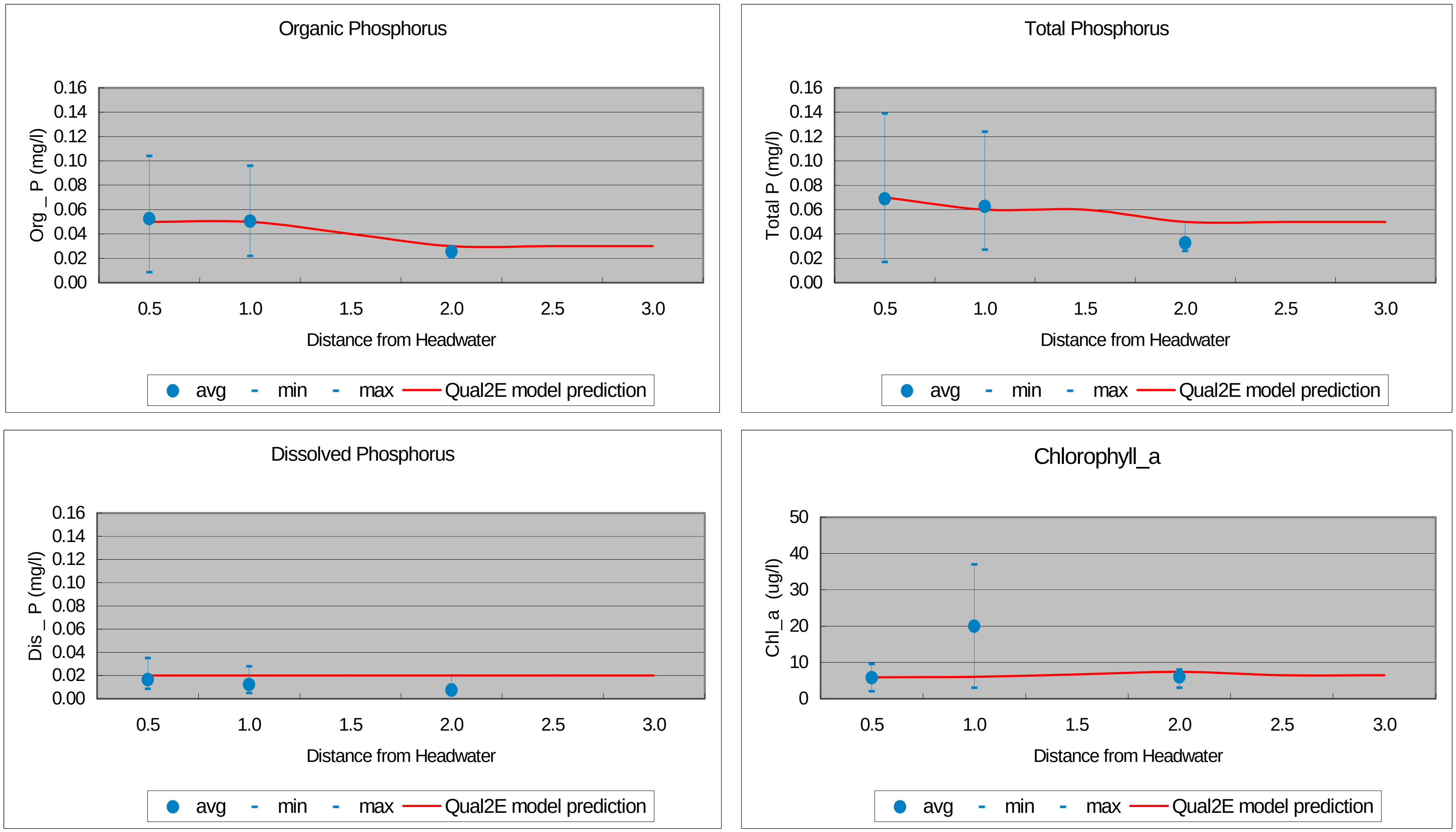


Figure 4 - 12 Chipman Pond Branch Org_P, Dis_P, Total P, and Chlorophyll_a Calibration

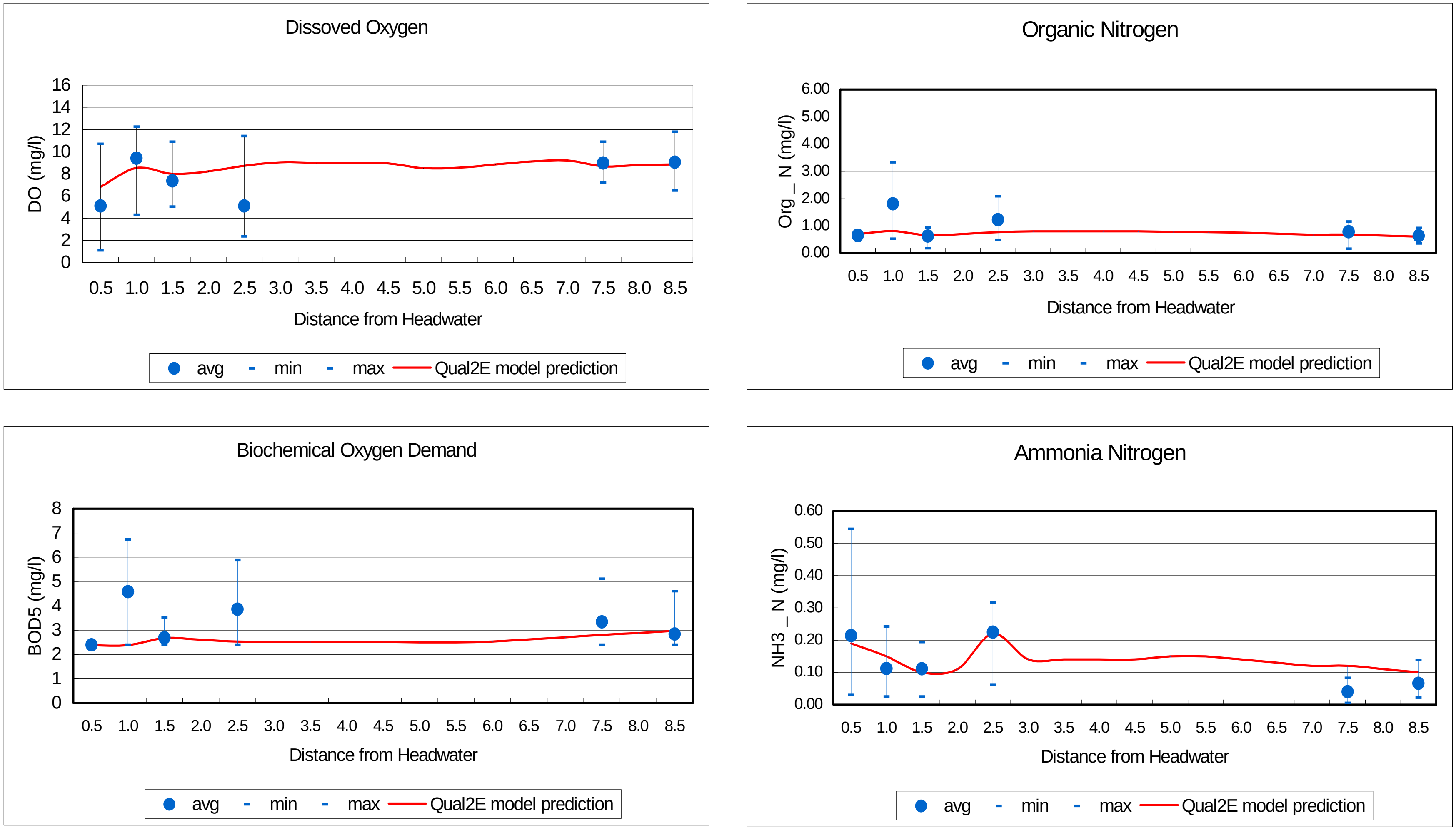
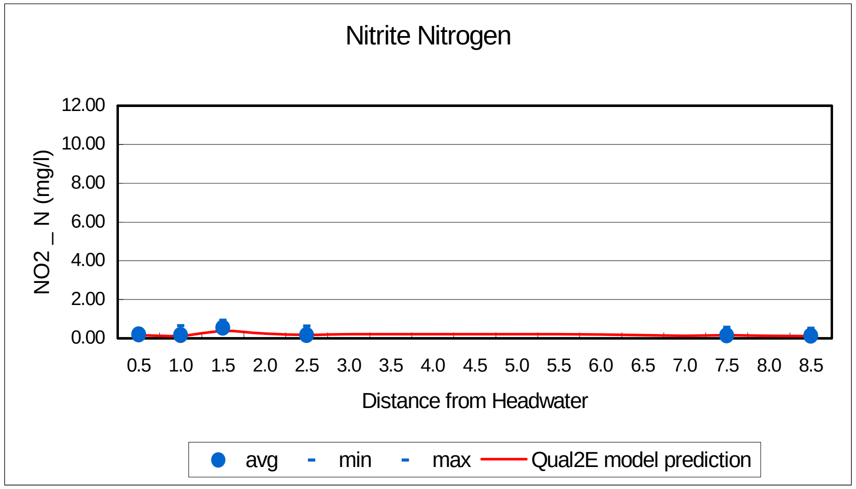
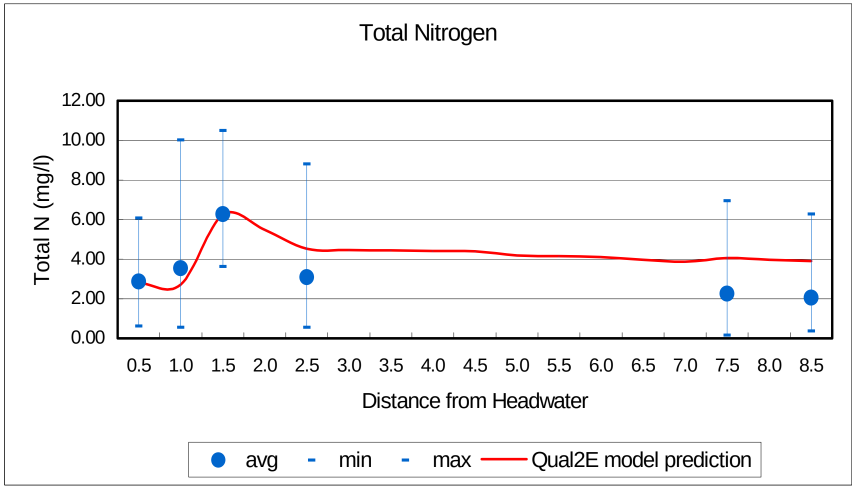


Figure 4 - 13 Clear Brook DO, BOD5, Org_N, and NH3_N Calibration





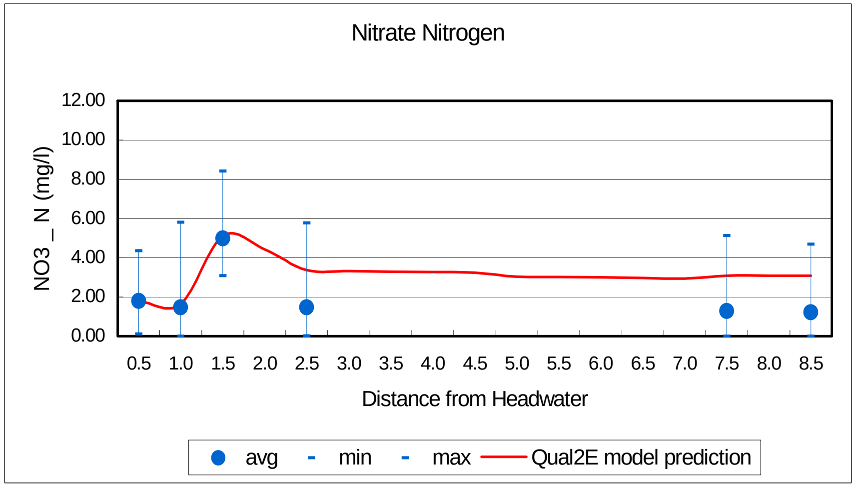


Figure 4 - 14 Clear Brook Nitrite, Nitrate and Total Nitrogen Calibration

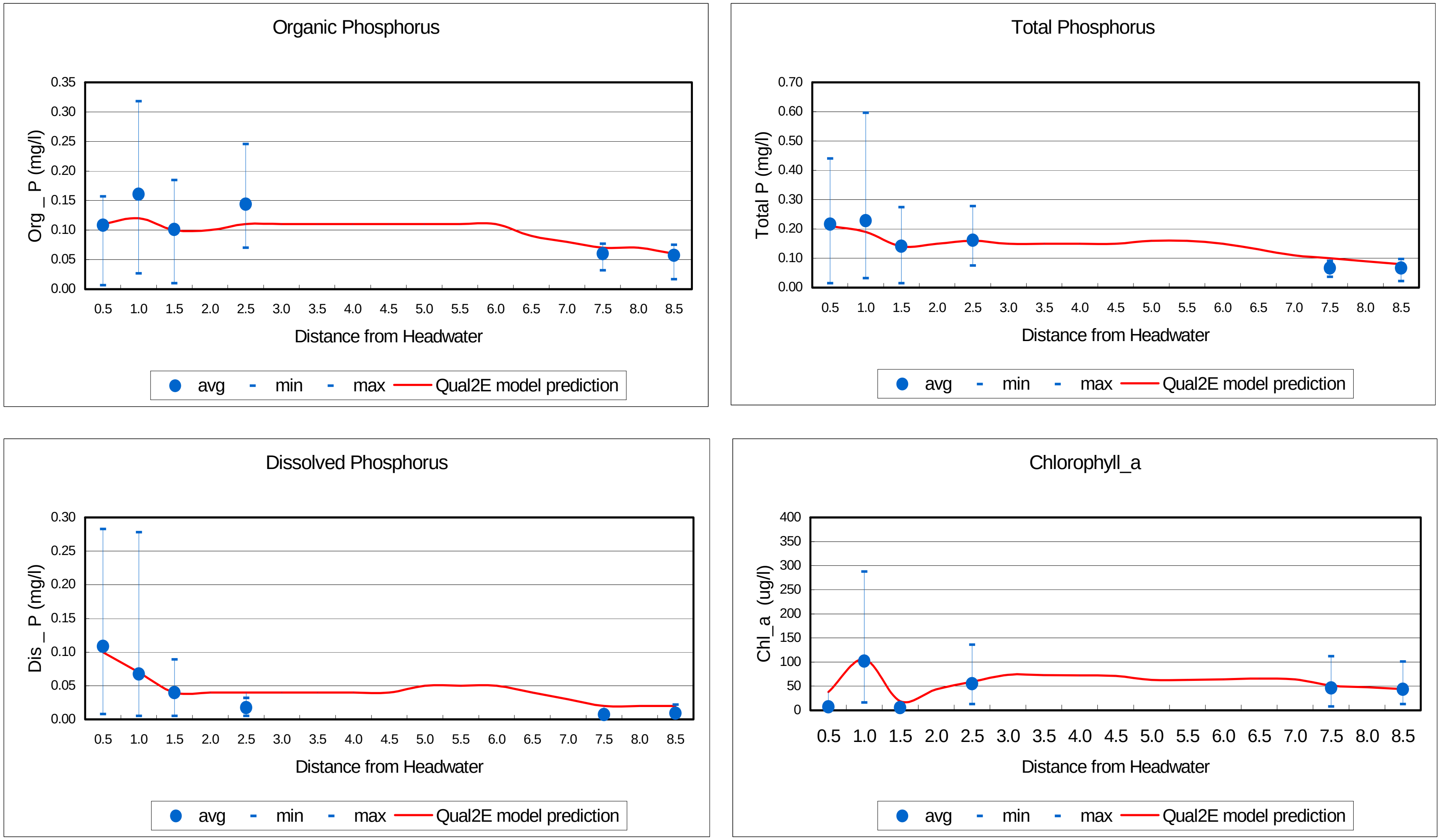


Figure 4 - 15 Clear Brook Org_P, Dis_P, Total P, and Chlorophyll_a Calibration

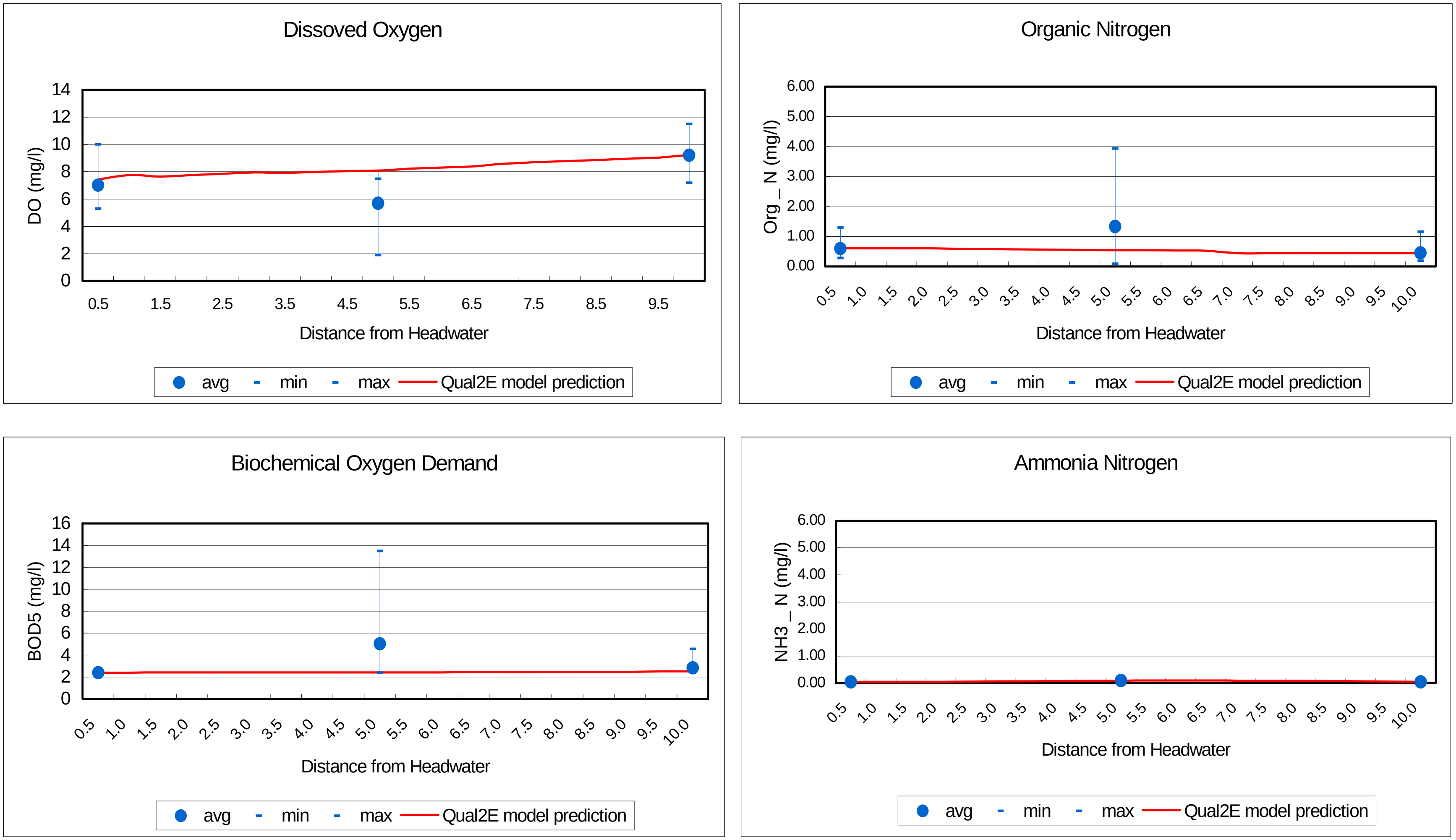


Figure 4 - 16 Deep Creek DO, BOD5, Org_N, and NH3_N Calibration

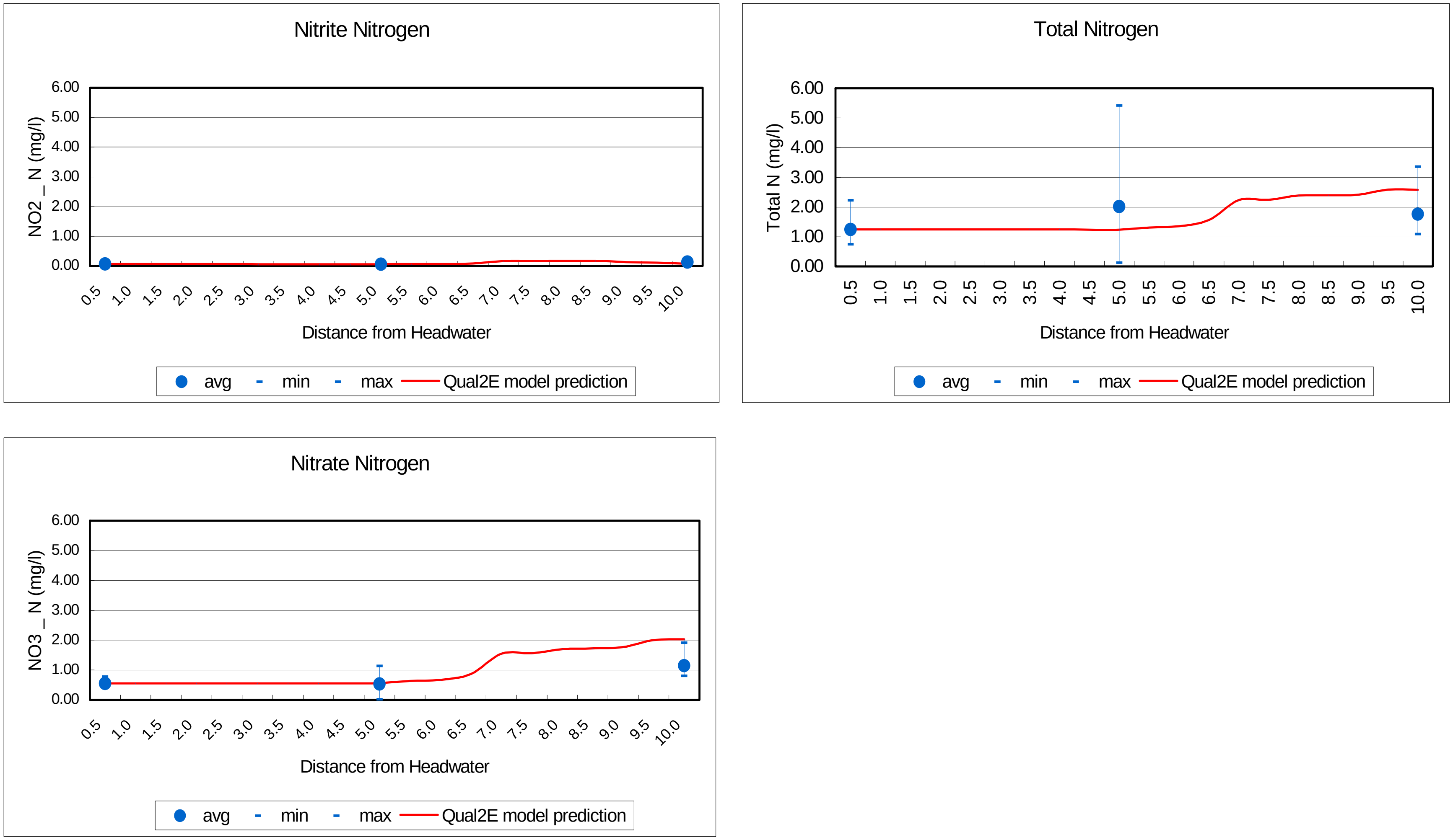


Figure 4 - 17 Deep Creek Nitrite, Nitrate and Total Nitrogen Calibration

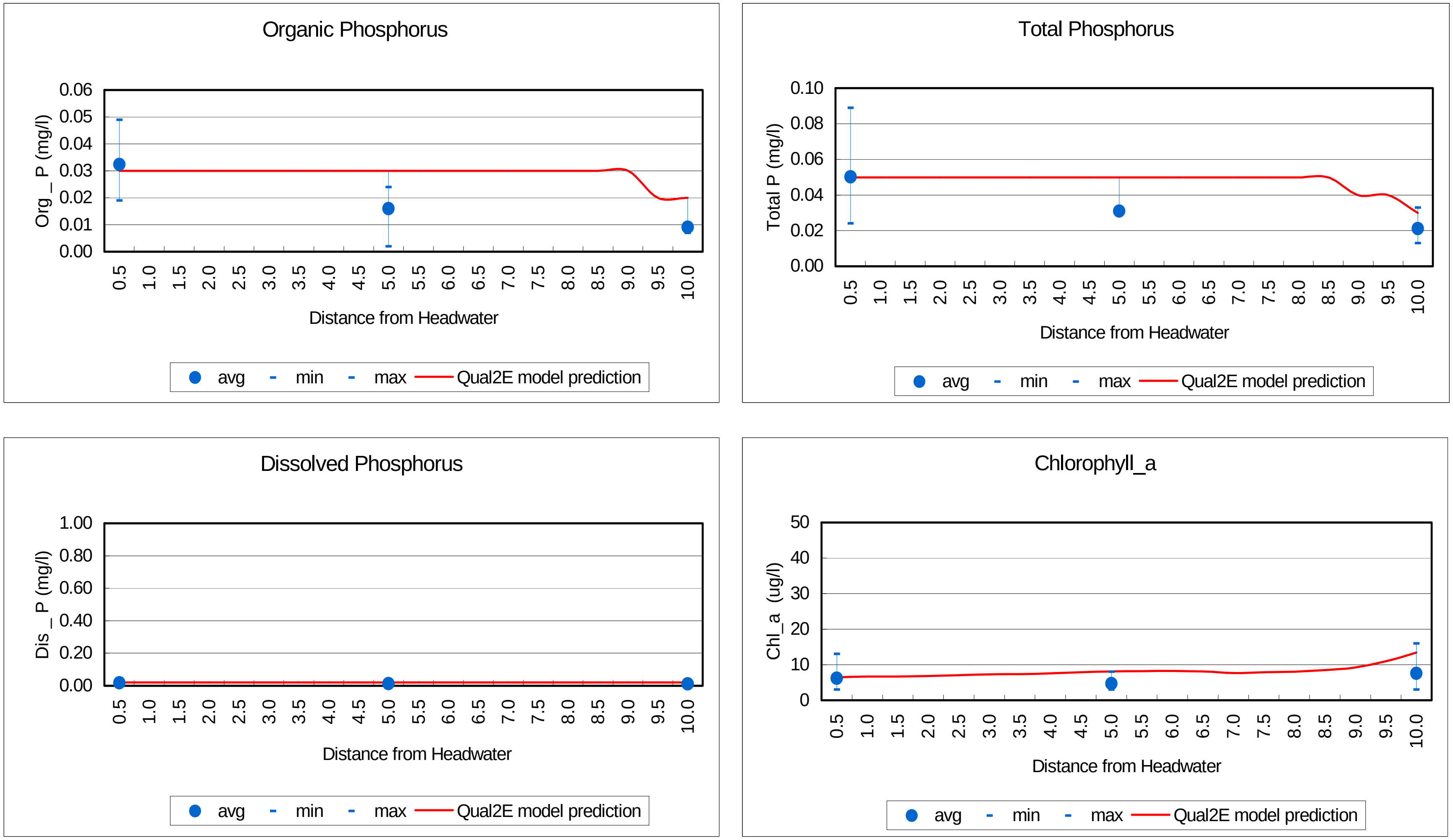


Figure 4 - 18 Deep Creek Org_P, Dis_P, Total P, and Chlorophyll_a Calibration

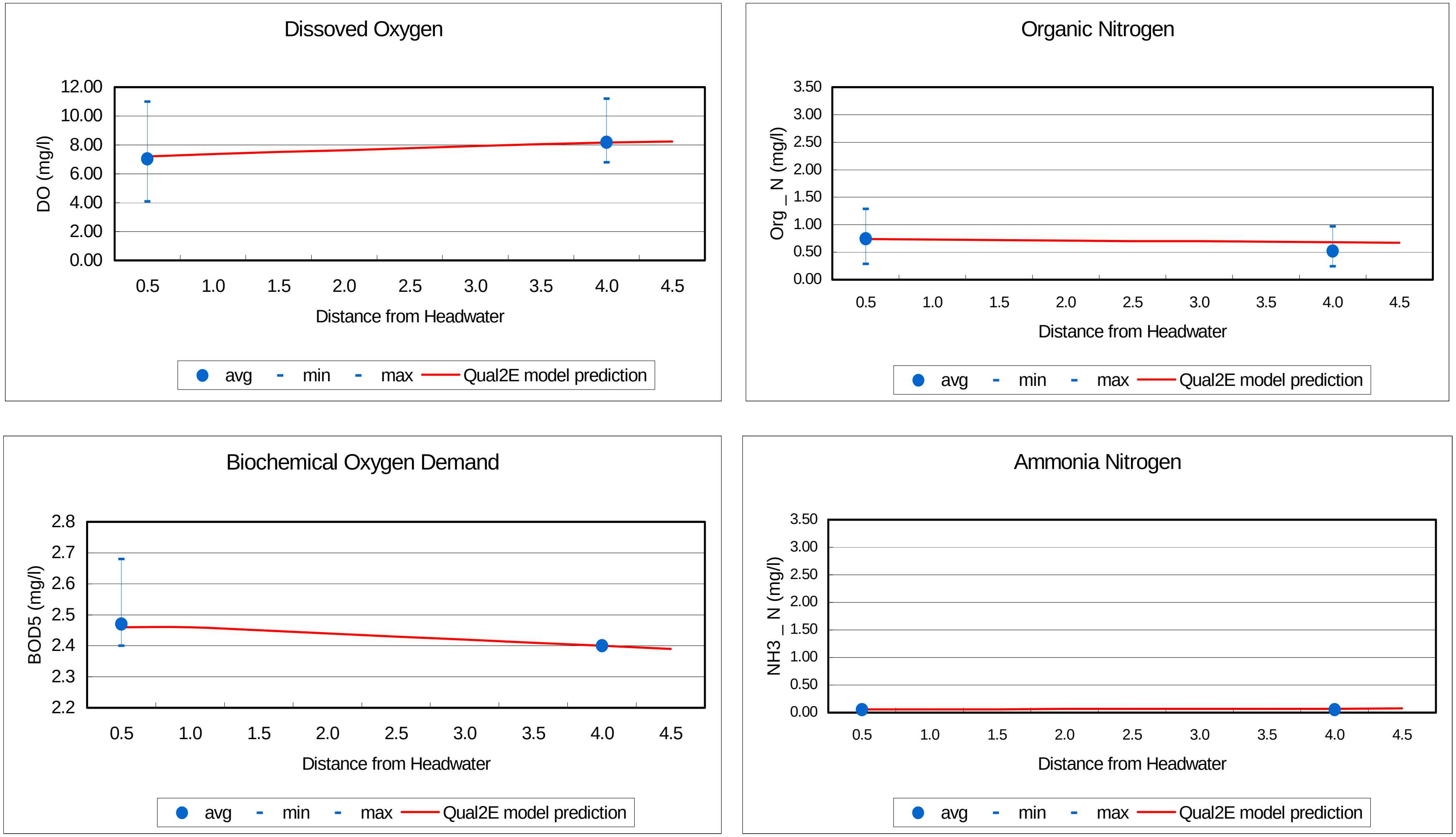


Figure 4 - 19 Gravelly Branch DO, BOD5, Org_N, and NH3_N Calibration

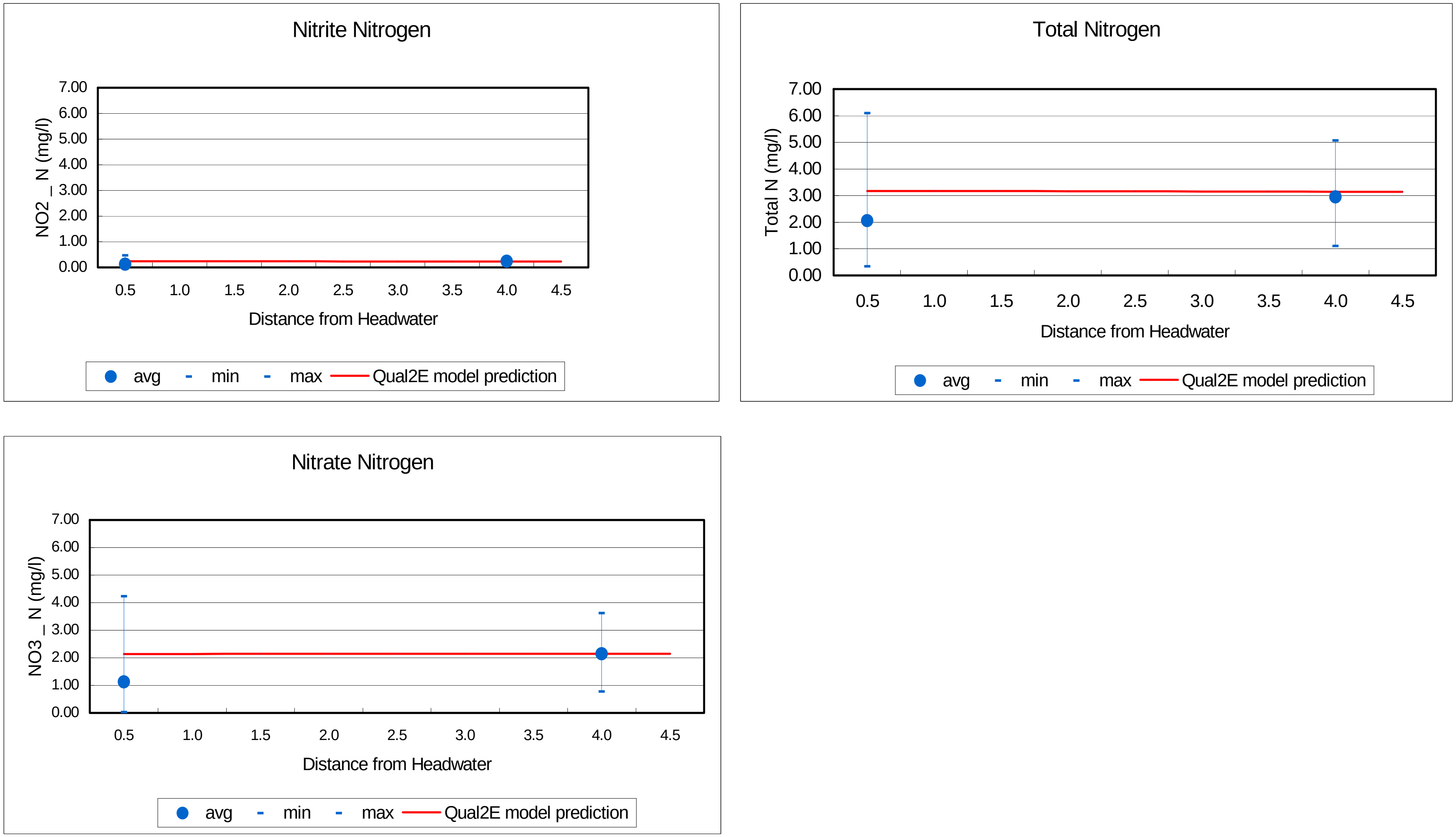


Figure 4 - 20 Gravelly Branch Nitrite, Nitrate and Total Nitrogen Calibration

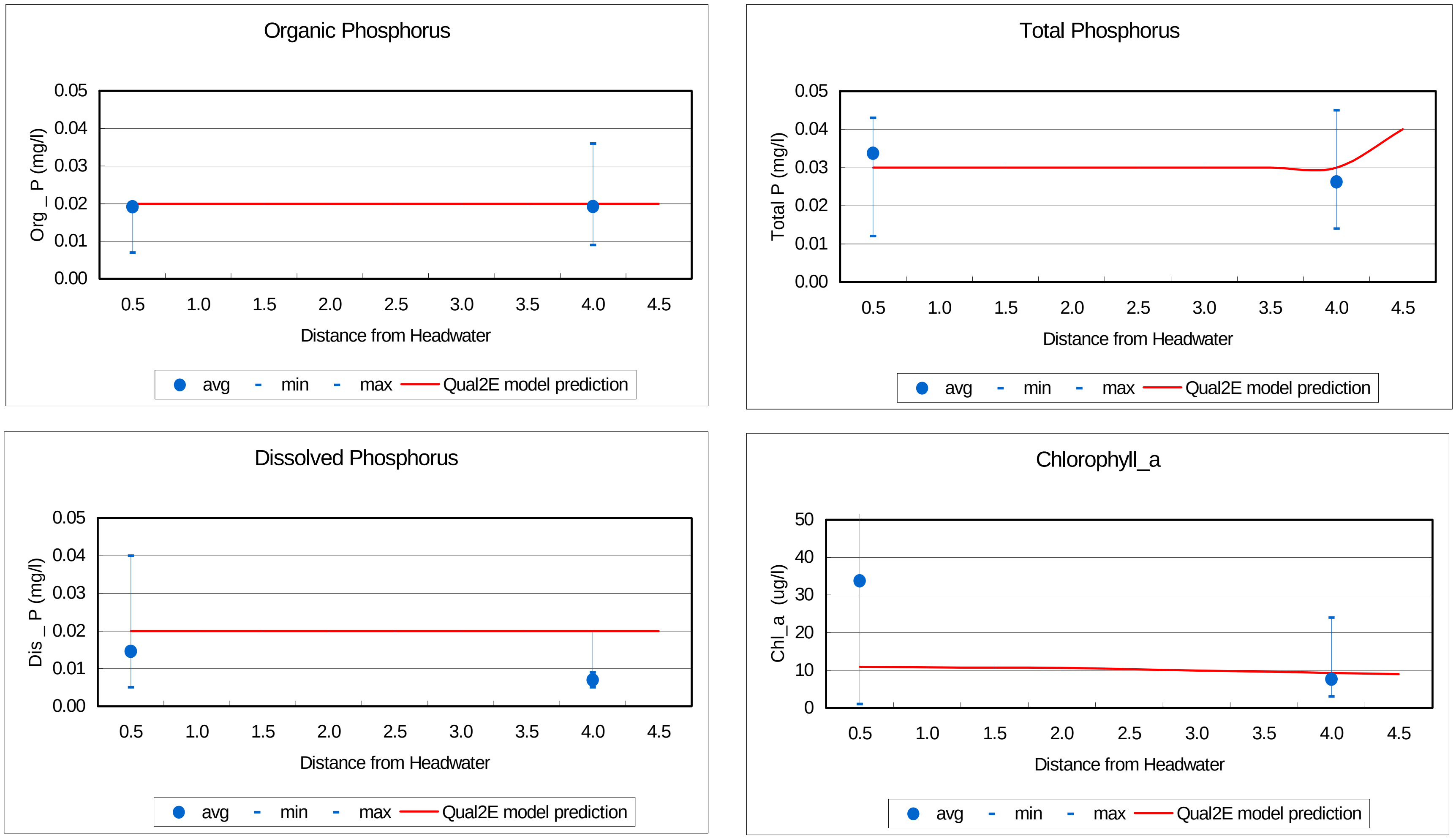


Figure 4 - 21 Gravelly Branch Org_P, Dis_P, Total P, and Chlorophyll_a Calibration

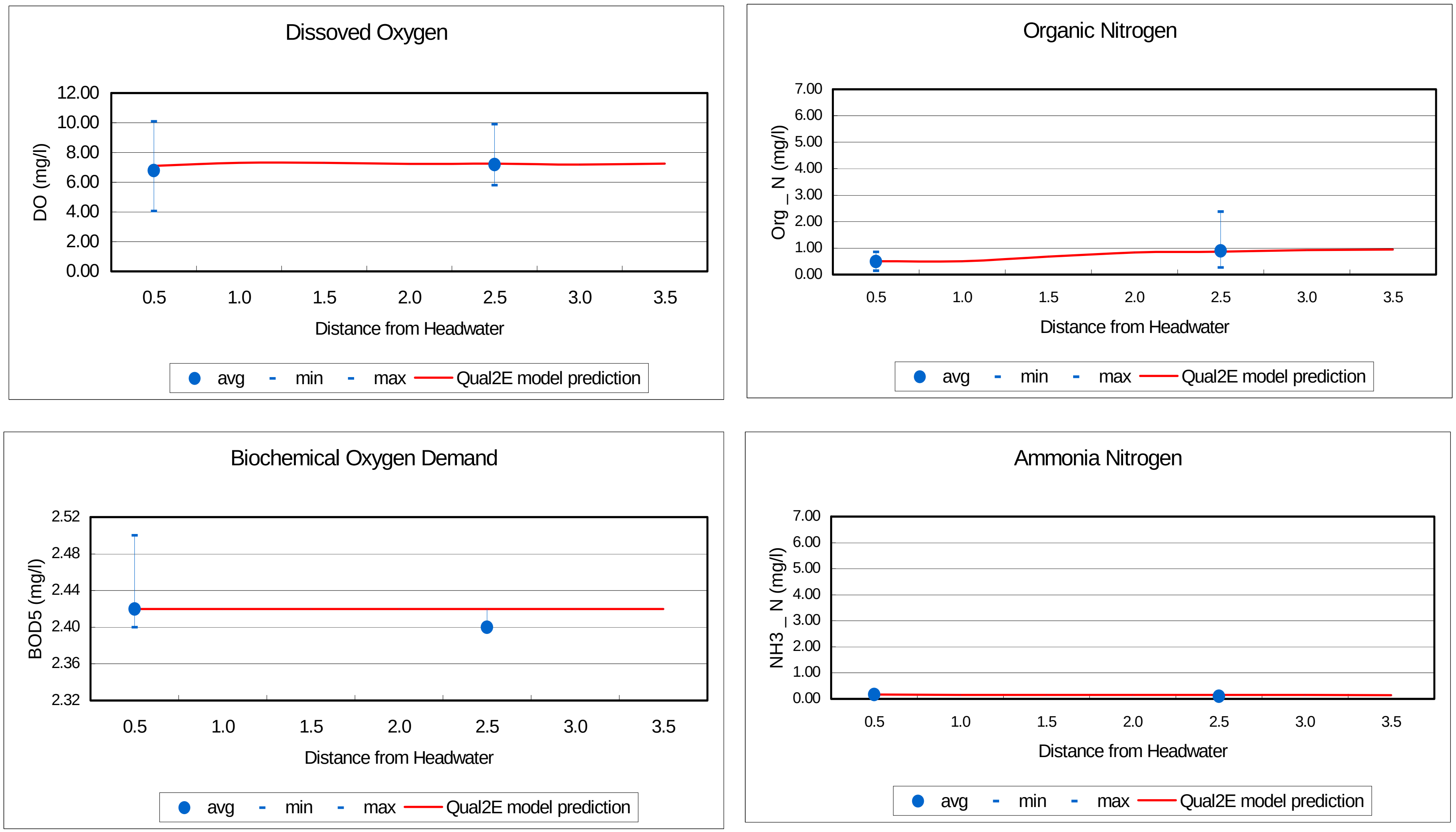


Figure 4 - 22 Gum Branch DO, BOD5, Org_N, and NH3_N Calibration

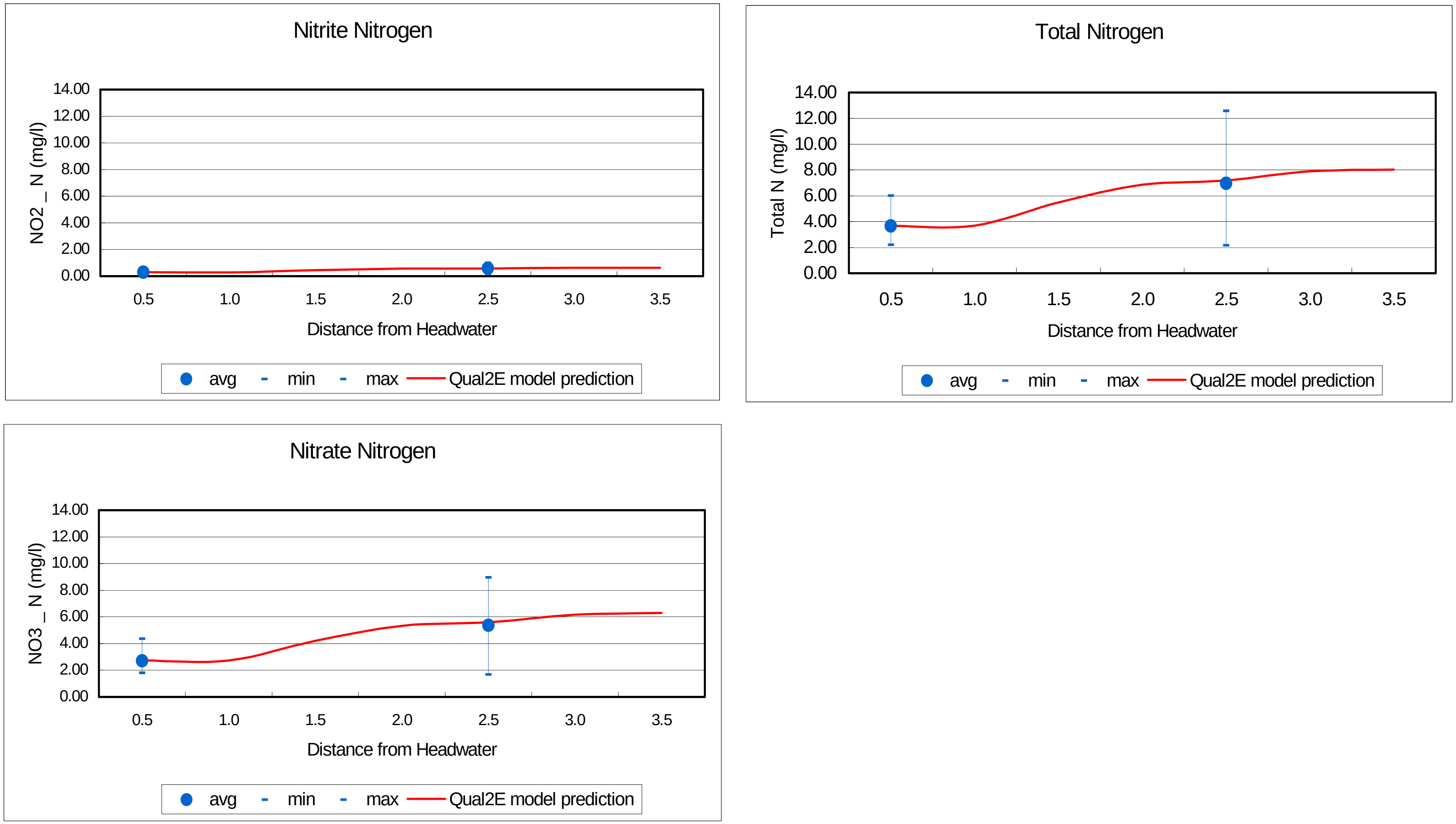


Figure 4 - 23 Gum Branch Nitrite, Nitrate and Total Nitrogen Calibration

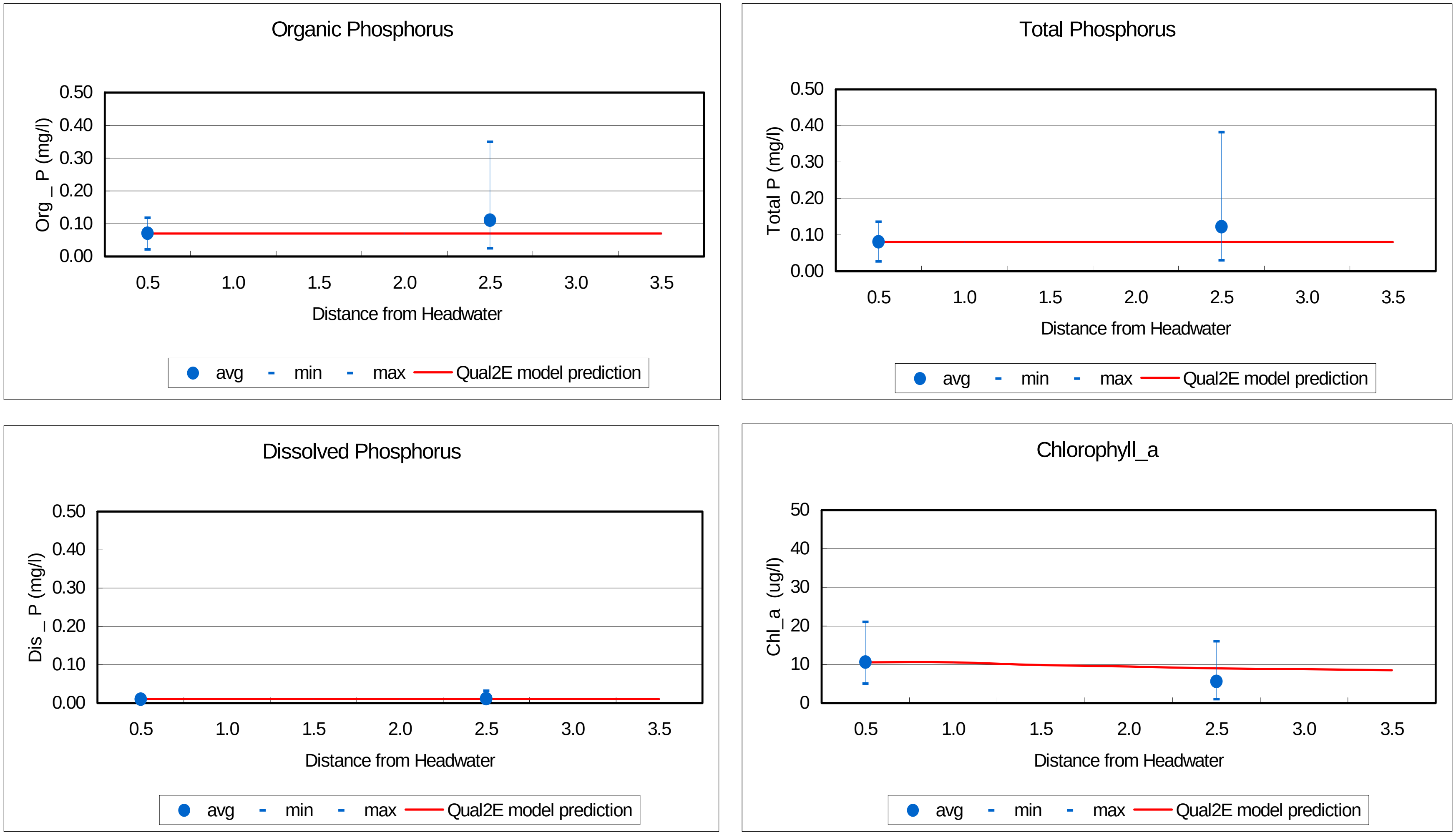


Figure 4 - 24 Gum Branch Org_P, Dis_P, Total P, and Chlorophyll_a Calibration

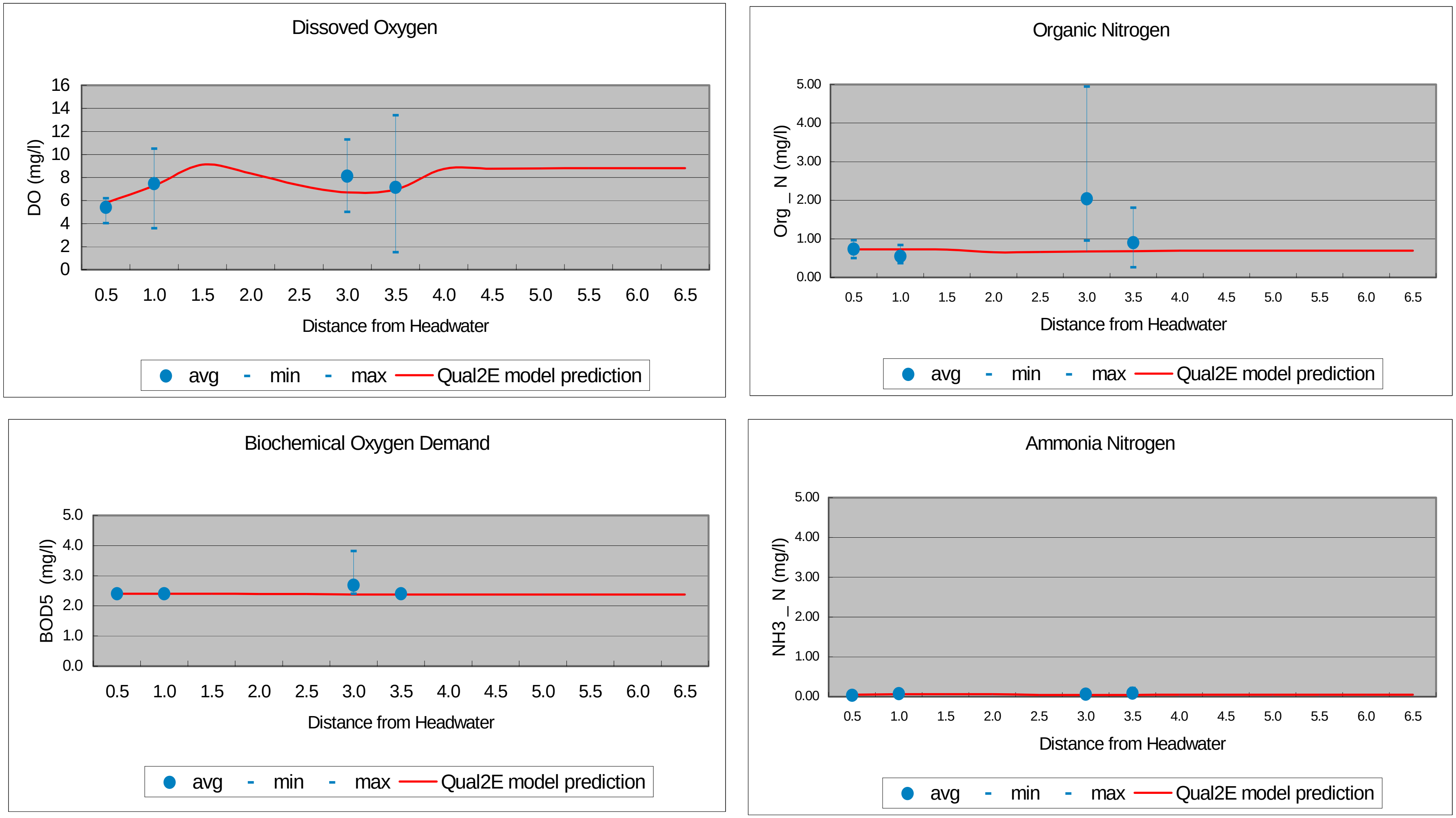


Figure 4 - 25 Hitch Pond Branch DO, BOD5, Org_N, and NH3_N Calibration

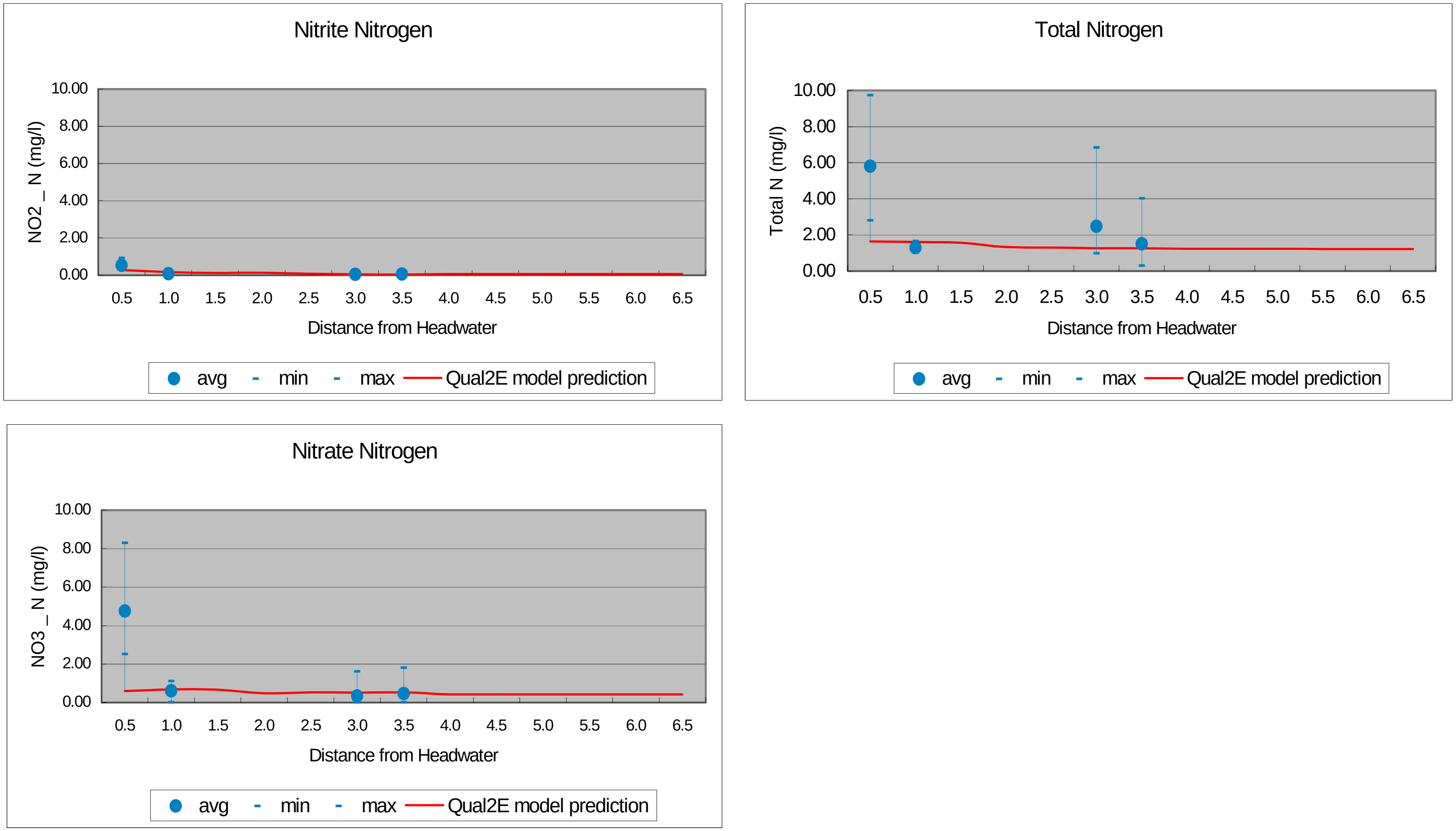


Figure 4 - 26 Hitch Pond Branch Nitrite, Nitrate and Total Nitrogen Calibration

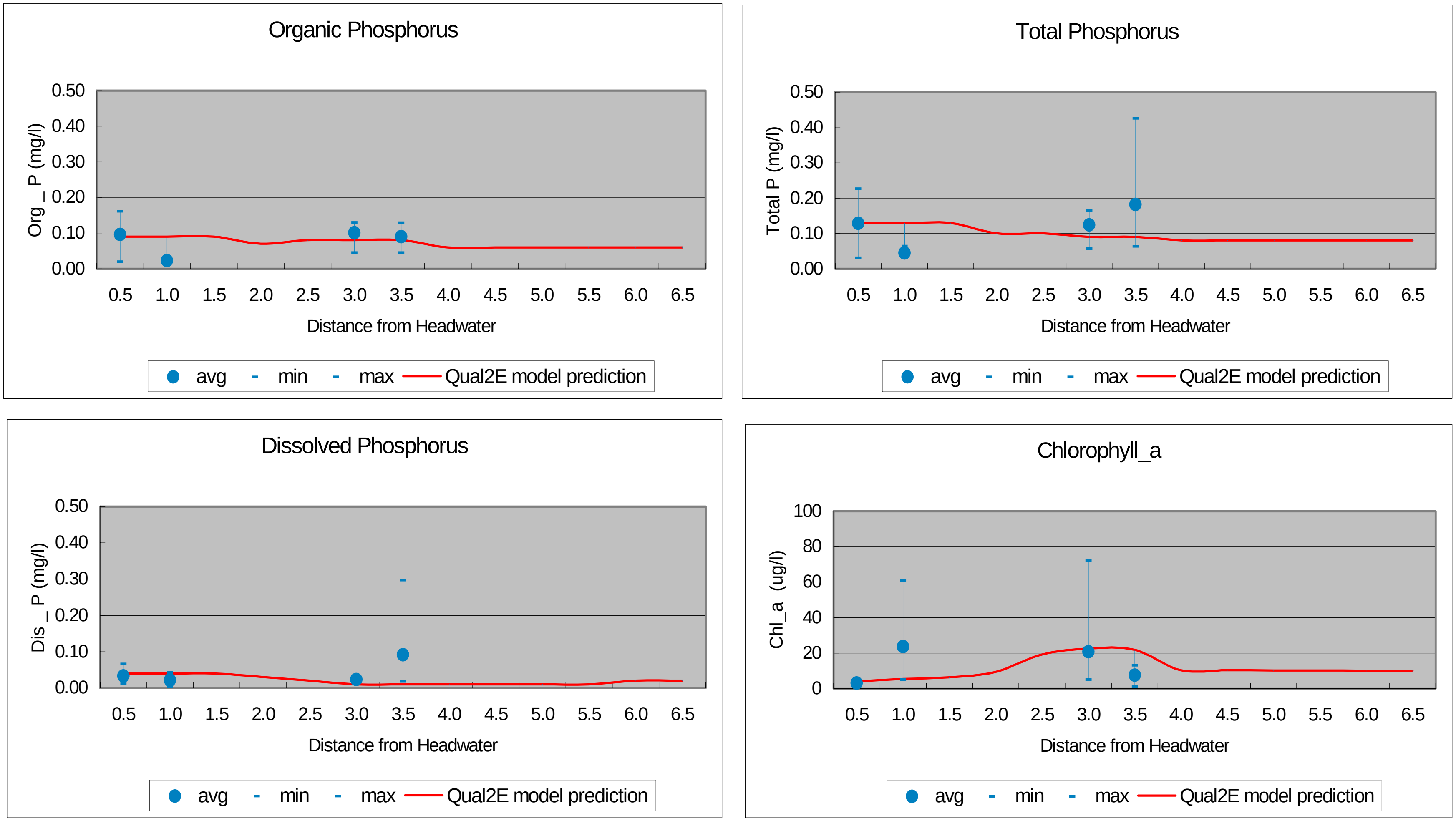


Figure 4 - 27 Hitch Pond Branch Org_P, Dis_P, Total P, and Chlorophyll_a Calibration

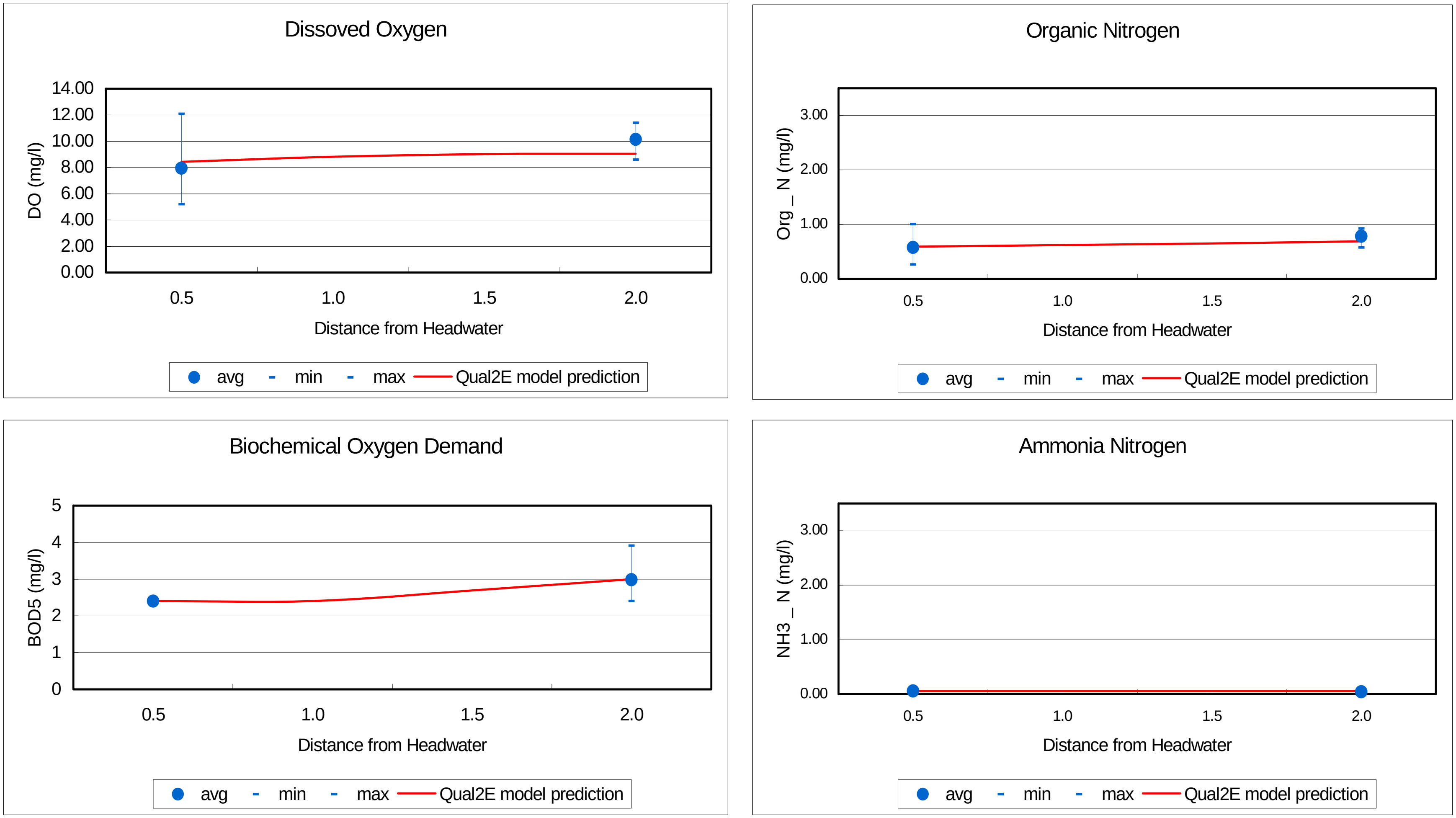


Figure 4 - 28 Horsey Pond DO, BOD5, Org_N, and NH3_N Calibration

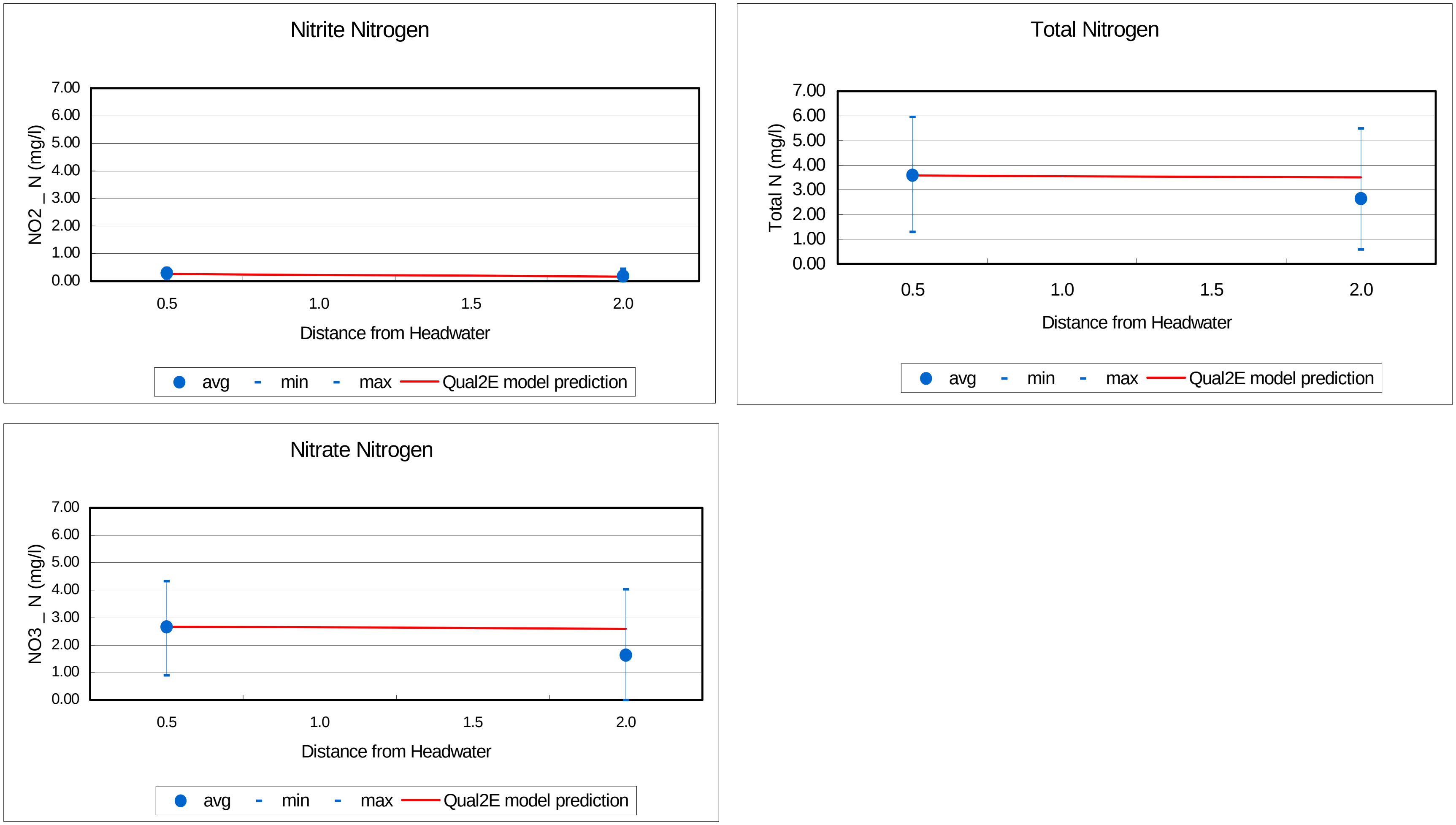


Figure 4 - 29 Horsey Pond Nitrite, Nitrate and Total Nitrogen Calibration

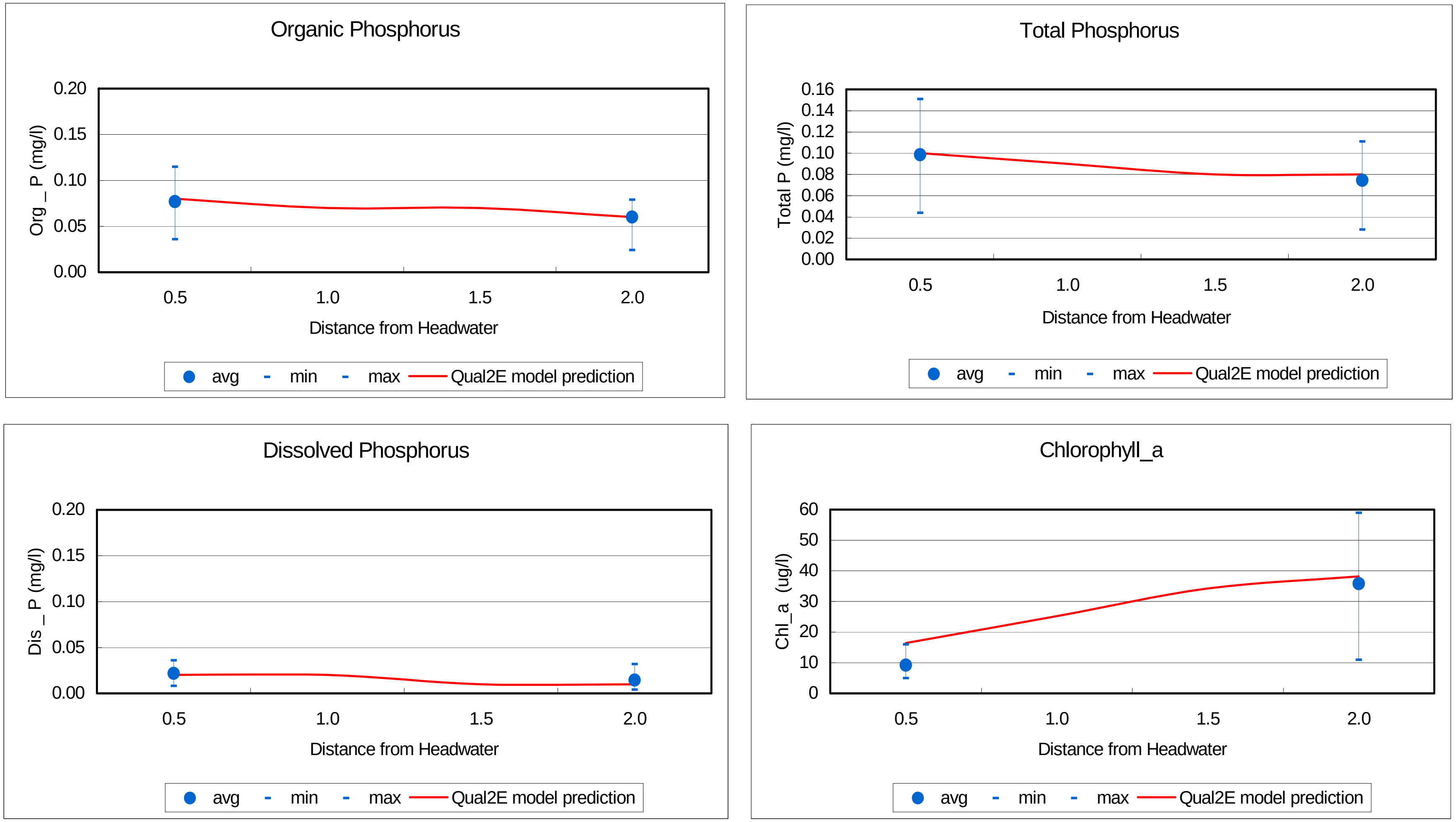


Figure 4 -30 Horsey Pond Org_P, Dis_P, Total P, and Chlorophyll_a Calibration

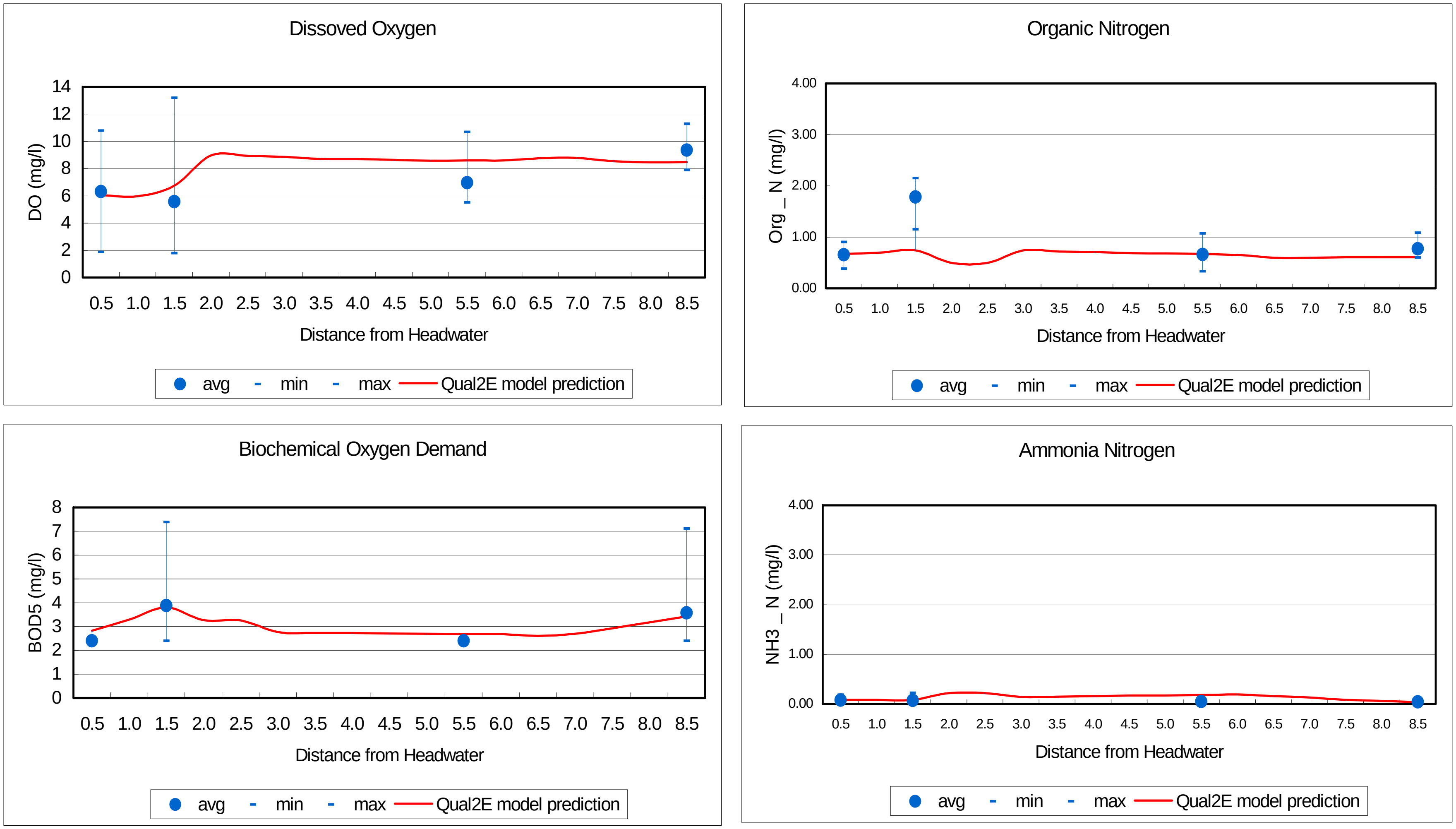


Figure 4 - 31 James Branch (incl. Record Pond) DO, BOD5, Org_N, and NH3_N Calibration

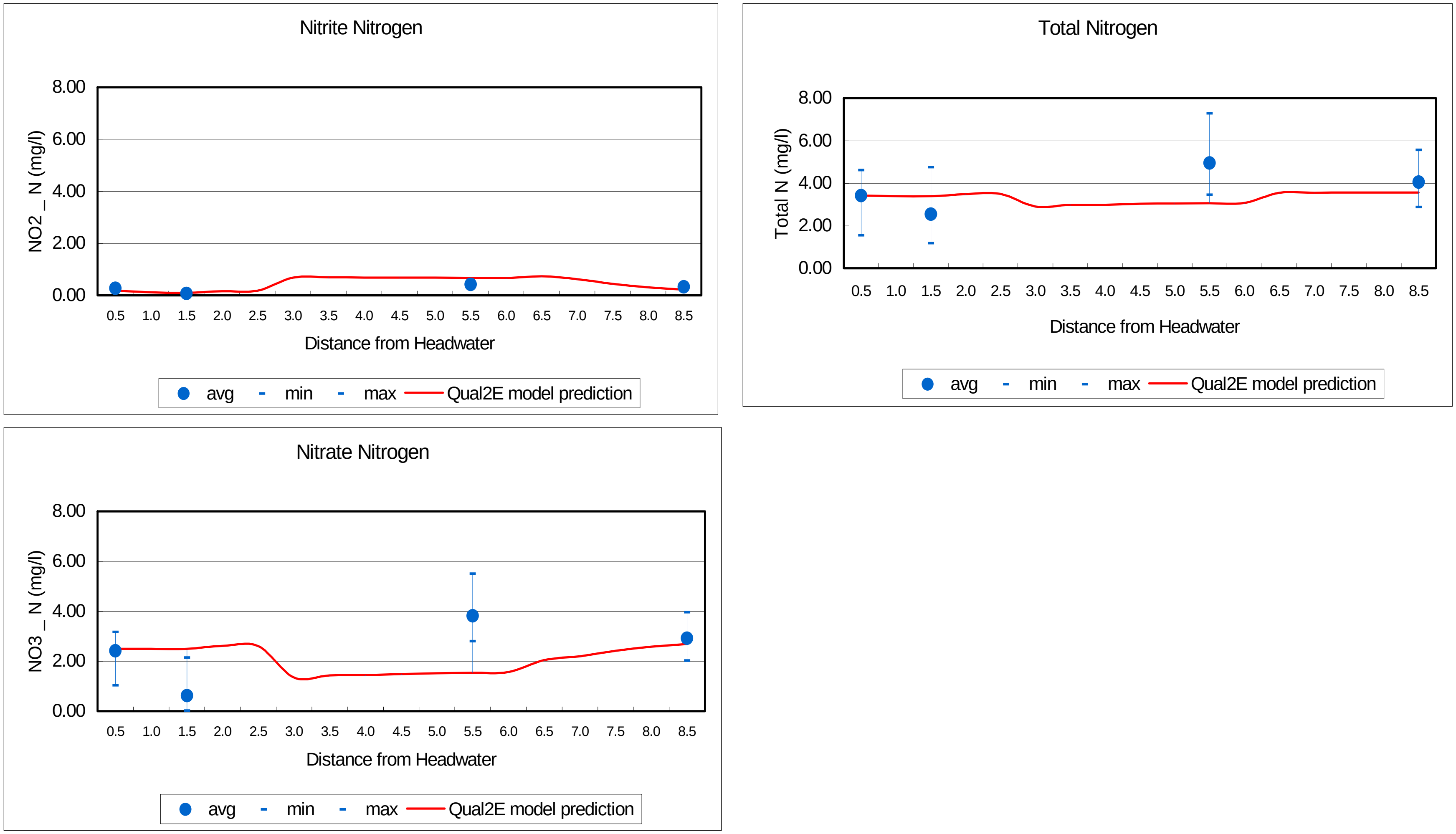


Figure 4 - 32 James Branch (incl. Record Pond) Nitrite, Nitrate and Total Nitrogen Calibration

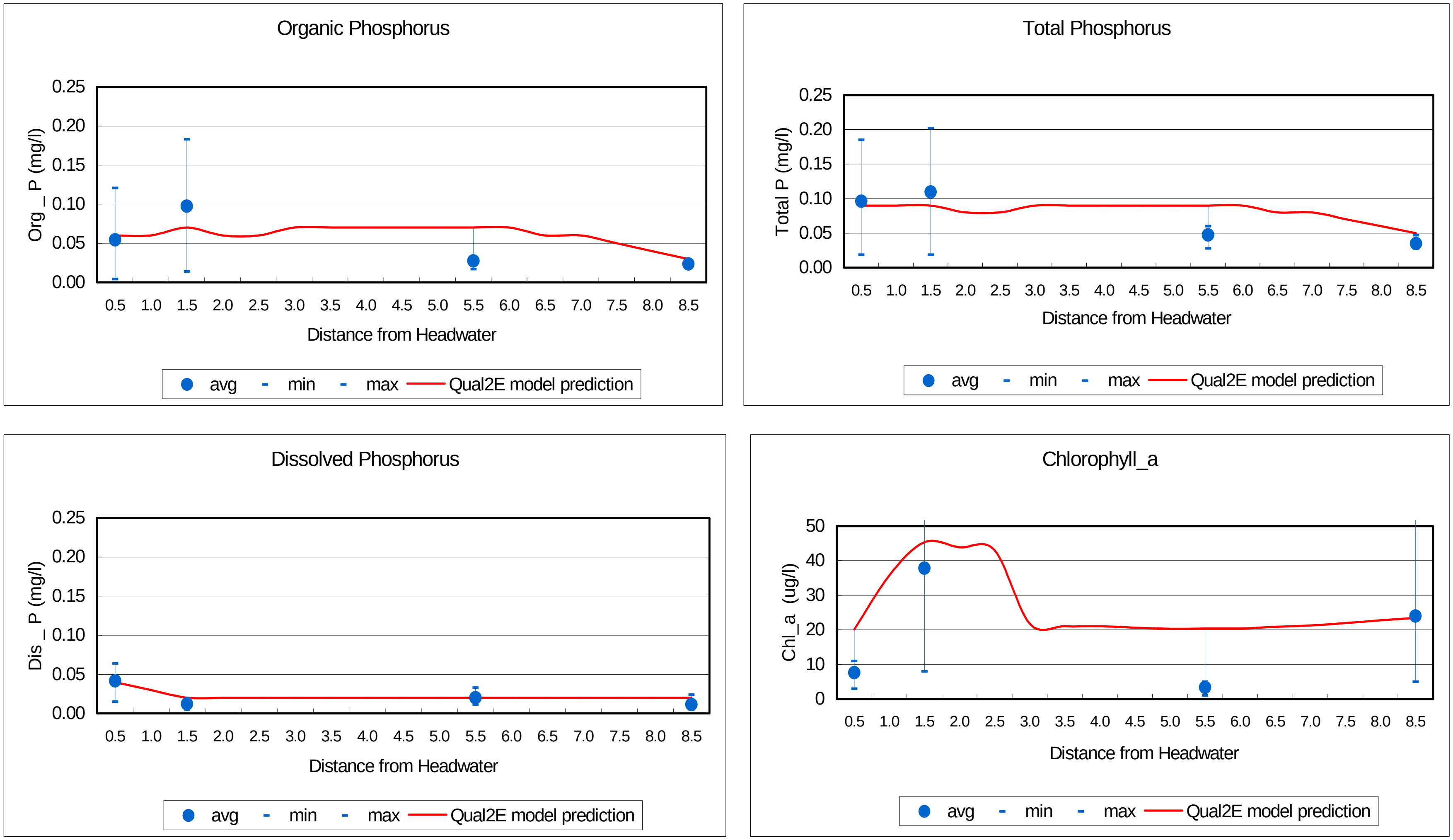


Figure 4 - 33 James Branch (incl. Record Pond) Org_P, Dis_P, Total P, and Chlorophyll_a Calibration

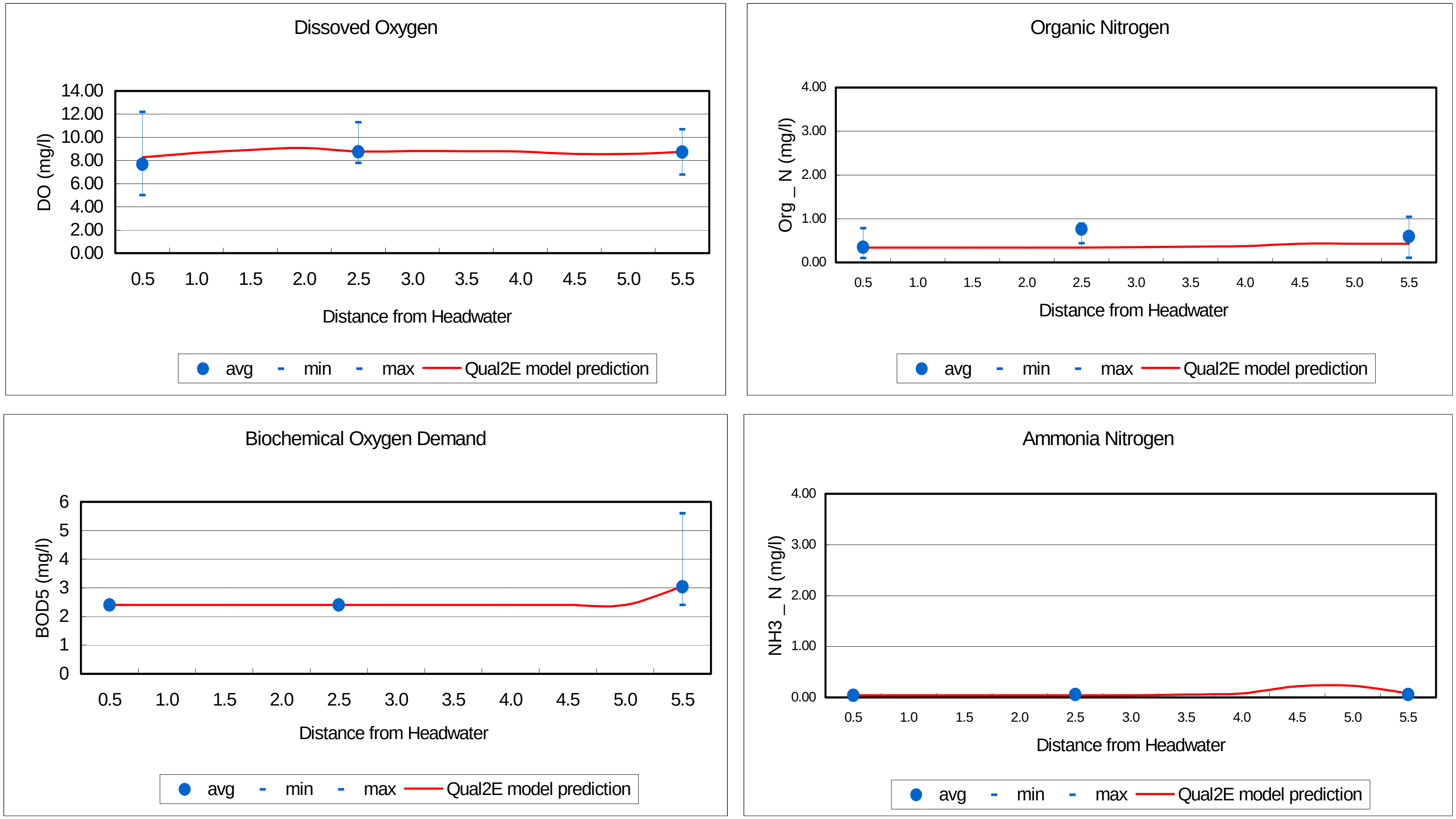
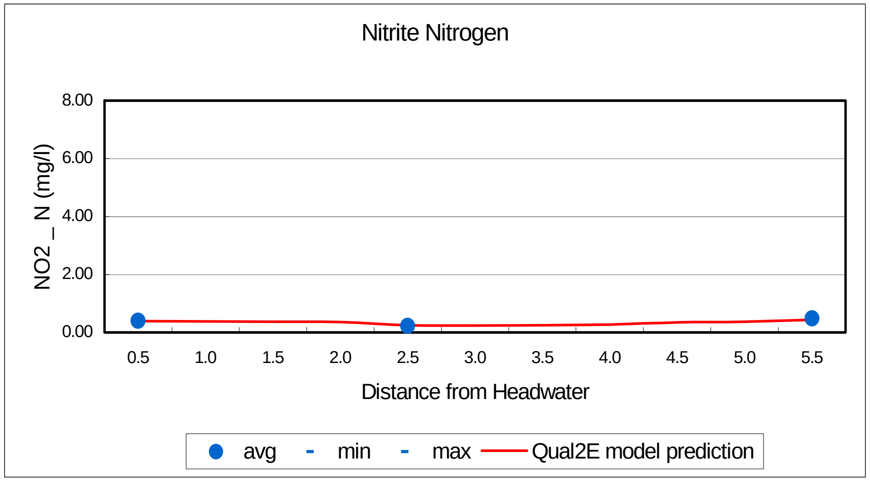
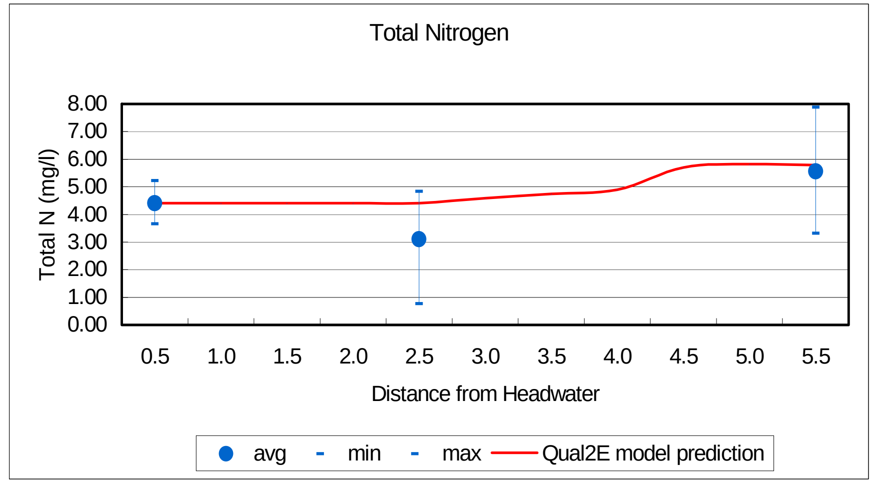


Figure 4 - 34 Tussocky Branch DO, BOD5, Org_N, and NH3_N Calibration





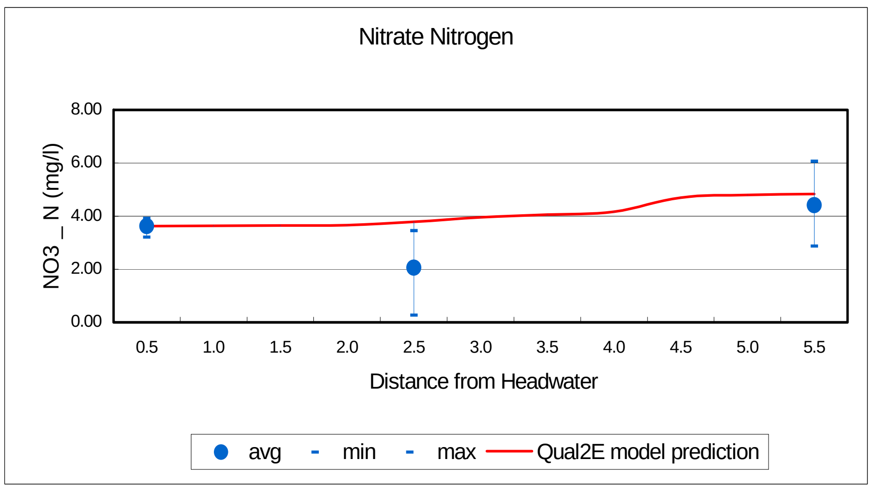


Figure 4 - 35 Tussocky Branch Nitrite, Nitrate and Total Nitrogen Calibration

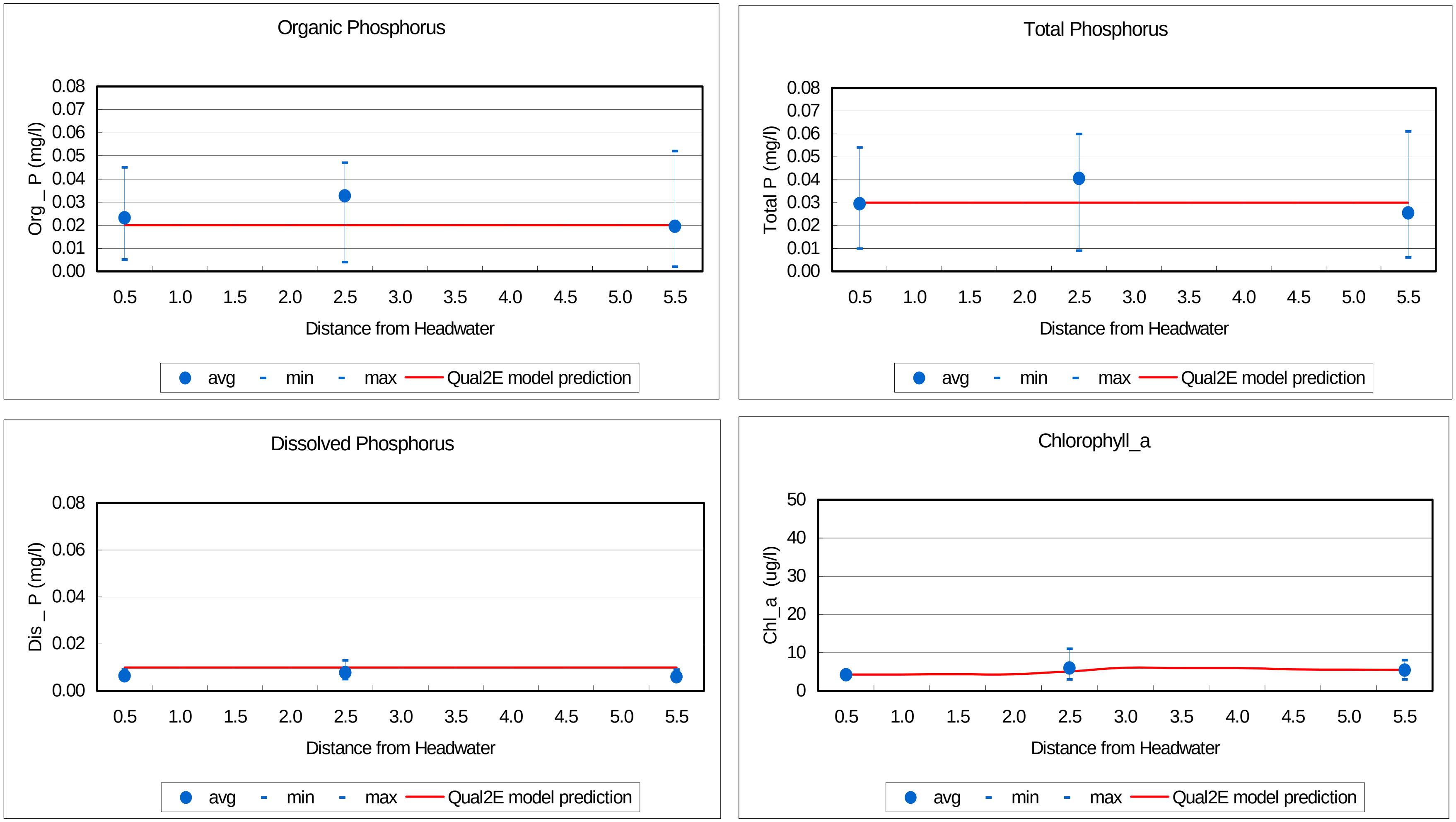


Figure 4 - 36 Tussocky Branch Org_P, Dis_P, Total P, and Chlorophyll_a Calibration

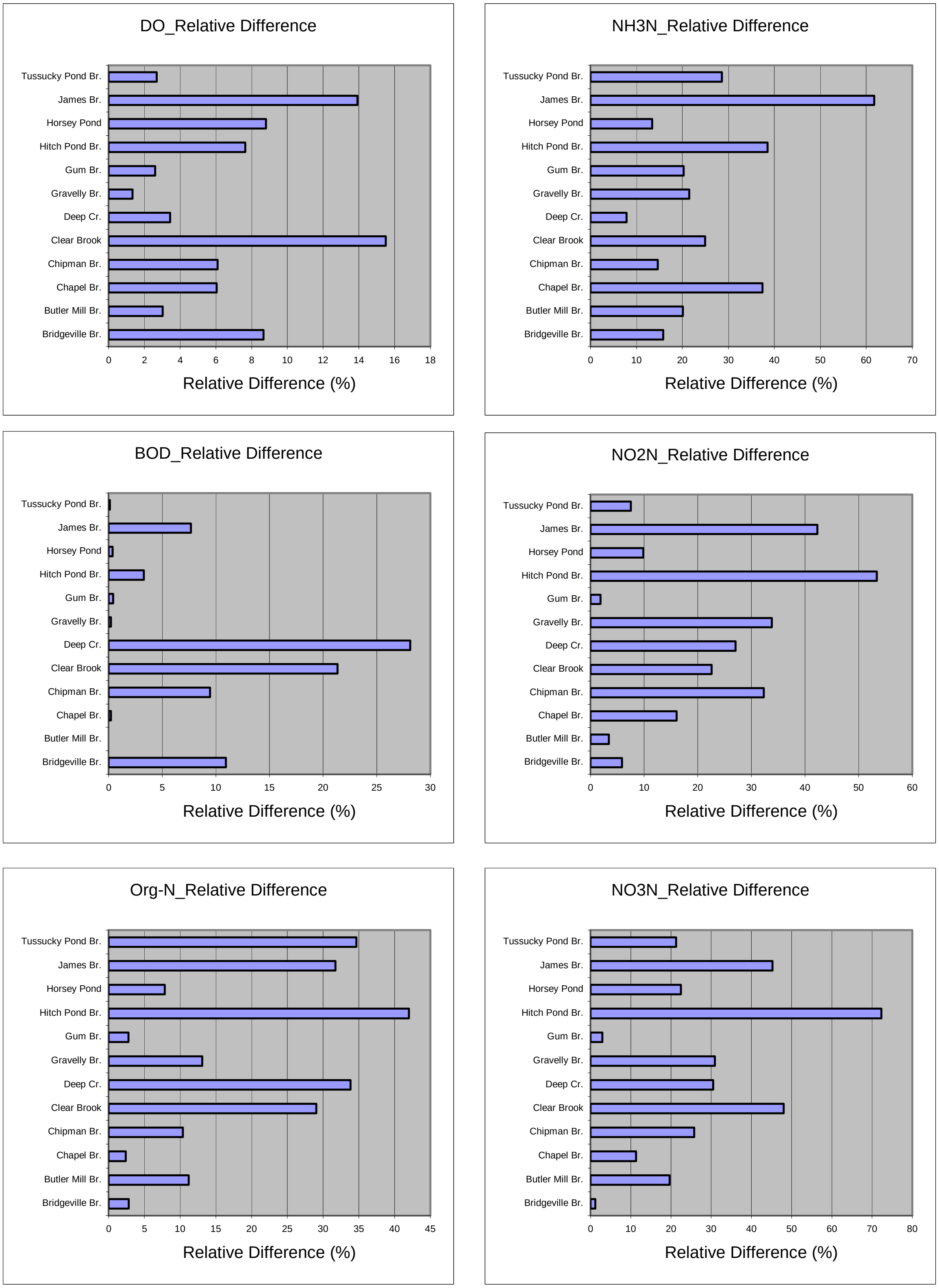


Figure 4 - 37 Relative Differences of Tributary Models for DO, BOD5, Org_N, NH3N, NO2N and NO3N

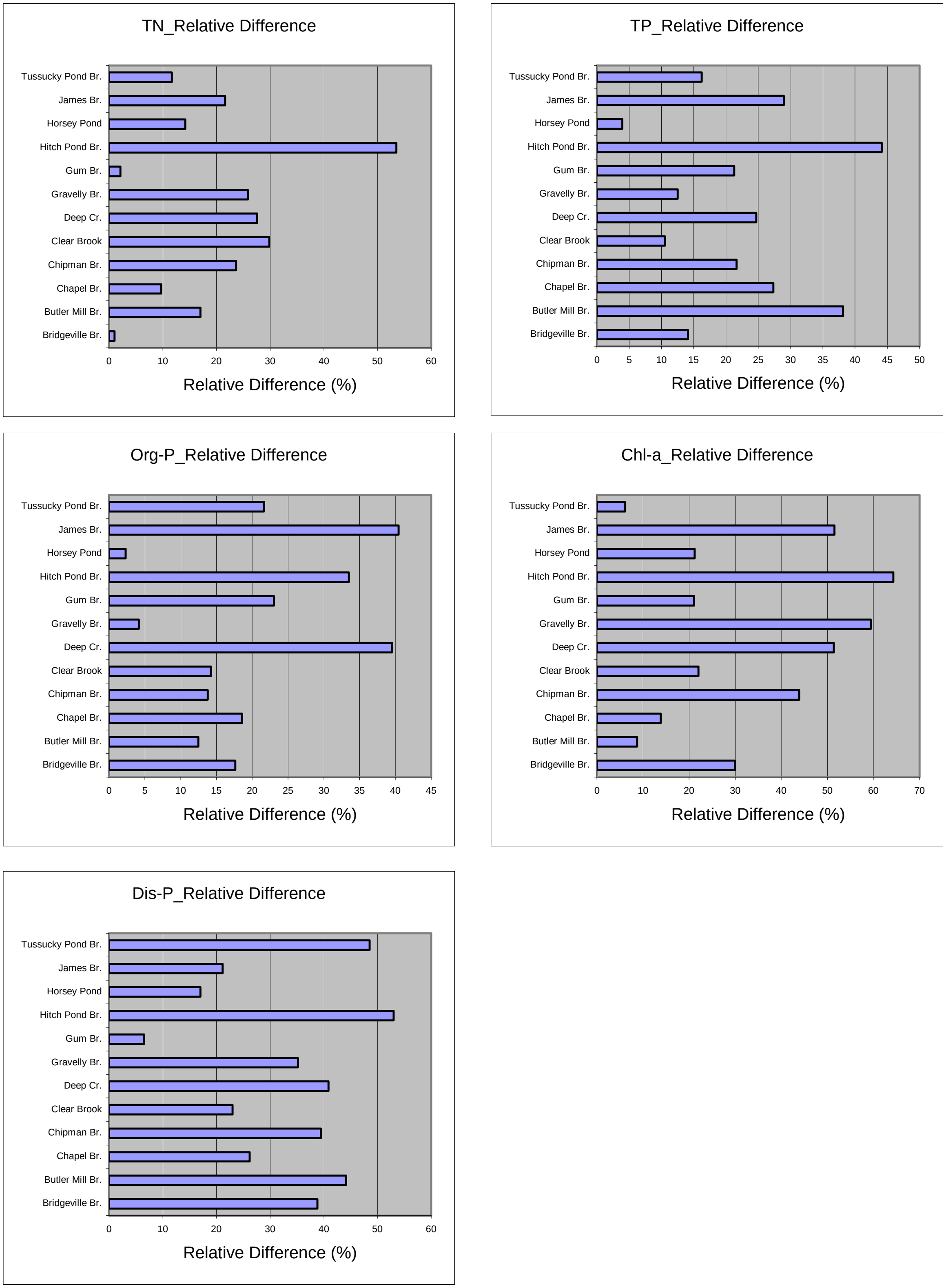


Figure 4 - 38 Relative Differences of Tributary Models for TN, Org_P, Dis_P, TP and Chlorophyll-a

5. Establishing TMDL for Tributaries and Ponds of Nanticoke River

EPA's regulations require an approvable TMDL containing following elements:

1. Waterbody name & location
2. Existing pollutant load
3. Deviation of load from the amount needed to attain water quality standards
4. Sources, by category or individually
5. Waste load allocation from point sources
6. Load allocation from nonpoint sources, including air deposition & natural background
7. Margin of safety
8. Seasonal variation
9. Allowance for reasonably foreseeable future growth

Elements one through four above are already addressed in previous four chapters. In addition, elements 5 through 9 of the above list are already addressed in the 1998 TMDL analysis for the Nanticoke River and Broad Creek(6), hence , they will not be repeated in this report.

In this chapter, the adequacy of the Nanticoke River and Broad Creek TMDL established in 1998 will be examined for tributaries and ponds within the watershed which are listed for nutrients and/or DO using Qual2E models. The 1998 TMDL for the Nanticoke River and Broad Creek requires 30% reduction of nitrogen load and 50% reduction of phosphorous load from nonpoint sources within the watershed. The above reduction levels will be applied to the calibrated tributary Qual2E models, and the results will be compared against the state water quality standards and targets. Furthermore, the tributary loads generated from the above exercise will be applied to WASP model for the main stems of Nanticoke River and Broad Creek to ensure that state water quality standards and targets are attained.

5.1 Tributaries and Ponds

To consider the water quality conditions of the tributaries under design "critical" situation, it is assumed that all stream flows are at 7Q10 which is 7-day, consecutive low flow with recurrence interval of 10 years. The state standards requires that water quality parameters meet the numeric criteria at the 7Q10 flow or above. With regard to design temperature, a minimum value of 21^0 C was used for the analysis. 21^0 C is the summer average water temperature for monitoring stations in the Nanticoke River watershed.

The existing Nanticoke River and Broad Creek TMDL, established in 1998, requires that non-point source loads be reduced by 30% for nitrogen and 50% for phosphorous (from 1992 baseline). These levels of nonpoint source reductions are applied to the calibrated Qual2E models for tributaries and ponds by reducing concentrations of nutrients from headwaters, tributaries, and incremental flows by 30% for nitrogen and 50% for phosphorous, respectively.

The results of this analysis for each of the twelve streams modeled are included in Appendix C. Furthermore, the results of dissolved oxygen (DO), total nitrogen (TN), and total phosphorous (TP) analyses for all tributaries and ponds are shown in Figure 5 -1 through Figure 5 -12.

As it can be seen from the above figures, concentration of DO along all tributaries and ponds meets the state water quality standard of 5.5 mg/l. With regard to nitrogen and phosphorous, the figures show that concentrations at some segments exceed the state targets of 3.0 mg/l of nitrogen and 0.1 mg/l of phosphorous. However, since the state targets are generally applied to minimize down stream impact of nutrients, the tributary loads as calculated in this analysis are applied to the main stem Nanticoke River and Broad Creek WASP model to assess if nutrient targets for the main stems are achieved.

5.2 Main Stems of the Nanticoke River and Broad Creek

To investigate the impact of the updated nonpoint source tributary loads on nutrient concentrations of main stems of Nanticoke River and Broad Creek, this analysis was performed using the existing main stem WASP model for Nanticoke River and Broad Creek. See Total Maximum Daily Load (TMDL) Analysis for Nanticoke River and Broad Creek, Delaware, DNREC, Final Report, December 1998 (6) for detail description of the main stem WASP model.

Table 5-1 compares major elements of the WASP model during 1998 analysis and present investigation. As it can be seen from the table, flow values and point source loads are kept unchanged for present analysis, while the nonpoint source loads from tributaries are updated based on the recently developed Qual2E model outputs.

Table 5 - 1 Comparison of Model Governing Conditions

Model Element	1998 TMDL Analysis	Present Analysis
Flow	1992 flow with 7-days 7Q10 flow replacement	same as 1998 TMDL analysis
PS Load	BNR level treatment for three large municipal facilities, plus current permitted flow and loads for other four treatment plants	same as 1998 TMDL analysis
NPS Load from tributaries	characteristic load - the mixture of literature values and averaged long-term monitoring data	Qual2E model outputs

Table 5 - 2 lists the concentrations of various pollutants entering the main stems of the Nanticoke River and Broad Creek from tributaries as estimated by the Qual2E models. These concentrations are the values generated by the Qual2E calibrated models and are generally higher than the

characteristic concentrations used in the 1998 WASP model development. The main stem WASP model internally applies the reduction levels of 30% N and 50% P to all tributary loads to comply with the existing TMDL load reduction targets.

Table 5 - 2 Nonpoint Source Concentrations (from Tributary Qual2E Models)

Tributary	NH3-N	NOX-N	Dis-P	Chl-a	BOD5	DO	Org-N	Org-P
	mg/l	mg/l	mg/l	ug/l	mg/l	mg/l	mg/l	mg/l
1. Gum Br.	0.150	6.930	0.010	8.47	2.42	7.24	0.950	0.070
2. Deep Creek	0.040	2.100	0.020	13.44	2.51	9.23	0.440	0.020
3. Gravelly Br.	0.080	2.380	0.020	9.01	2.39	8.25	0.670	0.020
4. Bridgeville Br	0.110	4.740	0.010	8.53	2.65	9.03	0.860	0.030
5. Clear Brook	0.100	3.200	0.020	43.46	2.97	8.85	0.600	0.060
6. Chapel Br	0.110	9.880	0.030	2.50	2.40	7.33	0.420	0.010
7. Butler Mill Br	0.100	4.360	0.040	3.98	2.40	7.41	0.510	0.020
8. Tussocky Br	0.080	5.270	0.010	5.45	3.05	8.76	0.430	0.020
9. Horsey Pond	0.060	2.760	0.010	38.15	3.00	9.05	0.690	0.060
10. Record Pond	0.080	3.810	0.020	22.92	3.12	8.87	0.630	0.020

The results of the main stem WASP model analysis are presented in Figures 5 - 13 through 5 - 16. For comparison, the 1998 TMDL analysis results are plotted on the same graphs. As it can be seen from the above figures, concentrations of nutrients (TN and TP) in the main stems of Nanticoke River and Broad Creek are slightly higher than the 1998 TMDL analysis, however, they are within the 20% confidence interval of the targets (as was the case during 1998 analysis).

5.3 Conclusion

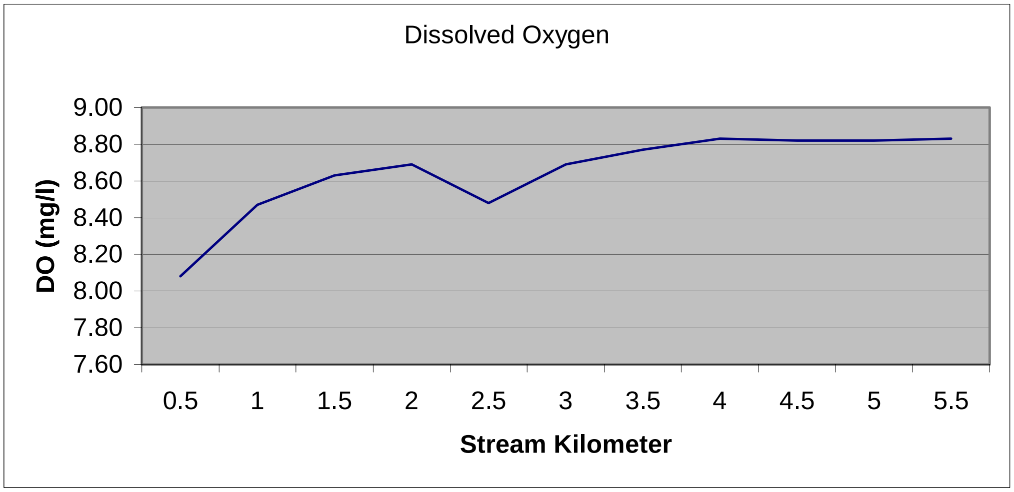
Based on the results of the analysis presented in this chapter, it can be concluded that the already established load reduction targets (30% for nitrogen and 50% for phosphorous) are sufficient to meet water quality standards at all tributaries and ponds listed for nutrients and/or DO. In addition, the results of the analysis show that implementing the above nutrient load reduction levels will result in meeting the total nitrogen and total phosphorous concentration targets in the main stems of the Nanticoke River and Broad Creek, with consideration of 20% confidence interval. This indicates that the 1998 TMDL regulation for the Nanticoke River and Broad Creek is adequate to protect all designated uses for the listed tributaries and ponds. Therefore, it is recommended that the existing regulation remain intact without any modification.

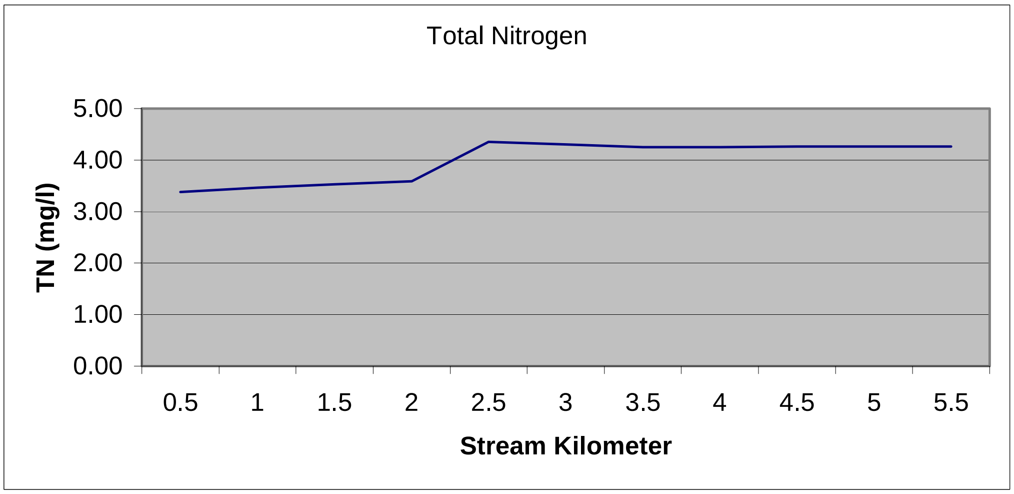
5.4 Public Participation

Delaware DNREC has made significant efforts to involve the stake holders and general public in development and implementation of the TMDL for the Nanticoke River and Broad Creek. These efforts include: formation of the Nanticoke River TMDL Advisory Committee, conducting public workshops and public hearings, public notice announcements in the local and statewide newspapers, and publication of the regulation in the Delaware Register. In addition, TMDL regulation and the technical document are made available through the Department's web site.

Since adoption of the TMDL Regulation in 1998, a Nanticoke Tributary Action Team is formed from local representatives and stake holders to develop a Pollution Control Strategy for implementing the TMDL requirements. The team members are meeting frequently and are in the process of drafting a TMDL implementation plan for the Nanticoke River basin.

With regard to the current study for tributaries and ponds of the Nanticoke River and Broad Creek, and since the requirement for nonpoint source load reduction levels are not different than the basin-wide load reduction levels established in 1998, no additional pubis hearing is planned at this time. However, the technical report will be posted on Department's web site to be accessed and reviewed by the general public.





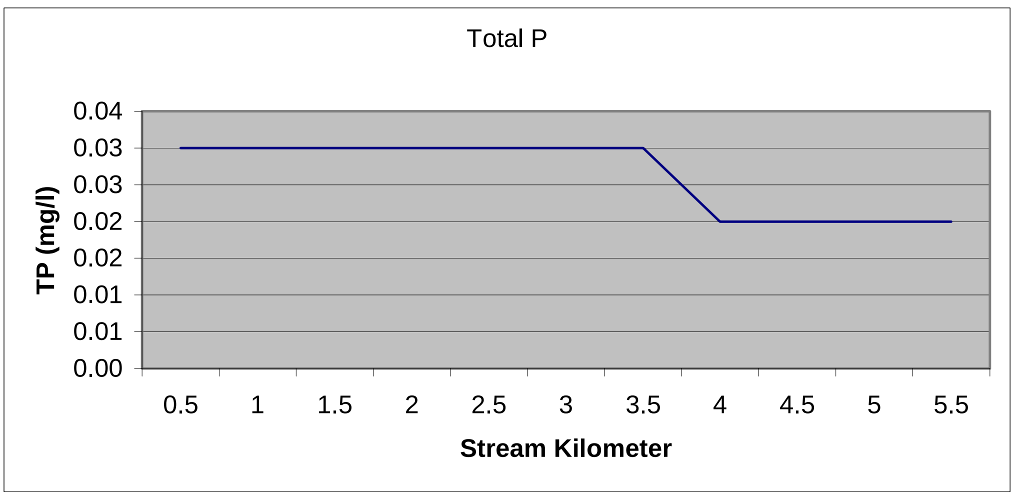
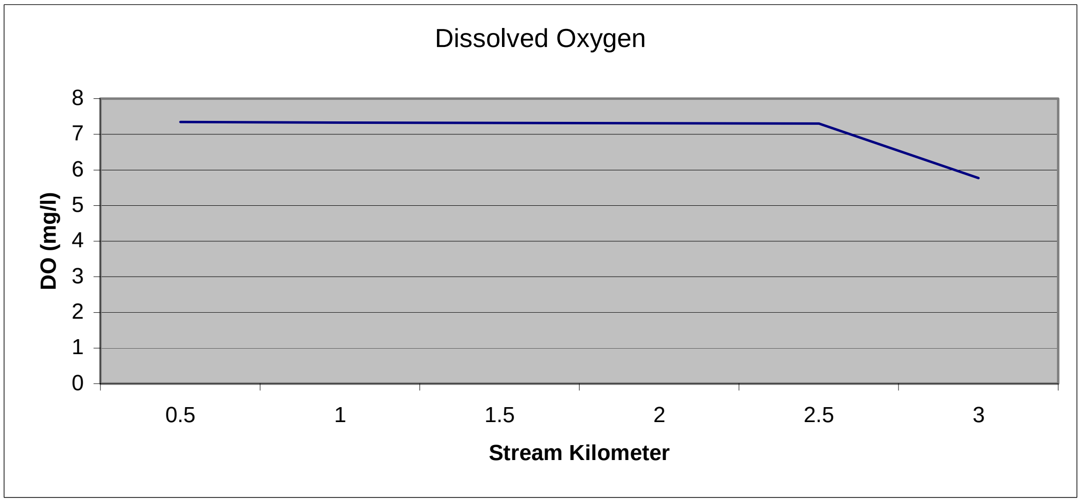
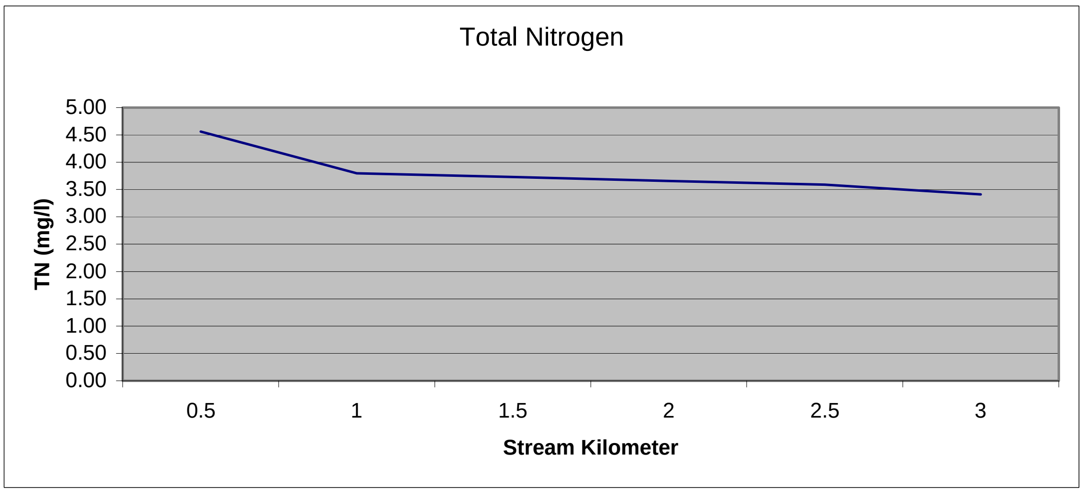


Figure 5 -1 Concentrations of DO, TN and TP along Bridgeville Branch During Critical (Design) Condition





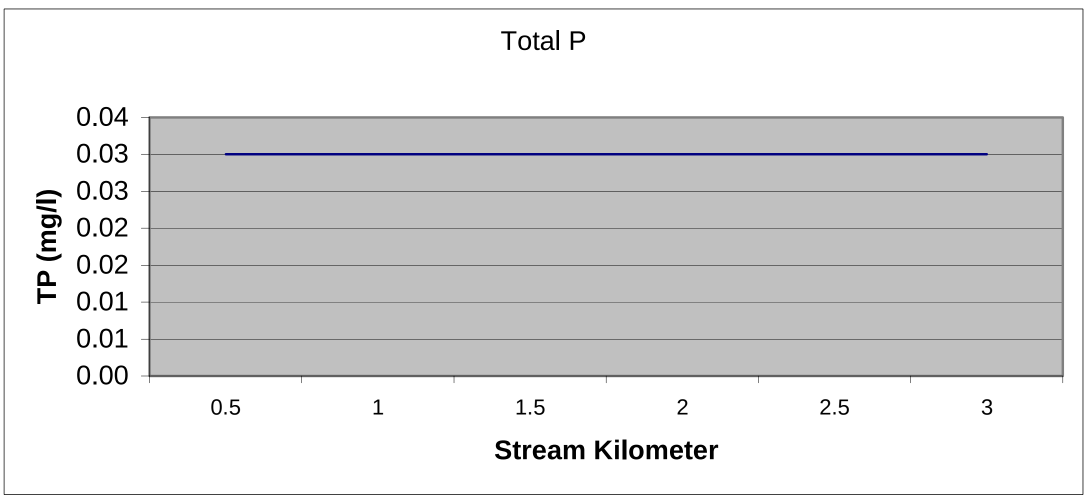


Figure 5 -2 Concentrations of DO, TN, and TP along Butler Branch During Critical (Design) Condition

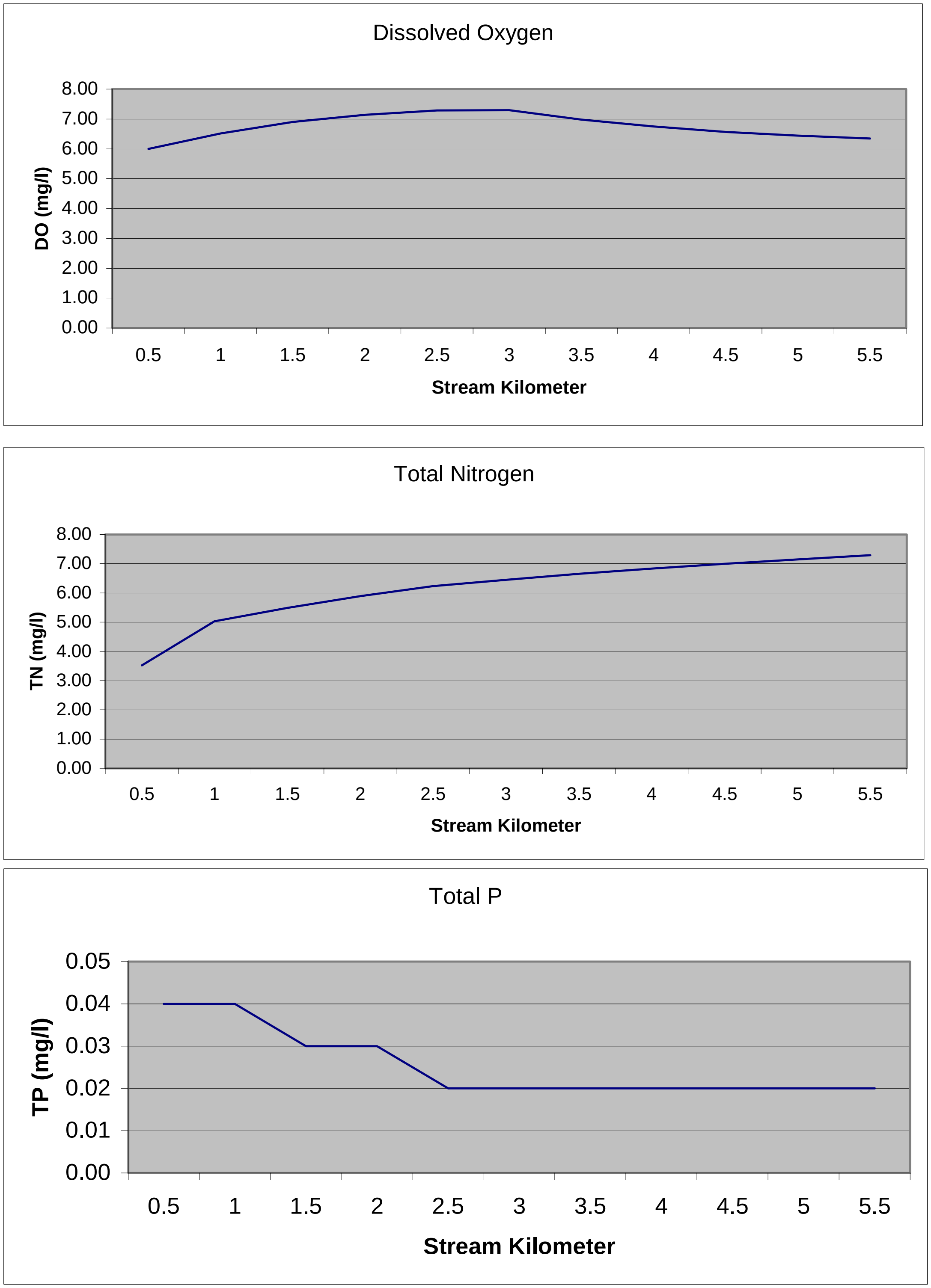
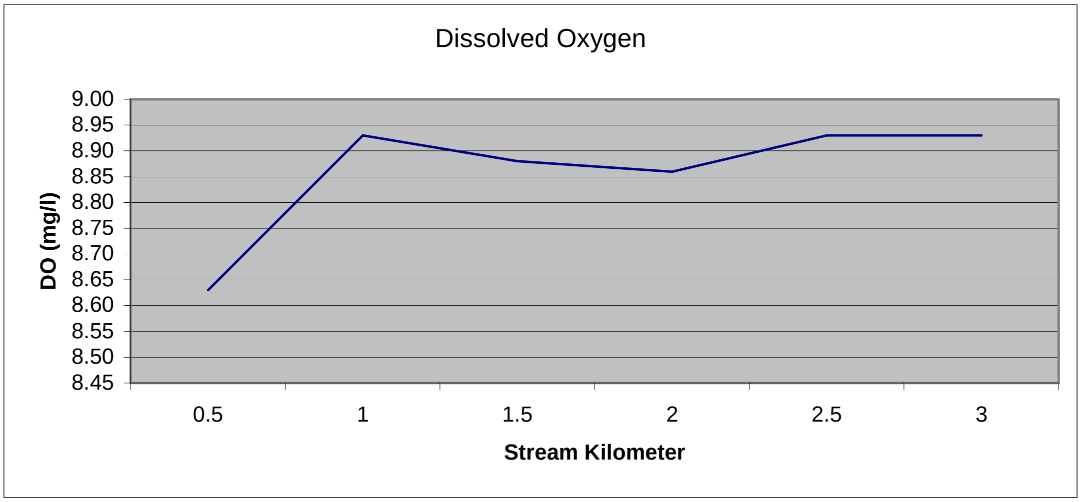
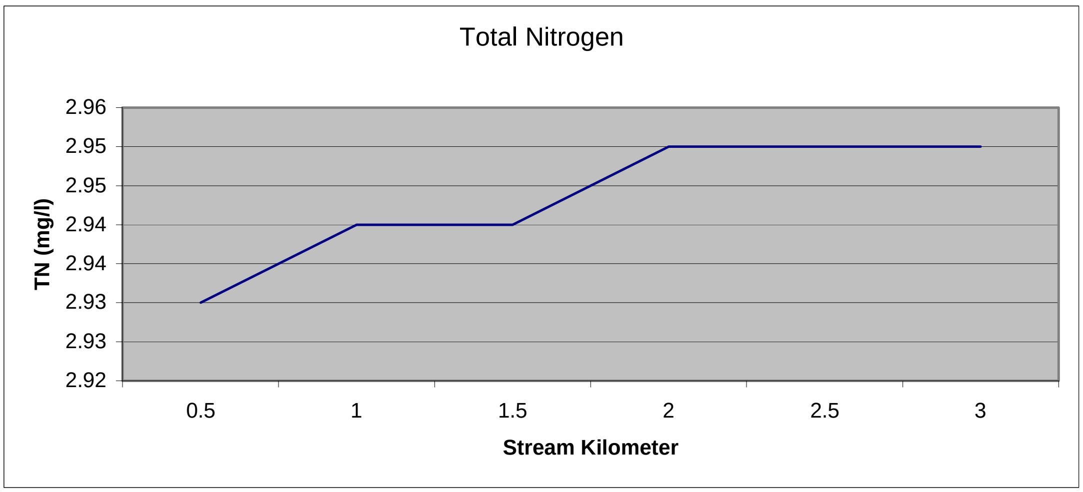


Figure 5 -3 Concentrations of DO, TN, and TP along Chapel Branch
During Critical (Design) Condition





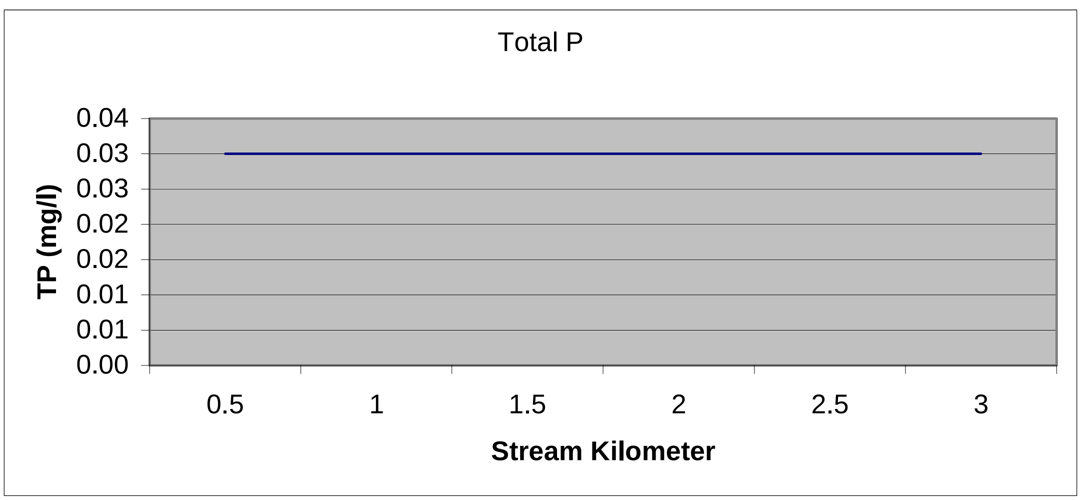
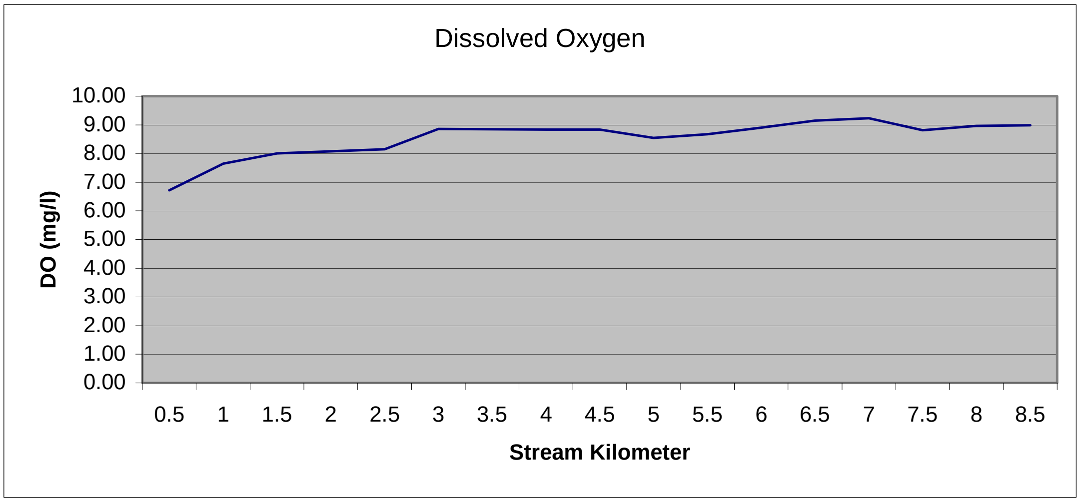
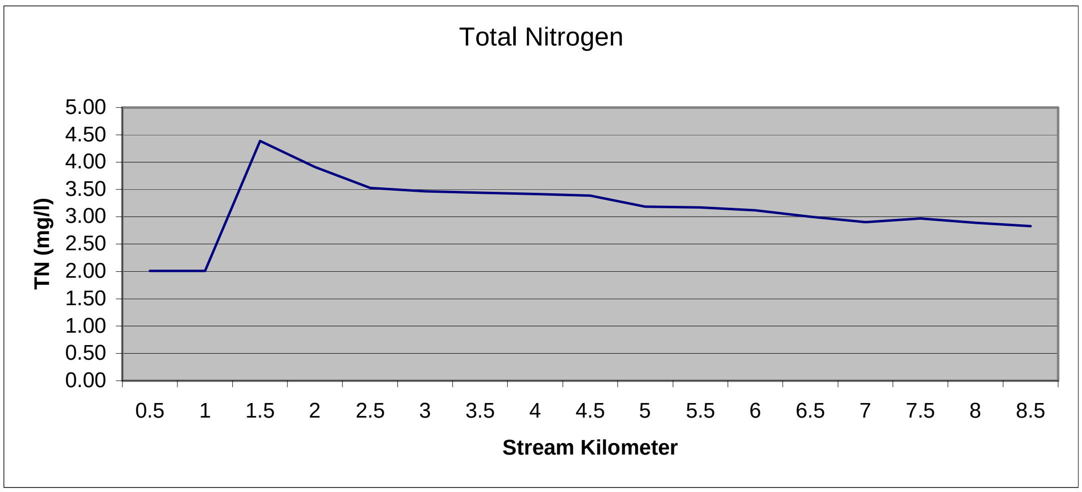


Figure 5 -4 Concentrations of DO, TN, and TP along Chipman Pond Branch
During Critical (Design) Condition





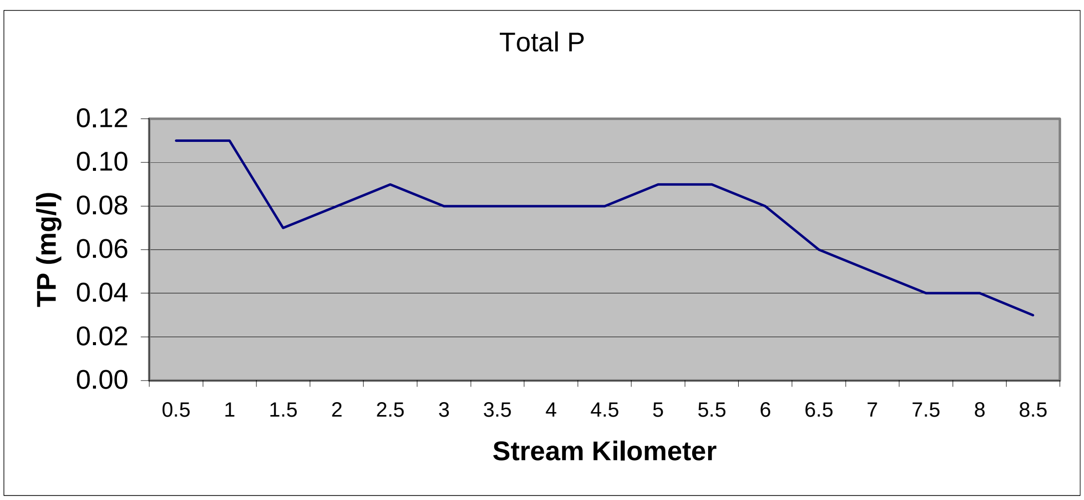


Figure 5 - 5 Concentrations of DO, TN, and TP along Clear Brook During Critical (Design) Condition

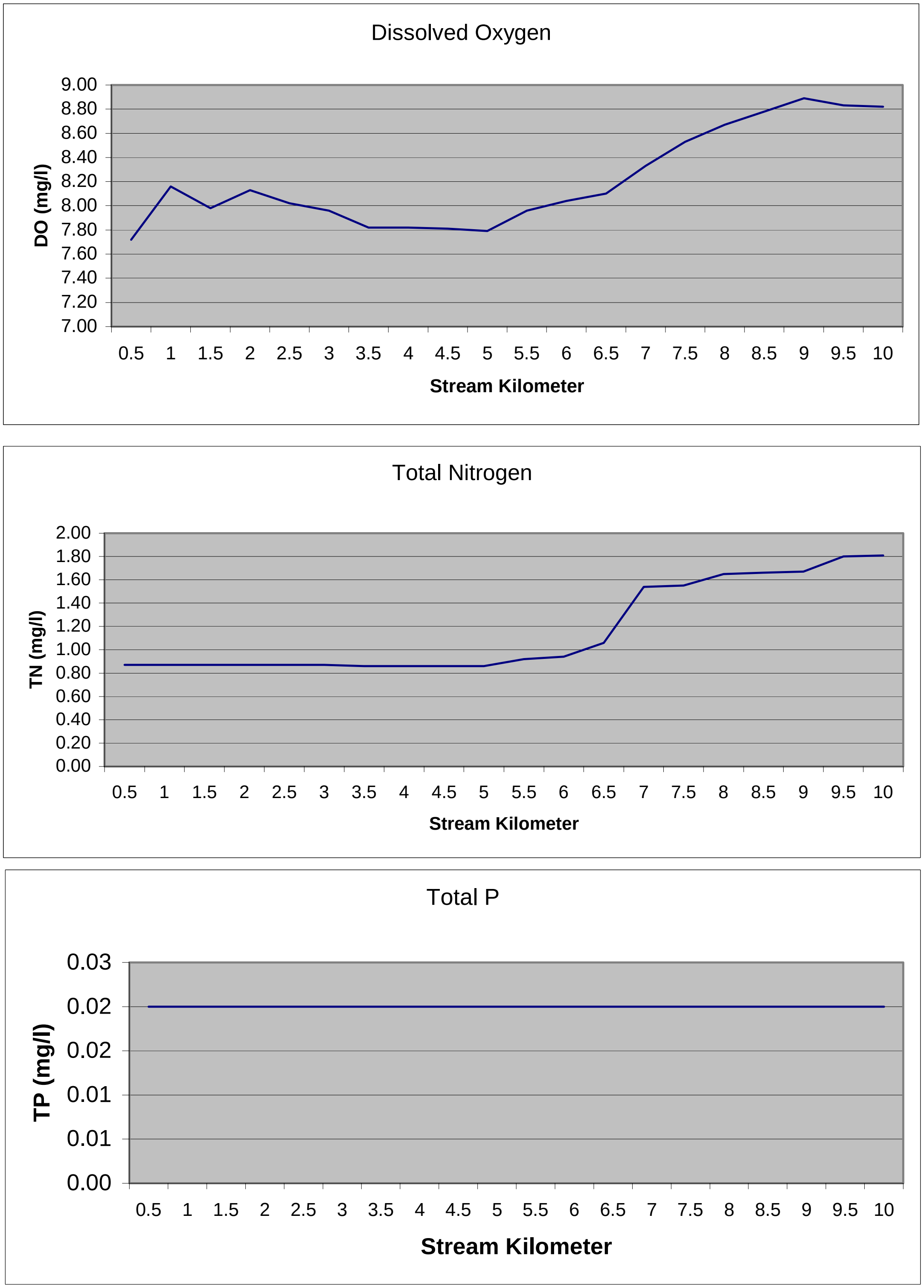


Figure 5 - 6 Concentrations of DO, TN, and TP along Deep Creek
During Critical (Design) Condition

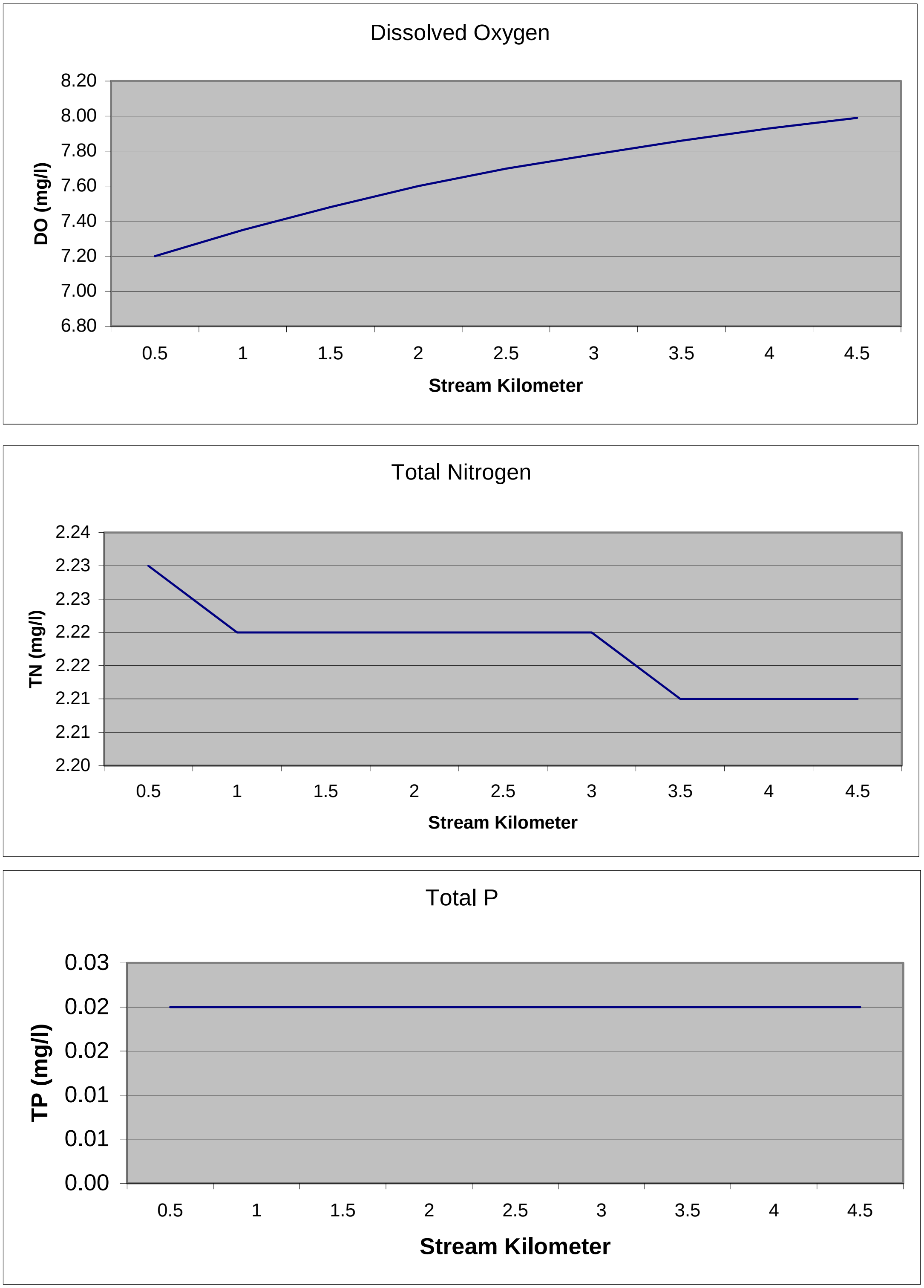


Figure 5 - 7 Concentrations of DO, TN, and TP along Gravelly Branch
During Critical (Design) Condition

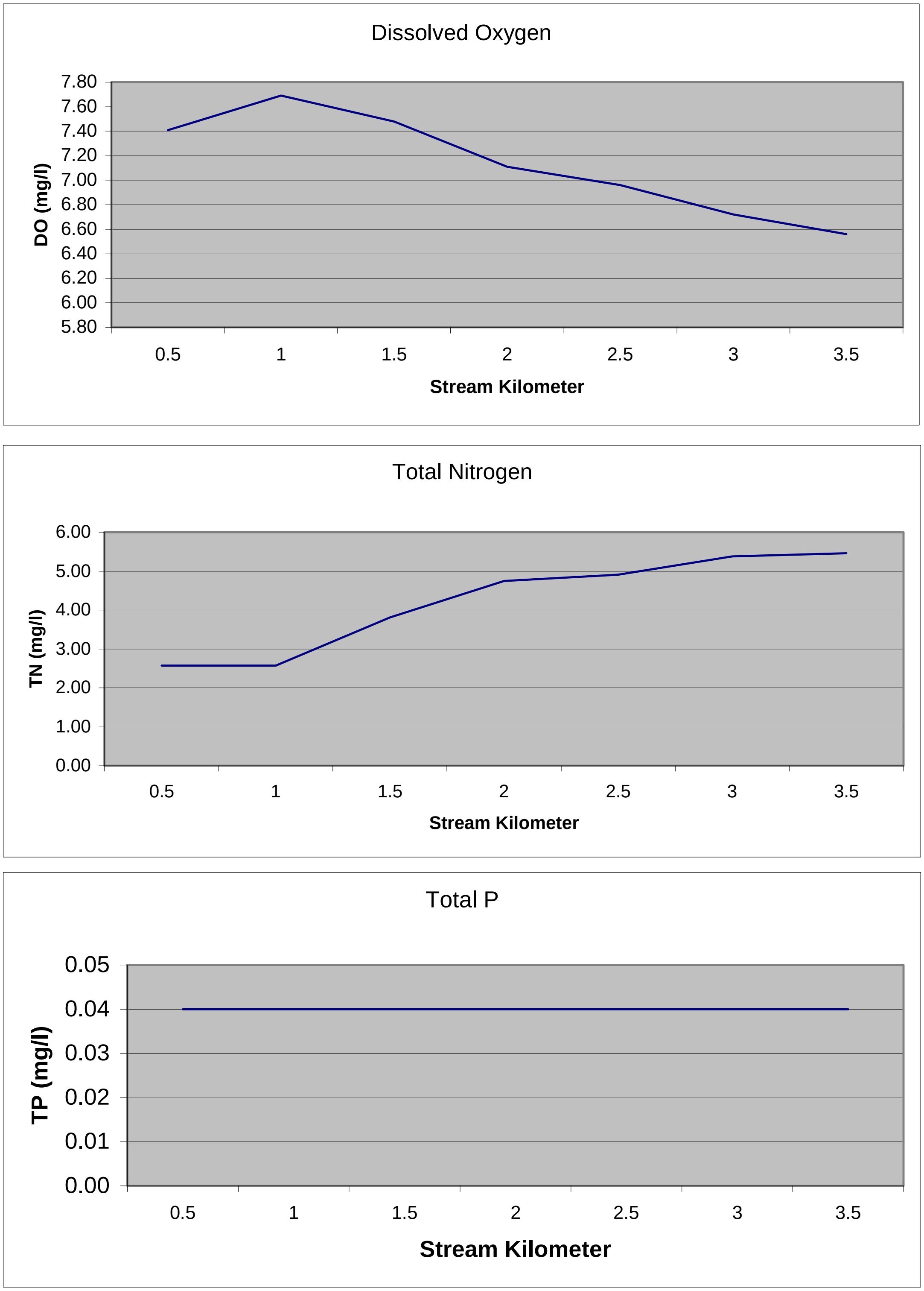
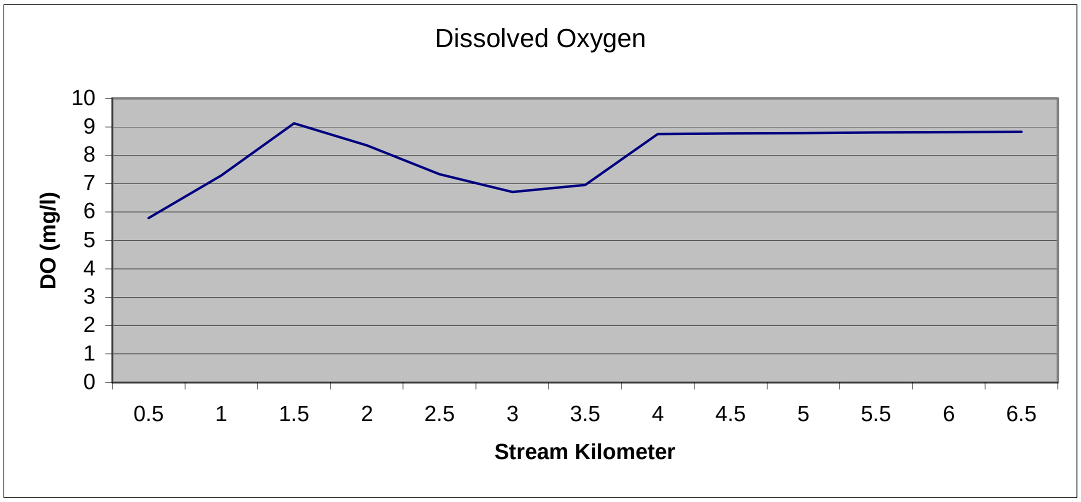
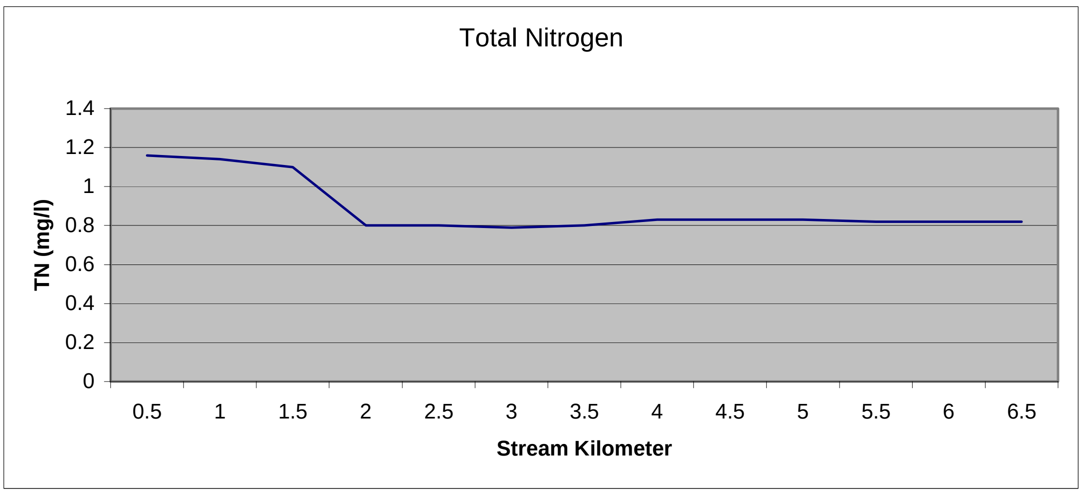


Figure 5 - 8 Concentrations of DO, TN, and TP along Gum Branch
During Critical (Design) Condition





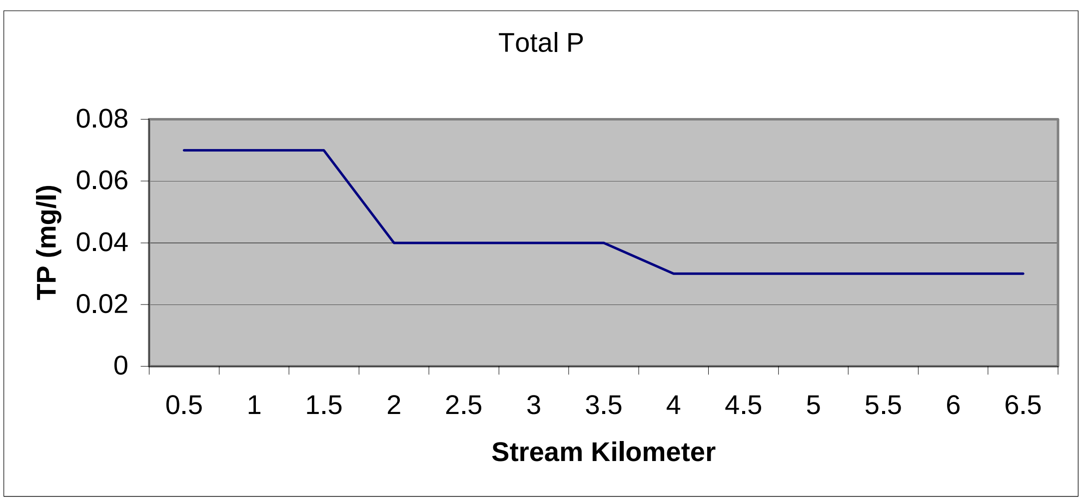
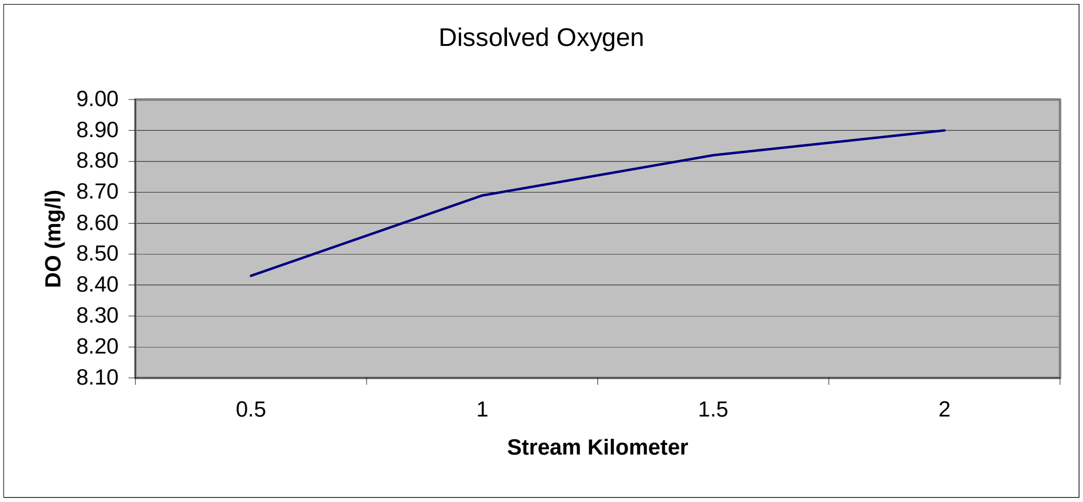
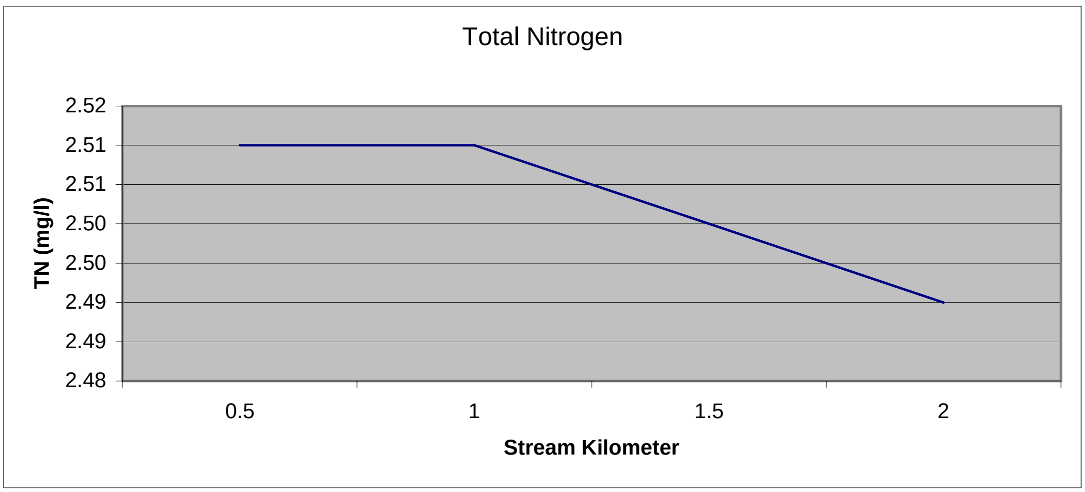


Figure 5 - 9 Concentrations of DO, TN, and TP along Hitch Pond Branch
During Critical (Design) Condition





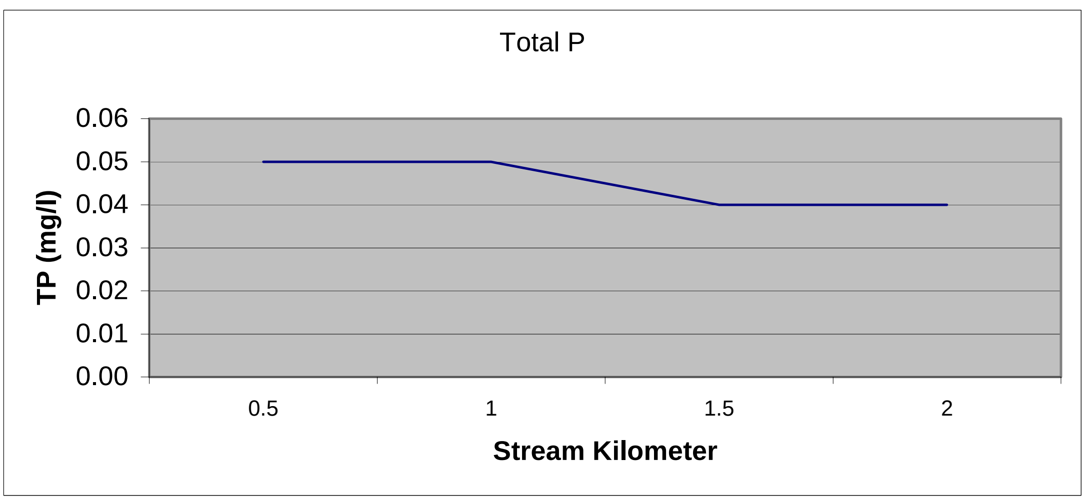


Figure 5 - 10 Concentrations of DO, TN, and TP along Horsey Pond During Critical (Design) Condition

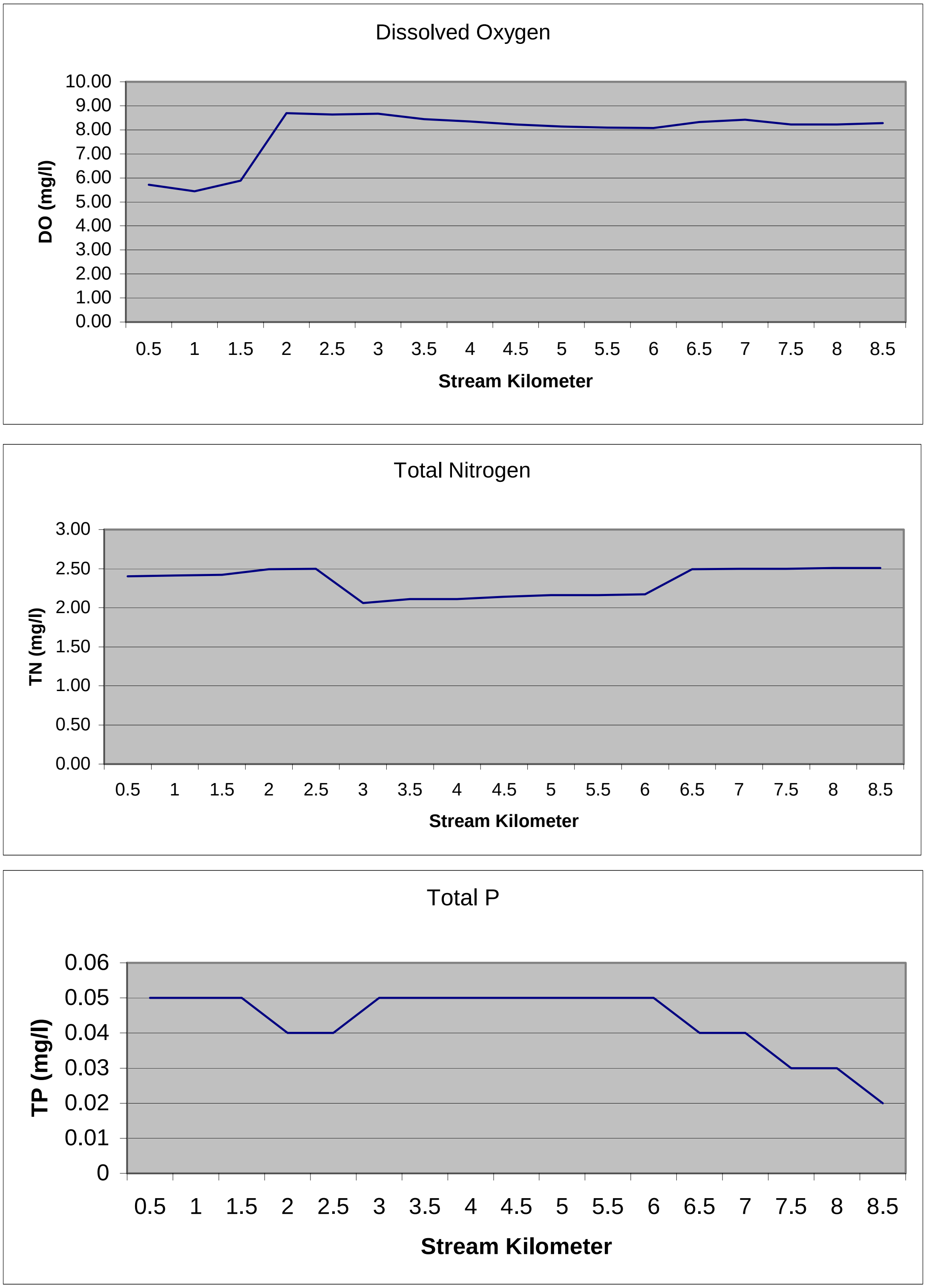
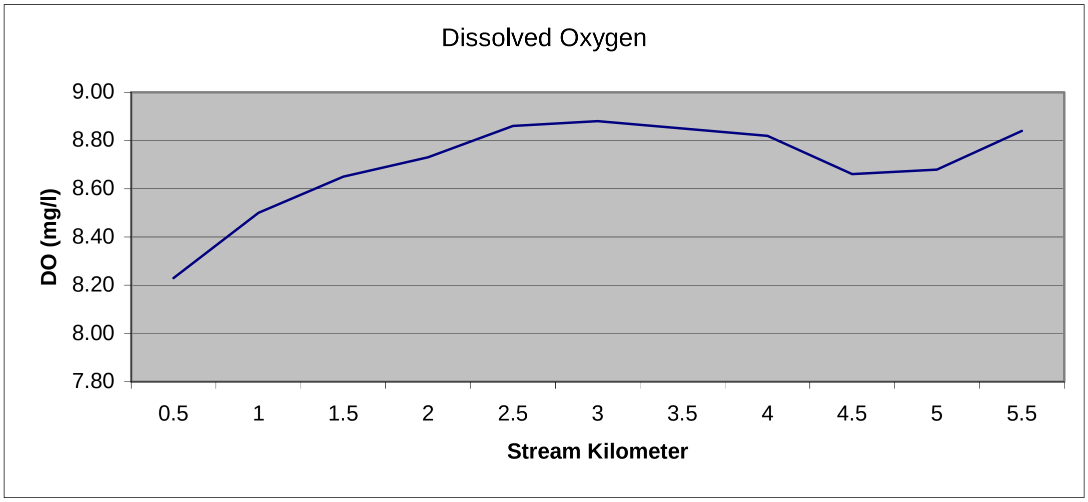
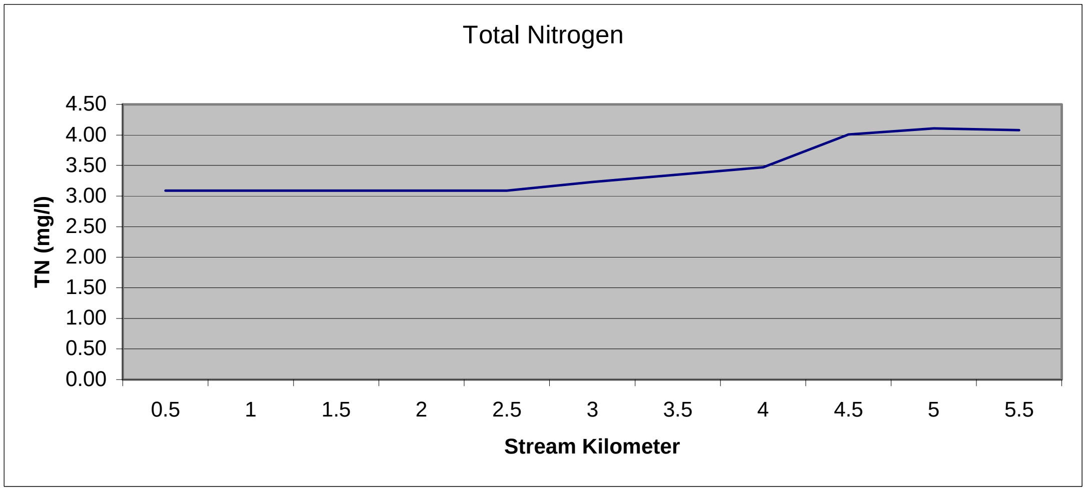


Figure 5 - 11 Concentrations of DO, TN, and TP along James Branch During Critical (Design) Condition





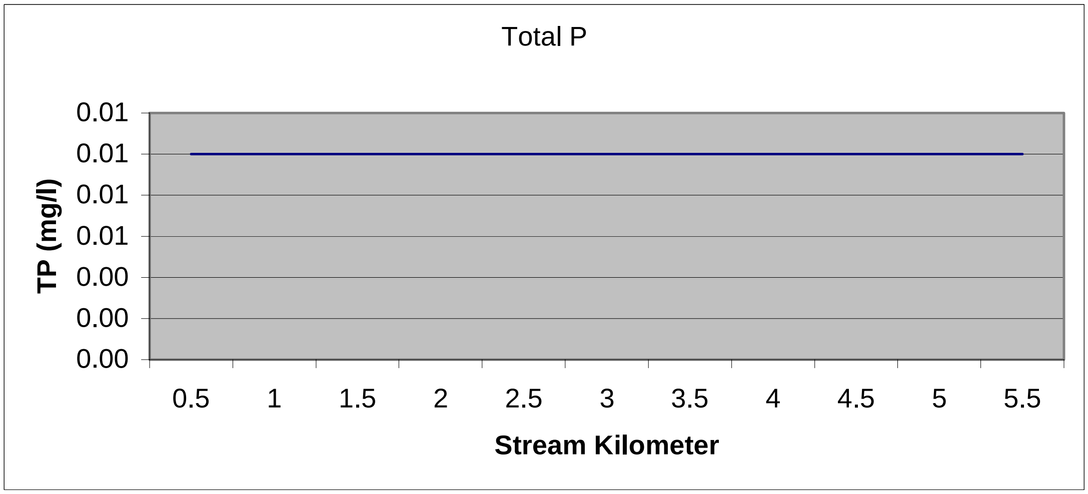


Figure 5 - 12 Concentrations of DO, TN, and TP along Tussocky Branch
During Critical (Design) Condition

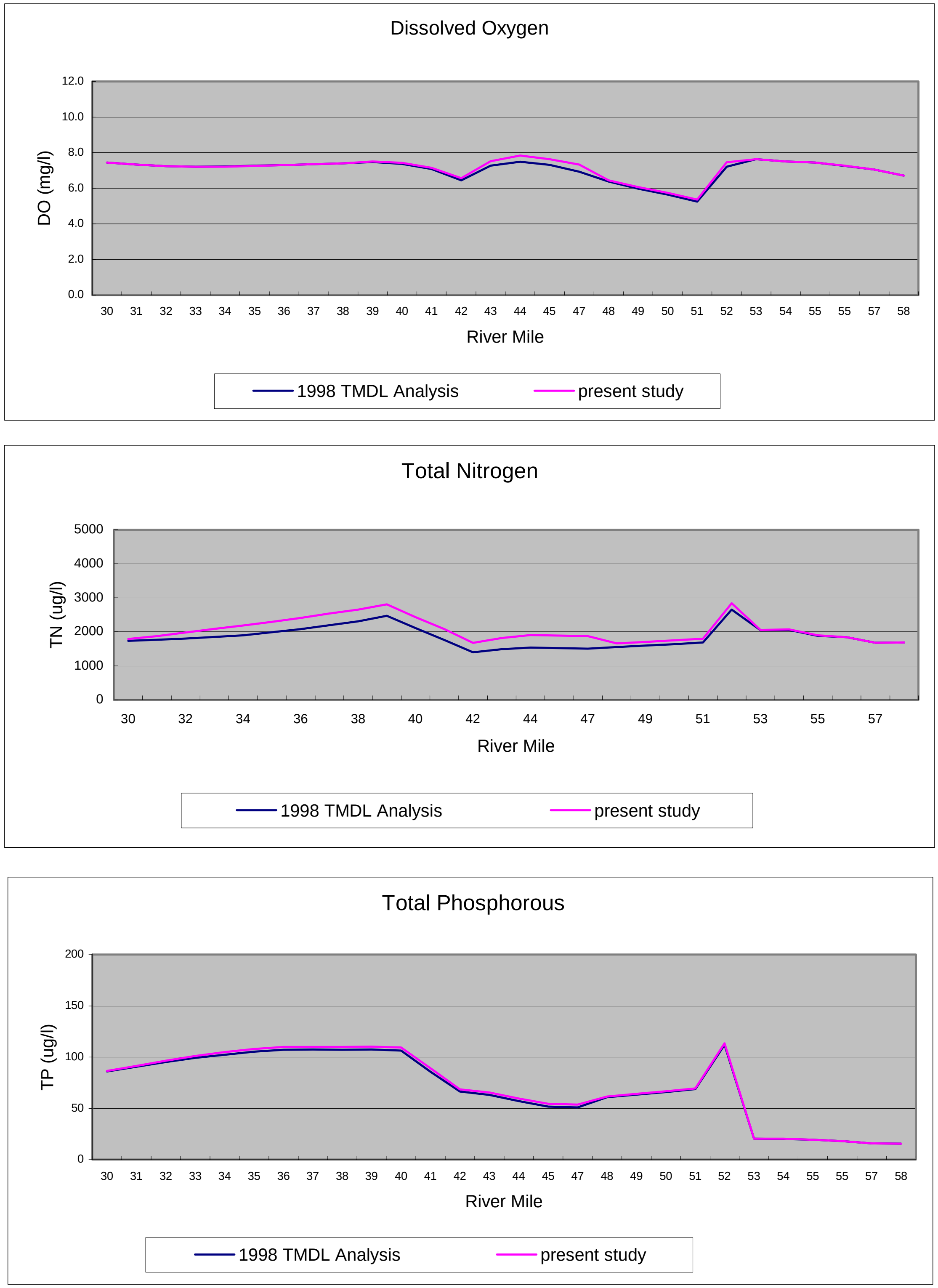
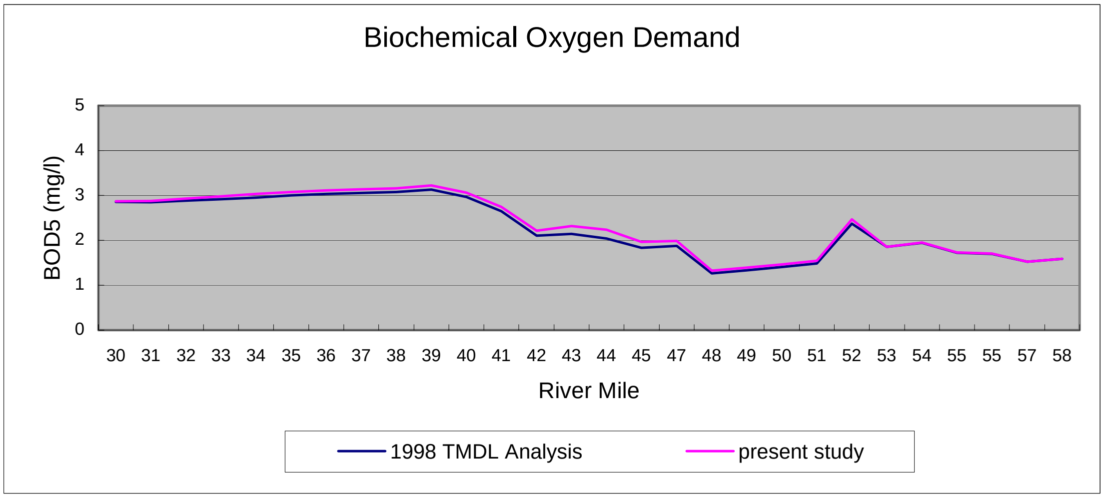


Figure 5 - 13 Concentrations of DO, TN, and TP along the Mainstem, Nanticoke River



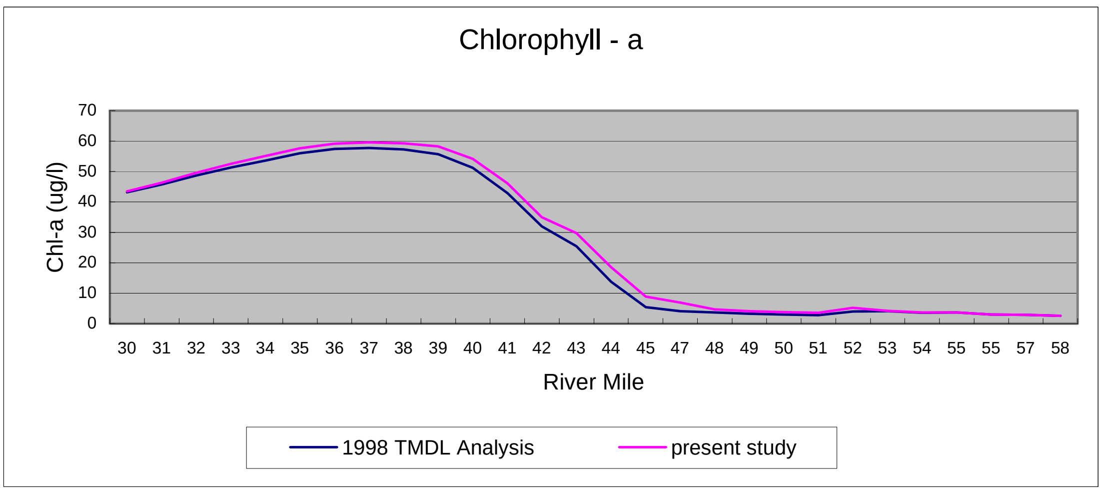
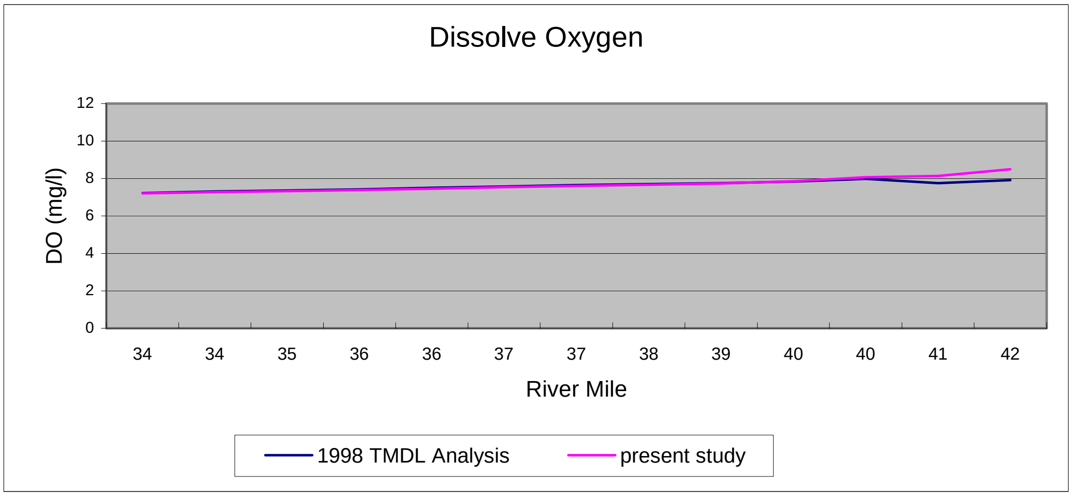
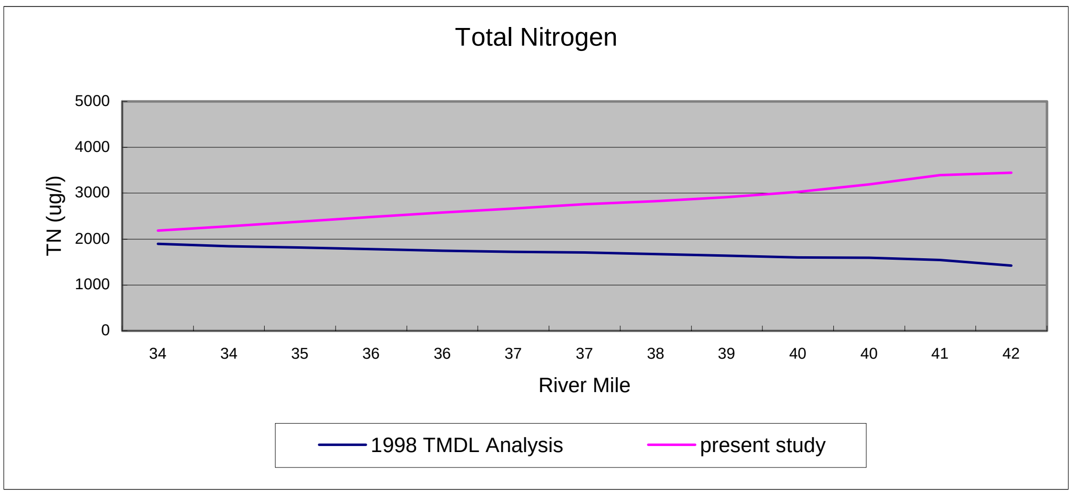


Figure 5 - 14 Concentrations of BOD5 and Chlorophyll-a along the Mainstem, Nanticoke River





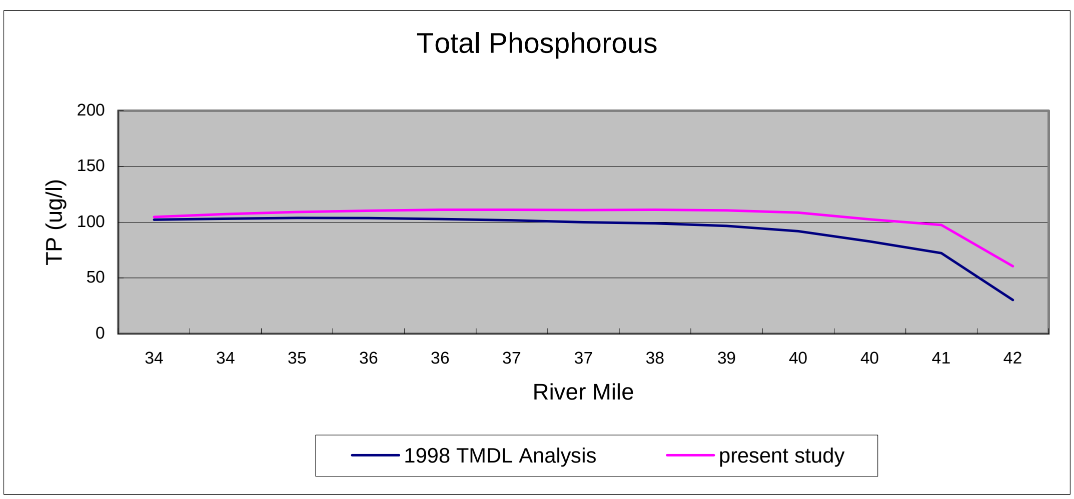
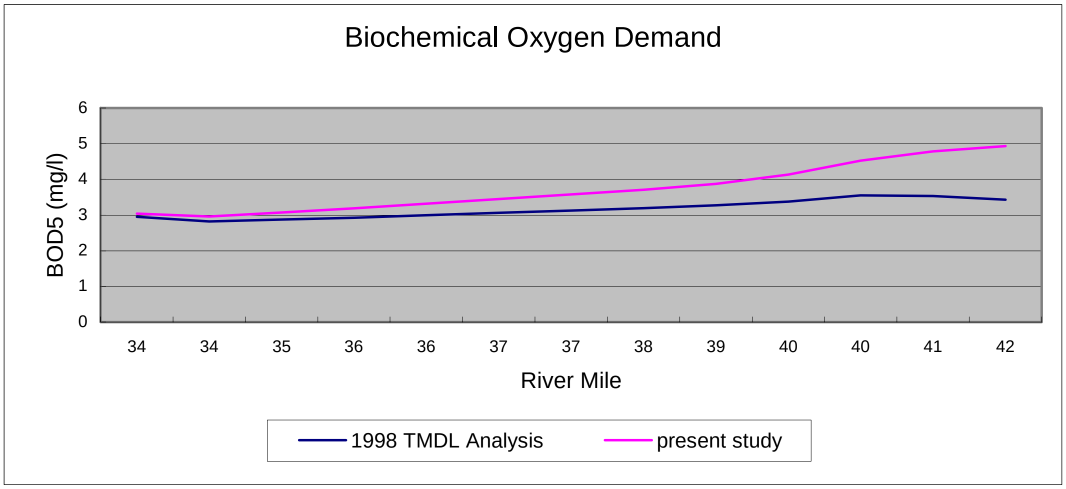


Figure 5 -15 Concentrations of DO, TN, and TP along the Mainstem, Broad Creek



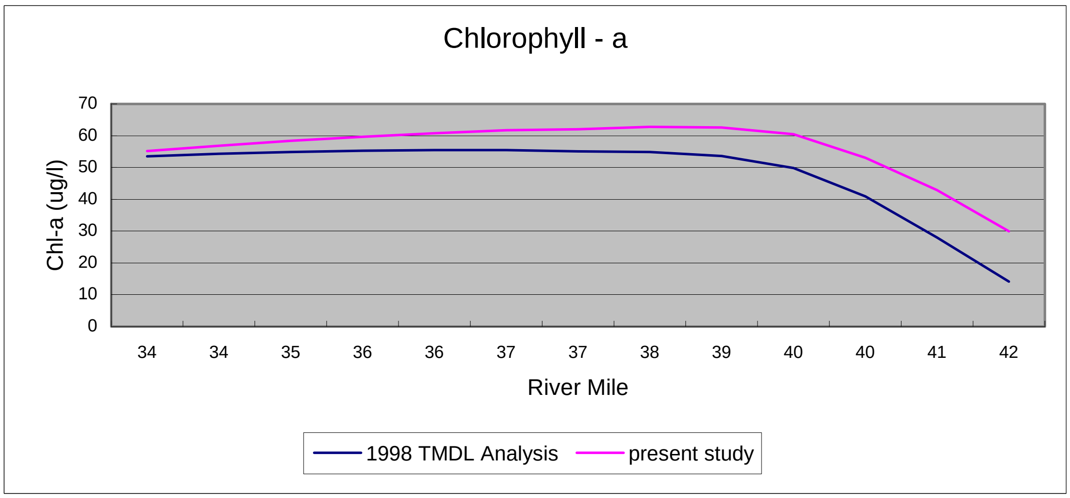


Figure 5 - 16 Concentrations of BOD5 and Chlorophyll-a along the Mainstem, Broad Creek

6. REFERENCES

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2. "Preliminary Water Quality Assessment of the Nanticoke River Watershed," Delaware Department of Natural Resources and Environmental Control, 1993.

3. "State of Delaware 1996 Watershed Assessment Report (305(b)),", Department of Natural Resources and Environmental Control, April 1, 1996.

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

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

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Appendix A: Water Quality Monitoring Data (during 1998-99)

Station	Date Sampled	CBOD, 5 Day	Chlorophyll-A	Flow	Nitrogen, Ammonia Total	Nitrogen, Kjeldahl Total	Nitrogen, Nitrate/Nitrite Total.	o-Phosphate, Diss.	Oxygen, Dissolved	Phosphorus, Total	Residue, Total Nonfilt. (TSS)	Temperature, Water
		mg/l	ug/l	cfs	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	ºC
303171	07/15/98	2.400	8		0.054	0.915	13.000	0.131	2.100	0.147	1.00	20.9
	09/28/98	2.400	11		0.058	0.432	12.300	0.368	2.000	0.417	12.00	21.1
	12/02/98	4.450	18	3.84	0.044	0.954	10.700	0.163	6.100	0.198	15.00	8.9
	05/04/99	2.400	8	19.46	0.092	0.330	10.200	0.137	7.400	0.275	15.00	13.5
	08/05/99	2.400	19	0.00	0.122	1.470	6.000	0.135	6.010	0.294	29.00	20.8
304011	07/13/98	2.770	91		0.028	1.340	0.656	0.018	9.600	0.069	16.00	26.8
	10/23/98	2.400	93		0.022		0.337	0.018	9.300		20.00	15.4
	03/11/99	3.980	93		0.018	0.476	3.250	0.014	12.000	0.138	37.00	5.5
	06/10/99	2.400	72		0.049	1.330	1.070	0.006	7.100	0.117	35.00	26.6
	07/29/99	2.400	72		0.062	1.020	0.011	0.005	6.020	0.151	40.00	28.8
304021	07/13/98	3.290	88		0.024	0.886	1.470	0.015	11.200	0.064	17.00	26.5
	10/23/98	2.400	120		0.005		1.390	0.013	10.100		25.00	15.3
	03/11/99	2.400	16		0.154	0.552	3.330	0.009	10.600	0.109	28.00	5.6
	06/10/99	2.400	128		0.061	1.110	1.650	0.005	7.500	0.108	30.00	27.4
	07/29/99	2.950	150		0.075	1.520	0.478	0.011	6.890	0.158	50.00	29.3
304031	07/10/98	2.880	117		0.083	0.578	1.880	0.009	6.500	0.107	32.00	25.6
	10/22/98	2.400	29		0.096		2.310	0.038	7.300		23.00	15.0
	03/10/99	2.400	11		0.102	0.392	3.490	0.006	10.800	0.098	15.00	5.0
	06/09/99	2.400	75		0.110	0.999	1.780	0.005	6.300	0.123	48.00	27.2
	07/28/99	3.040	147		0.069	1.270	0.813	0.005	7.340	0.162	43.00	29.4
304041	07/10/98	2.400	3		0.056	0.305	2.930	0.014	6.400	0.028	2.00	21.2
	10/22/98	2.400	3		0.019		4.290	0.018	9.000		4.00	12.6
	03/10/99	2.400	8		0.052	0.332	5.280	0.018	10.400	0.064	8.00	5.2
	06/09/99	2.400	5		0.059	1.320	3.480	0.010	6.400	0.042	3.00	23.4
	07/28/99	2.400	5		0.068	0.176	3.680	0.005	7.740	0.055	9.00	26.0
304051	07/09/98	4.180	5		0.078	1.440	3.850	0.038	8.900	0.045	3.00	21.4
	10/20/98	2.400	3		0.030		5.600	0.005	6.900		3.00	14.2
	03/10/99	2.400	5	11.00	0.124	0.485	5.240	0.005	14.200	0.036	4.00	7.6
	06/09/99	2.400	3	2.60	0.055	1.270	3.860	0.020	7.800	0.045	16.00	24.6
	07/27/99	5.270	29	1.49	0.152	0.704	5.060	0.037	8.810	0.138	28.00	26.3
304071	07/13/98	2.560	83		0.035	1.120	0.822	0.016	11.000	0.070	13.00	26.6

Appendix A: Water Quality Monitoring Data (during 1998-99)

Station	Date Sampled	CBOD, 5 Day	Chlorophyll-A	Flow	Nitrogen, Ammonia Total	Nitrogen, Kjeldahl Total	Nitrogen, Nitrate/Nitrite Total.	o-Phosphate, Diss.	Oxygen, Dissolved	Phosphorus, Total	Residue, Total Nonfilt. (TSS)	Temperature, Water
		mg/l	ug/l	cfs	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	ºC
304101	07/13/98	2.650	91		0.031	1.010	1.330	0.016	11.000	0.075	17.00	26.6
	10/23/98	2.470	117		0.005		1.140	0.010	10.000		22.00	15.0
	03/11/99	2.400	29		0.082	0.217	3.200	0.008	11.200	0.105	27.00	5.5
	06/10/99	2.400	72		0.058	0.724	0.916	0.006	7.500	0.076	20.00	27.6
	07/29/99	3.140	29		0.088	1.290	0.290	0.009	6.660	0.131	38.00	29.1
304141	07/13/98	3.550	91		0.029	1.260	1.780	0.013	11.300	0.078	20.00	26.6
	10/23/98	2.400	120		0.016		1.720	0.012	9.500		33.00	15.1
	03/11/99	2.400	16		0.249	0.755	3.640	0.009	10.200	0.090	24.00	5.1
	06/10/99	2.400	123		0.086	1.290	1.660	0.016	7.500	0.121	29.00	27.3
	07/29/99	2.770	166		0.089	1.090	0.747	0.011	6.630	0.114	32.00	30.0
304151	07/13/98	2.400	48		0.047	0.815	2.650	0.016	10.700	0.077	16.00	29.3
	10/23/98	2.400	115		0.016		1.850	0.015	9.600		23.00	15.4
	03/11/99	2.400	11		0.216	0.471	3.320	0.008	11.000	0.081	21.00	4.8
	06/10/99	2.400	128		0.066	1.380	1.600	0.020	7.500	0.129	39.00	27.0
	07/29/99	3.100	163		0.063	1.280	0.774	0.011	6.680	0.153	26.00	29.9
304171	07/13/98	3.190	69		0.023	1.010	1.740	0.017	11.600	0.075	17.00	26.8
	10/23/98	2.400	112		0.016		1.890	0.008	8.200		23.00	14.9
	03/11/99	2.400	13		0.295	0.338	3.380	0.007	10.800	0.063	20.00	4.6
	06/10/99	2.400	112		0.069	1.620	1.600	0.016	7.100	0.138	26.00	26.7
	07/29/99	2.840	163		0.061	1.180	0.805	0.014	6.420	0.129	25.00	29.8
304191	07/10/98	2.400	5		0.046	0.187	3.660	0.016	6.600	0.023	5.00	20.4
	10/22/98	2.400	3		0.065		4.500	0.052	9.300		3.00	13.4
	03/10/99	2.400	5		0.031	0.056	4.270	0.010	11.800	0.060	5.00	6.2
	06/09/99	2.400	1		0.093	0.954	4.240	0.022	8.000	0.069	7.00	24.2
	07/28/99	2.400	1		0.086	0.816	5.480	0.018	8.080	0.066	6.00	24.3
304271	07/09/98	2.400	3		0.032	0.180	2.030	0.024	5.400	0.024	6.00	21.6
	10/20/98	2.400	3		0.378		3.420	0.005	5.000		1.00	16.5
	03/10/99	2.400	5	9.31	0.028	0.181	4.390	0.005	11.700	0.022	6.00	6.4
	06/09/99	2.400	3	3.61	0.058	1.520	2.360	0.005	5.400	0.047	19.00	26.6
	07/27/99	2.400	3	1.61	0.091	1.400	7.720	0.048	7.920	0.082	12.00	20.6

Appendix A: Water Quality Monitoring Data (during 1998-99)

Station	Date Sampled	CBOD, 5 Day	Chlorophyll-A	Flow	Nitrogen, Ammonia Total	Nitrogen, Kjeldahl Total	Nitrogen, Nitrate/Nitrite Total.	o-Phosphate, Diss.	Oxygen, Dissolved	Phosphorus, Total	Residue, Total Nonfilt. (TSS)	Temperature, Water
		mg/l	ug/l	cfs	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	ºC
	07/27/99	2.400	3	1.00	0.179	0.446	0.559	0.009	4.370	0.034	3.00	27.3
304311	07/09/98	4.560	16		0.052	0.332	1.040	0.026	7.200	0.024	6.00	23.4
	10/22/98	2.400	3	11.61	0.010		1.290	0.016	11.100		6.00	15.6
	03/10/99	2.400	3	42.42	0.031	0.196	2.130	0.009	11.500	0.033	3.00	4.0
	06/09/99	2.400	13	12.17	0.067	1.230	1.000	0.005	8.100	0.015	9.00	27.4
	07/28/99	2.400	3		0.051	0.201	0.890	0.005	8.170	0.013	3.00	29.5
304321	07/08/98	2.400	32		0.139	1.060	0.829	0.009	6.600	0.053	10.00	25.8
	10/22/98	2.400	24		0.022		0.005	0.022	6.500		11.00	16.5
	03/10/99	2.400	13		0.055	0.645	5.210	0.005	10.500	0.097	7.00	5.8
	06/09/99	2.400	48		0.060	0.374	0.747	0.005	11.800	0.022	16.00	28.5
	07/28/99	4.600	101		0.052	0.700	0.014	0.005	9.870	0.095	15.00	29.6
304371	07/08/98	2.400	5		0.110	0.873	2.060	0.127	6.600	0.195	5.00	20.0
	10/20/98	2.400	11		0.172		0.130	0.016	2.000		10.00	15.7
	03/09/99	2.400	5	0.00	0.030	0.486	4.840	0.008	10.700	0.015	4.00	3.5
	06/08/99	2.400	8	0.00	0.545	1.240	0.992	0.283	1.100	0.440	12.00	23.3
304381	07/08/98	3.530	5		0.184	1.130	4.760	0.050	6.500	0.134	31.00	19.8
	10/20/98	2.400	3		0.025		4.620	0.015	7.000		1.00	15.2
	03/09/99	2.400	3	4.49	0.040	0.204	9.360	0.005	10.900	0.015	6.00	5.5
	07/27/99	2.400	11	0.43	0.194	0.868	3.430	0.089	5.040	0.274	40.00	25.1
304411	07/08/98	4.090	83		0.204	1.970	0.826	0.024	9.700	0.160	14.00	25.0
	10/20/98	3.060	83		0.025		0.005	0.014	8.900		12.00	18.0
	03/09/99	2.400	16		0.030	0.545	6.450	0.005	11.900	0.032	5.00	5.1
	06/08/99	6.740	40		0.242	1.590	0.855	0.017	4.300	0.125	9.00	27.0
	07/27/99	6.620	288	0.00	0.060	3.570	0.013	0.278	12.250	0.596	35.00	29.2
304421	07/10/98	2.400	1		0.138	1.250	6.880	0.040	7.200	0.043	8.00	20.1
304441	07/09/98	2.400	5		0.127	0.338	5.590	0.032	6.900	0.039	8.00	19.0
	10/19/98	2.400	3		0.023		9.960	0.005	7.200		7.00	17.0
	03/09/99	2.400	3	0.88	0.059	0.288	4.590	0.005	9.900	0.030	3.00	2.9
	06/08/99	2.400	1	1.09	0.075	0.747	7.790	0.007	5.800	0.039	3.00	19.5
	07/27/99	2.400	16	0.13	0.242	2.620	1.870	0.008	6.120	0.382	188.00	22.8

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Station	Date Sampled	CBOD, 5 Day	Chlorophyll-A	Flow	Nitrogen, Ammonia Total	Nitrogen, Kjeldahl Total	Nitrogen, Nitrate/Nitrite Total.	o-Phosphate, Diss.	Oxygen, Dissolved	Phosphorus, Total	Residue, Total Nonfilt. (TSS)	Temperature, Water
		mg/l	ug/l	cfs	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	ºC
	06/10/99	2.400	77		0.105	0.652	1.730	0.015	6.500	0.082	30.00	26.6
	07/29/99	2.840	160		0.068	1.240	0.826	0.012	6.730	0.155	49.00	29.4
304471	07/10/98	5.010	91		0.042	0.991	1.650	0.010	7.100	0.083	20.00	25.2
	10/22/98	2.400	3		0.056		2.390	0.016	7.600		6.00	14.2
	03/10/99	2.400	8		0.049	0.294	2.580	0.015	11.300	0.057	8.00	3.6
	06/09/99	2.400	75		0.187	2.930	2.070	0.005	5.200	0.426	294.00	27.0
	07/28/99	3.180	107		0.055	0.954	0.972	0.005	7.910	0.127	24.00	28.6
304531	07/09/98	2.400	5		0.145	0.337	2.390	0.018	7.900	0.027	4.00	20.1
	10/19/98	2.400	11		0.064		3.150	0.013	7.600		134.00	16.2
	03/09/99	2.400	11	2.13	0.055	0.203	4.850	0.005	10.100	0.052	9.00	4.5
	06/08/99	2.400	5	0.00	0.274	1.160	2.640	0.009	4.300	0.108	37.00	22.5
	07/27/99	2.500	21	0.31	0.308	0.955	2.010	0.005	4.060	0.136	28.00	21.9
304541	07/10/98	2.400	8		0.063	0.466	3.530	0.036	6.700	0.044	13.00	19.0
	10/21/98	2.400	3		0.079		1.200	0.024	1.800		10.00	13.8
	03/09/99	2.400	5	0.00	0.030	0.590	6.440	0.005	9.500	0.005	3.00	4.8
	06/08/99	2.400	1	0.00	0.193	0.812	3.440	0.045	4.700	0.074	3.00	19.9
	07/27/99	2.400	5	0.00	0.684	1.350	0.267	0.134	1.670	0.318	19.00	23.6
304551	10/21/98	2.400	11		0.045		3.510	0.011	8.400		5.00	16.3
	03/09/99	2.400	3	6.10	0.021	0.620	9.380	0.020	11.300	0.034	7.00	4.9
	06/08/99	2.400	1	0.32	0.056	1.100	7.750	0.034	6.500	0.063	1.00	18.6
	07/27/99	2.400	5	0.00	0.046	0.874	7.120	0.013	6.870	0.037	4.00	18.7
304561	07/10/98	2.400	1		0.161	1.340	7.660	0.061	6.700	0.076	6.00	20.8
	10/21/98	2.400	3		0.010		11.800	0.024	7.200		8.00	13.3
	03/09/99	2.400	3	3.06	0.043	0.153	3.720	0.008	12.300	0.024	4.00	3.7
	06/08/99	2.400	3	0.00	0.094	1.240	10.200	0.086	6.100	0.121	1.00	21.8
	07/27/99	2.400	5	0.00	0.081	0.349	0.603	0.015	3.080	0.048	2.00	19.2
304571	07/08/98	4.510	43		0.292	1.720	0.717	0.022	6.000	0.171	20.00	24.2
	10/20/98	2.400	64		0.149		0.016	0.032	3.000		20.00	17.4
	03/09/99	2.530	13	0.00	0.061	0.548	6.420	0.005	11.400	0.075	11.00	5.3
	06/08/99	3.970	21	0.00	0.316	1.140	0.831	0.012	2.800	0.121	10.00	26.8
	07/27/99	5.890	136	0.00	0.306	2.400	0.215	0.016	2.370	0.278	26.00	25.4

Appendix A: Water Quality Monitoring Data (during 1998-99)

Station	Date Sampled	CBOD, 5 Day	Chlorophyll-A	Flow	Nitrogen, Ammonia Total	Nitrogen, Kjeldahl Total	Nitrogen, Nitrate/Nitrite Total.	o-Phosphate, Diss.	Oxygen, Dissolved	Phosphorus, Total	Residue, Total Nonfilt. (TSS)	Temperature, Water
		mg/l	ug/l	cfs	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	ºC
	06/08/99	4.420	144	0.00	0.183	1.300	0.024	0.005	1.900	0.156	15.00	20.3
	07/27/99	13.500	1410	0.00	0.225	4.160	0.022	0.013	4.360	0.818	83.00	22.8
304601	07/09/98	2.400	5		0.050	0.455	0.588	0.034	7.000	0.089	6.00	18.2
	10/20/98	2.400	3		0.021		0.521	0.005	6.800		1.00	14.6
	03/09/99	2.400	5	14.13	0.027	0.435	0.865	0.005	10.000	0.025	6.00	6.6
	06/08/99	2.400	5	0.00	0.038	1.360	0.622	0.040	5.300	0.063	15.00	23.3
	07/27/99	2.400	13	0.00	0.063	0.301	0.440	0.005	5.980	0.024	6.00	23.3
304611	07/09/98	2.400	5		0.025	1.290	3.220	0.017	7.900	0.038	4.00	19.1
	10/20/98	2.400	5		0.020		4.070	0.005	3.600		1.00	15.4
	03/10/99	2.400	5	2.00	0.034	0.097	4.780	0.005	10.700	0.026	4.00	8.7
	06/09/99	2.400	8	0.00	0.100	1.350	4.350	0.017	7.300	0.061	17.00	22.5
	07/27/99	2.400	5	0.00	0.090	0.065	3.480	0.009	6.010	0.074	6.00	21.2
304621	07/08/98	4.470	3		0.198	1.930	1.290	0.050	6.200	0.115	23.00	20.5
	10/20/98	2.400	11		0.073		4.270	0.010	4.200		4.00	16.1
	03/09/99	2.400	3	0.00	0.070		6.660	0.005	7.700	0.065	6.00	5.4
	06/08/99	2.400	13	0.00	0.213		1.680	0.023	6.000	0.085	7.00	25.3
	07/27/99	2.400	21	0.00	0.153	0.189	6.420	0.005	4.230	0.092	24.00	21.0
304631	10/20/98	2.400	3		0.017		2.890	0.048	2.400		5.00	15.8
304641	07/09/98	5.560	5		0.026	0.320	4.510	0.019	7.600	0.025	7.00	17.0
	10/20/98	2.400	3		0.016		4.730	0.008	7.000		1.00	14.7
	03/09/99	2.400	5	2.50	0.012	0.348	5.680	0.005	10.600	0.043	3.00	7.3
	06/08/99	2.400	1	0.65	0.046	0.459	5.270	0.006	6.900	0.031	8.00	18.1
	07/27/99	2.400	1	0.70	0.051	0.506	5.360	0.005	7.900	0.015	7.00	18.3
304651	07/09/98	2.400	11		0.132	0.462	1.170	0.022	6.800	0.034	4.00	23.1
	10/20/98	2.400	3		0.023		1.380	0.012	8.600		1.00	17.0
	03/09/99	2.400	3	12.55	0.018	0.339	10.300	0.034	11.500	0.072	4.00	4.0
	06/08/99	2.400	8	1.08	0.034	0.161	1.120	0.007	8.800	0.047	7.00	27.1
307011	07/07/98	2.400	37		0.500	2.160	2.280	0.013	7.900	0.078	6.00	27.0
	10/22/98	2.660	5	17.13	0.048		2.900	0.010	9.100		6.00	15.5
	03/10/99	2.400	5		0.020	0.193	4.440	0.014	11.800	0.098	5.00	3.8

Appendix A: Water Quality Monitoring Data (during 1998-99)

Station	Date Sampled	CBOD, 5 Day	Chlorophyll-A	Flow	Nitrogen, Ammonia Total	Nitrogen, Kjeldahl Total	Nitrogen, Nitrate/Nitrite Total.	o-Phosphate, Diss.	Oxygen, Dissolved	Phosphorus, Total	Residue, Total Nonfilt. (TSS)	Temperature, Water
		mg/l	ug/l	cfs	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	ºC
307081	07/08/98	2.400	8		0.212	2.020	0.027	0.297	1.500	0.426	4.00	20.4
	03/08/99	2.400	1	12.05	0.016	0.280	2.010	0.024	13.400	0.063	3.00	4.9
	06/07/99	2.400	13	1.76	0.033	0.845	0.031	0.018	7.600	0.102	10.00	26.0
	07/26/99	2.400	8	1.45	0.101	0.816	0.015	0.027	6.080	0.136	5.00	29.7
307091	07/07/98	2.400	8		0.023	1.160	0.981	0.019	5.300	0.039	7.00	23.5
	10/19/98	7.390	144		0.005		0.024	0.008	1.800		271.00	17.1
	03/08/99	2.400	16	10.73	0.007	2.380	2.380	0.014	13.200	0.019	5.00	5.7
	06/07/99	3.940	8	3.44	0.225	2.210	0.087	0.015	4.200	0.202	5.00	23.6
	07/26/99	3.290	13	1.58	0.088	1.660	0.021	0.005	3.420	0.179	17.00	27.2
307101	07/07/98	2.400	8		0.074	0.978	3.180	0.006	7.800	0.009	4.00	25.1
	10/19/98	2.400	5		0.024		3.010	0.013	8.300		2.00	16.2
	03/08/99	2.400	3	3.06	0.043	0.464	3.840	0.010	11.300	0.060	4.00	6.6
	06/07/99	2.400	11	0.00	0.049	0.838	1.090	0.005	8.400	0.042	2.00	27.2
	07/26/99	2.400	3	0.00	0.110	0.999	0.307	0.005	7.940	0.051	4.00	30.0
307111	07/08/98	2.520	8		0.007	0.835	3.590	0.043	7.000	0.203	76.00	18.7
	10/21/98	2.400	5		0.042		5.060	0.008	7.500		14.00	12.1
	03/08/99	2.400	3	1.33	0.040	0.549	4.780	0.011	12.000	0.014	8.00	3.5
	06/07/99	2.400	8	0.00	0.074	0.372	5.710	0.005	5.000	0.051	4.00	18.6
	07/26/99	2.400	1	0.12	0.119	0.299	6.170	0.008	5.990	0.080	20.00	22.4
307121	07/08/98	2.400	11		0.112	0.762	7.100	0.027	7.600	0.046	8.00	18.0
	10/21/98	2.400	8		0.048		6.560	0.016	8.500		28.00	12.7
	03/08/99	2.400	3	0.00	0.032	0.634	10.700	0.015	12.300	0.020	4.00	5.2
	06/07/99	2.400	3	0.00	0.069	0.476	8.640	0.019	7.500	0.063	4.00	22.2
	07/26/99	2.400	8	0.00	0.108	0.173	8.290	0.012	7.660	0.075	9.00	24.1
307131	07/08/98	6.210	37		0.080	0.764	7.110	0.028	9.200	0.124	37.00	25.6
	10/21/98	2.400	32		0.023		1.770	0.008	8.900		10.00	16.4
	03/08/99	2.400			0.082	0.516	7.850	0.015	12.100	0.027	5.00	5.5
	06/07/99	2.400	3		0.065	0.556	4.000	0.005	7.100	0.042	4.00	26.0
	07/26/99	2.400	8	0.00	0.089	0.338	1.470	0.005	10.150	0.058	1.00	30.3
307151	07/07/98	2.400	11		0.031	1.140	3.430	0.036	7.600	0.101	21.00	20.8

Appendix A: Water Quality Monitoring Data (during 1998-99)

Station	Date Sampled	CBOD, 5 Day	Chlorophyll-A	Flow	Nitrogen, Ammonia Total	Nitrogen, Kjeldahl Total	Nitrogen, Nitrate/Nitrite Total.	o-Phosphate, Diss.	Oxygen, Dissolved	Phosphorus, Total	Residue, Total Nonfilt. (TSS)	Temperature, Water
		mg/l	ug/l	cfs	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	ºC
307181	07/07/98	3.820	72		0.015	1.130	0.023	0.012	11.000	0.142	15.00	30.4
	10/19/98	2.400	8		0.043		0.017	0.034	7.100		1.00	19.0
	03/08/99	2.400	8	0.00	0.057	5.050	1.800	0.019	11.300	0.057	5.00	4.0
	06/07/99	2.400	11		0.070	1.220	0.042	0.022	6.200	0.133	9.00	24.7
	07/26/99	2.400	5	0.00	0.102	0.972	0.014	0.030	5.020	0.164	10.00	28.3
307201	07/07/98	2.400	61		0.150	0.991	0.019	0.004	3.600	0.064	10.00	21.1
	03/08/99	2.400	5	1.01	0.033	0.402	1.250	0.019	10.500	0.039	5.00	5.2
	07/26/99	3.370	24	0.00	0.091	1.710	0.005	0.005	0.160	0.201	9.00	27.4
307221	07/07/98	2.400	3		0.048	0.995	2.370	0.011	7.200	0.067	18.00	24.0
	10/21/98	2.400	5		0.034		4.180	0.029	5.000		10.00	12.6
	03/08/99	2.400	8	0.48	0.046	0.329	3.440	0.024	10.200	0.050	6.00	3.7
	07/26/99	2.400	8	0.00	0.115	0.523	2.290	0.005	6.160	0.071	2.00	20.2
307281	07/08/98	2.400	3		0.013	1.930	3.410	0.032	7.000	0.048	6.00	19.3
	10/19/98	2.400	8		0.023		5.110	0.008	5.000		6.00	16.5
	03/08/99	2.400	5	9.29	0.038	0.542	3.600	0.014	11.500	0.018	7.00	2.0
	06/07/99	2.400	3	0.00	0.079	0.386	3.060	0.023	4.100	0.067	1.00	19.3
	07/26/99	2.400	3	0.00	0.131	0.737	1.890	0.023	2.890	0.086	5.00	23.0
307291	07/07/98	2.400	3		0.045	0.861	3.980	0.006	7.900	0.010	4.00	19.0
	10/19/98	2.400	3		0.011		4.360	0.007	5.000		1.00	16.5
	03/08/99	2.400	5	1.72	0.017	0.275	4.330	0.009	12.200	0.054	4.00	8.7
	06/07/99	2.400	5	0.00	0.074	0.108	3.880	0.005	6.400	0.019	3.00	19.1
	07/26/99	2.400	5	0.00	0.079	0.314	3.560	0.005	6.860	0.035	8.00	21.7
307331	07/07/98	2.400	1		1.820	2.820	11.700	0.004	5.800	0.016	3.00	21.9
307341	10/21/98	2.400	8		0.033		1.630	0.007	9.000		8.00	16.6
	03/08/99	2.400	3	12.75	0.058	0.888	7.740	0.012	12.600	0.026	2.00	4.5
	06/07/99	2.400	5	8.34	0.054	0.399	4.080	0.005	7.400	0.036	6.00	25.6
	07/26/99	2.400	8	5.00	0.073	0.677	1.250	0.005	9.590	0.036	2.00	29.5
307351	07/08/98	2.400	5		0.048	0.648	1.370	0.028	6.600	0.058	8.00	18.4
	10/21/98	2.400	5		0.035		0.141	0.052	3.000		25.00	13.0
	03/08/99	2.400	8	2.67	0.025	0.460	2.330	0.025	11.200	0.033	2.00	2.4

Appendix A: Water Quality Monitoring Data (during 1998-99)

Station	Date Sampled	CBOD, 5 Day	Chlorophyll-A	Flow	Nitrogen, Ammonia Total	Nitrogen, Kjeldahl Total	Nitrogen, Nitrate/Nitrite Total.	o-Phosphate, Diss.	Oxygen, Dissolved	Phosphorus, Total	Residue, Total Nonfilt. (TSS)	Temperature, Water
		mg/l	ug/l	cfs	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	ºC
	07/26/99	3.800	104	0.00	0.108	2.030	0.013	0.005	1.850	0.160	15.00	23.7
307381	07/07/98	2.400	3		0.045	0.994	2.610	0.064	6.400	0.087	7.00	21.1
	10/19/98	2.400	8		0.014		3.530	0.026	7.900		1.00	17.0
	03/08/99	2.400	11	0.00	0.021	0.449	3.520	0.015	10.800	0.019	2.00	2.4
	06/07/99	2.400	11	0.00	0.117	0.398	2.640	0.039	4.600	0.094	8.00	18.6
	07/26/99	2.400	5	0.00	0.183	1.090	1.160	0.064	1.870	0.185	3.00	23.4
307391	07/07/98	2.400	5		0.027	1.170	3.110	0.033	6.400	0.050	5.00	21.4
	10/19/98	2.400	1		0.020		6.120	0.011	6.600		3.00	16.0
	03/08/99	2.400	3	0.00	0.053	0.351	3.630	0.018	10.700	0.028	1.00	4.7
	06/07/99	2.400	5	0.00	0.056	0.632	4.710	0.018	5.600	0.052	4.00	19.7
	07/26/99	2.400	3	0.00	0.094	0.687	3.620	0.021	5.520	0.060	1.00	22.9
307401	07/07/98	7.110	56		0.086	1.170	2.250	0.009	9.600	0.047	6.00	26.9
	10/19/98	2.400	5		0.036		3.070	0.008	8.600		1.00	17.8
	03/08/99	2.400		89.42	0.020	0.625	4.400	0.024	11.300	0.028	3.00	5.7
	06/07/99	2.400	11	0.00	0.029	0.651	3.250	0.005	7.900	0.030	7.00	24.6
316011	07/09/98	2.400	24		0.078	0.728	0.860	0.009	6.800	0.023	3.00	21.9
	10/22/98	2.400	3		0.005		3.780	0.009	8.700		3.00	12.1
	03/10/99	2.400	5		0.032	0.248	1.500	0.007	11.200	0.045	2.00	5.0
	06/09/99	2.400	3	0.00	0.084	1.050	1.770	0.005	6.800	0.014	2.00	24.0
	07/28/99	2.400	3		0.060	0.258	4.020	0.005	7.410	0.023	4.00	20.3
316021	07/09/98	2.470	125		0.030	0.928	0.036	0.008	7.000	0.043	10.00	24.5
	10/20/98	2.400	1		0.042		4.700	0.040	7.300		1.00	15.2
	03/09/99	2.400	3	21.43	0.015	0.302	1.000	0.006	11.000	0.012	5.00	4.8
	06/08/99	2.400	8	6.12	0.114	1.400	0.497	0.014	4.100	0.038	12.00	25.7
	07/27/99	2.680	32	0.71	0.075	0.569	0.045	0.005	5.740	0.042	7.00	27.9
316031	07/09/98	2.400	5		0.070	0.426	0.618	0.083	5.600	0.086	7.00	19.6
	10/20/98	2.400	5		0.089		0.974	0.010	5.800		6.00	14.9
	03/09/99	2.400	5	0.00	0.029	0.096	1.360	0.023	9.800	0.041	5.00	5.6
	06/08/99	2.400	5	0.00	0.099	1.320	0.807	0.005	4.400	0.030	7.00	25.9
	07/27/99	2.400	16	0.00	0.091	0.309	0.722	0.005	5.170	0.027	8.00	27.8

Appendix B

Example of Qual2E Input and Output Data

(Output file from the calibration run for Bridgeville Branch named as Run002)

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                                     * * * QUAL-2E  STREAM QUALITY ROUTING MODEL * * *
                                                  Version 3.21  -  Feb. 1995

 $$$ (PROBLEM TITLES) $$$

CARD TYPE                             QUAL-2E PROGRAM TITLES
TITLE01             Bridgeville Br.  (Y99 Q= 0.20 m3/s) -   Calib Run 002  -  3
TITLE02             /31/00
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 DATA         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       =    3.00000          NUMBER OF JUNCTIONS     =   0.00000
NUM OF HEADWATERS       =    1.00000          NUMBER OF POINT LOADS   =   1.00000
TIME STEP (HOURS)       =    1.00000          LNTH. COMP. ELEMENT (DX)=   0.50000
MAXIMUM ROUTE TIME (HRS)= 100.00000           TIME INC. FOR RPT2 (HRS)=   1.00000
LATITUDE OF BASIN (DEG) =  38.50000           LONGITUDE OF BASIN (DEG)=  75.60000
STANDARD MARIDIAN (DEG) =  75.00000           DAY OF YEAR START TIME  = 213.00000
EVAP. COEF.,(AE)        =   0.00001           EVAP. COEF.,(BE)        =   0.00000
ELEV. OF BASIN (ELEV)   =  30.00000           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)=    1.1400
O PROD  BY ALGAE (MG O/MG A)   =    1.8000           O UPTAKE BY ALGAE (MG O/MG A)  =    1.6000
N CONTENT OF ALGAE (MG N/MG A) =    0.0900           P CONTENT OF ALGAE (MG O/MG A) =    0.0200
ALG MAX SPEC GROWTH RATE(1/DAY)=    3.0000           ALGAE RESPIRATION RATE (1/DAY) =    0.0500
N HALF SATURATION CONST (MG/L) =    0.1500           P HALF SATURATION CONST (MG/L) =    0.0010
LIN ALG SHADE CO (1/M-UGCHA/L) =    0.0088           NLIN SHADE (1/M-(UGCHA/L)**2/3)=    0.0000
LIGHT FUNCTION OPTION (LFNOPT) =    1.0000           LIGHT SAT'N COEF (LANGLEYS/MIN)=    0.0300
DAILY AVERAGING OPTION (LAVOPT)=    2.0000           LIGHT AVERAGING FACTOR (AFACT) =    0.9200
NUMBER OF DAYLIGHT HOURS (DLH) =   14.0000           TOTAL DAILY SOLR RAD (LANGLEYS)=  400.0000
ALGY GROWTH CALC OPTION(LGROPT)=    2.0000           ALGAL PREF FOR NH3-N (PREFN)   =    0.5000
ALG/TEMP SOLR RAD FACTOR(TFACT)=    0.4400           NITRIFICATION INHIBITION COEF  =    0.6000
ENDATA1A                            0.0000                                               0.0000

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

CARD TYPE     RATE CODE     THETA VALUE

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

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

CARD TYPE           REACH ORDER AND IDENT              R. MI/KM             R. MI/KM
STREAM REACH     1.0  RCH= Upper Bridgevil   FROM          5.5     TO           3.5
STREAM REACH     2.0  RCH= Mid Bridgeville   FROM          3.5     TO           2.0
STREAM REACH     3.0  RCH= Lower bridgevil   FROM          2.0     TO           0.0
ENDATA2          0.0                                       0.0                  0.0

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

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

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

CARD TYPE	REACH	ELEMENTS/REACH	COMPUTATIONAL FLAGS
FLAG FIELD	1.	4.	1.2.2.2.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	2.	3.	6.2.2.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	3.	4.	2.2.2.5.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
ENDATA4	0.	0.	0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.

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

CARD TYPE	REACH	COEF-DSPN	COEFQV	EXPOQV	COEFQH	EXPOQH	CMANN
HYDRAULICS	1.	60.00	0.173	0.125	1.585	0.785	0.055
HYDRAULICS	2.	60.00	0.253	0.169	0.642	0.371	0.055
HYDRAULICS	3.	60.00	0.336	0.586	0.507	0.233	0.055
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.	9.14	0.10	0.00	25.56	25.56	1002.00	0.00	1.00
TEMP/LCD	2.	9.14	0.10	0.00	25.56	25.56	1002.00	0.00	1.00
TEMP/LCD	3.	9.14	0.10	0.00	25.56	25.56	1002.00	0.00	1.00
ENDATA5A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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

CARD TYPE	REACH	K1	K3	SOD RATE	K2OPT	K2	COEQK2 OR TSIV COEF OR FOR OPT 8	EXPQK2 OR SLOPE FOR OPT 8
REACT COEF	1.	0.15	0.00	0.000	6.	0.00	0.000	0.00000
REACT COEF	2.	0.10	-0.50	0.000	4.	0.00	0.000	0.00000
REACT COEF	3.	0.01	-0.50	0.000	4.	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.	0.01	0.00	0.10	100.00	1.00	0.70	0.00	0.00
N AND P COEF	2.	0.01	0.00	0.10	50.00	1.00	0.30	0.00	0.00
N AND P COEF	3.	0.01	0.00	1.00	50.00	1.00	0.30	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	0.15	0.00	0.00	0.00	0.00
ALG/OTHER COEF	2.	50.00	0.00	0.15	0.00	0.00	0.00	0.00
ALG/OTHER COEF	3.	50.00	0.00	0.15	0.00	0.00	0.00	0.00
ENDATA6B	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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

CARD TYPE	REACH	TEMP	D.O.	BOD	CM-1	CM-2	CM-3	ANC	COLI
INITIAL COND-1	1.	17.38	7.10	2.40	0.00	0.00	0.00	0.00	0.00
INITIAL COND-1	2.	18.34	7.08	2.40	0.00	0.00	0.00	0.00	0.00
INITIAL COND-1	3.	18.82	9.32	3.33	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.	5.60	0.65	0.05	0.40	3.58	0.04	0.01
INITIAL COND-2	2.	3.40	0.70	0.11	0.40	3.59	0.03	0.02
INITIAL COND-2	3.	9.00	0.89	0.09	0.47	4.25	0.05	0.02
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.	0.030	17.38	7.10	2.40	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	2.	0.030	17.38	7.10	2.40	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	3.	0.020	17.38	7.10	2.40	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.	5.60	0.65	0.05	0.40	3.58	0.04	0.01
INCR INFLOW-2	2.	5.60	0.65	0.05	0.40	3.58	0.04	0.01
INCR INFLOW-2	3.	5.60	0.65	0.05	0.40	3.58	0.04	0.01
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.	Upper Bridgevil	0.07	17.38	7.10	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	0.00	5.60	0.65	0.05	0.40	3.58	0.04	0.01
ENDATA10A	0.	0.00	0.00	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.	Trib to Rch	0.00	0.05	17.38	7.10	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	0.00	5.60	1.50	0.05	1.00	6.00	0.04	0.01
ENDATA11A	0.	0.00	0.00	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

5-DAY BIOCHEMICAL OXYGEN DEMAND ITERATION 1

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	2.39	2.37	2.36	2.35																
2	2.40	2.43	2.45																	
3	2.50	2.55	2.60	2.65																

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

                                                     NUMBER OF
           VARIABLE              ITERATION         NONCONVERGENT
                                                     ELEMENTS


                   ALGAE AS CHL-A IN UG/L                                         ITERATION  1
RCH/CL  1     2     3     4     5     6     7     8     9    10    11    12    13    14    15    16    17    18    19    20

  1  5.91  6.20  6.49  6.76
  2  6.58  6.78  6.98
  3  7.31  7.73  8.15  8.58

                  ORGANIC PHOSPHORUS AS P IN MG/L                                 ITERATION  1
RCH/CL  1     2     3     4     5     6     7     8     9    10    11    12    13    14    15    16    17    18    19    20

  1  0.04  0.04  0.04  0.04
  2  0.04  0.04  0.04
  3  0.04  0.04  0.04  0.03

                  DISSOLVED PHOSPHORUS AS P IN MG/L                               ITERATION  1
RCH/CL  1     2     3     4     5     6     7     8     9    10    11    12    13    14    15    16    17    18    19    20

  1  0.01  0.01  0.01  0.01
  2  0.01  0.01  0.01
  3  0.01  0.01  0.01  0.01

                  ORGANIC NITROGEN AS N IN MG/L                                   ITERATION  1
RCH/CL  1     2     3     4     5     6     7     8     9    10    11    12    13    14    15    16    17    18    19    20

  1  0.65  0.65  0.65  0.65
  2  0.91  0.90  0.88
  3  0.88  0.87  0.86  0.86

                  AMMONIA AS N IN MG/L                                            ITERATION  1
RCH/CL  1     2     3     4     5     6     7     8     9    10    11    12    13    14    15    16    17    18    19    20

  1  0.07  0.09  0.11  0.12
  2  0.10  0.10  0.10
  3  0.11  0.11  0.11  0.11

                  NITRITE AS N IN MG/L                                            ITERATION  1
RCH/CL  1     2     3     4     5     6     7     8     9    10    11    12    13    14    15    16    17    18    19    20

  1  0.38  0.37  0.36  0.35
  2  0.54  0.52  0.50
  3  0.48  0.47  0.45  0.43

                  NITRATE AS N IN MG/L                                            ITERATION  1
RCH/CL  1     2     3     4     5     6     7     8     9    10    11    12    13    14    15    16    17    18    19    20

  1  3.60  3.61  3.62  3.63
  2  4.38  4.35  4.32
  3  4.32  4.31  4.31  4.31

                   DISSOLVED OXYGEN IN MG/L                                       ITERATION  1
RCH/CL  1     2     3     4     5     6     7     8     9    10    11    12    13    14    15    16    17    18    19    20

  1  7.51  7.81  8.02  8.16
  2  8.09  8.41  8.62
  3  8.78  8.90  8.98  9.03
 ALGAE GROWTH RATE                         1               11
 ALGAE GROWTH RATE                         2               11
 ALGAE GROWTH RATE                         3                9
 ALGAE GROWTH RATE                         4                0
   NITRIFICATION INHIBITION                   1                 0
 ALGAE GROWTH RATE                         5                0
   NITRIFICATION INHIBITION                   2                 0


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

      1. LIGHT AVERAGING OPTION.    LAVOPT= 2

          METHOD: MEAN SOLAR RADIATION DURING DAYLIGHT HOURS

          SOURCE OF SOLAR VALUES:   DATA TYPE 1A
              DAILY NET SOLAR RADIATION:  1474.000 BTU/FT-2 (  400.000 LANGLEYS)
              NUMBER OF DAYLIGHT HOURS:  0.0
              PHOTOSYNTHETIC ACTIVE FRACTION OF SOLAR RADIATION (TFACT): N/A
              MEAN SOLAR RADIATION ADJUSTMENT FACTOR (AFACT): 0.920


      2. LIGHT FUNCTION OPTION:   LFNOPT= 1

          HALF SATURATION METHOD, WITH HALF SATURATION COEF =  0.030 LANGLEYS/MIN


      3. GROWTH ATTENUATION OPTION FOR NUTRIENTS.   LGROPT= 2

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

DISSOLVED OXYGEN IN MG/L ITERATION 7

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	7.51	7.81	8.02	8.17																
2	8.09	8.41	8.62																	
3	8.78	8.90	8.98	9.03																

5-DAY BIOCHEMICAL OXYGEN DEMAND ITERATION 7

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	2.39	2.37	2.36	2.35																
2	2.40	2.43	2.45																	
3	2.50	2.55	2.60	2.65																

ORGANIC NITROGEN AS N IN MG/L ITERATION 7

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.65	0.65	0.65	0.65																
2	0.91	0.90	0.88																	
3	0.88	0.87	0.86	0.86																

AMMONIA AS N IN MG/L ITERATION 7

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.07	0.09	0.11	0.12																
2	0.10	0.10	0.10																	
3	0.11	0.11	0.11	0.11																

NITRITE AS N IN MG/L ITERATION 7

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.38	0.37	0.36	0.35																
2	0.54	0.52	0.50																	
3	0.48	0.46	0.45	0.43																

NITRATE AS N IN MG/L ITERATION 7

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	3.60	3.61	3.62	3.63																
2	4.38	4.35	4.32																	
3	4.32	4.32	4.31	4.31																

ORGANIC PHOSPHORUS AS P IN MG/L ITERATION 7

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

DISSOLVED PHOSPHORUS AS P IN MG/L ITERATION 7

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.01	0.01	0.01	0.01																
2	0.01	0.01	0.01																	
3	0.01	0.01	0.01	0.01																

ALGAE AS CHL-A IN UG/L ITERATION 7

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	5.91	6.21	6.50	6.78																
2	6.59	6.78	6.98																	
3	7.30	7.70	8.12	8.53																

ALGAE GROWTH RATES IN PER DAY ARE ITERATION 7

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1.24	1.24	1.25	1.25																
2	1.30	1.30	1.30																	
3	1.33	1.33	1.33	1.34																

PHOTOSYNTHESIS-RESPIRATION RATIOS ARE ITERATION 7

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	31.40	31.55	31.66	31.75																
2	31.60	31.61	31.62																	
3	31.65	31.68	31.70	31.73																

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

** HYDRAULICS SUMMARY **

ELE ORD	RCH NUM	ELE NUM	BEGIN LOC KILO	END LOC KILO	FLOW CMS	POINT SRCE CMS	INCR FLOW CMS	VEL MPS	TRVL TIME DAY	DEPTH M	WIDTH M	VOLUME K-CU-M	BOTTOM AREA K-SQ-M	X-SECT AREA SQ-M	DSPRSN COEF SQ-M/S
1	1	1	5.50	5.00	0.08	0.00	0.01	0.126	0.046	0.213	2.897	0.31	1.66	0.62	0.36
2	1	2	5.00	4.50	0.08	0.00	0.01	0.127	0.046	0.229	2.921	0.33	1.69	0.67	0.38
3	1	3	4.50	4.00	0.09	0.00	0.01	0.128	0.045	0.245	2.944	0.36	1.72	0.72	0.41
4	1	4	4.00	3.50	0.10	0.00	0.01	0.130	0.045	0.260	2.964	0.39	1.74	0.77	0.44
5	2	1	3.50	3.00	0.16	0.05	0.01	0.186	0.031	0.325	2.650	0.43	1.65	0.86	0.75
6	2	2	3.00	2.50	0.17	0.00	0.01	0.188	0.031	0.333	2.725	0.45	1.70	0.91	0.78
7	2	3	2.50	2.00	0.18	0.00	0.01	0.189	0.031	0.340	2.797	0.48	1.74	0.95	0.80
8	3	1	2.00	1.50	0.19	0.00	0.00	0.125	0.046	0.342	4.325	0.74	2.51	1.48	0.53
9	3	2	1.50	1.00	0.19	0.00	0.00	0.127	0.046	0.344	4.346	0.75	2.52	1.50	0.54
10	3	3	1.00	0.50	0.20	0.00	0.00	0.129	0.045	0.346	4.367	0.76	2.53	1.51	0.55
11	3	4	0.50	0.00	0.20	0.00	0.00	0.131	0.044	0.348	4.387	0.76	2.54	1.53	0.56

***** 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	9.61	6	4.75	0.13	0.00	0.00	0.01	0.00	0.08	82.93	0.88	0.62	0.00	0.00	0.00	0.00	0.00	0.00
1	2	9.61	6	4.55	0.13	0.00	0.00	0.01	0.00	0.08	82.93	0.88	0.62	0.00	0.00	0.00	0.00	0.00	0.00
1	3	9.61	6	4.20	0.13	0.00	0.00	0.01	0.00	0.08	82.93	0.88	0.62	0.00	0.00	0.00	0.00	0.00	0.00
1	4	9.61	6	3.89	0.13	0.00	0.00	0.01	0.00	0.08	82.93	0.88	0.62	0.00	0.00	0.00	0.00	0.00	0.00
2	1	9.42	4	8.54	0.09	-0.48	0.00	0.01	0.00	0.09	44.41	0.92	0.28	0.00	0.00	0.00	0.00	0.00	0.00
2	2	9.42	4	13.00	0.09	-0.48	0.00	0.01	0.00	0.09	44.41	0.92	0.28	0.00	0.00	0.00	0.00	0.00	0.00
2	3	9.42	4	12.57	0.09	-0.48	0.00	0.01	0.00	0.09	44.41	0.92	0.28	0.00	0.00	0.00	0.00	0.00	0.00
3	1	9.33	4	10.93	0.01	-0.49	0.00	0.01	0.00	0.91	45.96	0.94	0.28	0.00	0.00	0.00	0.00	0.00	0.00
3	2	9.33	4	9.34	0.01	-0.49	0.00	0.01	0.00	0.91	45.96	0.94	0.28	0.00	0.00	0.00	0.00	0.00	0.00
3	3	9.33	4	9.34	0.01	-0.49	0.00	0.01	0.00	0.91	45.96	0.94	0.28	0.00	0.00	0.00	0.00	0.00	0.00
3	4	9.33	4	9.33	0.01	-0.49	0.00	0.01	0.00	0.91	45.96	0.94	0.28	0.00	0.00	0.00	0.00	0.00	0.00

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

** WATER QUALITY VARIABLES **

RCH NUM	ELE NUM	TEMP DEG-C	CM-1	CM-2	CM-3	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM-N MG/L	ORGP MG/L	DIS-P MG/L	SUM-P MG/L	COLI #/100ML	ANC	CHLA UG/L
1	1	17.38	0.00	0.00	0.00	7.51	2.39	0.65	0.07	0.38	3.60	4.70	0.04	0.01	0.05	0.00	0.00	5.91
1	2	17.38	0.00	0.00	0.00	7.81	2.37	0.65	0.09	0.37	3.61	4.72	0.04	0.01	0.05	0.00	0.00	6.21
1	3	17.38	0.00	0.00	0.00	8.02	2.36	0.65	0.11	0.36	3.62	4.73	0.04	0.01	0.05	0.00	0.00	6.50
1	4	17.38	0.00	0.00	0.00	8.17	2.35	0.65	0.12	0.35	3.63	4.75	0.04	0.01	0.05	0.00	0.00	6.78
2	1	18.34	0.00	0.00	0.00	8.09	2.40	0.91	0.10	0.54	4.38	5.93	0.04	0.01	0.05	0.00	0.00	6.59
2	2	18.34	0.00	0.00	0.00	8.41	2.43	0.90	0.10	0.52	4.35	5.87	0.04	0.01	0.05	0.00	0.00	6.78
2	3	18.34	0.00	0.00	0.00	8.62	2.45	0.88	0.10	0.50	4.32	5.80	0.04	0.01	0.05	0.00	0.00	6.98
3	1	18.82	0.00	0.00	0.00	8.78	2.50	0.88	0.11	0.48	4.32	5.78	0.04	0.01	0.05	0.00	0.00	7.30
3	2	18.82	0.00	0.00	0.00	8.90	2.55	0.87	0.11	0.46	4.32	5.76	0.04	0.01	0.05	0.00	0.00	7.70
3	3	18.82	0.00	0.00	0.00	8.98	2.60	0.86	0.11	0.45	4.31	5.74	0.04	0.01	0.05	0.00	0.00	8.12
3	4	18.82	0.00	0.00	0.00	9.03	2.65	0.86	0.11	0.43	4.31	5.72	0.03	0.01	0.05	0.00	0.00	8.53

***** 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	5.91	1.24	0.04	0.00	31.40	0.25	0.50	0.02	0.20	0.50	0.96	0.92
2	1	2	6.21	1.24	0.04	0.00	31.55	0.27	0.50	0.02	0.20	0.50	0.96	0.93
3	1	3	6.50	1.25	0.04	0.00	31.66	0.28	0.50	0.03	0.21	0.50	0.96	0.93
4	1	4	6.78	1.25	0.04	0.00	31.75	0.30	0.50	0.03	0.21	0.50	0.96	0.93
5	2	1	6.59	1.30	0.05	0.00	31.60	0.30	0.50	0.02	0.21	0.50	0.97	0.93
6	2	2	6.78	1.30	0.05	0.00	31.61	0.31	0.50	0.02	0.21	0.50	0.97	0.93
7	2	3	6.98	1.30	0.05	0.00	31.62	0.32	0.50	0.02	0.21	0.50	0.97	0.93
8	3	1	7.30	1.33	0.05	0.00	31.65	0.34	0.50	0.02	0.21	0.50	0.97	0.93
9	3	2	7.70	1.33	0.05	0.00	31.68	0.36	0.50	0.02	0.22	0.50	0.97	0.93
10	3	3	8.12	1.33	0.05	0.00	31.70	0.38	0.50	0.02	0.22	0.50	0.97	0.93
11	3	4	8.53	1.34	0.05	0.00	31.73	0.40	0.50	0.03	0.23	0.50	0.97	0.93

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

** DISSOLVED OXYGEN DATA **

									COMPONENTS OF DISSOLVED OXYGEN MASS BALANCE (MG/L-DAY)						
ELE ORD	RCH NUM	ELE NUM	TEMP DEG-C	DO SAT MG/L	DO MG/L	DO DEF MG/L	DAM INPUT MG/L	NIT INHIB FACT	F-FNCTN INPUT	OXYGN REAIR	C-BOD	SOD	NET P-R	NH3-N	NO2-N
1	1	1	17.38	9.61	7.51	2.10	0.00	0.99	154.18	9.94	-0.32	0.00	0.25	-0.02	-0.38
2	1	2	17.38	9.61	7.81	1.80	0.00	0.99	13.76	8.19	-0.32	0.00	0.27	-0.03	-0.37
3	1	3	17.38	9.61	8.02	1.59	0.00	0.99	12.78	6.68	-0.31	0.00	0.28	-0.03	-0.36
4	1	4	17.38	9.61	8.17	1.44	0.00	0.99	11.93	5.62	-0.31	0.00	0.30	-0.03	-0.35
5	2	1	18.34	9.42	8.09	1.33	0.00	0.99	85.40	11.38	-0.22	0.00	0.30	-0.03	-0.57
6	2	2	18.34	9.42	8.41	1.01	0.00	0.99	13.53	13.18	-0.22	0.00	0.31	-0.03	-0.54
7	2	3	18.34	9.42	8.62	0.80	0.00	0.99	12.90	10.09	-0.23	0.00	0.32	-0.03	-0.52
8	3	1	18.82	9.33	8.78	0.55	0.00	0.99	4.14	5.97	-0.02	0.00	0.34	-0.33	-0.52
9	3	2	18.82	9.33	8.90	0.43	0.00	1.00	4.10	4.03	-0.02	0.00	0.36	-0.34	-0.50
10	3	3	18.82	9.33	8.98	0.35	0.00	1.00	4.05	3.29	-0.02	0.00	0.38	-0.34	-0.48
11	3	4	18.82	9.33	9.03	0.30	0.00	1.00	4.01	2.78	-0.03	0.00	0.40	-0.35	-0.47

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                            D I S S O L V E D   O X Y G E N   ( M G / L )
       0.0     1.0     2.0     3.0     4.0     5.0     6.0     7.0     8.0     9.0    10.0
R   5.5 +++.++++++++++++++++++++++++++++++++++++++++++++++++++++++++*++++++++++++++++++++
        +  .    +       +       +       +       +       +       +     * +       +       +
I       +  .    +       +       +       +       +       +       +       *       +       +
        +  .    +       +       +       +       +       +       +       +*      +       +
V       +  .                                                            *               +
        +  .                                                               *            +
E       +  .                                                                *           +
        +  .    +       +       +       +       +       +       +       +     * +       +
R       +   .   +       +       +       +       +       +       +       +      *+       +
        +   .   +       +       +       +       +       +       +       +      *+       +
    0.5 ++++.+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++*++++++++
       0.0     5.0    10.0    15.0    20.0    25.0    30.0    35.0    40.0    45.0    50.0
                    B I O C H E M I C A L   O X Y G E N   D E M A N D   ( M G / L )
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DISSOLVED OXYGEN = * * * *

BIOCHEMICAL OXYGEN DEMAND = ...

Appendix C: Tributary 7Q10 Flow Scenario (Run005) Results

	RCH NUM	ELE NUM	TEMP DEG-C	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM-N MG/L	ORGP MG/L	DIS-P MG/L	SUM-P MG/L	CHLA UG/L
Bridgeville Br.	1	1	21.00	8.08	2.38	0.45	0.14	0.27	2.52	3.38	0.02	0.01	0.03	6.03
	1	2	21.00	8.47	2.36	0.45	0.22	0.25	2.53	3.46	0.02	0.01	0.03	6.44
	1	3	21.00	8.63	2.35	0.45	0.29	0.24	2.54	3.53	0.02	0.01	0.03	6.85
	1	4	21.00	8.69	2.33	0.45	0.35	0.24	2.55	3.59	0.02	0.01	0.03	7.26
	2	1	21.00	8.48	2.39	0.64	0.24	0.37	3.09	4.35	0.02	0.01	0.03	6.96
	2	2	21.00	8.69	2.43	0.63	0.24	0.35	3.07	4.30	0.02	0.01	0.03	7.25
	2	3	21.00	8.77	2.47	0.62	0.25	0.34	3.05	4.25	0.02	0.01	0.03	7.54
	3	1	21.00	8.83	2.57	0.62	0.25	0.33	3.06	4.25	0.02	0.01	0.02	8.34
	3	2	21.00	8.82	2.71	0.61	0.24	0.32	3.08	4.26	0.02	0.01	0.02	9.72
	3	3	21.00	8.82	2.86	0.61	0.24	0.31	3.10	4.26	0.02	0.01	0.02	11.28
	3	4	21.00	8.83	3.02	0.60	0.24	0.31	3.12	4.26	0.02	0.01	0.02	12.99
Butler Mill Br.	1	1	21.00	7.35	2.40	0.43	0.05	0.45	3.63	4.56	0.01	0.02	0.03	3.92
	1	2	21.00	7.33	2.40	0.43	0.05	0.44	2.89	3.80	0.01	0.02	0.03	3.97
	1	3	21.00	7.32	2.40	0.43	0.05	0.42	2.84	3.73	0.01	0.02	0.03	4.05
	1	4	21.00	7.31	2.40	0.43	0.04	0.40	2.79	3.66	0.01	0.02	0.03	4.12
	1	5	21.00	7.30	2.40	0.43	0.04	0.39	2.74	3.59	0.01	0.02	0.03	4.18
	2	1	21.00	5.77	2.39	0.29	0.06	0.21	2.85	3.41	0.01	0.03	0.03	1.57
Chapel Br.	1	1	21.00	6.00	2.40	0.39	0.13	0.29	2.70	3.52	0.02	0.02	0.04	3.51
	1	2	21.00	6.51	2.40	0.38	0.11	0.43	4.11	5.03	0.02	0.02	0.04	3.05
	1	3	21.00	6.90	2.40	0.36	0.10	0.47	4.56	5.49	0.01	0.02	0.03	2.61
	1	4	21.00	7.14	2.40	0.34	0.09	0.50	4.95	5.89	0.01	0.02	0.03	2.28
	1	5	21.00	7.29	2.40	0.33	0.09	0.52	5.29	6.23	0.01	0.02	0.02	2.04
	2	1	21.00	7.30	2.40	0.31	0.09	0.53	5.53	6.45	0.01	0.02	0.02	1.81
	2	2	21.00	6.98	2.40	0.28	0.08	0.52	5.76	6.65	0.00	0.02	0.02	1.54
	2	3	21.00	6.75	2.40	0.26	0.08	0.52	5.97	6.83	0.00	0.01	0.02	1.33
	2	4	21.00	6.57	2.40	0.24	0.08	0.52	6.16	6.99	0.00	0.01	0.02	1.18
	2	5	21.00	6.44	2.40	0.22	0.08	0.51	6.34	7.15	0.00	0.01	0.02	1.06
	2	6	21.00	6.35	2.40	0.20	0.07	0.51	6.50	7.29	0.00	0.01	0.02	0.97
Chipman Pd Br.	1	1	21.00	8.63	2.41	0.31	0.05	0.26	2.32	2.93	0.03	0.01	0.03	5.81
	2	1	21.00	8.93	2.41	0.32	0.04	0.23	2.35	2.94	0.02	0.01	0.03	6.55
	2	2	21.00	8.88	2.40	0.33	0.03	0.19	2.40	2.94	0.02	0.01	0.03	8.29
	2	3	21.00	8.86	2.39	0.34	0.02	0.15	2.43	2.95	0.02	0.01	0.03	9.65
	3	1	21.00	8.93	2.39	0.35	0.02	0.14	2.45	2.95	0.02	0.01	0.03	10.22
	3	2	21.00	8.93	2.39	0.35	0.02	0.14	2.45	2.95	0.02	0.01	0.03	10.19
Clear Brook	1	1	21.00	6.72	2.39	0.45	0.13	0.10	1.33	2.01	0.05	0.06	0.11	0.00
	1	2	21.00	7.65	2.39	0.46	0.12	0.07	1.37	2.01	0.05	0.06	0.11	2.62
	2	1	21.00	8.00	2.67	0.43	0.07	0.22	3.66	4.39	0.05	0.03	0.07	0.00

Appendix C: Tributary 7Q10 Flow Scenario (Run005) Results

	RCH	ELE	TEMP	DO	BOD	ORGN	NH3N	NO2N	NO3N	SUM-N	ORGP	DIS-P	SUM-P	CHLA
	NUM	NUM	DEG-C	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	UG/L
	5	3	21.16	9.23	2.83	0.33	0.13	0.12	2.34	2.90	0.03	0.03	0.05	16.48
	5	4	21.16	8.81	2.96	0.35	0.11	0.12	2.39	2.97	0.02	0.02	0.04	14.75
	5	5	21.16	8.96	3.10	0.30	0.10	0.09	2.40	2.89	0.02	0.02	0.04	12.92
	5	6	21.16	8.99	3.25	0.27	0.09	0.07	2.40	2.83	0.02	0.01	0.03	10.50
Deep Cr	1	1	21.00	7.72	2.40	0.42	0.03	0.04	0.38	0.87	0.02	0.01	0.02	6.54
	1	2	21.00	8.16	2.40	0.42	0.03	0.04	0.38	0.87	0.02	0.01	0.02	6.90
	1	3	21.00	7.98	2.41	0.42	0.03	0.04	0.38	0.87	0.02	0.01	0.02	6.84
	1	4	21.00	8.13	2.41	0.42	0.03	0.04	0.38	0.87	0.02	0.01	0.02	7.07
	2	1	21.00	8.02	2.41	0.41	0.04	0.04	0.39	0.87	0.02	0.01	0.02	7.44
	2	2	21.00	7.96	2.41	0.40	0.05	0.04	0.39	0.87	0.02	0.01	0.02	7.84
	2	3	21.00	7.82	2.41	0.39	0.05	0.04	0.39	0.86	0.02	0.01	0.02	8.01
	2	4	21.00	7.82	2.41	0.38	0.06	0.03	0.39	0.86	0.02	0.01	0.02	8.43
	2	5	21.00	7.81	2.41	0.37	0.07	0.03	0.39	0.86	0.02	0.01	0.02	8.87
	2	6	21.00	7.79	2.41	0.36	0.07	0.03	0.39	0.86	0.02	0.01	0.02	9.25
	3	1	21.00	7.96	2.42	0.35	0.08	0.04	0.45	0.92	0.02	0.01	0.02	9.47
	3	2	21.00	8.04	2.42	0.35	0.08	0.04	0.47	0.94	0.02	0.01	0.02	9.67
	3	3	21.00	8.10	2.45	0.34	0.08	0.05	0.58	1.06	0.02	0.01	0.02	9.64
	3	4	21.00	8.33	2.44	0.29	0.07	0.11	1.07	1.54	0.02	0.01	0.02	8.82
	4	1	21.00	8.53	2.44	0.29	0.07	0.11	1.08	1.55	0.02	0.01	0.02	9.24
	4	2	21.00	8.67	2.46	0.29	0.06	0.11	1.19	1.65	0.01	0.01	0.02	9.64
	4	3	21.00	8.78	2.47	0.29	0.06	0.11	1.20	1.66	0.01	0.01	0.02	10.33
	5	1	21.00	8.89	2.47	0.29	0.05	0.08	1.25	1.67	0.01	0.01	0.02	5.49
	5	2	21.00	8.83	2.50	0.29	0.03	0.06	1.42	1.80	0.01	0.01	0.02	2.13
	5	3	21.00	8.82	2.50	0.29	0.02	0.04	1.46	1.81	0.01	0.01	0.02	0.86
Gravelly Br.	1	1	21.00	7.20	2.46	0.52	0.04	0.17	1.50	2.23	0.01	0.01	0.02	10.93
	1	2	21.00	7.35	2.46	0.51	0.04	0.17	1.50	2.22	0.01	0.01	0.02	10.86
	1	3	21.00	7.48	2.45	0.51	0.05	0.17	1.50	2.22	0.01	0.01	0.02	10.79
	1	4	21.00	7.60	2.45	0.51	0.05	0.16	1.50	2.22	0.01	0.01	0.02	10.71
	2	1	21.00	7.70	2.43	0.50	0.05	0.16	1.50	2.22	0.01	0.01	0.02	10.33
	2	2	21.00	7.78	2.42	0.50	0.05	0.16	1.51	2.22	0.01	0.01	0.02	9.97
	2	3	21.00	7.86	2.40	0.49	0.05	0.16	1.51	2.21	0.01	0.01	0.02	9.62
	2	4	21.00	7.93	2.39	0.49	0.05	0.16	1.51	2.21	0.01	0.01	0.02	9.28
	2	5	21.00	7.99	2.37	0.48	0.06	0.16	1.51	2.21	0.01	0.01	0.02	8.96
Gum Br.	1	1	21.00	7.41	2.42	0.35	0.11	0.21	1.90	2.57	0.04	0.01	0.04	10.47
	1	2	21.00	7.69	2.42	0.35	0.11	0.20	1.92	2.57	0.04	0.01	0.04	10.36
	2	1	21.00	7.48	2.42	0.47	0.10	0.30	2.92	3.81	0.04	0.01	0.04	7.78
	2	2	21.00	7.11	2.42	0.57	0.10	0.38	3.70	4.75	0.04	0.01	0.04	6.37

Appendix C: Tributary 7Q10 Flow Scenario (Run005) Results

	RCH NUM	ELE NUM	TEMP DEG-C	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM-N MG/L	ORGP MG/L	DIS-P MG/L	SUM-P MG/L	CHLA UG/L
	4	1	20.25	9.03	2.35	0.37	0.04	0.02	0.38	0.82	0.03	0.01	0.04	0.86
	4	2	20.25	9.03	2.35	0.37	0.05	0.02	0.38	0.81	0.03	0.01	0.04	0.86
	4	3	20.25	9.03	2.36	0.37	0.05	0.02	0.37	0.81	0.03	0.01	0.04	0.87
	4	4	20.25	9.03	2.36	0.37	0.05	0.02	0.37	0.81	0.03	0.01	0.04	0.88
	4	5	20.25	9.03	2.36	0.38	0.05	0.02	0.37	0.81	0.03	0.01	0.04	0.89
	4	6	20.25	9.03	2.36	0.38	0.05	0.02	0.37	0.81	0.03	0.01	0.04	0.90
Horsey Pond	1	1	21.00	8.43	2.39	0.41	0.04	0.16	1.89	2.51	0.04	0.01	0.05	6.50
	1	2	21.00	8.69	2.39	0.42	0.04	0.13	1.91	2.51	0.03	0.01	0.05	5.00
	2	1	21.00	8.82	2.96	0.43	0.05	0.10	1.92	2.50	0.03	0.01	0.04	5.41
	2	2	21.00	8.90	3.63	0.44	0.05	0.08	1.92	2.49	0.02	0.01	0.04	5.83
James Br.	1	1	21.00	5.71	4.11	0.47	0.07	0.07	1.78	2.40	0.03	0.02	0.05	12.05
	1	2	21.00	5.44	6.94	0.48	0.09	0.03	1.80	2.41	0.04	0.01	0.05	11.67
	1	3	21.00	5.89	11.32	0.48	0.12	0.02	1.81	2.42	0.04	0.01	0.05	9.46
	2	1	21.00	8.69	7.59	0.19	0.15	0.09	2.06	2.49	0.03	0.01	0.04	8.63
	2	2	21.00	8.64	7.47	0.19	0.15	0.10	2.06	2.50	0.03	0.01	0.04	8.61
	3	1	21.00	8.67	4.35	0.45	0.10	0.46	1.04	2.06	0.04	0.01	0.05	8.75
	3	2	21.00	8.44	4.21	0.43	0.11	0.46	1.10	2.11	0.03	0.01	0.05	8.68
	3	3	21.00	8.35	4.18	0.41	0.13	0.44	1.13	2.11	0.03	0.01	0.05	8.66
	3	4	21.00	8.23	4.10	0.39	0.14	0.44	1.17	2.14	0.03	0.01	0.05	8.62
	3	5	21.00	8.14	4.04	0.38	0.15	0.43	1.20	2.16	0.03	0.01	0.05	8.59
	3	6	21.00	8.10	4.01	0.36	0.16	0.42	1.23	2.16	0.03	0.01	0.05	8.58
	3	7	21.00	8.07	3.98	0.34	0.16	0.41	1.25	2.17	0.03	0.01	0.05	8.60
	3	8	21.00	8.32	3.56	0.33	0.13	0.47	1.56	2.49	0.03	0.01	0.04	12.07
	4	1	21.00	8.42	3.77	0.33	0.09	0.36	1.71	2.50	0.03	0.01	0.04	11.85
	4	2	21.00	8.23	4.23	0.34	0.05	0.23	1.89	2.50	0.02	0.01	0.03	11.35
	4	3	21.00	8.23	4.78	0.34	0.03	0.14	2.00	2.51	0.02	0.01	0.03	10.86
	4	4	21.00	8.28	5.38	0.34	0.02	0.09	2.06	2.51	0.01	0.01	0.02	10.36
Tussocky Br.	1	1	21.00	8.23	2.40	0.24	0.03	0.26	2.56	3.09	0.01	0.00	0.01	4.24
	1	2	21.00	8.50	2.40	0.24	0.03	0.24	2.58	3.09	0.01	0.00	0.01	4.27
	1	3	21.00	8.65	2.40	0.24	0.03	0.22	2.59	3.09	0.01	0.00	0.01	4.31
	1	4	21.00	8.73	2.40	0.24	0.03	0.21	2.61	3.09	0.01	0.00	0.01	4.34
	2	1	21.00	8.86	2.40	0.24	0.03	0.11	2.71	3.09	0.01	0.00	0.01	4.72
	3	1	21.00	8.88	2.39	0.25	0.02	0.11	2.85	3.23	0.01	0.00	0.01	5.03
	3	2	21.00	8.85	2.39	0.26	0.04	0.12	2.93	3.35	0.01	0.00	0.01	4.98
	3	3	21.00	8.82	2.39	0.27	0.05	0.14	3.01	3.47	0.01	0.00	0.01	4.93
	3	4	21.00	8.66	2.40	0.30	0.14	0.20	3.37	4.01	0.01	0.00	0.01	4.63
	3	5	21.00	8.68	2.40	0.31	0.14	0.22	3.44	4.11	0.01	0.00	0.01	4.57