Appendix A

MODELING FRAMEWORK

The computational framework chosen for the modeling of water quality in Breton Bay was the Water Quality Analysis Simulation Program version 5.1 (WASP 5.1). This program provides a generalized framework for modeling contaminant fate and transport in surface waters (Di Toro *et al.*, 1983) and is based on the finite-segment approach. It is a very versatile program, capable of being applied in a time-variable or steady state mode, spatial simulation in one, two or three dimensions, and uses linear or non-linear estimations of water quality kinetics. To date, WASP 5.1 has been employed in many modeling applications that have included river, lake, estuarine and ocean environments. The model has been used to investigate water quality concerns regarding dissolved oxygen, eutrophication, and toxic substances. WASP5.1 has been used in a wide range of applications by regulatory agencies, consulting firms, academic researches, and others.

WASP 5.1 is supported and distributed by U.S. EPA's Center for Exposure Assessment Modeling (CEAM) in Athens, GA (Ambrose *et al.*, 1993). EUTRO 5.1 is the component of WASP 5.1 that is applicable for modeling eutrophication, incorporating eight water quality constituents in the water column (Figure A1) and sediment bed.

WATER QUALITY MONITORING

MDE's Field Operations Program collected physical parameters and water quality samples from Breton Bay during 2001 and 2002. The physical parameters (DO, salinity, conductivity, and water temperature) were measured *in situ* at each water quality monitoring station. Grab samples were also collected for laboratory analysis. The samples were collected at a depth of ½ meter from the surface. Samples were placed in plastic bottles and preserved on ice until they were delivered to the University of Maryland Laboratory in Solomons, MD or the Department of Health and Mental Hygiene in Baltimore, MD for analysis. The field and laboratory protocols used to collect and process the samples are summarized in Table A1. The data collected in June, August and September 2001 were used to calibrate the growing season water quality model for Breton Bay. Figures A2 through A9 present growing season water quality profiles along the segments.

INPUT REQUIREMENTS [1]

Model Segmentation and Geometry

The spatial domain of the Breton Bay Eutrophication Model (BBEM) extends from the mouth of Breton Bay to approximately 6.5 miles up its mainstem. Following a review of the bathymetry for Breton Bay, the model was divided into seven water quality segments. Figure A10 shows the model segmentation for the development of BBEM. Table A2 lists the volumes, characteristic lengths and interfacial areas of the 7 segments.

Dispersion Coefficients

The dispersion coefficients were calibrated using the in-stream water quality data from Summer 2001 (June, August and September). The WASP 5.1 model was set up to model salinity. Salinity is a conservative constituent, which means there are no losses due to reactions in the water. The only source in the system is the salinity from the water at the tidal boundary at the mouth. For the model execution, salinities at all boundaries except the tidal boundary were set to zero. Flows were obtained from a nearby U.S. Geological Survey gage station as explained in more detail below. Figure A11 shows the results of the calibration of the dispersion coefficients based on data observed from June, August and September 2001 water quality survey in Breton Bay. Due to strong tidal influence, salinity data collected from May 2001 didn't show reasonable salinity gradient, and therefore was not included in the calibration for dispersion coefficient. For a similar reason, salinity data observed during average flow period were not suitable for dispersion coefficient calibration. Therefore, identical set of dispersion coefficients will be applied to both growing season and average annual flow condition in all BBEM segments. Final values of the dispersion coefficients are listed in Table A3.

Freshwater Flows

Freshwater flows were calculated after the Breton Bay drainage basin was delineated into subwatersheds contributing flows consistent with the seven water quality segments developed for the BBEM (Figures A10 and A12).

In order to ensure that flow estimations for BBEM model were as representative as possible, data from two USGS stations located on Breton Bay and adjacent watersheds (USGS gage #01661050, # 01661500, Figure A13) were collected and analyzed. The flow in BBEM calibration runs was calculated through the average flow data recorded in Summer 2001 from both gages. A drainage ratio (flow to drainage area) was calculated for each of the USGS stations, and an average of all the flow to area ratios was determined. The $7Q_{10}$ and annual average flows for the individual subwatersheds were determined by obtaining the $7Q_{10}$ flow and annual average flow from the individual reference USGS station. The flow for BBEM segments was calculated by multiplying the drainage area of each segment with the average drainage ratios obtained from the reference USGS gaging stations. Table A4 presents flows from different subwatersheds each flow conditions.

1 The WASP model requires all input data to be in metric units, and to be consistent with the model, all data in the Appendix will appear in metric units except the river length. Following are several conversion factors to aid in the comparison of numbers in the main document: mgd x (0.0438) = m^3/s cfs x (0.0283) = m^3/s | lb / (2.2) = kg | mg/l x mgd x (8.34) / (2.2) = kg/d |

Point and Nonpoint Source Loadings

The major nutrient load contributors to the Breton Bay are the Leonardtown WWTP, a major point source within the watershed, and tributaries to the bay. Under growing season conditions, nonpoint source loadings (from agriculture, forest and air deposition) along with the urban stormwater (considered as point source) were comprehensively estimated as the product of observed in-stream nutrient concentrations and estimated tributary flows. Being observed loads, they account for all sources. For average annual flow condition, nutrient loads were estimated as the product of land use areas and their designated nutrient-loading coefficients provided by EPA's Chesapeake Bay Program.

Loads from the nonpoint source and urban stormwater runoff in the BBEM calibration were calculated based on the observed data obtained from MCN0017, a water quality station located on McIntosh Run, (the largest tributary of Breton Bay, please refer to Figure A10 for its location) during the 2001 growing season water quality survey. Data from water quality stations near the upper boundaries were selected to represent the background nutrient conditions. The concentrations of the nutrients nitrogen and phosphorus are modeled in their speciated forms. The WASP 5.1 model simulates nitrogen as ammonia (NH_4^+), nitrate and nitrite (NO_{23}), and organic nitrogen (ON); and phosphorus as ortho-phosphate (PO_4) and organic phosphorus (OP). NH_4^+, NO_{23}, and PO_4 represent the dissolved forms of nitrogen and phosphorus. The dissolved forms of nutrients are more readily available for biological processes such as algae growth that can affect chlorophyll *a* levels and DO concentrations. The ratios of total nutrients to dissolved nutrients used in the model scenarios were adjusted to represent values that have been measured in the field.

Environmental Conditions

Eight environmental parameters were used for developing the model of Breton Bay. They are solar radiation, photoperiod, temperature (T), extinction coefficient (K_e), sediment oxygen demand (SOD), sediment ammonia flux (F_{NH4}), and sediment phosphate flux (F_{PO4}) (Table A5).

The light extinction coefficient, K_e, in the water column was derived from Secchi depth measurements using the following equation:

$$K_e = \frac{1.7}{D_s}$$

where:

K_e = light extinction coefficient (m^{-1})
D_s = Secchi depth (m)

Different SOD values were estimated for different BBEM reaches based on observed environmental conditions and literature values (Thomann and Muller, 1987). The highest SOD values were assumed to occur near the upper segments of the Breton Bay between the Town Run, the tributary carrying the effluent of Leonardtown WWTP, and McIntosh Run, the tributary carrying most of the NPS runoff from the upper watershed. In this region of model segments, the effluent from the Leonardtown WWTP, combined with nutrients coming from upstream, is impeded by tidal activity, thus high concentrations of nutrients and organic particles are likely to settle into the sediment.

Kinetic Coefficients

The water column kinetic coefficients are universal constants used in the BBEM model. They are formulated to characterize the kinetic interactions among the water quality constituents. The initial values were taken from past modeling studies of Potomac River (Clark and Roesh, 1978; Thomann and Fitzpatrick, 1982; Cerco, 1985) and the Patuxent River (Lung, 1993). The kinetic coefficients are listed in Table A6.

Initial Conditions

The initial conditions used in the model were chosen to reflect the observed values as closely as possible. However, because the model simulation was run for a long period of time until it reached equilibrium, it was found that initial conditions did not have a significant impact upon the final results.

CALIBRATION & SENSITIVITY ANALYSIS

The BBEM model for growing season period was calibrated using 2001 Breton Bay water quality survey data. The nutrient loadings from the Leonardtown WWTP were calculated for calibration based on observed nutrient concentrations and actual discharged flow. The non-WWTP loadings were calculated based on estimated flow and the observed nutrient concentrations. Figures A14 through A21 show the results of the calibration of the model for growing season conditions. Data from May 2001 were not considered during calibration process due to flat salinity gradient. Results suggest that the BBEM has successfully captured the trend of the DO in the Breton Bay showing a high risk of dissolved oxygen deficit in the upper Breton Bay estuary region. The model prediction is also consistent with the general trend of chlorophyll *a*. The general trend for the rest of the observed nutrient values along the model segments was also captured by the model's prediction.

SYSTEM RESPONSE

The BBEM was run through various iterated loading scenarios during growing season and average annual conditions to project the impacts of nutrients on algal production (as chlorophyll *a*) and low DO in Breton Bay. The responses of various scenarios from the BBEM were analyzed to determine the TMDLs of nitrogen, phosphorus and BOD for Breton Bay during growing season and average annual conditions.

Model Run Descriptions

Baseline Condition (Growing Season): This first scenario represents the baseline conditions during growing season period in Breton Bay. The scenario simulates a critical flow ($7Q_{10}$) condition when the system is poorly flushed and sun light and warm water temperatures are most conducive to create the water quality problems associated with excessive nutrient enrichment. The nutrient concentrations for the first scenario were calculated using observed data collected during Summer 2001 (June through September). The loads from the tributaries were computed as the product of the observed concentrations and estimated critical flow. These tributary loads integrate all natural and human induced sources, including direct atmospheric deposition, and loads from septic tanks, which are associated with river base flow during growing season conditions. The baseline condition also assumes maximum permitted flow from Leonardtown WWTP (0.68 MGD) with the estimated effluent condition (total nitrogen 8 mg/l, total phosphorus 2 mg/l) and current permitted biological oxygen demand (BOD) concentration (30 mg/l).

TMDL (Growing Season): The second scenario represents the future condition of maximum allowable loads during the growing season. The flow is the same as that used in the baseline scenario. This scenario simulates an estimated 30% comprehensive reduction from nitrogen, phosphorus and BOD loads from the tributaries (including all natural and human induced sources). In this future condition scenario, reductions in nutrient fluxes and oxygen demand from the sediment were assumed corresponding to the percentage reduction of nutrient input from the non-WWTP sources. The loads from Leonardtown WWTP were assumed at its maximum design flow (0.68 MGD) with total nitrogen, total phosphorus and BOD maintained at 4 mg/l, 0.3 mg/l and 15 mg/l. For this scenario in which the nutrient loads to the system were reduced, a method was developed to estimate the reductions in nutrient fluxes and SOD from the bottom sediment layer. First, an initial estimate was made of the total organic carbon, organic nitrogen and organic phosphorus settling to the bottom of each model segment from particulate organic nutrients, living algae and phaeophytin. This was done by running baseline condition scenario once with the assumed settling velocity for organic particulates and chlorophyll a, followed by running the same scenario with no settling activity (zero settling velocity). The difference in the amount of organic matter between the two runs was assumed to settle to the bottom where it will be available as the source of nutrient fluxes and SOD. This analysis was then repeated for the reduced loading scenarios. The percentage difference between the amount of nutrients settled in the baseline scenario and nutrient reduction scenarios was then applied to the nutrient fluxes and SOD in each segment. The reduced nutrient scenario was run again with the updated fluxes. More information about point source loads can be found in the technical memorandum entitled "*Nutrient Point Sources in the Breton Bay Watershed*".

Baseline Condition (Average Annual): This third scenario represents the baseline conditions of the waterbody at a simulated annual average condition in the Breton Bay. The model predicts the waterbody's response for nutrient input at average annual flow condition. The method of estimating the annual average flow is described in the previous fresh water flow section. The average annual baseline conditions assume maximum permitted flow from the Leonardtown WWTP (0.68 MGD) with estimated effluent condition (total nitrogen of 8 mg/l, total phosphorus of 2 mg/l) and the current permitted BOD concentration (30 mg/l). The point loads from urban stormwater and nonpoint source loads (atmosphere deposition, agricultural, forest) were calculated by multiplying different land use areas (2002 MDP land use data) and their designated nutrient loading coefficients from the EPA Chesapeake Bay Program Phase 4.3 watershed model.

TMDL (Annual Average): This fourth scenario represents the future condition of maximum allowable loads during annual average flow condition. The flow is the same as that used in the third scenario. This scenario simulates an estimated an comprehensive 30% reduction in nitrogen, phosphorus and BOD inputs from all non-WWTP sources including urban stormwater (point sources) along with agriculture practice, forest and air deposition from nonpoint sources. The loads from Leonardtown WWTP were assumed at its maximum allowable flow (0.68 MGD) with total nitrogen, total phosphorus and BOD maintained at 6 mg/l, 0.3 mg/l and 15 mg/l respectively. Estimation for the amount of nutrient flux and SOD reduction was also made similar to the methodology described in the summer TMDL section. More information about point source loads can be found in the technical memorandum entitled "*Nutrient Point Sources in the Breton Bay Watershed*".

Scenario Results

This section describes the results of the model scenarios described in the previous section. The BBEM results presented in this section are based on chlorophyll *a* level and daily minimum DO concentrations. These minimum DO concentrations account for diurnal fluctuations caused by photosynthesis and respiration of algae.

Baseline Condition (Growing Season): This scenario simulates critical low flow ($7Q_{10}$) conditions during the growing season. Municipal point source loads are assumed at the maximum, approved water and sewer plan flow and estimated effluent nutrient concentrations from the Leonardtown WWTP (0.68 MGD, total nitrogen 8 mg/l, total phosphorus 2 mg/l and BOD 30 mg/l**)**. The non-WWTP loadings were estimated from the observed water quality parameters (e.g., nutrient concentrations) based on the water quality survey data in 2001 and 2002. Results for this scenario, representing the baseline condition for the growing season, are illustrated in Figures A22-A29. The projected chlorophyll *a* level during the growing season is below 50 µg/l in all BBEM segments (Figure A23). However, the DO concentrations in the upper estuary portion of Breton Bay show a trend of falling below the 5mg/l standard (Figure A22), indicating potential risks of a DO deficit. This scenario also suggests a necessary reduction of the BOD level from both the point and non point source entering the Breton Bay to prohibit the aggravation of DO deficit. The TMDL scenario, presented later, establishes maximum allowable loads that address these apparent problems.

TMDL (Growing Season): The TMDL simulates the future condition of maximum allowable loads for critical low stream flow ($7Q_{10}$) conditions during growing season to meet the water quality standard criteria for Breton Bay. Results for the TMDL are illustrated in comparison to the appropriate baseline condition (solid line) in Figure A30-A37. Results from Figure A30 indicate that the minimum concentrations of dissolved oxygen in the upper segments have risen above the water quality criterion of 5.0 mg/l. Under the nutrient load reduction conditions described above for this scenario, the model results show that chlorophyll *a* concentrations are below the levels of 50 µg/l along the entire length of Breton Bay (Figure A31).

Baseline Condition (Average Annual): This scenario simulates average annual flow period. Nutrient loads for all non-WWTP sources (including urban stormwater as point source along with agriculture practice, forest and air deposition as nonpoint sources) are based on loading coefficients for different land use from the EPA Chesapeake Bay Program Phase 4.3 watershed model and land use areas from 2002 MDP data. For the Leonardtown WWTP, maximum approved flow and observed effluent nutrient concentrations (0.68 MGD) were assumed in this scenario. Results are illustrated in Figure A38-A45. Figure A39 indicates that the peak chlorophyll *a* level will exceed 50µg/l during average annual flow period in the upper segments. This prediction is consistent with the growing season baseline result indicating that excess growth of aquatic plants in the upper estuary region of Breton Bay during average flow season will set the stage for potential DO deficit during the growing season. The TMDL scenario, presented below, establishes maximum allowable loads that address these apparent problems.

TMDL (Average Annual): This scenario simulates the future condition of maximum allowable loads for annual average flow conditions to meet the water quality in Breton Bay. Results for the TMDL are illustrated in comparison to the appropriate baseline condition (solid line) in Figure A46-A53. Under the nutrient load reduction conditions described above for this scenario, the results show that excessive chlorophyll *a* concentrations predicted in the upper estuary portion of Breton Bay in the baseline scenario has been reduced to below 50µg/l (Figure A47). Results from Figure A46 also indicate that the minimum concentrations of dissolved oxygen along the length of the river are above the water quality standard of 5.0 mg/l.

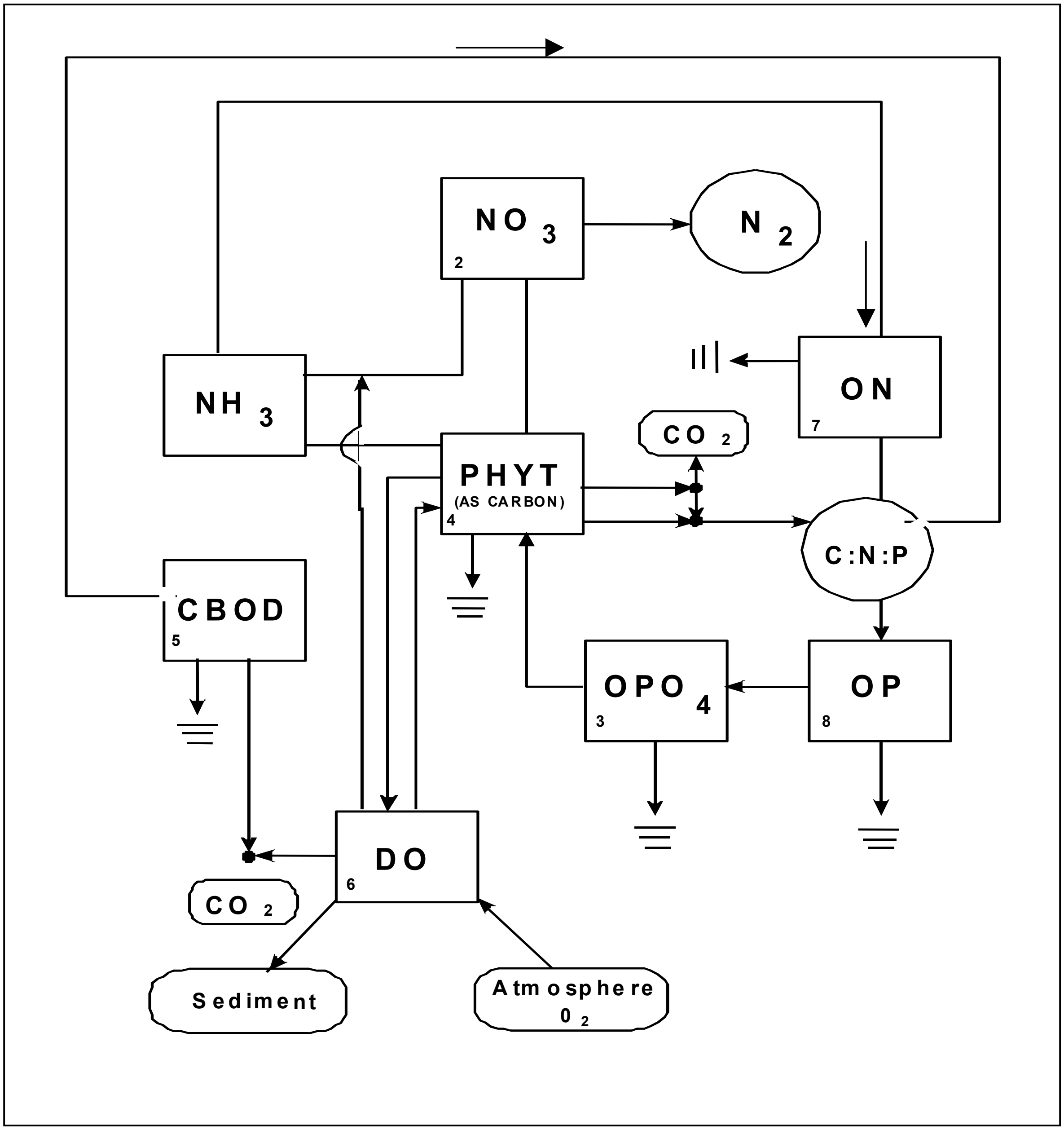

Figure A1: State Variables and Kinetic Interactions in EUTRO5

Table A1: Field and Laboratory Protocols

Parameter	Units	Detection Limits	*Method Reference*
IN SITU:			
Flow	cfs	0.01 cfs	Meter (Marsh-McBirney Model 2000 Flo-Mate)
Temperature	degrees Celsius	-5 deg. C to 50 deg. C	Linear thermistor network; Hydrolab Multiparameter Water Quality Monitoring Instruments Operating Manual (1995) Surveyor 3 or 4 (HMWQMIOM)
Dissolved Oxygen	mg/L	0 to 20 mg/l	Au/Ag polargraphic cell (Clark); HMWQMIOM
Conductivity	micro Siemens/cm (μS/cm)	0 to 100,000 μS/cm	Temperature-compensated, five electrode cell Surveyor 4; or six electrode Surveyor 3 (HMWQMIOM)
pH	pH units	0 to 14 units	Glass electrode and Ag/AgCl reference electrode pair; HMWQMIOM
Secchi Depth	meters	0.1 m	20.3 cm disk
GRAB SAMPLES:			
Ammonium	mg N / L	0.003	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Nitrate + Nitrite	mg N / L	0.0007	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Nitrite	mg N / L	0.0003	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Total Dissolved Nitrogen	mg N / L	0.03	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Particulate Nitrogen	mg N / L	0.0123	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Ortho-phosphate	mg P / L	0.0007	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Total Dissolved Phosphorus	mg P / L	0.0015	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Total Phosphorus	mg P / L		Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Particulate Phosphorus	mg P / L	0.0024	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Dissolved Organic Carbon	mg C / L	0.15	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Particulate Carbon	mg C / L	0.0759	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Silicate	mg Si / L	0.01	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Total Suspended Solids	mg / L	2.4	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Chlorophyll *a*	μg/L	1	Standard methods for the Examination of Water and Wastewater (15^{th} ed.) #1002G. Chlorophyll. Pp 950-954
BOD_5	mg/l	0.01	Oxidation ** EPA No. 405

Table A2: Physical characteristic of segments used in BBEM

Segment	Length	Width	Depth
1	797	997	3.66
2	1129	1559	4.07
3	1095	1570	3.97
4	1207	1510	3.97
5	1985	835	3.97
6	1625	602	2.03
7	1152	312	0.71

unit: meter

Table A3: Dispersion Coefficients used in the BBEM

Segment Pair	**Dispersion Coefficient (m^2/sec)**
0-1	28
1-2	26
2-3	26
3-4	24
4-5	24
5-6	23
6-7	23

Table A4: Subwatersheds flow contributions in BBEM

Subwatershed Drainage

Segment	Drainage Area (sq.mile)	$7Q_{10}$ Flow (m^3/sec)	Annual Average Flow (m^3/sec)
1	0.32	0.000	0.009
2	1.89	0.001	0.055
3	1.49	0.001	0.044
4	0.68	0.000	0.020
5	5.46	0.004	0.160
6	9.58	0.006	0.280
7	35.93	0.023	1.052

Table A5: Environmental parameters for BBEM growing season calibration

Segment	SOD (gO_2/m^2.day)	NH_4^+ flux (mg/m^2-day)	PO_4^{3-} flux (mg/m^2-day)
1	1.0	20	0.1
2	1.0	20	0.1
3	1.0	20	0.1
4	1.0	20	0.1
5	2.0	30	1.0
6	2.0	60	2.0
7	2.0	50	1.0

*Estimation base on model calibration and values in the technical report prepared in 1987 by Hydro Qual to Metropolitan Washington Council of Government on the evaluation of sediment oxygen demand in the Potomac estuary.

**Estimation base on model calibration and the range for sediment nutrient release rates for Potomac estuary illustrated in "Principals of Surface Water Quality Modeling and Control" by Thomann and Muller (1987).

Table A6: Eutro 5 Kinetic Coefficients used in BBEM

Constant	Code	Value
Nitrification rate	K12C	0.08 *day* -1 at 20^o C
temperature coefficient	K12T	1.08
Denitrification rate	K20C	0.08 *day* -1 at 20^o C
temperature coefficient	K20T	1.08
Saturated growth rate of phytoplankton	K1C	2.0 *day*-1 at 20^o C
temperature coefficient	K1T	1.08
Endogenous respiration rate	K1RC	0.125 *Day* -1 at 20^{o}C
temperature coefficient	K1RT	1.045
Nonpredatory phytoplankton death rate	K1D	0.125 *day* -1
Phytophankton Stoichometry		
Oxygen-to-carbon ratio	OCRB	2.67 $mg\ O_2 / mg\ C$
Carbon-to-chlorophyll ratio	CCHL	30
Nitrogen-to-carbon ratio	NCRB	0.25 *mg N/mg C*
Phosphorus-to-carbon ratio	PCRB	0.025 $mg\ PO_4\text{-}P/ mg\ C$
Half-saturation constants for phytoplankton growth		
Nitrogen	KMNG1	0.005 *mg* N / L
Phosphorus	KMPG1	0.002 *mg* P / P
Phytoplankton	KMPHY	0.0 *mg*C/*L*
Grazing rate on phytoplankton	K1G	0.0 *L / cell-day*
Fraction of dead phytoplankton recycled to organic		
nitrogen	FON	0.5
phosphorus	FOP	0.5
Light Formulation Switch	LGHTS	1 = Smith
Saturation light intensity for phytoplankton	IS1	350. *Ly/day*
BOD deoxygenation rate	KDC	0.20 *day* -1 at 20^o C
temperature coefficient	KDT	1.047
Reaeration rate constant	K2	0.36 *day* -1 at 20^o C
Mineralization rate of dissolved organic nitrogen	K71C	0.075 *day*-1
temperature coefficient	K71T	1.08
Mineralization rate of dissolved organic phosphorus	K83C	0.20 *dav* -1
temperature coefficient	K83T	1.08
Phytoplankton settling velocity		0.09 m/day
Organic settling velocity		0.09 m/day

Table A7: Parameters used for the Leonardtown WWTP in BBEM Scenarios

Parameter	*Calibration**	*Baseline (Growing Season)*	*Baseline(Annual)*	*TMDL (Growing Season)*	*TMDL(Annual)*	*Unit*
Flow (Design)	0.42	0.68	0.68	0.68	0.68	*MGD*
NH_3	3.0	4.9	4.9	2.5	3.7	*mg/l*
NO_{23}	1.0	1.7	1.7	0.8	1.2	*mg/l*
PO_4	3.0	1.8	1.8	0.27	0.27	*mg/l*
Chlorophyll a	0	0	0	0	0	*µg/l*
BOD	3.4	30	30	15	15	*mg/l*
DO	6.8	6.8	6.8	6.8	6.8	*mg/l*
Organic N	0.9	1.4	1.4	0.7	1.1	*mg/l*
Organic P	0.4	0.2	0.2	0.03	0.03	*mg/l*

***** Average effluent data from Leonardtown WWTP DMR (June/01-October/01)

Table A8: Tributary Loads used in various scenarios in BBEM

Growing Season Calibration

Segment	oxygen	CBOD	NH4	NO23	ORG-N	PO4	ORG-P	CHLA
2	16.90	9.33	0.23	0.73	0.82	0.044	0.055	0.05
3	13.39	7.39	0.19	0.58	0.65	0.035	0.044	0.04
5	48.90	26.99	0.68	2.13	2.38	0.127	0.160	0.16
6	94.83	53.06	3.39	6.03	4.97	4.722	0.881	0.28
7	300.95	117.65	4.47	13.99	15.66	0.833	1.053	1.04
unit	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day

Baseline Growing Season ($7Q_{10}$)

Segment	oxygen	CBOD	NH4	NO23	ORG-N	PO4	ORG-P	CHLA
2	0.77	0.43	0.011	0.033	0.037	0.002	0.003	0.002
3	0.61	0.34	0.008	0.026	0.030	0.002	0.002	0.002
5	2.24	1.24	0.031	0.097	0.109	0.006	0.007	0.006
6	16.84	121.71	12.64	4.501	1.92	1.140	0.253	0.010
7	14.81	8.17	0.206	0.644	0.41	0.038	0.048	0.038
Unit	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day

Baseline Average Annual Flow

Segment	oxygen	CBOD	NH4	NO23	ORG-N	PO4	ORG-P	CHLA
2	43.43	19.33	1.185	10.988	3.125	0.706	0.302	0.002
3	34.40	15.31	0.855	8.686	2.295	0.511	0.220	0.002
5	125.66	55.93	2.390	31.161	7.688	1.541	0.625	0.006
6	233.42	214.01	16.475	42.865	17.173	7.092	1.673	0.010
7	827.41	368.24	12.350	128.363	46.160	8.210	3.284	0.038
Unit	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day

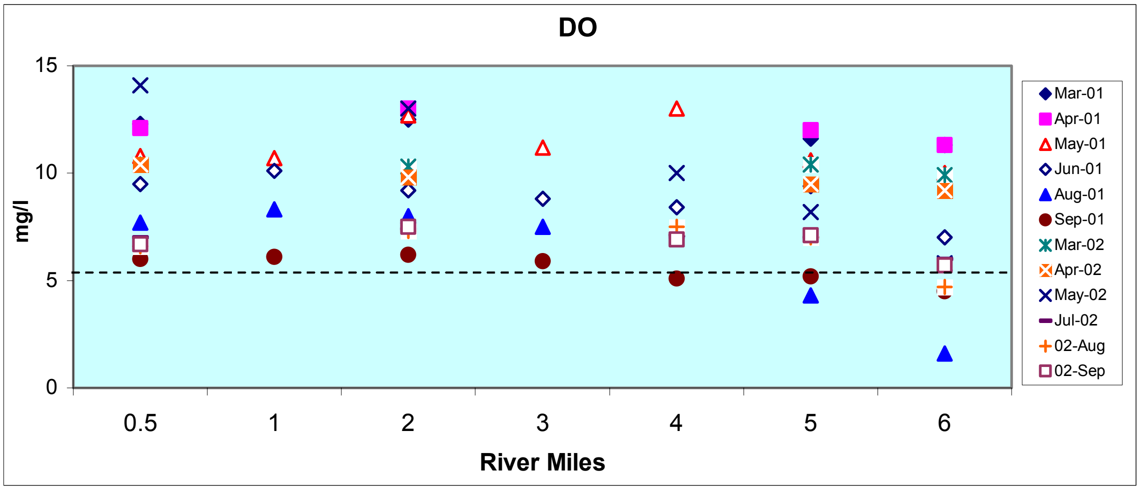

Figure A2: Longitudinal Profile of DO Data from Breton Bay Water Quality Survey

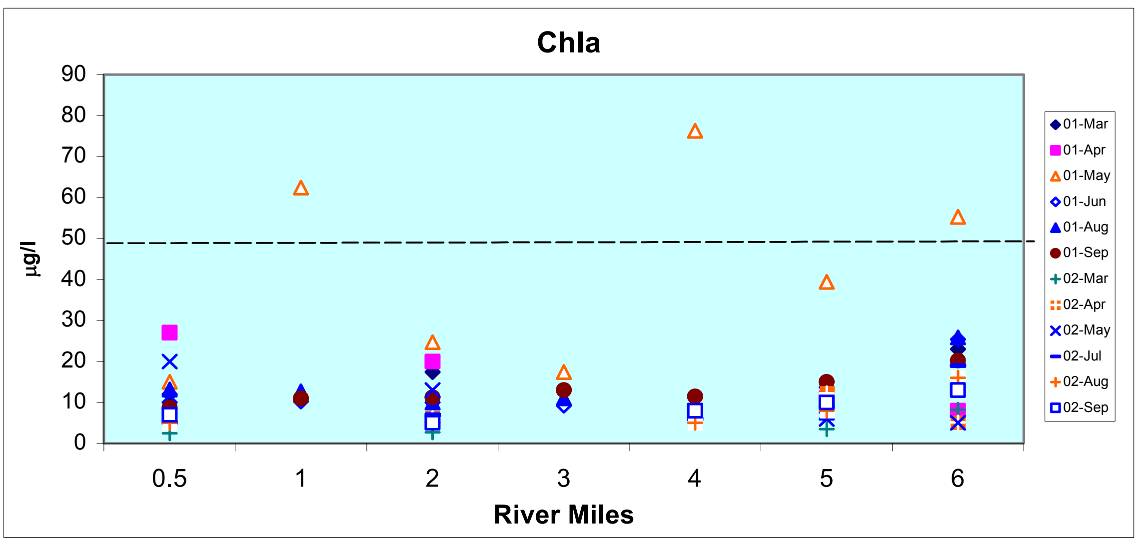

Figure A3: Longitudinal Profile of Chlorophyll a Data from Breton Bay Water Quality Survey

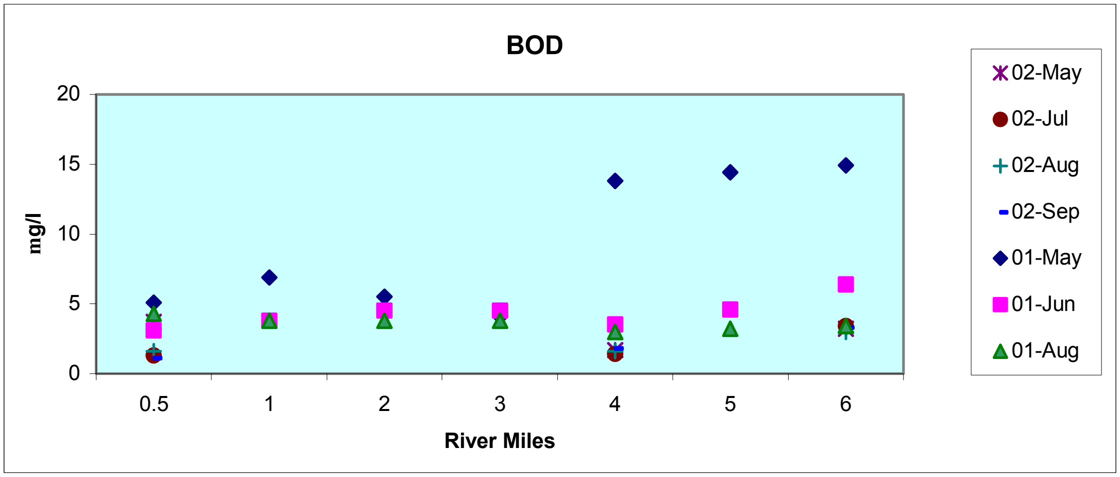

Figure A4: Longitudinal Profile of BOD Data from Breton Bay Water Quality Survey

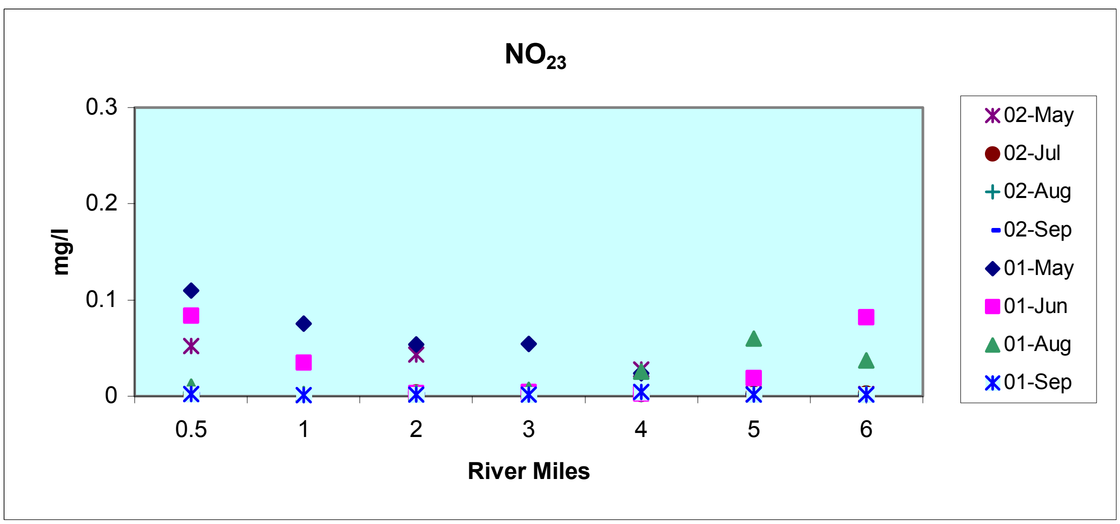

Figure A5: Longitudinal Profile of NO_{23} Data from Breton Bay Water Quality Survey

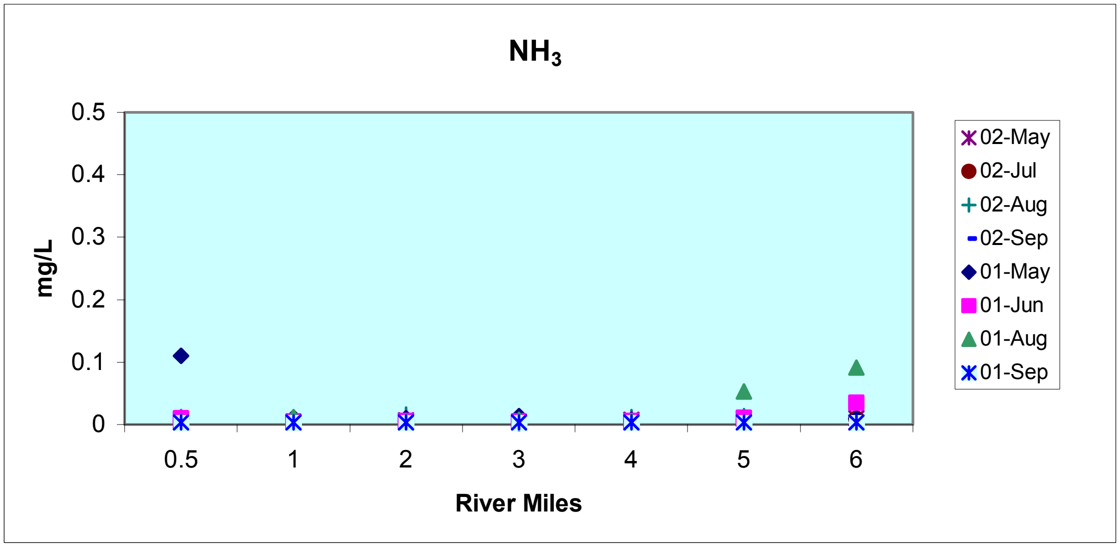

Figure A6: Longitudinal Profile of NH_3 Data from Breton Bay Water Quality Survey

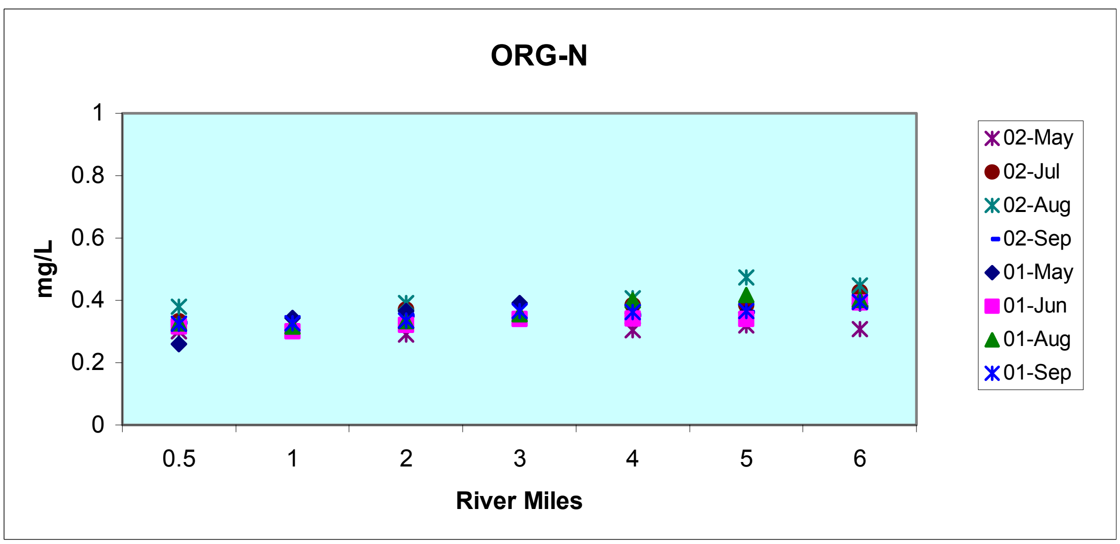

Figure A7: Longitudinal Profile of Total Organic Nitrogen Data from Breton Bay Water Quality Survey

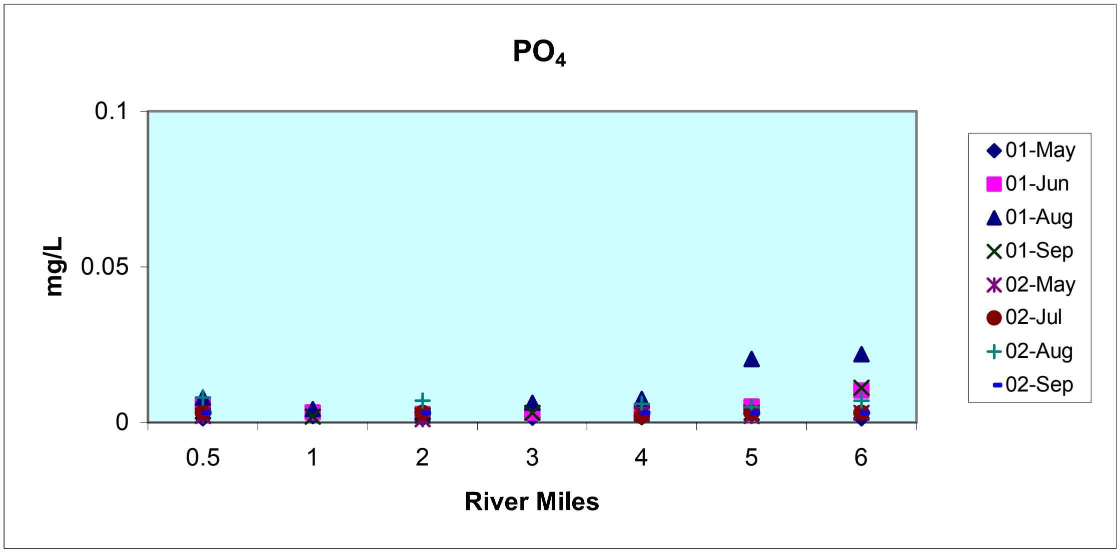

Figure A8: Longitudinal Profile of PO4 from Breton Bay Water Quality Survey

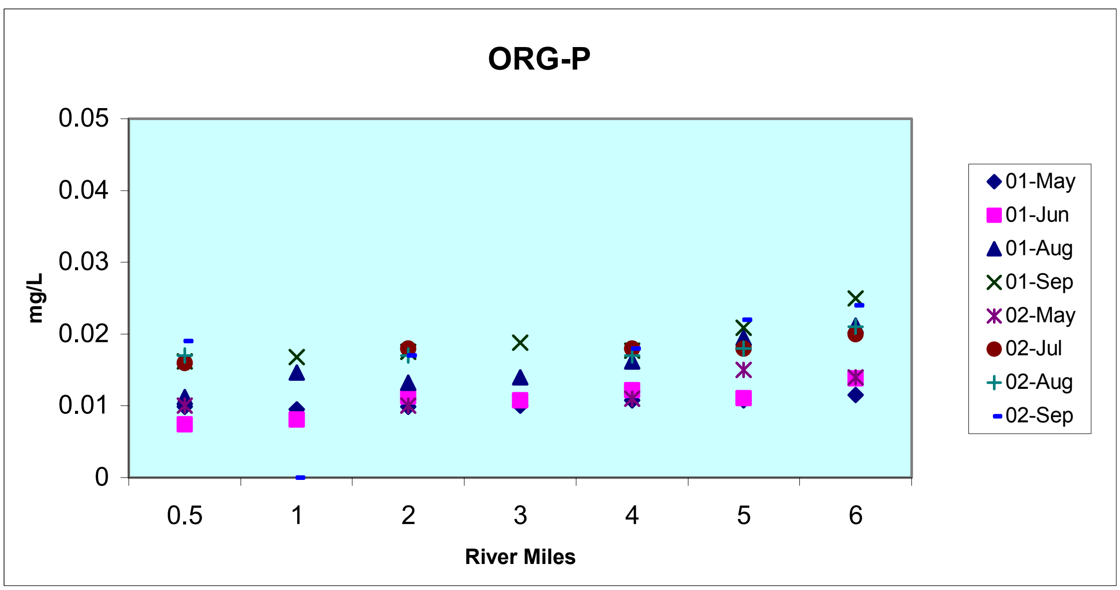

Figure A9: Longitudinal Profile of Total Organic Phosphorus Data from Breton Bay WQ Survey

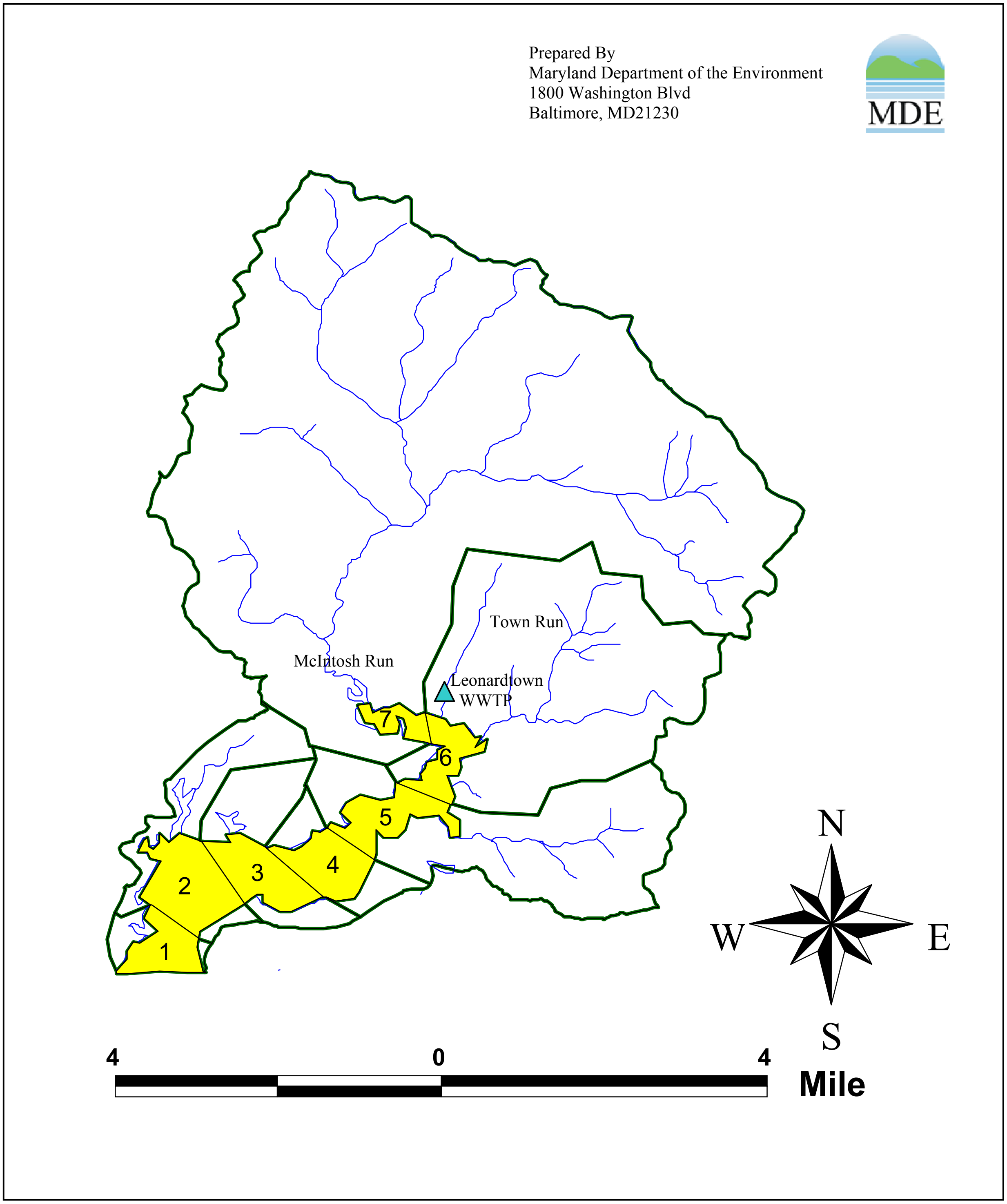

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Figure A10: BBEM model segmentation and associated subwatersheds

Model Calibration

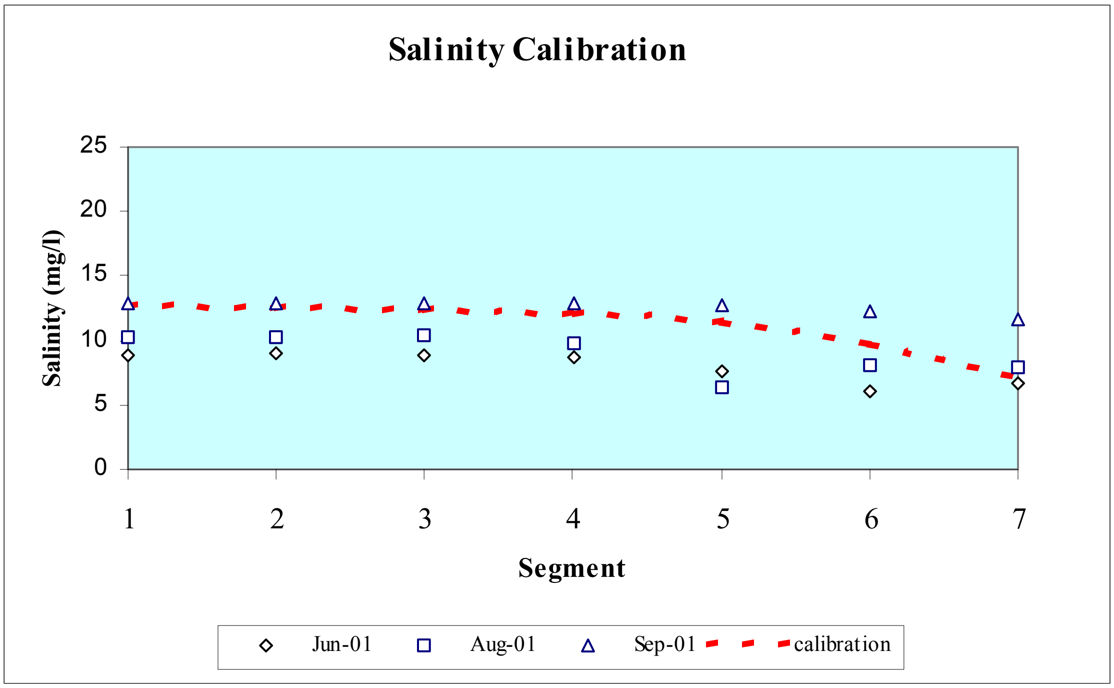

Figure A11: Salinity profile for the calibration of dispersion coefficients using 2001 Breton Bay water quality survey data

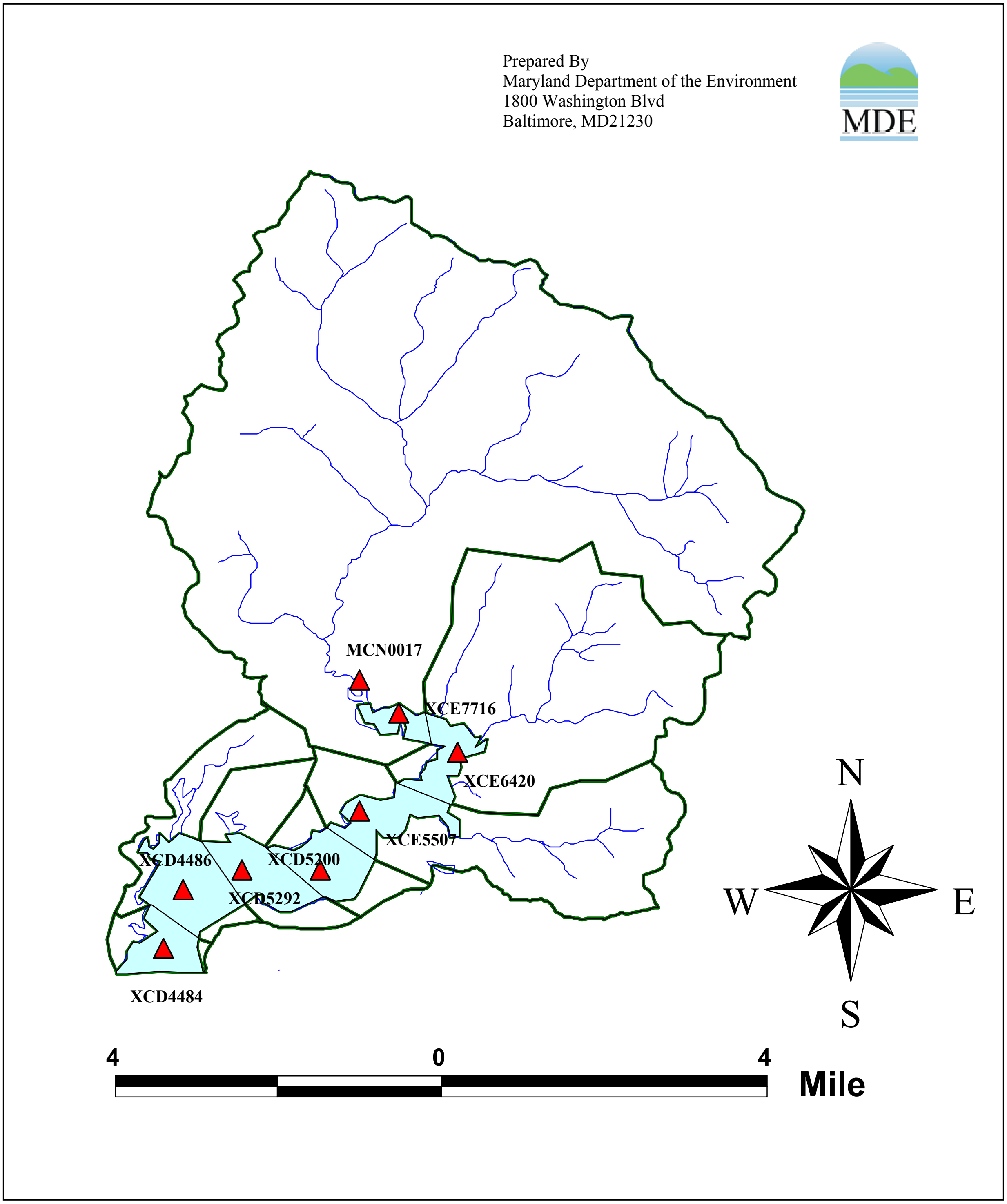

Figure A12: BBEM model segmentation and reference water quality stations

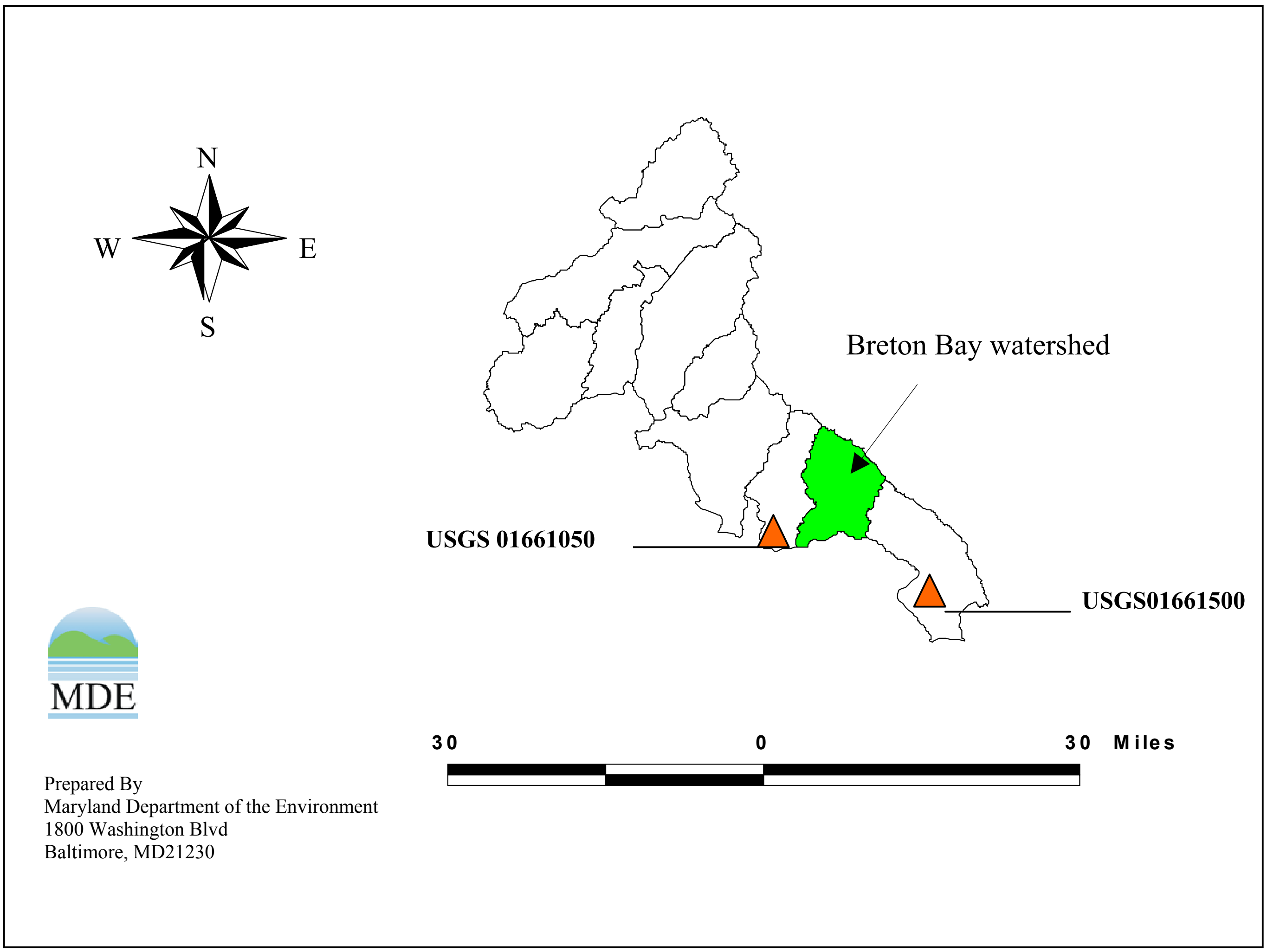

Figure A13: Relative locations of selected USGS gages from Southern Maryland hydrological region in BBEM flow estimation

Model Calibration

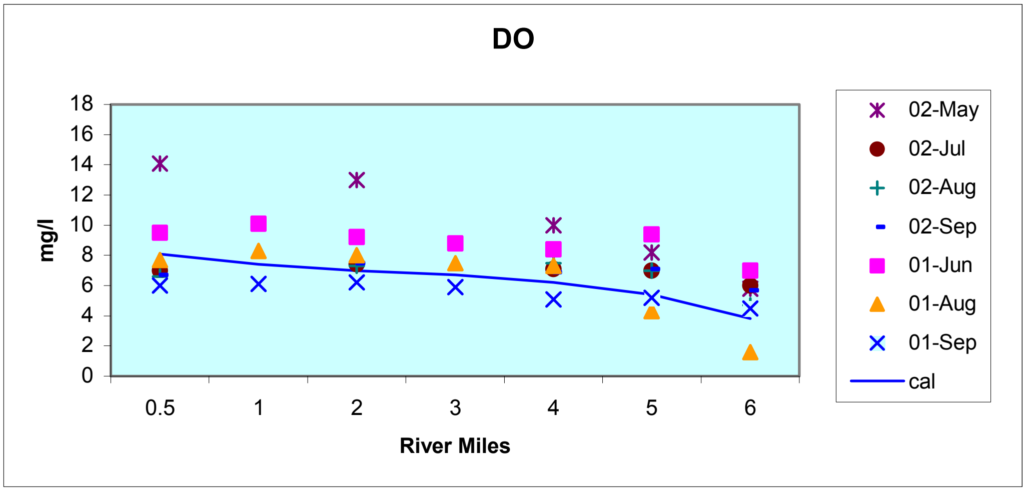

Figure A14: DO profile for the calibration of BBEM with Breton Bay survey data

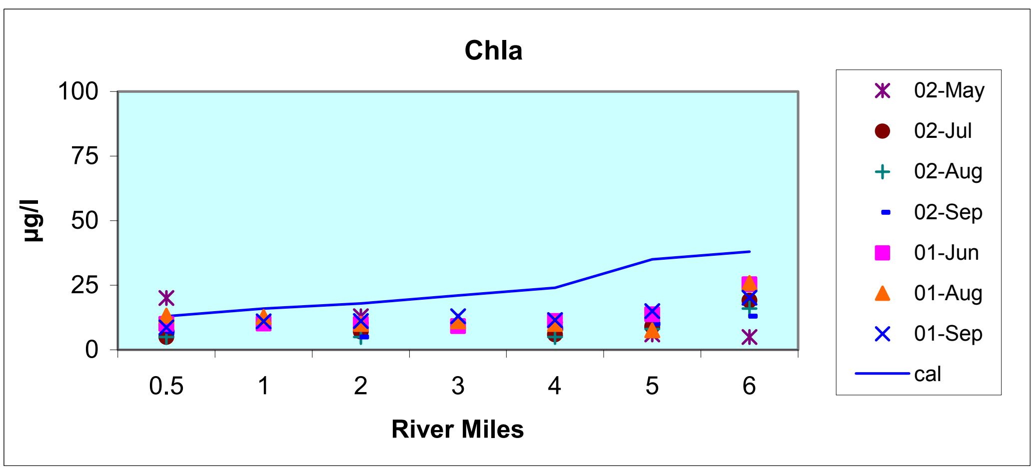

Figure A15: Chlorophyll profile for the calibration of BBEM using Breton Bay survey data

Model Calibration

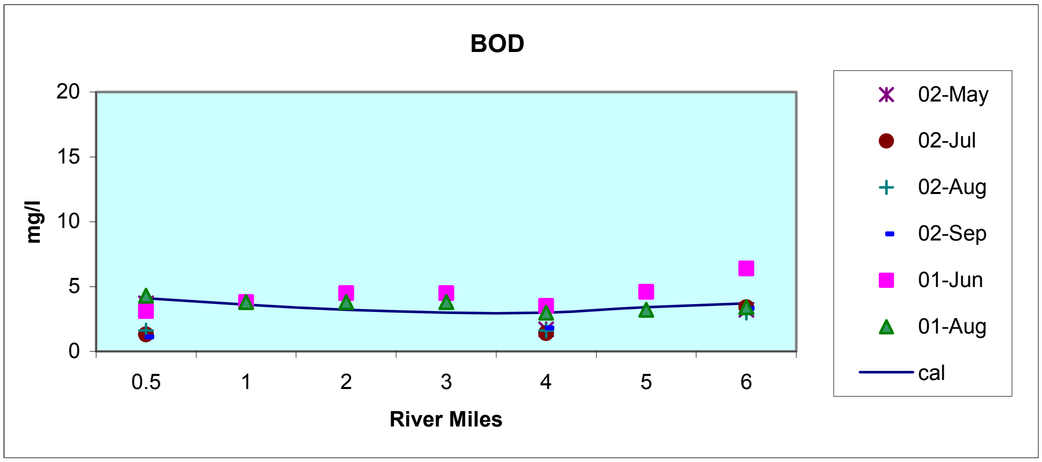

Figure A16: BOD profile for the calibration of BBEM using Breton Bay survey data

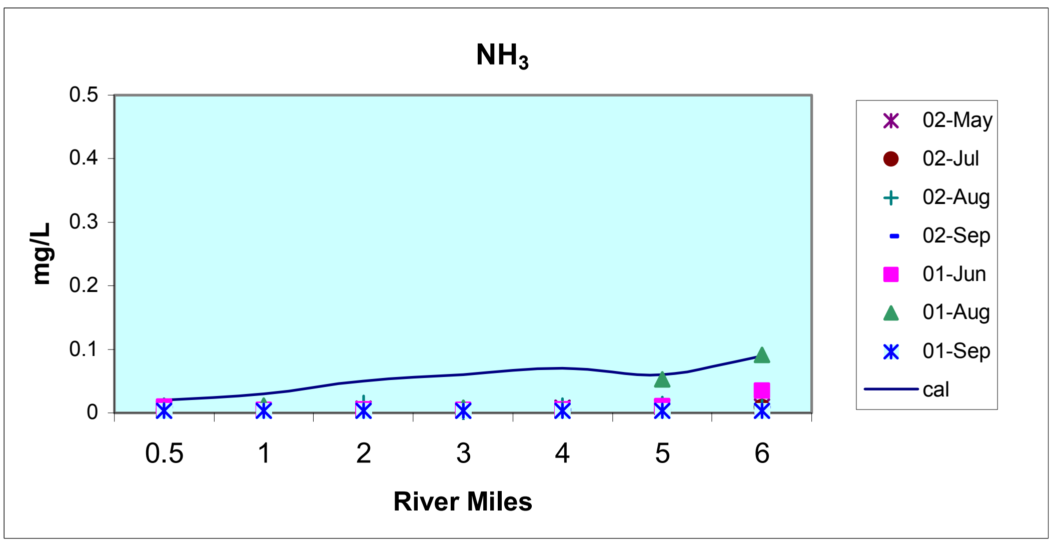

Figure A17: NH_3 profile for the calibration of BBEM using Breton Bay survey data

Model Calibration

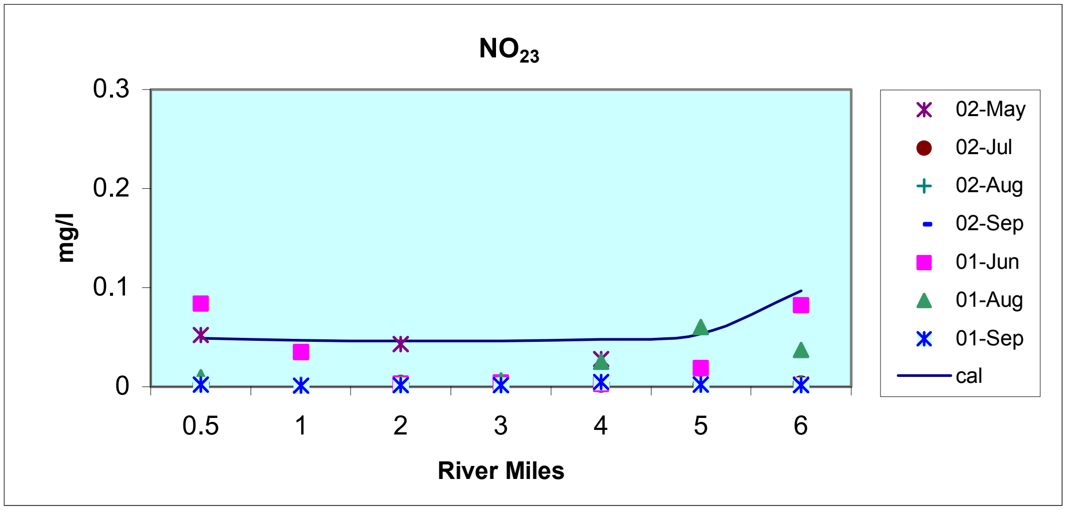

Figure A18: NO_{23} profile for the calibration of BBEM using Breton Bay survey data

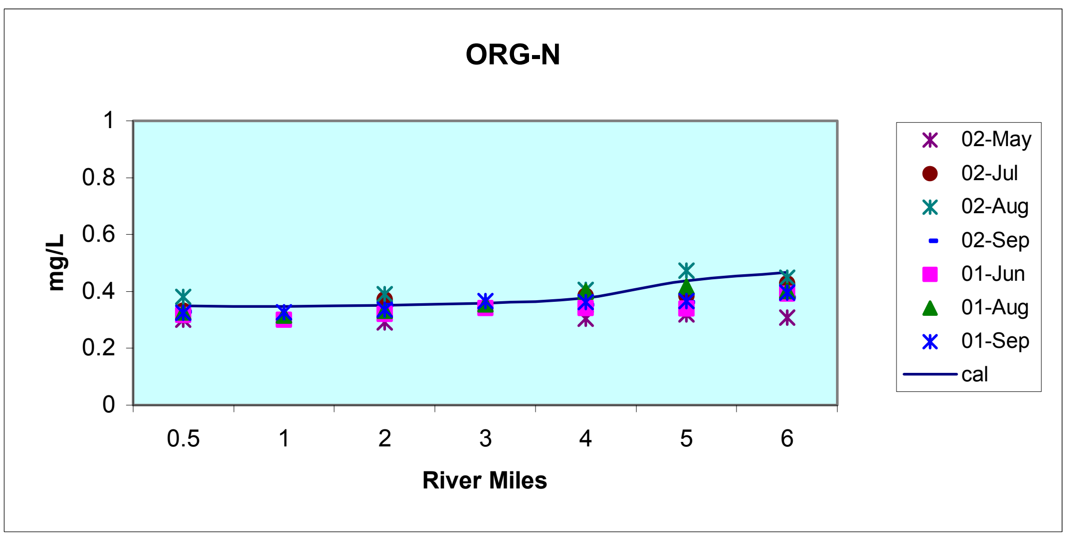

Figure A19: Org-N profile for the calibration of BBEM using Breton Bay survey data

Model Calibration

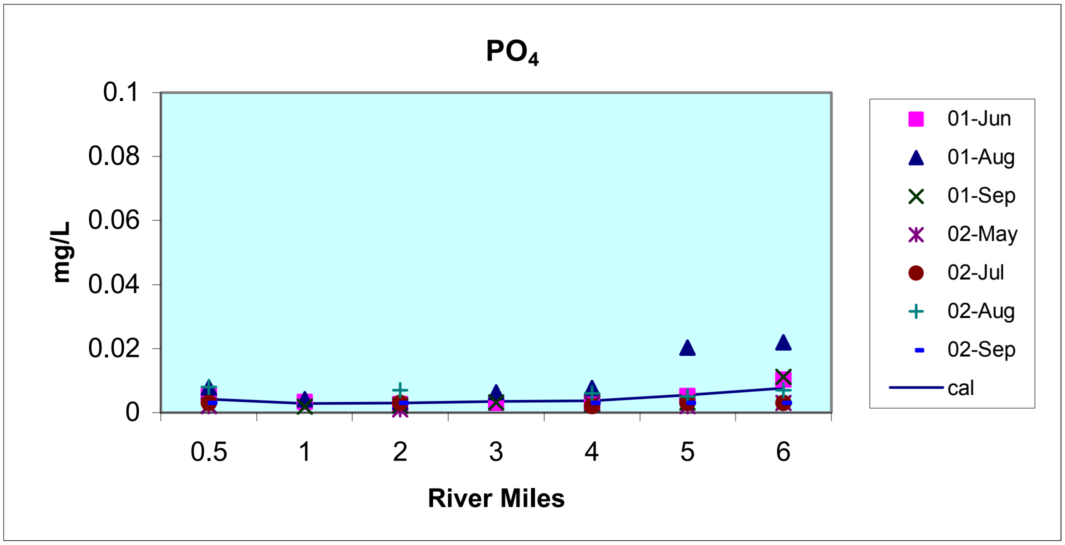

Figure A20: PO_4 profile for the calibration of BBEM using Breton Bay survey data

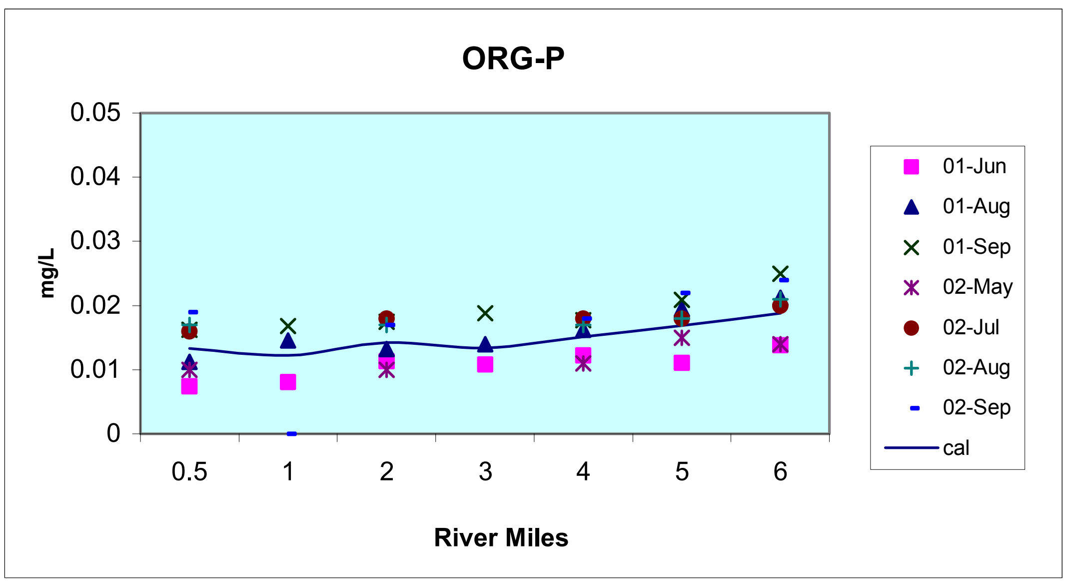

Figure A21: Org-P profile for the calibration of BBEM using Breton Bay survey data

Growing Season Baseline

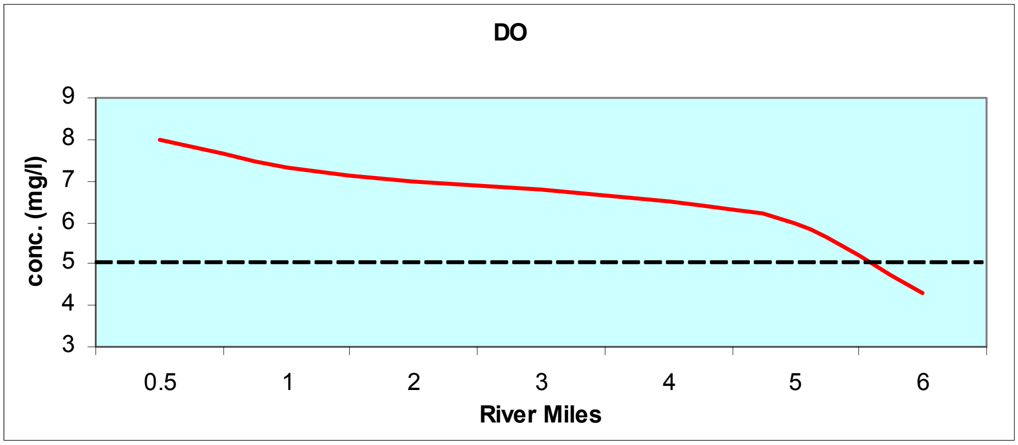

Figure A22: DO profile for Breton Bay Growing Season Summer Baseline condition

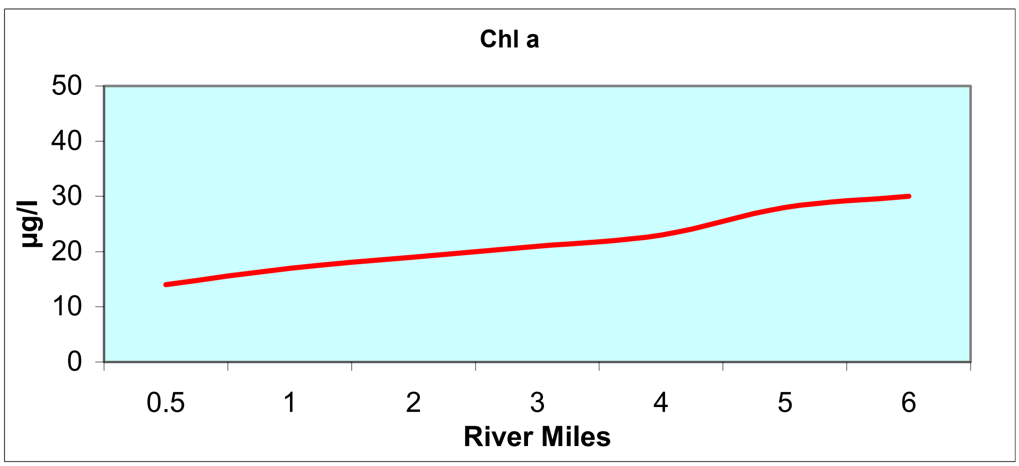

Figure A23: Chlorophyll profile for Growing Season Baseline Condition

Growing Season Baseline

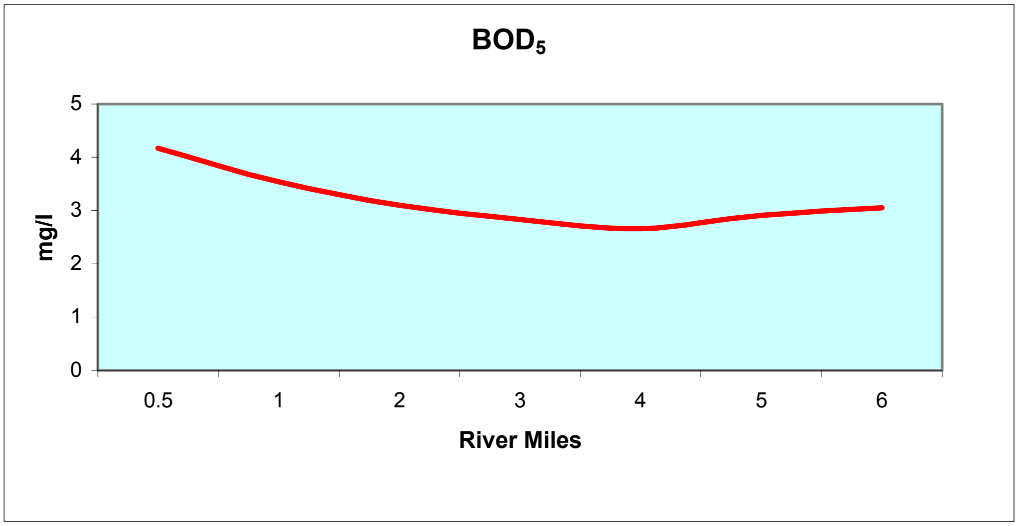

Figure A24: BOD_5 profile for Breton Bay Growing Season Baseline Condition

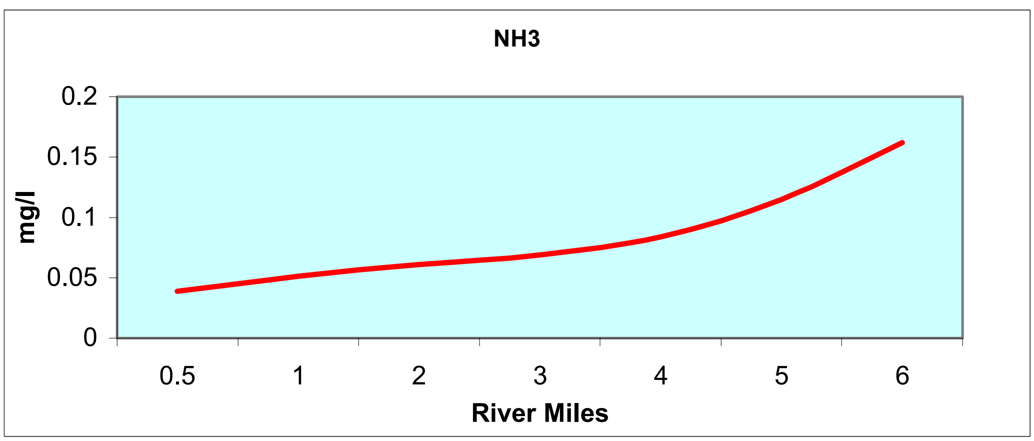

Figure A25: NH_3 profile for Growing Season Baseline Condition

Growing Season Baseline

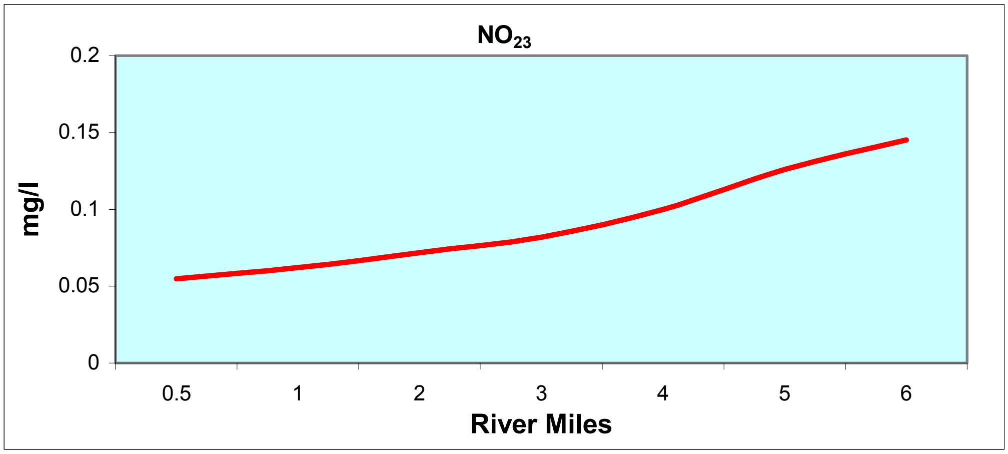

Figure A26: NO_{23} profile for Breton Bay Growing Season Baseline Condition

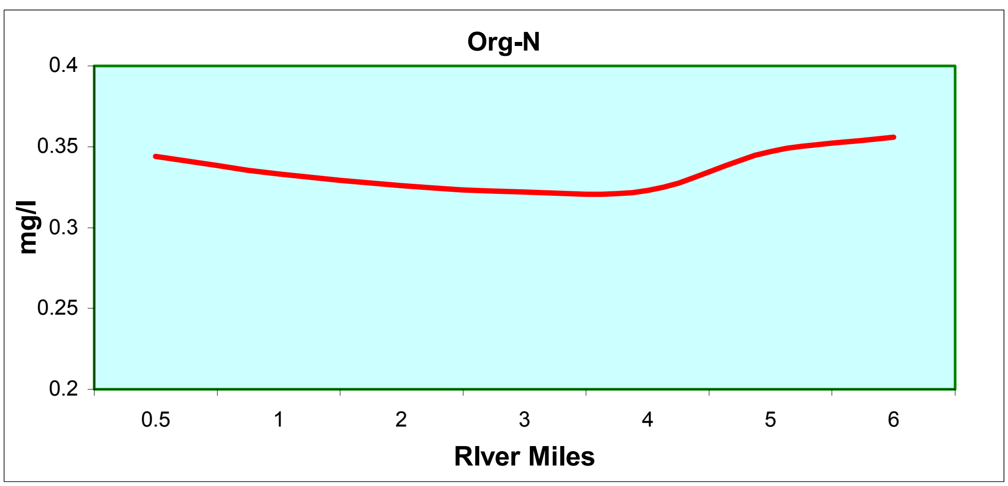

Figure A27: Organic Nitrogen profile for Breton Bay Growing Season Baseline Condition

Growing Season Baseline

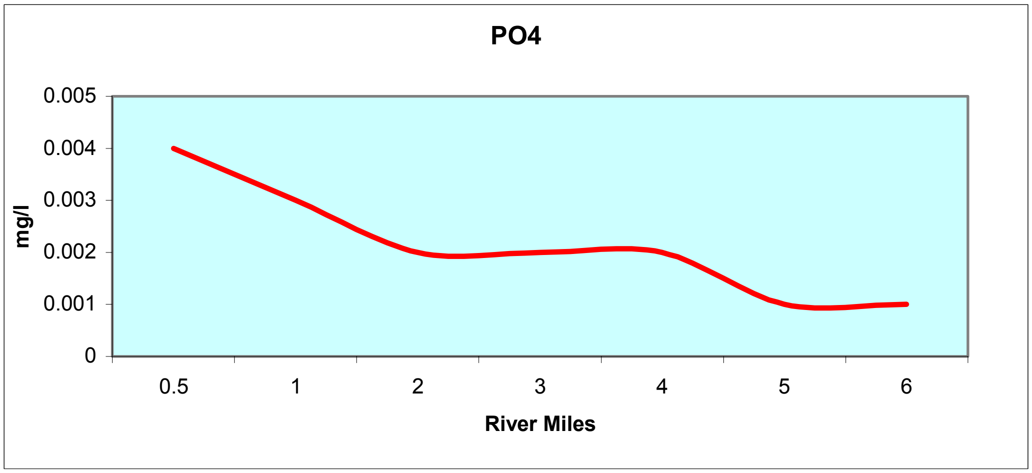

Figure A28: PO_4 profile for Breton Bay Growing Season Baseline Condition

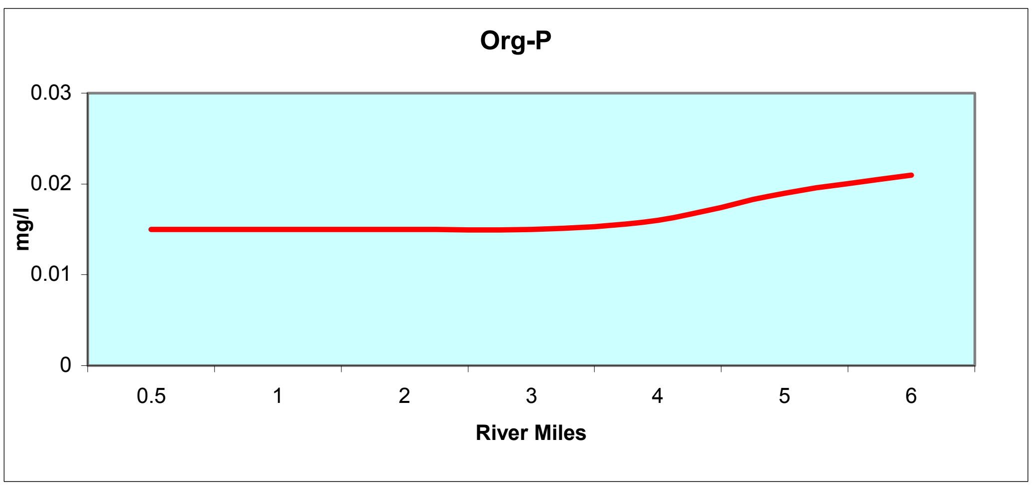

Figure A29: Organic phosphorus profile for Breton Bay Growing Season Baseline Condition

Growing Season TMDL

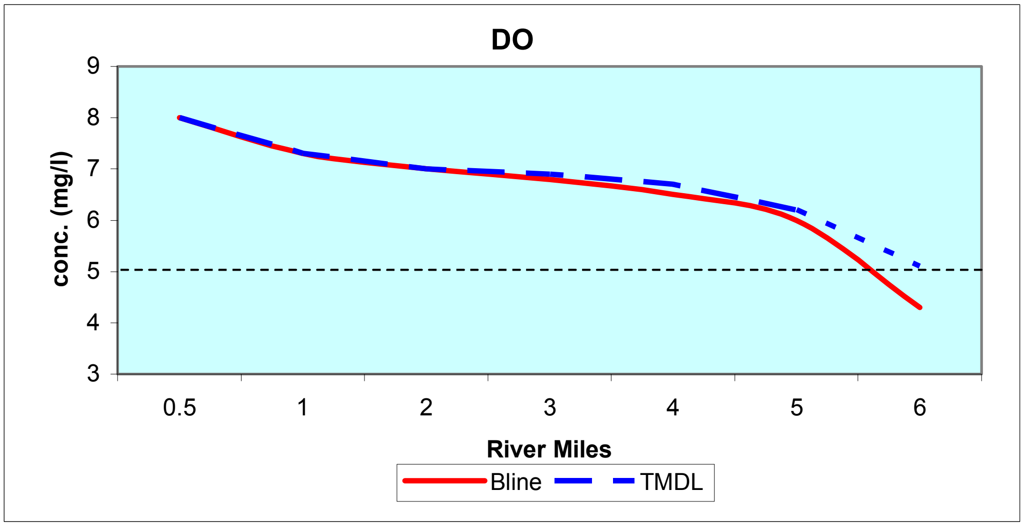

Figure A30: DO profile for Breton Bay Growing Season TMDL

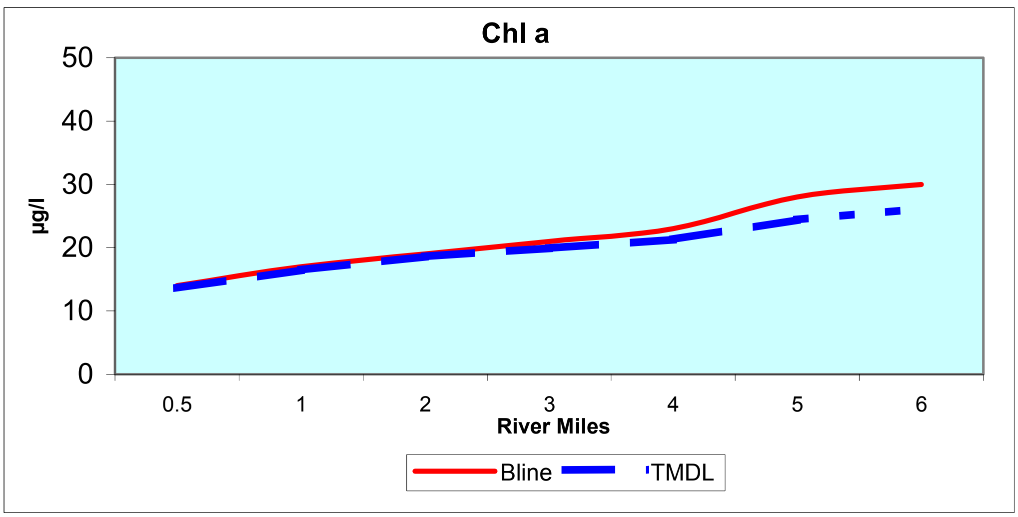

Figure A31: Chlorophyll a profile for Breton Bay Growing Season TMDL

Growing Season TMDL

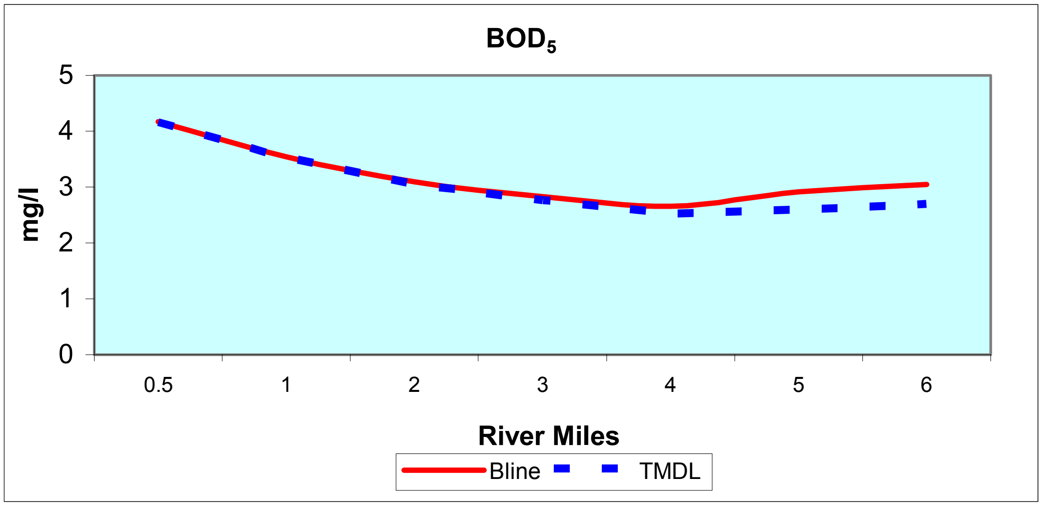

Figure A32: BOD_5 profile for Breton Bay Growing Season TMDL

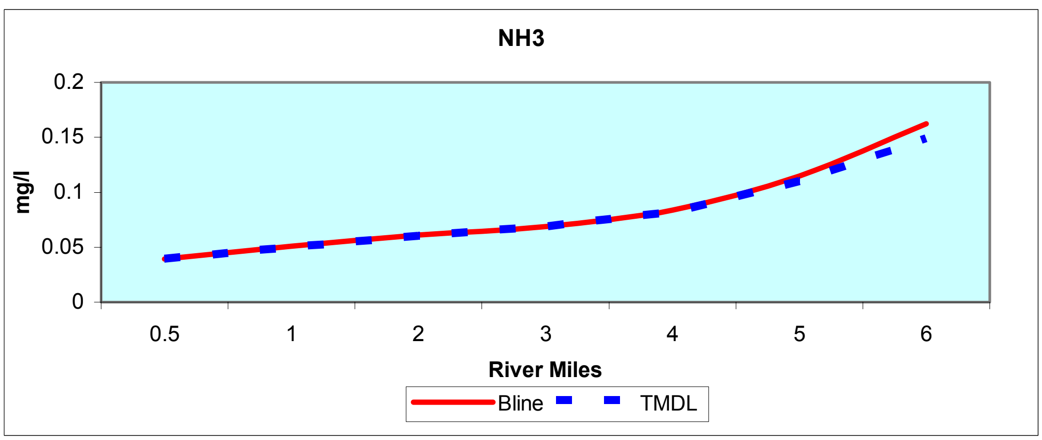

Figure A33: NH_3 profile for Breton Bay Growing Season TMDL

Growing Season TMDL

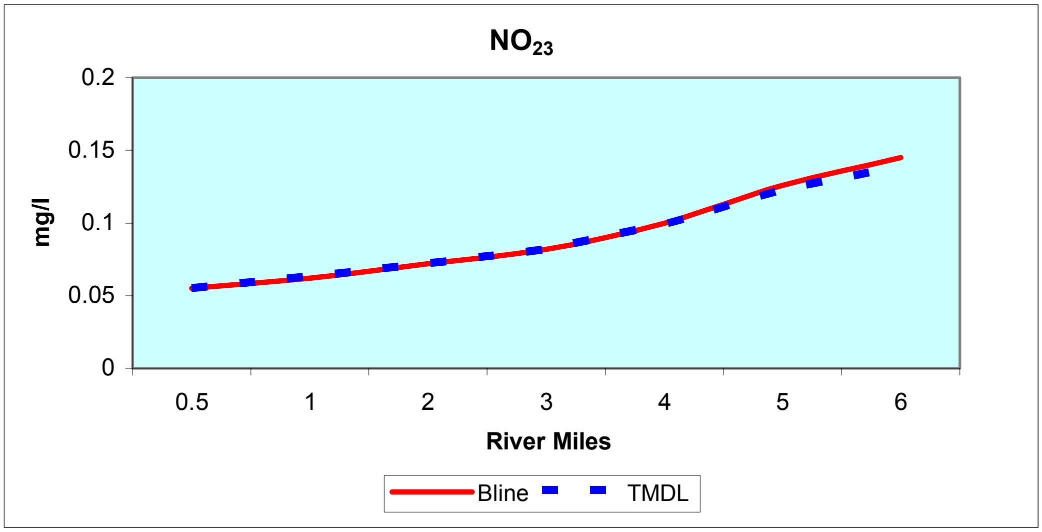

Figure A34: NO_{23} profile for Breton Bay Growing Season TMDL

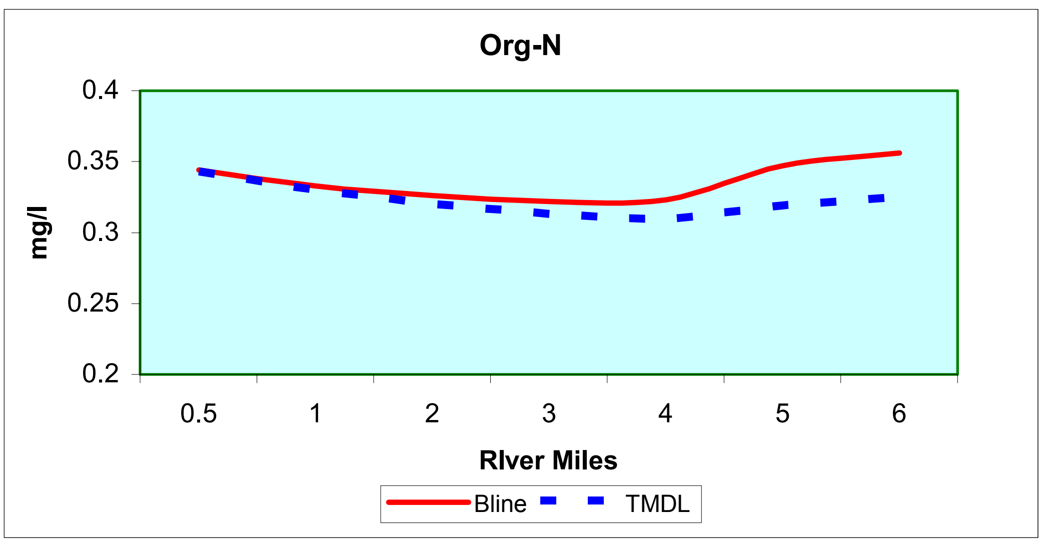

Figure A35: Organic Nitrogen profile for Breton Bay Growing Season TMDL

Growing Season TMDL

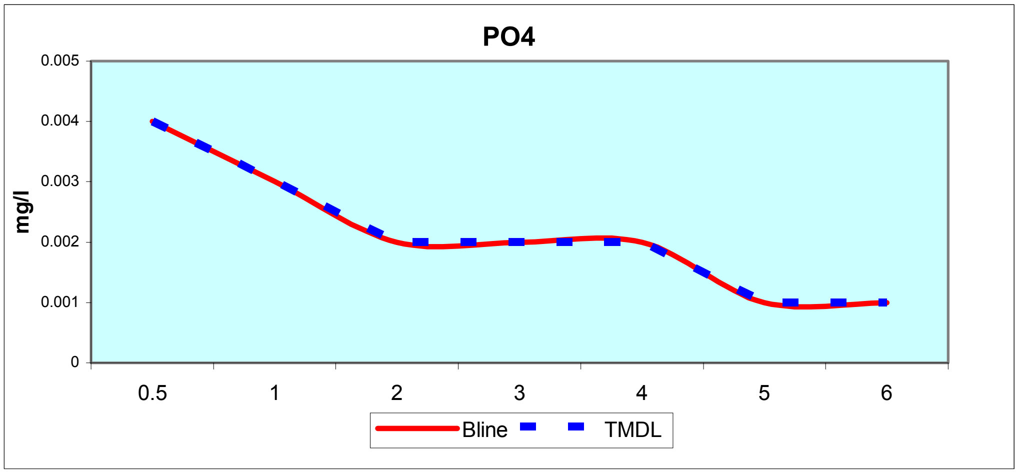

Figure A36: PO_4^{3-} profile for Breton Bay Growing Season TMDL

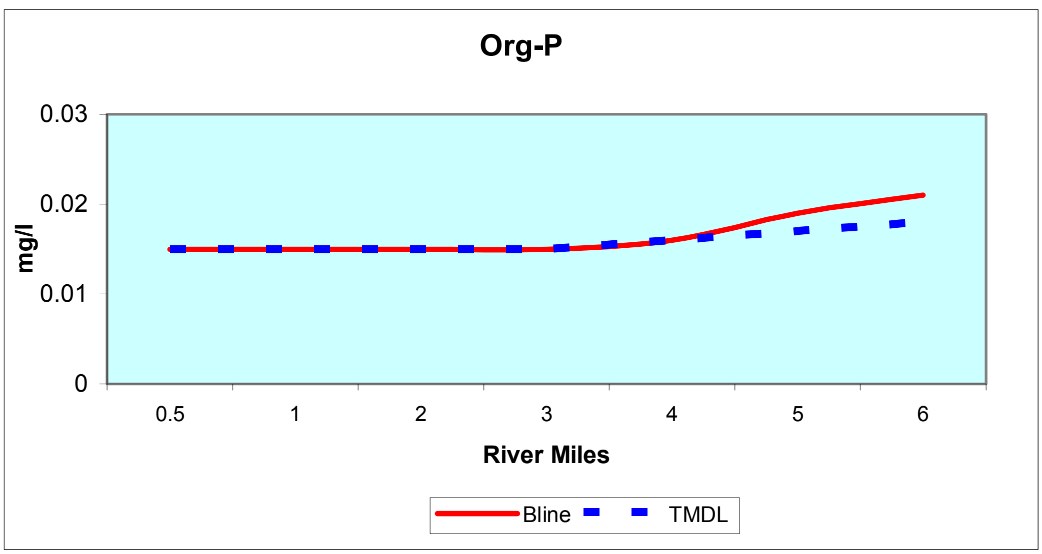

Figure A37: Organic Phosphorus profile for Breton Bay Growing Season TMDL

Average Annual Flow Baseline

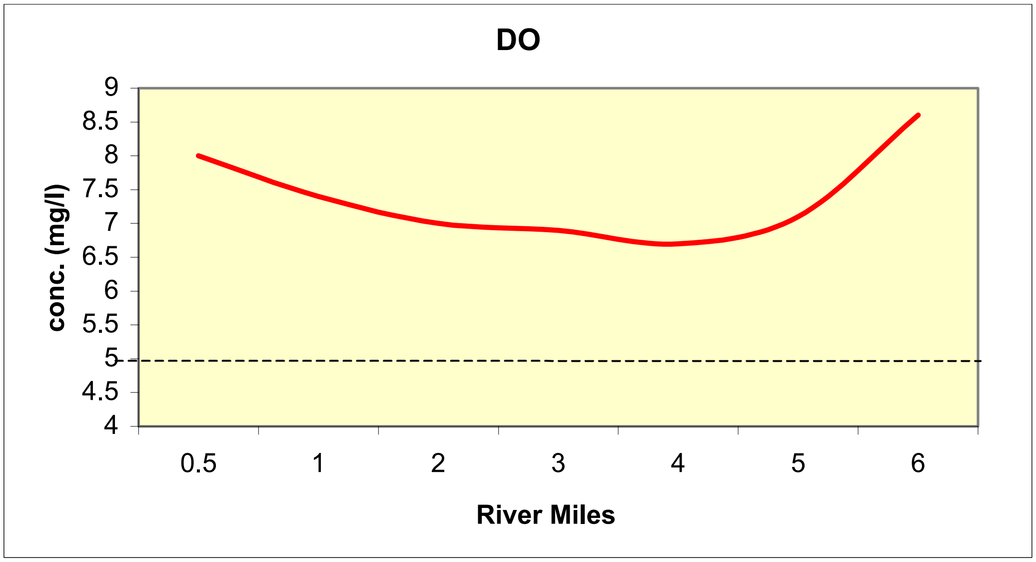

Figure A38: DO profile for Breton Bay Average Annual Flow Baseline Condition

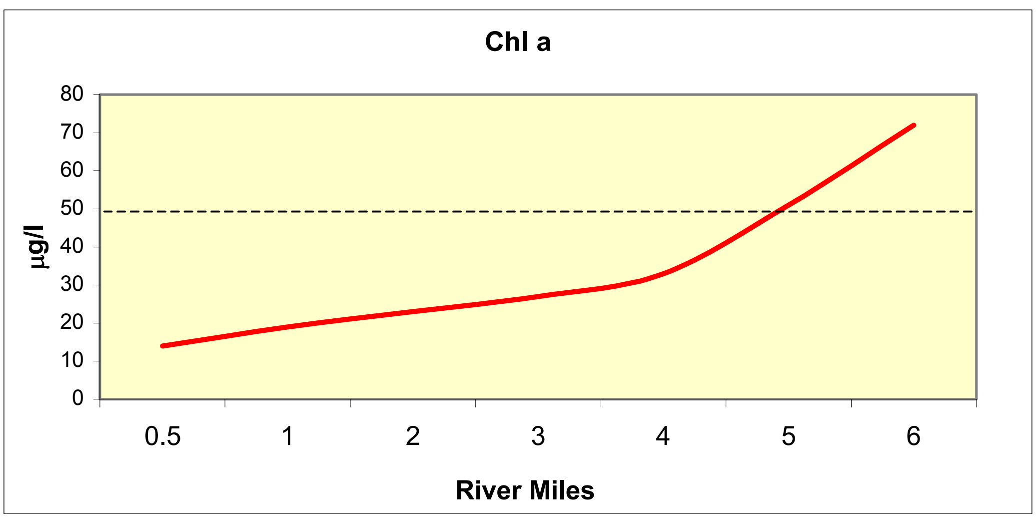

Figure A39: Chlorophyll a profile for Breton Bay Average Annual Flow Baseline Condition

Average Annual Flow Baseline

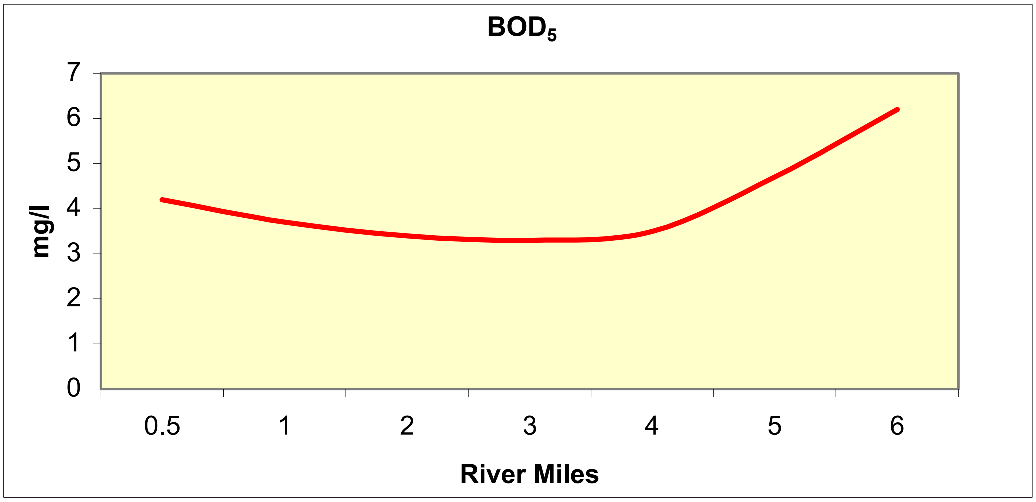

Figure A40: BOD_5 profile for Breton Bay Average Annual Flow Baseline Condition

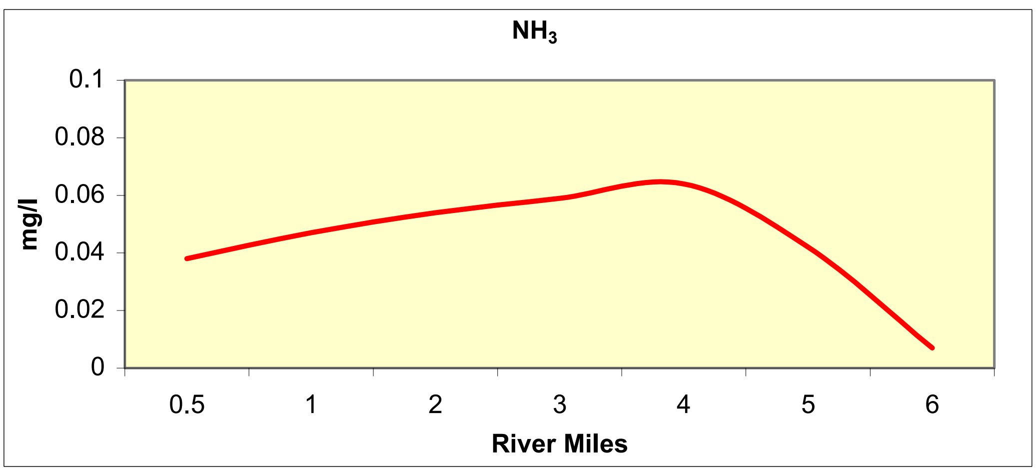

Figure A41: NH3 profile for Breton Bay Average Annual Flow Baseline Condition

Average Annual Flow Baseline

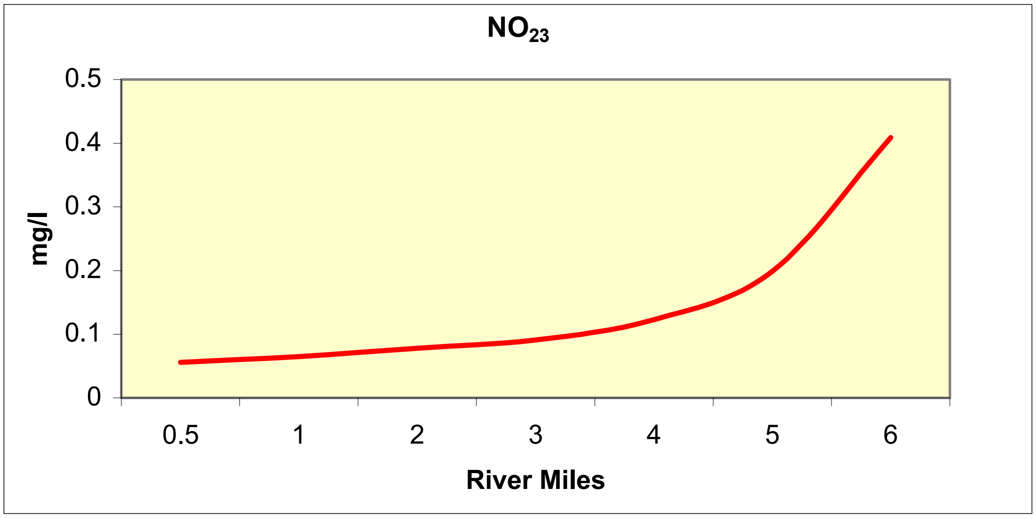

Figure A42: NO_{23} profile for Breton Bay Average Annual Flow Baseline Condition

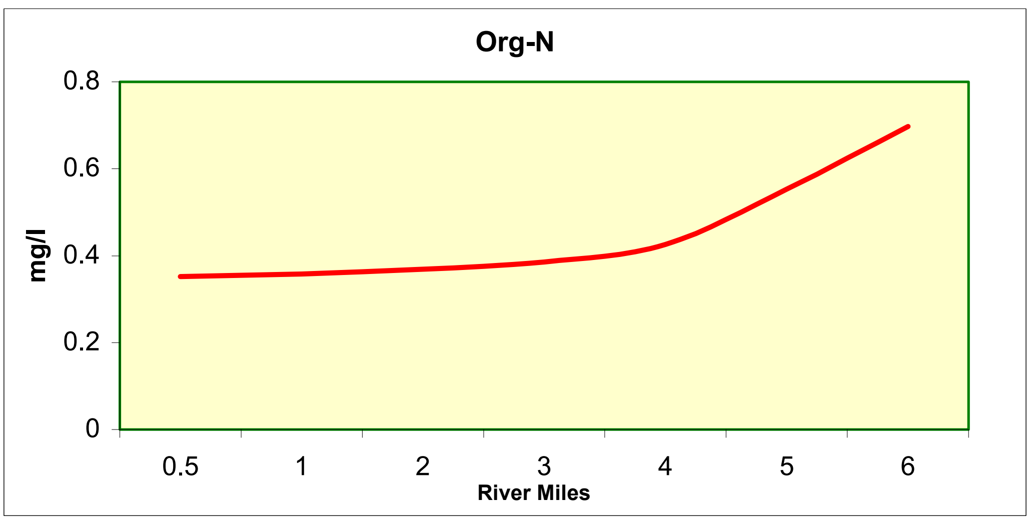

Figure A43: Organic Nitrogen profile for Breton Bay Average Annual Flow Baseline Condition

Average Annual Flow Baseline

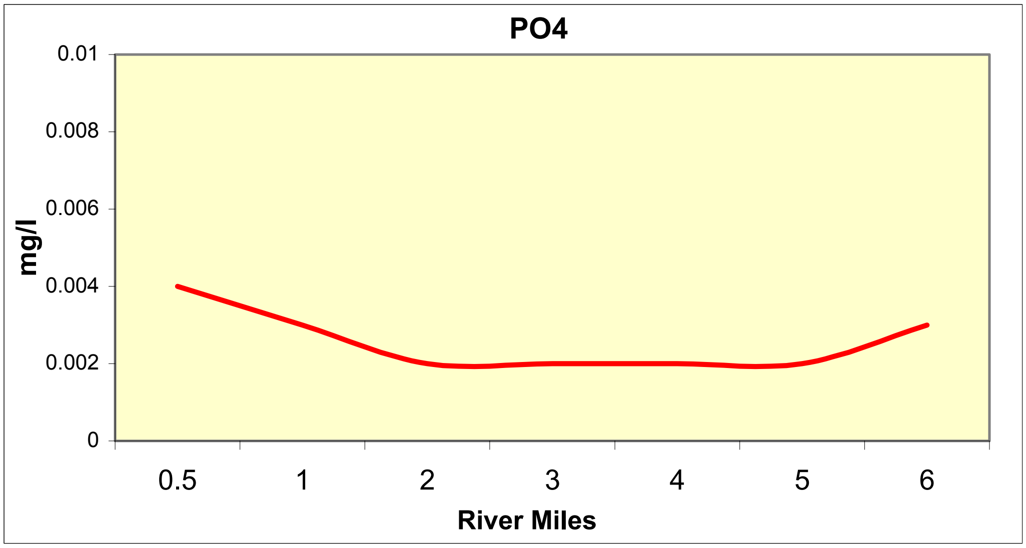

Figure A44: PO_4^{3-} profile for Breton Bay Average Annual Flow Baseline Condition

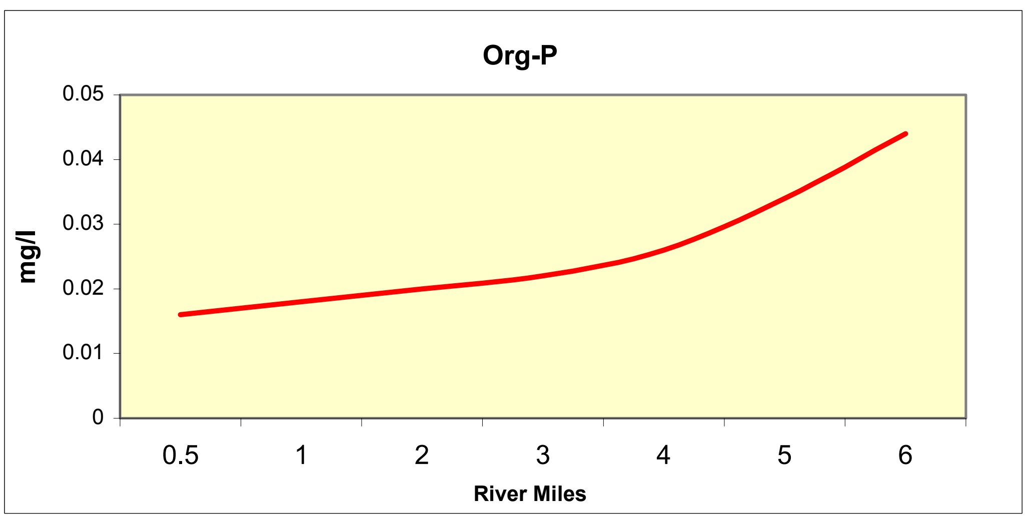

Figure A45: Organic Phosphorus profile for Breton Bay Average Annual Flow Baseline Condition

Average Annual Flow TMDL

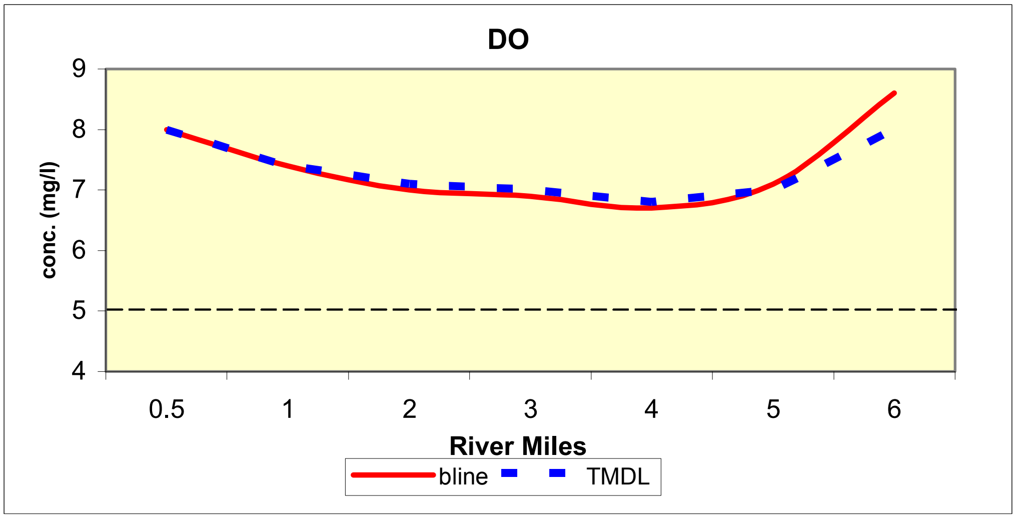

Figure A46: Dissolved Oxygen profile for Breton Bay Average Annual Flow TMDL

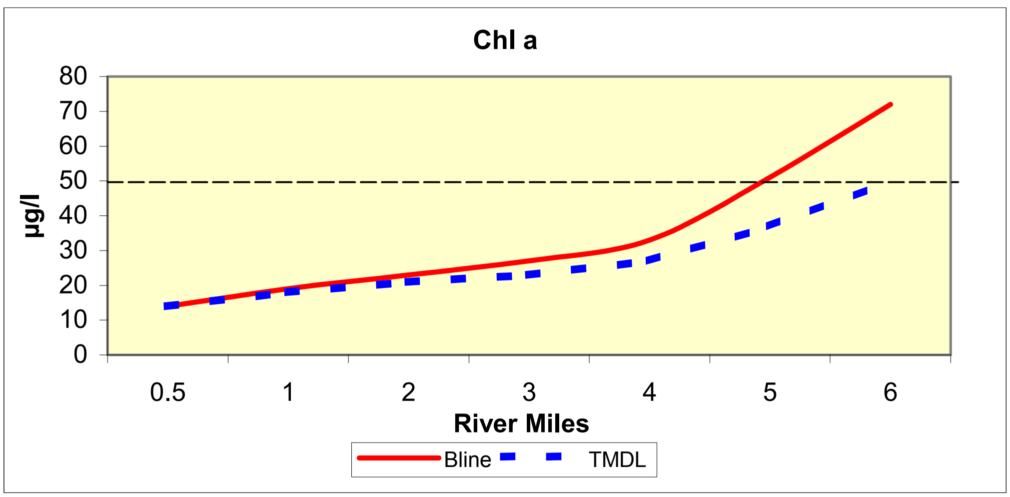

Figure A47: Chlorophyll A profile for Breton Bay Average Annual Flow TMDL

Average Annual Flow TMDL

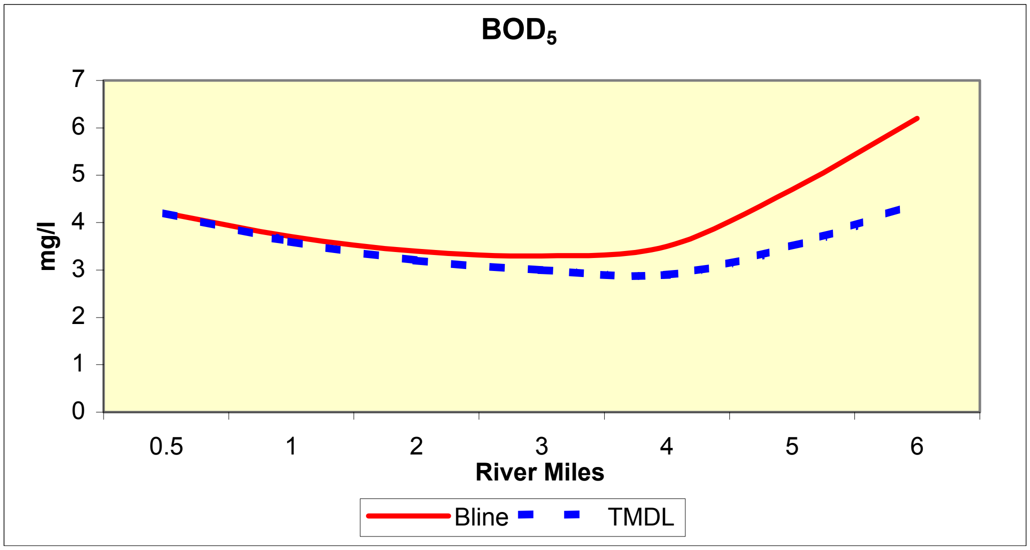

Figure A48: BOD profile for Breton Bay Average Annual Flow TMDL

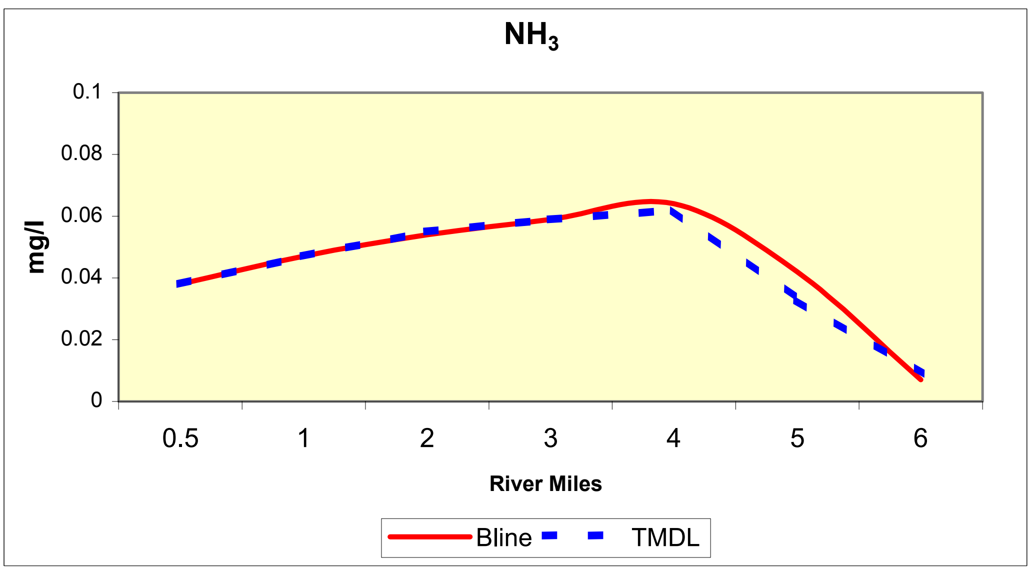

Figure A49: NH_3 profile for Breton Bay Average Annual Flow TMDL

Average Annual Flow TMDL

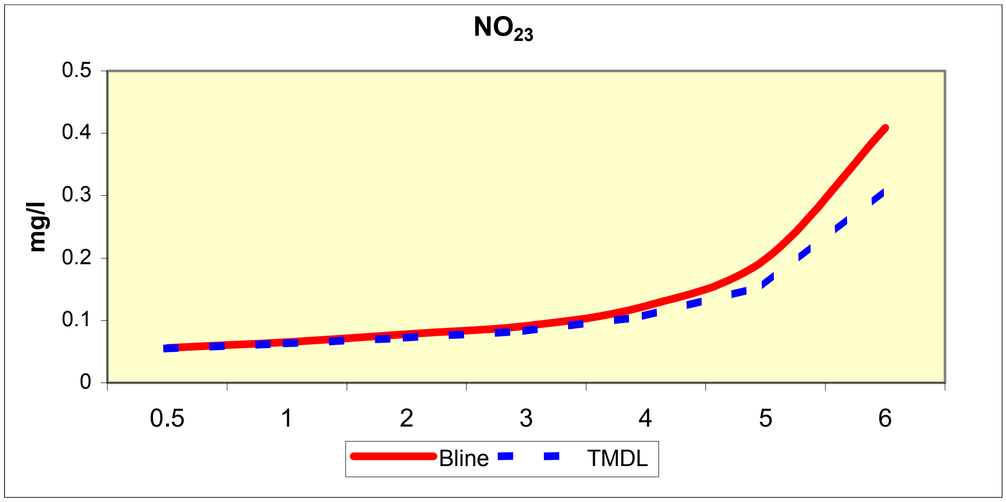

Figure A50: NO_{23} profile for Breton Bay Average Annual Flow TMDL

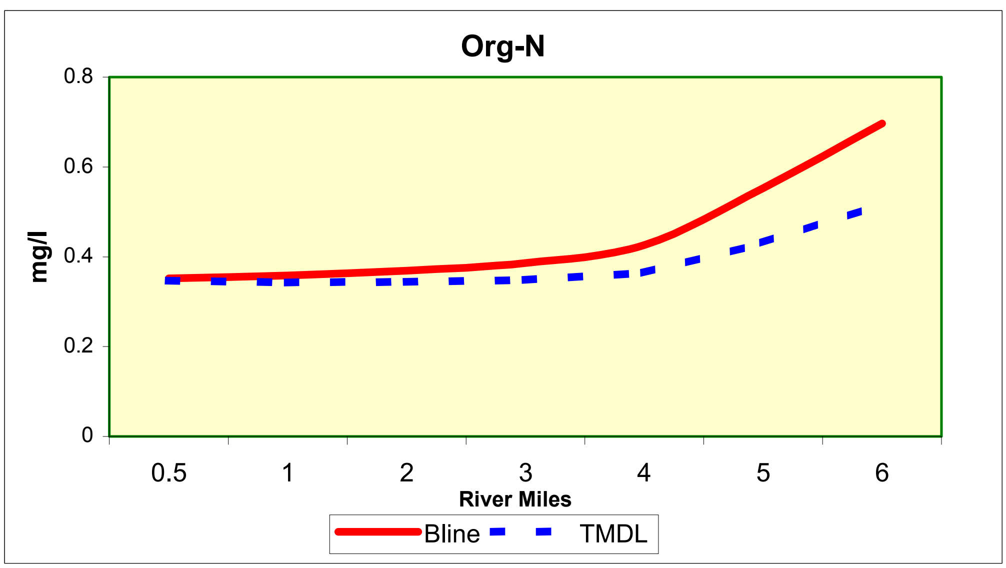

Figure A51: Organic N profile for Breton Bay Average Annual Flow TMDL

Average Annual Flow TMDL

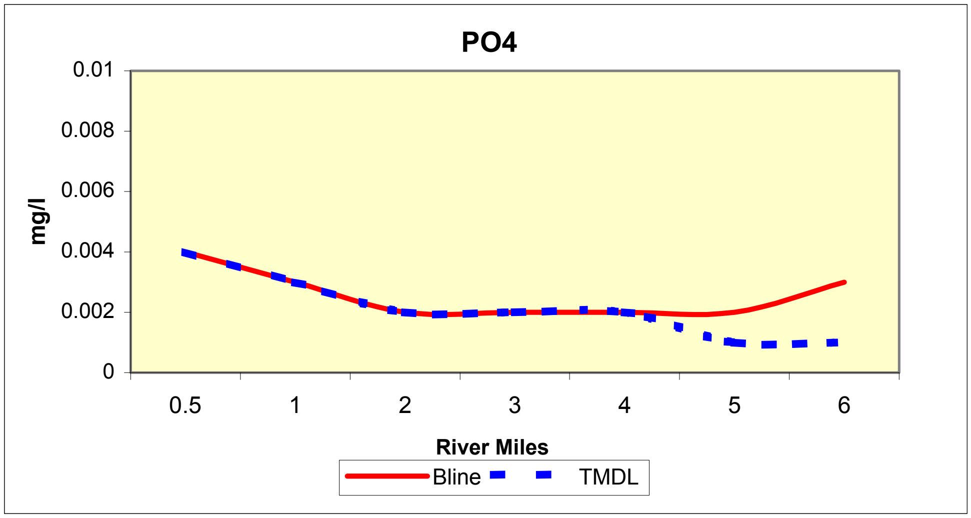

Figure A52: PO_4 profile for Breton Bay Average Annual Flow TMDL

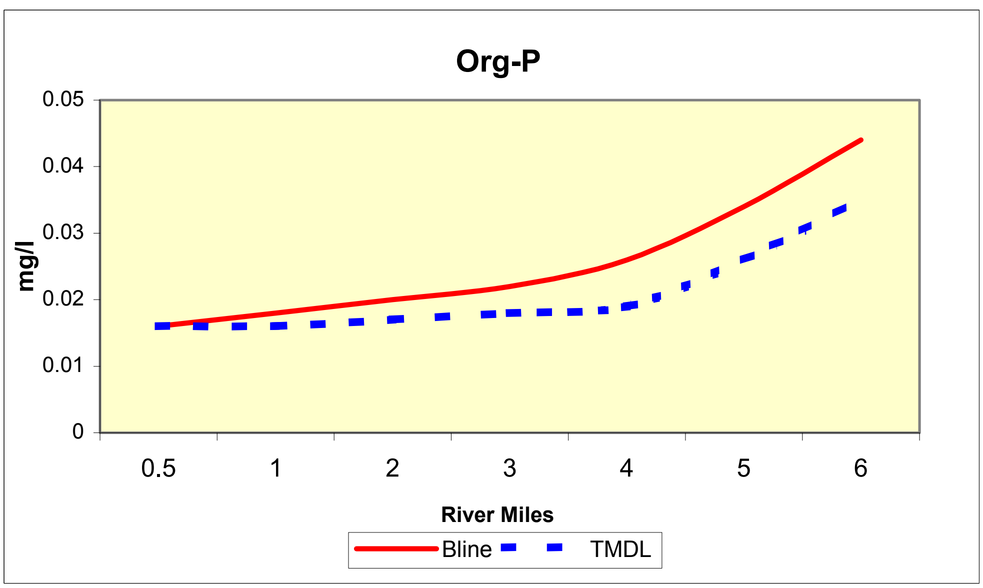

Figure A53: Organic P profile for Breton Bay Average Annual Flow TMDL

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