MODELING FRAMEWORK

The computational framework chosen for the modeling of water quality in Southeast Creek was the Water Quality Analysis Simulation Program version 5.1 (WASP5.1). 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 using linear or non-linear estimations of water quality kinetics. To date, WASP5.1 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.

WASP5.1 is supported and distributed by U.S. EPA's Center for Exposure Assessment Modeling (CEAM) in Athens, GA (Ambrose *et al*, 1993). EUTRO5.1 is the component of WASP5.1 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 staff collected physical and chemical samples on March 10, April 6, May 3, July 13, August 10, and September 8, 1999. The physical parameters, dissolved oxygen, 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 0.5 m from the surface. Samples were placed in plastic bottles and preserved on ice until they were delivered to the University of Maryland Laboratory at Solomon's, 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. Figures A2 – A6 present low flow and high flow water quality profiles along the mainstem of the river.

MODEL INPUT REQUIREMENTS [1]

Model Segmentation and Geometry

The spatial domain of the Southeast Creek Eutrophication Model (SCEM) extends from the confluence of Southeast Creek and the Chester River for about 5 miles (8 km) up the mainstem of the Creek. Following a review of the bathymetry for Southeast Creek, the model was divided into 20 segments (Figure A7). The Island Creek tributary was not segmented, because of

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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. 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 / (2.2046) = kg | ml (0.625) = km | mg/L x mgd x (8.34) / (2.2) = kg/d

insufficient data. Figure A7 shows the model segmentation for the development of SCEM. Table A2 lists the volumes, characteristic lengths and interfacial areas of the 20 segments.

Dispersion Coefficients

The dispersion coefficients were calibrated using the WASP5.1 model and in-stream water quality data from 1999. The WASP5.1 model was set up to simulate salinity. Salinity is a conservative constituent, meaning 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 model execution, salinity values at all boundaries, except the tidal boundary, were set to zero. Flows were obtained from regression equations for both low flow and high flow using data from USGS gage station in Kent County, Maryland (see the section on freshwater flows for more details). Figure A8 represents all salinity data collected in 1999. Figure A9 shows the data used for calibration and the model output for low flow and high flow periods in 1999. Dispersion coefficients are listed in Table A3.

Freshwater Flows

Freshwater flows were calculated on the basis of delineating the Southeast Creek drainage basin into 9 subwatersheds (Figure A10). These subwatersheds closely correspond with the Maryland Department of Natural Resources 12-digit basin codes. Where necessary, the subwatersheds were refined to assure they were consistent with the 20 segments developed for the SCEM. The SCEM was calibrated for two sets of flow conditions: high flow and low flow. The high flow corresponds to the months of March, April and May, and the low flow corresponds to the months of July, August and September.

The flows for the subwatersheds were estimated using an average flow from the USGS gages #01493000, #01493112, and #01493500 located near the Southeast Creek. A ratio of flow to drainage area was calculated and then multiplied by the area of the subwatersheds to estimate the high and low flows. For both high flow and low flow, each subwatershed was assumed to contribute a flow to the Southeast Creek mainstem. These flows and loads were assumed to be direct inputs to the SCEM. Table A4 presents flows from different subwatersheds during low, critical low, high and average annual conditions.

Nonpoint Source Loadings

Nonpoint source loadings were estimated for high flow, low flow and average annual flow conditions. For nonpoint sources, the concentrations of the nutrients nitrogen and phosphorus are modeled in their speciated forms. The WASP5.1 model simulates nitrogen as ammonia (NH_3), nitrate and nitrite ($NO_{2\text{-}3}$), and organic nitrogen (ON); and phosphorus as ortho-phosphate (PO_4) and organic phosphorus (OP). Ammonia, nitrate and nitrite, and ortho-phosphate represent the dissolved forms of nitrogen and phosphorus. The dissolved forms of nutrients are more readily available for biological processes such as algal growth that can affect chlorophyll *a* levels and dissolved oxygen concentrations. The ratios of total nutrients to dissolved nutrients used in the model scenarios represent values that have been measured in the field.

Loads for the high flow and low flow calibrations were estimated as the product of observed concentrations during high flow and low flow 1999, multiplied by their respective estimated flows. Water quality data from the 1999 survey was used to estimate boundary concentrations as follows: station XHH9772 was used for segment 1; station BWN0021 was used for segment 3, 8 and 14; station SEB0047 was used for segment 5 and 20; and the average for stations ILS0042 and GFB0018 was used for segment 2.

Average annual loads were determined using land use loading coefficients. The land use information was based on 1997 Maryland Office of Planning (MOP) land cover data, adjusted using crop acres from 1997 Farm Service Agency (FSA) data. The nonpoint source load was calculated by summing all of the individual land use areas and multiplying by the corresponding land use loading coefficients. The loading coefficients were based on the results of the Chesapeake Bay Watershed Model (U.S.EPA, 1996), a continuous simulation model. The Bay model loading rates are consistent with what would be expected in the year 2000 assuming continued Best Management Practice (BMP) implementation at a level consistent with the current rate of progress.

Both calibration loads and average annual loads reflect natural and human sources, including atmospheric deposition, loads coming from septic tanks, loads coming from urban development, agriculture, and forestland.

Point Source Loadings

For the point source loading, the concentrations of the nutrient parameters simulated by the model are considered in the same speciated forms as described. The Church Hill WWTP discharges directly into Southeast Creek (water quality model, segment 20).

The point source loading used in the calibration of the model was calculated from actual WWTP flows and concentrations stored in MDE's point source database. For higher stream flow conditions, point source loads were simulated as an average of March and April 1999 discharge reports data. For low flow stream conditions, point source loads were simulated as an average of July and September 1999 discharge report data. These data coincide with the time period in which data was collected and use for model calibration. Table A5 presents the point source flows and loadings used for the model calibration.

The point source loadings used for the baseline low flow scenario (first scenario) and for the baseline average annual flow scenario (second scenario) were calculated from the maximum allowable limit effluent concentrations described in the plant's surface water discharge NPDES permit (see scenario descriptions below). For model input parameters for which there is no maximum permit limit, concentrations were estimated based on the type of unit operations or treatment processes used by each plant under consideration.

Environmental Conditions

Seven environmental parameters were used for developing the model of Southeast Creek. They are solar radiation and photoperiod (see Table A6), temperature (T), extinction coefficient (K_e), salinity, sediment oxygen demand (SOD), sediment ammonia flux (FNH_4) and sediment phosphate flux (FPO_4) (Table A7).

Data for the solar radiation and photoperiod were taken from a water quality model study performed on the Potomac River in 1982 (Thomann, 1982). Data for salinity and temperature were taken from in-stream water quality measurements. Initial values of SOD, FNH_4 and FPO_4 were estimated then refined through the calibration process.

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

$$K_e = \frac{1.95}{D_s}$$

where:

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

It was estimated that nonliving organic nutrient components settle from the water column to the sediment at an estimated settling velocity of 0.0432 *m/day* ($5E10^{-7}$ *m/sec*), and phytoplankton was estimated to settle through the water column at a rate of 0.43 *m/day* ($5E10^{-6}$ *m/sec*). These values are within the range specified in the WASP5.1 manual. In general, it is reasonable to assume that 50% of the nonliving organics are in the particulate form.

Different SOD values were estimated for different SCEM reaches based on observed environmental conditions and literature values (Thomann, 1987). The lowest SOD value of 1.0 $g\ O_2/m^2 day$ was assumed to occur in the area upstream of the head of tide and nontidal areas of the creek. A maximum SOD value of 3.0 $g\ O_2/m^2 day$ was used in the area downstream (see Table A7).

Kinetic Coefficients

The water column kinetic coefficients are universal constants used in the SCEM 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 of Mattawoman Creek (Haire and Panday, 1985; Panday and Haire, 1986; Domotor *et al*., 1987), and the Patuxent River (Lung, 1993). The kinetic coefficients are listed in Table A8.

Initial Conditions

The initial conditions used in the model were chosen to reflect the observed values as closely as possible. However, because this is a steady-state model, the initial conditions will not impact the final results.

CALIBRATION & SENSITIVITY ANALYSIS

The SCEM model for salinity, which was used to estimate the dispersion coefficients, was calibrated with July, August and September 1999 salinity data. Figure A9 shows the salinity calibration for low and high flow periods. More information about the dispersion coefficients can be found in the *Model Input Requirements* section above.

The SCEM model for low flow was calibrated with July, August and September 1999 data. Tables A9, A10 and A11 show the nonpoint source flows and loads associated with the calibration input file (See *Point and Nonpoint Sources Loadings* above for details). Figures A11 – A18 show the results of the calibration of the model for low flow. The results show that the chlorophyll *a* trend is represented well, however some other parameters are in the lower side of the range, but the overall the trend is captured.

The SCEM model for high flow was calibrated with March, April and May 1999 data. The results are presented in Figures A19 to A26. As can be seen, the calibration curves present the trend of all the parameters very well.

Model sensitivity analyses were performed on the calibration and on the baseline condition scenarios for low flow and average annual flow to determine the reaction of the model to reductions in both nitrogen and phosphorus. The model was sensitive to reductions in phosphorus. However, it was not sensitive to reductions in nitrogen. During low flow conditions a 100% increase in point source and nonpoint source total nitrogen loads had no effect on chlorophyll *a* or dissolved oxygen concentrations. Table A12 shows ratios of Dissolved Inorganic Nitrogen (NH_4 + NO_2 + NO_3) to Dissolved Inorganic Phosphorus (PO_4). The ratio of DIN to DIP in all segments indicates that phosphorus limits the algal growth.

SYSTEM RESPONSE

The SCEM model was applied to several different nonpoint source loading conditions under various stream flows to project the impacts of nutrients on algal production (modeled as chlorophyll *a*) and low dissolved oxygen. By simulating various stream flows, the analysis accounts for seasonality.

Model Run Descriptions

Baseline Condition Scenarios:

First Scenario (Low Flow): The first scenario represents the baseline low flow conditions of the stream. The low flow was estimated using a regression analysis as described above for the USGS stations specified above in the Freshwater Flows section. The nonpoint source loads for this scenario were the same nonpoint source loads used in the low flow calibration of the model and computed as described above in the Nonpoint Source Loads Section. These nonpoint source loads are shown in Table A13. Because the loads are based on observed concentrations, they account for all background and human-induced sources. All the environmental parameters used for the first Scenario remained the same as for the low flow calibration of the model. The point sources used in this scenario were calculated as described above in the section "Point Source Loadings" and are shown in Table A14.

Second Scenario (Average Annual Flow): The second scenario represents the baseline conditions of the stream during average annual flow. The total average annual flow was estimated based on data from the USGS gages as described above and are shown in Table A15. Nonpoint source load estimation methods are described above. Point source loadings were the same used in the first scenario. All the environmental parameters remained the same as in the first scenario - except temperature. Temperature for this scenario was estimated by averaging the summer temperatures from the Chesapeake Bay Program 12-year historical data in the Maryland Eastern Shore area. This summer maximum average temperature, 28.8 ^{o}C, was used for all segments in the tidal portion of the river -a conservative assumption- and a temperature of 23.1 ^{o}C in the non tidal segments.

Future Condition TMDL Scenarios:

Third Scenario (Low Flow): The third scenario is the final result of a number of iterative model scenarios involving nutrient reductions that were explored to determine the maximum allowable loads during low flow conditions. For this scenario, the flow was the same as scenario one. The total nonpoint source loads were based on the 1999 MDE field data and reduced to meet the water quality criteria specified before. The point source loads reflect the plant's maximum water and sewer plant design flow and effluent concentrations as in the first scenario. All the environmental parameters (except nutrient fluxes and SOD) and kinetic coefficients used for the calibration of the model remained the same as scenario one. A description of the methods used to estimate the reductions of nonpoint and point sources, as well as nutrient fluxes and SOD for this scenario, are described in the following paragraphs.

- To estimate feasible phosphorus nonpoint source reductions, the percent of the nonpoint source load that is controllable was estimated for each subwatershed. It was assumed that all of the loads from cropland, feedlots, and urban were controllable, and loads from atmospheric deposition, septic tanks, pasture, and forest were not controllable. This analysis was performed on the average annual loads, because loads from specific land uses were not available for low flow. However, the percent controllable was applied to the low flow loads as well as the average annual loads. A margin of safety of 5% was included in the load calculation. Using the above calculated percent controllable, several iterative reductions were made to the nonpoint source loadings starting with a 10% reduction of phosphorus controllable loads up to the final phosphorus reductions used for the future low flow condition scenario. These reductions in nonpoint source loads, combined with the reduced point source loads from the baseline conditions scenario, meet the chlorophyll *a* goal of 50 μg/L, and the dissolved oxygen criterion of no less than 5.0 mg/L. The nonpoint source flows and concentrations for model scenario 3 can be seen in Table A15.

- The point sources loads were estimated using the plant's maximum design flow and maximum permit effluent concentrations. The point source has flows below 0.08 million gallons per day as noted in the main document, and it has only a small effect on the water quality of the river. More information about point source loads can be found in the technical memorandum entitled "*Significant Phosphorus Point Sources in the Southeast Creek Watershed*".

The following supplemental Computations demonstrate that the phosphorus reduction associated with this scenario will limit algal production to about 50 µg/L in Island Creek, where observed data indicated elevated chlorophyll *a* levels.

ILS0042	
Chla	63.9 µg/l
DO	3.5 mg/l
DIN	0.711 mg/l
DIP	0.061mg/l

$$\text{Potential Chlorophyll } \alpha \text{ based on Nitrogen } = N \times \left(\frac{Chla}{N}\right)$$

N = Total dissolved nitrogen concentration at each boundary

$$\text{Chlorophyll a to nitrogen ratio used in the model} = \frac{Chla}{N} = \frac{Chla}{C} x \frac{C}{N} = \frac{1}{20} x \frac{1}{0.25} = 0.2$$

$$\text{Potential Chlorophyll } \alpha \text{ based on Phosphorus } = P \times \left(\frac{Chla}{P}\right)$$

P = Total dissolved phosphorus concentration at each boundary

$$\text{Chlorophyll a to phosphorus ratio used in the model} = \frac{Chla}{P} = \frac{Chla}{C} x \frac{C}{P} = \frac{1}{20} x \frac{1}{0.025} = 2.0$$

Potential Chla for ISL0042	**Future Potential Chla at station ISL0042**
Based on N	Based on N
Chla(N) $= N * \frac{Chla}{N} = N * \frac{Chla}{C} * \frac{C}{N} = 0.711 * \frac{1}{20} * \frac{1}{0.25} = 0.1422 mg/l$ Chla(N) = 0.1422 mg/l * 1000 µg/mg = 142.2 µg/l	With a 20 % reduction in nitrogen concentration: Chla(N) = 142.2 mg/l *0.8 = 114 mg/l
Based on P	Based on P

Chla(P) = $P * \frac{Chla}{P} = P * \frac{Chla}{C} * \frac{C}{P} = 0.061 * \frac{1}{20} * \frac{1}{0.025} = 0.122 mg/l$ Chla(P) = 0.122 mg/l * 1000 µg/mg = 122 µg/l	With a 20 % reduction in phosphorus concentration: Chla(N) = 122 mg/l *0.8 = 122mg/l

Baseline Potential Chla at station ISL0042 = 122 µg/l Baseline Actual Chla at station ISL0042 = 63.9 µg/l Ratio = 52.2%	Future Potential Chla at station ISL0042 = 97.6 µg/l Future Actual Chla at station ISL0042 based on same actual/potential ratio as in the baseline = (52.2%)*(97.6) = 50.9 µg/l

The reduction in nutrients also affects the baseline boundary concentrations of chlorophyll *a* in the Creek for the model run. The amount of nitrogen and phosphorus available for algal growth was calculated after the reduction in nutrient loads to help estimate the amount of chlorophyll *a* entering the model boundaries. For the model scenarios 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 nitrogen and organic phosphorus settling to the river bottom, from particulate organic nutrients, living algae, and phaeophytin, in each segment. This was done by running the baseline condition scenario once with estimated settling of organics and chlorophyll *a*, then again with no settling. The difference in the amount of organic matter between the two runs was assumed to settle to the river bottom where it would be available as a source of nutrient flux and SOD. All phaeophytin was assumed to settle to the bottom. The amount of phaeophytin was estimated from in-stream water quality data. This analysis was then repeated for the reduced nutrient loading conditions. The percentage difference between the amount of nutrients that settled in the baseline condition scenarios and the amount that settled in the reduced loading scenarios was then applied to the nutrient fluxes in each segment. The reduced nutrient scenarios were then run again with the updated fluxes. A new value of settled organics was calculated, and new fluxes were calculated. The process was repeated several times, until the reduced fluxes remained constant.

Along with reductions in nutrient fluxes from the sediments, when the nutrient loads to the system are reduced, the sediment oxygen demand will also be reduced (US EPA, 1997). It was assumed that the SOD would be reduced in the same proportion as the sediment nutrient fluxes, to a minimum of 0.3 $gO_2/m^2\ day$.

Fourth Scenario (Average Annual Flow): The fourth scenario represents improved conditions associated with the maximum allowable loads to the stream during average annual flow. The flow was the same as in the second scenario. The phosphorus loads were reduced from the second scenario (average annual flow baseline scenario) to meet chlorophyll *a* and dissolved oxygen standards in the same way as in the third scenario. A 3% margin of safety was included in the load calculation. All environmental parameters and kinetic coefficients used for the calibration of the model (except nutrient fluxes and SOD) remained the same as in the second scenario. The nonpoint source loads for model scenario 4 can be seen in Table A16.

Scenario Results

Baseline Condition Scenarios:

First Scenario (Low Flow): The first scenario simulates the summer low flow conditions when high chlorophyll *a* levels and low dissolved oxygen concentrations may impair water quality. Nonpoint source loads and water quality parameters are the same as those used in the low flow calibration and are based on 1999 observed data. Point source loads were based on the maximum allowable effluent limits as described above in the Point Source Loadings section. The results for this first scenario can be seen in Figures A27-A34. As shown in the figures, the peak chlorophyll *a* level is 56.6 μg/l, which is above the management goal of 50 μg/l. The dissolved oxygen level is above the water quality criterion of 5.0 mg/l throughout most of the water body system, except in a small area downstream, where the DO falls below 5 mg/l.

Second Scenario (Average Annual Flow): The second scenario simulates average stream flow conditions, with average annual nonpoint source loads estimated from the CBP phase 4.3 modeling results. Results for this scenario, representing baseline conditions for average stream flow and loads, are summarized in Figures A34-A41. Under these conditions, the chlorophyll *a* concentrations are also above the desired goal of 50 μg/l with a maximum of 86 μg/l. The dissolved oxygen concentrations remain above the 5.0 mg/l criterion throughout the length of the river.

The SCEM calculates the daily average, minimum, and maximum dissolved oxygen concentrations in the stream. Accounting only for the daily average DO concentrations is not necessarily protective of water quality when one considers the effects of diurnal dissolved oxygen variation due to photosynthesis and algal respiration. The photosynthetic process utilizes radiant energy from the sun to convert water and carbon dioxide into glucose and oxygen. Because the photosynthetic process is dependent on solar radiant energy, the production of oxygen proceeds only during daylight hours. Concurrently with this production, however, the algae require oxygen for respiration, which proceeds continuously. Minimum values of dissolved oxygen usually occur in the early morning predawn hours when the algae have been without light for the longest period of time. Maximum values of dissolved oxygen usually occur in the early afternoon. The diurnal range (maximum minus minimum) may be large and if the daily mean level of dissolved oxygen is low, minimum values of dissolved oxygen during a day may approach zero creating a potential for a fish kill. Thus, for the rest of the model results, the minimum dissolved oxygen concentration is reported, to make sure that the chlorophyll *a* concentrations due to the TMDL loadings will not lower the DO concentrations below the standard of 5.0 mg/l.

Future Condition TMDL Scenarios:

Third Scenario (Low Flow): The third scenario simulates the future condition of maximum allowable loads for critical low stream flow conditions during the summer season. The results of this scenario (solid line), which corresponds to the maximum allowable loads for summer low flow conditions, are shown in Figures A43-A50 in comparison to the corresponding baseline scenario (dotted line). It can be seen that under the nutrient load reduction conditions, the water quality targets for dissolved oxygen and chlorophyll *a* are met at all locations in Southeast Creek.

To achieve the targeted goal of 50 μg/l a reduction of 19% of phosphorus loads from all 9 subwatersheds was made.

<u>Fourth Scenario (Average Annual Flow)</u>: The fourth scenario simulates the future condition of maximum allowable loads under average stream flow and average annual (1984 – 1999) loading conditions. The results for this scenario (solid line), which corresponds to the maximum allowable loads for average annual flow, are summarized and compared to the corresponding base-line flow (dotted line) in Figures A51-A58. Again the water quality criteria for dissolved oxygen (greater than 5 mg/l) and chlorophyll *a* (less than 50.5 μg/l) are met for the entire length of Southeast Creek.

According to the baseline, defined by the CBP watershed model, a reduction of 61% of phosphorus load was made from all 9 subwatersheds to achieve the goal of 50 μg/l. It should be noted that the CBP loading estimates are possibly over stating the current loads, as suggested by limited observed data (see Table A18). We advise further monitoring as part of future implementation efforts to establish a more accurate baseline of NPS leading values.

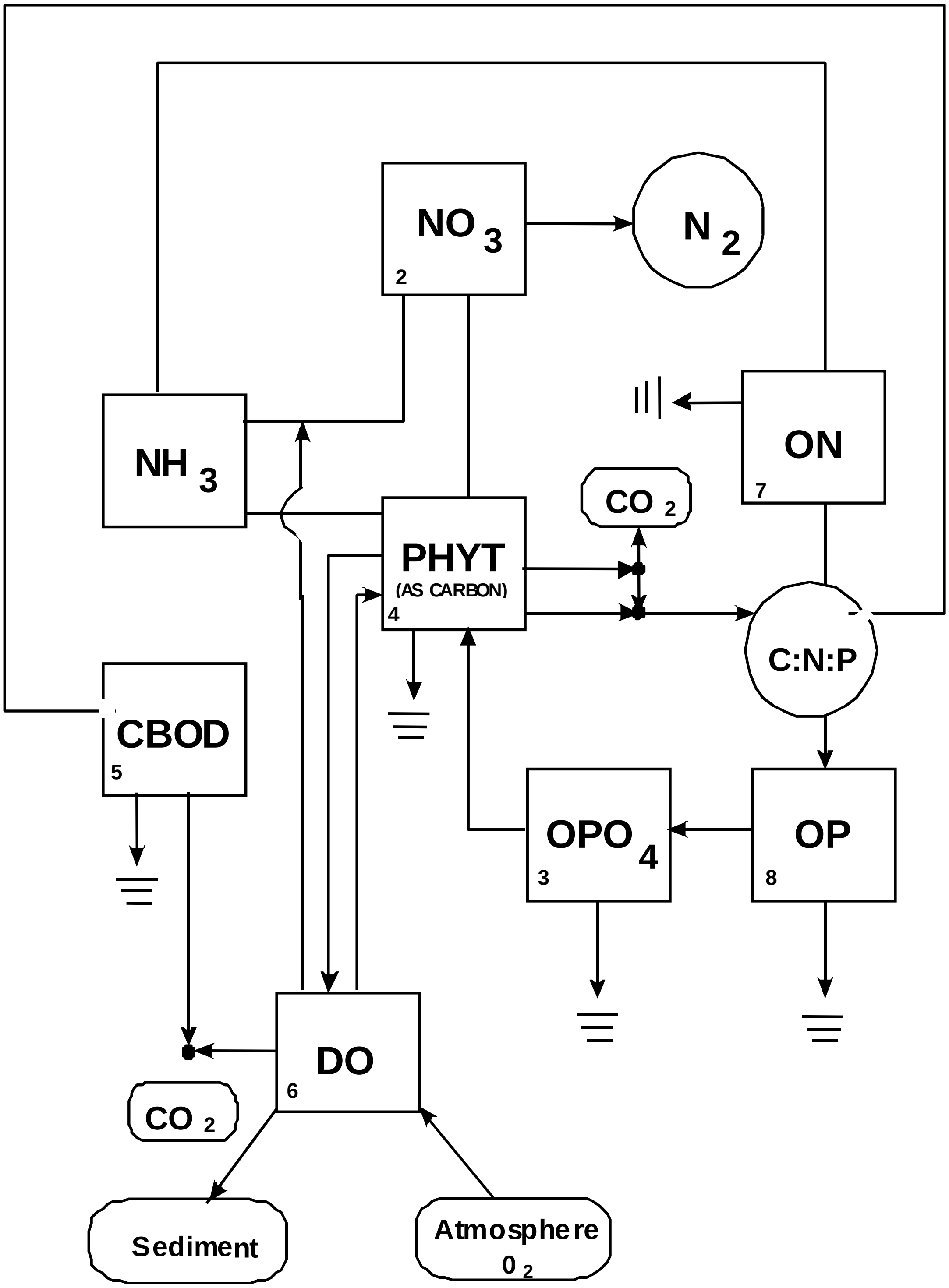
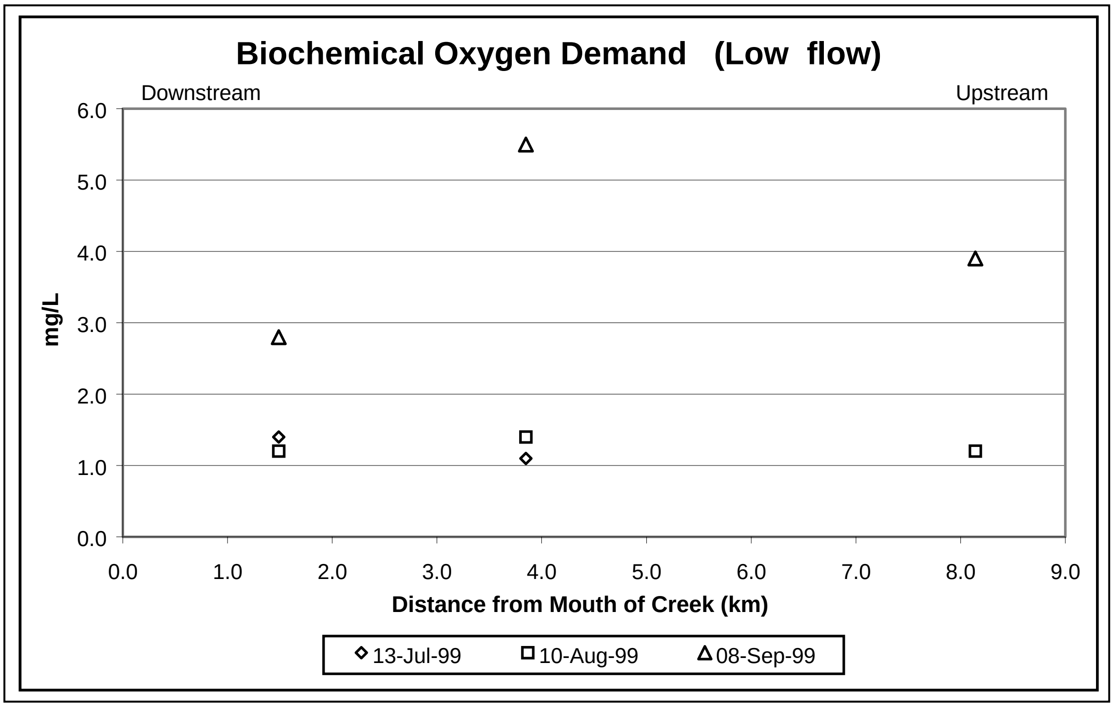


Figure A1: State Variables and Kinetic Interactions in EUTRO5

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)
Salinity	Parts per thousand (ppt)	0 to 70 ppt	Temperature-compensated, five electrode cell Surveyor 4; or six electrode Surveyor 3 (HMWQMIOM) Calculated base on Conductivity and formula fromUSGS Water Supply Paper 2311
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 mg/cu.M	Standard methods for the Examination of Water and Wastewater (15th ed.) #1002G. Chlorophyll. Pp 950-954
BOD_5	mg/l	0.01 mg/l	Oxidation ** EPA No. 405



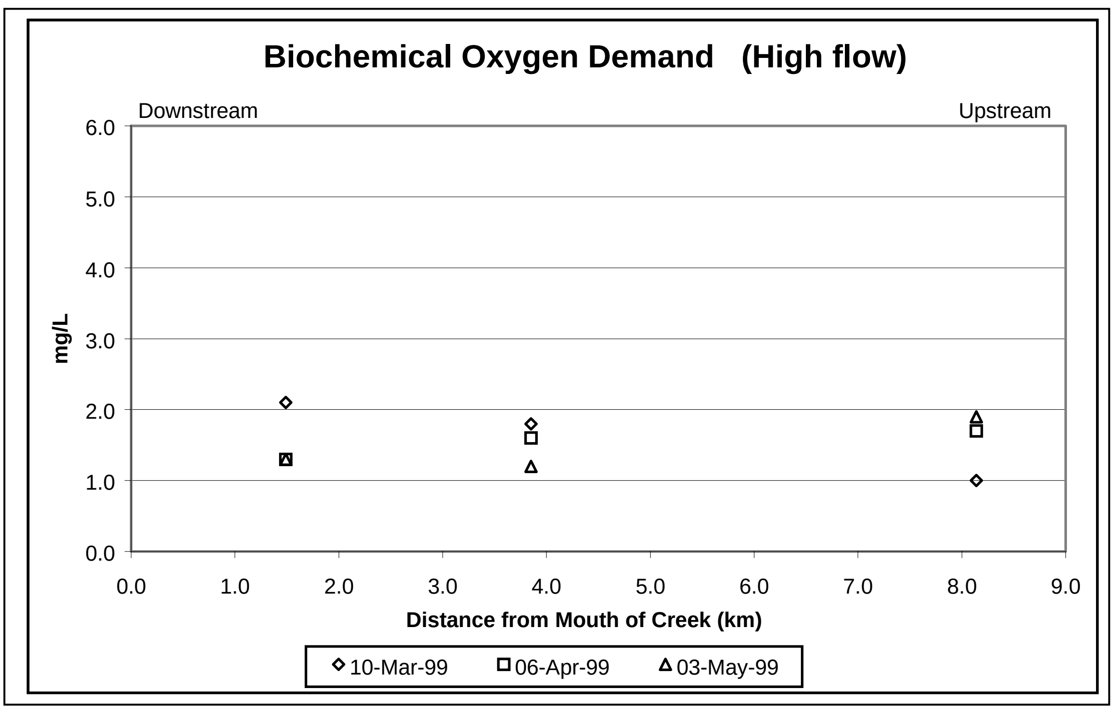


Figure A2: Longitudinal Profile of Biological Oxygen Demand (BOD) Data

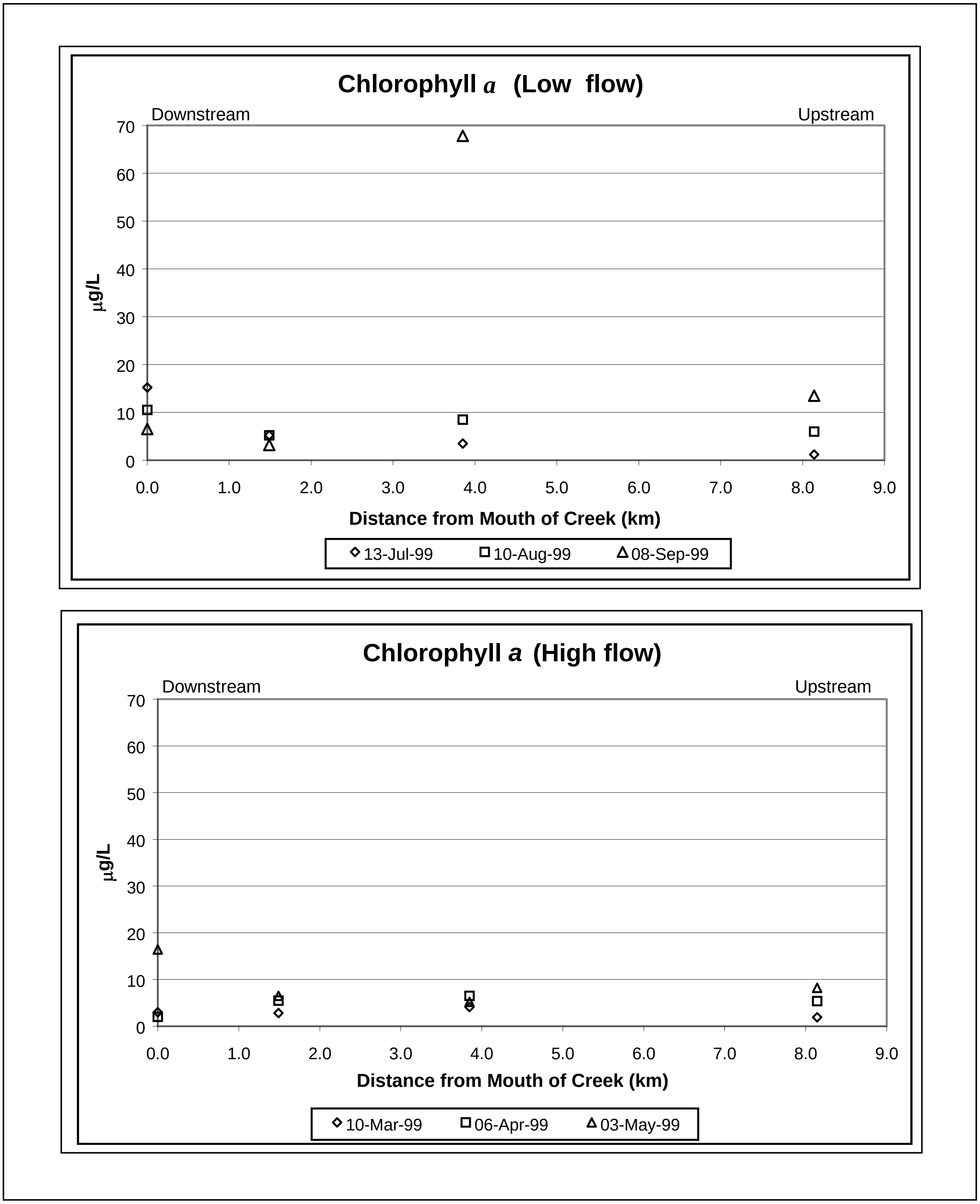


Figure A3: Longitudinal Profile of Chlorophyll *a* data

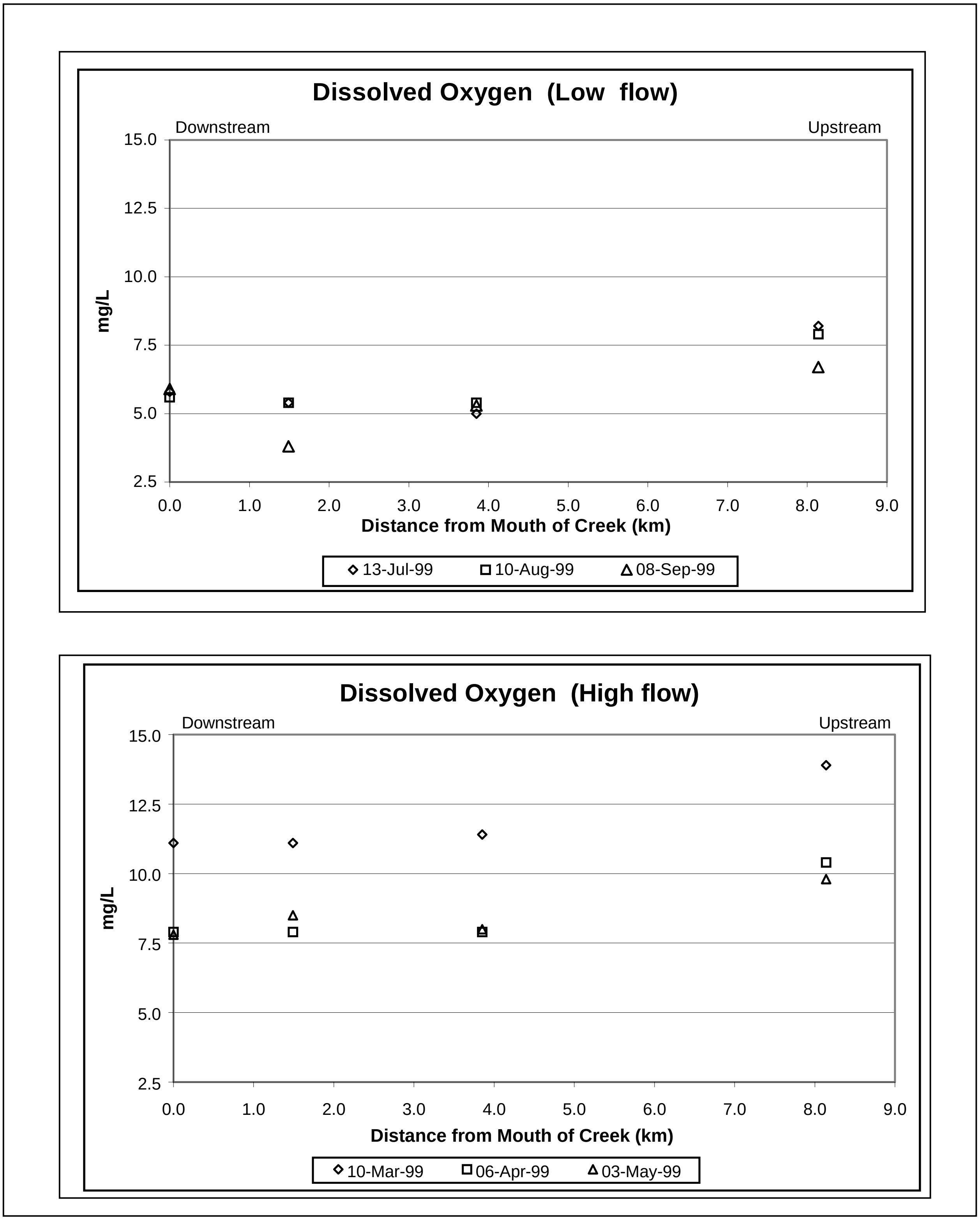
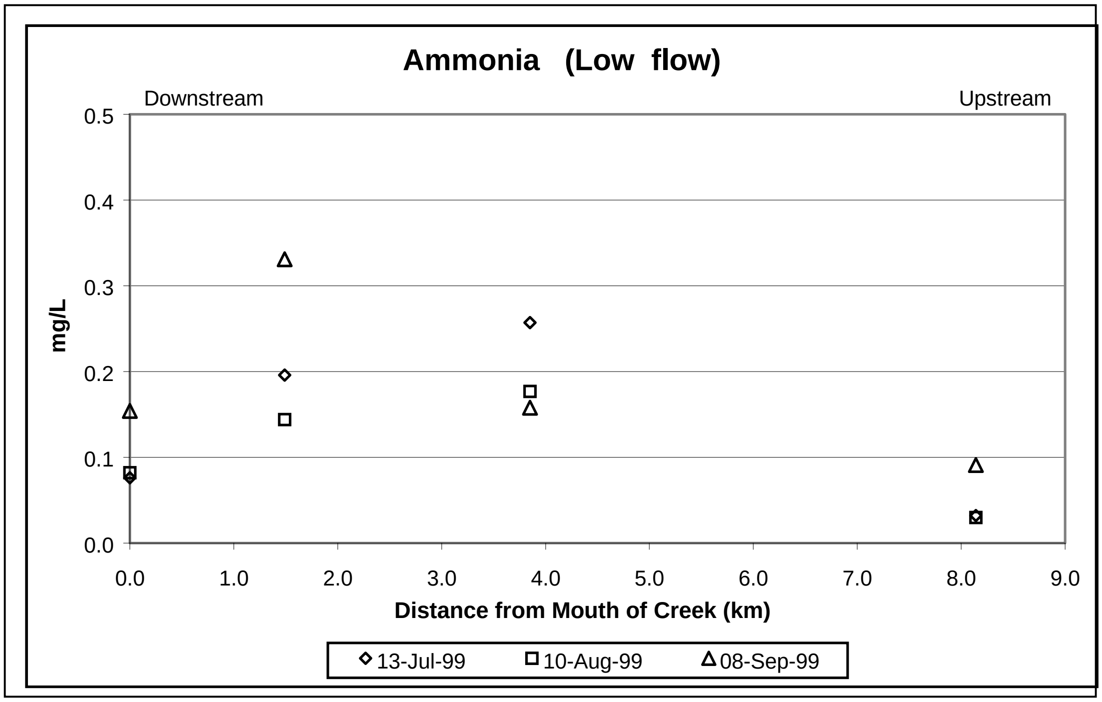


Figure A4: Longitudinal Profile of Dissolved Oxygen Data



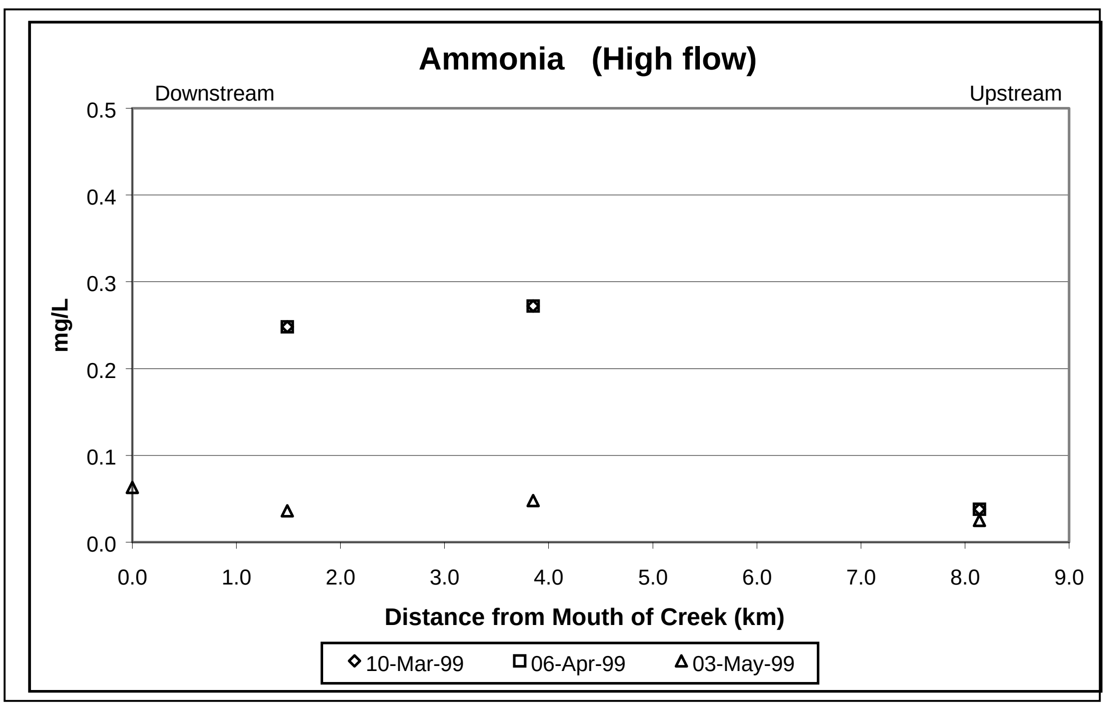


Figure A5: Longitudinal Profile of Ammonia Data

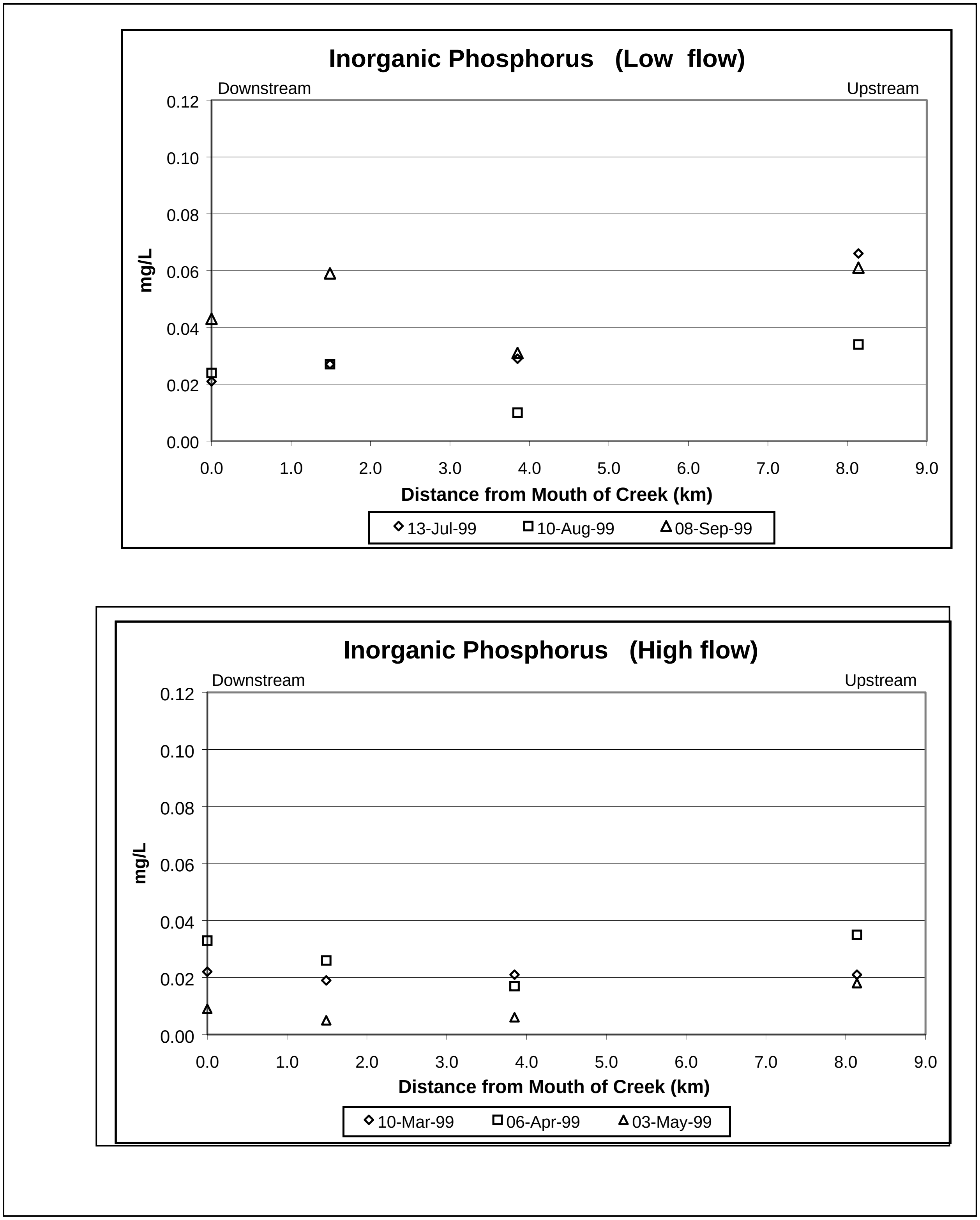


Figure A6: Longitudinal Profile of Inorganic Phosphorus Data

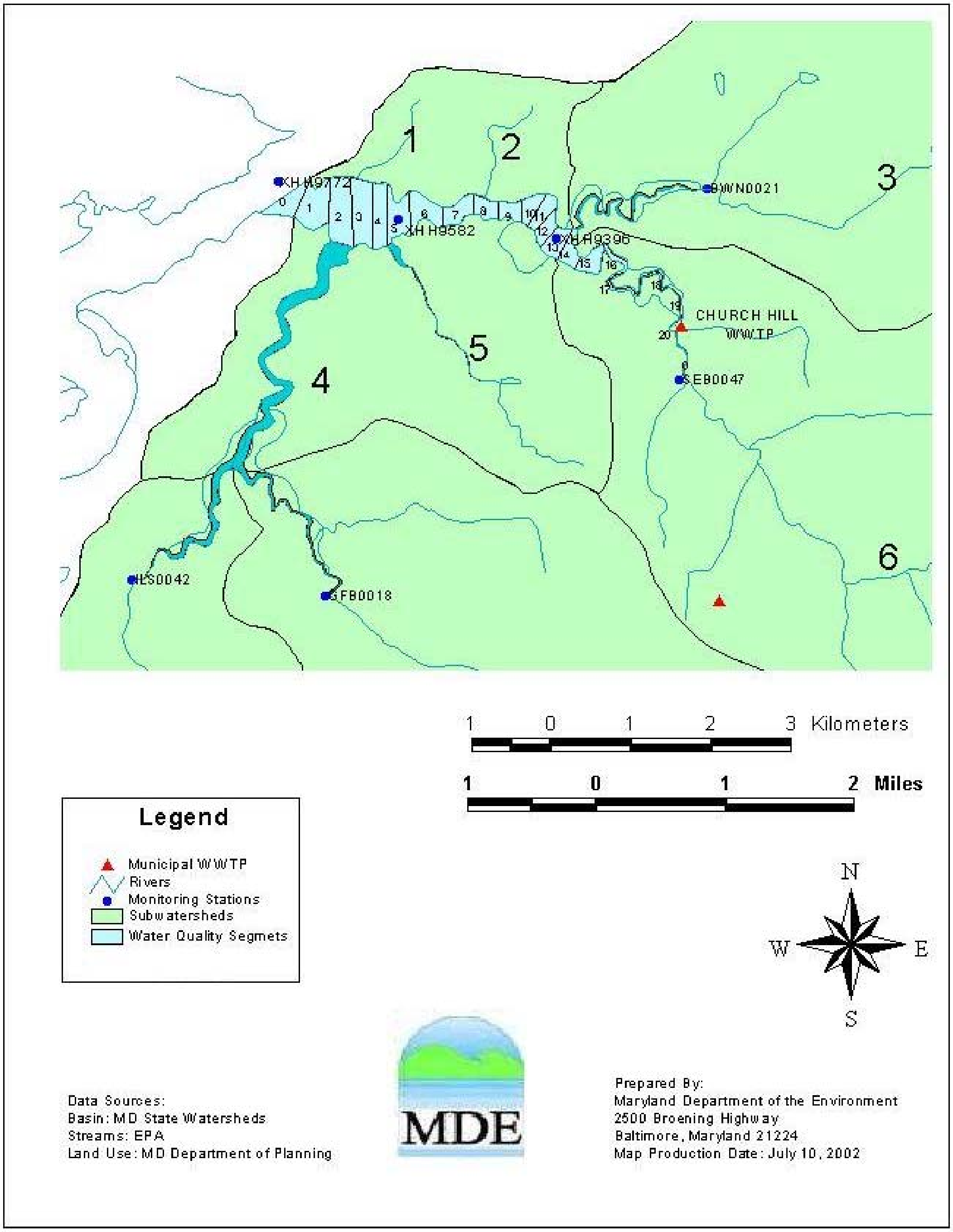
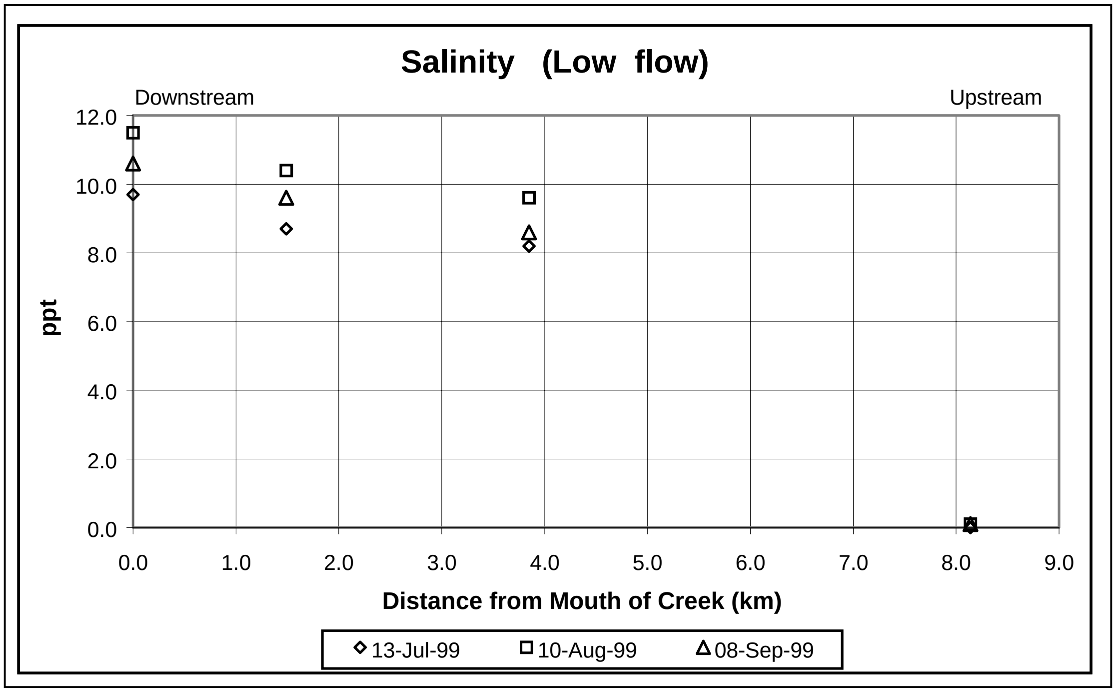


Figure A7: Model Segmentation

Table A2: Volumes, Characteristic Lengths, Interfacial Areas used in the SCEM

Segment Number	Average Depth, m	Surface m^2	Volume m^3
1	1.27	193629	245909
2	1.17	243746	285183
3	1.15	208613	238862
4	1.31	141058	184081
5	1.58	155139	244344
6	1.68	136832	229879
7	1.63	98786	161021
8	1.64	76710	125420
9	1.34	62412	83632
10	1.13	66752	75430
11	1.21	75848	91776
12	1.08	66194	71158
13	0.94	82431	77485
14	0.87	68183	59319
15	0.58	79927	45958
16	0.39	30865	12037
17	0.44	20132	8858
18	0.45	10443	4699
19	0.46	5684	2586
20	0.34	1995	678

Segment Pair	Interfacial Area m^2	Characteristic Length m
0 -1	713.0	299
1 - 2	723.0	337
2 - 3	985.0	284
3 - 4	985.0	220
4 - 5	1120.0	241
5 - 6	954.0	369
6 - 7	415.0	433
7 - 8	415.0	383
8 - 9	361.0	312
9 - 10	295.0	246
10 - 11	585.0	185
11 - 12	488.0	204
12 - 13	322.0	226
13 - 14	376.0	250
14 - 15	150.5	375
15 - 16	25.5	539
16 - 17	10.1	710
17 - 18	8.1	674
18 - 19	6.9	505
19 - 20	4.1	470
20 - 0	1.3	505



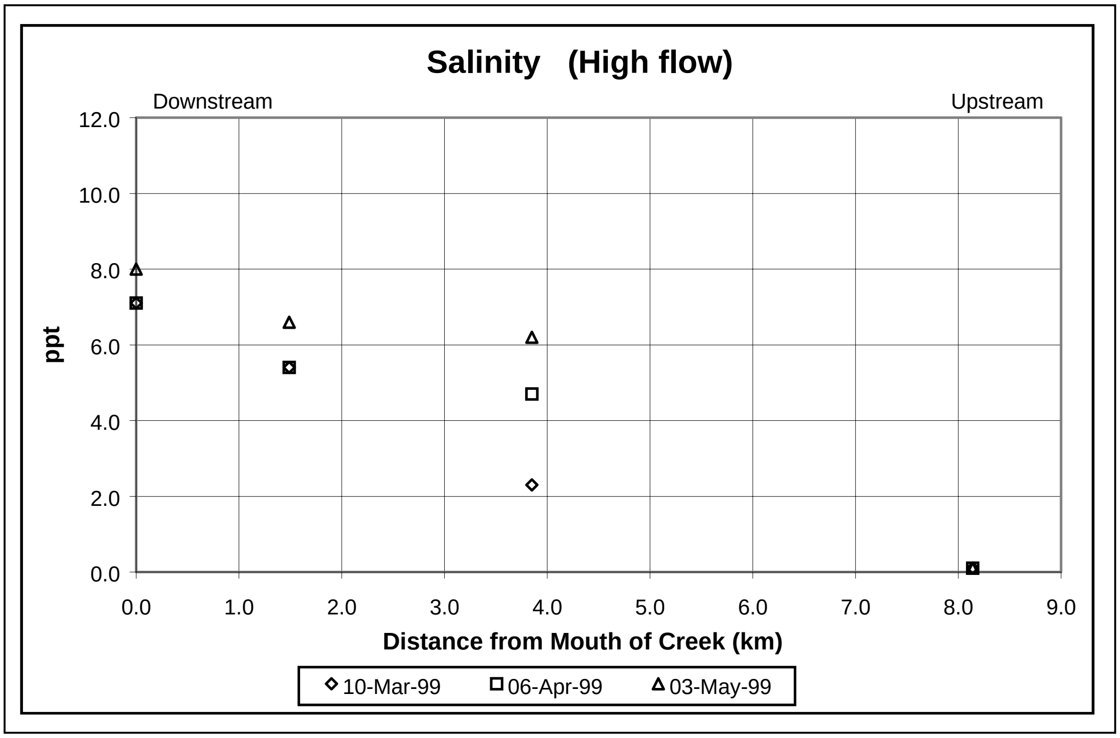
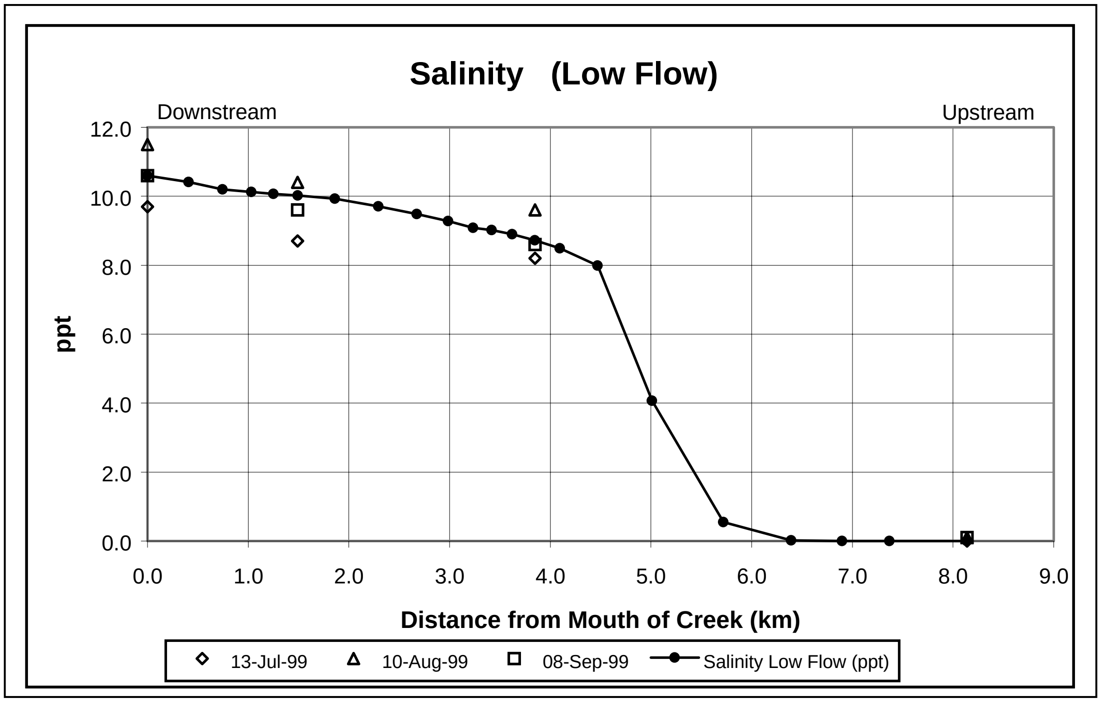


Figure A8: Longitudinal Profile of Salinity



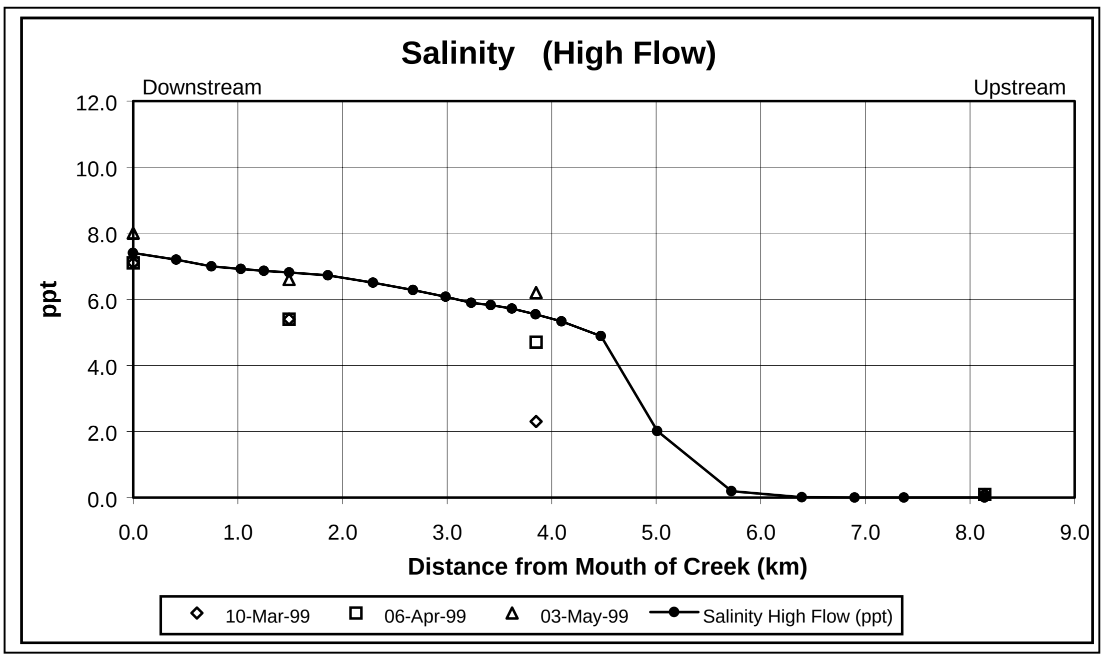


Figure A9: Results of Calibration of Exchange Coefficients

Table A3: Dispersion Coefficients used in the SCEM

Main River	
Segment Pair	Dispersion Coefficient (m^2/sec)
0 - 1	21.0
1 - 2	21.0
2 - 3	21.0
3 - 4	21.0
4 - 5	21.0
5 - 6	21.0
6 - 7	21.0
7 - 8	18.0
8 - 9	18.0
9 - 10	18.0
10 - 11	18.0
11 - 12	15.0
12 - 13	15.0
13 - 14	11.0
14 - 15	11.0
15 -16	6.0
16 - 17	3.0
17 - 18	1.0
18 - 19	0.0
19 - 20	0.0
20 - 0	0.0

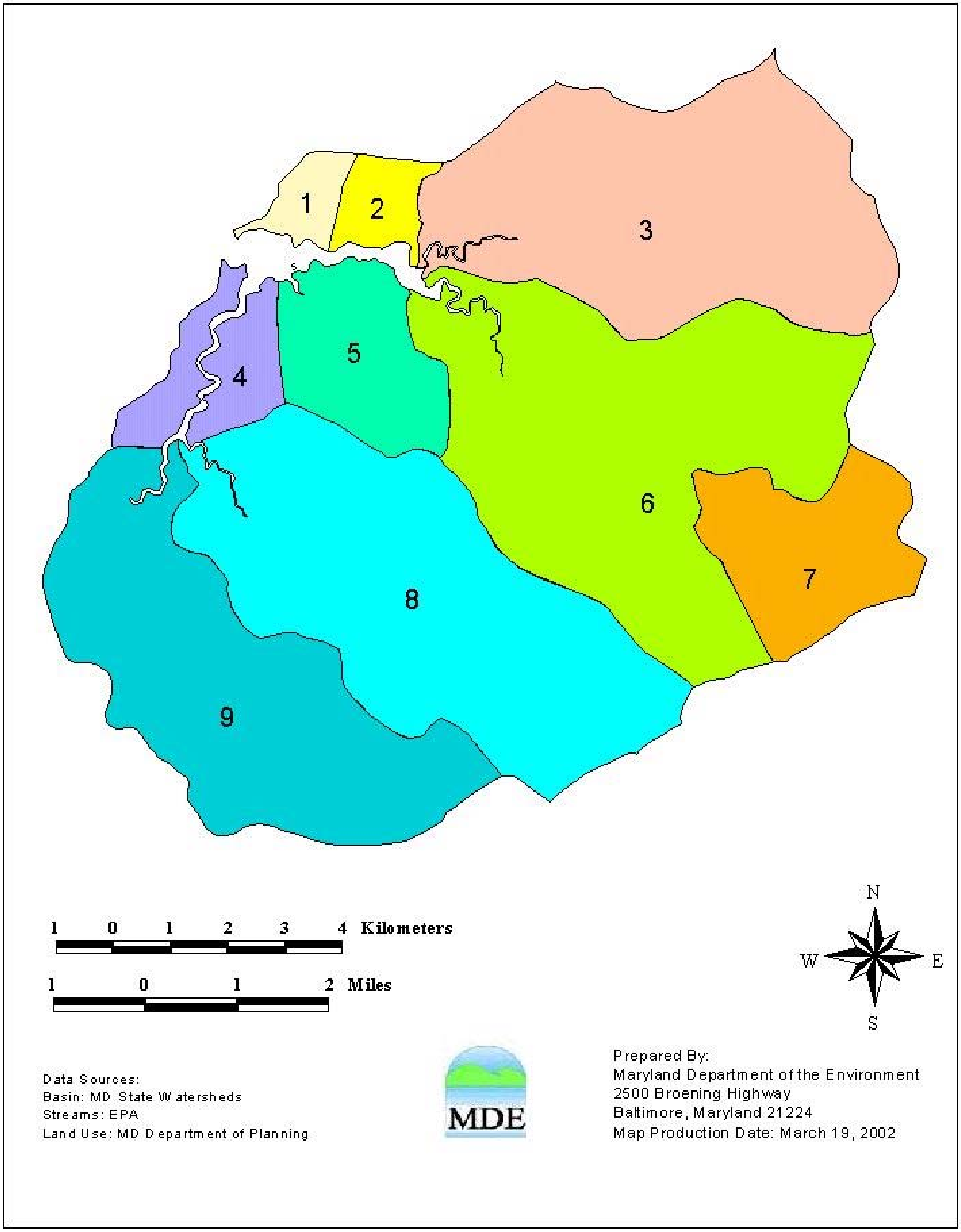


Figure A10: The Nine Subwatersheds of the Southeast Creek Drainage Basin

Table A4: Subwatersheds Flow for Low, Critical Low, High, and Average Conditions

Subwatershed Number	Low Flow, 1999 (m^3/s)	Critical Condition Low Flow, 7Q10 (m^3/s)	High Flow, 1999 (m^3/s)	Average Flow, 1984-1999 (m^3/s)
1	0.0117	0.0031	0.0174	0.0218
2	0.0148	0.0040	0.0219	0.0275
3	0.1795	0.0481	0.2659	0.3337
4	0.0312	0.0084	0.0462	0.0580
5	0.0495	0.0133	0.0734	0.0921
6	0.2105	0.0564	0.3118	0.3913
7	0.0597	0.0160	0.0884	0.1110
8	0.1990	0.0533	0.2948	0.3699
9	0.1609	0.0431	0.2383	0.2991

Table A5: Flows and Point Source Loadings for the Calibration of the Model

Parameter		Church Hill
Flow	High flow	201.84
	Low flow	276.46
NH4	High flow	1.0597
	Low flow	1.4514
NO23	High flow	0.1009
	Low flow	0.1382
PO4	High flow	0.3310
	Low flow	0.4534
CHL a	High flow	--
	Low flow	**--**
CBOD	High flow	1.6148
	Low flow	1.7970
DO	High flow	1.4533
	Low flow	1.4238
ON	High flow	0.2321
	Low flow	0.3179
OP	High flow	0.0626
	Low flow	0.0857

Table A6: Solar Radiation and Photoperiod used in the Calibration of the Model

Parameter	**Unit**	**High Flow** (Mar-May)	**Low Flow** (July-September)
Solar Radiation	*Langleys*	396.0	450.0
Photoperiod	*Fraction of a day*	0.50	0.58

Table A7: Environmental Parameters for the Calibration of the Model

Segment Number	Ke (m^{-1})		T (^0C)		Salinity (gm/l)		SOD (g O_2/m^2day)		FNH_4 (mg NH_4 N/m^2day)		FPO_4 (mg PO_4-P/m^2day)	
	High flow	Low flow	High flow	Low flow	High flow	Low flow	High flow	Low flow	High flow	Low flow	High flow	Low flow
1	4.5	3.0	11.3	26.1	7.20	10.41	1.0	3.0	10.0	75.0	1.0	1.0
2	4.5	3.0	11.3	26.1	6.99	10.20	1.0	3.0	10.0	75.0	1.0	1.0
3	4.5	3.0	11.3	26.1	6.92	10.13	1.0	3.0	10.0	75.0	1.0	1.0
4	4.5	3.0	11.3	26.1	6.86	10.07	1.0	3.0	10.0	75.0	1.0	1.0
5	4.5	3.0	11.3	26.1	6.81	10.02	1.0	3.0	10.0	75.0	1.0	1.0
6	4.5	3.0	11.3	26.1	6.72	9.93	1.0	2.0	10.0	75.0	1.0	1.0
7	5.1	4.0	11.3	26.1	6.50	9.71	1.0	1.0	10.0	75.0	1.0	1.0
8	5.1	4.0	11.3	26.1	6.28	9.48	1.0	1.0	10.0	75.0	1.0	1.0
9	5.1	4.0	11.3	26.1	6.08	9.28	1.0	1.0	10.0	75.0	1.0	1.0
10	5.1	4.0	11.3	26.1	5.90	9.09	1.0	1.0	10.0	75.0	1.0	1.0
11	5.1	4.0	11.3	26.1	5.83	9.02	1.0	1.0	10.0	75.0	1.0	1.0
12	5.1	4.0	11.3	26.1	5.72	8.90	1.0	1.0	10.0	75.0	1.0	1.0
13	5.1	4.0	11.3	26.1	5.55	8.72	1.0	1.0	10.0	75.0	1.0	1.0
14	5.1	4.0	11.3	26.1	5.33	8.49	1.0	1.0	10.0	75.0	1.0	1.0
15	5.1	4.0	11.3	26.1	4.88	7.99	1.0	1.0	10.0	50.0	1.0	1.0
16	7.5	6.7	7.8	20.4	2.01	4.07	1.0	1.0	10.0	25.0	1.0	1.0
17	7.5	6.7	7.8	20.4	0.19	0.55	1.0	1.0	10.0	25.0	1.0	1.0
18	7.5	6.7	7.8	20.4	0.01	0.02	1.0	1.0	10.0	25.0	1.0	1.0
19	7.5	6.7	7.8	20.4	0.00	0.00	1.0	1.0	10.0	25.0	1.0	1.0
20	7.5	6.7	7.8	20.4	0.00	0.00	1.0	1.0	10.0	25.0	1.0	1.0

Table A8: EUTRO5 Kinetic Coefficients

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	0.05 *day* -1 at 20^o C
temperature coefficient	K1RT	1.045
Nonpredatory phytoplankton death rate	K1D	0.05 *day* -1
Phytophankton Stoichometry		
Oxygen-to-carbon ratio	OCRB	2.67 $mg\ O_2 / mg\ C$
Carbon-to-chlorophyll ratio	CCHL	20
Nitrogen-to-carbon ratio	NCRB	0.25 *mg N/mg C*
Phosphorus-to-carbon ratio	PCRB	0.025 $mg\ PO_4$*-P/ mg C*
Half-saturation constants for phytoplankton growth		
Nitrogen	KMNG1	0.025 *mg* N / L
Phosphorus	KMPG1	0.0025*mg* P / L
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	300. *Ly/day*
BOD deoxygenation rate	KDC	0.2 *day* -1 at 20^o C
temperature coefficient	KDT	1.05
Half saturation const. for carb. deoxygenation	KBOD	0.5
Reaeration rate constant	K2	0.2 *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	K58C	0.15 *day* -1
temperature coefficient	K58T	1.08
Phytoplankton settling velocity		0.389 *m/day*
Organics settling velocity		0.0432*m/day*

Table A9: Contributing Watersheds to Model Segments, and Flows for the Segments

Segment Number	Contributing Subwatersheds	Low Flow (m^3/s)	Baseline Low Flow (m3/s)	High Flow (m^3/s)	Average Flow (m^3/s)
2	4 + 8 + 9	0.3911	0.1047	0.5793	0.7270
3	1	0.0117	0.0031	0.0174	0.0217
5	5	0.0495	0.0133	0.0734	0.0920
8	2	0.0148	0.0040	0.0219	0.0275
14	3	0.1795	0.0481	0.2659	0.3337
20	6 + 7	0.2702	0.0724	0.4003	0.5022

Table A10: Nonpoint Source Concentrations for the Low Flow Calibration of the Model

Segment Number	**NH4** *mg/l*	**NO_{23}** *mg/l*	**PO_4** *mg/l*	**CHL *a*** *μg/l*	**CBOD** *mg/l*	**DO** *mg/l*	**ON** *mg/l*	**OP** *mg/l*
2	0.2060	0.6528	0.1053	20.20	6.08	5.74	1.1635	0.0710
3	0.0360	6.6667	0.0303	3.77	3.00	8.07	0.5397	0.0150
5	0.0510	6.0533	0.0537	6.90	4.26	7.60	0.4050	0.0283
8	0.0360	6.6667	0.0303	3.77	3.00	8.07	0.5397	0.0150
14	0.0360	6.6667	0.0303	3.77	3.00	8.07	0.5397	0.0150
20	0.0510	6.0533	0.0537	6.90	4.26	7.60	0.4050	0.0283

Table A11: Nonpoint Source Concentrations for the High Flow Calibration of the Model

Segment Number	**NH4** *mg/l*	**NO_{23}** *mg/l*	**PO_4** *mg/l*	**CHL *a*** *μg/l*	**CBOD** *mg/l*	**DO** *mg/l*	**ON** *mg/l*	**OP** *mg/l*
2	0.0585	1.8887	0.0307	7.85	3.76	10.54	0.6443	0.0710
3	0.0317	4.5800	0.0170	4.40	2.56	11.03	0.2167	0.0150
5	0.0493	1.8887	0.0247	5.17	2.56	11.37	0.3300	0.0283
8	0.0317	4.5800	0.0170	4.40	2.56	11.03	0.2167	0.0150
14	0.0317	4.5800	0.0170	4.40	2.56	11.03	0.2167	0.0150
20	0.0493	1.8887	0.0247	5.17	2.56	11.37	0.3300	0.0283

Low Flow Calibration

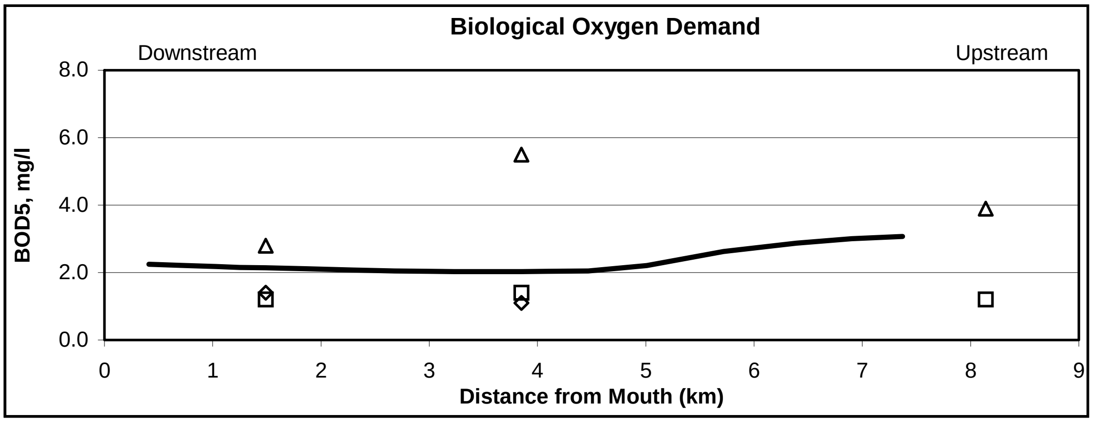


Figure A10: BOD vs. River Kilometer for the Calibration of the Model

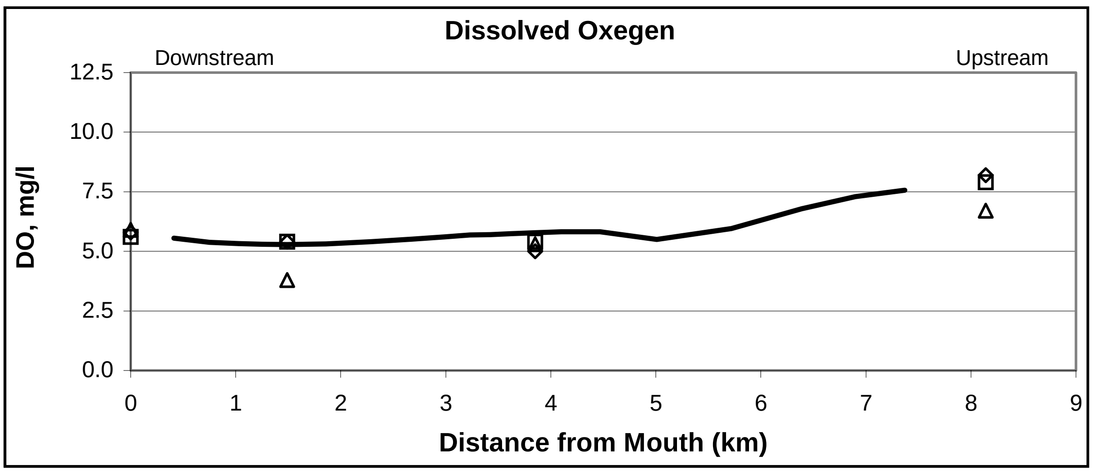


Figure A11: Dissolved Oxygen vs. River Kilometer for the Calibration of the Model

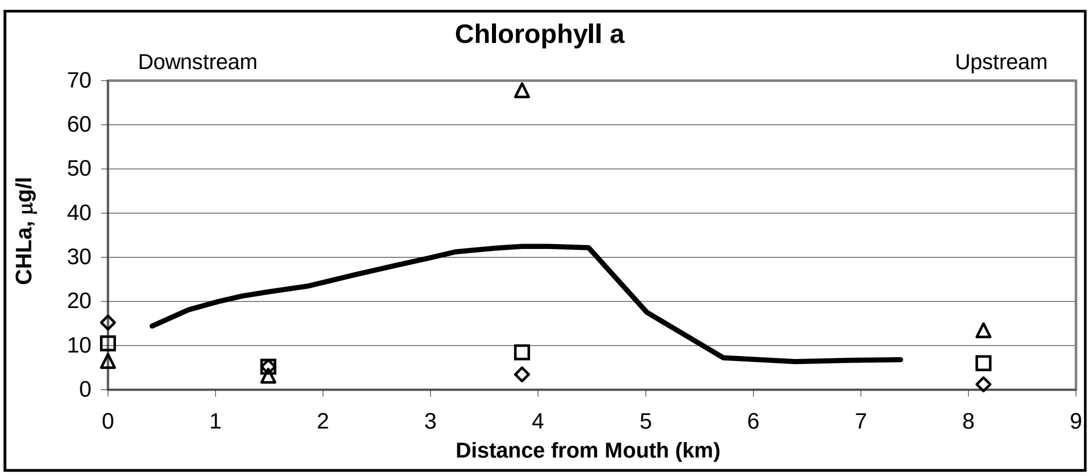


Figure A12: Chlorophyll a vs. River Kilometer for the Calibration of the Model

Monitoring Data: ◇ - Jul, △ - Aug, □ - Sep ——— Calibration

Low Flow Calibration

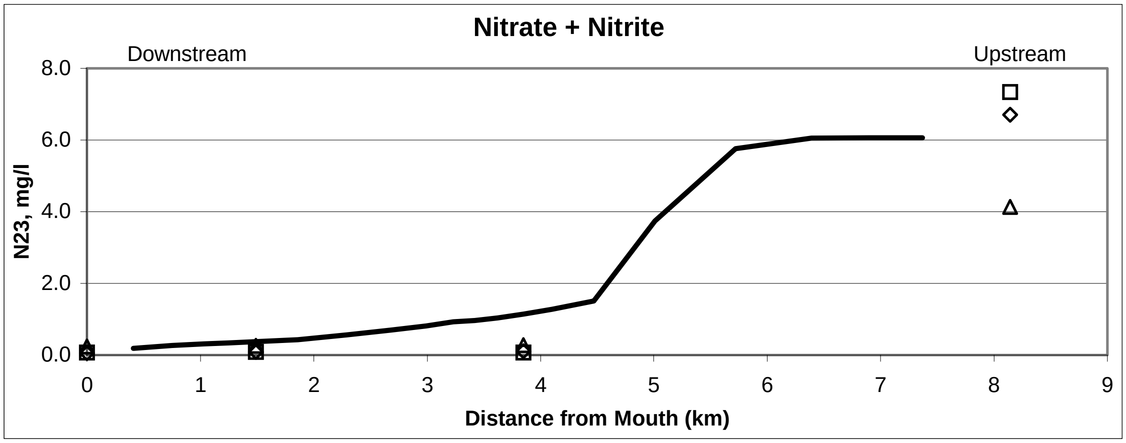


Figure A13: Nitrate (plus Nitrite) vs. River Kilometer for the Calibration of the Model

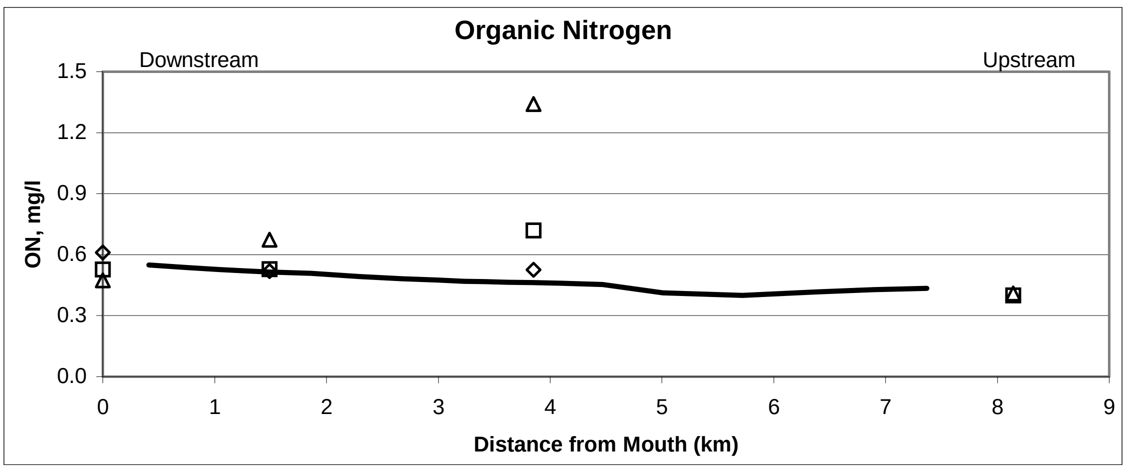


Figure A14: Organic Nitrogen vs. River Kilometer for the Calibration of the Model

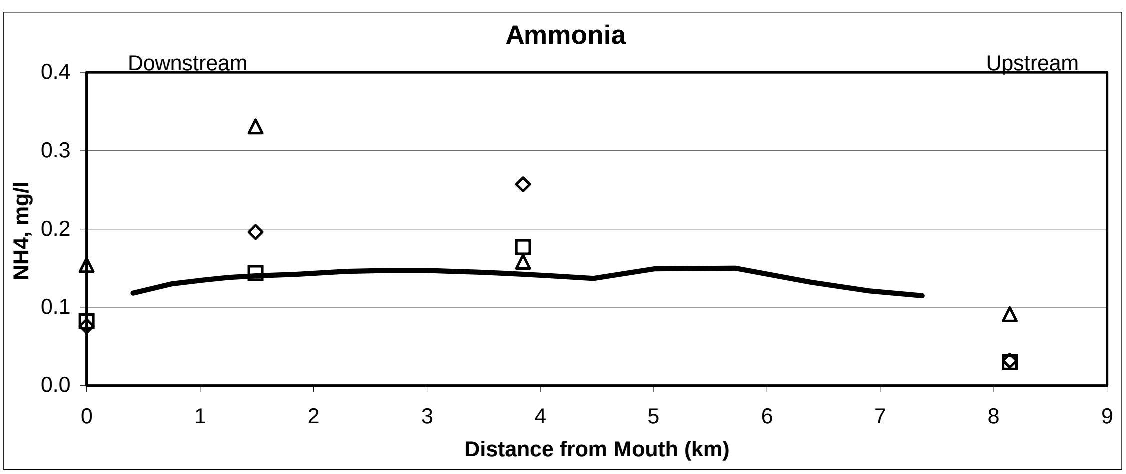


Figure A15: Ammonia vs. River Kilometer for the Calibration of the Model

Monitoring Data: ◇ - Jul, △ - Aug, □ - Sep ——— Calibration

Low Flow Calibration

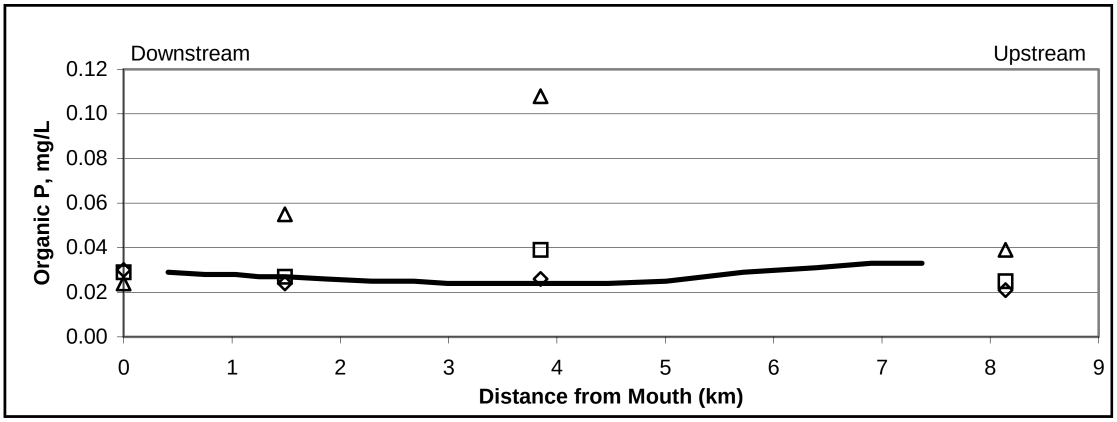


Figure A16: Organic Phosphorus vs. River Kilometer for the Calibration of the Model

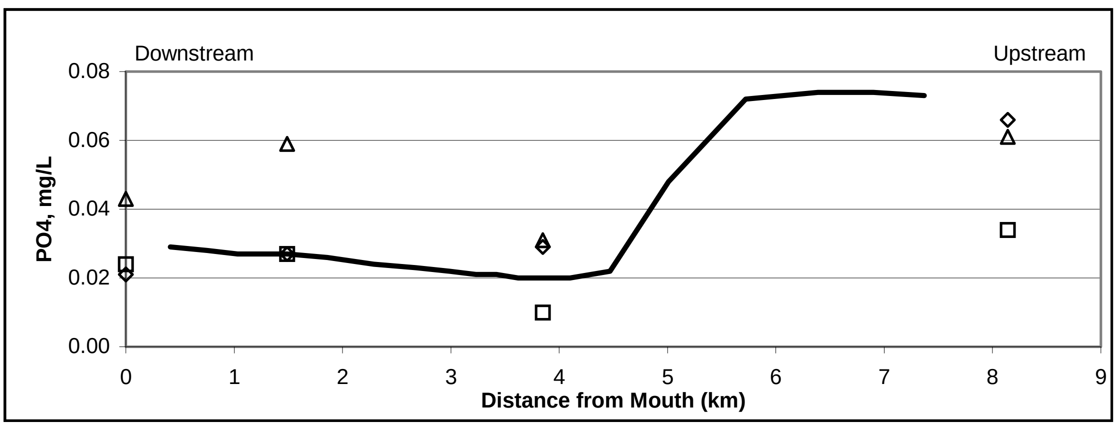


Figure A17: Ortho-Phosphate vs. River Kilometer for the Calibration of the Model

Monitoring Data: ◇ - Jul, △ - Aug, □ - Sep —— **Calibration**

High Flow Calibration

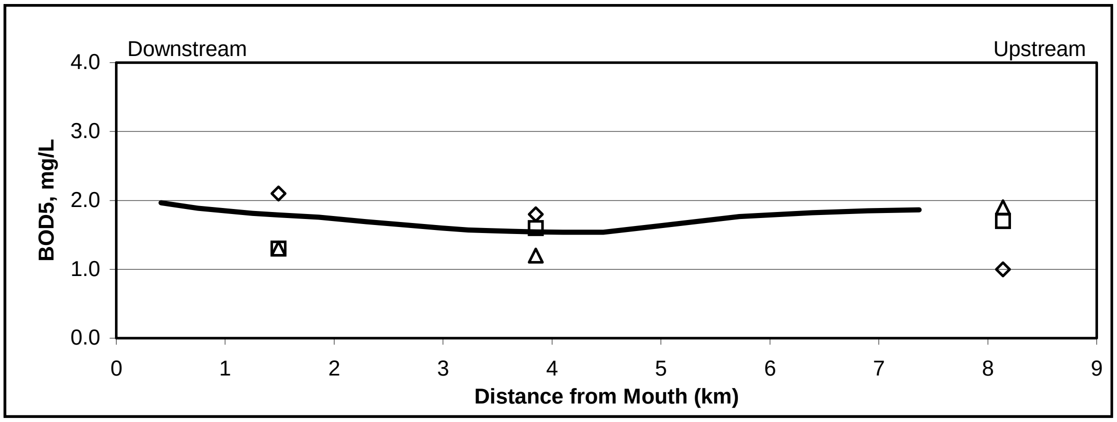


Figure A18: BOD vs. River Kilometer for the Calibration of the Model

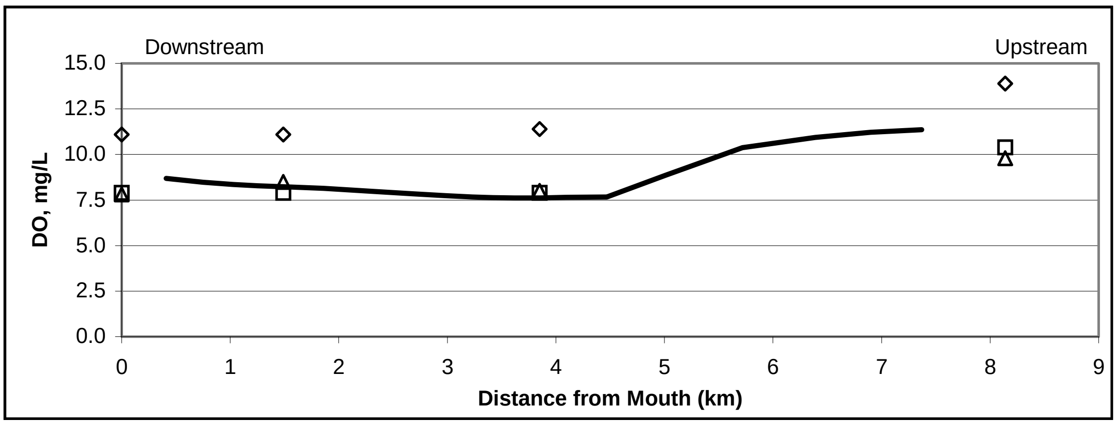


Figure A19: Dissolved Oxygen vs. River Kilometer for the Calibration of the Model

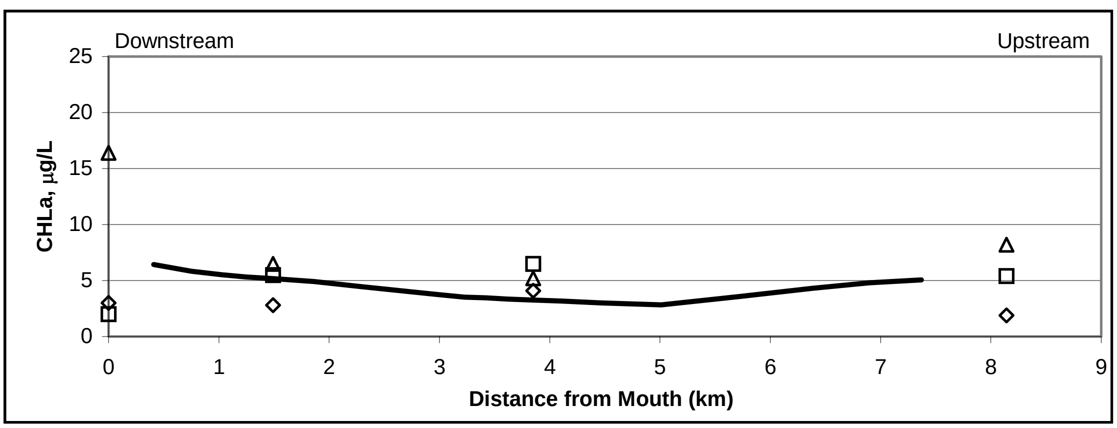


Figure A20: Chlorophyll *a* vs. River Kilometer for the Calibration of the Model

Monitoring Data: ◇ - Mar, △ - Apr, □ - May —— **Calibration**

High Flow Calibration

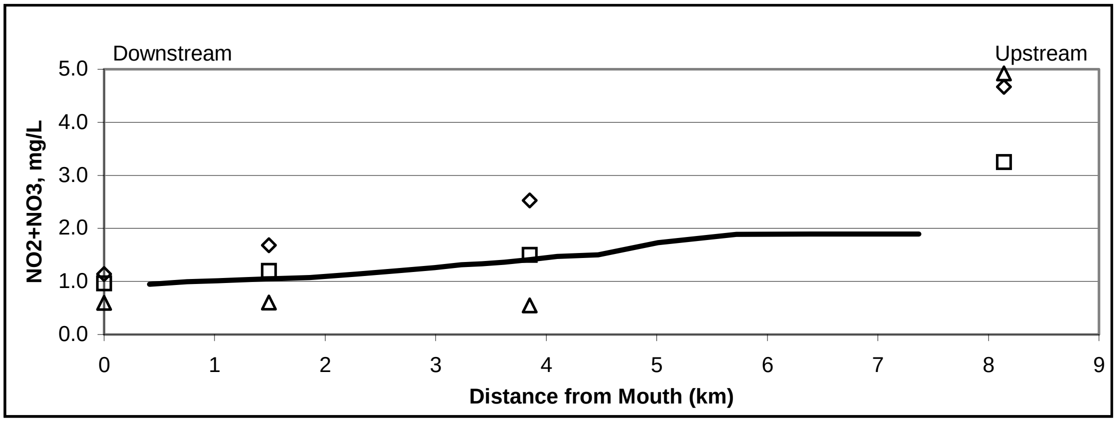


Figure A21: Nitrate & Nitrite vs. River Kilometer for the Calibration of the Model

Figure A22: Organic Nitrogen vs. River Kilometer for the Calibration of the Model

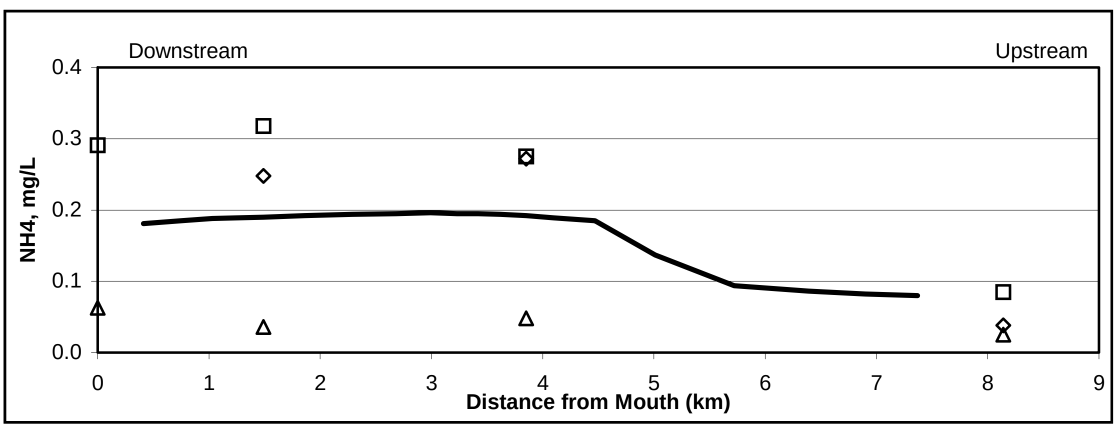


Figure A23: Ammonia vs. River Kilometer for the Calibration of the Model

Monitoring Data: ◇ - Mar, △ - Apr, □ - May —— **Calibration**

High Flow Calibration

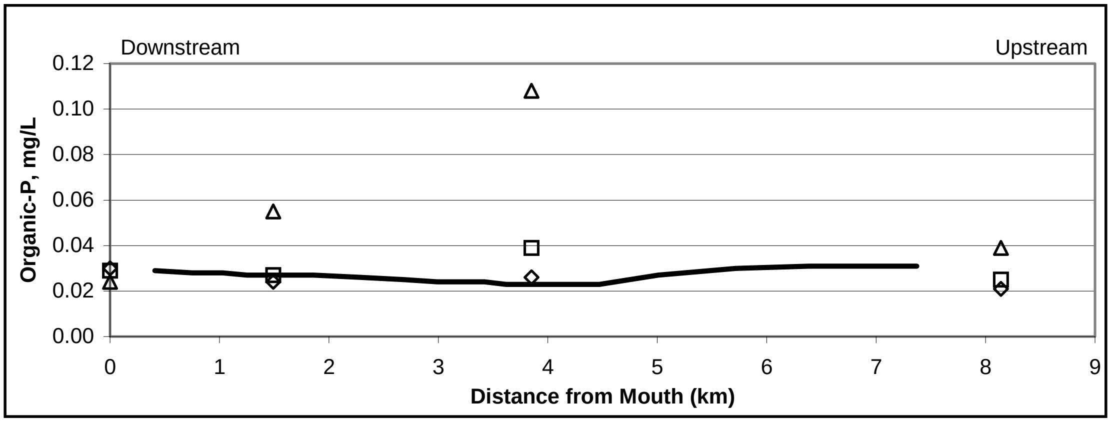


Figure A24: Organic Phosphorus vs. River Kilometer for the Calibration of the Model

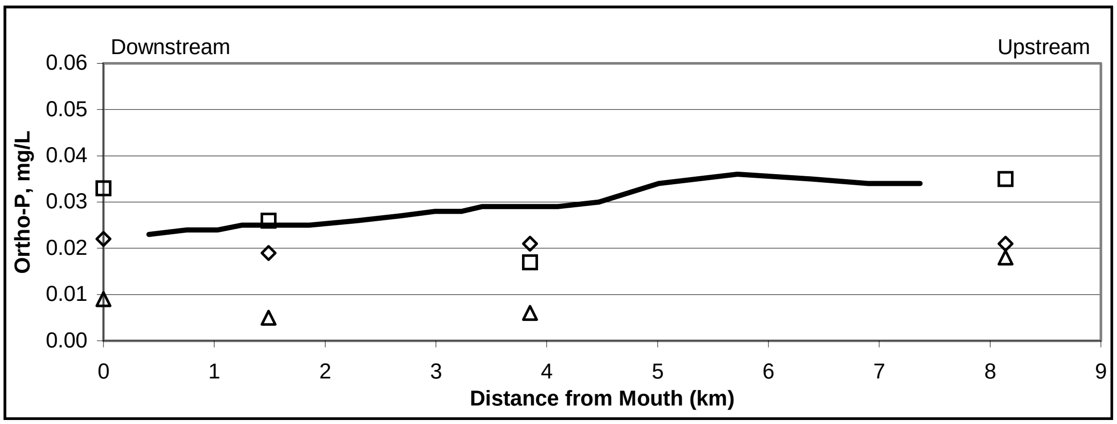


Figure A25: Ortho-Phosphate vs. River Kilometer for the Calibration of the Model

Monitoring Data: ◇ - Mar, △ - Apr, □ - May ——— Calibration

Table A12: Ratio DIN to DIP Concentration in Low and High Flow Calibration

Segment	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Low Flow	10.5	13.8	16.1	18.0	20.0	22.1	29.8
High Flow	49.0	49.1	50.1	48.8	49.5	50.6	51.3
Segment	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Low Flow	39.0	49.2	57.9	60.2	63.7	73.6	81.6
High Flow	51.9	52.1	53.9	52.7	53.7	55.3	57.3
Segment	**15**	**16**	**17**	**18**	**19**	**20**	
Low Flow	84.8	84.2	81.9	83.5	83.5	84.6	
High Flow	56.2	54.9	55.0	56.5	58.1	58.0	

Table A13: Nonpoint Source Concentrations for theLow Flow Baseline Condition Scenario

Segment Number	**NH4** *mg/l*	**NO_{23}** *mg/l*	**PO_4** *mg/l*	**CHL *a*** *$\mu g/l$*	**CBOD** *mg/l*	**DO** *mg/l*	**ON** *mg/l*	**OP** *mg/l*
2	0.2060	0.6528	0.1053	20.20	6.08	5.74	1.1635	0.0710
3	0.0360	6.6667	0.0303	3.77	3.00	8.07	0.5397	0.0150
5	0.0510	6.0533	0.0537	6.90	4.26	7.60	0.4050	0.0283
8	0.0360	6.6667	0.0303	3.77	3.00	8.07	0.5397	0.0150
14	0.0360	6.6667	0.0303	3.77	3.00	8.07	0.5397	0.0150
20	0.0510	6.0533	0.0537	6.90	4.26	7.60	0.4050	0.0283

Table A14: Flow and Point Source Loadings used in the Low Flow Baseline Condition Scenario, Average Baseline and TMDL Scenario

Parameter*	Baseline Low Flow	Baseline Average Annual	Low Flow and Average TMDLs Scenarios
Flow	302.89	302.89	302.89
NH_4	1.5899	1.5899	1.5899
$NO_{2\text{-}3}$	0.1514	0.1514	0.1514
PO_4	2.0377	2.0377	1.5282
Chl_a	0.00	0.00	0.00
CBOD	3.2872	3.2872	3.2872
DO	1.5596	1.5596	1.5596
ON	0.3483	0.3483	0.3483
OP	0.3865	0.3865	0.2889

All loadings in kg/day. Flow in m^3/day

Table A15: Nonpoint Source Concentrations for the Average Flow Baseline Condition Scenario

Segment Number	**NH4** *mg/l*	**NO_{23}** *mg/l*	**PO_4** *mg/l*	**CHL *a*** *μg/l*	**CBOD** *mg/l*	**DO** *mg/l*	**ON** *mg/l*	**OP** *mg/l*
2	0.3024	3.0298	0.3043	20.23	6.08	5.73	1.0719	0.0895
3	0.3967	3.8572	0.3994	3.77	3.01	8.07	1.3278	0.1167
5	0.3208	3.1514	0.3223	6.90	4.26	7.60	1.1251	0.0949
8	0.3608	3.5339	0.3631	3.77	3.01	8.07	1.2311	0.1064
14	0.3358	3.3060	0.3377	3.77	3.01	8.07	1.1638	0.0992
20	0.3288	3.2965	0.3315	6.90	4.26	7.60	1.1406	0.0970

Baseline Condition Low Flow Scenario (BCLFS)

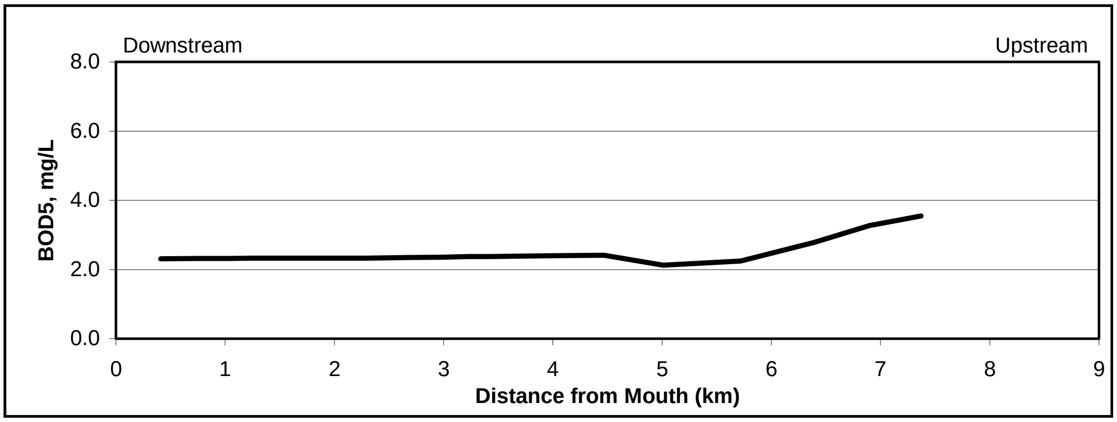


Figure A26: BOD vs. River Kilometer for the BCLFS

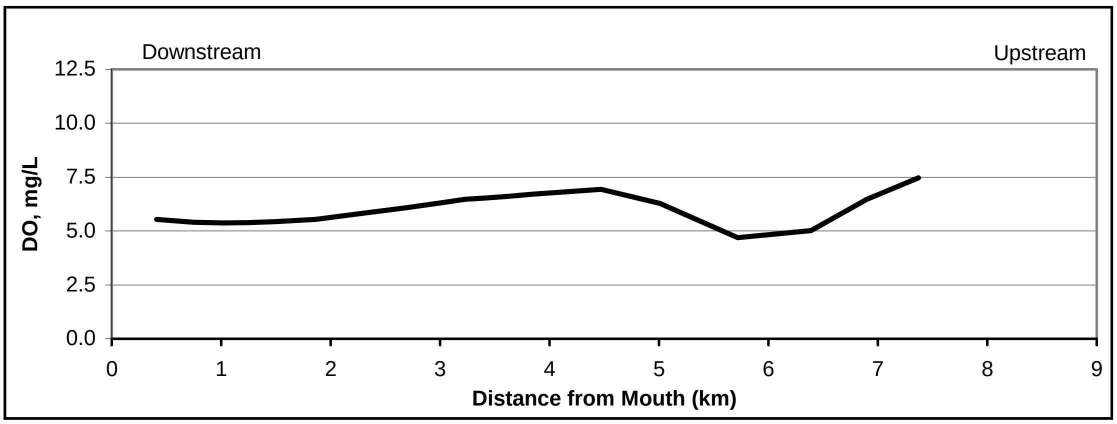


Figure A27: Dissolved Oxygen vs. River Kilometer for the BCLFS

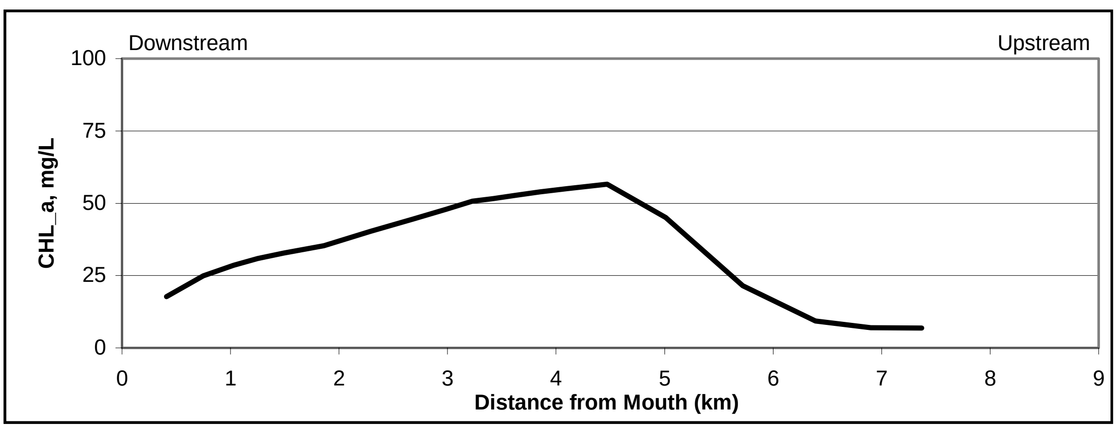


Figure A28: Chlorophyll *a* vs. River Kilometer for the BCLFS

Baseline Condition Low Flow Scenario (BCLFS)

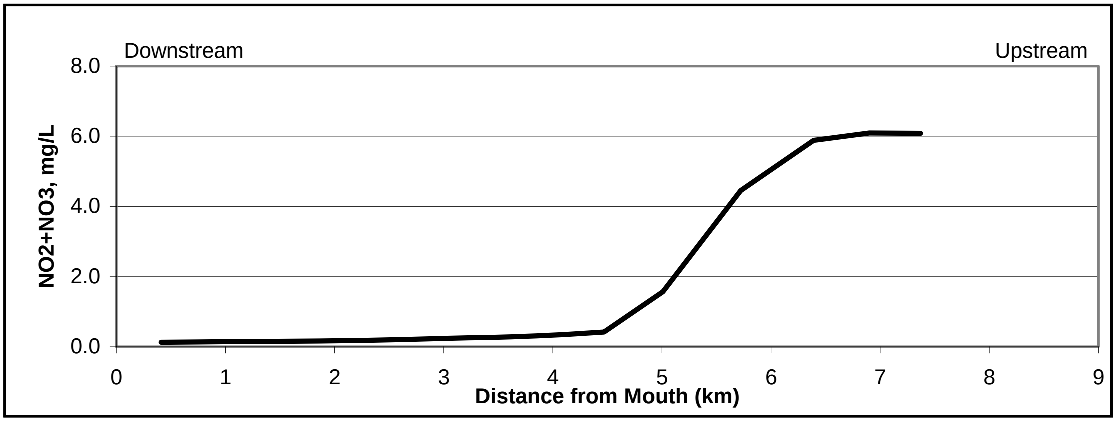


Figure A29: Nitrate (plus Nitrite) vs. River Kilometer for the BCLFS

Figure A30: Organic Nitrogen vs. River Kilometer for the BCLFS

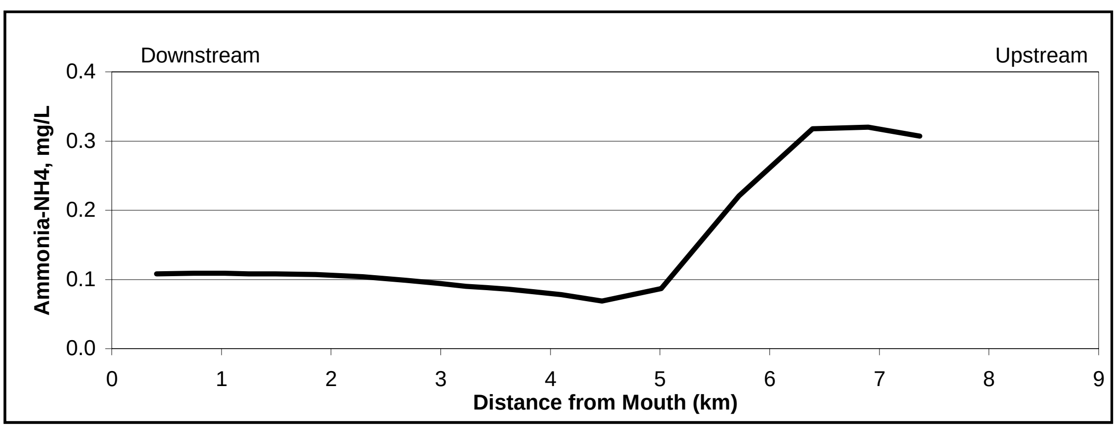


Figure A31: Ammonia vs. River Kilometer for the BCLFS

Baseline Condition Low Flow Scenario

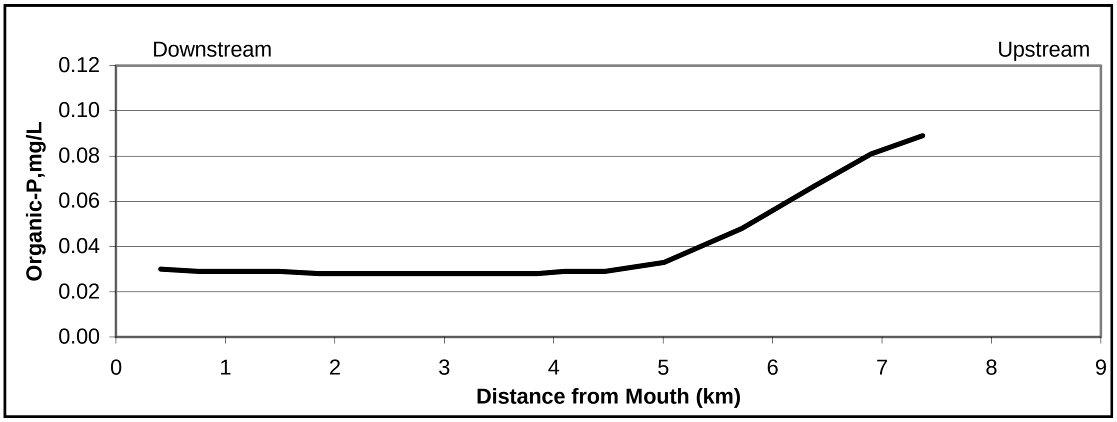


Figure A32: Organic Phosphorus vs. River Kilometer for the BCLFS

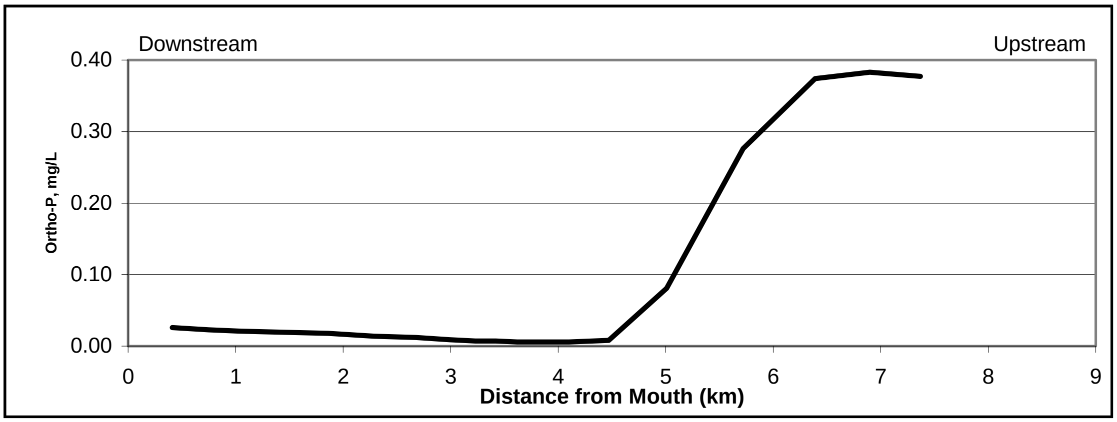


Figure A33: Ortho-Phosphorus vs. River Kilometer for the BCLFS

Baseline Condition Average Flow Scenario

Figure A34: BOD vs. River Kilometer for the Baseline Condition Average Flow Scenario (BCAFS)

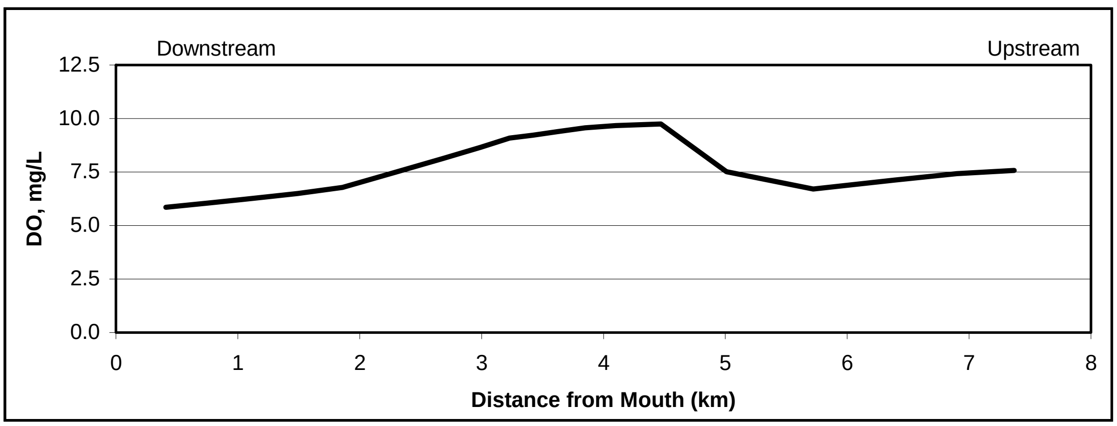


Figure A35: Dissolved Oxygen vs. River Kilometer for the BCAFS

Figure A36: Chlorophyll *a* vs. River Kilometer for the BCAFS

Baseline Condition Average Flow Scenario

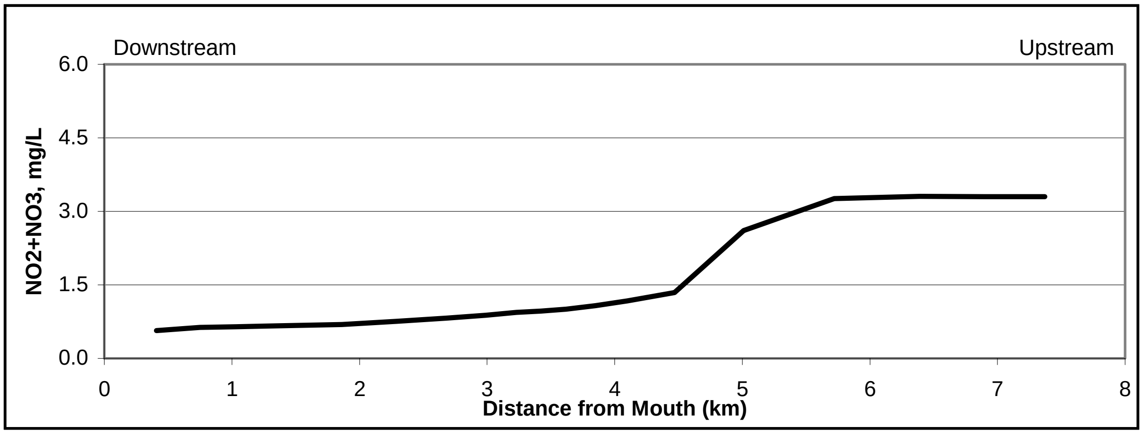


Figure A37: Nitrate (plus Nitrite) vs. River Kilometer for the BCAFS

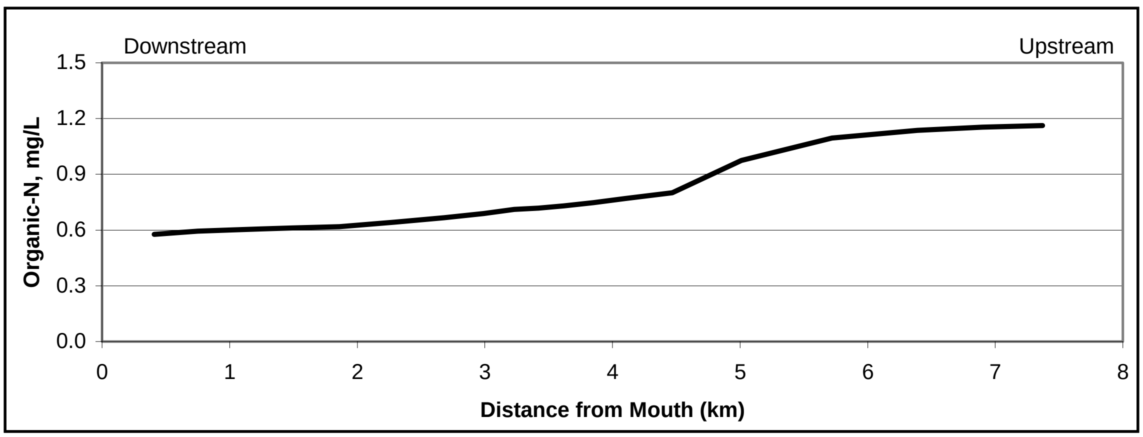


Figure A38: Organic Nitrogen vs. River Kilometer for the BCAFS

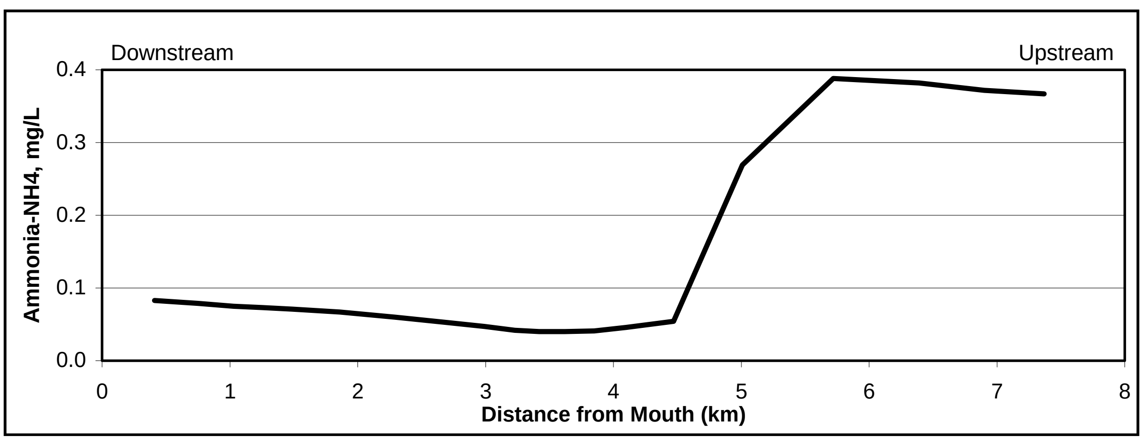


Figure A39: Ammonia vs. River Kilometer for the BCAFS

Baseline Condition Average Flow Scenario

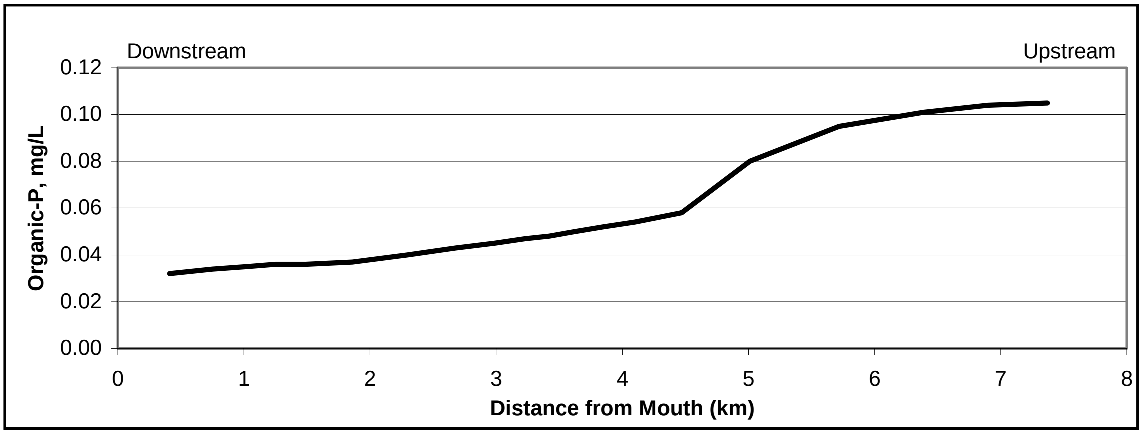


Figure A40: Organic Phosphorus vs. River Kilometer for the BCAFS

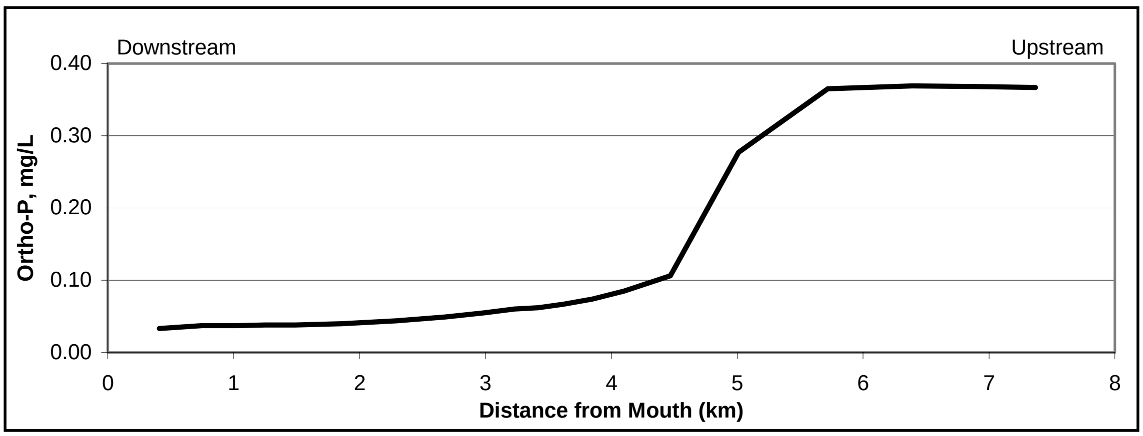


Figure A41: Ortho-Phosphorus vs. River Kilometer for the BCAFS

Table A16: Nonpoint Source Concentration for the Low Flow Future Condition Scenario

Segment Number	NH4 mg/l	NO_{23} mg/l	PO4 mg/l	CHL *a* µg/l	CBOD mg/l	DO mg/l	ON mg/l	OP mg/l
2	0.2060	0.6528	0.0.895	20.20	6.08	5.73	1.1635	0.0604
3	0.0360	6.6667	0.0258	3.77	3.00	8.07	0.5397	0.0128
5	0.0510	6.0533	0.0456	6.90	4.26	7.60	0.4050	0.0241
8	0.0360	6.6667	0.0258	3.77	3.00	8.07	0.5397	0.0128
14	0.0360	6.6667	0.0258	3.77	3.00	8.07	0.5397	0.0128
20	0.0510	6.0533	0.0456	6.90	4.26	7.60	0.4050	0.0241

Table A17: Nonpoint Source Concentration for the Average Flow Future Condition Scenario

Segment Number	NH4 mg/l	NO_{23} mg/l	PO4 mg/l	CHL *a* µg/l	CBOD mg/l	DO mg/l	ON mg/l	OP mg/l
2	0.3024	3.0298	0.1217	13.13	6.08	5.73	1.0719	0.0358
3	0.3967	3.8572	0.1597	2.45	3.01	8.07	1.3278	0.0467
5	0.3208	3.1514	0.1289	4.49	4.26	7.60	1.1251	0.0380
8	0.3608	3.5339	0.1452	2.45	3.01	8.07	1.2311	0.0426
14	0.3358	3.3060	0.1351	2.45	3.01	8.07	1.1638	0.0397
20	0.3288	3.2965	0.1326	4.49	4.26	7.60	1.1406	0.0388

Future Low Flow TMDL Scenario Results

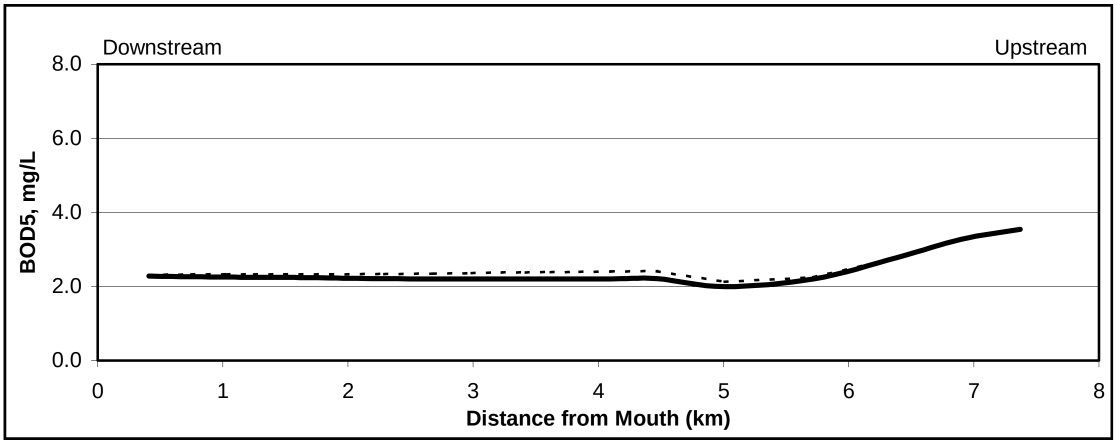


Figure A42: BOD vs. River Kilometer for the Future Low flow TMDL scenario

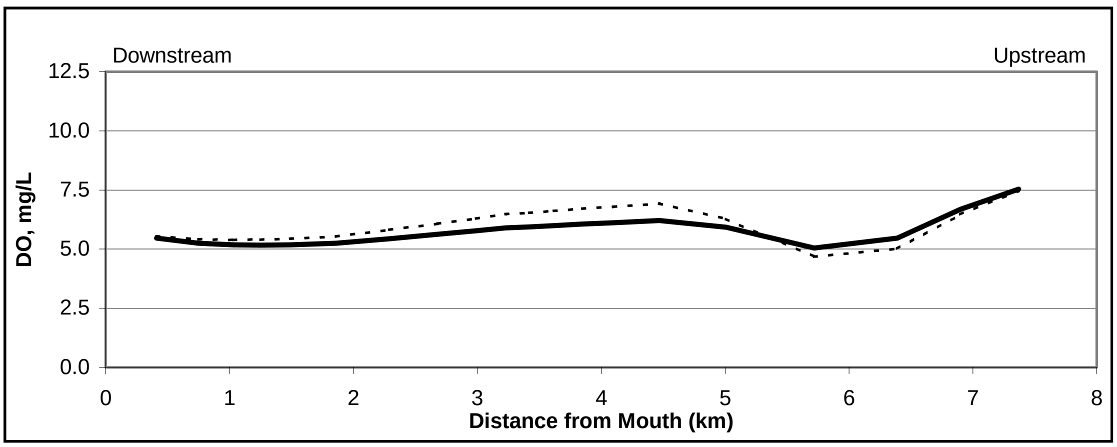


Figure A43: Dissolved Oxygen vs. River Kilometer for the Future Low Flow TMDL Scenario

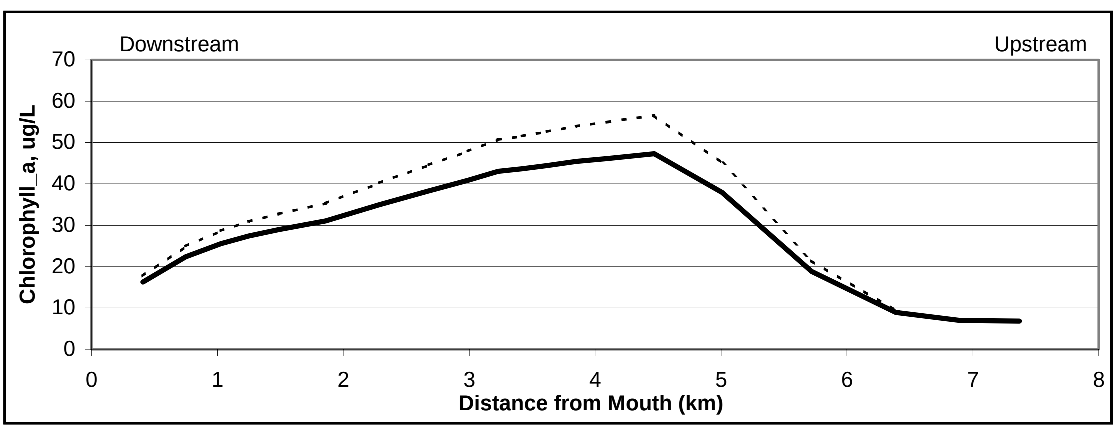


Figure A44: Chlorophyll *a* vs. River Kilometer for the Future Low Flow TMDL Scenario

Baseline Condition Low Flow Scenario (dashed line)
Future Low Flow TMDL Scenario (solid line)

Future Low Flow TMDL Scenario Results

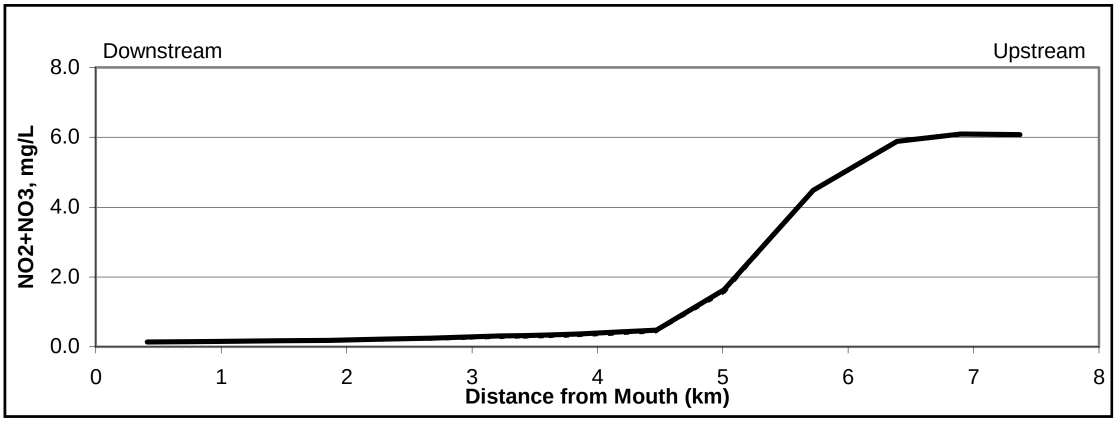


Figure A45: Nitrate (plus Nitrite) vs. River Kilometer for the Future Low Flow TMDL Scenario

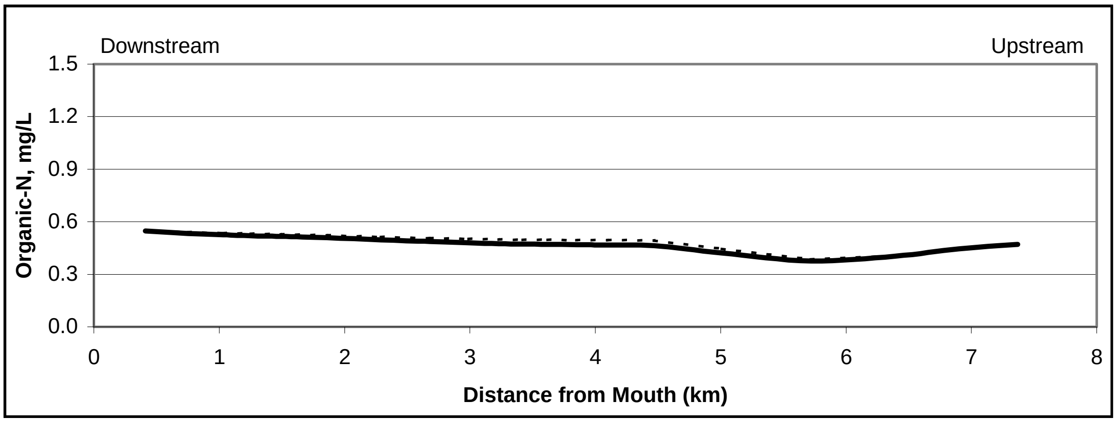


Figure A46: Organic Nitrogen vs. River Kilometer for the Future Low Flow TMDL Scenario

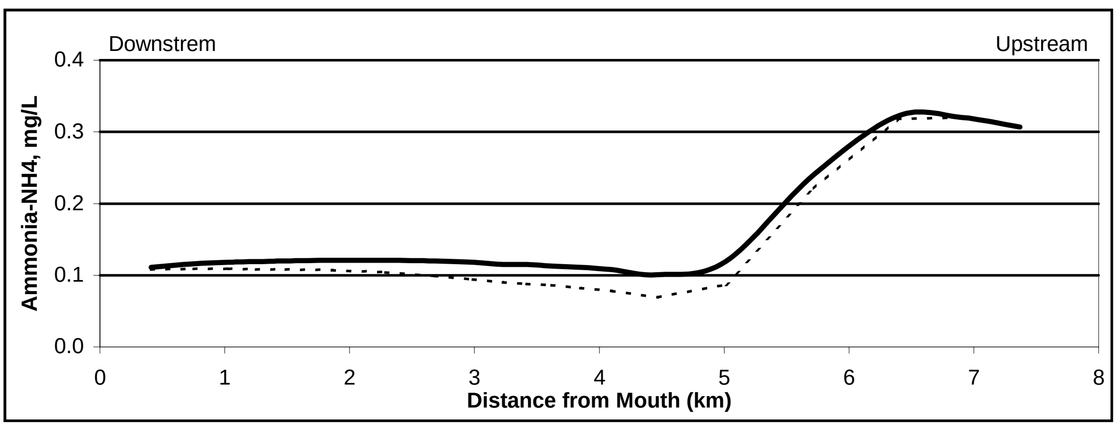


Figure A47: Ammonia vs. River Kilometer for the Future Low Flow TMDL Scenario

Baseline Condition Low Flow Scenario
Future Low Flow TMDL Scenario

Future Low Flow TMDL Scenario Results

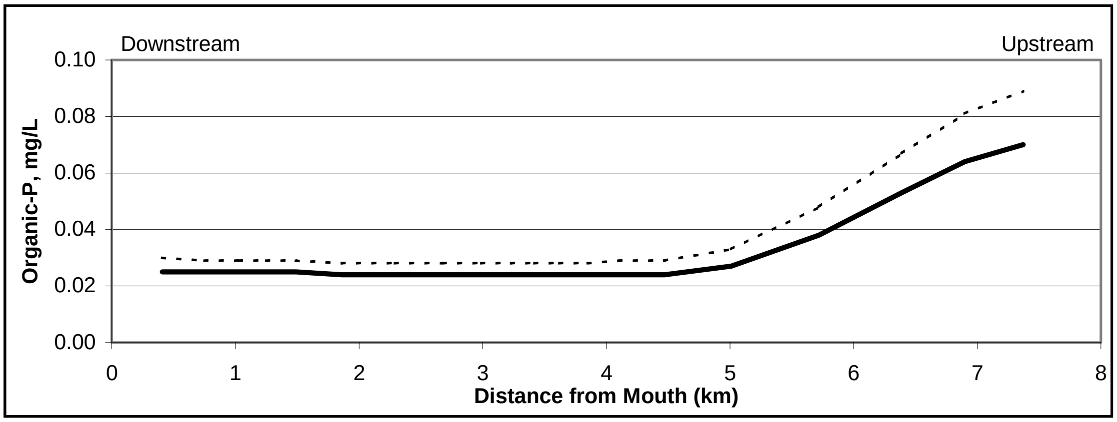


Figure A48: Organic Phosphorus vs. River Kilometer for the Future Low Flow TMDL Scenario

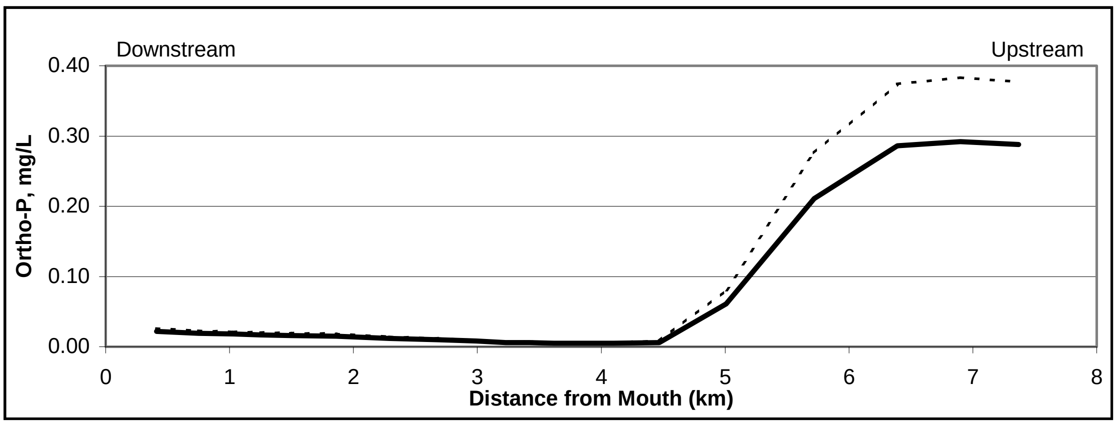


Figure A49: Ortho-Phosphate vs. River Mile for the Future Low Flow TMDL Scenario

--------- **Baseline Condition Low Flow Scenario**
——— **Future Low Flow TMDL Scenario**

Future Average Flow TMDL Scenario Results

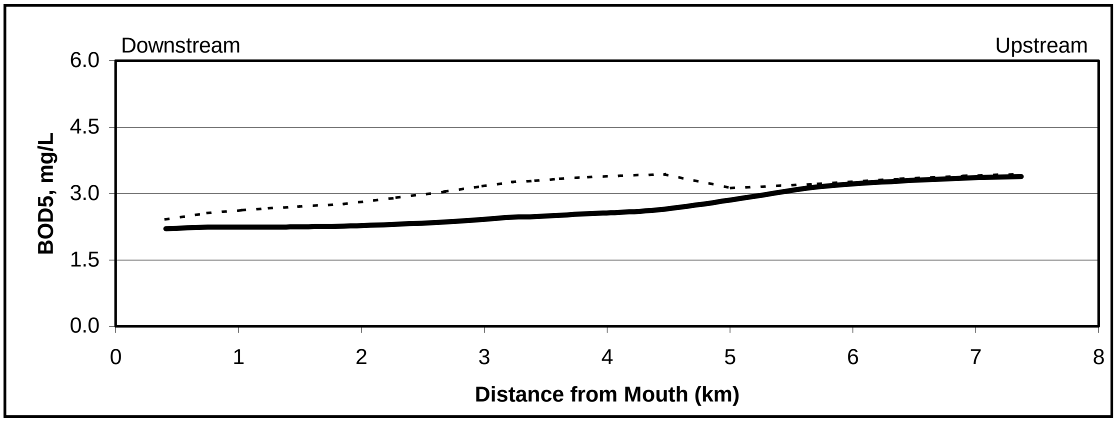


Figure A50: BOD vs. River Kilometer for the Future Average Flow TMDL scenario

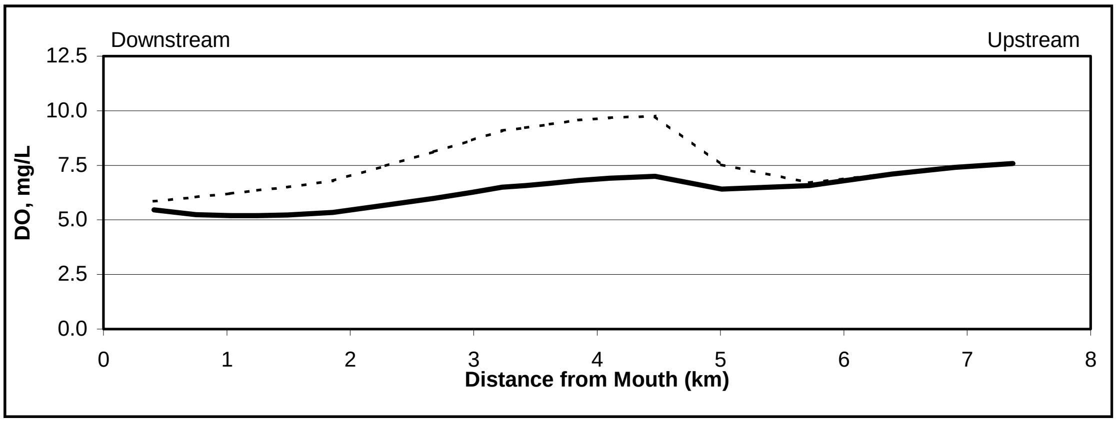


Figure A51: Dissolved Oxygen vs. River Kilometer for the Future Average Flow TMDL Scenario

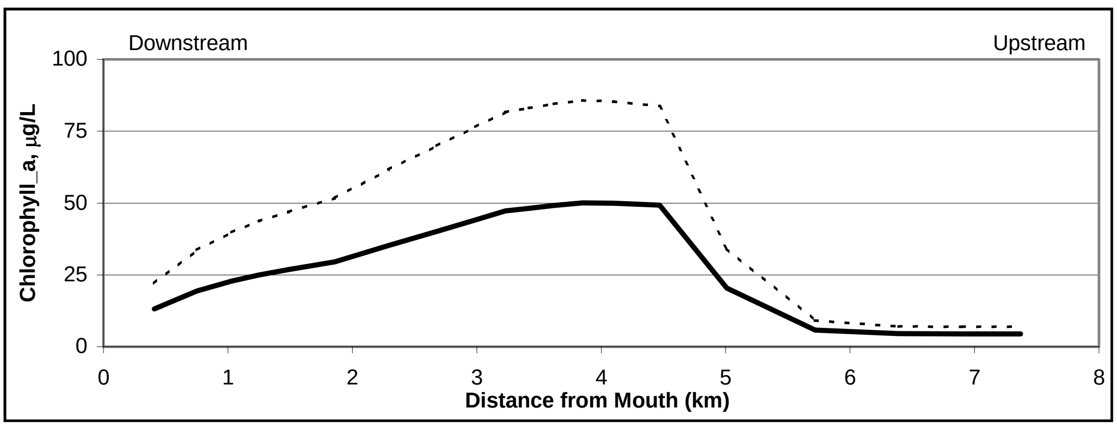


Figure A52: Chlorophyll *a* vs. River Kilometer for the Future Average Flow TMDL Scenario

--------- **Baseline Condition Average Flow Scenario**
——— **Future Average Flow TMDL Scenario**

Future Average Flow TMDL Scenario Results

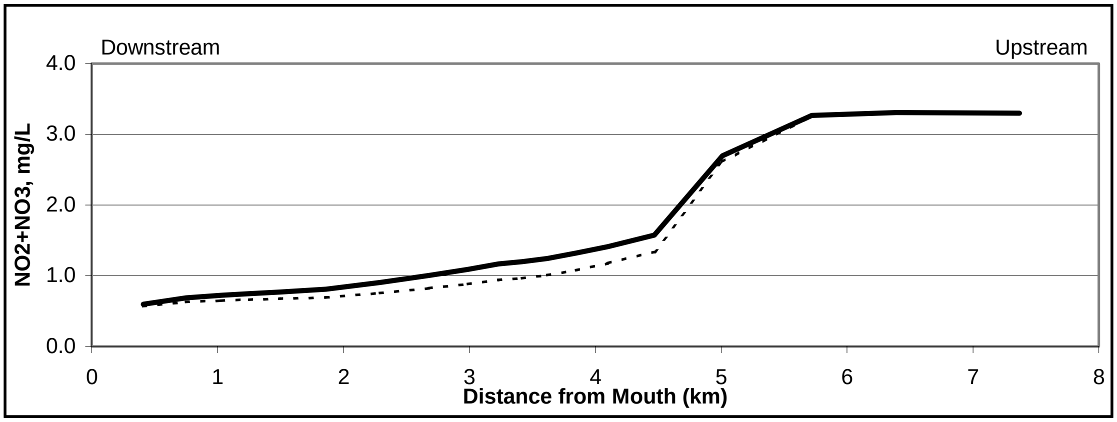


Figure A53: Nitrate (plus Nitrite) vs. River Kilometer for the Future Average Flow TMDL Scenario

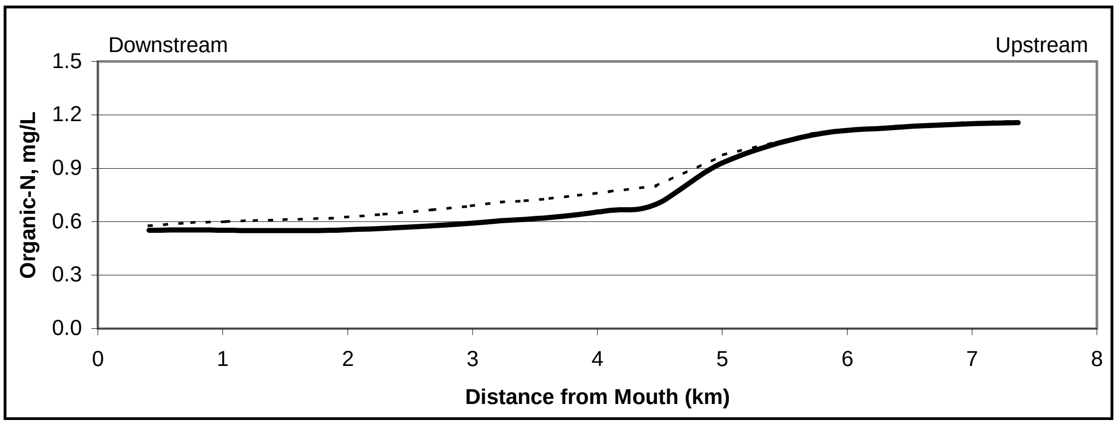


Figure A54: Organic Nitrogen vs. River Kilometer for the Future Average Flow TMDL Scenario

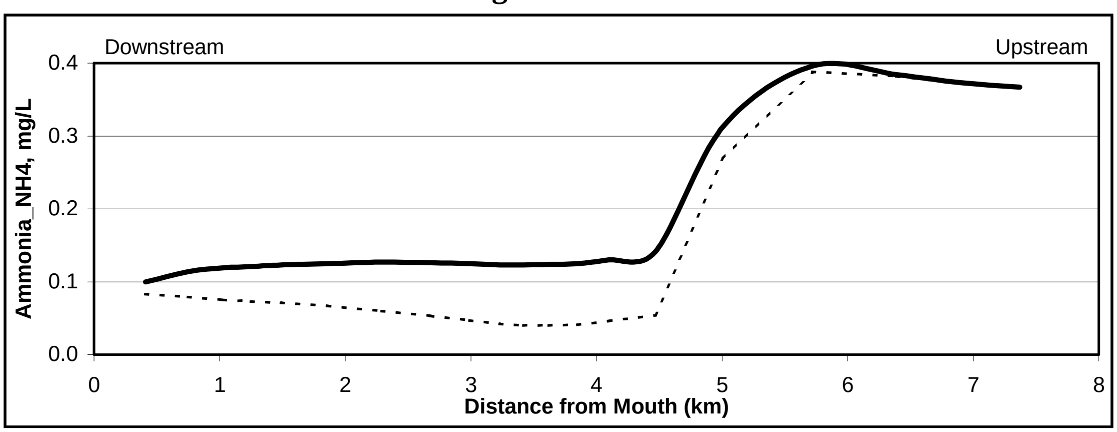


Figure A55: Ammonia vs. River Kilometer for the Future Average Flow TMDL Scenario

Baseline Condition Average Flow Scenario
Future Average Flow TMDL Scenario

Future Low Flow TMDL Scenario Results

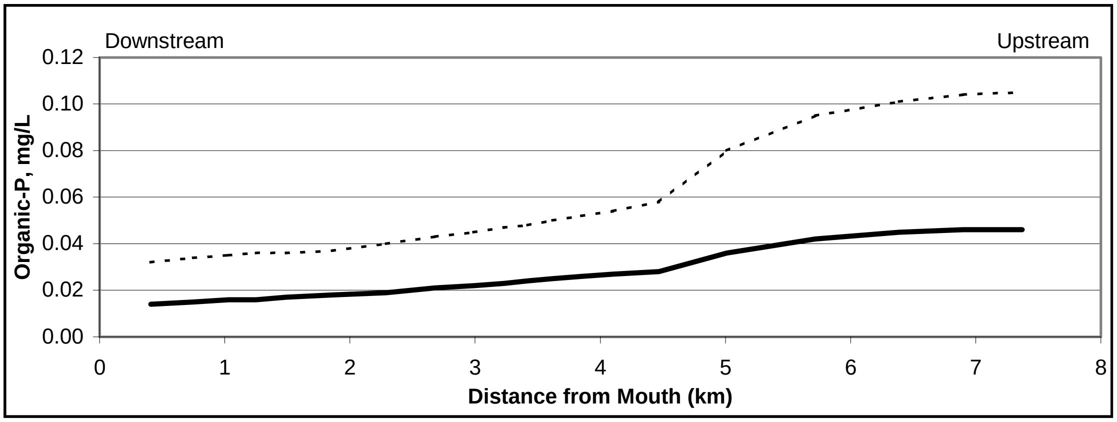


Figure A56: Organic Phosphorus vs. River Kilometer for the Future Average Flow TMDL Scenario

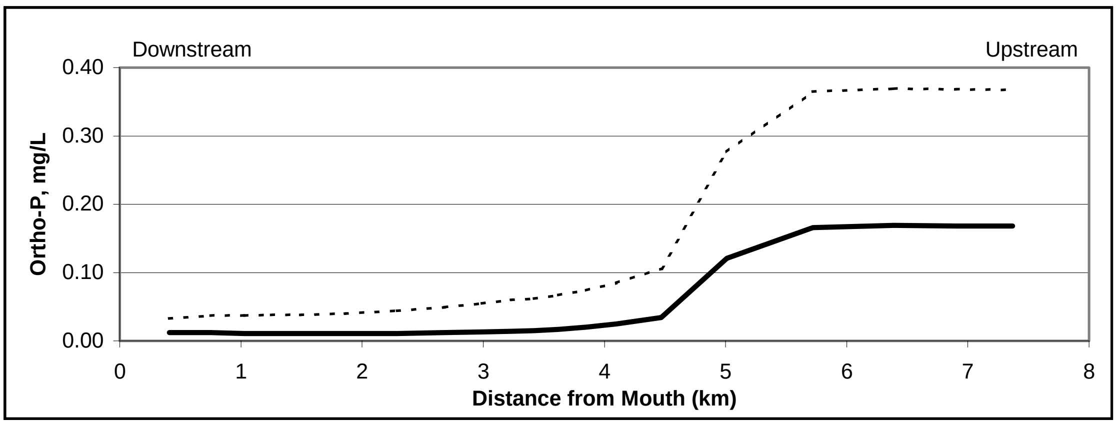


Figure A57: Ortho-Phosphate vs. River Kilometer for the Future Average Flow TMDL Scenario

Baseline Condition Average Flow Scenario
Future Average Flow TMDL Scenario

Table A18: Comparison of Total Phosphorus loads for different scenarios

Boundaries' Segments	Loads Total Phosphorus, in kg/day				
	Low Flow with 1999 MDE data	High Flow with 1999 MDE data	Average flow with 1999 MDE data	7Q10	Average flow with CBP loads
2	5.9571	5.0904	5.5238	1.5952	24.5376
3	0.0459	0.0481	0.0470	0.0121	0.9669
5	0.3510	0.3361	0.3436	0.0942	3.2875
8	0.0579	0.0605	0.0592	0.0157	1.1115
14	0.7025	0.7352	0.7189	0.1883	12.5847
20	1.8981	1.8330	1.8656	0.5083	18.5202
Total	9.0127	8.1033	8.5580	2.4138	61.0084

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