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Total Maximum Daily Load (TMDL) for Phosphorus in Upper Black Creek and Bigelow Creek

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1.0 Introduction

1.1 Background

In April of 1991, the United States Environmental Protection Agency (EPA) Office of Water's Assessment and Protection Division published "Guidance for Water Quality-based Decisions: The Total Maximum Daily Load (TMDL) Process." In July 1992, EPA published the final "Water Quality Planning and Management Regulation" (U.S. EPA April 1991). Together, these documents describe the roles and responsibilities of EPA and the states in meeting the requirements of Section 303(d) of the Federal Clean Water Act (CWA) as amended by the Water Quality Act of 1987, Public Law 100-4. Section 303(d) of the CWA requires each state to identify those waters within its boundaries not meeting water quality standards for any given pollutant applicable to the water's designated uses.

Further, Section 303(d) requires EPA and states to develop TMDLs for all pollutants violating or causing violation of applicable water quality standards for each impaired water body. A TMDL determines the maximum amount of pollutant that a water body is capable of assimilating while continuing to meet the existing water quality standards. Such loads are established for all the point and nonpoint sources of pollution that cause the impairment at levels necessary to meet the applicable standards with consideration given to seasonal variations and margin of safety. TMDLs provide the framework that allows states to establish and implement pollution control and management plans with the ultimate goal indicated in Section 101(a)(2) of the CWA: "water quality which provides for the protection and propagation of fish, shellfish, and wildlife, and recreation in and on the water, wherever attainable" (U. S. EPA March 1991).

1.2 Problem Statement

Black Creek is divided into three segments: Upper, Middle and Lower (Figure 1). The main stem of Black Creek runs over 46 miles before its confluence with the Genesee River and has a drainage area of about 202 square miles (129,280 acres). The headwaters of Black Creek originate in Wyoming County, New York, in the Town of Middlebury and then flow north into Genesee County. Within Genesee County the Upper Black Creek (UBC) watershed includes areas of the Towns of Bethany, Stafford, LeRoy, Batavia and Byron, and the City of Batavia.

Upper Black Creek (WI/PWL ID 0402-0048) was listed on the New York State Section 303(d) List of Impaired Waters Requiring a TMDL in 2004 due to impairments caused by phosphorus and is considered a high priority waterbody for TMDL development. Agriculture and municipal waste were identified as the source. The New York State Priority Waterbodies List indicates that aquatic life is known to be impaired and recreation is known to be stressed in UBC.

Bigelow Creek (WI/PWL ID 0402-0016), a subwatershed of UBC, was listed in the 303(d) list in 2004 due to phosphorus impairment with agriculture identified as the primary source. Aquatic life is known to be impaired in the Creek. Pathogens, silt/sediment and unknown toxicity have also been identified as suspected pollutants. Streambank erosion has also been identified as a suspected source of pollutants.

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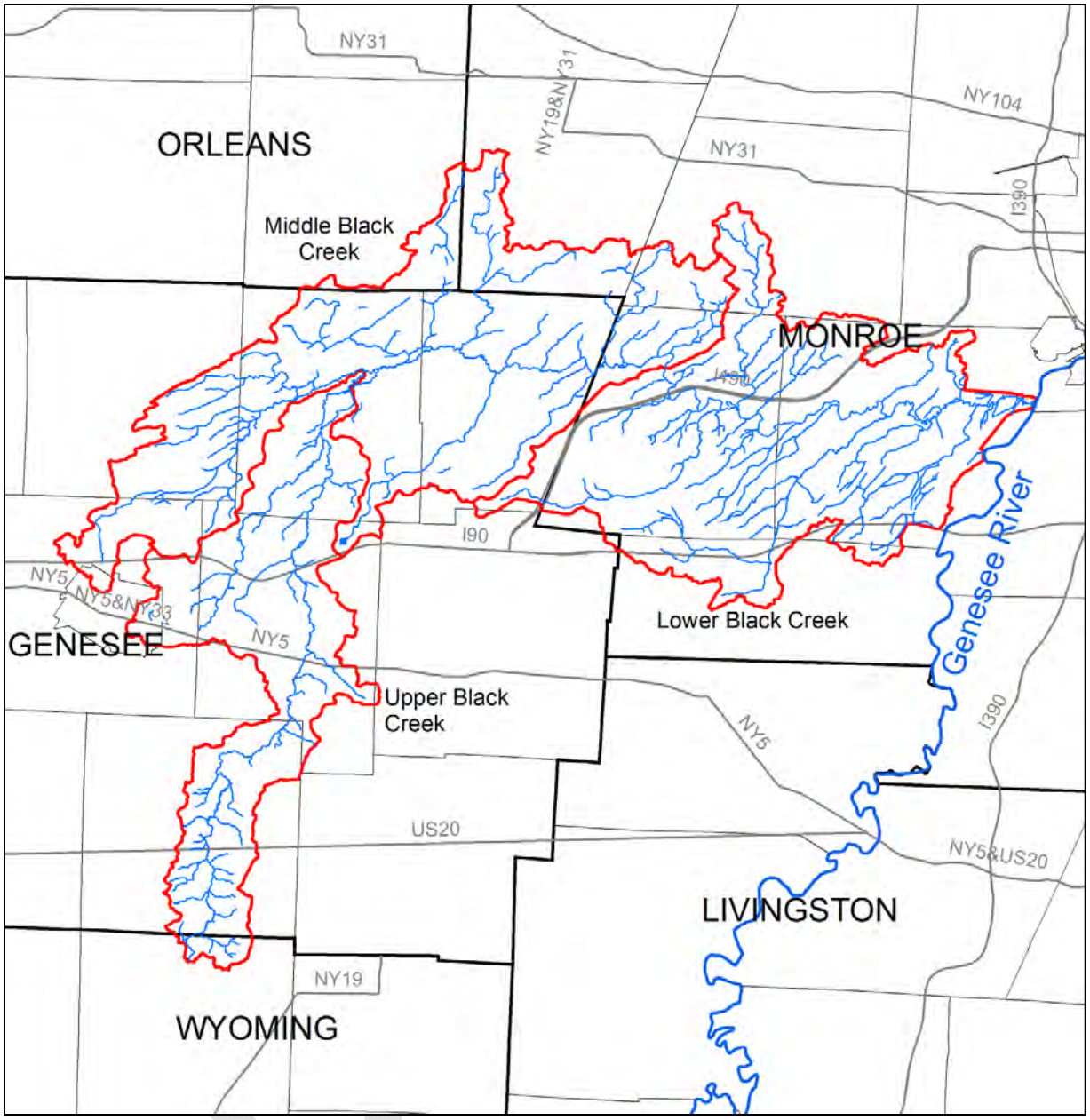

Figure 1: Black Creek watershed showing the Upper, Middle and Lower watershed segments.

An earlier effort to develop a TMDL was postponed because numeric nutrient criteria for phosphorus protective of the aquatic life use were not yet developed enough to identify an endpoint (CEI 2011b). Instead a watershed restoration strategy was developed to quantify the phosphorus loads to Black Creek and to identify different actions which could be undertaken.

Upper Black and Bigelow Creeks remain on the 303(d) List of Impaired Waters. This TMDL for phosphorus has been developed to address the impairments to aquatic life best uses in Upper Black and Bigelow Creeks. Part of the work associated with the development of this TMDL was the development of site specific numeric nutrient criteria to address the aquatic life best use impairments of these Creeks. The development of this TMDL has progressed with the

recognition that a watershed restoration based approach to nutrient management and protection of aquatic life is more practical and efficient than addressing nutrients alone.

2.0 System Characterization

2.1 Watershed Characterization

The Black Creek watershed is located within the Genesee River Basin and has a total drainage area of about 202 square miles (129,280 acres). Black Creek originates in northern Wyoming County, flows northerly until Byron in Genesee County, and then easterly to join the Genesee River 3 miles upriver of the Barge Canal in Monroe County. Downstream from Byron the Creek passes through the Byron-Bergen Swamp and then passes over a spillway dam in the Village of Churchville. The USGS maintains a stream gage (Site Number 04231000) below the dam.

Upper Black Creek (UBC) is defined as the portion of the watershed from the confluence of Spring and Black Creeks near Byron, upstream to the headwaters. The main stem of UBC is nearly 27 miles long and has a drainage area of 46 square miles (29,042 acres). The majority of UBC falls within Genesee County with only a small portion of the headwaters located within Wyoming County. The watershed contains the lands of six towns and one city. Upper Black Creek has one major tributary, Bigelow Creek, which has a drainage area of 10 square miles (6,436 acres) and a main channel stream length of 10.7 miles. The confluence between Bigelow and Black Creek is 3.8 miles upstream from the outlet of the UBC watershed. The headwaters of Bigelow Creek are located partially within the City of Batavia.

Digital land use/land cover data were obtained from the 2006 National Land Cover Database (NLCD2006) (Fry, et al. 2011). NLCD2006 is a consistent representation of land use across the conterminous United States at 30 meter resolution. Land use within UBC and Bigelow Creek is detailed in Table 1 and shown graphically in Figure 2 and Figure 3, respectively. Agriculture is the dominant land use in both watersheds. Developed land is also important due in part to the City of Batavia which is located partially within the Bigelow Creek watershed. Within the developed land use category in UBC, open space is 2,022 acres (7.0%), which can, in large part, be attributed to three golf courses found within the UBC watershed, two of which are located within the Bigelow Creek subwatershed. Roads appear within NLCD2006 as either high or low intensity developed land. Land use distribution throughout the watershed is shown in Figure 4.

Approximately 1,634 acres (5.6%) of the UBC watershed is served by sanitary sewer districts. The majority of this (1,444 acres, 5.0%) is served by the Town of Batavia sewer district, which is transferred out of the UBC watershed for treatment at the City of Batavia sewage treatment plant (STP) (SPDES number NY0026514). The Byron Sewer District provides sanitary sewer service in the northern end of the UBC watershed via two separate systems: the South Byron Sewer District STP serving approximately 72 acres (0.2%), and the Byron Sewer District STP serving approximately 118 acres (0.4%). Buildings within the remaining 94.4% of the UBC watershed are assumed to use on-site wastewater treatment (septic) systems.

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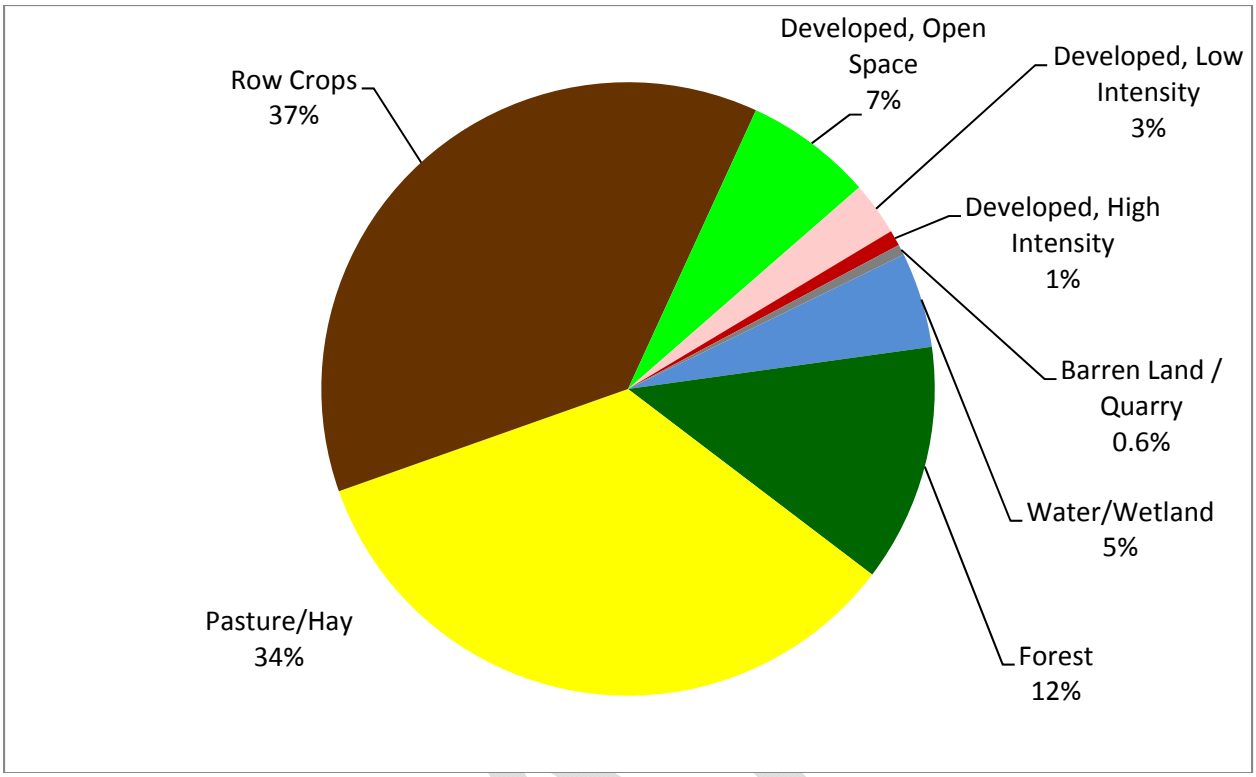

Figure 2: Land use in Upper Black Creek.

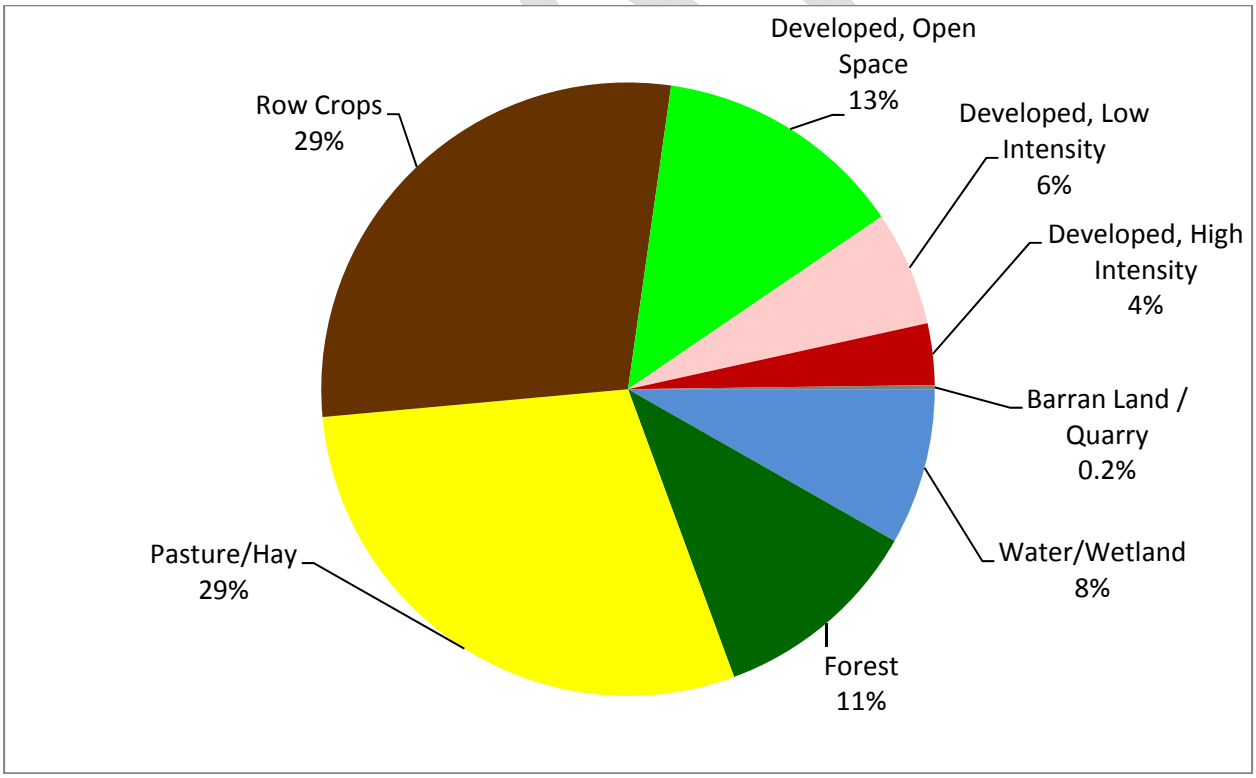

Figure 3: Land use in Bigelow Creek.

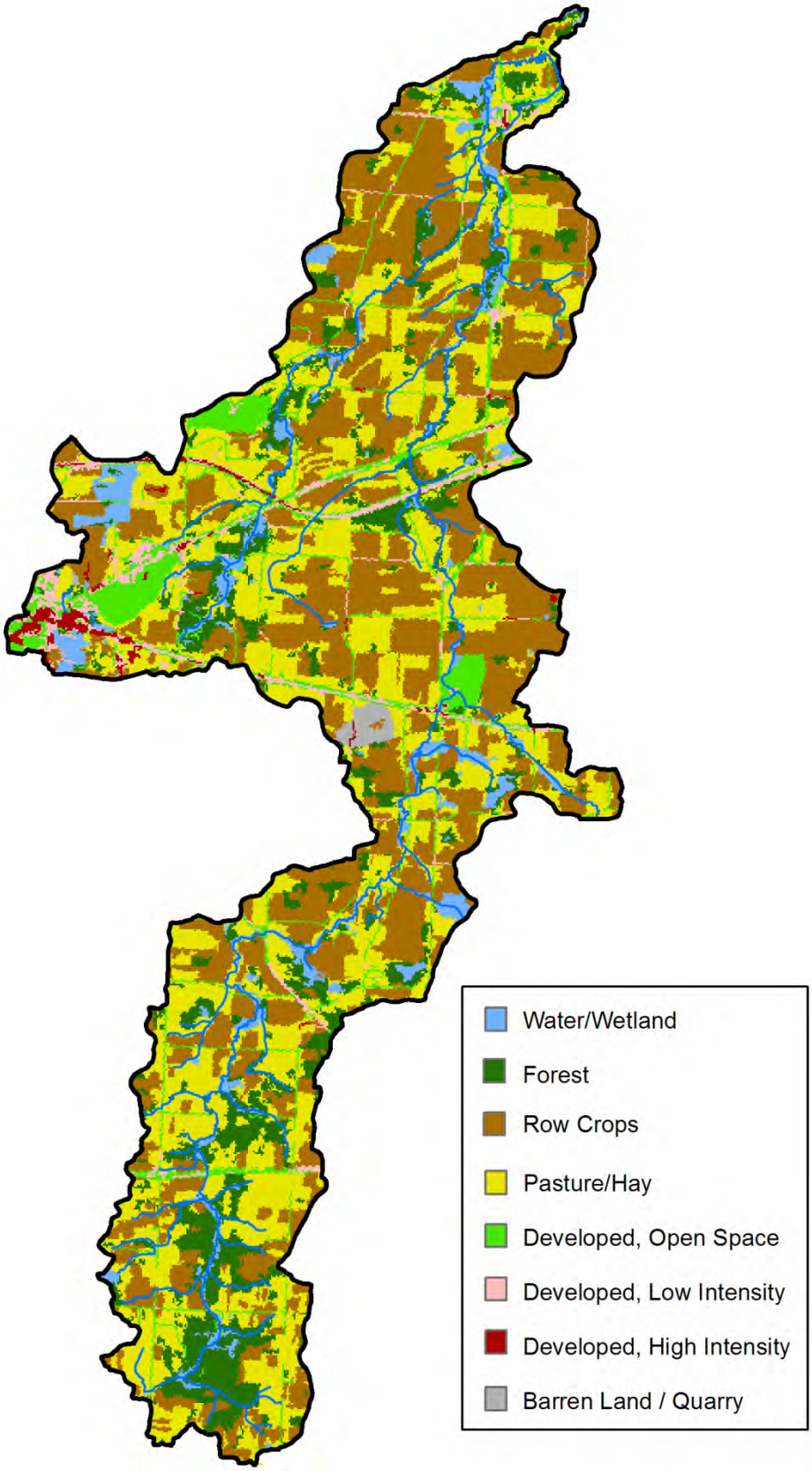

Figure 4: Land Use Distribution within the Upper Black Creek watershed

Table 1: Land Use in Upper Black and Bigelow Creeks. Upper Black Creek is inclusive of Bigelow Creek.

	Upper Black Creek		**Bigelow Creek**	
Land Use Description	**Area (acres)**	**Percent**	**Area (acres)**	**Percent**
Water/Wetland	1,464	5.0%	529	8.2%
Forest	3,684	12.7%	716	11%
Agriculture	20,645	71.7%	3719	58%
Pasture/Hay	*9,876*	*34.0%*	*1875*	*29%*
Row Crops	*10,769*	*37.1%*	*1844*	*29%*
Developed Land	3,090	10.6%	1448	22%
Open Space	*2,022*	*7.0%*	*850*	*13.2%*
Low Intensity	*825*	*2.8%*	*390*	*6.1%*
High Intensity	*242*	*0.8%*	*208*	*2.2%*
Barren Land/ Quarry	160	0.6%	13.9	0.2%
Total	**29,042**	**100%**	**6,442**	**100%**

2.2 Stream Characterization

Upper Black Creek originates within the northernmost portion of Wyoming County from lands dominated by agriculture. Flowing north into Genesee County, UBC enters a county park before returning to a predominantly agricultural land use. Between sites BLAK-03 and 04 the stream gradient decreases and the Creek exhibits deeper, slow moving waters (Figure 5). Land use is still dominated by agriculture; however, row crops become the dominant agricultural land use and forests decrease from more than 20% of the land use to less than 10%.

Between sites BLAK-04 and BLAK-05 (Figure 5), UBC passes over a large escarpment formed by the edge of the carbonate bedrock of the Onondaga Limestone (Reddy and Kappel 2010). The limestone formation is known to contain karst features and may be a potential source of water to UBC at the escarpment face. Modeling by Winslow (2012) of the Black Creek watershed indicated the formation may be a source of water in February, March and April.

The fraction of land use best described as rural residential increases in the portion of UBC below the escarpment; however agriculture is still the dominant land use, with row crops increasingly more important than hay/pasture.

Bigelow Creek (BC), a significant tributary to UBC, enters just below BLAK-08 (Figure 5). The headwaters of BC are within the City of Batavia. The area is served by both sanitary and stormwater sewers. Sanitary waste is transferred out of the basin. Several ponds and natural springs are located within the upper portions of BC. Agriculture accounts for nearly 60% of the land use while developed land, as a mix of open, low intensity and high intensity, account for another 20%.

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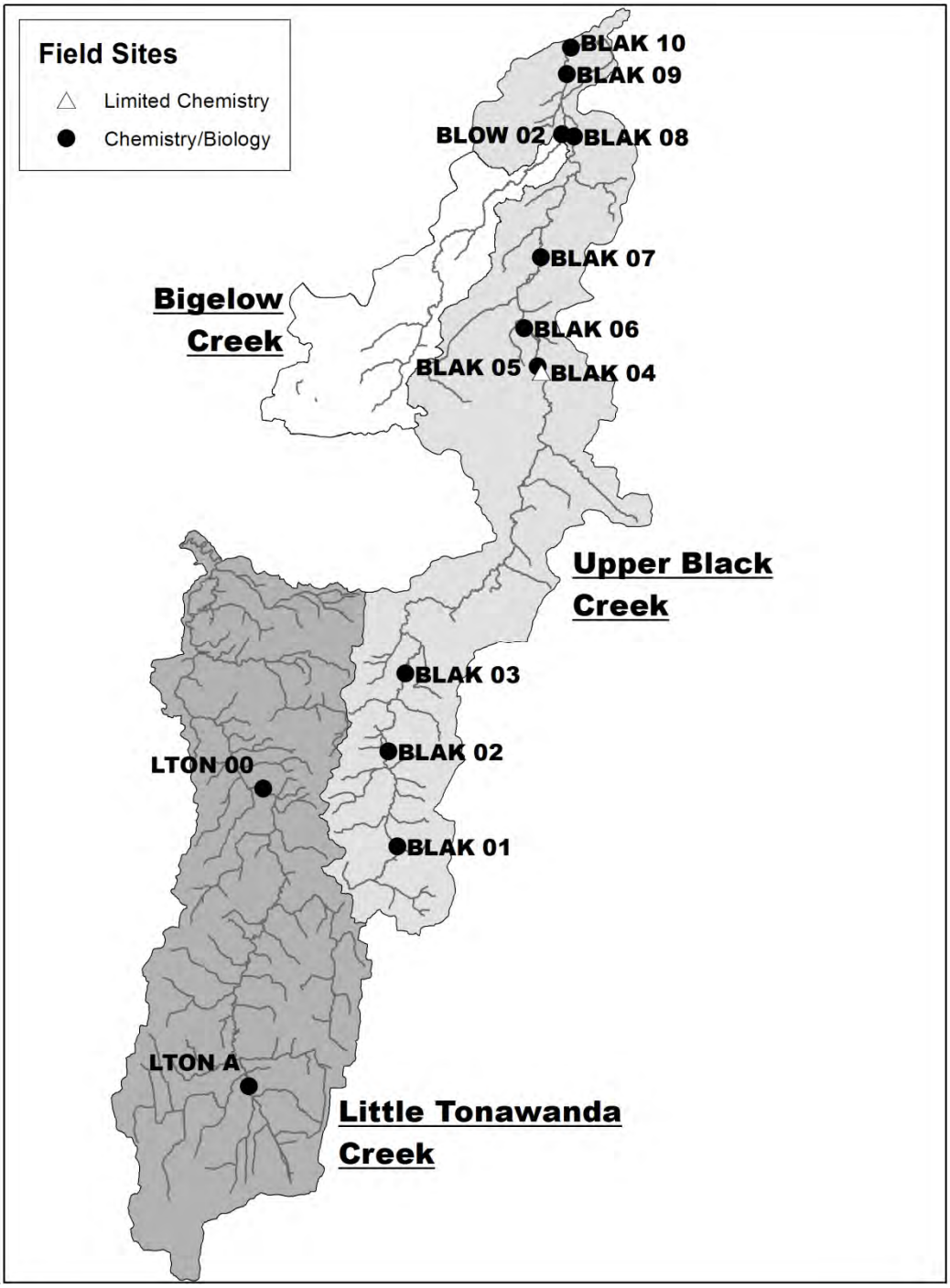

Figure 5: Sampling locations within the study watersheds.

The official water body classifications for New York State are contained in Title 6 of the New York Codes, Rules and Regulations. Black Creek is covered in Part 721; the Water Index Number is Ont. 117-19. The UBC watershed primarily contains waters identified as class "C."

Bigelow Creek (Ont. 117-19-30) has one tributary, Thornell Brook (Ont. 117-19-30-3) to which "C(T)" standards apply. Several ponded waters within the Bigelow Creek watershed are designated as class "B": Godfrey's Pond (Ont. 117-19-30-P 17), Horseshoe Lake (Ont. 117-19-30-P 18), Chapin's Pond (Ont. 117-19-30-P 18a) and Seven Springs Pond (Ont. 117-19-30-P 19). No water quality data for these waters is available.

The best usage of Class B waters is primary and secondary contact recreation and fishing. These waters shall be suitable for fish, shellfish and wildlife propagation and survival (NYSDEC 2008).

The best usage of Class C waters is fishing. These waters shall be suitable for fish, shellfish, and wildlife propagation and survival. The water quality shall be suitable for primary and secondary contact recreation, although other factors may limit the use for these purposes (NYSDEC 2008).

The symbol (T), appearing in an entry in the "standards" column in the classification tables of Parts 800 through 941 of 6 NYCCR Chapter X, means that the classified water in that specific item are trout waters. Any water quality standard, guidance value, or thermal criterion that specifically refers to trout or trout waters applies.

2.3 Water Quality

Several previous measurements of water quality data in Black Creek are available. A Water Quality Restoration Strategy (WQRS) prepared for New York State Department of Environmental Conservation (NYSDEC) by the Center for Environmental Initiatives (CEI) conducted water quality sampling within UBC in August and September of 2010 (CEI 2011b). Data from the 2000 NYSDEC Rotating Integrated Basin Studies (RIBS) was collected in Byron at the State Route 237 bridge with samples collected between April and November. The USGS collected data at the USGS gage station in Churchville (Site Number 04231000) below the Churchville dam. Summary data from the three sources are presented in Table 2. Only the CEI and RIBS data were collected within the UBC watershed. An additional 55 total phosphorus measurements made from 1970 to 1975 by the USGS are not reported here.

Table 2: Existing total phosphorus monitoring data in Black Creek

	CEI	RIBS	USGS
Year(s)	2010	2000	1998-2011
Location	Outlet of Upper Black Creek	State Route 237 in Byron	USGS gage in Churchville
Number of Samples	4	10	645
Min TP (µg/L)	70	21	17
Max TP (µg/L)	91	107	810
Avg. TP (µg/L)	83	58	70

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Table 3: Monitoring data collected in Black Creek by Winslow (2012) from June 2010 to June 2011.

Site	Upper Black Creek		Bigelow Creek		Middle Black Creek	
Condition	Event	Nonevent	Event	Nonevent	Event	Nonevent
Mean TP (µg/L)	198.5	69.0	200.4	60.2	94.6	54.9
Mean SRP (µg/L)	90.0	41.1	81.6	27.7	37.6	21.0
Mean TSS (µg/L)	37.9	6.3	41.2	5.7	17.4	6.8

Winslow (2012) sampled Black Creek for multiple water quality parameters at several locations throughout the watershed from June 2010 to June 2011. Parameters sampled included total phosphorus (TP), soluble reactive phosphorus (SRP) and total suspended solids (TSS). Samples were collected during or shortly after rainfall events (event) and during baseflow conditions (nonevent). Summary data from three sites are presented in Table 3. The Upper Black Creek sites corresponds roughly to site BLAK-10 (Figure 5), the Bigelow Creek site to sample site BLOW-02 (Figure 5) and Middle Black Creek was located near the dam in Churchville.

Phosphorus data collected for the development of this TMDL are summarized in Table 4. Additional details on the data collected are included in Appendix A. Site locations are shown in Figure 5.

2.4 Biological Conditions

Macroinvertebrates are excellent indicators of overall water quality. NYS has a long standing program of assessing biological conditions in streams using macroinvertebrate samples collected in riffles through its RIBS program. Assessments are carried out using a Biological Assessment Profile (BAP) score which consists of the mean of several individual 10-scale metrics.

Table 4: Base (non-event) flow average phosphorus concentrations collected from May 30 to September 19, 2012 for the development of this TMDL. For the purpose of this TMDL, these samples are considered to represent the summer growing season.

Site	Number of samples	Soluble Reactive Phosphorus (µg/L)	Total Phosphorus (µg/L)
BLAK-01	7	11	42
BLAK-02	7	8	23
BLAK-03	7	7	40
BLAK-04	6	53	75
BLAK-05	7	54	72
BLAK-06	7	50	65
BLAK-07	7	45	66
BLAK-08	7	67	93
BLAK-09	8	58	89
BLAK-10	8	81	124
BLOW-02	8	42	82
LTON-00	7	5	14
LTON-A	6	6	22

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Historically four individual metrics have been used by NYSDEC to determine the BAP score. A fifth metric, which specifically incorporates the impact of nutrients, has been developed and is used for the assessments associated with this TMDL. Water quality impact is assessed using the BAP score with a four-tiered scale of impact (non-, slight, moderate, or severe) (Smith, Heitzman, et al. 2012). A BAP score less than 5.0, corresponding to moderate of severe impact, designates impaired biological conditions which do not meet the fish, shellfish and wildlife propagation and survival best uses identified for these waters (Section 2.2).

As part of the RIBS program, NYSDEC has conducted biological monitoring within the UBC watershed several times since 1996, sampling a total of 3 sites. Two sites on the main stem of UBC were sampled: BLAK-08[1] at the Cockram Road Bride and BLAK-10 near the Route 237 bridge (Figure 5). Bigelow Creek at the Caswell Road bridge, site BLOW-02, was sampled once. Original assessments of impairment were based upon a four metric BAP score. To be consistent with the biological assessment metric used for this TMDL, the historic results were reassessed using the five metric BAP, the results from which are shown in Table 5. Summary data from previous assessments are included in Appendix D in the Priority Waterbodies List for UBC and Bigelow Creek.

Macroinvertebrate samples collected in September 2012 as part of the development of this TMDL indicates that the majority of UBC is moderately impacted based upon the 5-metric BAP score and would therefore be considered impaired (Figure 6). One site, BLAK-03, showed severe impact and two sites, BLAK-06 and BLOW-02, showed only slight impact and would not be considered impaired. Both of the Little Tonawanda (LTON) reference sites were slightly impacted. BAP scores in the upper watershed may have been suppressed due to low-flow or no-flow conditions during part of the summer. Low-flow or no-flow conditions may also have resulted in a decreased BAP score in the upper watershed of the neighboring Little Tonawanda Creek watershed (Figure 5), which was used as a watershed reflective of best attainable conditions during the numeric endpoint development (Appendix A).

Table 5: Results from past RIBS sampling in Upper Black Creek. A level of impact of moderate or severe is considered impaired. Historic data was reassessed using the 5 metric BAP criteria. See text for further details.

Site	Year	BAP Score	Level of Impact
BLAK-08	1996	3.68	Moderate
BLAK-08	2008	5.12	Slight
BLAK-10	1996	4.50	Moderate
BLAK-10	1999	4.13	Moderate
BLAK-10	2000	3.43	Moderate
BLAK-10	2004	5.07	Slight
BLAK-10	2009	4.78	Moderate
BLOW-02	1999	4.47	Moderate

[1] The site identification numbers used for this field work differed from those used by the RIBS program. The corresponding numbers are: BLAK-08 corresponds to RIBS site BLAK-01, BLAK-10 to RIBS site BLAK-02 and BLOW-02 to RIBS site BLOW-01.

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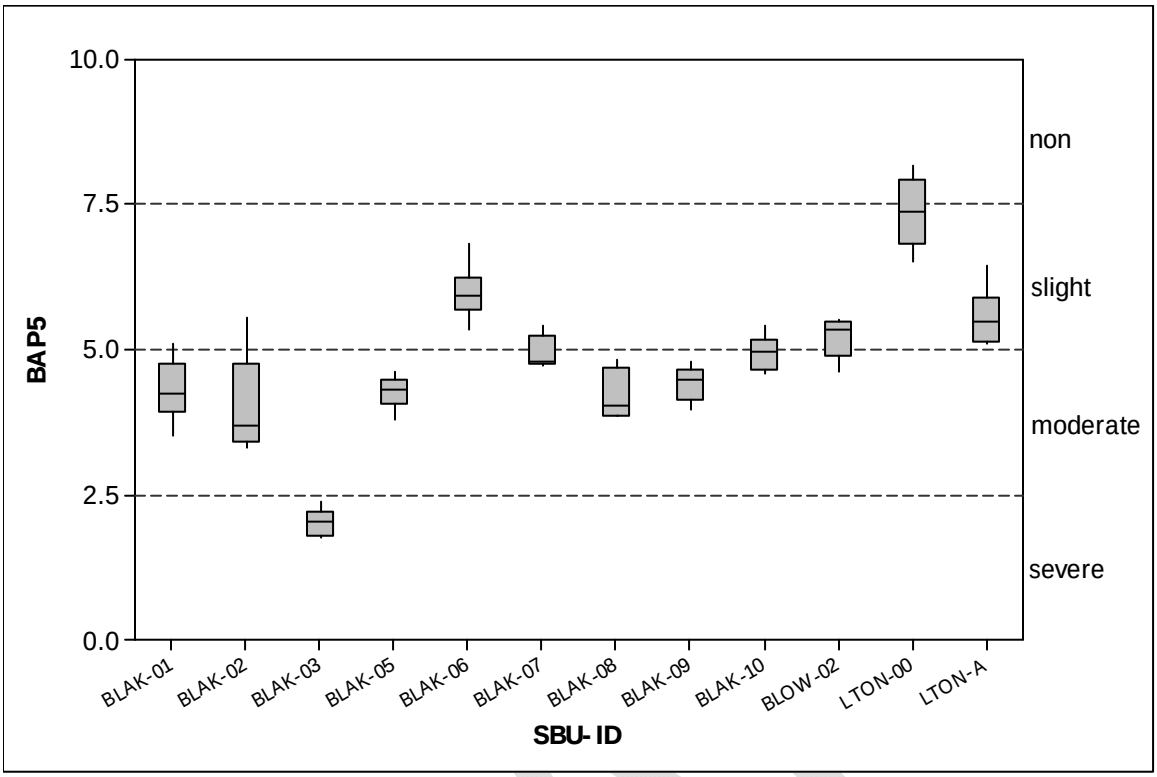

Figure 6: Five Metric BAP scores for 2012. Boxes show 25th percentile, median and 75th percentile scores. Whiskers indicate minimum and maximum measured values. Scores less than 5 are considered impaired by NYSDEC. See Figure 5 for site locations.

3.0 Water Quality Standards and Supporting Information for Numeric Water Quality Targets

3.1 Applicable Water Quality Standards

The official water body classifications are contained in Title 6 of the New York Codes, Rules and Regulations. The Black Creek watershed is covered in Part 821; Black Creek's Water Index Number is Ont. 117-19. The watershed contains primarily class "C" waters, however the Bigelow Creek (Ont. 117-19-30) watershed also contains both class "C(T)" and class "B" waters as previously discussed in Section 2.2.

New York State has a narrative standard for nutrients (phosphorus and nitrogen) applicable to all class "B" and "C" waters: "none in amounts that will result in growths of algae, weeds and slimes that will impair the waters for their best usages" (NYSDEC 2008). NYSDEC has not translated this standard into a numeric water quality criterion for lotic (flowing water) systems, including streams and rivers. Statewide numeric nutrient criteria are currently being developed. Part of the assessment associated with the development of this TMDL has been to develop site specific numeric nutrient criteria (Appendix A).

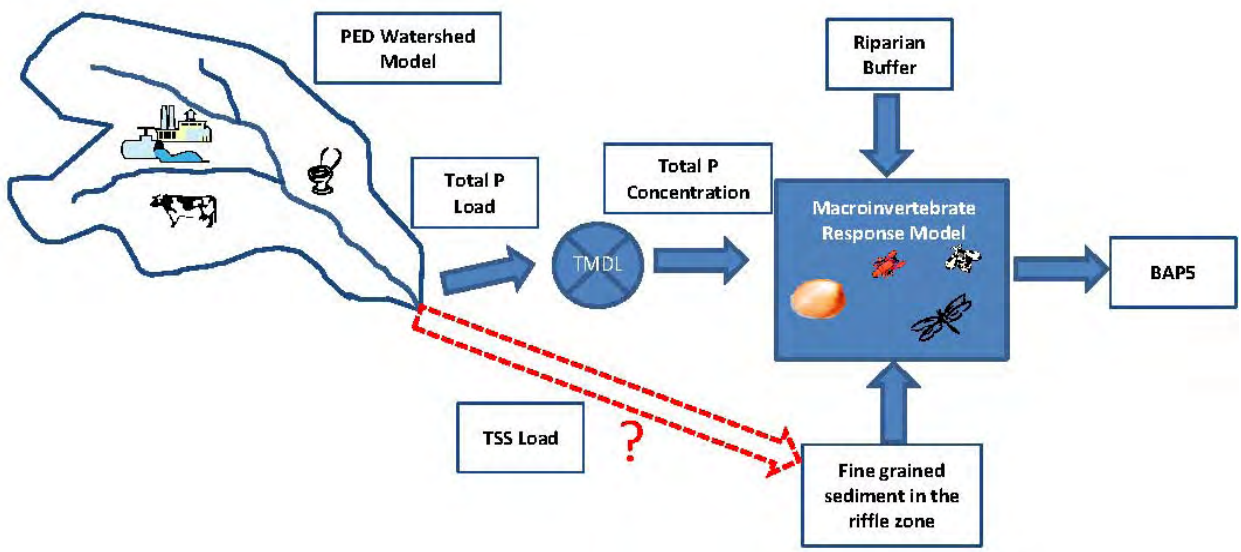

Figure 7: Conceptual diagram of the interaction between the different model component and the TMDL.

3.2 Modeling Approach

A suite of models were used for the development of this TMDL to estimate water flow and phosphorus loads from land within the watershed and to model the impact of these parameters on aquatic life within the watershed. An overview of each of the modeling components are presented below. Additional details on the watershed, sediment and phosphorus models are presented in Appendix C and on the macroinvertebrate response model in Appendix A. Conceptually, the interaction between the different models and the TMDL are depicted in Figure 7. The literature indicates the amount of fine grained material in the riffle zone may be attributed to erosion in the watershed (Cover, et al. 2006, Larsen, Baughan and Ormerod 2009); however, this relationship was not quantified as part of this TMDL.

3.2.1 Hydrology Model

The Parameter Efficient Distributed (PED) model is a semi-distributed rainfall-runoff model based upon the Thornthwaite and Mather (1955) water balance procedure and can be run at daily, weekly, or monthly time steps (Collick, et al. 2009, Tesemma, Mohamed and Steenhuis 2010, Steenhuis, et al. 2009). Watersheds are divided into three regions, each with a separate water balance. Conceptually, the three regions represent a restricted infiltration area, high infiltration area usually along the hillslope, and flatter (bottom) areas that potentially become saturated. The restricted infiltration areas are characteristic of exposed bedrock, hardpan, or other restricted infiltration areas which produce surface runoff. Water which infiltrates into the permeable hillslopes is transported via the subsurface as rapid interflow in the shallow subsurface or as baseflow through deeper soil and rock layers. The bottom areas which drain the surrounding hillslopes become surface runoff sources when saturated. Infiltrated water may also be lost from the subsurface via evapotranspiration. Precipitation may reach the stream as either subsurface flow from the permeable hillslopes or as overland flow from the restricted infiltration areas or the bottom areas once saturated. Methods described by Walter, et al. (2005) were used to model

snowmelt. Additional information including equations can be found in the referenced publications.

3.2.2 Sediment Model

Within the model, sediment is generated from each of the same three model regions (hillslope, baseflow, runoff) used in the hydrology. The model follows the form $L = aQ^n$ where L is the sediment load in kg/km^2/day, Q is flow in m^3/day, the exponent n is a calibrated parameter which is common across all model regions and the coefficient a is a calibrated parameter for each of the model regions. The coefficient a for runoff is much greater than for interflow or baseflow.

3.2.3 Phosphorus Model

The phosphorus model is comprised of two components, a particulate phosphorus (PP) model, which builds upon the sediment model and a soluble reactive phosphorus model (SRP). Total phosphorus is the sum of the PP and SRP fractions. The PP model uses an enrichment factor, $E= 12.5S^{-0.35}$, where S is the sediment load from the sediment model following the work of Vadas et al. (2005), Sharpley (1980) and Menzel (1980). For $S < 0.5$ kg/km^2/day, E = 15.9. Sediment particles are enriched with less phosphorus as more sediment is produced and transported. PP is calculated as the product of: the amount of sediment transported, the enrichment factor, and a reference soil phosphorus concentration. A single calibrated value of the reference soil phosphorus concentration was used in the PP model. PP loads from the STPs were incorporated explicitly into the model.

SRP in the model uses calibrated loading reference rates for up to 24 different combinations of: the four land use categories, the 2 water table depth categories and the three model hydrologic outflow types. Land use categories are row (assumed non-perennial) crops, grass (assumed perennial) crops, developed land and other land use which is primarily forest and wetlands. Shallow water tables reach the surface often enough to influence soil properties. SRP load is calculated as the product of: the reference concentration, the volume of water generated, and for the hillslope and baseflow categories, a temperature adjustment factor.

3.2.4 Macroinvertebrate Response Model

Macroinvertebrate community assemblages are driven by a wide range of physicochemical factors. Stream geomorphology and the flow of resources change in a predictable manner as they flow from headwaters downstream (Vannote et al. 1980). These changes are a result of natural physicochemical shifts that occur along a continuum throughout the watershed. Anthropogenic influences, however, can accelerate and alter resource flow changes through land use and habitat alterations. Additional nutrients and eutrophication of waterbodies result. The relationship between nutrients and primary production in streams is confounded by the complicated interaction of light, flow, substrate, substrate stability, sedimentation, temperature, shading, flooding, grazing, and a number of other interrelated variables (Smith, Tilman and Nekola 1999, Miltner and Rankin 1998). Habitat degradation that impacts any number of variables may potentially increase algal production (Hynes 1970, Cushing and Allan 2001, Delong and Brusven 1998). Nutrient enrichment also causes oxygen depletion resulting from

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plant respiration and decomposition. Eutrophication driven changes in primary production alter resource quality and quantity and therefore affect consumers such as macroinvertebrates and aquatic life through changes in community structure, function, and abundance (Rosemond, Mulholland and Elwood 1993).

Macroinvertebrates are excellent indicators of overall water quality. The species comprising the community each occupy a distinct niche defined and limited by a set of environmental requirements. The composition of the macroinvertebrate community is thus determined by many factors, including habitat, food source, flow regime, and temperature (Allan, Erickson and Fay 1997, Rempel, Richardson and Healey 2000). The NYSDEC Stream Biomonitoring Unit employs well established methods and a multi-metric index for the biological assessment of water quality using the macroinvertebrate community as indicators (Smith, et al. 2012). The multi-metric index, the 5 metric biological assessment profile (BAP) score, provides an overall assessment of the macroinvertebrate community, with BAP < 5 indicating moderate or severe impact. The BAP score is used by NYSDEC to assess attainment of the fish, shellfish and wildlife survival and propagation designated best use.

To identify a numeric endpoint for this TMDL, data collected during the summer 2012 growing season was used to quantify the macroinvertebrate community response to the phosphorus load, thus linking the indicator directly to the pollutant load while accounting for instream and habitat influences on the assimilative capacity of the stream. By using a multiple regression model it was determined that the variability in the BAP score could be explained by a constant and three linear terms. The independent variables selected were the concentration of a form of phosphorus (either the soluble reactive or total phosphorus, SRP or TP, respectively), the total riparian width (TRW) and the non-dimensional fraction of fines in the riffle (FFR). Growing season average phosphorus concentration data was used in the model development, based upon samples collected twice per month. For the purpose of this TMDL the growing season has been defined as June through September. Phosphorus concentrations in samples collected on May 16 and 17 were much lower than those collected during the rest of the sampling period. These samples were deemed not representative of the summer growing season. Samples collected on May 30 and 31 have phosphorus concentrations in good agreement with those collected in the June – September period. Chemistry data from the end of May were included in the calculation of the growing season average as these samples would be representative of concentrations measured in early June. TRW is the sum of the widths of riparian buffers on either side of the stream, in meters. FFR is the fraction of bed material less than 16 mm in diameter determined by pebble count in the riffle (Smith, et al. 2012).

Both TP and SRP were considered for use in the macroinvertebrate response model. SRP proved to be a stronger predictor of BAP score; however, for consistency with SPDES permits and the numeric nutrient criteria currently under development by NYSDEC, TP was selected for use in the model. Using TP is more conservative than SRP (Appendix A). The resulting equation for the macroinvertebrate response model was:

$$BAP = 5.59 - 17.4 \times TP + 0.091 \times TRW - 3.43 \times FFR$$

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This model indicates that BAP score may be improved by actions which decrease TP, increase TRW and/or decrease FFR. The equation had an R^2 of 70.0%.

3.3 Numeric Water Quality Target

As indicated in Section 2.2, the waters of Upper Black Creek and Bigelow Creek must be suitable for fish, shellfish and wildlife propagation and survival, as well as for primary and secondary contact recreation. Macroinvertebrates provide an excellent indicator of overall water quality and NYS has a long standing, robust program for assessing biological best use attainment using macroinvertebrates (Sections 2.4 and 3.2.4).

Attainment of the designated best uses for fish, shellfish and wildlife propagation and survival in New York is based upon achieving a BAP score of 5 or greater. As the 303(d) listings for Upper Black Creek and Bigelow Creek are due to aquatic life use impairments, attainment of BAP ≥ 5 would indicate the waterbodies are in attainment of that best use.

The numeric endpoint for this TMDL will be to achieve a BAP score of 5 or greater at the BLAK-08, BLAK-10 and BLOW-02 sites. This assessment criterion is consistent with the current criteria used by the NYSDEC stream biomonitoring unit (Smith, Heitzman, et al. 2012) and with the numeric nutrient criteria currently being developed by NYSDEC (Smith and Tran 2010). Assessment of the macroinvertebrate community at BLAK-10 was the reason UBC was determined to be impaired. BLOW-02 is being included as Bigelow Creek is listed separately on the 303(d) list as impaired for phosphorus. BLAK-08 is included to address the upper parts of the watershed, which is primarily agricultural, separate from the lower parts of UBC and from Bigelow Creek. This will ensure that sufficient restoration practices are targeted towards the upper parts of the watershed.

Based upon the macroinvertebrate response model, if only TP is to be reduced, the TP concentrations shown in Table 6 would need to be met in order to achieve a BAP ≥5. Many practices put in place to reduce TP may also have beneficial impacts upon FFR and/or TRW. Alternately, practices may be put in place solely to reduce FFR or increase TRW. Section 7.1 provides further information on how restoration of the stream corridor by decreasing FFR or increasing TRW may achieve BAP ≥ 5 with smaller decreases in TP concentrations. The criteria for delisting UBC from the 303(d) list will be the attainment of a BAP ≥ 5, independent of whether the TP concentrations shown in Table 6 are achieved.

Table 6: Maximum allowable TP concentration in order to achieve a BAP score of 5 given the values for FFR and TRW measured in September 2012.

Site	Fraction fines in riffle (FFR) (-)	Total Riparian Width (TRW) (m)	Total Phosphorus (TP) Target (mg/L)
BLAK-08	0.30	18	0.048
BLOW-02	0.39	20	0.083*
BLAK-10	0.30	20	0.121

***The 2012 assessment determined a BAP score greater than 5 for Bigelow Creek. The target concentration is therefore held constant at the measured value.**

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4.0 Source Assessment

4.1 Analysis of Phosphorus Contributions

This TMDL will focus on quantifying and reducing total phosphorus (TP). The models described in Section 3.2 were used to estimate phosphorus loading from the watershed to Upper Black Creek. The output from the model was used to determine the contribution of phosphorus from the different types of land use categories present within the watershed. Flow and concentration data were used when available to include point sources as discreet loads in the model.

4.2 Sources of Phosphorus Loading

Total phosphorus loads from the watershed for the period of 1979 to 2012 were estimated from the models. Point source loads were estimated from monitoring data when available. Sources and associated loads are shown in Table 7 and Figures 8, 9 and 10 for sites BLAK-08, BLAK-10 and BLOW-02, respectively. Nonpoint source loads were attributed to the different sectors using the results of the SRP model. Daily loads, as presented in this TMDL for source assessment and load allocations refers to a typical summer growing season day characterized by average phosphorus concentrations and median flows (see also Section 6.4). The summer growing season is defined here as June through September.

Table 7: Estimated phosphorus loads to Upper Black Creek and Bigelow Creek during the growing season (June to September). Upper Black Creek at BLAK-10 is inclusive of Bigelow Creek.

	Upper Black Creek at BLAK-08		**Bigelow Creek**		**Upper Black Creek at BLAK-10**	
Source	**Load (lb/d)**	**Percent**	**Load (lb/d)**	**Percent**	**Load (lb/d)**	**Percent**
Background (Forest, Wetland)	0.03	1%	0.01	2%	0.05	1%
Agriculture	1.49	64%	0.24	36%	1.84	46%
Developed Land (including septic systems)	0.37	16%	0.37	56%	0.80	20%
Point Sources	0.44	19%	0.04	6%	1.30	33%
Total	**2.33**	**100%**	**0.66**	**100%**	**3.99**	**100%**

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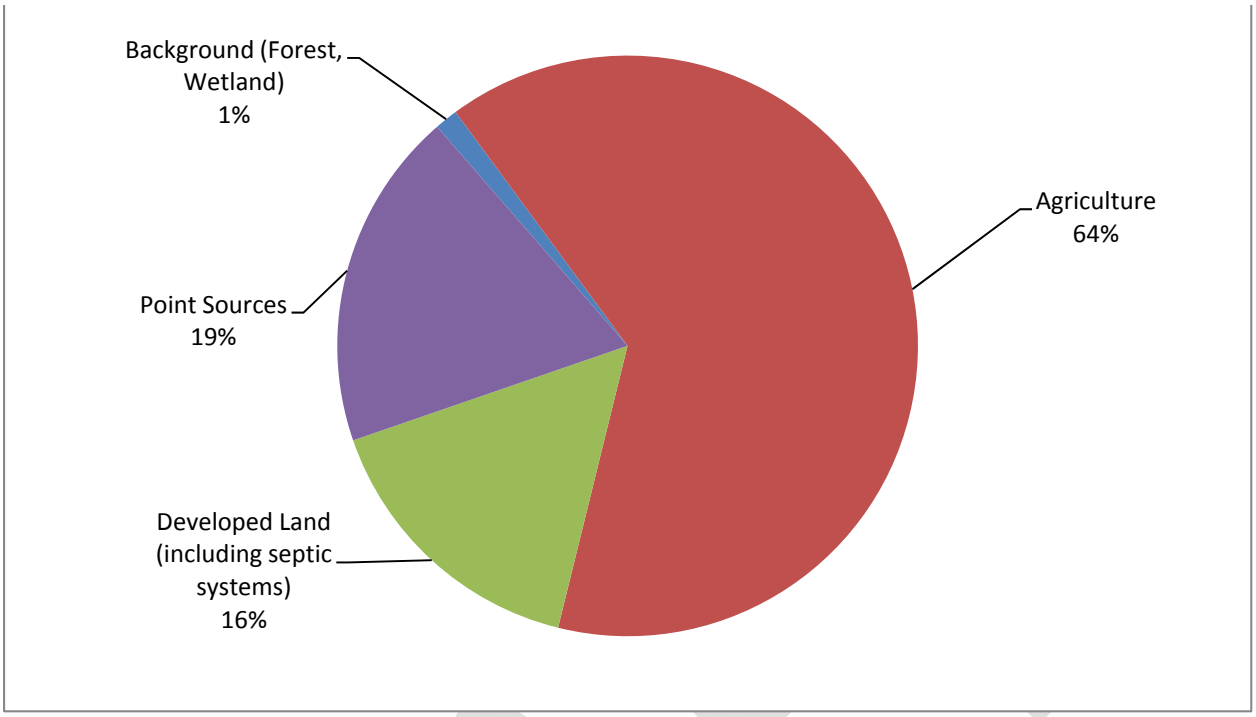

Figure 8: Estimated phosphorus loads to Upper Black Creek at BLAK-08

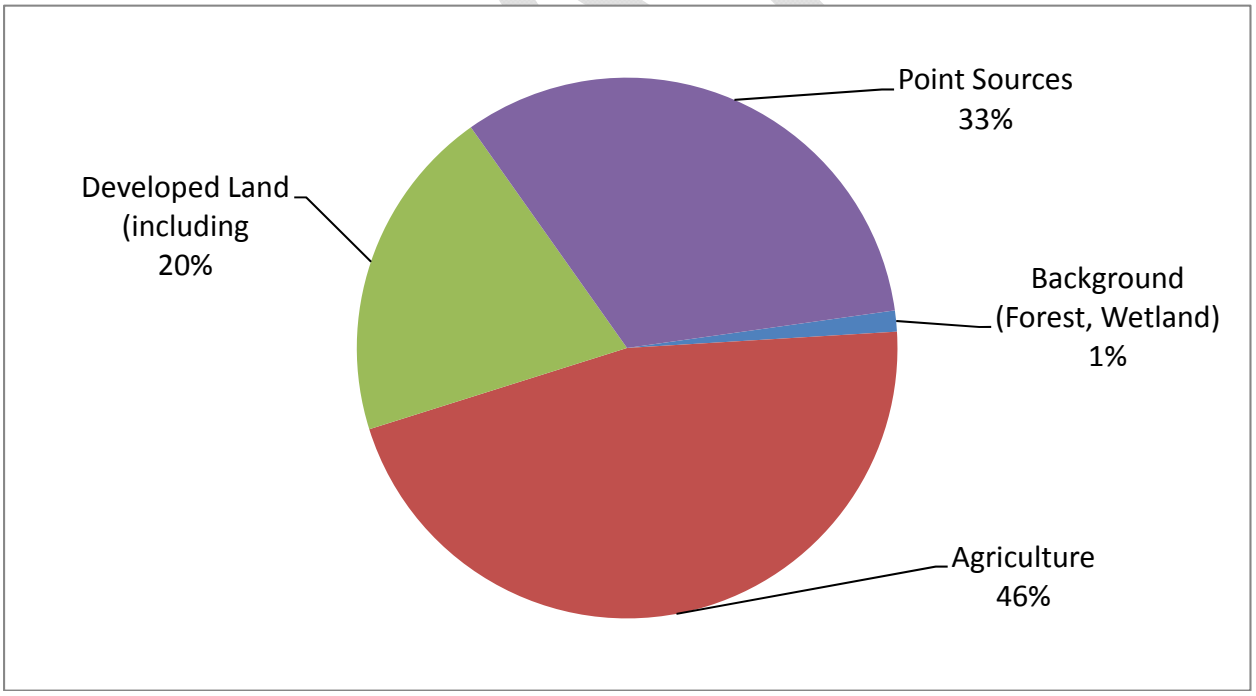

Figure 9: Estimated phosphorus loads to Upper Black Creek at BLAK-10.

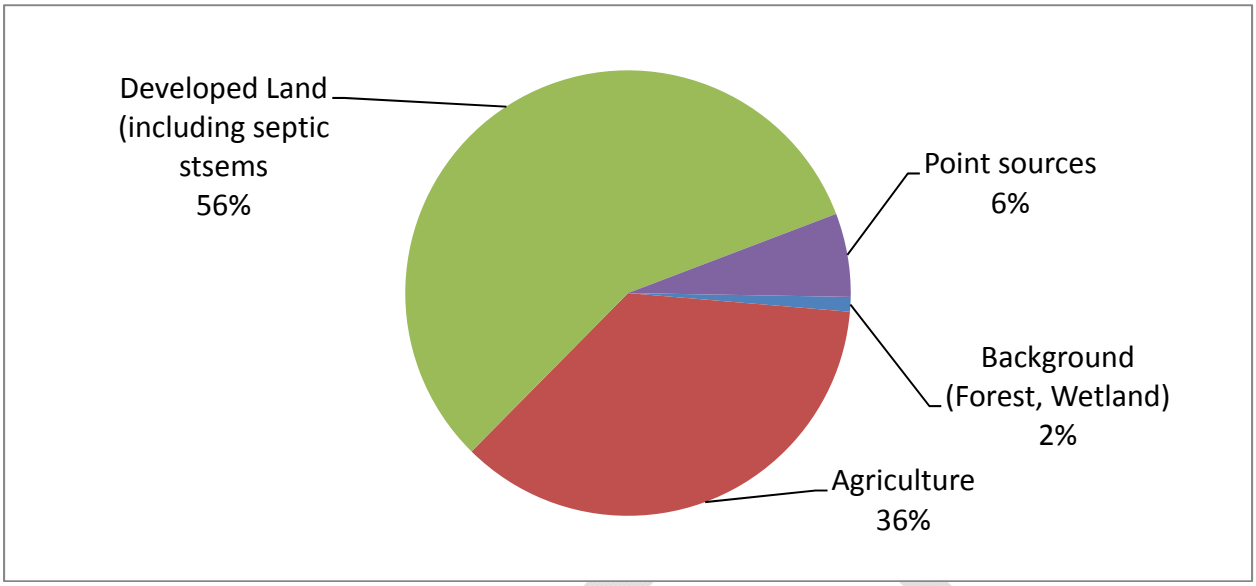

Figure 10: Estimated phosphorus loads to Bigelow Creek

4.2.1 SPDES Permits

Discharges of wastewater to the waters of New York are regulated under State Pollution Discharge Elimination System (SPDES) permits. Discharges within the UBC watershed which discharge phosphorus containing waste are listed in Table 8 and their locations within the watershed are shown in Figure 11. When available, growing season (June – September) loads are based off of reported flows and concentration values for that period. Otherwise, for point source discharges, growing season loads are calculated as one-third of the annual load. Point sources are estimated to contribute 1.30 lb/d of total phosphorus, or about 33% of the total load at BLAK-10.

Two publicly owned wastewater treatment plants currently discharge into the UBC watershed: the Byron Sewer District Sewage Treatment Plant (Byron SDSTP) and the South Byron Sewage District Sewage Treatment Plant (South Byron SDSTP). These two discharges, and North Byron SDSTP which discharges to Spring Creek, have been administrative combined under SPDES permit number NY0160971 as outfalls 001M, 002M and 003M, respectively. Effluent phosphorus concentrations were determined from a single effluent sample and mass balance calculations based upon water samples collected from UBC above and below the outfalls (Appendix B). Total phosphorus concentrations were estimated to be 3.70 mg/L for the Byron SDSTP and 2.85 mg/L for the South Byron SDSTP. SRP concentrations were estimated to be 3.42 mg/L and 2.72 mg/L, respectively. The permitted flow at Byron SDSTP is 0.053 MGD but DMR data from March 1999 to February 2013 indicate an annual average flow of only 0.033 MGD and a growing season average of 0.0264 MGD. The permitted flow at South Byron SDSTP is 0.025 MGD and the DMR data from the same period indicate an average flow of 0.019 MGD and a growing season average flow of 0.0159 MGD. Flows exceeded the permitted flow ten times at Byron SDSTP, primarily in the spring. At the South Byron SDSTP the permitted flow is exceeded frequently between October and May with a total of 25 excursions since March 2008.

The Batavia Country Club (NY0159069) is a private, commercial and institutional (PCI) permitted discharge within the Bigelow Creek watershed. There are no SRP measurements for the Batavia Country Club discharge. Conservatively, the estimated TP load was assumed to be all SRP. Sampling in Black Creek by SUNY Brockport also identified the Hanson Aggregate Stafford Quarry (NYR00D626) as a potential source of phosphorus (Table 8) (Winslow 2012). The phosphorus attributed to Hanson Quarry results from mine dewatering due to groundwater inflow and does not contain additional phosphorus from mine operations.

Two medium and one large concentrated animal feeding operation (CAFO) are located within the UBC watershed. Animal counts for each CAFO in 2009 and the number of acres of land to which manure was applied is listed in Table 9. Locations of the CAFOs are shown in Figure 11. East View Farm operates under a combined permit with Lor-Rob Dairy Farm. Some of the land application acreage may lie outside the watershed for those CAFOs near watershed boundary. Additionally, a number of CAFOs are also located just outside of the watershed which may land apply manure within UBC. These discrepancies are assumed to compensate one another. Under the nutrient management plans required of medium and large CAFOs, land application of manure is to occur at agronomic rates. Lands receiving manure in accordance with a comprehensive nutrient management plan are therefore no more a source of phosphorus than other types of agricultural lands receiving fertilizer i.e. row crops.

Table 8: Upper Black Creek SPDES permits

Permit	Name	Receiving Water	Annual Soluble Reactive Phosphorus (lb/yr)	Annual Total Phosphorus Load (lb/yr)	Growing Season Total Phosphorus Load (lb/d)
NY0160971 Outfall 001M*	Byron Sewer District Sewage Treatment Plant	Black Creek	312**	338**	0.81**
NY0160971 Outfall 002M*	South Byron Sewer District Sewage Treatment Plant	Black Creek	199**	208**	0.38**
NY0159069	Batavia Country Club	Bigelow Creek	≤14†	14†	0.04
NY0073610	Barber's/Batavia Party House	Groundwater	0	0	0
NYR00D626	Hanson Aggregate Stafford Quarry	Black Creek	2.1#	21.2#	0.06

* Permits for Byron, S. Byron and N. Byron SDSTPs have been administratively combined under a single permit (NY0160971) as outfalls 001M, 002M and 003M, respectively. South Byron was previously covered under permit NY0160989.

**See Appendix B for the calculation of these loads.

†2,000 gpd at 2.3 mg/L TP. No SRP data was available. Conservatively, SRP is assumed equal to TP.

Based off of samples collected from a drainage ditch receiving the water resulting from mine dewatering (Winslow 2012).

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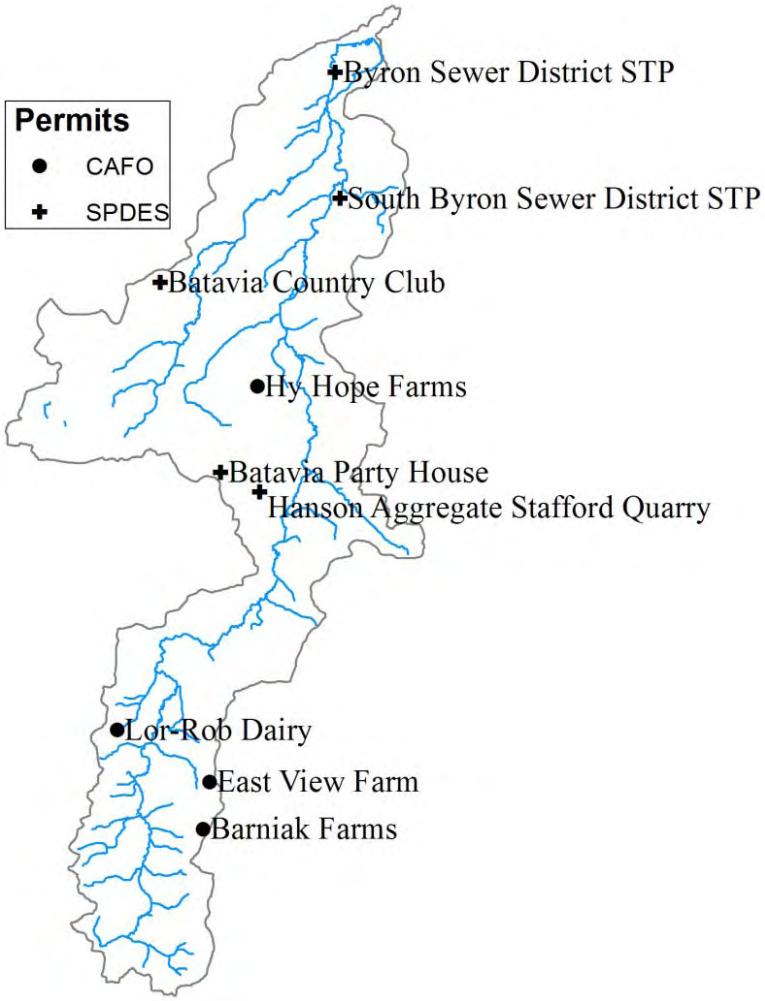

Figure 11: Location of permitted discharges within the Upper Black Creek watershed

Table 9: Upper Black Creek CAFOs

Permit	Name	Size	Mature Dairy Cattle**	Dairy Heifers**	Land Application Acres
NYA001421	Barniak Farms	Medium	620	600	1,830
NYA000271	Lor-Rob Dairy Farm	Large	2,156	1,572	2,500
NYA000102	Hy Hope Farms, Inc.	Medium	565	350	1,116
*	East View Farm	*	*	*	*

*Operates under a combined CAFO registration with Lor-Rob Dairy Farm. Animal counts combined.
**2009 data.

4.2.2 Onsite Wastewater Treatment (Septic) Systems

Nearly 95% (27,408 acres) of the UBC watershed relies upon onsite wastewater treatment systems (OWTS, also known as septic systems) for wastewater treatment. Properly operating systems dispose of wastewater to the subsurface where soils remove phosphorus. Systems may

fail for a number of reasons including: improper maintenance, poor soil permeability, insufficient distance to ground or surface waters and direct connections to surface waters.

CEI, in their preparation of the Water Quality Restoration Strategy for Upper Black Creek determined the phosphorus loads to UBC from OWTS (CEI 2011b, CEI 2011a). CEI estimated there are about 3,300 septic systems in UBC of varying age, type and level of maintenance. The following details CEI's estimates of OWTS systems within UBC (CEI 2011a):

> Following methodology of earlier New York TMDL studies approved by NYSDEC, CEI estimates that 100% of the septic systems within 50 feet of streams and 85% of the septic systems between 50 and 250 feet of streams should be categorized as substandard in some way. In addition, an estimated 15% of the septic systems greater than 250 feet from a stream are assumed to also be malfunctioning. Therefore CEI projects that a total of 627 (19%) of the 3,300 Upper Black Creek watershed septic systems are substandard. This overall percentage is similar to that reported from surveys in other states.
>
> Understanding the likely failure modes is also important. The AVGWLF model [used by CEI for the Water Quality Restoration Strategy development] provides for the following categories of substandard septic systems: direct discharge (i.e., piped directly to surface waters), short-circuiting (i.e., close proximity to surface/ground waters not allowing full treatment), and ponding (i.e. discharge to ground surface). Based on previous TMDL studies in NY, and utilizing its best judgment and understanding of the watershed, CEI estimates that:
>
> - Of the 73 systems within 50 feet of a stream, about 5% (4) were direct discharges and 95% (69) were defined as short-circuiting.
> - Of the 99 systems between 50 and 250 feet of a stream, approximately 3% (3) were direct discharges, 77% (76) were defined as short-circuiting, 5% (5) ponding, and the remaining 15% (15) were functioning normally.
> - Of the 3,127 systems greater than 250 feet of a stream, 15% (469) were estimated to be substandard, of which 1% (5) were estimated to have direct discharge, 19% (89) were ponded, and 80% (375) were short-circuited.
>
> Overall, in the Upper Black Creek watershed, approximately 627 (19%) of the estimated 3,300 Black Creek watershed septic systems were categorized as substandard, with 10 direct discharges, 96 ponded, and 521 short-circuits. Since the AVGWLF model deals with human populations, these system numbers can be converted to population numbers using the standard household size of 2.61 (2000 census).

Based on the assessment conducted by CEI, OWTS contributed about 85% of the combined OWTS and developed land annual TP load (CEI 2011b). Most of this load is assumed to be delivered as SRP however some seasonal variation in load may occur due to lower rates of failure during periods when groundwater tables are lower. OWTS were not included explicitly

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within the model used for the development of this TMDL. Their contribution is accounted for within the developed land use category. Above site BLAK-08, developed land contributes about 0.37 lb/d of the total load. If a similar percentage of the combined OWTS and developed land load is attributed to OWTS as indicated by CEI's data (85%), approximately 0.31 lb/d is attributable to OWTS at site BLAK-08. Within the Bigelow Creek watershed, developed land contributes 56% of the total load. Much of this comes from urban runoff from the developed lands in and around the City of Batavia. These lands are served by sanitary sewer and therefore do not contribute to the OWTS load. OWTS are still used within the rest of the subwatershed, thus the OWTS load for Bigelow Creek is estimated to be 0.08 lb/d based upon a similar loading rate (lb/acre/day) as observed in the rest of the watershed. Below BLAK-08 and BLOW-02 downstream to BLAK-10, developed land and OWTS contribute 0.06 lb/d, of which 0.05 lb/d is estimated to be attributable to OWTS.

4.2.3 Agricultural Runoff

Agricultural is the primary land use within UBC with row crops encompassing 10,769 acres (37.1%) of the watershed and pasture/hay encompassing an additional 9,876 acres (34.0%). These lands are estimated to contribute 1.84 lb/d of phosphorus, or about 46% of the total load at BLAK-10. Of that, 1.49 lb/d originates from above site BLAK-08. Within Bigelow Creek agricultural lands constitute about 58% of the total subwatershed area. Phosphorus loading is estimated at 0.24 lb/d during the growing season, or about 36% of the total load.

4.2.4 Urban and Residential Development Runoff

Developed land comprises 3,090 acres (10.6%) of the watershed. Of that, open space (parks, golf courses, etc.) contributes 2,022 acres (7.0%) and the remaining 1,068 acres (3.6%) are comprised of low intensity and high intensity development.

Of the 242 acres (0.8%) of high intensity development, roughly half occurs within the city of Batavia (Figure 4). The city of Batavia contains 24% of the developed land within UBC. Developed lands are estimated to contribute a combined 0.80 lb/d of phosphorus to UBC, or 20% of the total load at BLAK-10. Of that load, approximately 0.44 lb/d is attributed to OWTS, as discussed in Section 4.2.2. The remaining 0.36 lb/d is from developed lands, much of which originates from the developed lands in and around the City of Batavia, although there are sources throughout the watershed including roads and other developed areas.

4.2.5 Background

Forested land comprises 3,684 acres (12.7%) of the UBC watershed. Wetlands cover 1,464 acres (5%) of the watershed. Phosphorus contributions from natural background source areas comprised 0.05 lb/d, or 1% of the total phosphorus load at BLAK-10. Phosphorus contributions from water/wetlands and forest are considered a component of the background loading.

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4.2.6 Other Sources

Atmospheric deposition, wildlife, waterfowl, and domestic pets are also potential sources of phosphorus loading to the Creek. All of these small sources of phosphorus are incorporated into the land used loadings as identified in the TMDL analysis (and therefore are accounted for). The relative contribution of these sources is minor.

5.0 Determination of Load Capacity

The Parameter Efficient Distributed (PED) watershed model was used in combination with Macroinvertebrate Response Model to develop the Upper Black Creek phosphorus TMDL. This approach consisted of using PED to determine the growing season water volume and total phosphorus load delivered to the UBC and Macroinvertebrate Response Model to define the extent to which the watershed loads need to be reduced to meet the water quality target established in Section 3.3.

The determination of the load capacity for this TMDL uses growing season average total phosphorus concentrations and growing season median flows. The growing season was used in the analysis because this was the identified critical period characterized by high phosphorus concentrations, high temperatures (which increases productivity and decreasing dissolved oxygen [DO] saturation) and low stream flows. Outside the growing season conditions are less likely to cause impairment because of lower phosphorus concentrations, lower temperatures and higher flows. Seasonal median flow and mean phosphorus concentration were used because long term exposure to high phosphorus concentrations and low flows create the conditions for excess algal growth which decreases DO, leading to macroinvertebrate use impairment.

5.1 Model Results

The watershed model was used to estimate streamflow, sediment loads and phosphorus loads within Upper Black Creek from January 1, 1979 to April 12, 2013. Details of the model development and calibration are in Appendix C. The output of the watershed model was total phosphorus concentrations at each of the sampling locations (Figure 5) as well as locations downstream used for model development. Results from the phosphorus model for 2010 to 2012 are shown in Figure 12 for site BLAK-10. This site was one of the most data rich sites with total phosphorus (TP) and soluble reactive phosphorus (SRP) measurements during the summer of 2012 made by NYSDEC and from June 2010 to June 2012 made by Winslow (2012). Overall the model does a good job of predicting phosphorus concentrations. There is some indication that the model over predicts the concentration during dry events e.g. August 2012. This is an artifact of the hydrology model which tends to under predict stream flow during very dry periods, yielding less water available for dilution of point source loads.

While the focus of this study was on the growing season, others have modeled Upper Black Creek and reported total phosphorus loads on an annual basis. The annual loads predicted by this

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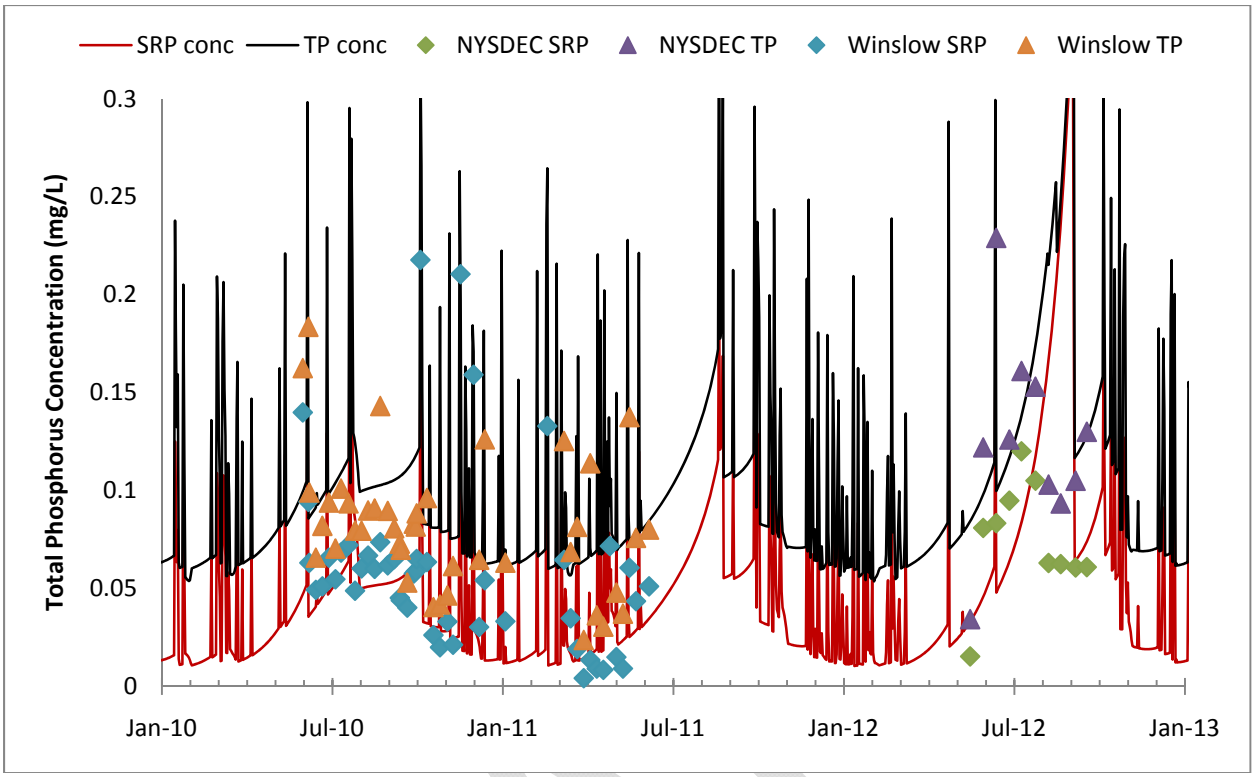

Figure 12: Time series of modeled total phosphorus (TP) and soluble reactive phosphorus (SRP) at BLAK-10 and corresponding measured concentrations.

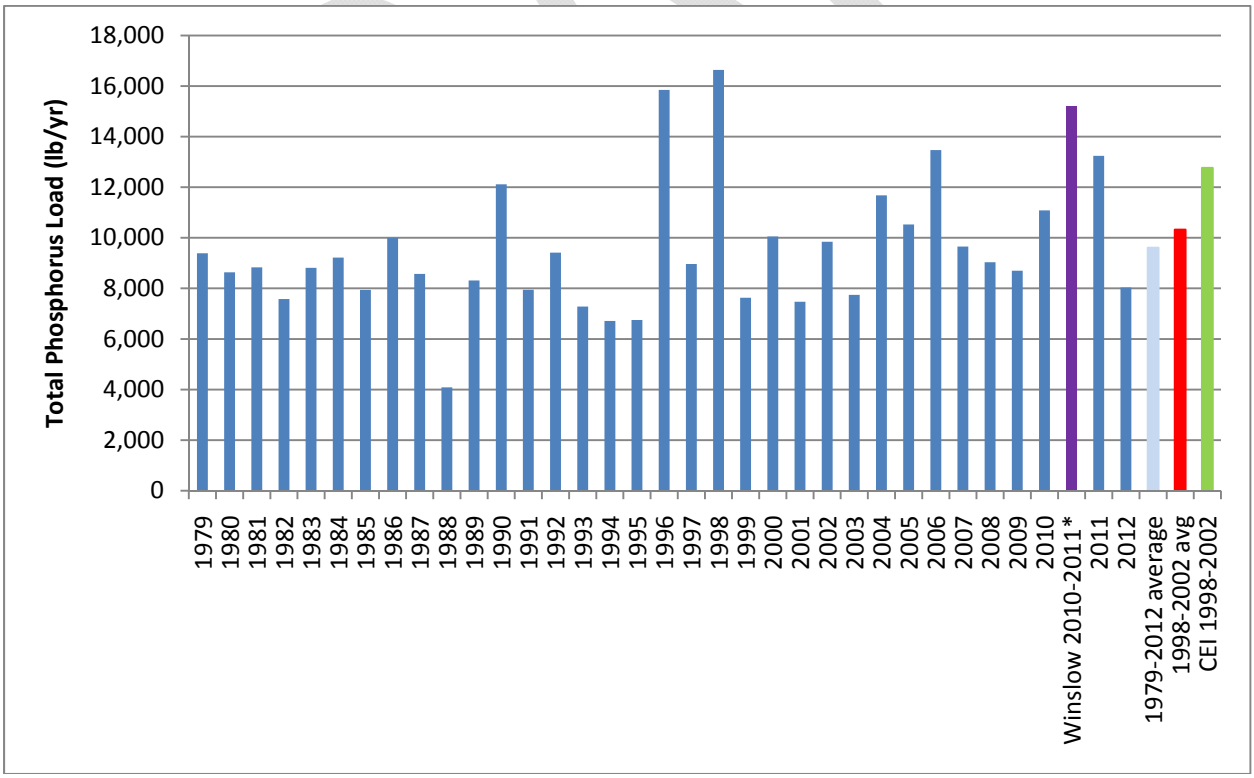

Figure 13: Annual phosphorus loads from this (blue) and other studies. *The data from Winslow (2012) covered June 2010 to June 2011.

model and several others (Winslow 2012, CEI 2011b) are shown in Figure 13 for the sake of comparison. The load predicted by Winslow for June 2010 to June 2011 is somewhat higher than the load from this study for either 2010 or 2011 although because of the different timeframes a direct comparison is not possible. CEI also modeled the watershed from 1998-2002 and produced a modeled load of 12,769 lb/yr. For the same time period the PED modeled TP load was 10,328 lb/yr, a difference of about 20%. CEI used a different numerical model which was calibrated using data from the USGS gage in Churchville so some discrepancy between the different models is expected.

The phosphorus model used for this TMDL has significant annual variation in load in response to different weather patterns. Dry years resulted in less delivered phosphorus (2008) while wet years resulted in greater phosphorus loads (1996, 1998).

Loading capacities of UBC and Bigelow Creek were determined using the growing season hydrology model results from 1979 through 2012. The growing season average target concentrations (Table 6) were used to determine growing season load capacities. The target concentrations were the concentrations determine by the macroinvertebrate response model (Section 3.2.4) which would result in use attainment through phosphorus reductions alone.

5.2 Load Duration Curves

Duration curves are useful when there is a correlation between water quality impairments and flow conditions. The U.S. EPA has prepared guidance for using load duration curves (LDCs) in the development of TMDLs (U.S. EPA 2007). LDCs are developed using time series of flow data and water quality data. Flow data may be measured or modeled. For TMDL development the water quality endpoint is a water quality standard or other water quality target. The LDC is developed by multiplying the stream flow by the water quality target, yielding an allowable load that is a function of stream flow. By using the flow time series to calculate flow percentiles, the duration curve identified how often a given flow, and therefore load, can occur.

LDCs may be developed for the entire year or may focus on smaller time periods such as seasons or months. For this TMDL the focus is upon reducing total phosphorus concentrations in the stream during the growing season, defined here as June through September. Flow and concentration data from the growing season were used to develop the LDCs. Focusing upon this period ensures that sufficient reductions will occur during the typical growing season flows when the impact upon the macroinvertebrates is the greatest.

Load capacities at three separate sites within UBC were determined for this TMDL. BLAK-10 is the bottom of the UBC watershed and was the assessment point which resulted in UBC being listed on the 303(d) list. Bigelow Creek also appears on the 303(d) list, thus the load capacity at BLOW-02 was determined in order to prepare a TMDL for this waterbody as well. The load capacity at BLAK-08 was also calculated as BLAK-08 is above the confluence of Upper Black and Bigelow Creeks. Development of a separate load allocation for the area above BLAK-08 will ensure sufficient load reduction occurs within the upper part of the watershed.

The growing season total phosphorus load duration curve for BLAK-10 is shown in Figure 14. The x-axis is the flow duration interval (FDI) : the fraction of time a given flow is met or

exceeded. Low FDI values (approaching 0) correlate to high flows; high values (approaching 1) correlate to low flows. During the growing season high flows are due primarily to summer storms. Note actual flows are not shown in the figure. Rather, the y-axis is the associated total phosphorus load in lb/d for a given flow. The blue solid line is the modeled 1979-2012 growing season load. At the 50th percentile flow, the modeled phosphorus load is 3.99 lb/d. The *NYSDEC 2012* data points are the phosphorus loads calculated based upon the samples collected during summer 2012 as part of this TMDL. Data points labeled *Winslow* are the total phosphorus loads calculated using the phosphorus samples collected by M. Winslow from June 2010 through June 2011 (Winslow 2012). Only those samples which fall within the June-September growing season are shown. The load attributed to the Byron SDSTP is shown by the *Byron SDSTP current* line. Only at the lowest flows (flow duration approaching 1) does the Bryon SDSTP contribute most of the load at BLAK-10. Such low flows are not generally sustained for long periods of time. Given the conceptual model (Appendix A.1) the impact of short term high phosphorus concentration upon the macroinvertebrate population is minimal.

In Figure 14 the BLAK-10 target load (blue dashed line) is the total phosphorus load based upon meeting the total phosphorus target of 0.121 mg/L identified in Table 6. At low flows UBC provides dilution for point source discharges while at higher flows UBC may be impacted by nonpoint sources of total phosphorus. It is recognized that at the lowest flows, flow duration interval approaching 1, the point sources contribute more phosphorus than the stream can

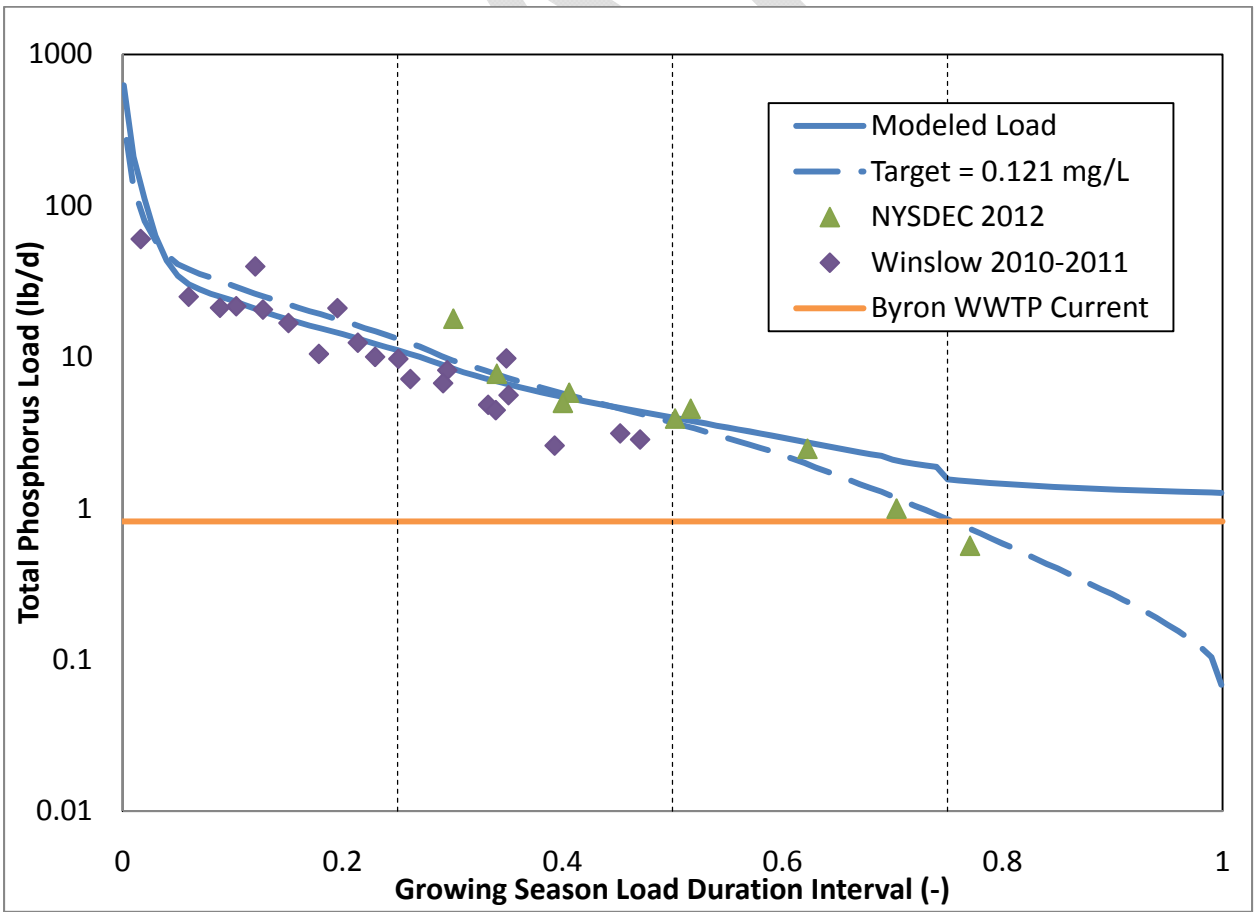

Figure 14: Growing season total phosphorus load duration curve for BLAK-10

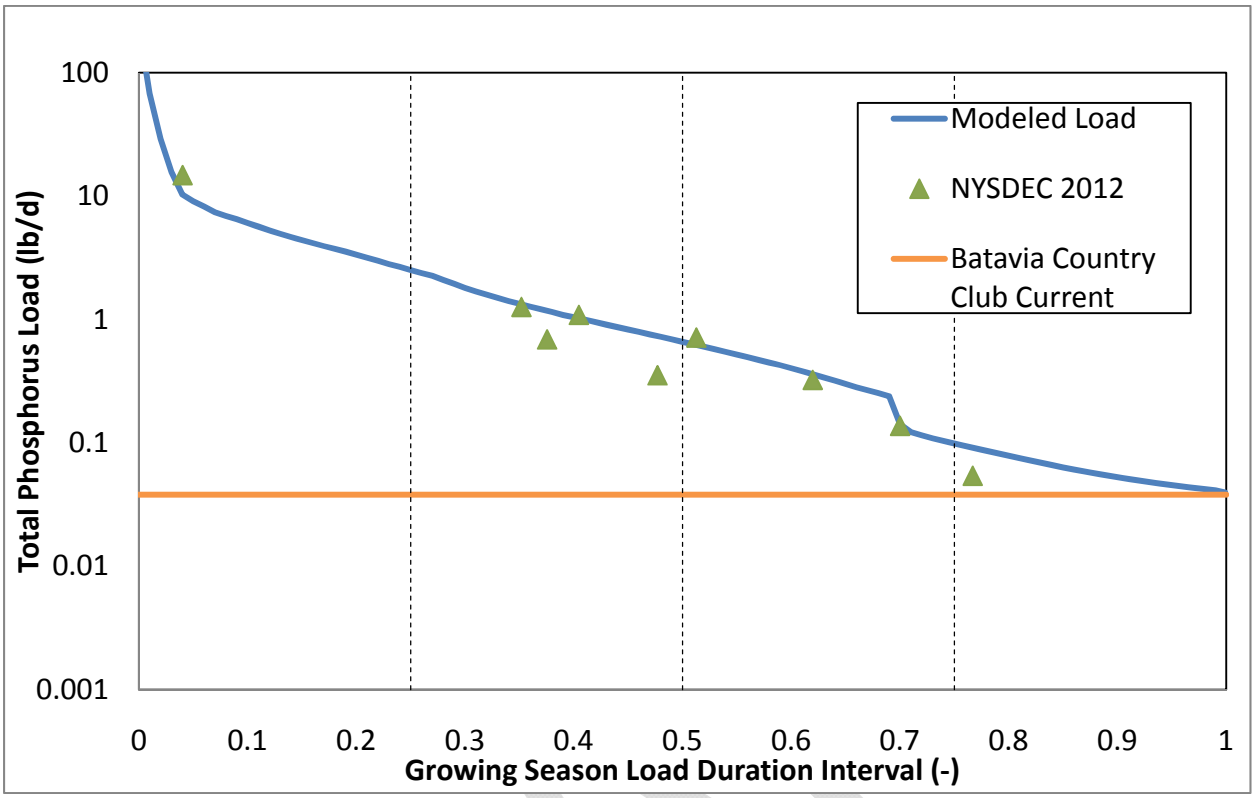

Figure 15: Total phosphorus load duration curve for Bigelow Creek during the growing season.

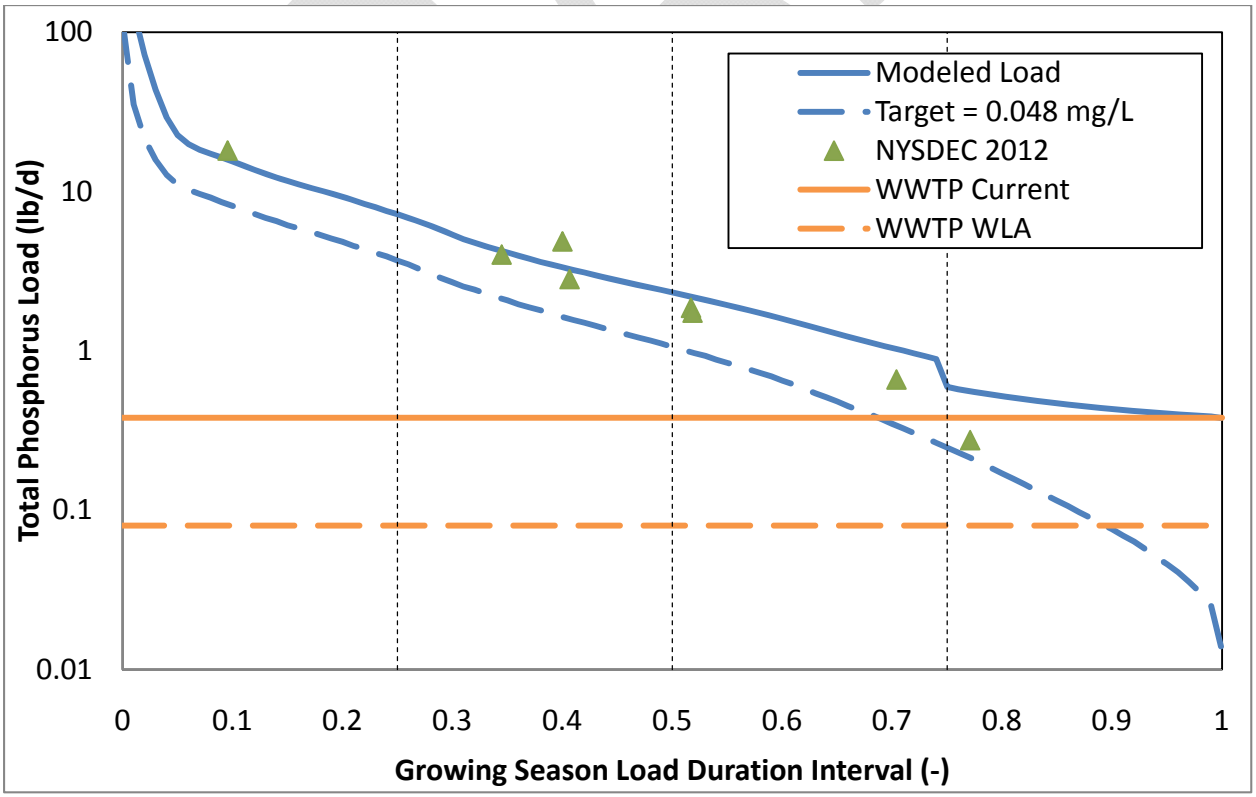

Figure 16: Growing season total phosphorus load duration curve for BLAk-08

Table 10: Growing season load reductions needed at each site to achieve target loads.

	Current load (lb/d)	TMDL target load (lb/d)	Percent Reduction
BLAK-08	2.33	1.06	55%
BLOW-02	0.66	0.66	0%
BLAK-10	3.99	3.70	7%

assimilate. Such low flows occur infrequently and are typically not sustained for long periods of time. Short periods of high phosphorus concentrations are unlikely to cause significant impacts. Thus, a longer, average flow was used for the loading capacity analysis, which was conducted using the 50th percentile growing season flow. This is representative of average conditions during the critical period. As the growing season average concentration was used in the endpoint development, average flow conditions were used to determine the average target load.

Load duration curves for BLOW-02 and BLAK-08 are shown in Figures 15 and 16, respectively. The current load and target load for each site are listed in Table 10.

6.0 Pollutant Load Allocation

Separate load allocation tables have been developed for the three identified reaches. Allocations for the headwaters of UBC to site BLAK-08 (Table 11, Figure 17), Bigelow Creek (Table 12, Figure 18) and for the area between the confluence of Upper Black and Bigelow Creeks downstream to site BLAK-10 (Table 13, Figure 19) are below. Allocations for UBC at BLAK-08 and Bigelow Creek appear in the TMDL allocation table for BLAK-10 as part of the load allocation.

Table 11: TMDL allocations from the headwaters to BLAK-08 in order to meet a phosphorus reduction target of 0.048 mg/L.

Source	Growing Season Total Phosphorus Load (lb/d)			% Reduction
	Current	Allocated	Reduction	
Background (forest and water/wetland)	0.03	0.03	0	0%
Agriculture	1.49	0.65	0.84	56%
Developed land including septic systems	0.37	0.19	0.18	49%
LOAD ALLOCATION	**1.89**	**0.87**	**1.02**	**54%**
S. Byron SDSTP (NY0160971 002M)	0.38	0.08	0.30	79%
Hanson Aggregate Stafford Quarry (NYR00D626)	0.06	0.06	0	0%
WASTE LOAD ALLOCATION	**0.44**	**0.14**	**0.30**	**68%**
WLA + LA	2.33	1.01	1.32	57%
MARGIN OF SAFETY (5%)	-	0.05	-	-
TOTAL	2.33	1.06	1.27	55%

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Table 12: TMDL allocations for Bigelow Creek from headwaters to BLOW-02 in order to meet a total phosphorus target of 0.083 mg/.

Source	Growing Season Total Phosphorus Load (lb/d)			% Reduction
	Current	Allocated	Reduction	
Background (forest and water/wetland)	0.01	0.01	0	0%
Agriculture	0.24	0.21	0.03	13%
Developed land including septic systems	0.37	0.33	0.04	11%
LOAD ALLOCATION	**0.62**	**0.55**	**0.07**	**11%**
Batavia Country Club (NY0159069)	0.04	0.04	0	0%
WASTE LOAD ALLOCATION	**0.04**	**0.04**	**0**	**0%**
WLA + LA	0.66	0.59	0.07	11%
MARGIN OF SAFETY (10%)	-	0.07	-	-
TOTAL	0.66	0.66	0	0%

Table 13: TMDL allocations for Upper Black Creek at BLAK-10 in order to meet a phosphorus reduction target of 0.121 mg/L.

Source	Growing Season Total Phosphorus Load (lb/d)			% Reduction
	Current	Allocated	Reduction	
Background (forest and water/wetland)	0.01	0.01	0	0%
Agriculture	0.11	0.11	0	0%
Developed land including septic systems	0.06	0.06	0	0%
Load from UBC at BLAK-08**	2.33	1.01	1.32	57%
Load from Bigelow Creek**	0.66	0.59	0.07	11%
LOAD ALLOCATION	**3.17**	**1.78**	**1.39**	**44%**
Byron SDSTP (NY0160971 001M)	0.82	0.82	0	0%
WASTE LOAD ALLOCATION	**0.82**	**0.82**	**0**	**0%**
WLA + LA	3.99	2.60	1.39	35%
MARGIN OF SAFETY (30%)	-	1.10	-	-
TOTAL	3.99	3.70	0.29	7%

**Percent reductions to point and nonpoint sources are the same as those called for at these upstream sites (Table 11 and Table 12)

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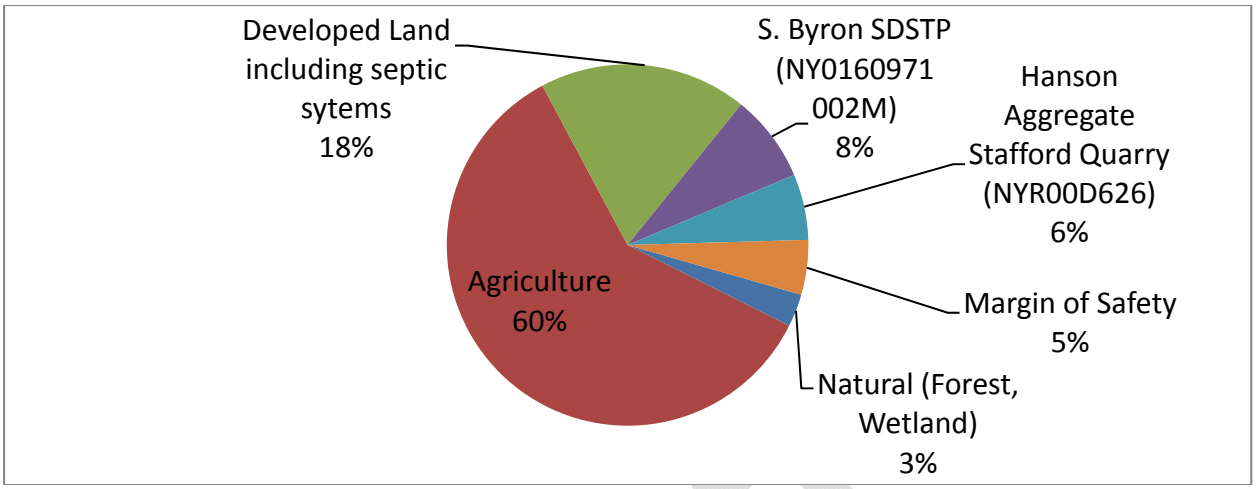

Figure 17: Total phosphorus load allocations at BLAK-08

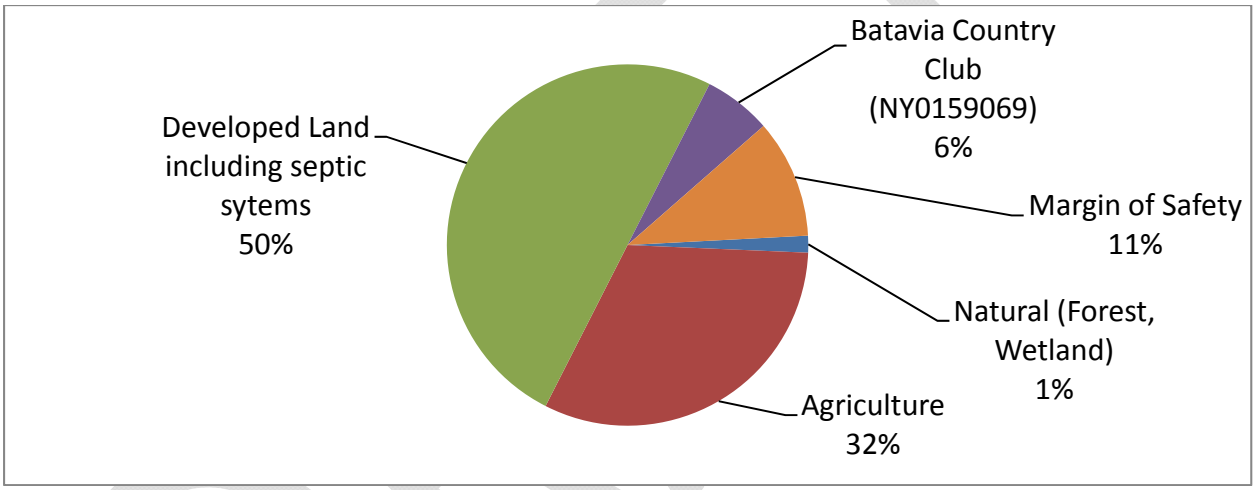

Figure 18: Total phosphorus load allocations at BLOW-02

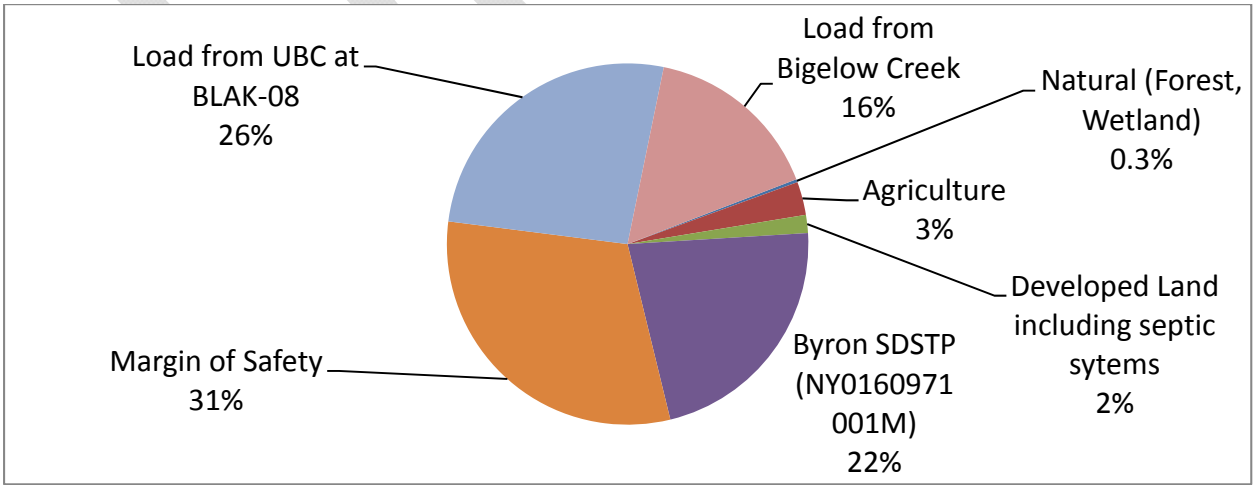

Figure 19: Total phosphorus load allocations at BLAK-10

Allocations at each site were developed based upon meeting the phosphorus reduction targets identified in Table 6 which assumed only phosphorus reductions without any improvements to the stream corridor. Restoration practices which increase the total riparian width or decrease the amount of fine particulate are predicted to increase the allowable amount of total phosphorus while still being able to attain all of the identified best uses for these waterbodies. This would in turn increase the total maximum daily load and decrease the overall amount of phosphorus reductions required. A stream restoration based approach to meeting the endpoint of this TMDL is discussed further in 7.1.

6.1 Waste Load Allocation

Growing season waste load allocations (WLAs) have been set for each of the 3 reaches. At BLAK-08 the WLA is 0.14 lbs/d during the growing season, split between the S. Byron SDSTP and the Hanson Aggregate Stafford Quarry. In Bigelow Creek the WLA is 0.04 lbs/d during the growing season, allocated to the Batavia Country Club. At BLAK-10 a WLA of 0.82 lbs/d during the growing season is allocated to the Byron SDSTP. In the BLAK-08 reach load reduction will be required from the S. Byron SDSTP. Reductions from the other permitted point sources are not needed in order to meet the TMDLs for those reaches. Reductions from the quarry will not be required as the water discharged from the mine in reflective of background conditions.

6.1.1 Byron SDSTP (NY0160971 001M)

No load reduction is needed at this time in order to meet the target total phosphorus concentration identified in Table 6. Monitoring of total phosphorus will be incorporated into this facility's SPDES permit upon approval of this TMDL. Load from this facility will be capped at the amount identified in Table 13. The facility will be given three years following TMDL approval to come into compliance with the specified load cap. This will allow for better characterization of their effluent and, if necessary, time to come into compliance with the WLA. Additional load reductions from the S. Byron SDSTP beyond what is specified in this TMDL may also be credited towards this facility. Load reductions achieved at the Byron SDSTP may not be credited towards the S. Byron SDSTP.

6.1.2 South Byron SDSTP (NY0160971 002M)

The WLA for the South Byron SDSTP is equivalent to achieving 0.6 mg/L TP at the growing season average flow of 0.0159 MGD, yielding a WLA of 0.08 lbs/d of TP. While the TMDL is targeting the June through September growing season, the permit will include TP limits from June 1 through October 31 to be consistent with existing seasonal limits. This will extend the period of TP reduction one month beyond the period established by the TMDL. To allow time to identify and implement treatment technologies which are effective for small plants such as this, the WLA indicated in Table 11 will take effect ten years following approval of this TMDL. This period will also allow for an adaptive management approach which may reduce some or all of the load reduction required from this facility. A compliance schedule will be included in the facility permit upon TMDL approval. This WLA may be changed in the future via a TMDL

revision if, prior to achievement of the indicated WLA, subsequent assessments of Upper Black Creek indicate no use impairments as determined by a BAP ≥ 5. Any such revisions to the approved TMDL would need to be approved by the U.S. EPA.

6.1.4 Other Point Sources

Hanson Aggregate Stafford Quarry accounts for 0.06 lbs/d of TP during the growing season. Water discharge from the mine contains approximately 20 µg/L of TP, significantly less than found in the receiving water and generally reflective of natural background concentrations of TP. Due to the relatively small contribution of this discharge to Upper Black Creek and the lack of cost effective means for phosphorus control for this discharge, no reductions are proposed. Under the proposed allocations, the discharge will contribute 6% of the growing season TP load at BLAK-08.

As Bigelow Creek was found to meet the aquatic life use criteria of a BAP score of 5 or greater, no reduction from the Batavia Country Club load is specified in Table 12. This discharge will contribute 6% of the load to Bigelow Creek under the TMDL. Monitoring of TP will be incorporated into this facility's permit upon approval of this TMDL. Trading and offsets with the nonpoint source sector in Bigelow Creek will be considered for this facility.

6.2 Load Allocation

The load allocations (LA) for the segments are 0.87 lbs/d, 0.55 lbs/d and 1.74 lbs/d during the growing season for UBC above BLAK-08, Bigelow Creek, and UBC above BLAK-10, respectively. The LA for BLAK-10 incorporates incoming loads from the upstream BLAK-08 and BLOW-02 reaches. Excluding the upstream contributions, nonpoint sources contribute 0.18 lb/d of TP to BLAK-10. Nonpoint sources that contribute total phosphorus to Upper Black Creek include loads from natural sources (including forested lands, wetlands and stream banks), developed lands, on-site wastewater treatment systems, and agricultural lands.

Phosphorus originating from natural sources is a minor source and is assumed unlikely to be reduced further. Therefore the load allocations for these sources are set at the current loading.

6.2.1 Developed Lands Including Onsite Wastewater Treatment Systems

The LAs for the developed lands including onsite wastewater treatment (septic) systems are 0.37 lbs/d (19% of the total load) for BLAK-08, 0.33 lbs/d (50%) for Bigelow Creek, and 0.06 lbs/d (2%) for BLAK-10. Reductions are sought from the developed lands within each of the watersheds in order to meet the overall load reductions needed.

6.2.2 Agricultural Lands

Agricultural lands represent a significant non-point source of load to all regions of Upper Black and Bigelow Creeks. The LA for agriculture at BLAK-08 is 0.65 lbs/d, or 61% of the allowable load. In Bigelow Creek the agriculture LA is 0.21 lbs/d (32%) and at BLAK-10 is 0.11 lbs/d (3%).

6.3 Margin of Safety

A margin of safety (MOS) can be implicit (incorporated into the TMDL analysis through conservative assumptions) or explicit (expressed in the TMDL as a portion of the loadings) or a combination of both. An implicit MOS can be provided by making conservative assumptions at various steps in the TMDL development process (e.g., by selecting conservative model input parameters or a conservative TMDL target).

A MOS of 5% was specified at BLAK-08. A smaller than typical MOS was specified because recent historic data (Table 5) indicated this reach was in attainment of the aquatic life best use. Substantial load reductions are still being specified from this reach based upon the 2012 assessment.

In Bigelow Creek no load reductions were specified because the reach was found to meet the aquatic life best use during the 2012 assessment. To ensure the reach continues to meet this best use, a fraction of the current loading is being set aside. A MOS of 10% has been included in the analysis.

At BLAK-10 reductions from the Bigelow Creek and BLAK-08 reaches reduced loading below the amount needed to attain the TP target specified in Table 6. The extra capacity was assigned to the MOS. At 30%, the MOS is larger than typically specified but is justified because: 1) historic assessments (Table 5) indicate the BAP score may be lower than measured in 2012 and 2) meeting the TMDL at BLAK-10 relies upon upstream load reductions but in-stream attenuation of phosphorus is not considered in the load calculations.

6.4 Critical Conditions

Critical conditions for this TMDL have been identified as the typical (median) flow conditions during the growing season. During this period high phosphorus loads from agricultural activities coupled with low summer flows available for point source effluent dilution result in high phosphorus concentrations in the stream. Lower dissolved oxygen (DO) saturation concentrations due to increased temperature coupled with increased algae growth as a result of the increased phosphorus concentrations and temperatures will result in diel changes in DO concentrations. Short term fluctuations of low flow or high phosphorus concentrations are less critical as these transient conditions do not have large impacts upon the algae grow out behavior which creates the aquatic life best use impact. Protection of the best uses during the critical growing season will ensure that these best uses are also met during other conditions when flows are greater and phosphorus concentrations are lower.

The sampling associated with the development of this TMDL occurred during what was later identified as a dry year. The MA7CD10 (7 day average flow with a 10 year recurrence interval) flow value at the Churchville gage (USGS gage 04231000) is 1.55 cfs, based upon data from 1/1/1964 to 4/12/2013. Low flows of 1.7 and 1.8 cfs were measured on 7/21/12 and 9/4/12, respectively, at the Churchville gage. As part of 7, 30, and 90 day averages, these low flows corresponded to approximately 5 year, 5 year, and 3 year return frequencies. As the USGS gage is located below the Churchville dam, flows measured by the gage may be augmented by the

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storage capacity behind the dam during periods of dry weather. Above the dam stream flows may have been more severely impacted by the dry conditions. This is supported by field observations on 7/25/12 when the sampling personnel observed dry conditions at all sampling sites except BLAK-09, BLAK-10 and BLOW-02.

6.5 Seasonal Variation

As this TMDL is focused on the growing season, substantial seasonal variation within this period is not anticipated during typical base flow conditions. These flows formed the basis upon which the macroinvertebrate response model, and therefore TP targets, was based upon. Those loads which are delivered during the June through September period each year were identified as having the greatest impact upon that year's macroinvertebrate community. Some seasonality is anticipated within the growing season time frame due to differing weather patterns from year to year. This is taken into account by using multiple years of modeled hydrology and phosphorus results within the analysis.

7.0 Implementation

One of the critical factors in the successful development and implementation of TMDLs is the identification of potential management alternatives, such as best management practices (BMPs) and the screening and selection of final alternatives in collaboration with the involved stakeholders. Development of this TMDL is aided by the parallel development of a Black Creek Watershed Management Plan by the Genesee/Finger Lakes Regional Planning Council[2]. The Black Creek Watershed Characterization Report was recently released (Genesee/Finger Lakes Regional Planning Council 2012) and work on the Management Plan in ongoing. The plan will serve to build consensus among watershed municipalities, State agencies, non-governmental organizations and the public on the short and long term actions needed to protect and restore water quality and quantity in the watershed. NYSDEC, in coordination with these local interests, will address the sources of impairment using regulatory and non-regulatory tools by matching management strategies with sources and aligning available resources to support implementation.

NYSDEC recognizes that TMDL designated load reductions alone may not be sufficient to address all concerns of nutrient driven impairment within streams. The TMDL establishes the required nutrient reduction targets and provides some regulatory framework to effect those reductions. However, the nutrient load only affects the potential for impairment. The implementation plan therefore calls for the collection of additional monitoring data, as discussed in Section 7.3, to determine the effectiveness of nutrient reduction management practices.

7.1 Stream Restoration Approach to Implementation

The macroinvertebrate response model (Section 3.2.4) indicates that the macroinvertebrate community, as assessed by the BAP score, is influenced by total phosphorus (TP) concentrations, total riparian width (TRW) and fraction of fines in the riffle (FFR). Restoration of the best uses

[2] http://www.gflrpc.org/blackoatka htm

of UBC may therefore be attained by influencing any or all of those parameters. Implementation of practices which, for example, reduce TP and increase TRW, may be more cost effective than practices which reduce TP alone.

Table 6 listed the TP targets in order to reach BAP ≥ 5 through TP reductions alone. A more holistic, watershed based approach would reduce TP while simultaneously increasing TRW and decrease FFR. Thus, for each site, improvements in TRW or FFR may reduce the amount of TP reduction needed. Conceptually, this is demonstrated in the following tables for BLAK-08 (Table 14), BLOW-02 (Table 15), and BLAK-10 (Table 16). In each table the current condition based upon the 2012 measured values for FFR, TP and TRW are in the upper right corner of the table in bold. Combinations of TP, TRW and FFR which result is BAP ≥ 5 are shaded in dark gray. At BLAK-08 (Table 14) for example, to achieve a BAP ≥ 5, TRW could be increased to 25 m, TP could be reduced to 0.048 mg/L, or some combination of both, such as increasing TRW to 25 m and decreasing TP to 0.08 mg/L.

Table 14: The macroinvertebrate response model indicates that the BAP score is influenced by the total phosphorus (TP) concentration, total riparian width (TRW) and fraction of fines in the riffle (FFR). The table indicates the degree to which TP, TRW, or both would need to be changed in order to achieve a BAP score of 5 or greater (cells shaded dark gray), assuming FFR remains constant. The position of BLAK-08 in the table as assessed in 2012 is TP = 0.093 mg/L, TRW = 18 m and FFR = 0.3 (upper right corner in bold). Light gray shaded cells indicate those additional cells which become acceptable restoration targets with a reduction of FFR by 0.05.

FFR = 0.30	Total Phosphorus (mg/L)						
Total Riparian Width (m)	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.09**	**0.093**
18	5.1	4.9	4.8	4.6	4.4	4.3	**4.21**
20	5.3	5.1	4.9	4.8	4.6	4.4	4.4
25	5.8	5.6	5.4	5.2	5.1	4.9	4.8
30	6.2	6.1	5.9	5.7	5.5	5.4	5.3

Table 15: Similar to Table 14, except for site BLOW-02. The 2012 assessment found this site to already have a BAP score greater than 5. Improvements to the stream corridor could still result in a greater BAP score as shown indicated.

FFR = 0.39	Total Phosphorus (mg/L)					
Total Riparian Width (m)	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.082**
20	6.0	5.8	5.6	5.4	5.3	**5.22**
25	6.4	6.2	6.1	5.9	5.7	5.7
30	6.9	6.7	6.5	6.3	6.2	6.1

Table 16: Similar to Table 14, except for site BLAK-10

FFR = 0.30	Total Phosphorus (mg/L)		
Total Riparian Width (m)	**0.11**	**0.12**	**0.124**
20	5.2	5.0	**4.95**
25	5.6	5.5	5.4

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In all of the tables FFR is held constant at the value measured in 2012. However, as many management practices which reduce TP or increase TRW will also decrease FFR, additional combinations of TP and FFR result in BAP ≥ 5 if FFR is also reduced. In each of the tables, those additional cells which become acceptable restoration targets due to a reduction in FFR of 0.05 are shaded in light gray. At site BLAK-08 (Table 14) a reduction of FFR by 0.05 would make the following additional conditions viable restoration targets: (TP = 0.05 mg/L, TRW = 18 m, FFR = 0.25), (0.06 mg/L, 20 m, 0.25), (0.09 mg/L, 25 m, 0.25) and (0.093 mg/L, 25 m, 0.25).

NYSDEC was recently awarded a 2013 Sustain Our Great Lakes grant to support a "Trees for Tribs" program to restore 30,000 linear feet of riparian buffer. The program will plant a minimum of 15,000 trees and shrubs throughout high priority stretches of tributaries to the Genesee River basin. The stream restoration strategy outlined in this section aligns well with the goals of the "Trees for Tribs" program. All qualified parties are urged to take full advantage of the opportunity provided by this grant to establish or improve riparian buffers along Upper Black and Bigelow Creeks.

7.1.1 Implementation at BLAK-03

One site that were assessed during the 2012 field sampling should be noted specifically with respect to implementation, site BLAK-03. The macroinvertebrate population at BLAK-03 was found to be severely impacted (Figure 6) despite relatively low phosphorus concentrations (Table 4). The site overall had poor habitat. It was characterized by a deepened, straight, and over wide channel creating lentic (ponded) conditions favorable for stream warming and primary production. Large growths of filamentous green algae were observed throughout the summer growing season. Further, the site had little to no riparian buffer or canopy, undercut and eroding banks, and high amounts of fine sediment on the bed. The site was located just downstream of significant agricultural operations including a CAFO and row crops. The altered stream reach extends roughly 200 feet upstream and 400 feet downstream from the sampling location (Figure 5). Due to the location of BLAK-03 in the headwaters of UBC, this TMDL does not directly address this site. However, severe impacts were observed. The reach of river surrounding BLAK-03 would be an excellent candidate for an extensive stream restoration approach including riparian buffers, stream stabilization and agricultural practice BMPs.

7.2 Reasonable Assurance for Implementation

This TMDL was written with waste load allocations for one publically owned wastewater treatment plant and substantial load reductions from agriculture, onsite wastewater treatment (septic) systems and developed land above BLAK-08. Lesser nonpoint source reductions are also specified throughout the rest of the watershed. Meeting the necessary load reductions using this approach is the most technically achievable and financially viable. Reasonable assurance of meeting the TMDL is provided by requiring load reductions from the point sources, which are the most direct and verifiable, along with significant reductions from nonpoint sources. An adaptive management approach is proposed for the implementation, with an initial focus on nonpoint source controls and stream corridor restoration coupled with additional monitoring.

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Load reduction from point source will require sufficient time to identify and implement an appropriate treatment. Point source loads will be held constant initially and stream corridor restoration may reduce the overall reduction required. With approval from NYSDEC, required point source reductions could be offset by additional nonpoint source controls and/or stream restoration practices. Monitoring will be needed to ensure sufficient amounts of phosphorus removal and stream corridor restoration occur in order to meet the endpoint of this TMDL.

7.2.1 Recommended Phosphorus Management Strategies for Onsite Wastewater Treatment (Septic) Systems

A systematic approach, such as the formation of a management district, may be beneficial to achieving the load reductions specified above. New York State had begun to offer funding for the abatement of inadequate onsite wastewater treatment systems through the development and implementation of a septic system management program by a responsible management entity. Municipal sewer system expansion should be investigated for high priority areas including those developed areas along the Black Creek stream corridor in the vicinity of the Byron and South Byron SDSTP, the remaining areas of development within the town of Batavia and those areas where a large number of failing onsite systems have been identified.

The New York State Household Detergent and Nutrient Runoff Law became effective on August 14, 2010 which prohibits the sale of automatic dishwasher detergent for household use that contains more than 0.5% phosphorus by weight. Similar prohibitions for commercial establishments became effective July 1, 2013 (Environmental Conservation Law [ECL] § 35). Studies show that this measure could reduce the phosphorus content of domestic sewage by approximately 10%.

Genesee County is developing a GIS database to track the location and maintenance information associated with these systems (Genesee/Finger Lakes Regional Planning Council 2012). Additional effort should be made to verify failing systems requiring replacement in accordance with the State Sanitary Code. State funding is also available for a voluntary septic system inspection and maintenance program or a septic system local law requiring inspection and repair. Property owners should be educated on proper maintenance of their septic systems and encouraged to make preventative repairs.

To further assist municipalities, NYSDEC in involved in the development of a statewide training program for onsite wastewater treatment system professionals. A largely volunteer industry group called the Onsite Wastewater Treatment Training Network (OTN) has been formed. NYSDEC provides financial support and staff support to OTN.

7.2.2 Recommended Phosphorus Management Strategies for Wastewater Treatment Facilities

WLAs for the Byron and S. Byron SDSTPs will be expressed in their SPDES permits as a seasonal (June – October) average load, expressed in pounds per day. It is recognized that the treatment processes at the South Bryon SDSTPs, household septic tanks followed by a communal sand filter, cannot easily incorporate phosphorus controls. However, the need to

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reduce phosphorus concentrations in the effluent from the STP is also clearly demonstrated in this TMDL. A compliance schedule will be built into the permit for this facility to allow time to identify and implement an appropriate phosphorus control (Table 17). Control measures could take the form of regionalization of the wastewater treatment, perhaps including the Byron, North Byron, South Byron and the Bergen treatment plants. Other options may include tertiary treatment wetlands, land application or other innovative phosphorus removal techniques.

The macroinvertebrate response model indicated that higher concentrations of TP in UBC may be allowable if improvements to the stream corridor are made, particularly increasing riparian buffer widths and decreasing the amount of fines found in riffles (Section 7.1). Sufficient restoration of the riparian corridor may alleviate some of the burden on the STP by allowing higher concentrations of TP than the targets indicated in Table 6, upon which the TMDL allocations of Table 11 are based. It is not expected that stream corridor restoration will remove the need for phosphorus reduction from the STP entirely, but it may be more cost effective to implement some intermediate form of phosphorus control coupled with stream corridor restoration activities rather than trying to reduce TP alone. As the goal of this TMDL is to restore best uses as assessed by the macroinvertebrate community, attainment of this goal and delisting from the 303(d) list will be based upon achieving a BAP score of 5 or greater. If this is demonstrated to have occurred to the satisfaction of NYSDEC prior to the STP achieving the Waste Load Allocations, NYSDEC can revise this TMDL to reduce the burden upon the STP. Such a revision would need to be approved by the U.S. EPA, and would only occur after substantial BMP implementation throughout the watershed.

As the South Byron SDSTP is upstream of the Byron SDSTP, reductions in phosphorus load from S. Byron beyond what is specified in Table 11 may be credited towards the WLA for the Byron SDSTP (Table 13) should additional capacity be needed now or in the future. Additional reductions from the S. Byron SDSTP will have benefits within the local area of the outfall as well as downstream at the outfall for the Bryon SDSTP, hence the allowable transfer of credits from the S. Byron SDSTP to the Byron SDSTP. Load reductions at Byron SDSTP may not be credited towards the S. Byron SDSTP as there would be no upstream benefit.

At this time there appears to be no reasonable options for reducing the phosphorus load from the Hanson Aggregate Stafford Quarry dewatering operations. Phosphorus concentrations in the water pumped out of the quarry, at approximately 20 µg/L, is already at the current limit of technology for phosphorus removal. Furthermore, no phosphorus is added to the water removed from the quarry, thus the concentration is reflective of background conditions for that area.

Table 17: Milestones for achieving the WLAs for the S. Byron SDSTPs.

Milestone	**S. Byron SDSTP (years following TMDL approval)**
Complete study of potential options	3
Submit final designs for approval	5
Achieve WLA	10

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7.2.3 Recommended Phosphorus Management Strategies for Agricultural Runoff

The New York State Agricultural Environmental Management (AEM) Program was codified into law in 2000. Its goal is to support farmers in their efforts to protect water quality and conserve natural resources while enhancing farm viability. AEM provide a forum to showcase the soil and water conservation stewardship farmers provide. It also provides information to farmers about Concentrated Animal Feeding Operations (CAFO) regulatory requirements, which helps to assure compliance. Details of the AEM program can be found at the New York State Soil and Water Conservation Committee (SWCC) website, http://www.nys-soilandwater.org/aem/index.html.

Using a voluntary approach to meet local, state and national water quality objectives, AEM has become the primary program for agricultural conservation in New York. It also has become the umbrella program for integrating/coordinating all local, state and federal agricultural programs. For instance, farm eligibility for cost sharing under the SWCC Agricultural Non-point Source Abatement and Control Grants Program is contingent upon AEM participation.

AEM core concepts include a voluntary and incentive-based approach, attending to specific farm needs and reducing farmer liability by providing approved protocols to follow. AEM provides a locally led, coordinated and confidential planning and assessment method that addresses watershed needs. The assessment process increases farmer awareness of the impact farm activities have on the environment and by design encourages farmer participation which is an important overall goal of this implementation plan.

The AEM program relies on a five-tiered process:

- Tier 1 – Survey current activities, future plans and potential environmental concerns.
- Tier 2 – Document current land stewardship; identify and prioritize areas of concern.
- Tier 3 – Develop a conservation plan, by certified planners, addressing areas of concern tailored to farm economic and environmental goals.
- Tier 4 – Implement the plan using available financial, educational and technical assistance.
- Tier 5 – Conduct evaluations to ensure the protection of the environment and farm viability.

Estimates of BMP implementation on farms within Genesee County indicate more than 40% of AEM participating farms implement nutrient management, stream bank protection, barnyard management and some form of cropland management, including residue management, buffers, rotations and/or cover crops. Other BMPs are utilized in the county to a lesser extent including conservation tillage, strip cropping, grazing land management, terraces/diversions and agricultural land conversions (Genesee/Finger Lakes Regional Planning Council 2012).

The National Resources Conservation Service's Environmental Quality Incentives Program (EQIP) has also assisted with BMP implementation in the watershed. Approximately 270 BMPs have been put in place through the EQIP program. Black Creek is also one watershed targeted through a sediment reduction grant awarded by the Great Lakes Commission. Projects associated

with this GLC grant are still being implemented. Any sediment reductions within UBC will have a positive benefit by reducing both sediment and phosphorus loads delivered to the creeks.

The Genesee and Wyoming County's Soil and Water Conservation Districts should continue to implement the AEM program on farms in the watershed, focusing on identification of management practices that reduce phosphorus loads. These practices would be eligible for state or federal funding and because they address a water quality impairment associated with this TMDL they should score well.

Tier 1 could be used to identify farmers that for economic or personal reasons may be changing or scaling back operations, or contemplating selling land. These farmers would be candidates for conservation easements or conversion of cropland to hay, as would farms indentified in Tier 2 with highly erodible soils and/or needing stream management. Ideally, Tier 3 would include a Comprehensive Nutrient Management Plan with phosphorus indexing at the appropriate state in the planning process. Additional practices could be fully implemented in Tier 4 to reduce phosphorus loads, such as conservation tillage, stream fencing, rotational grazing and cover crops. Also, riparian buffers reduce losses from upland fields and stabilize stream banks in addition to reducing load by taking land out of production.

Results from the macroinvertebrate model indicate that those BMPs which target stream corridor restoration may have the greatest impact upon improving the macroinvertebrate community. Implementation of forest stream buffers may prove the most beneficial as these will reduce phosphorus in overland flow, reduce the amount of fine sediment delivered to the creeks and increase total riparian width. Targeting all three of these factors should result in greater benefit to the macroinvertebrate community than targeting any one factor alone. Vegetative buffer strips, at a cost of $30/pound of phosphorus removal, were identified by CEI as the most cost effective BMP for reducing phosphorus loading in UBC (CEI 2011b).

The Water Quality Restoration Strategy also identified additional BMPs which may be cost effective to implement in UBC (CEI 2011b). The top eight, in terms of cost per pound of phosphorus removal, are listed in Table 18.

During public meetings associated with the Water Quality Restoration Strategy development agricultural interests in UBC indicated that cover crops are the most favorable agricultural BMP (CEI 2011b). There are some barriers to implementation, particularly cost, farmer buy-in, and weather. Meeting participants encouraged the agricultural entities to show more farmers the economic benefits of cover crops. Vegetative buffers were also discussed as potential BMPs but it was noted that farmers are reluctant to take acres out of production without adequate compensation. While vegetative buffers may have a greater benefit to the stream, both buffers and cover crops would have beneficial impacts on UBC by reducing phosphorus and decreasing the delivered sediment load. Cost shares for these practices may be available through the Genesee and Wyoming Counties' Soil and Water Conservation Districts.

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Table 18: Cost effective BMPs for implementation in Upper Black Creek as identified by CEI (2011b). Shaded BMPs were less cost effective, but may also be of interest.

Best Management Practice	Scenario	Setup cost	5 year maintenance cost	5 Year total cost	Phosphorus Reduced (pounds)	$/pound of phosphorus reduced
Vegetative buffer strips	1 mile	$1,500	$3,025	$4,525	149	$30
AWMS runoff control	1 farm	$35,000	$1,750	$36,750	162	$227
Precision feed management	1 farm	$30,000	$50,000	$80,000	296	$270
Alternative manure use – composting	1 cow	$500	$25	$525	1.8	$286
Nutrient management	1 acre	$25	$25	$48	0.15	$343
Manure incorporation into soil	1 farm	$100,000	$40,000	$140,000	245	$571
Streambank fencing	1 mile	$23,000	$800	$23,800	32	$752
Cover crops	1 acre	$0	$175	$175	0.14	$1,288

The macroinvertebrate response model indicated BMPs which will improve the riparian corridor will positively impact the macroinvertebrate population. Riparian buffers may have the greatest impact as they will increase the riparian buffer width, filter out fines from overland flow and reduce phosphorus loading. Where possible, and particularly where little to no buffer currently exists or where erosion problems are already known, riparian buffers should be established.

The watershed model indicated row crops, particularly those situated on lands with shallow groundwater tables, are a significant contributor of soluble reactive phosphorus to UBC. BMPs which will reduce phosphorus loads from this land use category should be encouraged.

7.2.4 Recommended Phosphorus Management Strategies for Urban Stormwater Runoff

NYSDEC issued SPDES general permits GP-0-10-001 for construction activities, and GP-0-10-002 for stormwater discharges from municipal separate stormwater sewer systems (MS4s) in response to the federal Phase II Stormwater rules. GP-0-10-002 applies to urbanized areas of New York State, so it does not cover the Upper Black Creek watershed. The Black Creek Watershed Characterization (Genesee/Finger Lakes Regional Planning Council 2012) indicates that enforcement of the construction activities permit throughout the Black Creek watershed will be important for managing urban stormwater runoff. The report also recommends that local municipalities update their local regulatory framework to aid in the implementation of the 2010

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updates to the NYS Stormwater Management Design Manual. The updates are intended to address runoff reduction and the planning and design of green infrastructure.

Additionally, stormwater management in rural areas can be addressed through Nonpoint Source Management Program. There are several measured which could directly or indirectly reduce phosphorus loads in stormwater discharges if implemented in the watershed.

- Public education regarding:
    - Lawn care, specifically reducing fertilizer use, using phosphorus-free products and the requirements of the NYS Household Detergent and Nutrient Runoff Law (ECL § 35) which restricts both the sale and application of fertilizers containing phosphorus.
    - Cleaning up pet waste.
    - Discouraging waterfowl congregation by restoring natural shoreline vegetation.
- Management practices to address any significant existing erosion sites.
- Construction site and post construction stormwater runoff control ordinance, inspection and enforcement programs.
- Pollution prevention practices for road and ditch maintenance.
- Management practices for the handling, storage and use of roadway deicing products.

The Dishwasher Detergent and Nutrient Runoff Law which went into effect January 1, 2012, restricts the sale and application residential fertilizers containing phosphorus (ECL Article 17, Title 21). The law prohibits the use of phosphorus containing lawn fertilizer unless establishing a new lawn or a soil tests shows the lawn does not have enough phosphorus. The law also prohibits the applications of lawn fertilizers on impervious surfaces and within certain distances from any surface waters. Application of fertilizers containing nitrogen, phosphorus or potassium between December 1st and April 1st is also prohibited. The law applies to all fertilizer for lawns and non-agricultural turf. The three golf courses within UBC are subject to the provisions of this law. While research is still ongoing, studies suggest that reductions of phosphorus in stormwater runoff from lawns may be as much as forty percent. While the law went into effect prior to the monitoring associated with this TMDL, substantial reductions are still expected as it may take several years before the reduced phosphorus loading rate is reflected in the load delivered to the creeks.

An additional report by the Genesee/Finger Lakes Regional Planning Council (2005) identified locations of stream bank erosion within the watershed. Surveys of the stream by Winslow (2012) also identified locations of stream bank erosion. These reports should be utilized to target remediation practices to reduce these sources of sediment and phosphorus.

7.2.5 Additional Protection Measures

Measures to further protect water quality and limit the increase of phosphorus load that would otherwise offset load reduction efforts should be considered. The basic protections afforded by local zoning ordinances could be enhanced to limit non-compatible development, preserve natural vegetation along stream banks and promote smart growth and low impact development. Identification of wildlife habitats, sensitive environmental areas and key open spaces within the

watershed could lead to their preservation or protection by way of conservation easements or other voluntary controls.

In addition to preservation and protection, restoration of wetland, stream and riparian resources within the watershed would contribute to phosphorus load reductions. Easements and incentives for private land owners, combined with active restoration of riparian wetlands, riparian forest, stream meanders, in-stream structure and other lost or degraded aspects of stream systems would contribute to sediment and phosphorus retention within the watershed, as well as improve aesthetics, recreational use, aquatic habitat and potentially land values.

7.3 Follow-up Monitoring

Through a combination of NYSDEC programs, follow-up monitoring of UBC will be carried out every two years. The RIBS program is schedule to return to the Genesee River Basin in 2014 to 2016. Additional monitoring will be conducted through the Trees for Tribs grant recently awarded to NYSDEC for the Genesee River basin. Monitoring will be targeted at the assessment sites specified in this TMDL with additional efforts to characterize the stream before and after any upgrades to the S. Byron SDSTP.

In the long term NYSDEC's Rotating Integrated Basin Studies (RIBS) program will serve as the primary means for follow up monitoring. The RIBS program collects chemistry and macroinvertebrate samples throughout New York State on a rotating basis, returning to each basin every five years.

8.0 Public Participation

CEI, during the preparation of the Water Quality Restoration Strategy (WQRS), received written comments during the public comment period ending on November 18, 2011. Verbal comments were also received during a public meeting held on October 25, 2011. Comments relative to this work are summarized below. The full record of comments and responses can be found in the WQRS document (CEI 2011b).

Numerous comments were received regarding animal manure contributions of phosphorus both generally and specifically with regards to CAFOs. With substantial numbers of animals in the watershed, land application of manure at agronomic rates is a necessary practice to minimize the amount of phosphorus which reaches the UBC. The CAFOs listed in Table 9 are required to do this according to their Certified Nutrient Management Plans, but this is an applicable BMP for all sizes of operations.

Comments indicated cover crops were the preferred BMP. Analysis indicated that cover crops may not be the most cost effective means for phosphorus reductions (Table 18). Cover crops, however, may be part of a comprehensive effort to reduce phosphorus loading to UBC from the agricultural sector.

Vegetative (riparian) buffer strips were noted as quite effective if sited properly. However, it was pointed out that farmers are often reluctant to take land out of production. The analysis by CEI

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and the analysis conducted in this TMDL indicated that riparian buffer strips may be a particularly effective BMP for reducing phosphorus loads to UBC and for improving water quality conditions in UBC overall.

NYSDEC met with representatives from the Town of Byron and the operators of the Byron and S. Byron SDSTP on August 21, 2013. The meeting was held to inform the town representative of the TMDL and its potential implications and to solicit any feedback they may have had regarding the load reductions and implementation.

The availability of this TMDL for public review and comment was announced in the September 25, 2013 edition of the Environmental Notice Bulletin. Comments were accepted for 30 days following the notice, with all comments received by COB October 25, 2013 given consideration during the preparation of the final document. The comments received, and responses, are in the following section.

8.1 Public Comments

To be included following the close of the public comment period.

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Appendix A: Numeric Endpoint Development

The current water quality standard for nutrients (phosphorus and nitrogen) in New York State is a narrative standard: "none in amounts that will result in growths of algae, weeds and slimes that will impair the waters for their best usages" (NYSDEC 2008). The development of a TMDL requires a scientifically defensible numeric endpoint which will ensure the best uses of the waterbody are met. As part of the Upper Black Creek TMDL process, a numeric endpoint was developed for Upper Black Creek (UBC). The endpoint was developed based upon extensive field sampling, data analysis and modeling of the UBC and Little Tonawanda Creek (LTC) watersheds. The neighboring LTC watershed was selected as a best attainable reference site against which to compare UBC. Combined, these efforts were used to correlate water chemistry, habitat and macroinvertebrate use in order to identify a phosphorus concentration which would still be protective of all of the best uses indicated for UBC.

A.1 Conceptual Model

The U.S. EPA (2013) has put together a simple conceptual model diagram to relate anthropogenic impacts to impairment of biological assemblages (Figure 20). Text associated with the diagram explains:

> Enrichment of aquatic systems due to excess nutrient concentrations is a common cause of biological impairment. Although aquatic plants and microbes require nitrogen (N) and phosphorus (P) for growth and reproduction, excess nutrient inputs may adversely affect biotic communities. Often these excess inputs of N and P are related to human activities and sources in the watershed, which influence in-stream nutrient concentrations via six dominant pathways: (1) by increasing the delivery of N or P from the watershed; (2) by increasing the amount of N or P in soils transported into streams; (3) by increasing the amount of N or P in surface runoff; (4) by increasing the amount of N or P in subsurface waters; (5) by increasing the amount of N or P in wet or dry deposition; and (6) by increasing the amount of N or P in discharged waters (i.e., point source effluents). For example, many human activities (e.g., agricultural practices, residential and commercial development) lead to land cover alteration, with subsequent increases in surface runoff and watershed erosion; this land cover alteration can increase the mobilization of N and P bound to watershed soils, ultimately increasing nutrient delivery to streams. Other sources (e.g., fertilizers and animal wastes associated with agricultural and residential practices, geology of the landscape) may directly elevate N and P concentrations within the watershed. Increases in watershed N or P loading associated with these sources can eventually reach streams via surface runoff, via subsurface waters (e.g., groundwater inputs), or attached to washed-in particles.
>
> Once in the stream, N or P may occur in dissolved organic, dissolved inorganic or particulate forms, with transformations occurring among these forms depending on environmental conditions (e.g., dissolved oxygen concentrations). Although N and P may be considered candidate causes, excess nutrients are not proximate stressors. Fish and invertebrates are usually not directly adversely affected by excess nutrient concentrations, but rather are affected by other proximate stressors resulting from nutrient enrichment.

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Nutrients can be associated with biological impairment by several pathways. Dissolved N and P can be taken up by primary producers (algae and macrophytes) and microbes, although whether primary producers respond to increased nutrient concentrations is dependent on adequate light levels. Increases in plant and microbial biomass or productivity may negatively impact aquatic fauna in multiple ways. For example, increases in microbial assemblages may lead to greater microbial infection of invertebrates or fish, or altered benthic organic matter processing (e.g., faster processing rates). Increased respiration of microbes and plants often leads to decreases in dissolved oxygen concentrations (see the dissolved oxygen module for more detailed information on this pathway), especially during times when photosynthesis is limited (e.g., at night). In addition, increased photosynthesis may lead to increased pH; this increase may be especially important when N is elevated, as unionized ammonia, a toxic form of N, is more prevalent at high pH. Blooms of certain algal taxa also may result in increased production and release of toxins that can affect fish or invertebrates.

Increased plant or algal production may translate to increased food resources, which can benefit herbivorous organisms but may adversely impact other taxa by altering the food resources derived from detritus. Changes in plant assemblage structure also may occur with enrichment, and these changes can affect aquatic fauna by altering habitat structure or by altering the quantity or quality of food resources. Changes in community structure may occur even without overall increases in primary producers, due to alterations of nutrient availability ratios. Increases in suspended organic matter (i.e., phytoplankton or suspended benthic algae) also can negatively affect aquatic biota, for example by increasing turbidity.

Within the Upper Black Creek watershed the most probable pathway of impact, and the conceptual model adopted for this project, begins with the most probable anthropogenic influences of agriculture, urban development and industry (sewage treatment plants). The result is an increased delivery of phosphorus to the stream. Increases nutrient delivery coupled with increased light availability due to land cover alterations increased the growth of macrophytes, periphyton and phytoplankton (proximate stressors). The interacting stressor, a change in dissolved oxygen, provides the link between the proximate stressors and the biotic response of biologically impaired invertebrate assemblages. As can be seen in the diagram (Figure 20) the conceptual model adopted for this project is a simplification of a complex ecological system.

The field work and subsequent analysis undertaken for this TMDL quantified several of the mechanisms which are known to potentially influence the relationship between increased nutrient delivery and impaired biological assemblages. Emphasis was placed upon quantifying the chemistry, habitat, and biological assemblages in UBC as described further in the following section.

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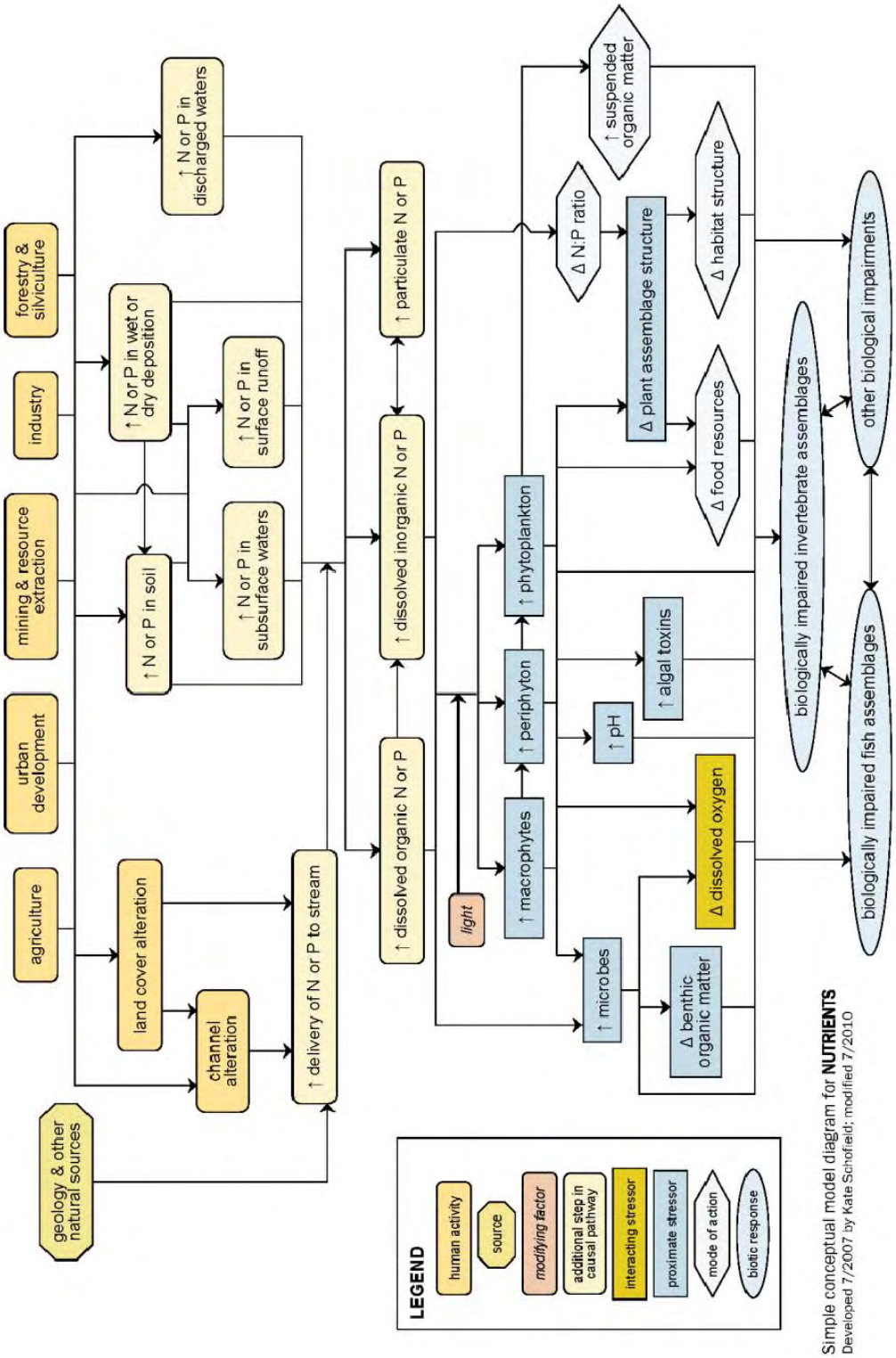

Figure 20: Simple conceptual model diagram for nutrients (U.S. EPA 2013).

A.2 Field Sampling

Field sampling was undertaken during the summer of 2012 to provide the data used to determine a relationship between water chemistry, habitat parameters and macroinvertebrate use impairment within the UBC watershed. Measurements made during the field sampling are shown in Table 19.

Chemistry samples were collected biweekly from May 14 to September 17 at 11 sites within the UBC watershed, including 1 within the Bigelow Creek sub-watershed, and at an additional 2 sites within the neighboring Little Tonawanda Creek watershed (Table 20, Figure 5). Samples were collected using a cross sectional, depth integrated methodology following the NYSDEC RIBS SOP (Smith, et al. 2012). Limited chemistry parameters were measured at BLAK-04, just upstream of a large escarpment while the full parameter set was measured on the downstream side, BLAK-05. These sites were selected to quantify any impacts groundwater entering the stream through the escarpment face may have had upon the chemistry of UBC.

Recent rains resulted in high flows during sample collection on June 12 and 13, 2012. Data from that sampling date was not used as it was deemed non-representative of the base flow conditions being used for this study. No flow conditions were encountered at all sites except BLAK-09, BLAK-10 and BLOW-02 during sample collection on July 25, 2012.

Table 19: Parameters measured during the field sampling

Chemistry	Habitat Assessment	Biological
Temperature (field and continuous)	Grain Size (Pebble count)	Macroinvertebrates (Traveling kick samples)
Dissolved Oxygen (field)	Silt cover	Suspended Chlorophyll *a* (lab**)
pH (field)	Percent embedded	Suspended Chlorophyll *a* (Hyrolab)
Conductivity (field)	Stream habitat cover	Benthic Diatoms (BenthoTorch)
Ammonia	Riparian closure	Benthic Green algae (BenthoTorch)
Nitrogen, Total Kjeldahl	Canopy angle	Benthic Cyanobacteria (BenthoTorch)
Nitrate	Bank characterization	
Nitrite	Nearby land use/ land cover	
Phosphorus, Total*	Channel morphology	
Phosphorus, Ortho*	Depth	
Turbidity	Velocity	
Suspended Solids, Total		
Dissolved Solids, Total		
Alkalinity, Total*		
Chloride		
Sulfate		

* Parameters indicated comprised the limited chemistry parameters measured at BLAK-04.
**Chlorophyll *a* samples sent to the analytical laboratory analysis were collected only at BLAK-10, LTON-00 and BLOW-02.

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Table 20: Field sampling sites and parameters. Table 19 lists the individual measurements included in each parameter set.

Site ID	Watershed	Latitude	Longitude	Parameters
BLAK-01	Upper Black Creek	42.87935	-78.1185	Chemistry, Biology, Habitat
BLAK-02	Upper Black Creek	42.904	-78.1229	Chemistry. Biology, Habitat
BLAK-03	Upper Black Creek	42.9244	-78.1178	Chemistry, Biology, Habitat
BLAK-04	Upper Black Creek	43.00428	-78.0737	Limited Chemistry
BLAK-05	Upper Black Creek	43.00573	-78.075	Chemistry, Biology, Habitat
BLAK-06	Upper Black Creek	43.01557	-78.0802	Chemistry, Biology, Habitat
BLAK-07	Upper Black Creek	43.0341	-78.0754	Chemistry, Biology, Habitat
BLAK-08*	Upper Black Creek	43.06578	-78.0652	Chemistry, Biology, Habitat
BLAK-09	Upper Black Creek	43.082	-78.0685	Chemistry, Biology, Habitat
BLAK-10*	Upper Black Creek	43.08883	-78.0674	Chemistry, Biology, Habitat, Chl-*a*
LTON-00*	Little Tonawanda Creek	42.89305	-78.1667	Chemistry, Biology, Habitat, Chl-*a*
LTON-A	Little Tonawanda Creek	42.8155	-78.1677	Chemistry, Biology, Habitat
BLOW-02*	Bigelow Creek	43.06632	-78.0695	Chemistry, Biology, Habitat, Chl-*a*

*Previously sampled location. See section 2.4.

Habitat and periphyton measurements were made during the week of September 17, 2012. Habitat assessments were conducted using the NYSDEC habitat assessment procedures (Smith, et al. 2012) and a modified version of the USGS National Water Quality Assessment Program habitat assessment protocol (Fitzpatrick, et al. 1998). The NYSDEC method was used for consistency with program methods and for potential future integration into similar applications using these established methods. The modified NAWQA protocols were used to collect data using more quantitative methods. Habitat assessments and algal measurements were made and macroinvertebrate samples were collected at all locations except BLAK-04 (Figure 5).

Periphyton measurements were made using a bbe BenthoTorch, providing in situ quantification of Chlorophyll-a (Chl-a) fluorescence. Results are presented as surface density (μg/cm^2) of Chl-a, attributed to diatoms, green algae and cyanobacteria. Measurements were taken at one meter intervals, minimum of three measurements per transect, during each of the 5 transects completed at each site. The data, as a function of phosphorus concentrations, are shown in Figure 21. Shown are the averages of all chlorophyll-a measurement made at a site. The error bars are one standard deviation. No relationship between periphyton surface density and other measured parameters, e.g. SRP, TP, riparian cover, were evident. Site selection, measurement collection methods and time of year may all have contributed to the inconclusive results. The BenthoTorch had not previously been used by NYSDEC. The results obtained indicate that a more comprehensive assessment of the instrument and its output is needed before any meaningful conclusions can be drawn. Though collected, the data were not used in the development of this TMDL.

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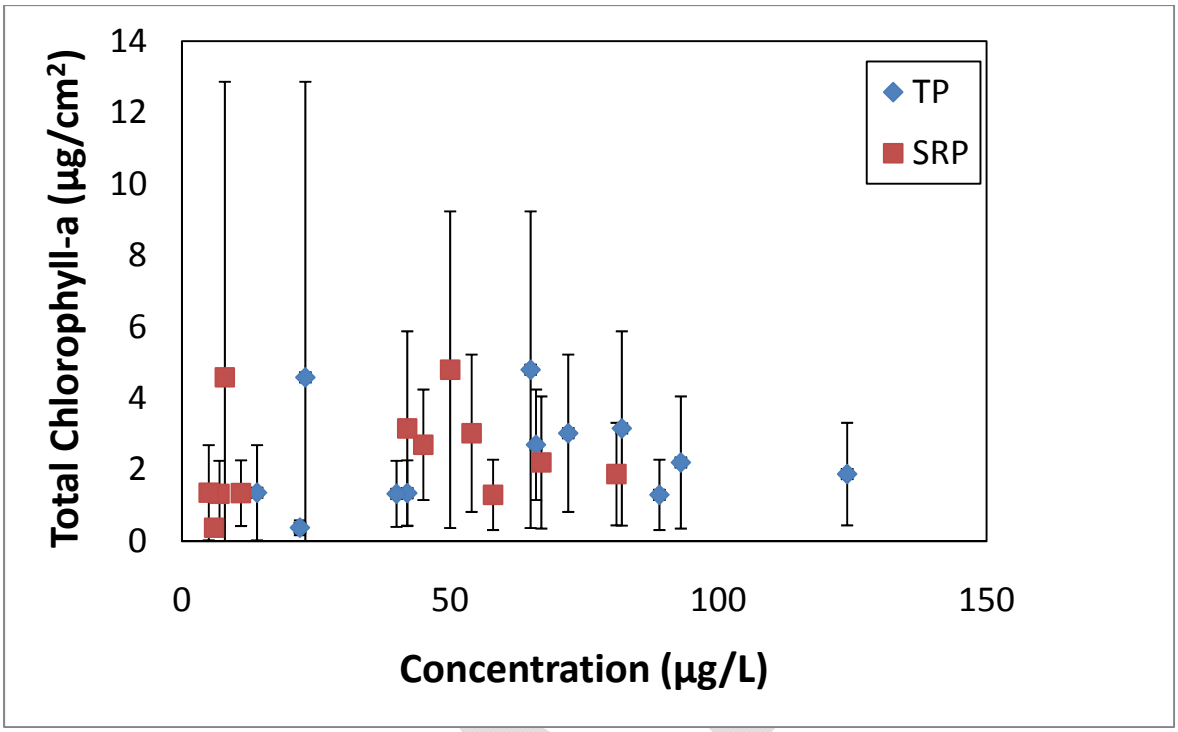

Figure 21: Average chlorophyll-a measurements made at each site during the September field assessment as a function of growing season average phosphorus concentrations. Error bars are ± 1 standard deviation.

Macroinvertebrate samples were collected in parallel with the habitat assessment. Six replicated macroinvertebrate samples were collected at each site using a two minute, five meter traveling kicknet sampling methodology (Smith, et al. 2012). Samples were collected from riffles with cobble and gravel substrate using an 800 × 900 micro mesh net, preserved in 95% ethanol and shipped to a contract laboratory for processing. One hundred organism subsamples were randomly sorted from each sample and identified to the lowest possible taxonomic level. New York State's multimetric index of biological integrity was used to determine water quality from each site (Smith, et al. 2012). In agreement with the draft numeric nutrient criteria currently being developed by NYSDEC (Smith and Tran 2010), this method calculates species richness (Spp), Ephemeroptera-Plecoptera-Tricoptera richness (EPT) (Lenat 1988), Hilsenhoff's biotic index score (HBI) (Hilsenhoff 1987), percent model affinity (PMA) (Novak and Bode 1992), and the nutrient biotic index for phosphorus (NBI-P) (Smith, Bode and Kleppel 2007). The result of each of the indices is placed on a common 10 scale and the mean of the adjusted values determined. The result, called the Biological Assessment Profile (BAP) score, is a single value for which a four-tiered scale of water quality impact (non-, slight, moderate or severe) has been established (Smith, Heitzman, et al. 2012).

A.3 Model Development

Averages for all water chemistry data, habitat, and biological metrics (Spp, EPT, HBI, PMA, BAP, NBI-P, nitrogen nutrient biotic index [NBI-N]) were analyzed together using a Spearman rank-order (Sprho) correlation to reduce the number of possible variables. Correlation thresholds between biological metrics and physical-chemical variables for the Sprho were R = 0.4 and p=0.05. The initial set of 80 variables was reduced to 15. Because the ultimate goal of this

project was to yield variables influencing the biological endpoint, only variables that could directly be influenced through management activities were used for further analyses.

Non-metric multidimensional scaling and Bray-Curtis similarity analysis using square root transformed community assemblage data indicated a community shift in study sites with drainage areas greater than 10 square miles, referred to here as river sites (Figure 22). This ecological threshold for a community shift is consistent with state-wide analysis of headwater streams, defined as streams with drainage areas less than 10 square miles (unpublished data, B. Duffy). According to the data collected, factors other than nutrients appear to influence the biological community at the headwaters locations (BLAK-01, -02, -03, and LTON-A). Figure 22 shows similarities within the macroinvertebrate community assemblages, with those sites which plot near each other having similar communities. All of the headwaters sites plot separately from the rest of the Upper Black Creek and Bigelow Creek sites. The reference sites, LTON-00 and LTON-A, also plot apart from the other sites. Different community assemblages are expected between best attainable reference sites and those sites showing some impact. Figure 23 shows the relationship between total phosphorus and the mean BAP score from the September 2012 sampling. The river sites show a clear linear relationship, indicating BAP scores improves with decreasing phosphorus concentrations. The headwaters sites do not follow such a clear pattern. It is not clear that decreasing phosphorus concentrations at these sites would improve the BAP scores. There are likely other stressors affecting these sites. These headwaters sites were particularly susceptible to low flows during the 2012 growing season. With only four sites, however, there is insufficient data to draw any conclusions regarding the impacts of flow or other stressors on the macroinvertebrate communities at the headwaters sites. As a result, only the river sites were considered in subsequent analysis.

Variables retained for use in the development of the multiple regression model were total riparian width (TRW) in meters, total suspended solids (TSS) in mg/L, average riparian closure (ARC) in percent, soluble reactive phosphorus (SRP) in mg/L, total phosphorus (TP) in mg/L, and fraction fines in the riffle (FFR), where fines have a diameter less than 16 mm. This set of variables was analyzed using a best subset regression (BSR). BSR uses the best variables in combination to explain the greatest amount of variability in the response variable. To be consistent with NYSDEC assessment methodology the BAP score was chosen as the response variable.

The results from the BSR (Table 21) show how well the mean BAP scores are explained by the indicated different combinations of variables. In general, the fewest number of variables should be used while still achieving a high adjusted R^2 value. Fewer variables generally result in lower R^2 values while more variables increase the risk of over fitting the model. A model based upon total riparian width (TRW), fraction of fines in the riffle (FFR) and soluble reactive phosphorus (SRP) provided the best statistical metrics while minimizing the number of variables (shown in bold in Table 21). These variables were used to develop the model using multiple regression analysis (MRA).The resulting equation was:

$$\text{BAP (mean)} = 5.99 - 26.5\times\text{SRP} + 0.0837\times\text{TRW} - 3.78\times\text{FFR}$$

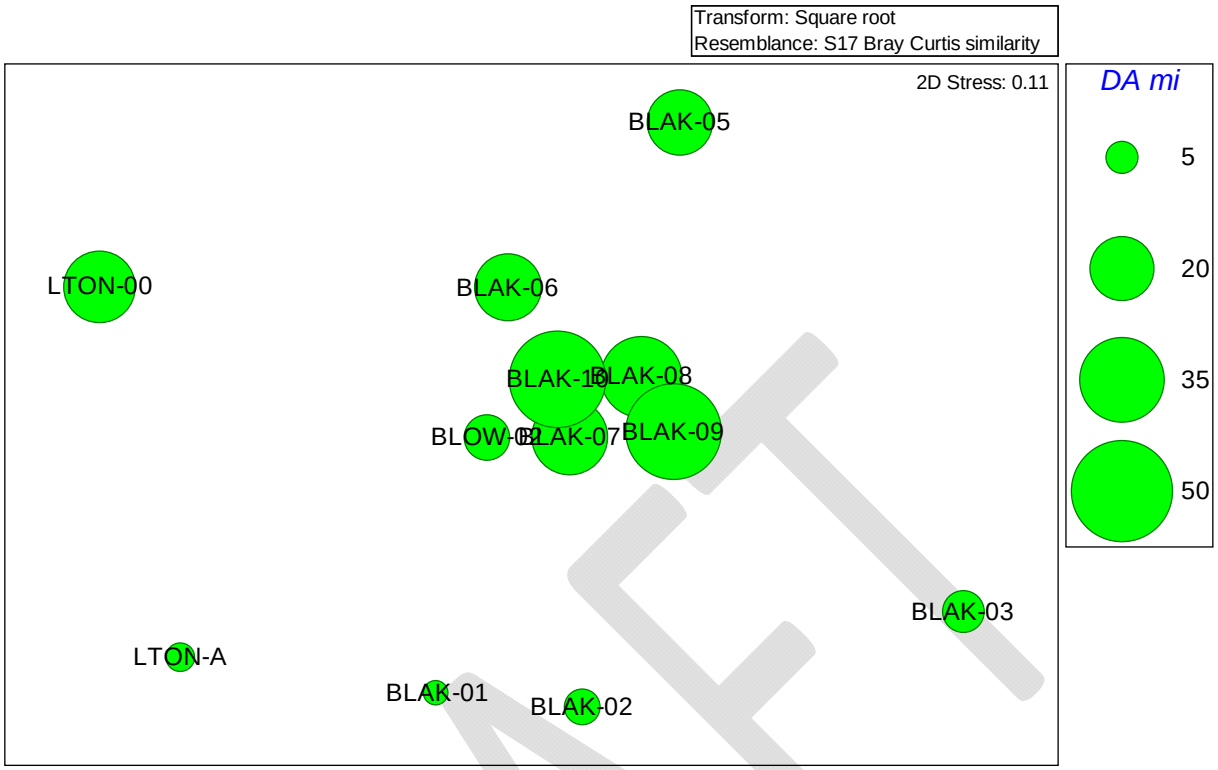

Figure 22: nMDS taxa ordination plot of sites for the Upper Black Creek TMDL. Locations with drainages areas (DA) less than 10 square miles separate from other sites in the study.

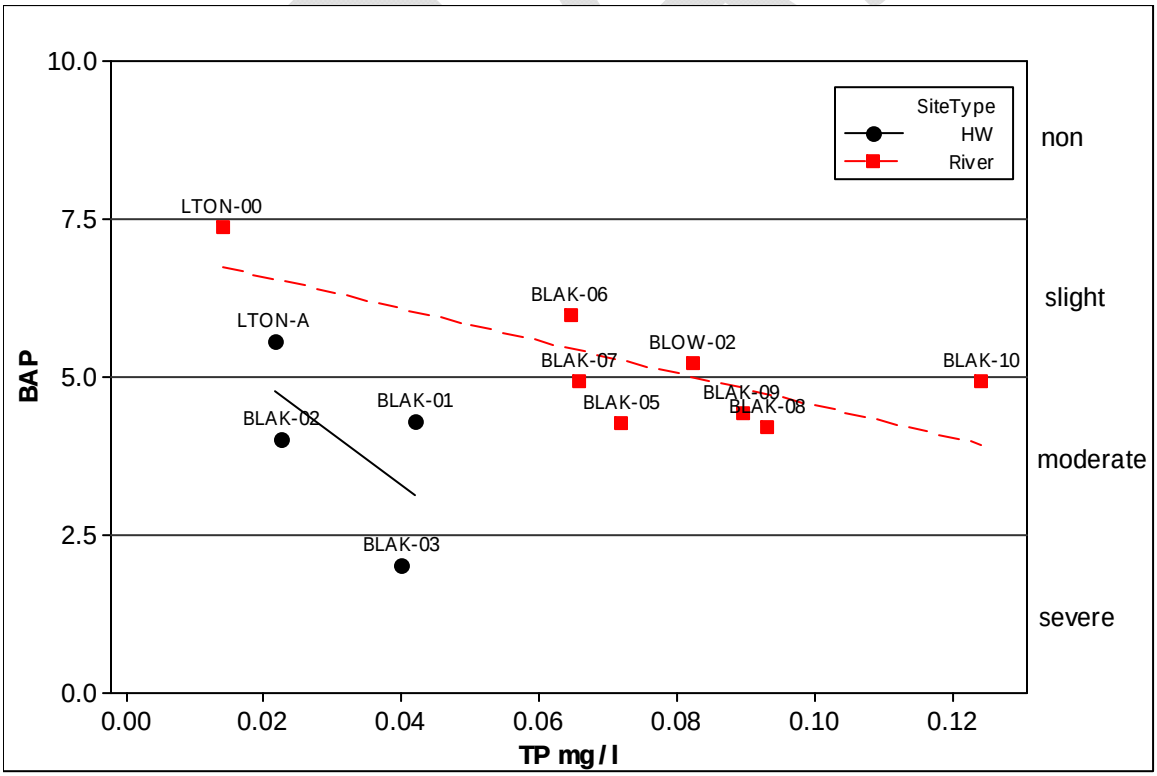

Figure 23: Scatter plot showing the relationship between total phosphorus (TP) and the mean BAP score for the headwaters sites (HW) and the river sites. HW sites are those with drainage areas less than 10 square miles.

Table 21: Results from the best subset regression of manageable variables in the Upper Black Creek study area.

Number of variables	R^2	Adjusted R^2	Mallows Cp	S	TRW	TSS	ARC	SRP	TP	FFR
1	61.9	55.6	26.6	0.70				X		
1	55.2	47.7	32.0	0.76					X	
2	70.7	59	21.5	0.68			X	X		
2	69.6	57.5	22.4	0.69				X		X
3	**88.4**	**80.4**	**9**	**0.46**	**X**			**X**		**X**
3	82.8	70.0	13.8	0.58		X	X	X		
4	91.0	78.9	9.2	0.48	X			X	X	X
4	90.5	77.8	9.6	0.49	X		X	X		X
5	97.7	91.9	5.9	0.30	X		X	X	X	X
5	95.3	83.5	7.8	0.43	X	X	X	X		X
6	98.8	91.3	7	.31	X	X	X	X	X	X

The equation has an adjusted R^2 = 80.4% and p = 0.023 and indicates that multiple factors influence the biological response in flowing waters. Achievement of BAP ≥ 5 can be achieved by SRP reductions alone, however increasing TRW or decreasing FFR would also have beneficial impacts.

A similar analysis was performed using total phosphorus (TP), rather than SRP. Similar conclusions were reached, with the explanatory variables of TRW and FFR again identified. The resulting equation was:

$$\text{BAP (mean)} = 5.59 - 17.4\times\text{TP} + 0.091\times\text{TRW} - 3.43\times\text{FFR}$$

Figure 24 shows the results of the MRA for calculated TP mean BAP scores plotted against the measured mean BAP scores. The TP equation was not as strong a predictor of BAP score, with an adjusted R^2 of 68.4% and p = 0.057. For consistency with SPDES permits and stream numeric nutrient criteria currently under development, however, the TP relationship was selected for the development of this TMDL.

There is some uncertainty surrounding the resulting equation from the MRA. In Figure 24 the 95th percentile confidence interval for the regression equation is shown as red dashed lines. The 95th percentile prediction interval is shown by the green dotted lines. Due to the uncertainty in the relationship, meeting restoration targets consisting of some combination of TP reductions, TRW increases and FFR decreases does not guarantee a BAP ≥ 5 will be attained. Conservative assumptions have been built into the analysis to make that outcome more likely (Section 6.3). The converse is also true which is supportive of using the BAP score as the endpoint for this TMDL rather than the nutrient loads specified in Tables 11, 12 and 13.

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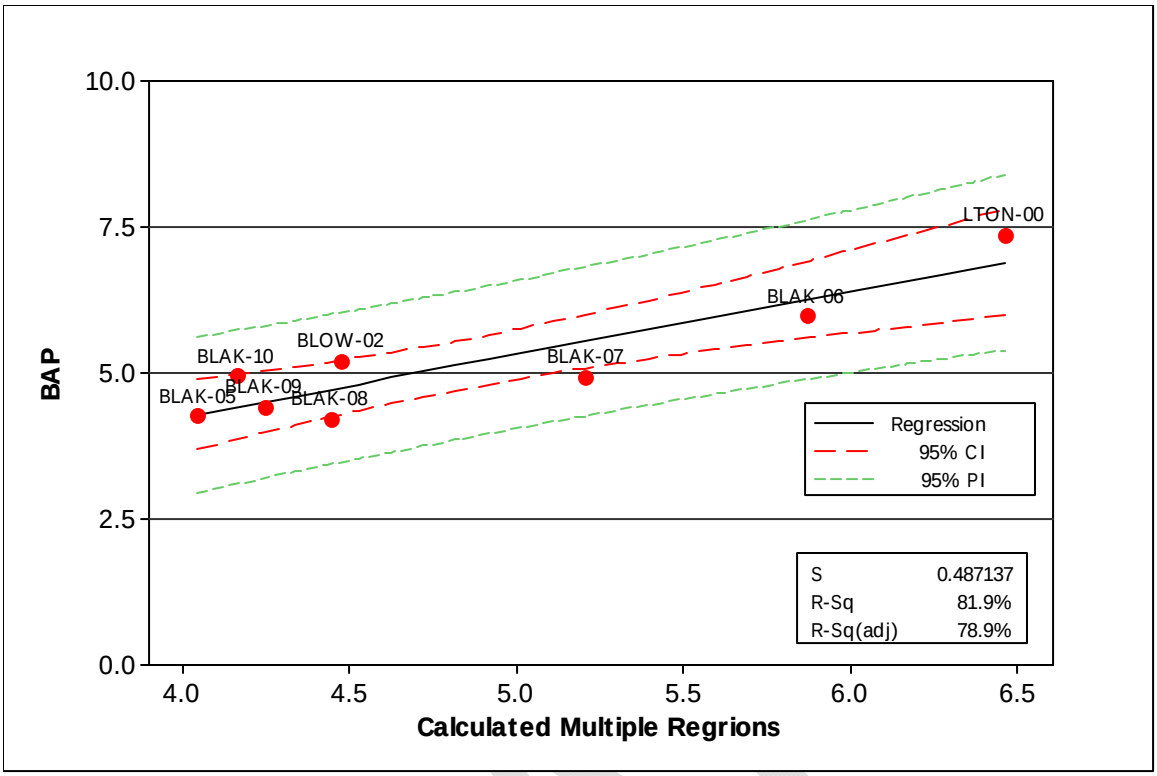

Figure 24: Results of the total phosphorus multiple regression analysis (MRA) showing the MRA mean BAP score against the measured mean BAP score. Shown are the total phosphorus regression line (black, solid), the 95th percentile confidence interval about the mean (red dashed) and the 95th percentile prediction interval (green dotted).

Phosphorus is generally the limiting nutrient in freshwater systems; however, it has been noted "that co-limitation by both nitrogen and phosphorus may be common in many systems and regions" (U.S. EPA 2010). Several species of nitrogen were measured during the field sampling.

During the Spearman rank-order analysis the nitrogen species ranked similar to the phosphorus species. When included in the best subset regression analysis phosphorus was found to be a better predictor of the BAP score than was nitrogen. While the inclusion of nitrogen into the regression model did improve the predictive power, it was only by a similar amount as when other variables were included as a fourth factor in the analysis. Based upon the analysis results phosphorus was determined to be the limiting factor and nitrogen was not considered further.

SRP and TP targets may be calculated from their respective equations above assuming a BAP score of 5 is to be achieved through phosphorus reductions alone. A strong relationship between SRP and TP was indicated by the 2012 data (Figure 25). Taking into consideration this relationship, meeting the reduction targets for TP would provide more than the needed amount of SRP reduction as well. For example, at BLAK-08, the TP reduction target is 0.048 mg/L. Applying the TP-SRP relationship, the equivalent SRP concentration would be 0.025 mg/L, less than the 0.037 mg/L SRP target determined from the SRP equation above. Basing the TMDL off of the TP relationship would therefore be a conservative measure.

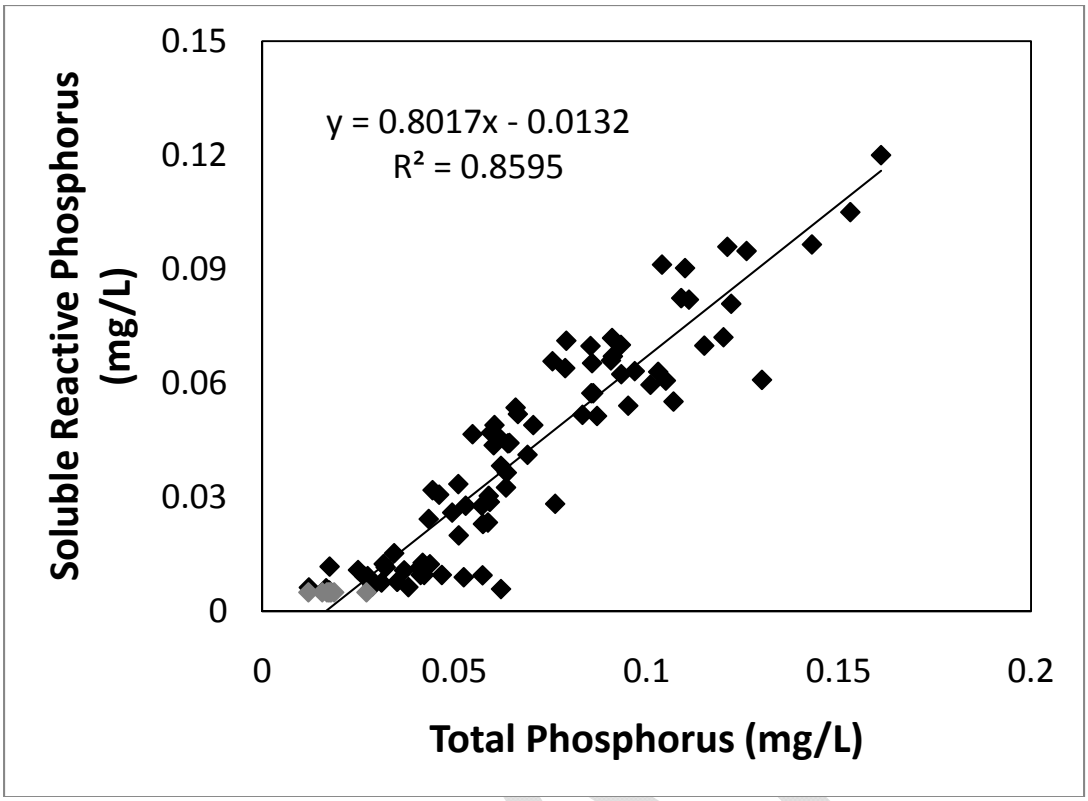

Figure 25: Relationship between TP and SRP in the data collected during summer 2012. Grey points were below the detection limit for SRP.

A.4 Model Application

Application of the macroinvertebrate response model developed in the previous section requires specification of how and when the model will be applied. The rational used to make decisions on how to account for assessed conditions within the model framework and how the target values will be expressed are described in the following sections.

A.4.1 Accounting for assessed conditions

The BAP scores predicted by the equation developed in the previous section under predicted the level of impairment at BLAK-08 relative to the value measured during field sampling, and over predicted the extent of impairment at BLAK-10 and BLOW-02 (Table 22). For example, the field assessment found BLOW-02 to be unimpaired (BAP > 5.0) while the regression equation predicted the site to be impaired (BAP < 5.0). Implementation of TP values derived from the above equations in the TMDL would likely result in insufficient reductions from BLAK-08 and an excessive amount of reduction from BLAK-10 and BLOW-02.

Table 22: Modeled and measured BAP scores

Site	Predicted mean BAP	Measured mean BAP
BLAK-08	4.58	4.21
BLAK-10	4.24	4.95
BLOW-02	4.65	5.22

Table 23: Measured and target total phosphorus values

site	Measured TP	Target TP
BLAK-08	0.093	0.048
BLAK-10	0.124	0.121
BLOW-02	0.082	0.082* (* held at measured)

To correct for the site specific differences between the measured BAP score and the model predicted BAP score the measured BAP score was used as the starting point of the analysis while retaining the regression analysis relationship between the three covariates and the BAP score. The relative improvement in the BAP score at each site is accomplished through changes in the covariates, each weighted by the respective prefactors from the regression equation.

For BLAK-08, the calculation is as follows:
Change in BAP score needed = Target BAP – Measured BAP = 5.0 – 4.21 = 0.79.

Change in regression covariates = Target covariate values – Measured covariate values

$$= [-17.4\times TP_t+0.091\times TRW_t-3.43\times FFR_t] - [-17.4\times TP_m+0.091\times TRW_m-3.43\times FFR_m]$$

$$= [-17.4\times TP_t+0.091\times TRW_t-3.43\times FFR_t] - [-17.4\times 0.093+0.091\times 18-3.43\times 0.3]$$

where the subscripts t and m are for the target and measured values of the covariates, respectively. The changes in BAP score is set equal to the change in regression covariates, thus allowing the following to be solved for any combination of target values for TP, TRW and FFR:

$$0.79 = [-17.4\times TP_t+0.091\times TRW_t-3.43\times FFR_t] - [-17.4\times 0.093+0.091\times 18-3.43\times 0.3]$$

In the case where TRW_t and FFR_t are unchanged from the measured values, TP_t may be solved for directly. For the TMDL, this would be equivalent to setting phosphorus reduction targets based upon achieving a BAP score of 5.0 through phosphorus reductions alone. The resulting TP targets are shown in Table 23. Note that for Bigelow Creek (site BLOW-02) the 2012 assessment was above the impairment threshold of a BAP score equal to 5. Therefore, the target TP concentration is set at the concentration measured for in 2012.

A.4.2 Application of the target concentrations

The macroinvertebrate response model (MRM) developed above provides a total phosphorus target endpoint which has been used for the development of this TMDL. The MRM does not specify how this endpoint is to be applied. The decision of how and when the endpoint is to be applied is, however, still informed by the science behind the development of the MRM.

The MRM was developed using average phosphorus concentrations from June through September (growing season). This was done because this was the identified critical period when phosphorus concentrations were high and flows in the stream were low, creating stressful condition for the macroinvertebrates. The applicability of the MRM is therefore the same: an average TP concentration calculated over the growing season. From the WLA and permitting

perspective, the applicable period was extended to include the month of October as this aligns with other seasonal permit limits. This will require phosphorus reductions from the point sources to extend outside of the critical period.

Using the load duration approach (Section 5.2) requires the selection of where on the load duration curve the loading and therefore required reduction will be assessed. Consistent with concept of long term average phosphorus concentrations leading to the aquatic life use impairment, the median flow value on the load duration curve was used. The load duration curves were also developed using flow values only from the applicable MRM model period, June through September. On any given growing season day, the flow will have a 50% chance of being greater than the flow used to develop the TMDL, or the flow will have a 50% chance of being less than the value used to develop the TMDL. Use of the median flow value in combination with the growing season mean TP value, allows the TMDL to be developed using typical growing season conditions.

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Appendix B: Phosphorus concentrations and loads from the Byron and South Byron Sewage District Sewage Treatment Plants

The Byron Sewage District Sewage Treatment Plant (SDSTP, NY0160971 outfall 001M) and the South Byron SDSTP (NY0160971 outfall 002M) do not regularly measure the amount of phosphorus in their effluents. NYSDEC, in cooperation with the facility operations staff, collected samples for phosphorus analysis on July 3, 2013. Concentrations of total phosphorus and soluble reactive phosphorus in the effluent samples are in Table 24.

Table 24: Results from effluents samples collected on 7/3/13.

	Soluble Reactive Phosphorus (mg/L)	Total Phosphorus (mg/L)
Bryon SDSTP	3.42	3.70
S. Byron SDSTP	2.72	2.85

These estimates agreed well with mass balance calculated concentrations based upon stream phosphorus concentrations, modeled flows and monthly average effluent flows: Byron TP = 5.2 mg/L, SRP = 4.2 mg/L and S. Byron TP = 3.0 mg/L, SRP = 2.94 mg/L. This provides assurance that the concentrations in Table 24 are representative of at least the May through September period. Since the mass balance approach can provides only an estimate of the phosphorus concentrations, the effluent sample results were used to characterize the STPs in the TMDL development.

Some seasonality exists in the STP flows with growing season flows on average less than the annual average flows. The loads attributed to each STP during the growing season and on an annual basis are shown in Table 25.

Table 25: Estimates phosphorus loads for the Byron and South Byron SDSTPs

	Growing Season			Annual		
	Average Flow (MGD)	Total Phosphorus Load (lb/d)	Soluble Reactive Phosphorus Load (lb/d)	Average Flow (MGD)	Total Phosphorus Load (lb/d)	Soluble Reactive Phosphorus Load (lb/d)
Byron SDSTP	0.026	0.81	0.75	0.030	0.93	0.85
S. Byron SDSTP	0.016	0.38	0.36	0.024	0.60	0.55

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Appendix C: Watershed Numerical Modeling

The watershed model was developed and calibrated to the Upper Black Creek watershed by Cornell University. Presented here is an overview of the model and calibration results. Full details of the model development and calibration can be found in the final report (Pacenka, et al. 2013).

The watershed numerical modeling consisted of three separate components: a hydrology model, a sediment model and a phosphorus model. The hydrology model drives both the sediment and the phosphorus models and the sediment model feeds into the phosphorus model. Each model is described below.

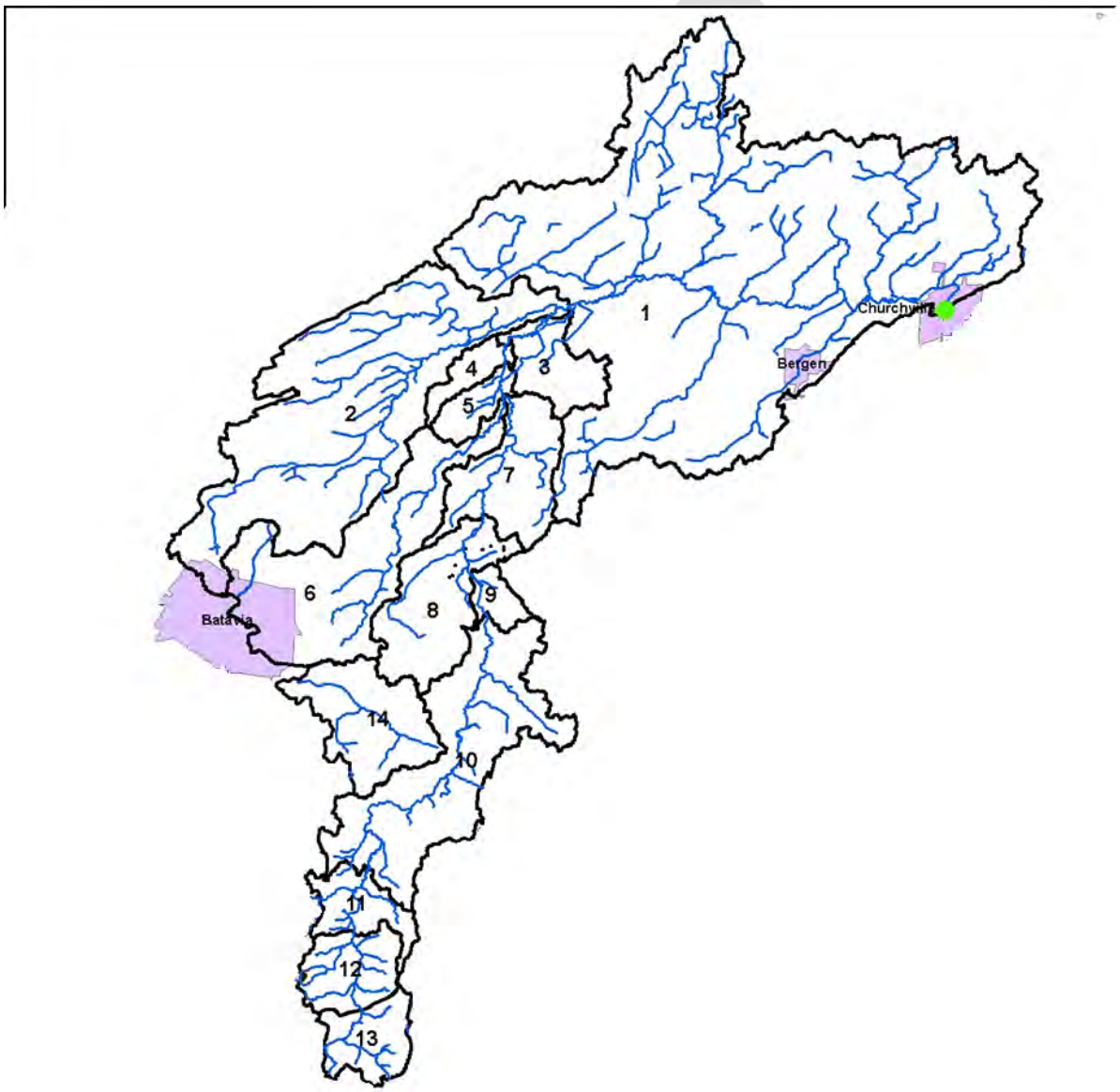

Figure 26: Model subbasins

The modeled watershed consisted of 14 subbasins extending from the headwaters of Black Creek to the USGS gage at Churchville (Figure 26). Subbasin delineations were dictated by sampling locations and stream confluences. The model was extended below the BLAK-10 sampling site (subbasin 3) to incorporate the USGS gage at Churchville into the model domain.

C.1 Hydrology

The Parameter Efficient Distributed (PED) model is a semi-distributed rainfall-runoff model based upon the Thornthwaite and Mather (1955) water balance procedure and can be run at daily, weekly, or monthly time steps (Collick, et al. 2009, Tesemma, Mohamed and Steenhuis 2010, Steenhuis, et al. 2009). Figure 27 provides an overview of the PED hydrology model, and Figure 28 presents its algebra. It represents a watershed as a hillslope containing three land surface areas: a restricted infiltration area anywhere along the slope, an infiltration area usually at midslope, and a frequently saturated area along the stream. Beneath the three surface zones are a shallow aquifer zone in the rendered bedrock, and the top of the aquifer constitutes an interflow zone into which the aquifer spills after it fills up. When incoming precipitation (P) fills either the restricted infiltration area or the downslope saturating area to capacity, they spill over into the stream immediately. The infiltration area spills into the aquifer. The aquifer spills into the interflow pathway. Each of the three surface areas has a slower outflow as well: they evaporate water back into the atmosphere following the classic Thornthwaite-Mather climatic water balance scheme.

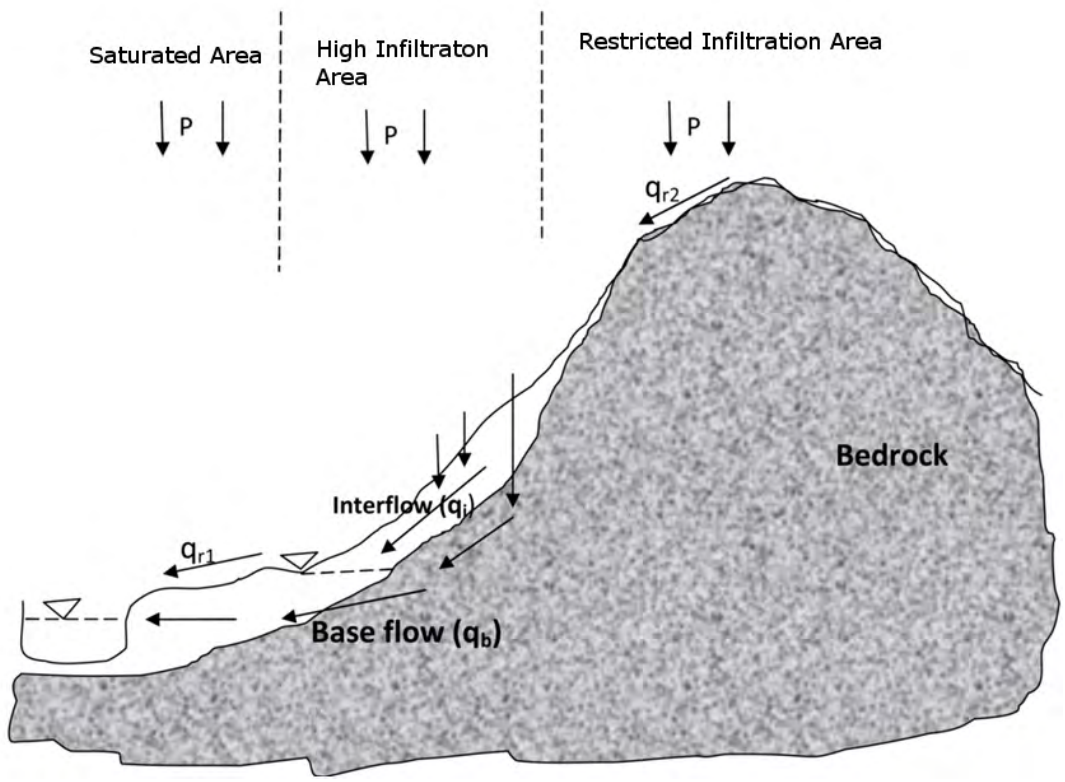

Figure 27: PED hydrology for a single basin

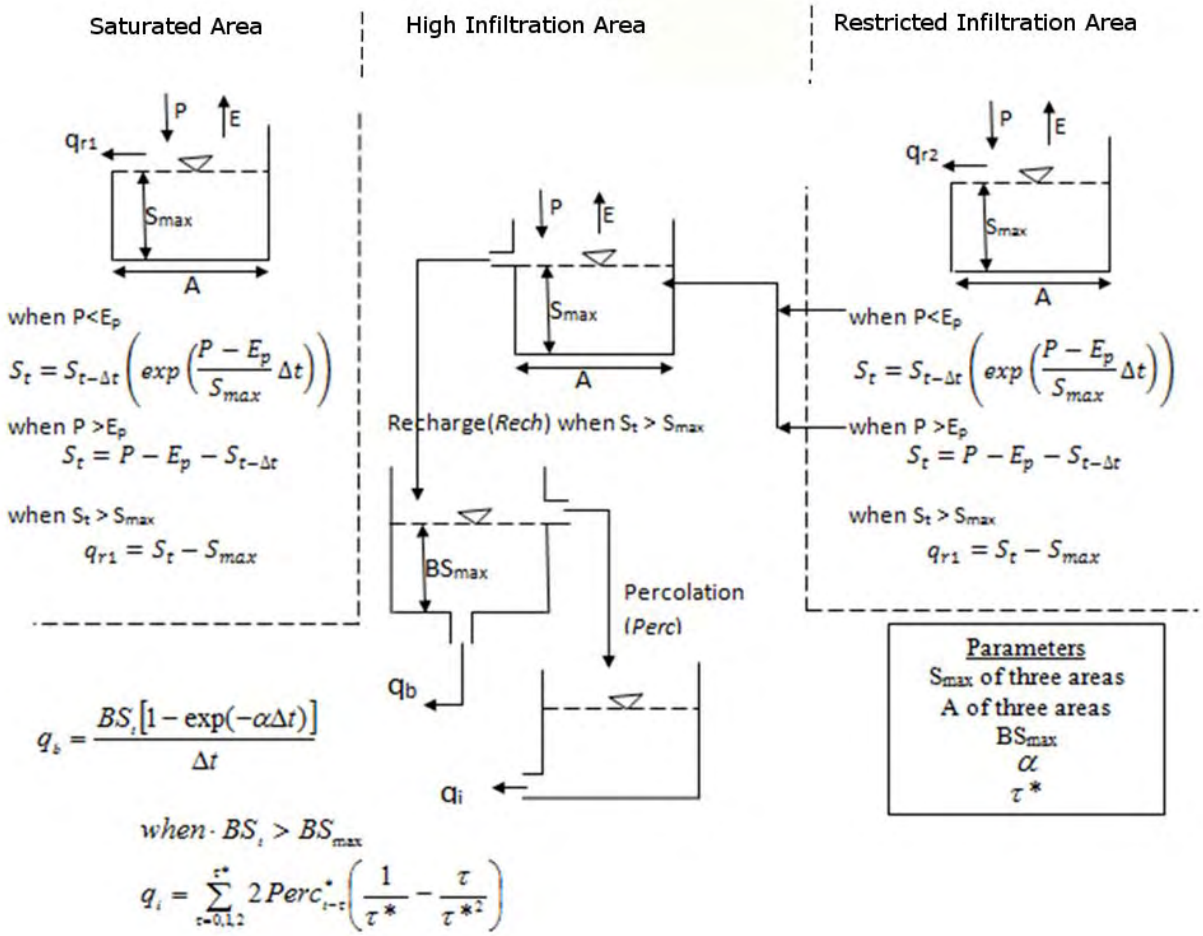

Figure 28: Five overflowing buckets of the PED hydrology model.

The aquifer zone slowly drains to the stream providing baseflow. The interflow zone's outlet is also to the stream; it drains faster than the aquifer and slower than the limited infiltration or saturated zones. Methods described by Walter, et al. (2005) were used to model snowmelt. Additional information including equations can be found in the referenced publications.

Each of the three surface storages and the aquifer have a maximum capacity parameter (in mm). The aquifer zone and the interflow zone additionally have time parameters (in days) which represent how rapidly they release water to the stream.

The fraction of the subbasin that each hydrologic land surface areas (restricted infiltration, infiltration and saturated area) constitutes needs to be specified for each subbasin. The aquifer and interflow zones are implicitly beneath the entire basin. In Figures 27 and 28 *P* is liquid precipitation (rainfall + snowmelt) (mm/d), *E* is evapotranspiration (mm/d), *q* are outbound fluxes (mm/d) and *S* is storage (mm). Subscripts indicate baseflow (*b*), interflow (*i*) and surface runoff (*r1* and *r2*). Initial values for storage in each zone are also required, except for the interflow zone which is assumed to start empty. Time series of precipitation and temperature are also required.

Table 26: Time-constant data used to characterize the wastewater treatment plants within the model.

Facility	Subbasin	Flow (cmd)	SRP load (kg/yr)	PP load (kg/yr)
Byron	4	100	130	10
South Byron	7	60	60	2
Batavia Country Club	6	7.6	6.4	0

Calculations within the model are carried out on a “per unit area” basis for each subbasin within the model (Figure 26). Subbasins are connected to form the entire watershed through a network of "nodes." To derive the water budget for a node, i.e. for all land upstream from that node, the network algebra model simply adds together the daily outflows of all subbasins topologically upstream from the node, weighting the PED outflows (in mm) by the subbasin sizes (in kilometers squared). The units of the nodal water budgets are for convenience cubic meters per day (cmd) which requires a multiplier of 1000 to convert from mm × km^2/day to cmd. WWTP discharges are included explicitly in the model by adding the discharge volume to each node downstream of the WWTP's subbasin. Details for each WWTP as modeled are shown in Table 26.

C.1.1 Hydrology Calibration

The entire Black Creek basin was assumed to have uniform meteorology identical to that occurring at the Rochester Airport, east of the watershed outlet, which represented the most complete dataset. Occasional missing data from the Airport weather station were filled in using data from the Batavia weather station. Potential evapotranspiration was fixed at a 3.5 mm/day summer maximum, which is scaled to the rest of the year using a sine wave having a zero value in early January.

The Black Creek watershed was divided into 13 subbasins (Figure 26) with subbasins 3-13 constituting Upper Black Creek. Subbasins 1, 2, 3 and auxiliary subbasin 14 fall outside of the Upper Black Creek (UBC) watershed but were included in the model domain for model calibration and validation purposes. Subbasin 1 covers the Black Creek watershed from Spring Creek, a tributary to Black Creek which joins Black Creek just below site BLAK-10, to the USGS gage at Churchville. Subbasin 2 is Spring Creek itself. Subbasin 3 is the small drainage area of Black Creek from Spring Creek upstream to the BLAK-10 site. Subbasin 14 was an added subbasin that could be used within the model framework to account for subsurface inter-basin transfers of water through the karst region of UBC; however, this was not used within the final implementation. Table 27 provides details on the subbasins. The nodal network is shown in Figure 29 with nodes prefixed by N and subbasins prefixed by S.

Candidate model parameter value sets were compared for how well modeled flow values fit to measured flow values, considering both June-September fit and annual overall fit. The Nash-Sutcliffe efficiency (NSE) and the coefficient of determination (R^2) were the primary statistics used with a goal of at least 0.4 for both measures. Values of NSE may vary from negative infinity to positive one. NSE = 1 corresponds to a perfect match of modeled data to the observed data. NSE = 0 indicates the model predictions are as accurate as using the mean of the observed data as a constant value. NSE values were also calculated from seven day average flows when

Table 27: Subbasins used in the Black Creek watershed model

No.	Primary Stream	Description	Area (km^2)
S1	Black Creek	Drainage of Black Creek from Spring Creek to the USGS gauge below the dam at Churchville	156.0
S2	Spring Creek	Entire drainage of Spring Creek, to mouth at Black Creek	58.1
S3	Black Creek	Drainage of Black Creek from Route NY 237 Byron to Spring Creek	7.8
S4	Black Creek	Drainage of Black Creek from Trestle Park bridge to Route NY 237 bridge.	3.3
S5	Black Creek	Drainage of Black Creek from junction with Bigelow Creek to Trestle Park bridge	3.8
S6	Bigelow Creek	Entire drainage of Bigelow Creek, to mouth at Black Creek	31.4
S7	Black Creek	Drainage of Black Creek from Griswold Rd. bridge to Bigelow Creek	13.6
S8	Black Creek	Drainage of Black Creek from Tyler Rd. bridge (abandoned) to Griswold Rd. bridge	15.7
S9	Black Creek	Drainage of Black Creek from brink of Morganville Falls to Tyler Rd. bridge	2.9
S10	Black Creek	Drainage of Black Creek from McLernon Rd. bridge to brink of Morganville Falls	31.8
S11	Black Creek	Drainage of Black Creek from Route US 20 bridge to McLernon Rd. bridge	6.4
S12	Black Creek	Drainage of Black Creek from foot bridge in Genesee County Park to Route US 20 bridge.	8.3
S13	Black Creek	Drainage of Black Creek from headwaters to foot bridge in Genesee County Park	7.2
S14	(unnamed sinking stream south of Rte 5 near Batavia and Stafford)	Area delineated by Richards and Boehm (2012)	9.5

daily observed data were available. R^2 is a measure of correlation between the modeled and measured values, with $R^2 = 1$ indicating a perfect correlation and $R^2 = 0$ indication no correlation. The percent bias was also calculated as an overall metric of the model tendency to over- or under-predict the measured values. Low values of percent bias indicate better model predictions. The optimal value of percent bias is zero but ±10% is generally acceptable. Fitting was done for the period of 2007 through 2012, and then the results were tested against the water quality monitoring period 2010 through 2012 as a dependent "calibration" period (Table 30).

Accurate modeling of base flows during the summer growing period became much more important as the macroinvertebrate response model began to revolve around the growing season phosphorus load.

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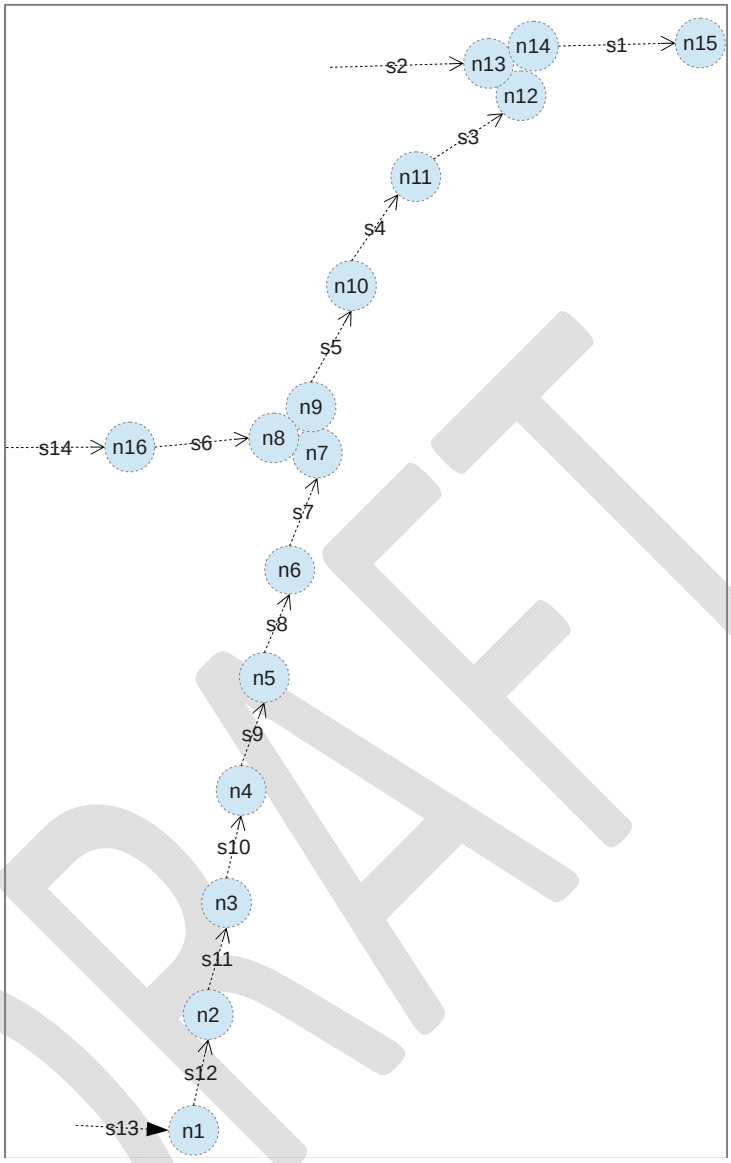

Figure 29: Subbasin nodal network for the Black Creek watershed model

The fitting results reflect a sequential approach. First, measurements of flow made by Winslow (2012) provided data for independent fitting for each of subbasins 2 (Spring Creek) and 6 (Bigelow Creek). With their fitted parameters frozen, parameters in the remaining subbasins were varied in attempts to obtain adequate fits to summer and year-round flows at the Churchville USGS gauge. During this third step, parameters for subbasin 1 (which is heavily influenced by the large Bergen-Byron swamp and an impoundment) were allowed to vary independently from parameters forced to be uniform across the remaining subbasins (3-5, 7-13). Final subbasin parameters are in Table 29. Modeled and measured flows at the Churchville gauge are shown in Figures 30 and 31.

Table 28: Nodes used within the Black Creek watershed model

No.	Stream	Location	Monitoring point	Contributing subbasins
N1	Black Creek	Footbridge in Genesee County Park	DEC BLAK-01	13
N2	Black Creek	Route US20 bridge	BLAK-02	12-13
N3	Black Creek	McLernon Road bridge	BLAK-03	11-13
N4	Black Creek	Brink of falls at Morganville	BLAK-04	10-13
N5	Black Creek	Tyler Rd. (abandoned) bridge	BLAK-06	9-13
N6	Black Creek	Griswold Rd. bridge	BLAK-07	8-13
N7	Black Creek	Above junction with Bigelow Creek	BLAK-08	7-13
N8	Bigelow Creek	Above junction with Black Creek	DEC BLOW-02, Brockport Bigelow	6 (+14 if used)
N9	Black Creek	Below junction with Bigelow Creek	(none)	6-13 (+14)
N10	Black Creek	Trestle Park foot bridge	BLAK-09	5-13 (+14)
N11	Black Creek	Route NY 237 bridge north of Byron	BLAK-10, Brockport Upper Black	4-13 (+14)
N12	Black Creek	Above junction with Spring Creek	(none)	3-13 (+14)
N13	Spring Creek	Above junction with Black Creek	Brockport Spring Creek	2
N14	Black Creek	Below junction with Spring Creek	(none)	2-13 (+14)
N15	Black Creek	USGS gauge at Churchville	USGS Churchville stream gauge	1-13 (+14)
N16	(Unnamed sinking stream)	Terminus of stream in sinkhole in wetland N 42.98060 W 78.14867	(none)	14

Table 29: Final subbasin hydrology parameters

Parameter group	Value
Saturated runoff producing area	Subbasin 6 (Bigelow Creek): 17% All other subbasins: 9%. Remainder of each subbasin is infiltration area.
Aquifer storage capacity	Subbasin 1: 65 mm All other subbasins: 45 mm
Aquifer drainage half life	Subbasin 1: 32 days Subbasins 2 and 6: 17 days All other subbasins: 19 days
Runoff1 soil moisture capacity and initial storage	120 mm Initially fully saturated
Runoff2 soil moisture capacity and initial storage	(Land type not used)
Recharge3 soil moisture capacity and initial storage	150 mm Initially fully saturated

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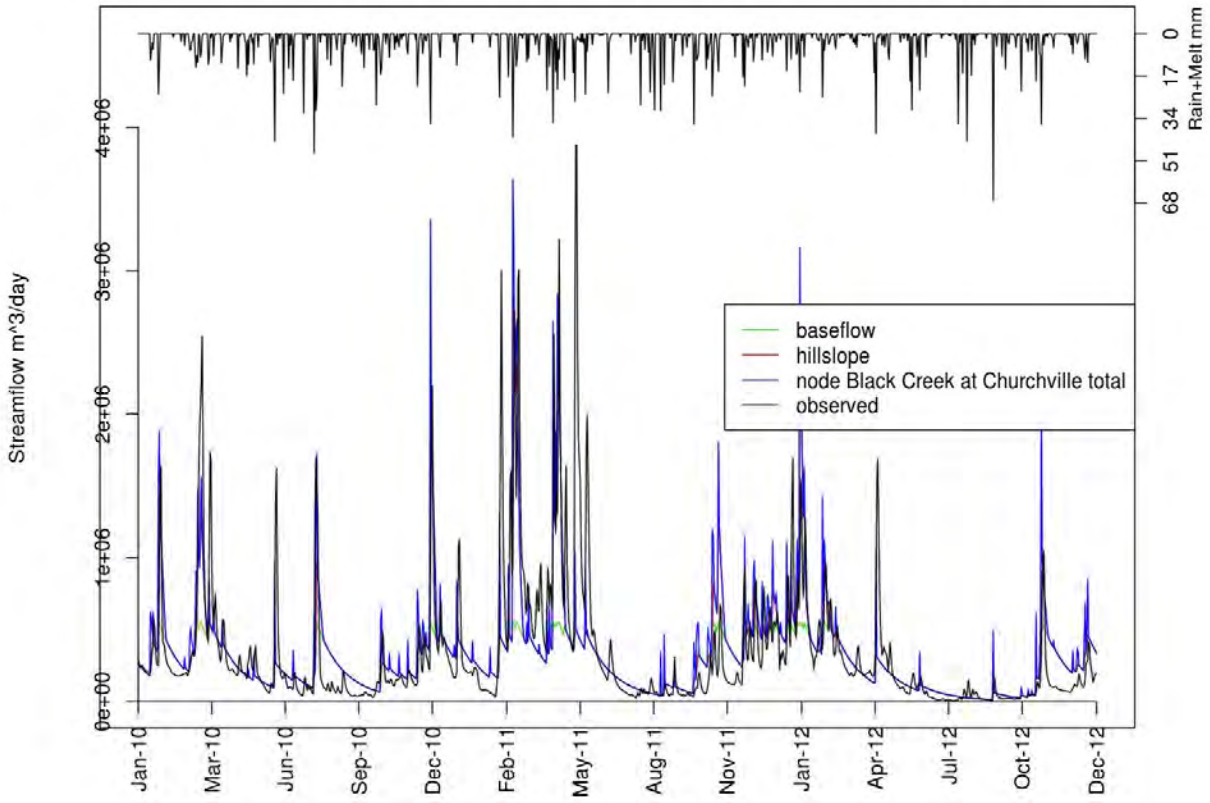

Figure 30: Measured and modeled flows at the Churchville gage for 2010 through 2012.

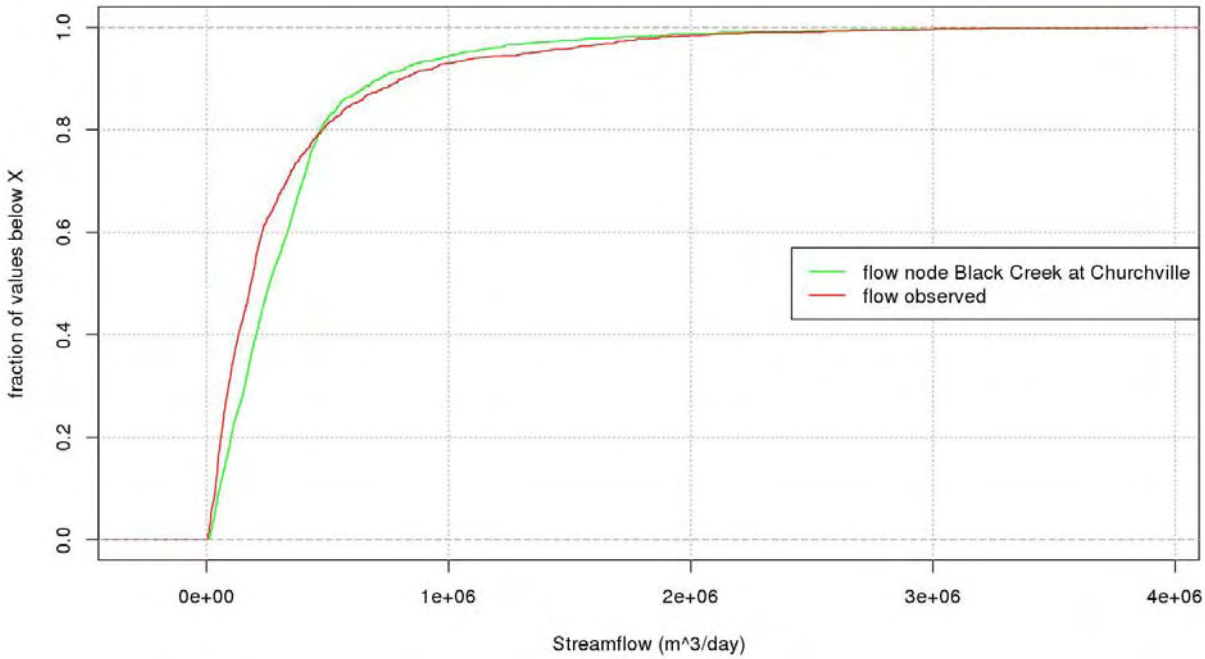

Figure 31: Cumulative frequency distribution of flow at Churchville for 2010 through 2012.

Table 30: Model calibration statistics. Calculation points are at the downstream end of the identified subbasin which corresponds to a node within the model framework.

2010-2012 Calibration period*	NSE 1 day	NSE 7 day	R^2	Percent bias
Subbasin 6 (Bigelow Creek)	0.57	-	0.59	-14
Subbasin 2 (Spring Creek)	0.56	-	0.56	-7
Subbasin 3 (BLAK-10)	0.10	-	0.63	+26
Subbasin 1 (Churchville gage full year)	0.36	0.57	0.41	+6
Subbasin 1 (Churchville gage June - September)	0.43	0.60	0.46	+23

* Most important subset of 2007-2012 parameter fitting period.

C.1.2 Hydrology Validation

Validation of the hydrology model used data from the USGS gage at Churchville, the only observed flow data source for the basin aside from Winslow's 2010-2011 set. The same statistical measures and targets were used for evaluation (Table 31). In most cases the model produces a reasonable approximation to the flow measured at Churchville. The modeled flows are biased high during the summer months, as they were during the calibration period. This reflects the dual pursuit of annual realism and summer realism in the modeling work. Summer hydrology cannot be modeled in isolation from the annual hydrologic cycle, most importantly because of the carryover of water in ground water which may drain to the stream months after it has been recharged. Since bias was a secondary parameter, hydrology fitting efforts were closed with the statistical bias intact and disclosed.

Table 31: Fit statistics for the hydrology model validation

Time period	Full Year			June - September		
	NSE 1 day	NSE 7 day	Percent Bias	NSE 1 day	NSE 7 day	Percent Bias
1979-1984	0.55	0.75	+3	-0.52	0.23	+26
1985-1989	0.44	0.70	-3	0.38	0.64	+16
2000-2004	0.39	-	0	0.56	-	+26

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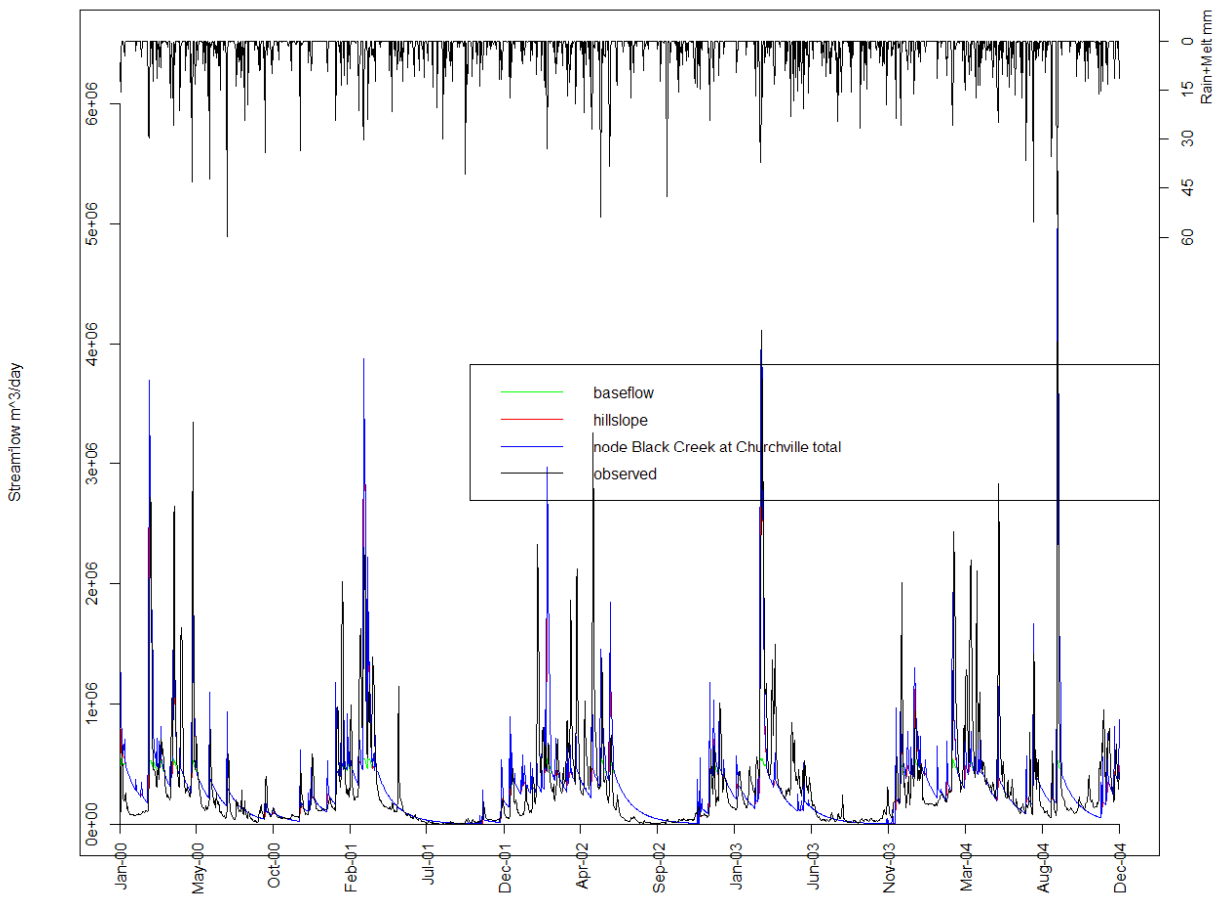

Figure 32: Measured and modeled flows at the USGS gage site in Churchville during the validation period.

C.2 Sediment

Sediment is modeled solely to enable development of a particulate phosphorus model, discussed in a later section. The sediment model builds upon the flow estimates of the hydrology model to predict sediment loading. The PED hydrology model provides four daily flow series per subbasin, of which the Black Creek flow model uses three: saturated area runoff (*r*), interflow (*i*), and baseflow (*b*). The PED sediment model employs these three flow series separately:

$$L_b = a_b Q_b^n$$
$$L_i = a_i Q_i^n$$
$$L_r = a_r Q_r^n$$

in which the *L* values are a subbasin's respective daily loads of sediment, eventually converted to kg/km^2/day. The three *Q* values are the corresponding daily flows (expressed in mm over the whole subbasin), *n* is an empirical exponent related to stream power (theoretical value=1.4), and the a_b, a_i and a_r are empirical multipliers. The three sediment time series may be added into a single series which represents the subbasin's total sediment yield.

The PED sediment model represents the watershed as a network of linked subbasins identical to that described for the hydrology component of the model. Total sediment loading to a node is

calculated as the area-weighted sum of unit-area loadings for all subbasins upstream from the node and expressed in kg/day. A concentration at the node can be computed by dividing the total sediment load in kg/day by the flow in cubic meters per day and multiplying by a factor of 1000 to yield units of mg/L.

C.2.1 Sediment Model Fitting

The sediment model was fitted to total suspended solids (TSS, mg/L) measurements made by Winslow (2012), then cross-checked against NYS DEC data. Biweekly measurements of TSS by Winslow provided a time series from June 2010 to June 2011 at three locations: Black Creek at BLAK-10, Bigelow Creek at BLOW-02 and Spring Creek, a tributary to Black Creek, just downstream from BLAK-10. Estimated parameters which produced the best fit statistics at the three sites are listed in Table 32. Fit statistics to the NYSDEC data based on the same parameter set are also shown. Overall, the parameter value set which represented the Winslow dataset well represented the NYSDEC dataset poorly, and the parameter set which represented the DEC data well represented the Winslow data poorly. The Winslow dataset covered a reasonable range of baseflow and event flow conditions (Figure 33) and is can be used for fitting all model parameters. The NYSDEC dataset could not be used to calibrate the entire PED sediment model because only a single runoff event was sampled. The model provided quantitatively reasonable results when compared to the Winslow data, but only qualitatively representative results for the NYSDEC data (Figure 34).

Table 32: Sediment model parameters and fit statistics

	Winslow 2010-2011	**NYSDEC 2012**
tlimit – runoff1	30	
tlimit – interflow & baseflow	11	
exponent (*b*)	1.5	
BLAK-10 NSE	0.48	-0.37
BLAK-10 % bias	-9	-72
BLAK-10 R^2	0.49	0.10
BLOW-02 NSE	0.50	-1.3
BLOW-02 % bias	-9	13
BLOW-02 R^2	0.51	0.74
Spring Creek NSE	0.45	-
Spring Creek % bias	-12	-
Spring Creek R^2	0.48	-

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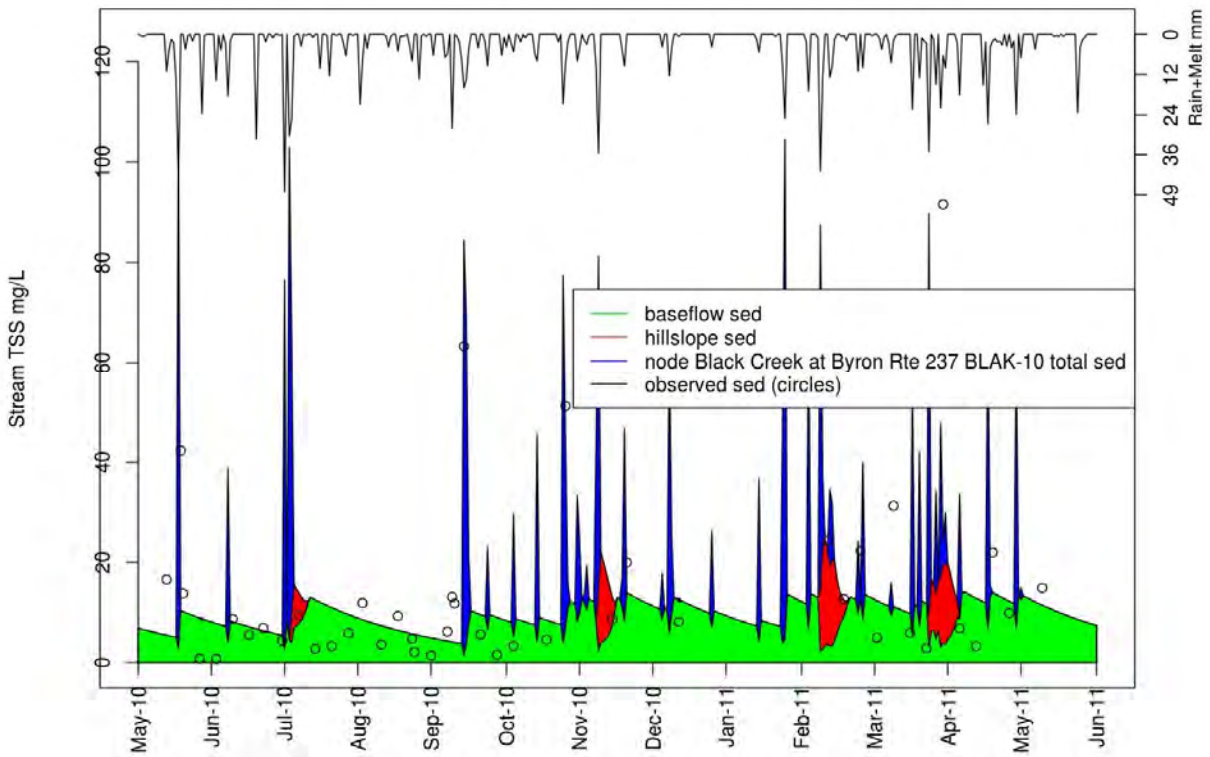

Figure 33: Measured TSS values from Winslow (circles) and modeled TSS at the BLAK-10 site.

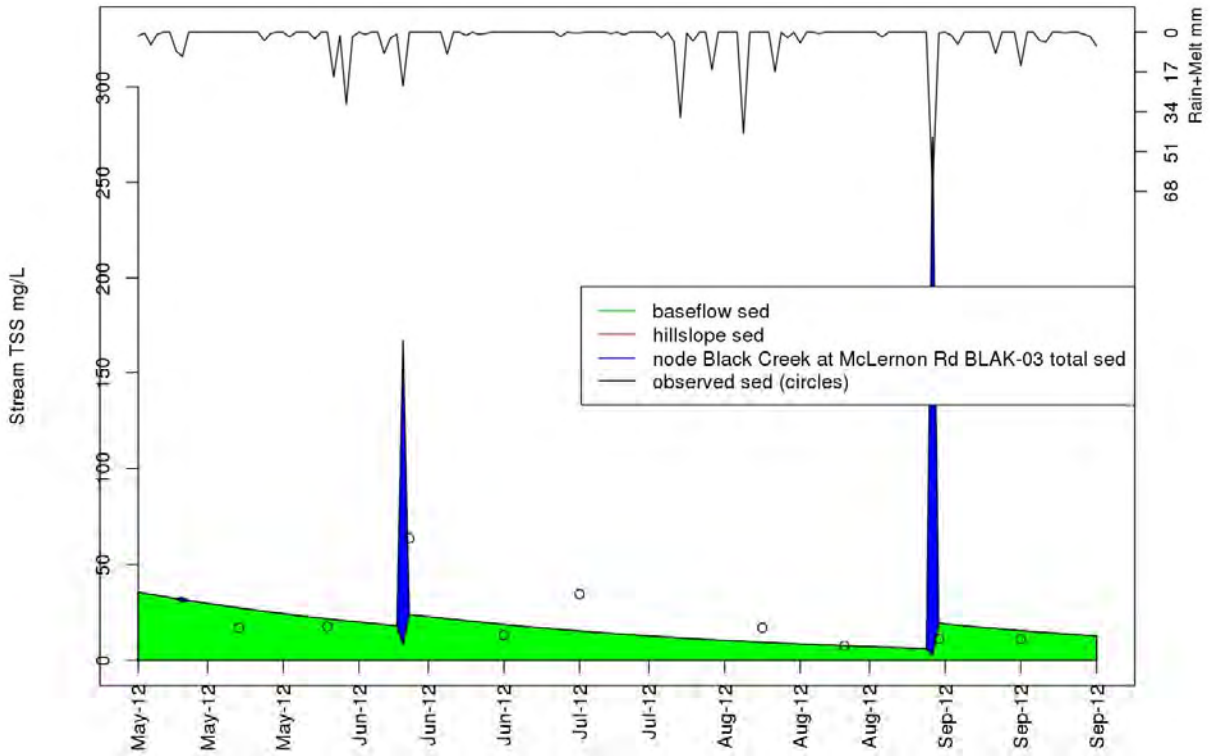

Figure 34: Measured TSS values from NYSDEC (circles) and modeled TSS at the BLAk-10 site.

C.3 Phosphorus

The phosphorus model is comprised of two parts, a soluble reactive phosphorus (SRP) model, and a particulate phosphorus (PP) model. SRP is a soluble form of phosphorus transported with water and is primarily present as orthophosphate. PP is phosphorus associated with and transported with particulates. The PP model builds off of the sediment transport model. Total phosphorus (TP) is the sum of SRP and PP.

C.3.1 Particulate Phosphorus

Particulate phosphorus (PP) is one constituent within TSS. A loading of PP is customarily modeled as a weight concentration of phosphorus within total sediment, times a sediment load. PED borrows this formulation, computing particular phosphorus load L (kg/day) as the product of the amount of delivered sediment (*S*), a phosphorus reference concentration (c_{pp}) and an enrichment ratio (*E*):

$$L = c_{pp} E S$$

Sediment delivery is a result of the sediment model and the reference concentration (mg P / kg sediment) is a calibration parameter having weight concentration units. The enrichment ratio (*E*) is calculated with the formula from USDA's Annual Phosphorus Loss Estimator (which cites Sharpley (1980) and Menzel (1980) for enrichment). Enrichment is a function of the sediment load (*S, kg/ha/day*) and takes the form:

$$E = 12.5S^{-0.35}$$

As the sediment load increases the enrichment factor decreases resulting in the transported particulate carrying a smaller concentration of phosphorus. This is physically sensible because only the smaller and lighter sediment particles, such as clay and organic matter, contain or carry phosphorus. Sand, gravel, and other larger particles that begin to appear when water velocities and sediment concentrations increase do not carry much phosphorus.

Below a sediment transport threshold of S = 0.5 kg/ha/day, enrichment is capped at E=15.9 ($=12.5*0.5^{-0.35}$). The PP reference concentration was set at 1.15×10^{-4} mg PP (kg sediment)$^{-1}$ to track the means of pooled Winslow and DEC sampling data. Output from the PP model is in kg PP/km^2 for each of the sediment generating land types.

Model results are shown in Figures 35 - 37 for site BLAK-10. Overall, the model fitted only using the midpoint of the Winslow and DEC data tracks lower than the Winslow data (low bias) and tracks higher than the DEC data (high bias). This is reflected in the model fit statistics (Table 33). As with the sediment model, a particulate P model intended to track annual and event dynamics will not reproduce low level fluctuations that occur during baseflow (red periods on the figures); at best it can be forced through their center.

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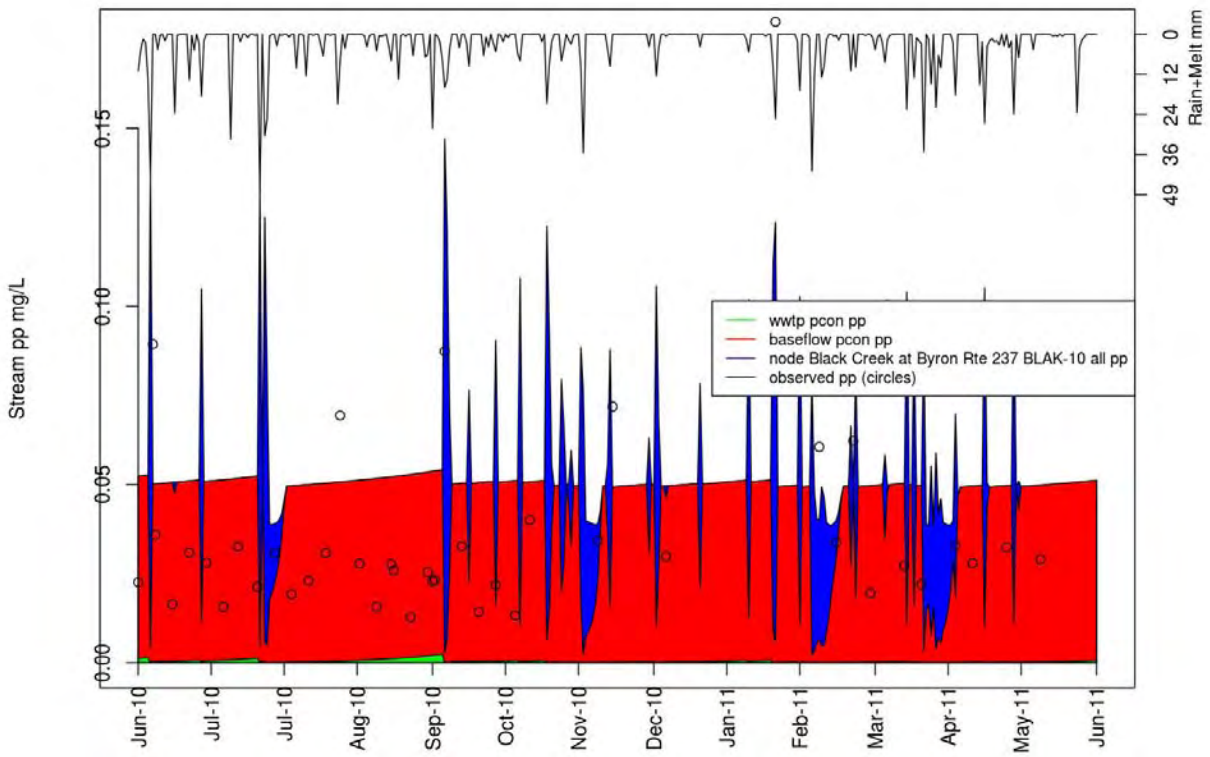

Figure 35: Model results for particulate phosphorus concentration at site BLAK-10.

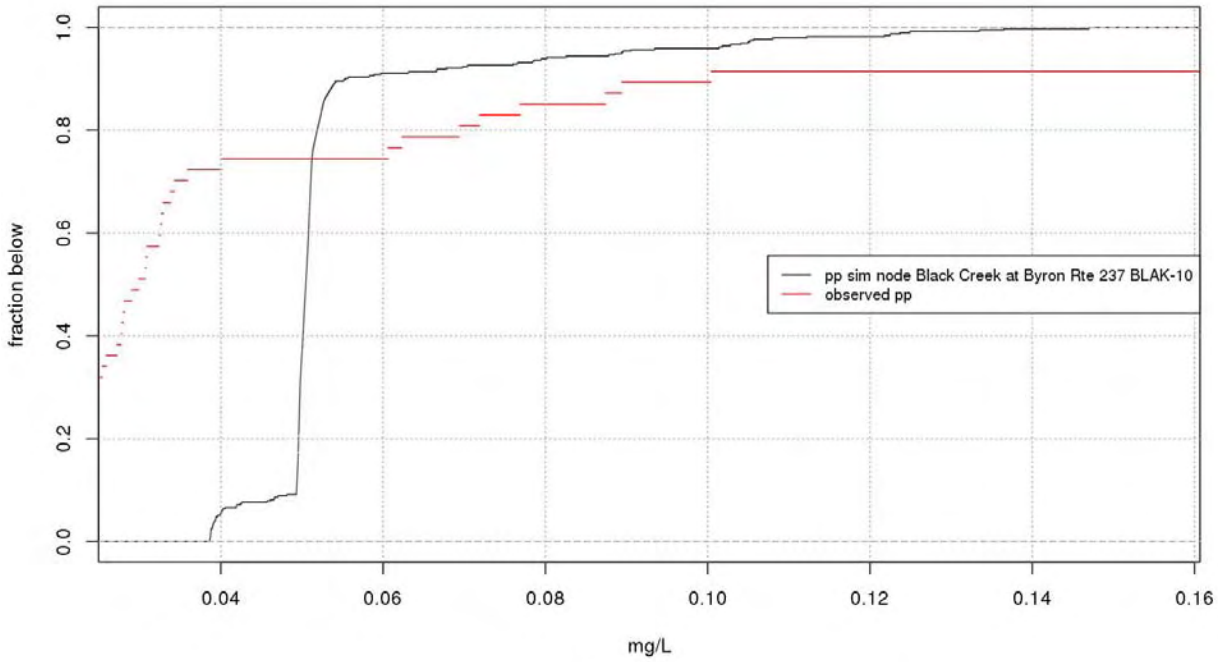

Figure 36: Cumulative frequency distribution of particulate phosphorus concentrations at site BLAK-10. Observed data are Winslow's from 2010-2011.

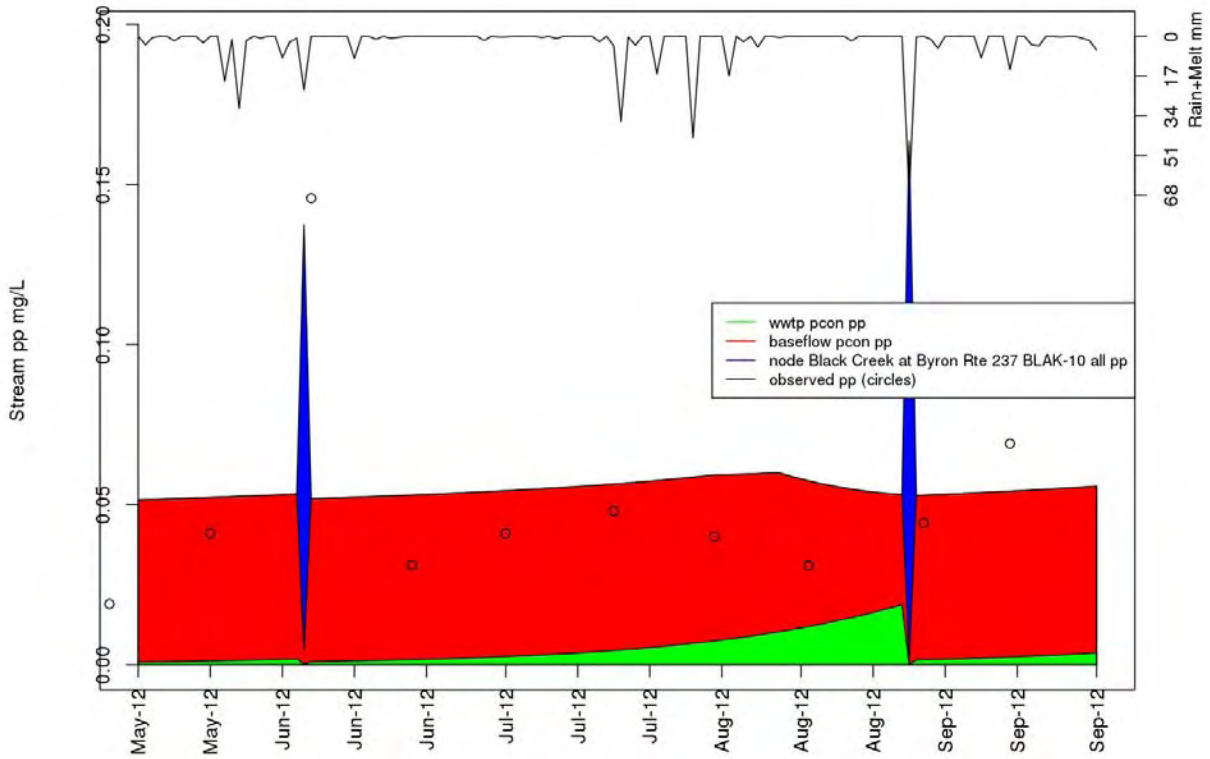

Figure 37: Model results for particulate phosphorus concentrations at site BLAK-10 during summer 2012.

Table 33: Particulate phosphorus model fit statistics

	Winslow data (2010-2012)			NYSDEC 2012		
Site	NSE 1 day	Percent Bias	R^2	NSE 1 day	Percent Bias	R^2
BLAK-10	+0.09	-5	0.11	-0.005	+6	0.06
Bigelow Creek	+0.09	-15	0.14	+0.15	+33	0.85*
Spring Creek	+0.09	0	0.11	-	-	-

* misleadingly high, NSE is more representative

C.3.2 Soluble Reactive Phosphorus

The SRP model centers on reference SRP concentrations for up to 32 combinations of SRP-oriented land use types (row crops, grass crops, developed land and other lands), shallow versus deeper water table, and the four hydrologic model outflow types (runoff1, runoff2, interflow, and baseflow). The 32 drops to 24 when the runoff2 type is eliminated as it was not used in this model implementation. For technical reasons the water table depth aspect did not need to be separated, thus there remained 12 distinct reference SRP concentrations to estimate in a way that reflects the spatial and time variations in observed SRP concentrations in streams.

Reference SRP concentrations (*c, in mg/L*) are calibration parameters. SRP loads from individual SRP land types are the product of amount of land in the subbasin within the land use and land type (i.e. row crops on shallow water table land), the associated reference concentration, and an amount of flow from the hydrology model (*q*).

For the interflow and baseflow types an additional temperature dependent factor (t_{adj}) is also included to provide seasonality in reference concentrations. The temperature seasonality takes the form:

$$t_{adj} = 2.5^{\frac{t_s - t_r}{10}}$$

where t_s is the soil temperature for the day of year, and t_r is a reference temperature equal to 9.0 °C. Soil temperature is itself modeled as an annual sine wave, modified by a time lag factor, and taking into account the temperature damping effect of a small depth of soil. Load (kg/km^2/day) calculations for a single type of SRP land among the eight choices take the form:

$$L_{r1} = c_{r1} \times q_{r1}$$

$$L_i = c_i \times t_{adj}(t) \times q_i$$
$$L_b = c_b \times t_{adj}(t) \times q_b$$

in which subscripts identify the different land types: runoff1 (*r1*), interflow (*i*) and baseflow (*b*). The separate Cornell modeling document describes how these three concentrations are selected from the twelve calibration parameters associated with the SRP land types.

Both the SRP and PP model components utilize the same basin and node network as the hydrology component. The network also incorporates the SRP and PP loadings from wastewater treatment plants, shown earlier in Table 26.

As with the sediment model, the SRP model was fitted first to the Brockport full-year data set (Winslow 2012), and then checked against the NYSDEC sampling done in 2012. Fitting was done by pooling all of Winslow's observations at three locations, and using a constrained genetic algorithm to find the combinations of 12 parameters that yielded overall the best fit between simulated and observed space/time variation of SRP. This employed full-year Nash-Sutcliffe efficiency as the statistic to maximize. Unlike the sediment and PP models, the SRP model has enough parameters due to its land use overlay (12) to be able to track spatial differences in SRP concentrations in streams. (The different level of detail among SRP, PP, and sediment models was a strategic choice partly based on the relative importance of SRP versus PP in biological activity in the summer. SRP concentrations represent roughly two thirds of total P in the DEC monitoring data.)

Fitted values for the reference concentrations (*c*) resulting from the calibration to the Winslow station data are listed in Table 34. Model predictions of SRP are compared to measured values in Figures 38 and 39 for Bigelow Creek during Winslow's sampling period. The model accurately captures the seasonal variation in SRP concentration and is able to capture some of the higher

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concentration events. It over predicts concentrations during periods of low stream flow such as during July and August in 2010. Fit statistics are shown in Table 35. Again as with the DEC sediment and PP data, during baseflow periods there is no model mechanism to reproduce low level fluctuations in concentration, thus Nash-Sutcliffe values hover around zero. When there is a high flow event in the observed data, as in BLAK-06, a NSE is more meaningful as long as the modeled event day is the same as the observed event day. There are different levels of bias in at the DEC stations taken separately. The worst is at the most upstream Black Creek sites where simulated concentrations were much higher than observed. Farther downstream the bias is much lower. The companion Cornell modeling document includes additional graphics that evaluate the degree of model fit to spatial differences in the DEC 2012 monitoring data, concluding that even without calibration to the DEC data their spatial differences were still preserved.

Table 34: SRP reference concentrations (*c*) in the phosphorus model, fitted to Winslow data. Units are mg/L.

	Row Crops	Grass	Natural	Developed
Runoff1	0.192	0.544	0.103	0.227
Hillslope	0.040	0.016	0.116	0.118
Baseflow	0.025	0.00425	0.0212	0.0421

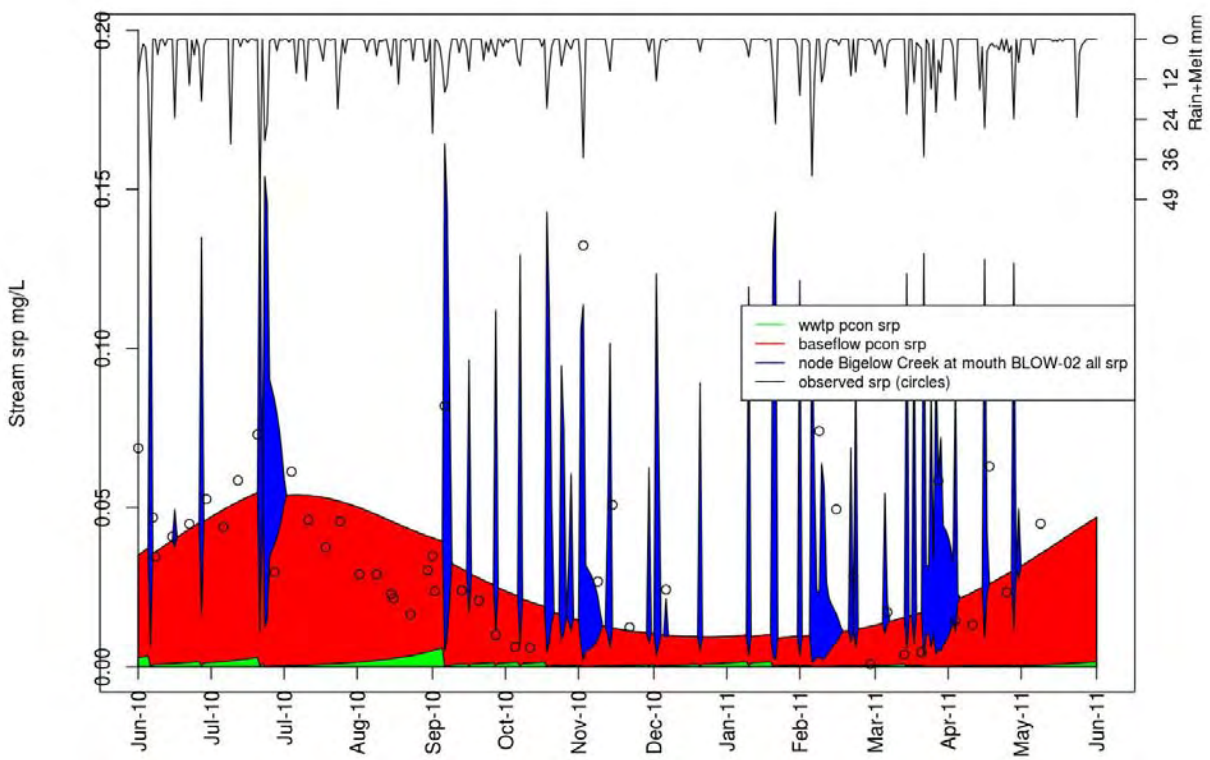

Figure 38: Soluble reactive phosphorus concentration model results and measured values at Bigelow Creek (BLOW-02)

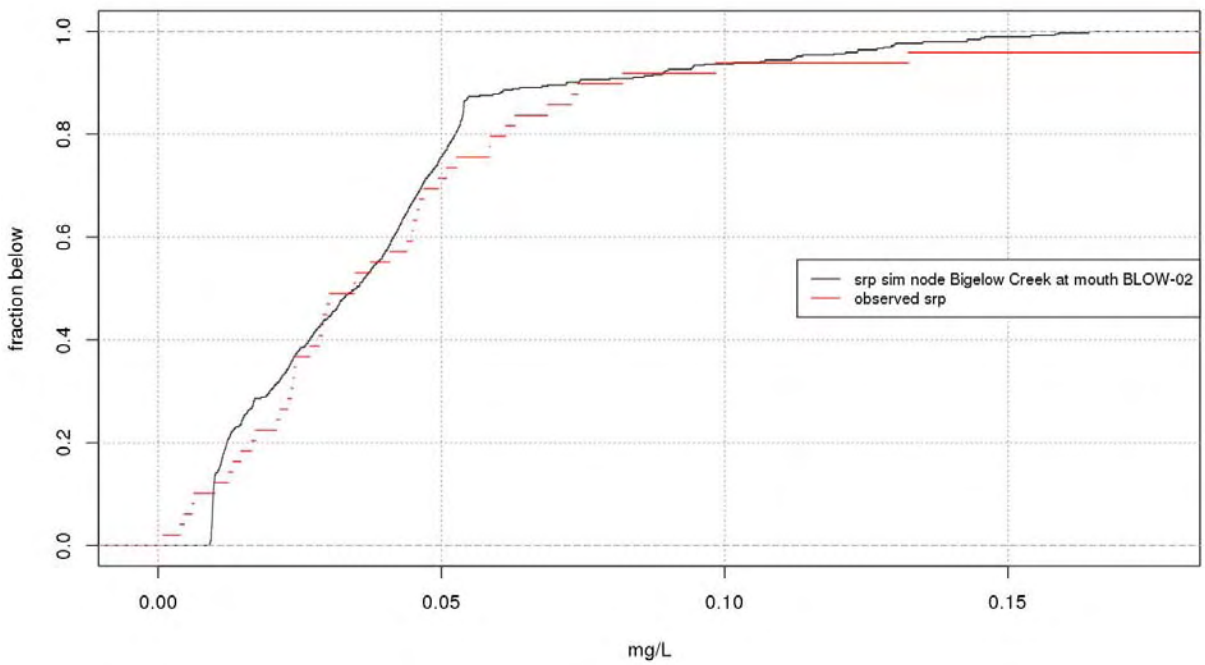

Figure 39: Cumulative frequency distribution of the measured and modeled soluble reactive phosphorus concentrations at the Bigelow Creek site (BLOW-02).

Table 35: Soluble reactive phosphorus model fit statistics

	Winslow data (2010-2011)			NYSDEC 2012		
Site	NSE 1 day	Percent Bias	R^2	NSE 1 day	Percent Bias	R^2
BLAK-01	-	-	-	-149	+156	0
BLAK-02	-	-	-	0.4	+97	0.96*
BLAK-03	-	-	-	-30	+18	0.13
BLAK-04	-	-	-	-0.4	-47	0.05
BLAK-06	-	-	-	0.67	-20	0.77*
BLAK-07	-	-	-	-3.4	+14	0.11
BLAK-08	-	-	-	-3.1	+19	0.01
BLAK-09	-	-	-	-1.4	+3	0.02
BLAK-10	0.45	-17	0.50	-5.0	+25	0.02
Bigelow Creek	0.31	-6	0.31	-4.3	+62	0.02
Spring Creek	0	3	0.21	-	-	-

* misleadingly high

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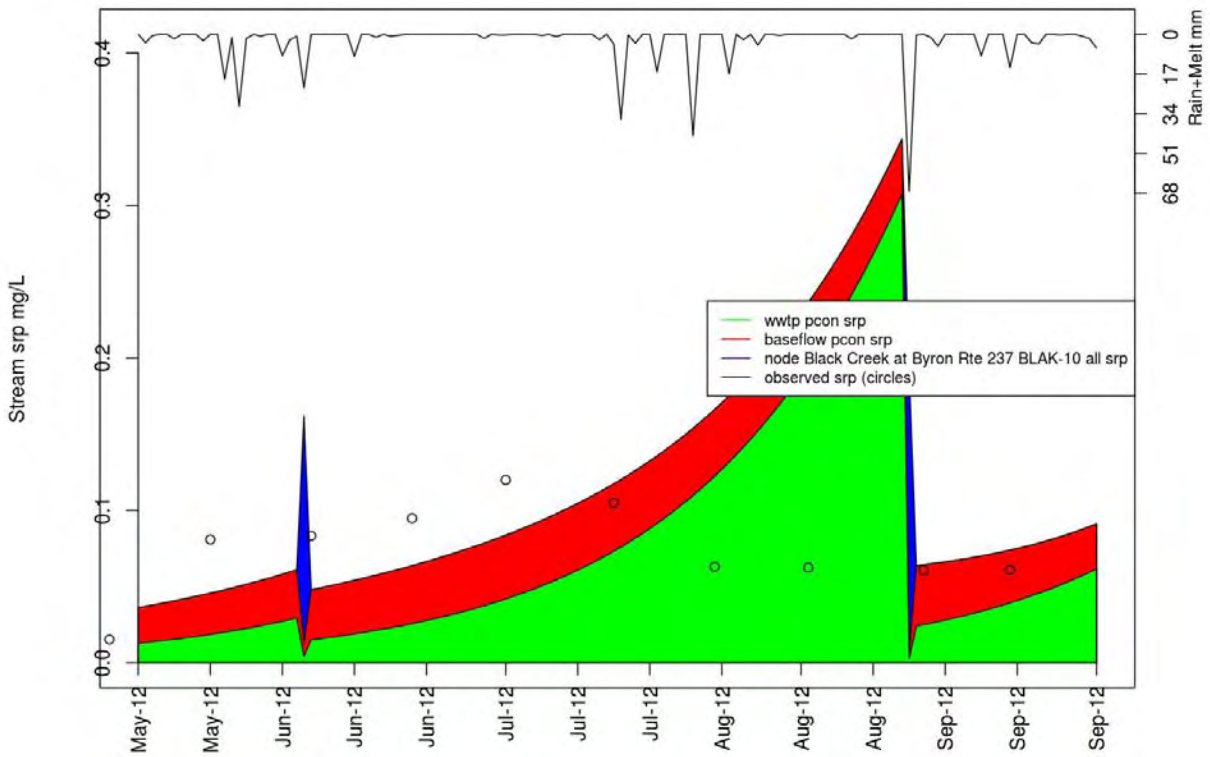

Figure 40: Model predictions of soluble reactive phosphorus concentrations at site BLAK-10.

Figure 40 shows the model predictions of SRP when the model calibrated to Winslow's data is applied Black Creek during the 2012 summer period. Again, there appears to be an over prediction of SRP concentration when the model predicts periods of low flow (August 2012).

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Appendix D: Priority Waterbodies List

PWL listings for Upper Black Creek and Bigelow Creek are on the following pages.

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Black Creek, Upper, and minor tribs (0402-0048) Impaired Seg

Waterbody Location Information

Revised: 01/02/02

Water Index No:	Ont 117- 19			**Drain Basin:**	Genesee River
Hydro Unit Code:	04130003/080	**Str Class:**	C		Lower Genesee River
Waterbody Type:	River			**Reg/County:**	8/Genesee Co. (19)
Waterbody Size:	56.3 Miles			**Quad Map:**	BYRON (I-08-3) ...
Seg Description:	stream and tribs above Byron				

Water Quality Problem/Issue Information

(CAPS indicate MAJOR Use Impacts/Pollutants/Sources)

Use(s) Impacted	Severity	Problem Documentation
AQUATIC LIFE	Impaired	Known
Recreation	Stressed	Known

Type of Pollutant(s)

Known: NUTRIENTS, Silt/Sediment
Suspected: - - -
Possible: Pathogens

Source(s) of Pollutant(s)

Known: AGRICULTURE, MUNICIPAL (South Byron WWTP), Streambank Erosion
Suspected: - - -
Possible: Urban Runoff

Resolution/Management Information

Issue Resolvability: 1 (Needs Verification/Study (see STATUS))
Verification Status: 4 (Source Identified, Strategy Needed)
Lead Agency/Office: DOW/Reg8 **Resolution Potential:** Medium
TMDL/303d Status: (TMDL Not Required (No Impairment))

Further Details

Aquatic life support, recreation and aesthetics in Upper Black Creek are affected by municipal and industrial discharges to the creek. Nutrient enrichment, silt/sediment and other pollutants from nonpoint sources in this agricultural watershed also contribute to water quality problems.

NYSDEC Rotating Intensive Basin Studies (RIBS) Intensive Network monitoring of Black Creek in Byron (at State Route 237) was conducted in 2000. Overall water quality at this site, which is downstream of the Byron (T) wastewater treatment plant, is fair. The macroinvertebrate community is moderately impacted, with nutrient and toxic inputs identified as the most likely causes. Total dissolved solids in the water column and cadmium in the bottom sediments are present at concentrations above the levels of concern. However, no fish advisories are in effect, and no acute or chronic toxicity was apparent in the water column from the three tests conducted in 2000. (DEC/DOW, BWAR/RIBS, January 2003)

A biological (macroinvertebrate) assessment of Black Creek in South Byron was conducted in 1999. Sampling results indicated moderately impacted water quality conditions, with municipal and/or industrial waste discharges identified as

the most likely causes. These findings were similar to those of a biomonitoring survey of Black Creek conducted in 1996. (Biological Assessment of Black Creek, Bode et al, DEC/DOW, SBU, June 1997) That survey found slight to moderate impacts from nutrient enrichment and organic wastes were indicated at sites along the reach. Prolific growths of algae in the stream were also noted. The Byron and South Byron WWTP discharges and nonpoint agricultural sources were identified as possible sources. (DEC/DOW, BWAR/SBU, January 2003)

This segment includes the entire stream and all tribs above Bigelow Creek (-30) near Byron. The waters of this segment are Class C. (May 2001)

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Bigelow Creek and tribs (0402-0016) Impaired Seg

Waterbody Location Information

Revised: 01/02/02

Water Index No:	Ont 117- 19-30			**Drain Basin:**	Genesee River
Hydro Unit Code:	04130003/080	**Str Class:**	C		Lower Genesee River
Waterbody Type:	River			**Reg/County:**	8/Genesee Co. (19)
Waterbody Size:	11.8 Miles			**Quad Map:**	BYRON (I-08-3) ...
Seg Description:	entire stream and tribs				

Water Quality Problem/Issue Information

(CAPS indicate MAJOR Use Impacts/Pollutants/Sources)

Use(s) Impacted	Severity	Problem Documentation
AQUATIC LIFE	Impaired	Known
Recreation	Stressed	Known

Type of Pollutant(s)

Known: NUTRIENTS
Suspected: Pathogens, Silt/Sediment, Unknown Toxicity
Possible: - - -

Source(s) of Pollutant(s)

Known: AGRICULTURE
Suspected: Streambank Erosion
Possible: - - -

Resolution/Management Information

Issue Resolvability: 1 (Needs Verification/Study (see STATUS))
Verification Status: 4 (Source Identified, Strategy Needed)
Lead Agency/Office: DOW/Reg8 **Resolution Potential:** Medium
TMDL/303d Status: (TMDL Not Required (No Impairment))

Further Details

Aquatic life support, recreation and aesthetics in Bigelow Creek are affected by nutrient enrichment, silt/sediment and other pollutants from nonpoint sources in this agricultural watershed. Some indication of aquatic toxicity are also present.

A biological (macroinvertebrate) assessment of Bigelow Creek in South Byron was conducted in 1999. Sampling results indicated moderately impacted water quality conditions. Nutrient enrichment and toxic inputs were indicated by Impact Source Determination. (DEC/DOW, BWAR/SBU, January 2001)

Bathing beaches on Horseshoe Lake and Godfrey Pond (which are in this reach but listed separately) have been closed in the past due to high coliform counts. However beaches were reopened in 1987 and no closures have occurred recently. The problems had been attributed to poor agricultural management practices (barnyard runoff, livestock access to stream, manure spreading, etc) and have largely been corrected. (Genesee County WQCC, April 2001)

This segment includes the entire stream and all tribs. The waters of the segment, including Thornell Brook (-3), are Class C and C(T). Mill Pond (-16), Godfrey Pond (-17) and Horseshoe Lake (-18) are listed separately. (May 2001)