TOTAL PHOSPHORUS TMDL FOR THE WISSAHICKON CREEK WATERSHED, PENNSYLVANIA

Draft
May 2015

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ACKNOWLEDGMENTS

Tetra Tech, Inc. (Tetra Tech) in Fairfax, Virginia contributed substantial work on this study for the U.S. Environmental Protection Agency, Region 3 (EPA). Completion of this study depended on generous informational and data support from various groups. Special acknowledgment is made to the following groups who provided critical support and guidance at various phases throughout the project:

- Pennsylvania Department of Environmental Protection
- Philadelphia Water Department
- United States Geological Survey
- Friends of the Wissahickon
- Wissahickon Valley Watershed Association
- Municipalities of the Wissahickon Creek Watershed

EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency, Region 3 (EPA) is establishing a total maximum daily load (TMDL) for total phosphorus (TP) the Wissahickon Creek Watershed in southeastern Pennsylvania. Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (codified at Title 40 of the *Code of Federal Regulations* Part 130) require states to develop TMDLs for impaired water bodies. A TMDL establishes the amount of a pollutant that a waterbody can assimilate without exceeding its water quality standard for that pollutant. TMDLs provide the scientific basis for a state to establish water quality-based controls to reduce pollution from both point and nonpoint sources to restore and maintain the quality of the state's water resources.

The Wissahickon Creek drains approximately 64 square miles and extends 24.1 miles in a southeasterly direction through lower Montgomery County and northwestern Philadelphia County before entering the Schuylkill River. The watershed covers portions of sixteen municipalities which include urbanized areas. The headwaters and upper portions of the watershed consist primarily of residential, agricultural, and wooded land use. The mid-section of the watershed is dominated by industrial, commercial, and residential land use, and includes a limestone quarry that adds flow to the creek. The lower 6.8 miles of the stream is enclosed by Fairmount Park, a predominantly wooded area, while the remaining lower watershed is dominated by residential land use.

Multiple stream segments in the Wissahickon Creek watershed have been identified as not protective of aquatic life due to nutrients and other nutrient related conditions such as organic enrichment and low dissolved oxygen. Nutrients are a natural part of an aquatic ecosystem. They also support the growth of algae and aquatic plants, which in turn provide food and habitat for fish, shellfish, and smaller organisms that live in water. However, when excess nutrients enter the environment, algae grows to amounts beyond what the ecosystems can handle and ultimately impair the use of a stream for aquatic life.

Excessive nutrient concentrations in streams and rivers do not have a direct toxicological effect on insects, fish, and other animal aquatic life, but does cause indirect effects from the adverse impacts on algal and other plant aquatic life. Excessive nutrient concentrations directly impact algae and other aquatic plant life by altering the diversity and composition of those assemblages needed to support a healthy ecosystem. Excessive nutrients contribute to increased algal growth which leads to changes in the physical and chemical stream environment associated with eutrophication such as low dissolved oxygen (DO), changes to pH, loss of reproductive habitat, alteration on the availability of palatable algal taxa, etc. Such significant increases in algae harm water quality, food resources and habitats, and decrease the DO that fish and other aquatic life need to survive.

EPA is establishing this TMDL for TP as a supplemental action to restore the aquatic life use impairment caused by excessive nutrient concentrations in the Wissahickon Creek Watershed. In October 2003, EPA established TMDLs for the pollutants ammonia nitrogen, nitrate-nitrite, orthophosphate, and carbonaceous biochemical oxygen demand, to support restoration of the aquatic life use impairment in the Wissahickon Creek Watershed caused by nutrients (herein

referred to as the 2003 Nutrient TMDL). The 2003 Nutrient TMDL was intended to ensure the Pennsylvania's water quality standard for DO, a variable for eutrophic conditions, was met during critical conditions. Although the 2003 Nutrient TMDL adequately addressed DO concentrations, it did not adequately address nuisance algal growth and its negative impact on aquatic life uses. For this reason, the stream segments previously addressed in the 2003 Nutrient TMDL are still impaired due to nutrients and must be further addressed in this TMDL. This TMDL addresses the nuisance algal growth by focusing on TP, a nutrient that did not have water quality goal in the 2003 Nutrient TMDL. This TP TMDL does not replace the TMDLs for ammonia nitrogen, nitrate-nitrite, orthophosphate, and carbonaceous biochemical oxygen demand pollutants, and should be viewed as supplemental to the 2003 Nutrient TMDL.

EPA developed the Wissahickon Creek watershed TMDL based on extensive information on the streamflow characteristics of the watershed, distribution and acreage of various land uses, meteorological data, and many other factors. During 2005, EPA, as well as the United States Geological Survey (USGS), National Oceanic and Atmospheric Administration (NOAA), Philadelphia Water Department (PWD), and Pennsylvania Department of Environmental Protection (PADEP), collected a substantial amount of environmental data through extensive monitoring in the Wissahickon Creek Watershed. The data collected helped provide a clear picture of the environmental characteristics of the watershed.

Knowledge of the TP sources and transport of TP within the watershed was also necessary in developing the TMDL. For purposes of a TMDL, it is important to distinguish the sources of TP based on their classification as a point sources which are regulated or a nonpoint sources which are not regulated under the Clean Water Act in order to assign wasteload allocations (WLA) to point sources or load allocations (LA) to nonpoint sources. Almost all of the TP in the Wissahickon Creek Watershed is attributable to point sources which require coverage by a National Pollutant Discharge Elimination System (NPDES) permit, which is a mechanism for implementation of this TMDL. There are several municipal waste water treatment plants (WWTPs) in the Wissahickon Creek watershed which are sources of TP. These WWTPs make up the majority of the streamflow during low-flow periods. In addition, the entire Wissahickon Creek Watershed lies within the political boundaries of municipal separate stormwater sewer systems (MS4s), which are regulated as point sources. Discharges from MS4s are generated by runoff from urban land and impervious areas such as paved streets, parking lots, and rooftops during precipitation events. These discharges often contain concentrations of various pollutants including TP. Due to a lack of refined sewersheds that would delineate areas contributing stormwater discharges to the Wissahickon Creek and its tributaries through regulated MS4s, this TMDL assigns TP loadings from all land-uses within the political boundaries of the MS4s to the respective MS4. EPA acknowledges that this methodology may include loadings from nonpoint sources that may exist within the political boundaries of MS4s such as agricultural lands, golf courses, etc. Therefore, this TMDL fully evaluates any loadings from potential nonpoint sources and their impacts on the watershed, but does not disaggregate loadings based on regulatory status. Septic systems are the only category of nonpoint sources identified as a separate source of TP in this TMDL. There are also numerous other point sources scattered through the watershed which were determined to have *de minimis* discharges of TP.

EPA developed a scientifically supported nutrient endpoint for this TMDL, since Pennsylvania has applicable narrative criteria, but no numeric water quality criteria for nutrients. This TP endpoint for the TMDL was developed based on a separate EPA study to determine an appropriately protective endpoint for the northern Piedmont region of Pennsylvania, in which the Wissahickon flows. EPA applied a weight of evidence approach, (as discussed in Section 1 of the report) showing that a TP endpoint of 40 micrograms per liter (µg/L) would be both protective of aquatic life uses in this region and defensible (Paul and Zheng 2007).

In the development of this TMDL and its allocations, EPA relied on two computer models that use observed and simulated data to replicate what is occurring in the Wissahickon Creek watershed to make future predictions on water quality. The computer modeling process consisted of several steps. First, the characteristics of the drainage area including land use, soil type, and stream geometry, were entered into the models. The models were then calibrated using observed data to ensure reasonably accurate representation of the Wissahickon Creek watershed. Once the models were calibrated, EPA used them to determine the reductions in TP necessary to meet the TP endpoint, and the basis to support the TMDL pollutant allocations.

The TMDL itself is composed of waste load allocations (WLA) for point sources and load allocations (LA) for nonpoint sources, and includes a margin of safety (MOS) to account for the uncertainty in the relationship between TP loads and the water quality of the receiving waterbody. The TMDL components are illustrated using the following equation:

$$\text{TMDL} = \Sigma\ WLAs + \Sigma\ LAs + MOS$$

The final TMDL for the Wissahickon Creek Watershed expressed as annual loadings is shown in Table E-1. The TMDL is also expressed as daily loadings in Section 5 of this report. The nutrient TMDL for the Wissahickon Creek Watershed used an implicit MOS because the assumptions made in the development of the TMDL were conservative.

This TMDL will inform future NPDES permits (re)issued in the watershed. Federal regulations require that NPDES permit effluent limits be consistent with the assumptions and requirements of the TMDL WLAs. While the applicable permit effluent limits need not be identical to the WLA, EPA anticipates future permits will include more stringent limits on TP discharged by sewage treatment plants and requirements for MS4 communities to develop and implement short and long-term plans to control TP in stormwater.

EPA is required to seek public comment pursuant to 40 C.F.R. §130.7(d)(2) for TMDLs developed by EPA. Public participation for this TMDL development process is discussed in Section 7.

Table E-1. Annual TMDL loads for TP for the Wissahickon Creek watershed.

Source Group	Allocation Type	Source	Baseline TP Load* (lbs/year)	Allocated TP Load (lbs/year)	Percent Reduction (%)
Point Sources: WWTP	WLA	Upper Dublin (PA0029441)	9634.00	171.47	98.2
		Abington (PA0026867)	45734.00	361.45	99.2
		Ambler (PA0026603)	81115.00	798.63	99.0
		Upper Gwynedd (PA0023256)	47311.00	282.58	99.4
		North Wales (PA0022586)	3976.08	47.71	98.8
Point Sources: MS4	WLA	Abington (PAG130012)	9574.45	209.60	97.8
		Ambler (PAG130036)	2707.77	79.37	97.1
		Cheltenham (PAG130054)	576.99	27.82	95.2
		Horsham (PAG130157)	563.86	15.28	97.3
		Lansdale (PAG130038)	1912.30	26.03	98.6
		Lower Gwynedd (PAG130072)	23505.76	1458.61	93.8
		Montgomery (PAG130016)	5143.51	119.85	97.7
		North Wales (PAG130005)	1639.47	27.01	98.4
		Philadelphia (PA0054712)	24799.61	2404.14	90.3
		Springfield (PAG130130)	15038.23	641.87	95.7
		Upper Dublin (PAG130075)	30535.65	1587.65	94.8
		Upper Gwynedd (PAG130031)	12149.69	458.51	96.2
		Upper Moreland (PAG130019)	156.50	1.78	98.9
		Whitemarsh (PAG130103)	16595.84	1373.25	91.7
		Whitpain (PAG130137)	12295.91	784.40	93.6
		Worcester (PAG130026)	314.64	9.82	96.9
Nonpoint Sources	LA	Septics	2289.11	274.69	88.0
Total Point Sources: WWTP			**187770.08**	**1661.84**	**99.1**
Total Point Sources: MS4			**157510.18**	**9224.99**	**94.1**
Total Nonpoint Sources			**2289.11**	**274.69**	**88.0**
Total			**347569.37**	**11161.52**	**96.8**

*For septics and MS4s, the baseline TP load represents existing TP loadings from 2005-2006. For WWTPs, baseline TP loads are calculated using observed phosphorus data and effluent discharge rate, or the flow used to calculate effluent limitations for a National Pollutant Discharge Elimination System (NPDES) permit.

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1. INTRODUCTION AND BACKGROUND

Section 303(d) of the Clean Water Act and its implementing Water Quality Planning and Management Regulations (Title 40 of the Code of Federal Regulations (CFR) Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are not supporting their designated uses even if pollutant sources have implemented controls sufficient/necessary to meet technology-based effluent limitations and guidelines. A TMDL establishes the maximum allowable load (mass per unit of time) of a pollutant a waterbody is able to assimilate and still support its designated use(s). The maximum allowable load is determined based on the relationship between pollutant sources and in-stream water quality. A TMDL provides the scientific basis for a state to establish water quality-based controls to reduce pollution from both point and nonpoint sources to restore and maintain the quality of the state's water resources. The development of TMDLs requires an assessment of streams' assimilative capacity, critical conditions, and other considerations.

The U.S. Environmental Protection Agency, Region 3 (EPA) is establishing a watershed-based TMDL for total phosphorus (TP) to address the nutrient impairment of the Wissahickon Creek Watershed. Through various biological investigations, the Pennsylvania Department of Environmental Protection (PADEP) identified impairments of aquatic life use through observed impacts on the benthic community as a result of increasing algal biomass (including nuisance algal growth) from eutrophic conditions; and, therefore listed much of the Wissahickon Creek Watershed on Pennsylvania's 303(d) list of impaired waters for nutrients in 1996 to 2002. Portions of the Wissahickon Creek Watershed are also listed as impaired due to other pollutants including: dissolved oxygen (DO) associated with biological oxygen demand (BOD); organic enrichment resulting in low DO concentrations; as well as, siltation and pathogens. The U.S. Environmental Protection Agency, Region 3 (EPA) established TMDLs in October 2003 to address the aquatic life use impairment caused by nutrients and sediment. It is expected that PADEP will address pathogens and organic enrichment (low DO not related to excessive nutrients) through separate TMDLs unless water quality standards are attained through other means. The 2003 TMDL can be found at: http://www.epa.gov/reg3wapd/tmdl/pa_tmdl/wissahickon/index.htm

The 2003 TMDLs for the pollutants, ammonia nitrogen, nitrate-nitrite, orthophosphate, and carbonaceous BOD, to support restoration the aquatic life use impairment in the Wissahickon Creek Watershed caused by nutrients (herein referred to as the "2003 Nutrient TMDL"). Since that time, despite implementation of the 2003 Nutrient TMDL, PADEP and others have provided documentation that the watershed DO levels have improved but the stream remains impaired for the aquatic life use caused from excessive nutrients resulting from nuisance algal growth. Although the 2003 Nutrient TMDL adequately addressed DO concentrations, it did not include TMDLs for either total nitrogen (TN) or total phosphorus (TP); and, thus, did not adequately address nuisance algal growth and its negative impact on aquatic life uses. For this reason, the stream segments previously addressed in the 2003 Nutrient TMDL are still impaired due to excessive nutrient concentrations and must be further addressed in this TMDL. This TMDL addresses the nuisance algal growth by focusing on TP, a nutrient that did not have water quality goal in the 2003 Nutrient TMDL. This TP TMDL does not replace the TMDLs for ammonia nitrogen, nitrate-nitrite, orthophosphate, and carbonaceous BOD pollutants, and should be viewed as supplemental to the 2003 Nutrient TMDL.

1.1. History of the Wissahickon Nutrient TMDLs

As explained in more detail below in Section 1.3, from 1996 to 2002 Pennsylvania identified on its 303(d) list to include approximately 95 miles of the Wissahickon Creek and its tributaries as impaired for siltation, nutrients (approximately 54 miles), and DO related impairments. EPA established both nutrient and sediment TMDLs in 2003 to address those impairments. The 2003 Nutrient TMDL was intended to ensure the Pennsylvania's water quality standard for DO, a variable for eutrophic conditions, was met during critical conditions defined as low-flow when the stream is dominated by effluent from municipal WWTPs. The 2015 TP TMDL is a watershed based TMDL supplementing the 2003 Nutrient TMDL, and is intended to addresses remaining impairment due to excessive nutrient concentrations.

During the time of both the 2003 TMDLs and this TMDL, Pennsylvania has not established numeric criteria for nutrients, such as TN or TP, in its WQS protective of aquatic life uses for its streams. Pennsylvania has narrative WQS criteria as well as other numeric criteria, such as dissolved oxygen, related to the effects of nutrients on aquatic life. Therefore, for each TMDL, EPA had to take steps to determine an appropriate water quality goal, or endpoint, to establish the nutrient TMDL. For the 2003 TMDLs, EPA established a DO endpoint based on consideration of all biological indicators and stressors identified in the biological assessments. EPA determined that the link between nutrient concentrations, DO concentrations, and biological activity in streams was a necessary component of the nutrient endpoint derivations. Based on analyses of 2002 data collected by PADEP, for the 2003 TMDL endpoint, EPA's evaluation found a pronounced diurnal fluctuation of DO and the seasonal standard for minimum DO concentrations were not met at several locations of the Wissahickon Creek and its tributaries. Periphyton algal biomass above nuisance levels often produces large diurnal fluctuations in DO. Of the components of in-stream biological activity, only DO had a numeric criteria for protection of aquatic life in stream segments of the Wissahickon Creek watershed. As a result, EPA determined the DO was an appropriate surrogate numeric endpoint for the aquatic life use impairment cause by nutrients; the 2003 nutrient TMDL therefore was based on achieving and maintaining the both the minimum and maximum daily average DO criteria (i.e., the surrogate nutrient endpoints).

Based on restoring and protecting the achievement of the state's numeric criteria for DO, applicable at that time, for the protection of aquatic life, in the 2003 TMDL, EPA calculated the assimilative capacity of the waterbody for the pollutants impairing DO, and then allocated specific amounts of ammonia nitrogen, nitrate-nitrite, orthophosphate, and carbonaceous biochemical oxygen demand to certain point sources (fourteen in total) and nonpoint sources. Wasteload allocations (WLAs) for the municipal wastewater treatment plants (WWTPs) were also based on the assumption that permits would be modified to require those point sources to increase minimum effluent DO concentrations. The municipal WWTPs included: Ambler Borough (PA0026603); Abington Township (PA0026867); Borough of North Wales

(PA0022586)[1]; Upper Gwynedd Township (PA0023256); and Upper Dublin Township (PA0029441). Nonpoint sources and point sources that only discharge during precipitation events were not given allocations. The critical period associated with the high observed nutrient concentrations causing low DO and harming aquatic life was low-flow conditions when those sources would not be discharging.

PADEP found that the 2003 Nutrient TMDL allocations and endpoints were not sufficient to achieve all water quality standards. During the public comment period for the 2003 TMDL, PADEP indicated that controlling nuisance algal growth may require additional reductions to in-stream concentrations of phosphorus below that which are necessary to meet the DO standard; in other words the achievement of the DO criteria may not be sufficient to address the aquatic life impairment resulting from nuisance algae. In the 2003 TMDL, EPA agreed that the control of in-stream concentrations of phosphorus to ensure DO criteria are met may not be sufficient to adequately control algae to maintain ‘below nuisance’ levels. However, site-specific data had not yet been collected to determine the levels of TP in-stream that would be necessary to control the growth of algae beyond the DO considerations; thus, a TP endpoint could not be considered for the 2003 TMDL. EPA believed the 2003 Nutrient TMDL would make progress, and that future TMDLs may be necessary.

Understanding the nutrient levels in healthy streams is beneficial in establishing an endpoint to control excessive or nuisance algal growth to restore the aquatic life use. As a result, EPA and PADEP continued to study in-stream nutrient levels in watersheds supporting the aquatic life use and, therefore, not exhibiting harmful impacts on aquatic life as a result of excessive algal growth caused by excessive nutrient levels. PADEP requested EPA to amend its 2003 Nutrient TMDL with a TP endpoint, in order to tighten the TP controls. Specifically, PADEP asked EPA to model “using the new algae based endpoint for phosphorus of 0.24 mg/L in stream” (PADEP 2005a). EPA considered this endpoint and others in consultation with PADEP. EPA agreed with PADEP that the 2003 TMDL did not fully protect aquatic life uses from the effects of nutrients. Through a separate nutrient endpoint identification study finalized in 2007 and updated in 2011, EPA reinterpreted Pennsylvania’s narrative water quality criteria and derived a numeric endpoint of 40 μg/L TP for the Northern Piedmont Ecoregion of Pennsylvania to protect aquatic life uses. EPA further ensured its appropriate application to the Wissahickon Creek Watershed through a stressor verification analysis conducted in 2012. This TP TMDL is a result of PADEP’s request, EPA interpretation of Pennsylvania’s narrative water quality criteria in order to protect the all designated uses, and the continued nutrient impairment of the Wissahickon Creek and its tributaries as discussed in Section 1.3. Derivation of the endpoint is further discussed in more detail in Section 1.5.

Concurrent with the request, additional in-stream data was collected within the Wissahickon Creek Watershed through monitoring in 2005 by PADEP and others to better characterize the nutrient levels and nutrient related impacts. Due to the focused monitoring in 2005, much additional data was available to support more refined modeling of the linkage between the in-stream nutrient concentrations and the biological responses. EPA used that data in addition to

[1] Currently the discharge from the Borough of North Wales has been eliminated. During the modeling period (2005-2006) for this TP TMDL, Borough of North Wales was an active discharger.

other existing data discussed below in Section 2 of this report, to support this TMDL modeling. Based in part on the additional data, EPA modified the modeling approach used in the 2003 Nutrient TMDL to better simulate the nutrient loadings to the stream and the responses by nutrient in-stream processes and biological systems for this TP TMDL. First, EPA upgraded the Environmental Fluid Dynamics Code (EFDC) application used in the 2003 Nutrient TMDL to incorporate more than 160 stream cross-sections and allow for simulation of the competition of multiple algal species, individual interactions with nutrients and substrate (e.g. flood scour effects), and other factors such a temperature and light availability (e.g. seasonal changes in tree canopy). Second, EPA used a dynamic modeling approach for this TP TMDL rather than the steady state modeling approach used in the 2003 Nutrient TMDL. The modeling approach in the 2003 Nutrient TMDL was based on steady state conditions to represent the effluent dominant receiving stream during low-flow; whereas, this TP TMDL modeling approach is dynamic and takes into account surface and subsurface nutrients loadings in all flow conditions including low and high flow periods using Loading Simulation Program in C++ (LSPC). The use of LSPC allowed for improved calibration of the model with the flow gauge stations because it could better account for flow variations resulting from the losing/gaining stream reaches within the watershed. Improved model calibration leads to a more accurate representation of the Wissahickon Creek Watershed. The modeling approach for this TMDL is discussed in further detail in Section 4.

1.2. Watershed Description

The Wissahickon Creek drains approximately 64 square miles and extends 24.1 miles in a southeasterly direction through lower Montgomery County and northwestern Philadelphia County (Figure 1-1). Major tributaries in the basin include Sandy Run and Pine Run, draining a heavily urbanized area east of the mid-section of the watershed. Other tributaries to Wissahickon Creek include Trewellyn Creek, Willow Run - East, Willow Run - West, Rose Valley Tributary, Paper Mill Run, Creshiem Creek, Monoshone Creek, Prophecy Creek, Lorraine Run, Wises Mill Tributary, and Valley Road Tributary. The Wissahickon Creek drains to the Schuylkill River which in turn drains to the Delaware River.

The watershed covers portions of sixteen municipalities which include urbanized areas. The headwaters and upper portions of the watershed consist primarily of residential, agricultural, and wooded land use. The mid-section of the watershed is dominated by industrial, commercial, and residential land use, and includes a limestone quarry. The lower 6.8 miles of the watershed is largely enclosed by Fairmount Park, a predominately wooded area which is maintained for recreational use by the City of Philadelphia. The mainstem and tributaries of the lower portion of the watershed receives very significant stormwater discharges from surrounding roads and other impervious surfaces from the single and multi-family residential areas.

In addition to the hydrologic impacts of the land-uses within the watershed, hydrology is also affected by other human activities. As discussed in the 2003 TMDL, the flow in the stream is dominated by effluent from the municipal WWTPs during low-flow conditions meaning that the groundwater base flow is small in comparison. The limestone quarry contributes pumped flow to the lower portion of the watershed through Lorraine Run. Throughout the watershed, there are low level dams.

The watershed straddles a geologic “fall-line” located in the mid-section of the watershed. The upper portion of the watershed is characterized as “losing” streams, meaning stream flow is moving into the subsurface. However, based on a report by the United States Geological Survey (USGS) entitled *Water Budgets for Selected Watersheds in the Delaware River Basin, Eastern Pennsylvania and Western New Jersey* (USGS, 2005), water lost upstream may be re-introduced downstream through groundwater.

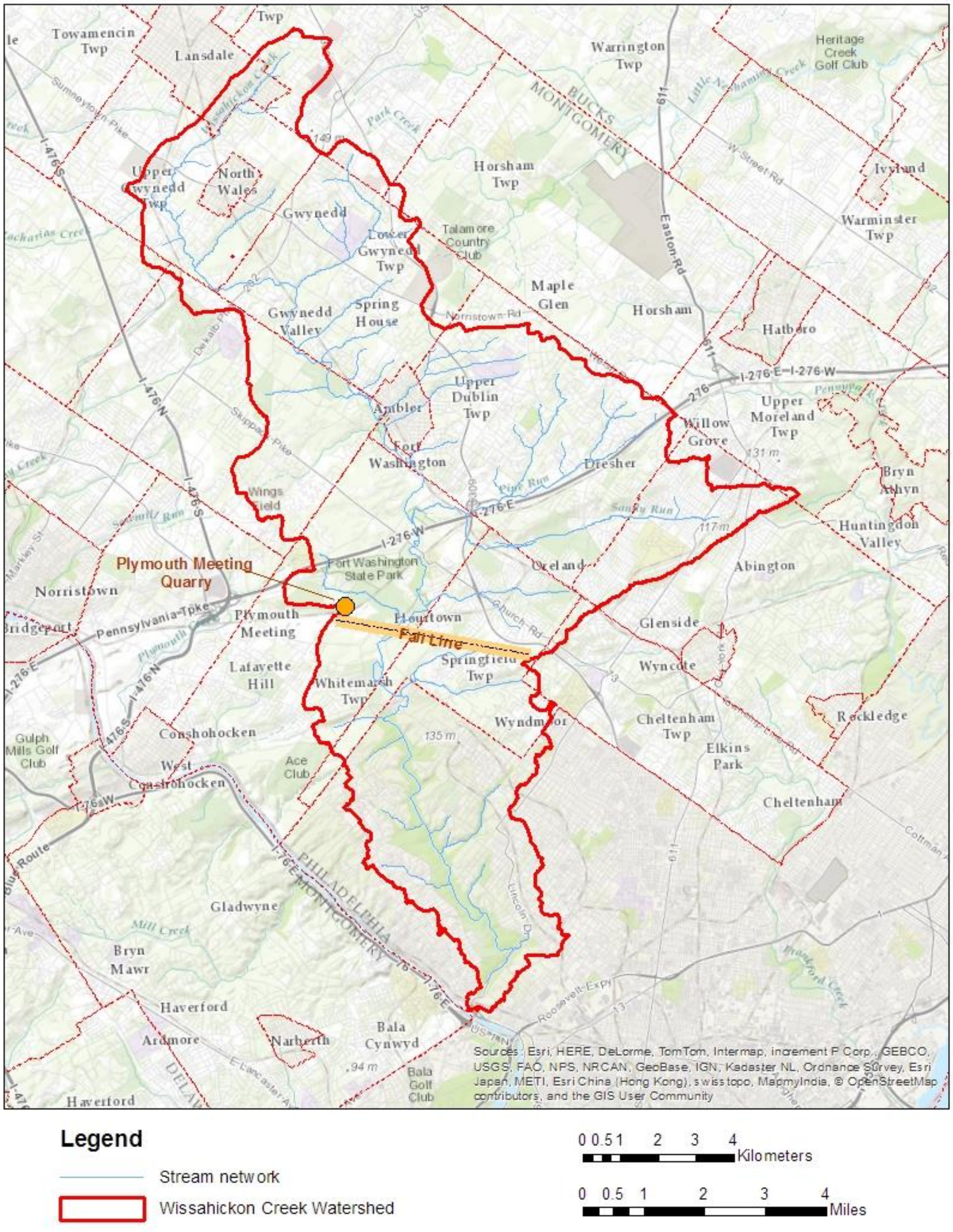

Figure 1-1. Site map of the Wissahickon Creek Watershed.

1.3. Impaired Waterbodies

PADEP has identified the Wissahickon Creek and its tributaries as impaired. Waters are assessed as impaired when an applicable water quality standard is not being attained. Every two years states are required to submit Water Quality Assessment Reports under Sections 305(b) and 303(d) of the Clean Water Act describing the condition of waters in the state. PADEP submitted its most current report on October 23, 2014 entitled, *2014 Pennsylvania Integrated Water Quality Monitoring and Assessment Report – Clean Water Act Section 305(b) Report and 303(d) List* (2014 Integrated Report). EPA approved the 303(d) portion of the Report and list on December 19, 2014. The 2014 Integrated Report can be found at: http://www.portal.state.pa.us/portal/server.pt/community/water_quality_standards/10556/draft_integrated_water_quality_report_-_2014/1702856.

Much of the Wissahickon Creek Watershed is impaired for not meeting one or more designated uses for a variety of pollutants. Specifically, PADEP's 2014 Integrated Report indicates that portions of Wissahickon Creek Watershed are impaired for aquatic life use and recreational use. Pollutants causing the aquatic life use impairment are: siltation, nutrients, DO/BOD, organic enrichment/low DO, and other unknown pollutants. Pollutants causing the recreational use impairment are pathogens[2] and other unknown causes. In summary, PADEP listed the Wissahickon Creek and its tributaries in 1996 to 2002 for siltation (approximately 95 miles), nutrients (approximately 54 miles), DO related impairments (approximately 10 miles).

As discussed earlier in this report, TMDLs have been established for the Wissahickon Creek Watershed, and others are still needed. An Integrated Report not only identifies impaired waterbodies, but also provides prioritization for TMDL development. The 2014 Integrated Report identifies stream segments that have TMDLs in place to address the pollutant of concern (Category 4a) and which segments need TMDLs (Category 5); however, listing a waterbody in either category means the waterbody is still impaired. EPA established the 2003 TMDLs in to address the aquatic life use impairment caused by nutrients and sediment which remain in effect. It is expected that PADEP will address pathogens and organic enrichment (low DO not related to excessive nutrients) through separate TMDLs unless water quality standards are attained through other means.

The Wissahickon Creek and its tributaries are still impaired for nutrients, despite the 2003 Nutrient TMDL. Pollutant controls are being implemented, but the stream ecology has not improved (PADEP 2015). This TP TMDL is a watershed based TMDL and includes the individual stream segments previously addressed in the 2003 Nutrient TMDL that are still impaired due to excessive nutrient concentrations and must be further addressed in this TMDL. EPA is developing this TP TMDL based in part on the 2014 Integrated Report.

Nutrients are essential to the health and diversity of our surface waters. However, in excessive amounts, nutrients cause eutrophication which results in overgrowth of algae which can lead to adverse ecological effects. Nitrogen and phosphorus are the primary causes of eutrophication

[2] The 2014 Integrated Report listed some of the pathogen impaired segments as impaired for the potable water supply use in error, and EPA expects corrections in the 2016 Integrated Report.

and algal blooms are often a response to enrichment. Adverse ecological effects include but are not limited to: low dissolved oxygen (DO), severe diurnal swings in DO and pH, cloudy murky water, reduced habitat, alteration of the native composition and species diversity of aquatic communities, and fish kills. Harmful algal blooms (e.g., brown tides, toxic *Pfiesteria piscicida* outbreaks, and some types of red tides) are also associated with excess nutrients. Although nutrients are required to support a healthy biological assembly, excessive nutrient loading (eutrophic conditions) can be detrimental. Nutrients can be re-introduced into a waterbody from the sediment, or by microbial transformation, potentially resulting in a long recovery period even after pollutant sources have been reduced.

In 2012, EPA conducted a study to evaluate the validity of PADEPs identification of nutrients as a cause, or "stressor," of the aquatic life beneficial use impairment based on the invertebrate assemblage indicators in its listing of the Wissahickon Creek and its tributaries. This impact on invertebrates was associated with notable observations of excessive algal growth in the channel, the proliferation of which was presumed due, in part, to excess nutrient concentrations which were felt to contribute to impairment of the use. The stream was, therefore, listed for nutrient impairment, among other stressors, the mitigation of which is intended to contribute to restoring aquatic life use (Paul 2012). Based on a conceptual model of how nutrients impact invertebrates, EPA concluded that the predicted responses were observed. Concentrations of both N and P are substantially elevated in the Wissahickon; moreover, in several sites they appear enriched to concentrations that are consistently associated with eutrophic conditions, with a high likelihood of eliciting eutrophic responses including excess and nuisance algal biomass conditions (Paul 2012). The findings are documented in the report entitled, *Evaluation of Nutrients as a Stressor of Aquatic Life in Wissahickon Creek, PA*, (the "Stressor Verification Study").

Nutrients impairments have been well documented within the Wissahickon Creek Watershed. Biological investigations have repeatedly documented a problem regarding eutrophic conditions in the Wissahickon mainstem and tributaries (Boyer 1975; Strekal 1976; Boyer 1989; Schubert 1996; Boyer 1997; Everett 2002). TP concentrations decreased substantially in 1988 as a result of a combination of the phosphate ban and wastewater treatment plant upgrades and/or phasing out of smaller treatment plants. However, levels are still significant enough to result in nuisance algal growth (Boyer 1997). Results of a 1998 survey of the periphyton conducted by PADEP indicate that excess nutrient levels in the Wissahickon Creek may be contributing to impairments found in the watershed by causing an alteration in the benthic community as a result of increasing algal biomass (Everett 2002). Analysis of the periphyton data by the Academy of Natural Sciences of Philadelphia (ANSP) concluded that the Wissahickon Creek is a nutrient enriched system, with eutrophic conditions present in the stream as a whole. ANSP further concluded that this eutrophication can be attributed to sewage treatment plant (STP) effluents and possibly leached fertilizers and other runoff (West 2000; Everett 2002). As further evidence of eutrophic conditions, diurnal dissolved oxygen sampling performed by PADEP in 1999 and 2002 showed repeated violations of State water quality criteria. Algae were observed to grow to nuisance levels throughout the watershed, and continuous water quality monitoring suggests algae are primarily responsible for dissolved oxygen (DO) and pH fluctuations that may stress natural fish and invertebrate communities (PWD 2007). Significant reductions of instream phosphorus concentration are needed to reduce algal density, severity of DO fluctuations, and support a more diverse and healthy aquatic ecosystem overall (PWD 2007).

1.4. Water Quality Standards

Under the Clean Water Act, States and authorized Tribes are responsible for setting water quality standards to protect the physical, biological, and chemical integrity of their waters. Water quality standards (WQS) are provisions of State or Federal law which consist of a designated use or uses for the waters of the United States and criteria for such waters based upon such uses. Criteria are "elements of State water quality standards, expressed as constituent concentrations, levels, or narrative statements, representing a quality of water that supports a particular use. When criteria are met, water quality will generally protect the designated use" (USEPA 1994).

Statewide and designated water uses are applicable to the basin of Wissahickon Creek pursuant to *Pennsylvania Code*, Title 25, Environmental Protection, Department of Environmental Protection, Chapter 93.4 and Chapter 93.9(f), respectively. The protected uses applicable to the Wissahickon Creek Watershed are shown in Table 1-1 and include: warm water fishes (WWF), migratory fishes (MF), and trout stocking (TSF).

Table 1-1. Applicable protected uses for the Wissahickon Creek Watershed.

Symbol	Protected Use	Description
Aquatic Life (Statewide)		
WWF	Warm Water Fishes	Maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat.
Aquatic Life (Designated)		
MF	Migratory Fishes	Passage, maintenance and propagation of anadromous and catadromous fishes and other fishes which move to or from flowing waters to complete their life cycle in other waters.
TSF	Trout Stocking	Maintenance of stocked trout from February 15 to July 31 and maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat.
Water Supply (Statewide)		
PWS	Potable Water Supply	Used by the public as defined by the Federal Safe Drinking Water Act, 42 U.S.C.A. § 300F, or by other water users that require a permit from the Department under the Pennsylvania Safe Drinking Water Act (35 P. S. §§ 721.1—721.18), or the act of June 24, 1939 (P. L. 842, No. 365) (32 P. S. §§ 631—641), after conventional treatment, for drinking, culinary and other domestic purposes, such as inclusion into foods, either directly or indirectly.
IWS	Industrial Water Supply	Use by industry for inclusion into nonfood products, processing and cooling.
LWS	Livestock Water Supply	Use by livestock and poultry for drinking and cleansing.
AWS	Wildlife Water Supply	Use for waterfowl habitat and for drinking and cleansing by wildlife.
IRS	Irrigation	Used to supplement precipitation for crop production, maintenance of golf courses and athletic fields and other commercial horticultural activities.
Recreation (Statewide)		
B	Boating	Use of the water for power boating, sail boating, canoeing and rowing for recreational purposes when surface water flow or impoundment conditions allow.
F	Fishing	Use of the water for the legal taking of fish. For recreation or consumption.
WC	Water Contact Sports	Use of the water for swimming and related activities.
E	Esthetics	Use of the water as an esthetic setting to recreational pursuits.

Most states have narrative criteria applicable to nutrients. Few States have adopted numeric criteria to protect aquatic life uses. Fewer States still have adopted numeric nutrient criteria for these parameters to prevent and control nuisance algal growth for the protection of aquatic life and recreation. EPA's nutrient criteria development guidance recommends that States and authorized Tribes develop criteria for both causal variables, TN and TP, and the primary response variables, chlorophyll *a* and some measure of turbidity. Other indicators such as DO and macrophyte growth or speciation, and other fauna and flora changes are also deemed useful. DO is an indicator because periphyton algal biomass above nuisance levels often produces large diurnal fluctuations in DO and pH which both have universally adopted numeric criteria.

Pennsylvania does not currently have specific numeric water quality criteria for the nutrients, but does have an applicable narrative criteria. Pennsylvania' narrative water quality criteria state:

Water may not contain substances attributable to point or nonpoint source discharges in concentration or amounts sufficient to be inimical or harmful to the water uses to be protected or to human, animal, plant or aquatic life. (25 PA Code Chapter 93.6 (a)); and,

In addition to other substances listed within or addressed by this chapter, specific substances to be controlled include, but are not limited to, floating materials, oil, grease, scum and substances which produce color, tastes, odors, turbidity or settle to form deposits. (25 PA Code Chapter 93.6 (b)).

Excessive nutrient concentrations in streams and rivers do not have a direct toxicological effect on insects, fish, and other aquatic life, but exert indirect effects that ultimately impair the use of a stream for aquatic life. Excessive nutrients do, however, affect algae and plant aquatic life directly, altering the diversity and composition of those assemblages. Excessive nutrients contribute to increased algal growth which leads to changes in the physical and chemical stream environment associated with eutrophication (e.g., low DO, changes to pH, loss of reproductive habitat, alteration on the availability of palatable algal taxa, etc). For example, DO levels in the stream decrease when algae respire in evening hours or when algae are broken down by bacterial decomposition upon completion of their life-cycle. The effects of nutrients are influenced by a number of other factors as well, such as light, flow, and temperature.

Pennsylvania's criteria for pH is 6.0 to 9.0 for the protected uses (CWF, WWF, TSF, and MF). Pennsylvania has adopted a numeric DO criteria for TSF designated use which is more restrictive than the other designated uses. On May 22, 2014, EPA approved changes to Pennsylvania's TSF DO criteria after the modeling for this TMDL was complete. The current DO criteria is presented in Table 1-2. The former DO criteria applicable in the 2003 Nutrient TMDL is provided as reference in Table 1-3.

Table 1-2. Current DO criteria.

Period	7-Day Average	Minimum
February 15–July 31	6.0 mg/L	5.0 mg/L
August 1–February 14	5.5 mg/L	5.0 mg/L

Table 1-3. Applicable DO criteria during 2005.

Period	7-Day Average	Minimum
February 15–July 31	6.0 mg/L	5.0 mg/L
August 1–February 14	5.0 mg/L	4.0 mg/L

1.5. TMDL Targets

Since there are presently no numeric water quality criteria for nutrients defined by PADEP, EPA developed an interpretation of PADEP's narrative criteria for purposes of the TMDL called a "numeric target or endpoint." EPA's selected a target endpoint of 40 µg/L TP. Nutrient levels that lead to aquatic life impairments vary from one region of the country to another due to geographical variations (e.g., soil, climate). The Wissahickon Creek Watershed is located in the Northern Piedmont ecoregion, which is a subregion of the Southeastern Temperate Forested

Plains and Hills. Although EPA guidance recommends nutrient criteria values for ecoregions across the nation, including the Southeastern Temperate Forested Plains and Hills, EPA encourages states encouraged to determine more precise numeric levels for nutrient parameters needed to protect aquatic life, recreational, or other uses on site-specific or subregion-specific conditions. In order to interpret Pennsylvania's narrative water quality criteria to develop appropriate nutrient endpoints in this TMDL, EPA conducted a scientific study for the Northern Piedmont ecoregion. The methodology for deriving the more precise TMDL endpoint is similar to that applied for nutrient criteria development to identify nutrient targets that would protect aquatic life uses in these watersheds.

In determining nutrient endpoints for developing TMDLs to protect aquatic life uses of Northern Piedmont streams in southeastern Pennsylvania, EPA relied on various approaches to evaluate the data from watersheds within the Northern Piedmont ecoregion. Using all of the following analytical approaches: reference distribution based analysis, stressor-responses analyses, literature based values, and a mechanistic model. In 2010, USEPA published revised guidance for conducting nutrient stressor-response analyses entitled, *Using Stressor-response Relationships to Derive Numeric Nutrient Criteria*. EPA conducted follow-up analysis of the 2007 endpoint identification study to ensure the stressor-response analyses conformed to the updated guidance, added an additional piece of scientific literature published subsequent to the original study, and included a mechanistic model as an additional line of evidence (Paul *et al* 2011). The 2007 study identified the 40 µg/L TP endpoint as an appropriate and protective endpoint for nutrients in that ecoregion. The 2011 study, using the additional line of evidence and revised statistical tools, confirmed that 40ug/l TP as an appropriately protective value.

Endpoints are best derived when clear connections to use impairment can be made (Paul and Zheng 2007). EPA's nutrient criteria development guidance recommends that a state adopt criteria for both causal variables (TN and TP) and both response variables (chlorophyll *a* and some measure of turbidity) to be fully effective for the prevention of eutrophic conditions.

However, controlling nuisance algal growths is often more cost-effective where one causal variable (nitrogen (N) or phosphorus (P)) is the limiting nutrient. Defining the limiting nutrient is the first step in identifying nutrient-algal relationships to control nutrient enrichment and algal growth (EPA 2000). EPA's analyses concluded that streams in the Northern Piedmont ecoregion are predominately P-limited; and, there was not a strong correlation between nitrogen and biological variables because the streams are not N-limited. The fact that N is not limiting also means that TN likely contributes less to use impairment from eutrophication in this region (Paul and Zheng 2007).

EPA selected a TP endpoint based on a weight-of-evidence analysis and clear connection to the use impairment documented in the Wissahickon Creek. As discussed earlier, EPA verified nutrients were a stressor in Wissahickon Creek. The 40 µg/L TP endpoint was selected as the target for this TMDL based on the tendency for phosphorus to limit productivity in the Piedmont ecoregion waters, and appropriateness of controlling only one causal variable.
For the original 2007 endpoint identification study, our analyses relied on a weight-of-evidence analysis drawing on many different analytical approaches. The follow-up 2011 endpoint analysis provided further support for the 40 µg/L TP endpoint. Each of the different approaches

produced slightly different candidate values for a TP endpoint that are summarized in Table 1-4. Using a weight-of-evidence approach, the analyses were weighted based on their applicability and the strength of the analysis. The stressor-response analyses were weighted more heavily than the reference-approach analyses due to the linkage between nutrient concentrations to specific aquatic life (both invertebrate and algal) endpoints. Using invertebrate taxa metrics, conditional probability analyses evaluated those TP concentrations which increased the risk of exceeding degradation thresholds developed for these macroinvertebrate metrics in comparable Northern Piedmont streams in Maryland. For the diatom Tropic State Index (TSI), the same analysis was used to identify TP concentration associated with a shift from meso-eutrophic to eutrophic conditions. The scientific literature was variably weighted, since it included data from regions proximate to Pennsylvania. In the follow-up analysis, there were minimal changes to the candidate values.

Table 1-4. Summary of the revised list of the candidate endpoints for each of the analytical approaches from 2011 endpoint study.

	Approach	2007 TP Endpoint (μg/L)	2012 TP Endpoint (μg/L)
Reference Approach		**2-37**	**2-37**
	Reference Site 75th Percentile	16-17	16-17
	All Sites 25th Percentile	17	17
	Modeled Reference Expectation	2-37	2-37
Stressor-Response		**36-64**	**8-85**
	Conditional Probability – EPT taxa	38	38
	Conditional Probability – % Clingers	39	39
	Conditional Probability – % Urban Intolerant	64	64
	Conditional Probability – Diatoms TSI	36	36
	Simple linear regression interpolation – EPT taxa	*	10-85
	Simple linear regression interpolation – Percent intolerant urban individuals	*	8-82
	Simple linear regression interpolation – Percent Clinger individuals	*	8-52
Other Literature		**13-100**	**13-100**
	USEPA Recommended Regional Criteria	37	37
	USEPA Regional Criteria Approach – Local Data	40-51	40-51
	Algal Growth Saturation	25-50	25-50
	Nationwide Meta-Study TP-Chlorophyll	21-60	21-60
	USGS Regional Reference Study	20	20
	USGS National Nutrient Criteria Study	13-20	13-20
	New England Nutrient Criteria Study	40	40
	Virginia Nutrient Criteria Study	50	50
	New Jersey TDI	25-50	25-50
	Delaware Threshold	50-100	50-100
	National Reference Criteria Study	*	60
Mechanistic Model			**20-33**
	Indian Creek	*	20-33

* Approach added during the re-evaluation.

The resultant concentrations from the new stressor-response analyses changed the range of endpoints derived with that method from 36-64 to 8-85, but still included the original endpoint. The overall range from 2-100 remained the same. The additional scientific study estimating regional reference concentration recommends a value in the range of previous literature values and similar to the original endpoint. The mechanistic model of chlorophyll in streams used to derive a TP endpoint to meet acceptable benthic chlorophyll concentrations reached a value comparable to the original endpoint. Based on that information and analysis, for this TMDL, EPA selected the 40 ug/l TP endpoint as an appropriate and protective TMDL target value consistent with PADEP's narrative criteria.

The TP endpoint is an average in-stream concentration to be achieved throughout the watershed during the growing season from April 1 to October 31, which is typically the time during which the greatest risk of deleterious algal growth exists in streams. To achieve this target, the TMDL accounts for all TP loading available during the growing season, including the TP that enters the Wissahickon Creek and its tributaries during the non-growing season which gets deposited into the sediment and can get reintroduced during the growing season.

A more detailed description of the analyses and conclusions described above can be found in a summary report entitled, *Development of Nutrient Endpoints for the Northern Piedmont Ecoregion of Pennsylvania: TMDL Application*. Likewise, the follow-up analyses is in a summary report entitled, *Development of Nutrient Endpoints for the Northern Piedmont Ecoregion of Pennsylvania: TMDL Application – Follow-up Analyses*.

2. AVAILABLE DATA

Since EPA established the 2003 Nutrient TMDL, there has been an abundance of additional water quality and hydrology monitoring in the Wissahickon Creek Watershed. While water quality and hydrology monitoring are ongoing even to this day, some monitoring activities are limited to a particular period of time. And while some data from these monitoring activities is readily available to EPA, other information is only available upon request. In 2011, EPA made requests for additional information to various stakeholders in the watershed to support this TMDL development. This section provides an inventory of the data collected by EPA from various sources; and is only intended to present the breadth of the data collected to support the TMDL development. See Section 4 for more information on the technical aspects of how the TMDL was developed.

EPA received water quality and hydrology data collected by Philadelphia Water Department (PWD), Pennsylvania Department of Environmental Protection (PADEP), and the United States Geological Survey (USGS). Surveyed reach geometry data was available from PWD (2007) at numerous locations spatially distributed throughout the watershed. EPA obtained meteorological data from the National Climatic Data Center and from the North American Land Data Assimilation System. Land use data from the Delaware Valley Regional Planning Commission (DVRPC) was used to develop hydrologic response units (HRUs) for modeling. Discharge Monitoring Reports (DMRs) obtained from EPA and PADEP for certain NPDES permitted point sources were used to characterize discharges to the Wissahickon Creek Watershed.

EPA assembled the collected data into a Water Resources Database (WRDB) for this project. WRDB has many summary and graphing features which substantially aided the process of evaluating the inventory of data. The inventory was evaluated to determine the most suitable time period whereby the data was sufficient to give an accurate representation of the watershed (i.e., the “modeling period”). EPA selected the calendar year of 2005-2006 as the modeling period due to the wealth of data available, specifically for parameters that are either not measured on a routine basis or data collected at sites not routinely monitored. Additional information about the WRDB project developed to house the water quality and hydrology data for this TMDL is found in Appendix A.

Although more information was available beyond the modeling period, it should not be interpreted that all inventoried data was used in the two models. The modeling period of 2005-2006 is also not a limitation on what data was used, because wider ranges of information may have been necessary to support the modeling efforts, such as meteorological data prior to 2005. See Section 4 for a discussion of the modeling approach and how data was used. The inventory includes information about the source of the data, the location the data was collected, the type of data collected, and the range of dates for which the data was assembled for this effort (which may not be reflective of the actual time period for which data was collected especially in situations where data collection is ongoing). All data was reviewed for quality assurance purposes.

2.1 Hydrology

There are two USGS observation stations in the Wissahickon Creek Watershed. Each station records and reports flow at 15-minute increments. The flow observations collected during the 2011 information gathering efforts are summarized in Table 2-1.

Table 2-1. Flow observations USGS observation stations.

Station ID	Station Name	Drainage Area (mi^2)	No. of Obs.	First Date	Last Date
01473900	Wissahickon Creek at Fort Washington, PA	40.8	386,410	06/01/2000	07/05/2011
01474000	Wissahickon Creek at Mouth, Philadelphia, PA	64.0	688,523	10/15/1993	7/5/2011

2.2 Water Quality

2.2.1 United States Geological Survey

USGS maintains water quality data sondes at each of the flow monitoring locations in the watershed. They continuously record water temperature, specific conductivity, turbidity, and pH, and record dissolved oxygen data at a 30-minute interval. The information obtained during the 2011 information gathering efforts are summarized by stations and parameters in Table 2-2 and

Table 2-3, respectively.

Table 2-2. USGS continuous sample observations stations.

Station ID	Station Name	No. Obs	First Date	Last Date
01473900	Wissahickon Creek at Fort Washington, PA	187,535	2000-11-03	2011-07-05
01474000	Wissahickon Creek at Mouth, Philadelphia, PA	189,446	2007-04-30	2011-07-05

Table 2-3. USGS continuous sample parameter summary.

Parameter Name	Units	No. Obs	Mean	First Date	Last Date
Dissolved Oxygen	mg/L	73,798	8.9	2000-11-03	2011-07-05
pH	pHU	75,262	7.9	2000-11-03	2011-07-05
Specific Conductivity at 25 deg C	uMHO/cm	76,612	713	2000-11-03	2011-07-05
Turbidity	NTU	73,380	12	2006-10-18	2011-07-05
Water Temperature	deg C	77,929	16.7	2000-11-03	2011-07-05

2.2.2 Philadelphia Water Department

PWD data gathered during the 2011 information gathering efforts consisted of grab samples and continuous monitoring. The grab sample stations are noted in Table 2-4, and the parameters monitored are shown in Table 2-5. Two of the PWD stations are co-located with the two USGS stations. See Section 2.2.4 for a cross reference.

Table 2-4. PWD grab sample observation stations

Station	Station Name	First Date	Last Date	No. Obs
MCRR002	Radium Run 0.2m upstream from the Wissahickon confluence	2005-05-18	2005-07-11	404
WS005	Wissahickon Creek 125 yds below Ridge Ave Dam	2005-01-04	2011-07-12	1395
WS014	Wissahickon Creek above Ridge Ave Dam	2009-06-30	2011-06-27	88
WS024	Wissahickon Creek at Upper Ridge Ave Dam	2009-04-28	2009-05-07	10
WS076	Wissahickon Creek 150 yds upstream of Gypsy Lane	2005-01-13	2010-08-12	1751
WS1075	Wissahickon Creek at Skippack Rd	2005-01-13	2011-06-27	727
WS1210	Wissahickon Creek at Morris Rd	2005-01-13	2008-05-21	265
WS122	300 ft d/s of Monoshone Cr confluence	2005-01-13	2005-09-08	236
WS1850	Wissahickon Creek at Swedesford & Township Line	2005-01-13	2010-08-12	733
WS1879	Wissahickon Creek 10 m dwnstr of Upper Gwynedd STP	2006-06-15	2006-08-21	17
WS1882	Wissahickon Creek 40 m upstr Upper Gwynedd STP	2006-06-15	2006-06-19	6
WS1963	North Wales Rd/West Walnut St bridge	2005-11-03	2005-11-03	9
WS2141	800ft u/s of Sumneytown Pike bridge	2005-11-03	2005-11-03	9
WS354	500 feet d/s of Livezy Rd dam	2005-01-13	2005-09-08	237
WS363	Wissahickon Creek at Livezy Dam	2010-08-12	2010-08-12	8
WS492	350 ft d/s of Rex Av bridge	2005-01-13	2005-09-08	238
WS754	Morris Arboretum Northwestern 1300 ft u/s of Northwest Av	2005-01-13	2010-08-12	1571
WS844	Wissahickon Creek at Stenton Ave	2007-03-20	2007-04-24	8
WS976	Wissahickon Creek at Valley Green Road	2007-03-20	2007-04-24	15
WSBM007	Bell's Mill trib adjacent to FPC parking lot	2005-09-14	2007-04-16	312
WSBM090	330 ft d/s of start of tributary	2005-09-14	2005-10-10	446
WSCC016	Cresheim Creek at concrete bridge upstr of Devil's Pool	2006-06-19	2006-10-19	442
WSCR008	400 ft u/s of Wissahickon confl	2005-11-09	2005-11-21	242
WSMC001	Mouth of the Monoshone Cr	2008-02-11	2008-06-23	4
WSMC016	Monoshone Cr d/s of Rittenhousetown stone bridge	2005-05-18	2007-04-27	276
WSMC025	Monoshone Cr 400 ft u/s of Rittenhousetown stone bridge	2005-05-18	2010-09-20	184
WSMC076	50 ft d/s of Monoshone outfall W-065-5	2005-05-18	2005-09-29	22
WSPC017	400 ft u/s of Butler Av bridge	2005-01-13	2005-09-08	229
WSSR058	Sandy Run at Bethlehem Pike	2005-01-13	2008-05-21	279
WSWM006	Wise's Mill trib approx 100 m u/s of Forbidden Dr	2005-11-14	2006-11-08	492

Table 2-5. PWD grab sample parameter summary

Parameter Name	Units	No. Obs	Mean	First Date	Last Date
BOD 30d	mg/L	118	6.91	2005-01-13	2005-09-08
BOD 5d	mg/L	120	1.40	2005-01-13	2005-09-08
CBOD 5d	mg/L	118	1.06	2005-01-13	2005-09-08
Chlorophyll-a	ug/L	97	3.01	2005-01-13	2005-09-08
Dissolved Oxygen	mg/L	271	9.93	2005-01-13	2011-06-27
Nitrite	mgN/L	661	0.04	2005-01-13	2008-05-21
Nitrate	mgN/L	760	3.46	2005-01-04	2011-06-27
pH	pHU	352	7.78	2005-01-04	2011-07-12
Orthophosphate	mgP/L	753	0.41	2005-01-04	2011-06-27
Total Kjeldahl Nitrogen	mgN/L	514	1.30	2005-01-13	2006-07-23
Total Ammonia	mgN/L	641	0.13	2005-01-04	2011-07-12
Total Phosphorus	mgP/L	440	0.70	2005-01-13	2008-05-21
Total Suspended Solids	mg/L	651	60.67	2005-01-13	2007-04-27
Turbidity	NTU	964	17.82	2005-01-04	2011-07-12

The data sonde sample stations are noted in Table 2-6. The parameters monitored are shown in Table 2-7.

Table 2-6. PWD data sonde observation stations.

Station	Station Name	First Date	Last Date	No. Obs
WS076	Wissahickon Creek 150 yds upstream of Gypsy Lane	2005-03-10	2005-11-17	89620
WS1075	Wissahickon Creek at Skippack Rd	2005-03-10	2005-11-21	103341
WS1210	Wissahickon Creek at Morris Rd	2005-03-10	2005-11-02	87982
WS1850	Wissahickon Creek at Swedesford & Township Line	2004-08-10	2005-11-02	110580
WS354	500 feet d/s of Livezy Rd dam	2005-03-10	2005-10-13	81314
WS754	Morris Arboretum Northwestern 1300 ft u/s of Northwest Av	2004-08-10	2005-10-22	114361
WSCR008	400 ft u/s of Wissahickon confl	2005-11-09	2005-11-21	5713
WSLR005	Valley Green Rd bridge	2004-08-10	2004-09-14	15520
WSSR058	Sandy Run at Bethlehem Pike	2004-08-10	2004-09-14	18643
WSWM006	Wise's Mill trib approx 100 m u/s of Forbidden Dr	2005-11-09	2005-11-21	5728

Table 2-7. PWD data sonde sample parameter summary.

Parameter Name	Units	No. Obs	Mean	First Date	Last Date
Corrected Depth	in	114085	17.13	2004-08-10	2005-11-21
Dissolved Oxygen	mg/L	115510	8.56	2004-08-10	2005-11-21
pH	pHU	115510	7.78	2004-08-10	2005-11-21
Specific Conductivity at 25 deg C	uMHO/cm	115510	812	2004-08-10	2005-11-21
Turbidity	NTU	55173	70	2004-08-10	2005-11-17
Water Temperature	deg C	115510	17.54	2004-08-10	2005-11-21

2.2.3 Pennsylvania Department of Environmental Protection

During the 2011 information gathering efforts, EPA collected information from PADEP. PADEP observation stations are co-located with the USGS stations and are listed in Table 2-8. The grab sample parameters are summarized in Table 2-9. See Section 2.2.4 for a cross reference between the PADEP and USGS stations.

Table 2-8. PADEP observation stations.

Station	Station Name	First Date	Last Date	No. Obs
WQN0115	Wissahickon Cr at Mouth	2002-02-11	2011-03-30	824
WQN0193	Wissahickon Cr at Fort Washington	2002-02-07	2011-03-14	750

Table 2-9. PADEP grab sample parameter summary.

Parameter Name	Units	No. Obs	Mean	First Date	Last Date
Dissolved Oxygen	mg/L	101	11.81	2002-02-07	2011-03-30
Dissolved Organic Carbon	mg/L	7	3.53	2009-10-08	2011-03-14
Flow	cfs	84	91.11	2002-02-07	2010-06-28
Nitrite	mgN/L	102	0.04	2002-02-07	2011-03-30
Nitrate	mgN/L	102	5.46	2002-02-07	2011-03-30
pH	pHU	204	7.99	2002-02-07	2011-03-30
Orthophosphate	mgP/L	100	0.71	2002-04-08	2011-03-30
Specific Conductivity at 25 deg C	uMHO/cm	204	739	2002-02-07	2011-03-30
Total Nitrogen	mgN/L	103	6.06	2002-02-07	2011-03-30
Total Ammonia	mgN/L	102	0.05	2002-02-07	2011-03-30
Total Organic Carbon	mg/L	37	4.76	2002-02-07	2005-03-07
Total Phosphorus	mgP/L	102	0.81	2002-02-07	2011-03-30
Total Suspended Solids	mg/L	102	10.94	2002-02-07	2011-03-30
Water Temperature	deg C	102	12.95	2002-02-07	2011-03-30

2.2.4 Co-located Stations

The locations of the two USGS observation stations were also used as locations by PWD and PADEP to perform water quality observations. A cross-reference is provided in Table 2-10.

Table 2-10. Locations used for both USGS and PADEP observation stations.

Station Name	River Mile	USGS Station ID	PWD Station ID	PADEP Station ID
Wissahickon Cr at Fort Washington, PA	10.75	01473900	WS1075	WQN0193
Wissahickon Cr at Mouth, Philadelphia, PA	0.05	01474000	WS0005	WQN0115

2.3 Stream Geometry

Philadelphia Water Department provided stream geometry data to assist with characterization of stream morphology in the Wissahickon Creek Watershed. Over 160 locations in the watershed were surveyed to provide stream width and depth information, which are particularly useful in characterizing stream morphology and for defining the stream network in a modeling environment. Locations of the cross section data from PWD are shown in Figure 2-1. Section 4.1.2 discusses how these data were applied in the Wissahickon modeling.

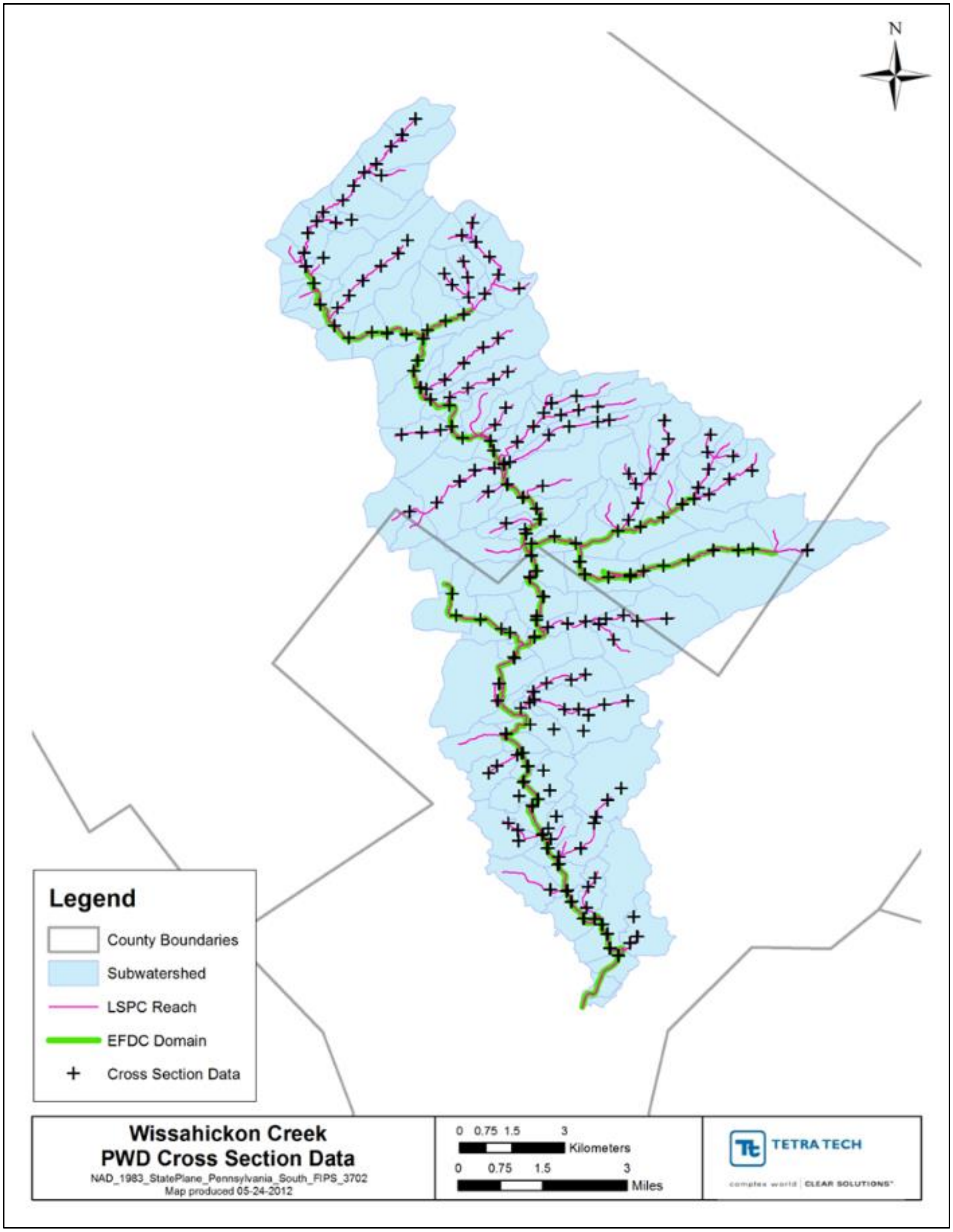

Figure 2-1. PWD stream cross section measurement locations in the Wissahickon Creek Watershed.

2.4 Meteorology

Meteorological data is a critical component of the watershed modeling effort because weather conditions drive the hydrology and associated water quality responses. Meteorological data for stations in and around the vicinity of the Wissahickon Creek Watershed was available from the National Climatic Data Center (NCDC). The weather data include temperature, precipitation, and snow measurements, and other surface airways information (e.g., pressure and wind speed measurements). Two stations with daily observations and three stations with hourly observations were identified as having adequate data. The NCDC weather stations used are shown in Table 2-11. In addition to those stations, hourly precipitation data was acquired from the North American Land Data Assimilation System (NLDAS) Phase 2 (Mitchell et al., 2004). The NLDAS precipitation data are distributed by NASA/NOAA in the NASA GDS format and were acquired using EPAs BASINS modeling system. Processing of the weather data for use in the watershed model is described in Section 5.

NLDAS integrates a large quantity of observation-based and model reanalysis data to drive offline (not coupled to the atmosphere) land-surface models (LSMs), and executes at 1/8th-degree grid spacing over central North America, enabled by the Land Information System (LIS) (Kumar et al. 2006; Peters-Lidard et al. 2007). The NLDAS data comes at a spatial resolution of 1/8th degree (approximately 12 km) and an hourly temporal resolution between 1/1/1979 and present. Figure 2-2 shows the NLDAS model grid superimposed on the Wissahickon Creek Watershed. Each grid cell represents a unique precipitation dataset. Data from three grid cell locations, labeled on Figure 2-2 as Y121X397, Y121X398, and Y120X398, were used in the Wissahickon Creek Watershed TMDL.

Table 2-11. NCDC weather stations located in the vicinity of the Wissahickon Creek Watershed.

Station ID	Station Name	Elevation (ft)	Percent Complete	Start Date	End Date	Temporal Scale
PA6370	NORRISTOWN	230	100%	5/21/1948	12/27/2010	Daily
PA1737	CONSHOHOCKEN	230	99%	5/1/1948	12/27/2010	Daily
94732	NE PHILADELPHIA AIRPORT	101	100%	7/1/1996	1/31/2012	Hourly
14793	WILLOW GROVE NAS	335	86%	7/30/1996	5/11/2011	Hourly
64752	WINGS FIELD AIRPORT	302	75%	1/27/2003	1/31/2012	Hourly

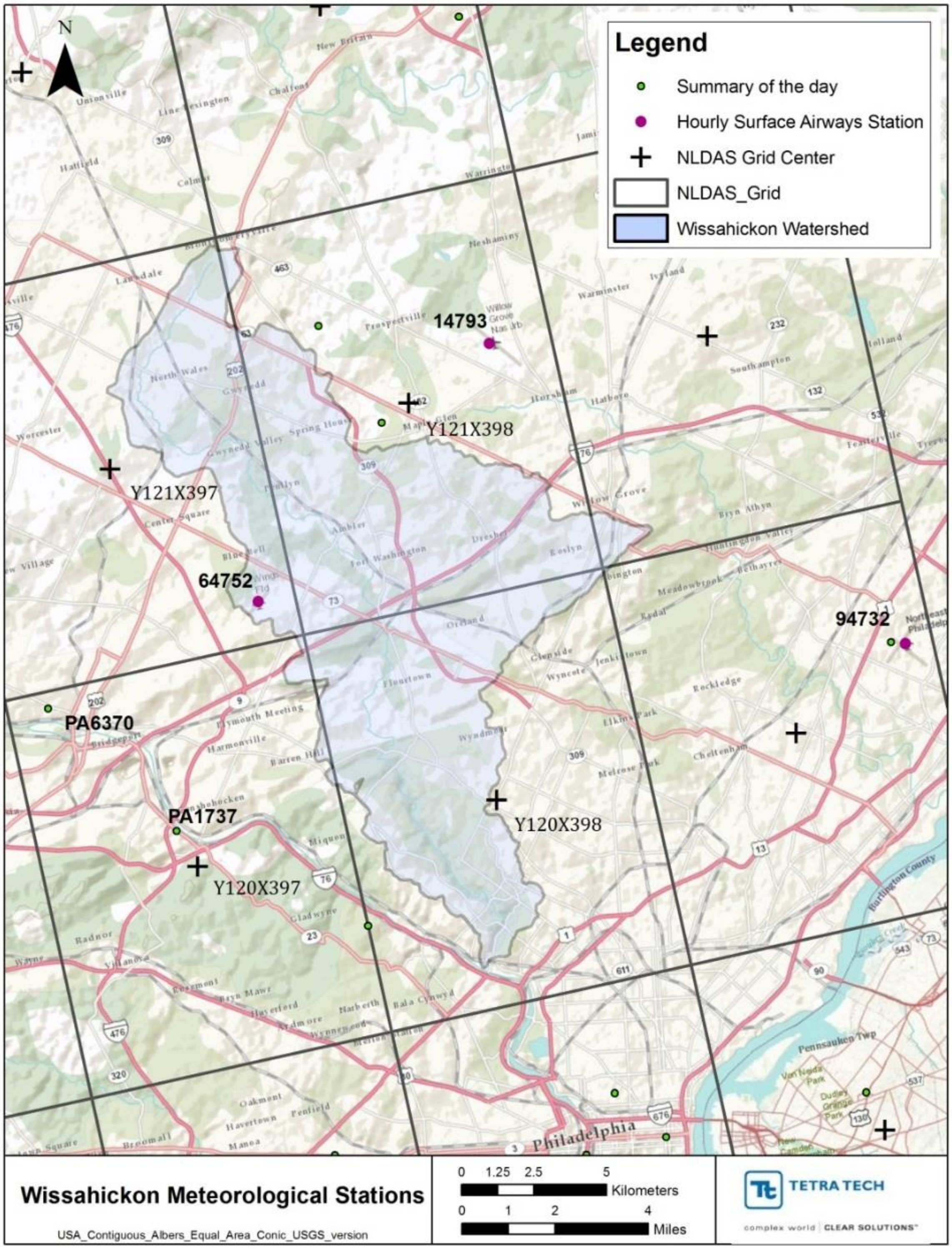

Figure 2-2. Meteorological stations in the vicinity of the Wissahickon Creek Watershed and NLDAS grid cell locations.

2.5 Discharge Monitoring Reports

A discharge monitoring report (DMR) is a standardized form submitted by point sources as required by their National Pollutant Discharge Elimination System (NPDES) permits, usually monthly. Not all point sources are required to submit DMRs, or have less frequent submission of DMRs than monthly. EPA conducted a file review at PADEP offices and collected various information such as DMRs, permits, notices of violations, and other correspondences. DMRs from the municipal WWTPs (listed in Table 2-12) contribute the majority of the treated wastewater to the Wissahickon Creek Watershed and were found to be the only sources with data pertaining to phosphorus during the 2005-2006 modeling period. These DMRs were used support the modeling effort.

Table 2-12. Summary of DMR data.

NPDES ID	Facility Name	Parameter	2005												2006											
			J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PA0023256	Upper Gwynedd Township WWTP	Flow	●	●	●	●	●	●	●	●	●	○	●	●	●	●	●	●	●	●	●	●	●	○	●	●
		ORP	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	■	■	■	■	■	■	■	■	■	■	■	■	■
PA0022586	North Wales Borough WWTP	Flow	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
		ORP	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
PA0026603	Ambler Borough STP	Flow	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	○	●
		ORP	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
PA0029441	Upper Dublin Township WWTP	Flow	○	●	●	●	●	●	●	●	○	●	○	●	●	●	●	●	●	○	○	●	●	●	●	●
		ORP	□	□	□	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	□	Δ	Δ	Δ	Δ	Δ	□	□	□	◊	◊	◊	◊
PA0026867	Abington Township STP	Flow	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
		ORP	Δ	Δ	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊

● Daily flow DMR data
○ Monthly flow DMR data
■ Bi-weekly ORP DMR data
◊ Calculated based on sub-weekly TP DMR data
Δ Calculated based on monthly TP DMR data
□ Recycled ORP data from same facility within 2005-2006 time period

2.6 Land Use and Soil Geography Data

General land use and land cover data for the Wissahickon Creek Watershed were obtained from the Delaware Valley Regional Planning Commission (DVRPC). This data set includes 29 categories, 22 of which are in the Wissahickon Creek Watershed. Table 2-13 summarizes the resulting HRUs in this watershed.

Table 2-13. Hydrologic Response Units in the Wissahickon Creek Watershed

Modeled Land use/HRU	Land use Grouping	Total Area (acres)	Total Area (%)
Agriculture (B Soils)	Agriculture	768.73	1.89%
Agriculture (C Soils)	Agriculture	1,939.61	4.77%
Commercial	Impervious Developed	1,307.99	3.22%
Community Services	Pervious Developed	1,377.05	3.39%
Golf	Golf	1,482.15	3.65%
Light Industrial	Impervious Developed	579.12	1.43%
Mining	Pervious Developed	119.81	0.29%
Parking: Agriculture	Pervious Developed	5.56	0.01%
Parking: Community Services	Pervious Developed	646.68	1.59%
All other Parking	Impervious Developed	574.86	1.41%
Recreation (B Soils)	Pervious Developed	1,058.53	2.61%
Recreation (C Soils)	Pervious Developed	525.23	1.29%
Residential: Multi-family	Residential	1,994.15	4.91%
Residential: Row Home	Residential	210.64	0.52%
Residential: Single Family Detached (B Soils)	Residential	14,358.04	35.34%
Residential: Single Family Detached (C Soils)	Residential	4,219.97	10.39%
Transportation	Impervious Developed	512.09	1.26%
Utility	Pervious Developed	333.94	0.82%
Vacant	Pervious Developed	1,327.09	3.27%
Water	Background	303.34	0.75%
Wooded (B Soils)	Background	4,364.72	10.74%
Wooded (C Soils)	Background	2,621.79	6.45%

3. SOURCE ASSESSMENT

PADEP's 2014 Integrated Report identified the sources of nutrients as being municipal point sources and urban runoff/storm sewers. Nutrients enter streams through direct discharge of treated wastewater, nonpoint source runoff of applied nutrient fertilizer, eroded nutrient bearing sediment, accumulated atmospheric nutrient inputs from surfaces during storms, and erosion of nutrient bearing soils from hillslopes or streambanks that occur as a result of land and channel alteration (Paul 2012). Point and nonpoint source nutrient inputs result in increases in nutrient concentrations in surface water from direct runoff as well as increases in soil nutrient concentrations and subsurface water concentrations that are released over time (Allan 1995, Dodds 2002). The effect of these direct and indirect nutrient inputs are an increase in dissolved organic, inorganic and particulate nutrient concentrations under both storm and base-flow conditions (USEPA 2000b). Within the stream channel, nutrients will cycle between dissolved and organic/particulate forms as mineralization and uptake occur and nutrients move through the stream network (Stream Solute Workshop 1990).

EPA's 2003 Nutrient TMDL included an evaluation of the sources of nutrients that impacted the DO levels in the Wissahickon Creek Watershed during the critical low-flow condition. EPA determined that during low-flow conditions the flow in the stream is dominated by effluent from wastewater treatment plants and other point sources that discharge on a daily basis. Point source dischargers, excluding those that were only discharging during storm events, were given WLAs.

Sources of nutrients were re-evaluated for this TP TMDL to account for contribution of TP that impact the stream under various conditions. The critical condition for the TP endpoint is different than the low-flow critical condition considered in the 2003 Nutrient TMDL, and discussed further in Section 5. This section discusses the point and nonpoint sources of TP in the Wissahickon Creek Watershed and other factors impacting water quality such as in-stream concentrations of TP.

3.1 Point Sources

A point source, according to 40 *Code of Federal Regulations* (CFR) 122.3, is any discernible, confined, and discrete conveyance, including any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, landfill leachate collection system, and vessel or other floating craft from which pollutants are or might be discharged. The NPDES program, established under Clean Water Act sections 318, 402, and 405, generally requires permits for the discharge of pollutants from point sources.

Permitted dischargers to the Wissahickon Creek Watershed that discharge continuously range from single family residences (about 400 to 700 gallons per day) to municipal wastewater treatment plants (WWTP) with effluent discharge rates up to 6.5 million gallons per day (MGD). The Wissahickon Creek Watershed also receives stormwater discharges from municipal separate storm sewer systems (MS4s) and other stormwater dischargers. However, certain point sources were not considered to be substantive nutrient sources. A list of such point sources with *de minimis* discharges of TP appears in Appendix B. The TMDL does not set forth a specific allocation for these *de minimis* point sources but accounts for them in the model and background loading. See Section 4.1.4. below for further discussion.

3.1.1 Municipal Wastewater Treatment Plants

During the modeling period of 2005-2006, there were five municipal WWTPs discharging to the Wissahickon: Ambler Borough STP (6.5 MGD), Upper Gwynedd Township WWTP (5.7 MGD), Abington Township STP (3.91 MGD), Upper Dublin Township WWTP (1.1 MGD), and North Wales Borough WWTP (0.835 MGD). As of that time, the NPDES effluent limits consistent with the 2003 TMDL wasteload allocations had not become effective for any of the WWTPs, but monitoring and reporting requirements were in effect for many of them. The effluent limits for TP and orthophosphate in place during the 2005-2006 modeling period are shown in Table 3-1.

Table 3-1. Municipal WWTPs and their effluent limitations in effect in 2005 – 2006.

Parameter	Abington Township (PA0026867)	Ambler Borough (PA0026603)	North Wales Borough (PA0022586)	Upper Dublin Township (PA0029441)	Upper Gwynedd Township (PA0023256)
In Effect on January 1, 2005					
Flow (MGD) (Measurement Frequency)	Monitor and Report only Monthly Average and Daily Maximum (continuous)	Monitor and Report only Monthly Average and Daily Maximum (continuous)	Monitor and Report only Monthly Average and Daily Maximum (continuous)	Monitor and Report only Monthly Average and Daily Maximum (continuous)	Monitor and Report only Monthly Average and Daily Maximum (continuous)
TP (mg/L) (Measurement Frequency)	Monitor and Report only Monthly Average and Instaneous Maximum (2/week)	Monitor and Report only Monthly Average (1/week)	No Requirement	No Requirement	Monitor and Report only Monthly Average[2] (2/week)
Orthophosphate (mg/L) (Measurement Frequency)	No Requirement	No Requirement	No Requirement	No Requirement	Report
Permit Re-issuance during 2005-2006					
Effective Date	August 1, 2005	December 1, 2005	July 1, 2005	March 1, 2006	December 1, 2005
Flow (MGD) (Measurement Frequency)	Monitor and Report only Monthly Average (continuous)	Monitor and Report only Monthly Average and Daily Maximum (continuous)	Monitor and Report only Monthly Average and Daily Maximum (continuous)	Monitor and Report only Monthly Average and Daily Maximum (continuous)	Monitor and Report only Monthly Average (continuous)
TP (mg/L) (Measurement Frequency)	Monitor and Report only Monthly Average and Daily Maximum (2/week)	Monitor and Report only Monthly Average (1/week)[1]	Monitor and Report only Monthly Average (1/week)[1]	Monitor and Report only Monthly Average (2/week)[1]	Monitor and Report only Monthly Average (2/week)[1]
Orthophosphate (mg/L) (Measurement Frequency)	No Requirement[1]	No Requirement	Monitor and Report only Monthly Average (1/week)[1]	Monitor and Report only Monthly Average (2/week)[1]	Monitor and Report only Monthly Average (2/week)[1]

[1] New limits became effective after December 31, 2006.
[2] Season requirement from April 1st thru October 31st

3.1.2 Municipal Separate Stormwater Sewer Systems (MS4s)

Stormwater discharges are generated by runoff from urban land and impervious areas such as paved streets, parking lots, and rooftops during precipitation events. These discharges often contain high concentrations of pollutants that can eventually enter nearby water bodies. For regulatory purposes, stormwater discharges from urbanized areas may be point sources and require coverage by an NPDES MS4 permit.

Under the NPDES stormwater program, operators of large, medium, and regulated small MS4s must obtain authorization to discharge pollutants. The Stormwater Phase I Rule (55 Federal Register 47990, November 16, 1990) requires all operators of medium and large MS4s to obtain an NPDES permit and develop a stormwater management program. Medium and large MS4s are defined by the size of the population in the MS4 area, not including the population served by combined sewer systems. A medium MS4 has a population between 100,000 and 249,999; a large MS4 has a population of 250,000 or more. Phase II of the rule extends coverage of the NPDES Storm Water Program to certain small MS4s. Small MS4s are defined as any MS4 that is not a medium or large MS4 covered by Phase I of the NPDES Storm Water Program. Only a select subset of small MS4s, referred to as regulated small MS4s, require an NPDES stormwater permit. Regulated small MS4s are defined as (1) all small MS4s in urbanized areas (UAs) as defined by the Bureau of the Census, and (2) those small MS4s outside a UA that are designated by NPDES permitting authorities.

The entire Wissahickon Creek Watershed is subject to MS4 permitting. The City of Philadelphia portion of the watershed is covered by a Phase I MS4 permit. All of the other municipalities in the watershed are considered urbanized according to US Census Data and, therefore, are subject to PADEP's permit for Phase II municipalities (PAG-13). Portions of 16 MS4 communities intersect the boundaries of the Wissahickon Creek Watershed. A geographic information system (GIS) coverage of Pennsylvania municipalities was used to establish the political boundaries of the MS4 communities. Table 3-2 lists the MS4 municipalities having some portion inside the watershed. Some community MS4 boundaries have minimal overlap with the Wissahickon watershed as they are primarily located in adjacent watersheds.

Table 3-2. Phase II MS4s in the Wissahickon Creek Watershed in 2005 - 2006

MS4 Community	Area Inside Watershed (Miles^2)	Percent of Watershed
Upper Dublin	12.0	18.9
Philadelphia	10.6	16.7
Lower Gwynedd	8.2	13.0
Whitemarsh	8.2	12.9
Springfield	6.5	10.2
Whitpain	5.2	8.2
Upper Gwynedd	5.0	7.9
Abington	3.6	5.7
Montgomery	1.5	2.4
Ambler	0.8	1.3
Lansdale	0.7	1.1
North Wales	0.6	0.9
Cheltenham	0.3	0.4
Horsham	0.1	0.2
Worcester	0.1	0.2
Upper Moreland	0.04	0.1

EPA lacked specific MS4 sewershed boundary information; therefore, all land uses within the political boundaries were assumed to be within the jurisdiction of the MS4s for purposes of this modeling effort. EPA believes there may be some land uses, such as privately-owned golf courses, agriculture, and wooded areas, within these political boundaries that are either nonpoint sources or point sources that may not be subject to the NPDES permitting program.

3.2 Nonpoint Sources

In addition to point sources, nonpoint sources contribute to water quality impairments in the Wissahickon Creek Watershed. Nonpoint sources represent contributions from diffuse, non-permitted sources. Nonpoint sources can be precipitation driven and occur as runoff from common, widespread land uses, such as golf courses, agricultural lands, wooded areas, and other landuses. Nonpoint sources can also be non-precipitation driven events such as contributions from groundwater, septic systems, or direct deposition of pollutants from wildlife and livestock.

Golf courses, agricultural lands, and wooded areas make up 3.65%, 6.66%, and 17.19% of the watershed, respectively (see Table 2-13 in Section 2). As discussed in Section 3.1.2, the entire watershed is within the MS4 political boundaries, and there are no additional lands beyond those political boundaries for characterization. Without the sewershed maps, EPA had no way to separate the nonpoint and point source discharges. Thus, for this modeling effort, all lands within the political boundaries were assumed to be within the MS4 jurisdiction. However, the nutrient loads themselves considered the land use and soil types, and thus any precipitation driven nonpoint sources have been modeled (See Section 4).

3.2.1 Septic Systems

EPA is aware that there are septic systems within the Wissahickon Creek Watershed. However, because the majority of the area is served by sanitary sewer systems, the contributions of nutrients from septic systems are extremely small in comparison to point source contributions. The septic systems in the watershed were represented in the modeling system as nonpoint sources based on limited municipal data available to characterize the number and location of septic systems. This data was used to establish the allocation and associated percent reduction of that source based on the limited data. See Section 5 for additional information.

3.2.2 Background

EPA has accounted for background nutrient loads from groundwater. Although low-flow conditions are dominated by point source contributions, a small amount of base flow is present with background nutrient concentrations likely controlled by groundwater. These background contributions are extremely small in comparison to point source contributions during low-flow conditions.

3.3 Other Water Quality Factors

There are other human activities that affect water quality in Wissahickon Creek Watershed. While not actually sources of nutrients, low level dams and Plymouth Meeting Quarry affect the nutrients levels in the ecosystem as discussed below.

3.3.1 Low Level Dams

Low level dams located throughout the watershed provide opportunity for in-stream sources of nutrients through sediment release from pooled areas. In preparation for the 2003 TMDL and to assess the impacts from these dams, PADEP monitored water quality upstream and downstream of two dams on Wissahickon Creek (EPA 2003a). If impacts proved significant, a more robust assessment of nutrient loads from the dams would be considered. However, except for a small increase in TP at one of the dams (Gross Dam), impacts were determined to be minimal. In the 2003 TMDL, rather than attribute a source of nutrients to dams, the effects were accounted for in the water quality calibration of the model. However for this TMDL revision effort, dams were added as explicit features in the modeling system as a more accurate representation of the watershed.

3.3.2 Plymouth Meeting Quarry (formerly Corson's Quarry)

Plymouth Meeting Quarry discharges an average of 12.5 cubic feet per second (cfs) to Lorraine Run. This flow rate is the historical average from this site, and is the same rate used in the 2003 Wissahickon Creek TMDL. This flow (with a relatively low level of pollutants) represents a significant contributor to Wissahickon Creek base flow and provides reductions to Wissahickon Creek nutrient concentrations by increasing the assimilative capacity for certain pollutants including nutrients of both Lorraine Run and the mainstem of Wissahickon Creek during the critical low flow period. To assess the benefits of the quarry discharge, EPA undertook a

sensitivity analysis using the low-flow model. Results of analysis are reported in the *Modeling Report for Wissahickon Creek, Pennsylvania Nutrient TMDL Development* (hereafter referred to as Nutrient Modeling Report) and showed that if quarry discharges are discontinued, additional DO problems will likely result in the bottom portions of Wissahickon Creek below Lorraine Run (EPA 2003b). Also, due to the substantial reduction of stream flow that would occur in Lorraine Run, aquatic life within the stream would be affected beyond problems associated with low DO. Therefore, the discharge from Plymouth Meeting Quarry benefits the water quality of Wissahickon Creek and Lorraine Run, and continued operation of the quarry should be encouraged. The previous and current TMDL was based on the assumption that this discharge will continue its operation and maintain its current discharge rate and pollutant concentrations. The Nutrient Modeling Report can be found at:
http://www.epa.gov/reg3wapd/tmdl/pa_tmdl/wissahickon/NUTRIENT_MODEL_REPORT/index.htm

4. TMDL TECHNICAL APPROACH

This section describes how the TMDL represents through modeling the relationship between the in-stream Wissahickon Creek water quality targets and source loadings, a critical component of TMDL development. It allows evaluation of management options that will achieve the desired source reductions necessary to meet water quality standards. The link can be established through a range of techniques, from qualitative assumptions based on sound scientific principles to sophisticated modeling techniques. Ideally, the linkage will be supported by monitoring data that allow the TMDL developer to associate certain water body responses with conditions. This TMDL uses a modeling framework to provide the most accurate and reliable representations of the complex water quality processes based on the available data within the Wissahickon Creek Watershed currently available. Quality controlled monitoring data collected over many years from dozens of stations provides the most direct measures of watershed water quality conditions and biological responses. The two models were integral in synthesizing the enormous amount of monitoring data and assessing pollutant load reductions needed to restore water quality. Although models have some inherent uncertainty, the amount of data and resources taken to develop, calibrate, and verify the accuracy of both models used in the Wissahickon Creek Watershed TMDL minimized the uncertainty.

The nutrient TMDL for the Wissahickon Creek Watershed used a modeling platform linking the Loading Simulation Program in C++ (LSPC) and the Environmental Fluid Dynamics Code (EFDC). LSPC is a modeling system capable of representing loads from nonpoint and point sources in the watershed and simulating in-stream processes. EFDC is a receiving water model capable of simulating three-dimensional flow, transport, and biogeochemical processes in surface water systems including rivers, lakes, estuaries, reservoirs, wetlands, and coastal regions.

4.1 LSPC Watershed Model Description and Configuration

LSPC is a comprehensive watershed model used to simulate watershed hydrology and pollutant transport, as well as stream hydraulics and in-stream water quality. It is capable of simulating flow; the behavior of sediment, metals, nutrients, pesticides, and other conventional pollutants; temperature; and pH for pervious and impervious lands and for waterbodies. LSPC is essentially a recoded C++ version of selected Hydrologic Simulation Program FORTRAN (HSPF) modules. LSPC's algorithms are identical to HSPF's. The HSPF framework is developed in a modular fashion with many different components that can be assembled in different ways, depending on the objectives of the individual project. The model includes these major modules:

- PERLND - for simulating watershed processes on pervious land areas
- IMPLND - for simulating processes on impervious land areas
- RCHRES - for simulating processes in streams and vertically mixed lakes

All of these modules include many submodules that calculate the various hydrologic and water quality processes in the watershed. Many options are available for both simplified and complex process formulations. Spatially, the watershed is divided into a series of subbasins or subwatersheds representing the drainage areas that contribute to each of the stream reaches. These subwatersheds are then further subdivided into segments representing different land uses.

For the developed areas, the land use segments are further divided into pervious and impervious fractions. The stream network links the surface runoff and subsurface flow contributions from each of the land segments and subwatersheds, and routes them through the waterbodies using storage-routing techniques. The stream-routing component considers direct precipitation and evaporation from the water surfaces, as well as flow contributions from the watershed, tributaries, and upstream stream reaches. Flow withdrawals and diversions can also be accommodated.

Important routines for water quality simulation include the QUAL module, which simulates the behavior of a generalized water quality constituent by linking land use surface runoff, associated pollutant loadings, and in-stream conditions. It allows for a constituent to be present or in a sediment-associated state, and in its simplest configuration, it represents all transformations and removal processes using simple, first-order decay approaches. The framework is flexible and allows modeling of different combinations of constituents depending on data availability and the objectives of the study.

Initial configuration of the LSPC model involved subdividing the watersheds into modeling units, followed by continuous simulation of flow and water quality for these units using land use, meteorological, soils, and stream data.

4.1.1 Watershed Sudivision

To represent watershed loadings and the resulting concentrations of nutrients, the watershed was divided into hydrologically connected subwatersheds. The LSPC model split the Wissahickon Creek Watershed into 118 subwatersheds.

4.1.2 Watershed Representation

The LSPC model split the Wissahickon Creek Watershed into 22 hydrologic response units (HRU), representing unique combinations of land use and hydrologic soil group (HSG). The watershed consists of over 50 percent residential HRUs (single family, multi-family, etc.) and 17 percent woods (HSG B & C). Table 4-1 lists the areas of the modeled HRUs and associated major land use categories; their spatial distribution is depicted in Figure 4-1. While the watershed is dominated by residential HRUs, the lower third of the watershed has a high density of woods adjacent to Wissahickon Creek.

Table 4-1. Hydrologic Response Units (HRUs) in the Wissahickon Creek Watershed.

Modeled Landuse/HRU	Landuse Grouping	Total Area (acres)	Total Area (%)
Agriculture_B[a]	Agriculture	768.73	1.89
Agriculture_C[b]	Agriculture	1939.61	4.77
Commercial	Impervious Developed	1307.99	3.22
Community Services	Pervious Developed	1377.05	3.39
Golf	Golf	1482.15	3.65
Light Industrial	Impervious Developed	579.12	1.43
Mining	Pervious Developed	119.81	0.29
Parking: Agriculture	Pervious Developed	5.56	0.01
Parking: Community Services	Pervious Developed	646.68	1.59
All other Parking	Impervious Developed	574.86	1.41
Recreation_B[a]	Pervious Developed	1058.53	2.61
Recreation_C[b]	Pervious Developed	525.23	1.29
Residential: Multi-family	Residential	1994.15	4.91
Residential: Row Home	Residential	210.64	0.52
Residential: Single_Family Detached_B[a]	Residential	14358.04	35.34
Residential: Single_Family Detached_C[b]	Residential	4219.97	10.39
Transportation	Impervious Developed	512.09	1.26
Utility	Pervious Developed	333.94	0.82
Vacant	Pervious Developed	1327.09	3.27
Water	Background	303.34	0.75
Wooded_B[a]	Background	4364.72	10.74
Wooded_C[b]	Background	2621.79	6.45

a. Soil group B
b. Soil group C

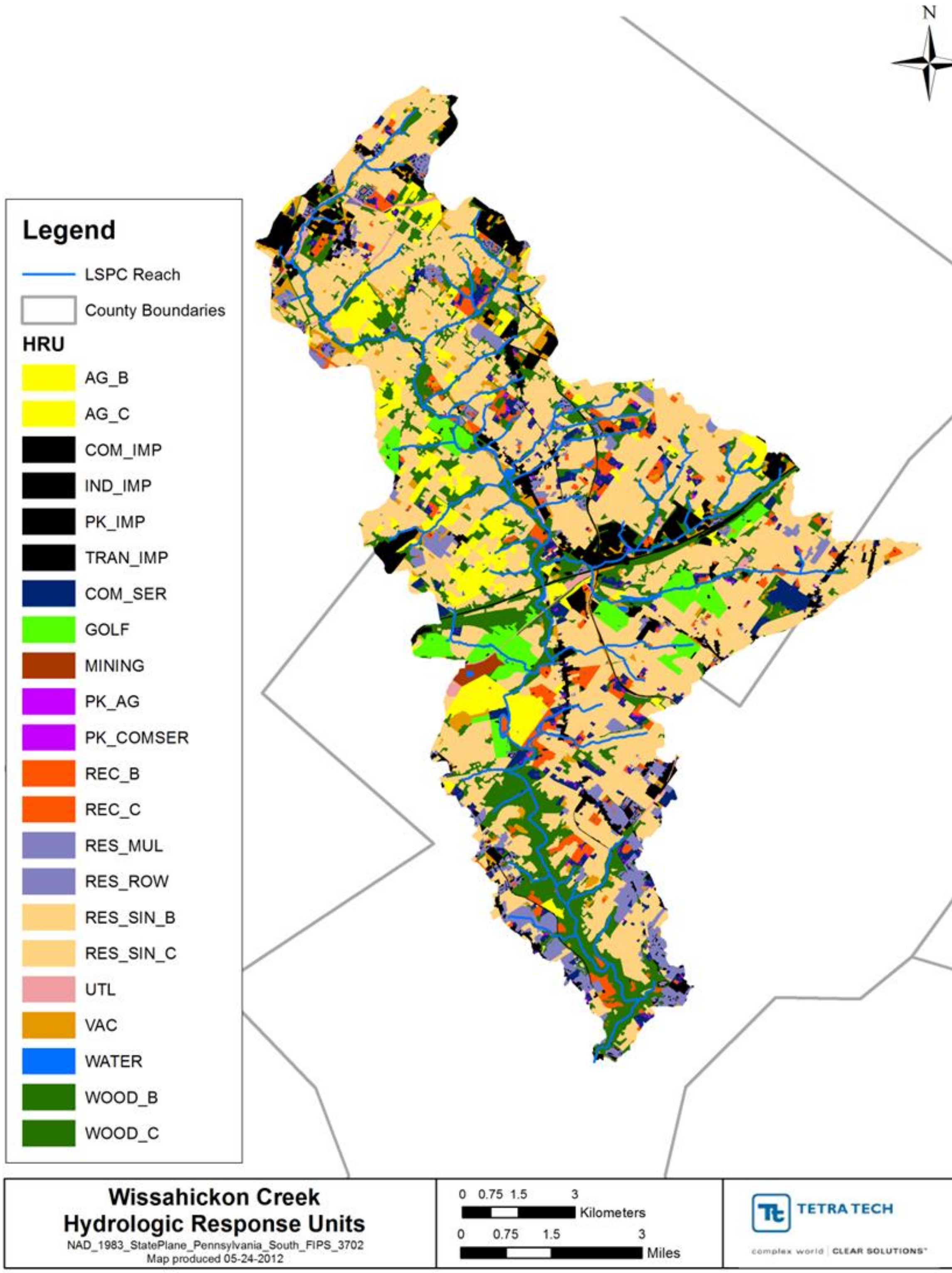

Figure 4-1. Spatial distribution of Wissahickon Creek Watershed model HRUs.

In LSPC, physical attributes of the watershed such as elevation, land segment slope, and length of overland flow are considered to be fixed, intrinsic properties of the natural system. Therefore, mean subwatershed elevation, average slope by land use and subwatershed, and mean reach elevation were estimated from a geographic information system (GIS) analysis and entered as constant physical attributes in the model. Further representation of detailed stream cross-sections from field observations helps to reduce the uncertainty often inherent in watershed models.

Surveyed stream cross-sections were available from PWD (2007) at various locations spatially distributed throughout the watershed as shown in Figure 4-2. Because LSPC can support only one stream cross-section per subwatershed, if more than one stream cross-section was surveyed in a given subwatershed, the arithmetic mean of those cross-sections was used. Figure 4-2 also shows example stream cross-sections as modeled for both a headwater and a mainstem segment of Wissahickon Creek.

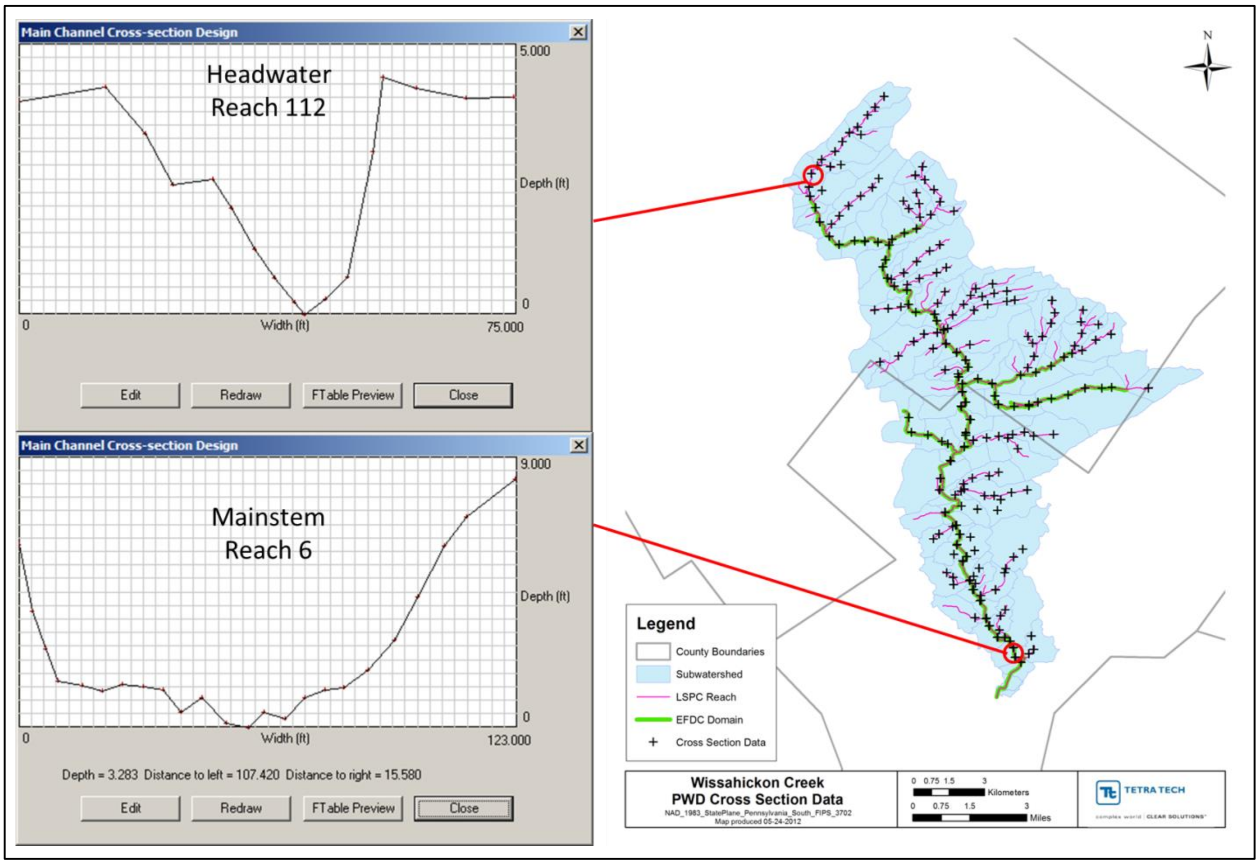

Figure 4-2. Modeled stream cross-sections for a headwater and mainstem segment (left) and locations of field-surveyed stream cross-section data (right).

Reach elevation from both field survey data and Digital Elevation Model (DEM) were used to improve the model's representation of mean reach elevation. Surveyed reach elevations were recorded at over 200 points in almost 100 subwatersheds throughout the Wissahickon Creek Watershed.

In a GIS framework, reaches were sampled at approximately 6,000 points. At each of these points, the elevations from the intersection of the reach lines and the DEM were extracted and geometrically averaged for each subwatershed. Figure 4-3 shows good agreement between the DEM-derived and the field-surveyed data. Therefore, for basins without surveyed data, the DEM was directly used to estimate the average reach elevation (Figure 4-4).

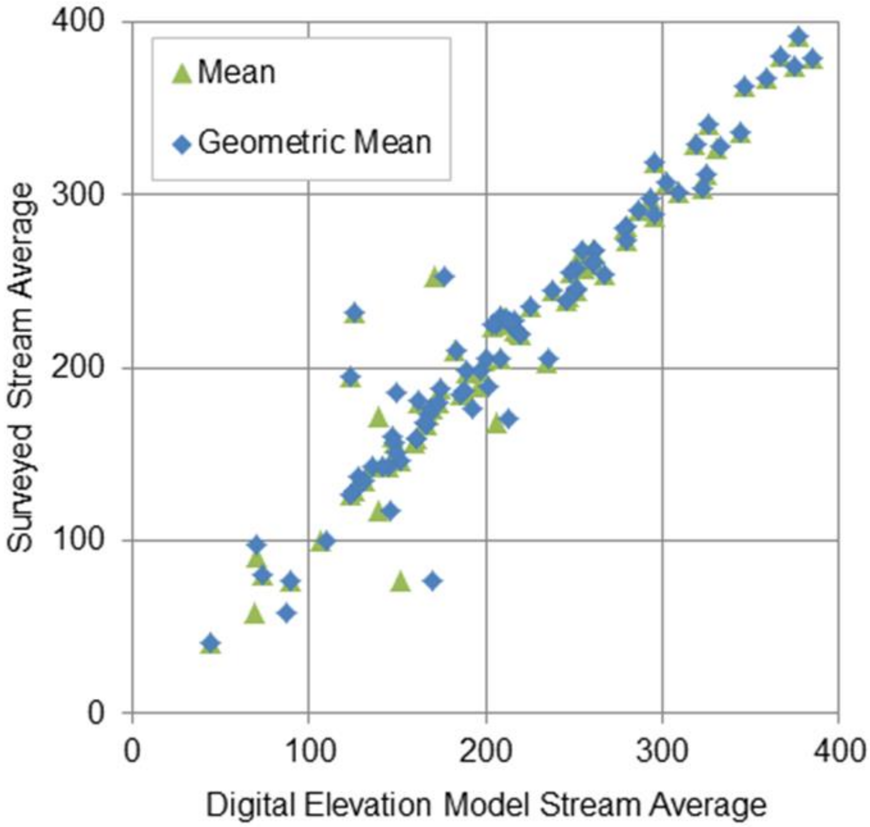

Figure 4-3. Comparison of DEM derived reach elevation and field-surveyed data at various streams in the Wissahickon Creek Watershed.

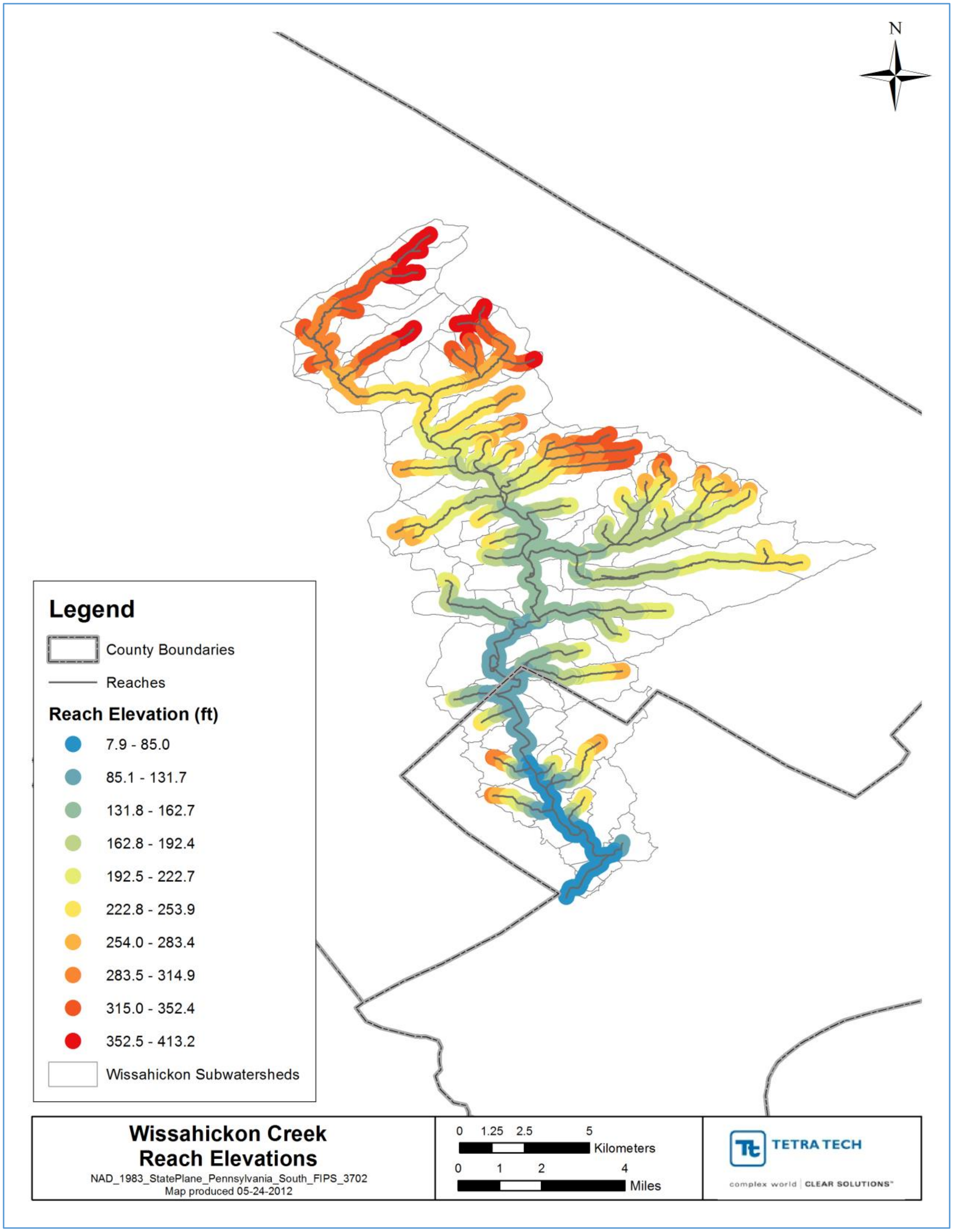

Figure 4-4. Reach elevation throughout the Wissahickon Creek Watershed.

4.1.3 Meteorological Data

Meteorological data is a critical component of watershed modeling because weather directly impacts hydrology and associated water quality. Appropriate representation of precipitation, wind speed, potential evapotranspiration, cloud cover, temperature, and dew point temperature is required to develop a valid model. As discussed in Section 2, daily and hourly meteorological data from in and around the Wissahickon Creek Watershed was obtained from NOAAs National Climatic Data Center (NCDC) and the North American Land Data Assimilation System (NLDAS). Section 2 provides more detail on NCDC and NLDAS.

In general, hourly precipitation (or higher resolution) data are recommended and preferred for nonpoint source modeling, especially in urbanized areas, because smaller temporal resolution accounts for intensity-associated effects of peak runoff and erosion. Three NCDC stations provided hourly precipitation data in addition to the other parameters required for the creation of the LSPC weather input file. However, the datasets for two of the three stations were incomplete. In an effort to obtain a more complete dataset, NLDAS gridded data was compared to NCDC observed station data to determine if it adequately represented the meteorological patterns in the watershed. For example, Figure 4-5 compares the NLDAS gridded precipitation data to the NCDC observed precipitation data from the Conshohocken station. The observed precipitation data from the Conshohocken station follows the NLDAS gridded precipitation data from grid points Y121X397, Y121X398, and Y120X398 closely.

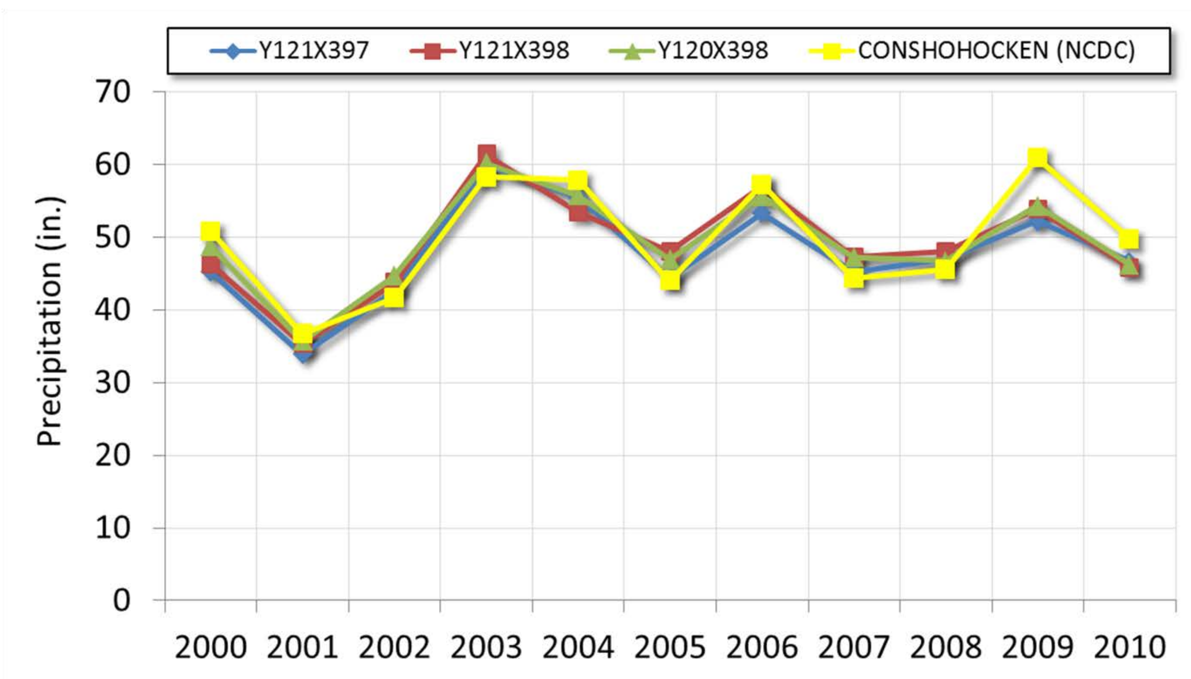

Figure 4-5. Comparison of NLDAS hourly precipitation data vs. NCDC observed data at Conshohocken station

Since NLDAS offered a complete, hourly dataset that adequately represented the meteorological patterns of the watershed, the NLDAS gridded data were used to create an LSPC weather input file. Therefore, the NCDC station data was not used. Figure 2-2 in Section 2 shows the locations of NLDAS grid points.

Watershed modeling requires continuous periods of high quality data. The period between 1/1/2005 and 12/31/2006 was selected as the modeling period because it temporally coincides with the other data sources such as land use representation and point source discharge records (see Section 2).

Potential evapotranspiration was computed using the Penman Method. This uses an energy balance equation that required ambient air temperatures with a default constant monthly variable ET coefficient as well as solar radiation, wind speed, dew point temperature and cloud cover. Solar radiation data were not available at any of the station locations in the vicinity of the modeling domain. Clear sky solar radiation was first computed according to the latitude and longitude and corrected based on the derived cloud cover information to generate the solar radiation time series. Algorithms for computing clear sky solar radiation were based on those in the CE-QUAL-W2 model code (Cole and Wells 2008).

4.1.4 Point Source Representation

Five point source dischargers were selected for initial representation in the LSPC watershed model: (1) Abington, (2) Ambler, (3) North Wales, (4) Upper Gwynedd, and (5) Upper Dublin. The Plymouth Meeting Quarry was simulated explicitly in the LSPC model as described in Section 3.3.2.

Based on limited data, EPA represented the entire Wissahickon Creek Watershed as subject to MS4 permitting. The City of Philadelphia is covered by a Phase I MS4 permit. All of the other municipalities in the watershed are considered urbanized according to US Census Data and, therefore, are subject to PADEP's permit for Phase II municipalities (PAG-13). Portions of 16 MS4 communities intersect the boundaries of the Wissahickon Creek Watershed. Although not explicitly represented, all storm water permits are accounted for, as they are nested within the MS4 loads. A geographic information system (GIS) shapefile of Pennsylvania municipalities was used to establish the boundaries of the MS4 communities. This representation can be refined between point sources and nonpoint sources upon receipt of sewershed information from the individual municipalities and/or other information from nonpoint sources.

For the other existing point sources which did not have NPDES phosphorus effluent limitations (including total phosphorus and orthophosphate), EPA determined that such facilities were not substantive sources of nutrients. EPA did not explicitly represent them in the modeling or allocation tables. The *de minimis* TP loading associated with such sources is contained in the background loading and accounted for in the model calibration and assumptions of the TMDL. A list of such point sources with *de minimis* discharges of TP appears in Appendix B.

4.1.5 Nonpoint Source Representation

Septic system loads were aggregated by subwatershed for the LSPC model. Because septic tank information was only available at the municipality level, some assumptions regarding the spatial distribution of septic tanks needed to be made. First, it was assumed that septic tanks are only present in single family residential, detached land uses and that within that land use category, the number of septic tanks are uniformly distributed. Second, each subwatershed was spatially joined to one or more municipalities. Third, considering the total area of single family residential detached land cover within that municipality and the coincident land cover of the subwatershed, a percent of septic system area could be calculated. Finally, summing the product of these percentages with the number of tanks in the coincident municipalities yielded an estimate for the number of septic systems in each subwatershed, shown in Figure 4-6.

Background contributions were modeled explicitly in the LSPC model. Various land use distribution data was obtained from the Delaware River Valley Planning Commission, as discussed in Section 2.6. The forested land contributes "background" level loads to surface waters, and these contributions were explicitly tracked in the allocation scenario. However, reductions were not applied to the forested land use group in the TMDL scenario.

For the Wissahickon Creek Watershed, septic systems were represented as an aggregated nonpoint source for each of the 66 subwatersheds where septic systems were present. All estimates are based on the assumption that systems are functioning properly. A constant daily load of 12 g/day per system of nitrogen (nitrate-nitrite as N) and 1.5 g/day per system of dissolved phosphorous was multiplied by the number of systems in each subwatershed as an estimate of nutrient loading from septic systems (Haith et al 1992).

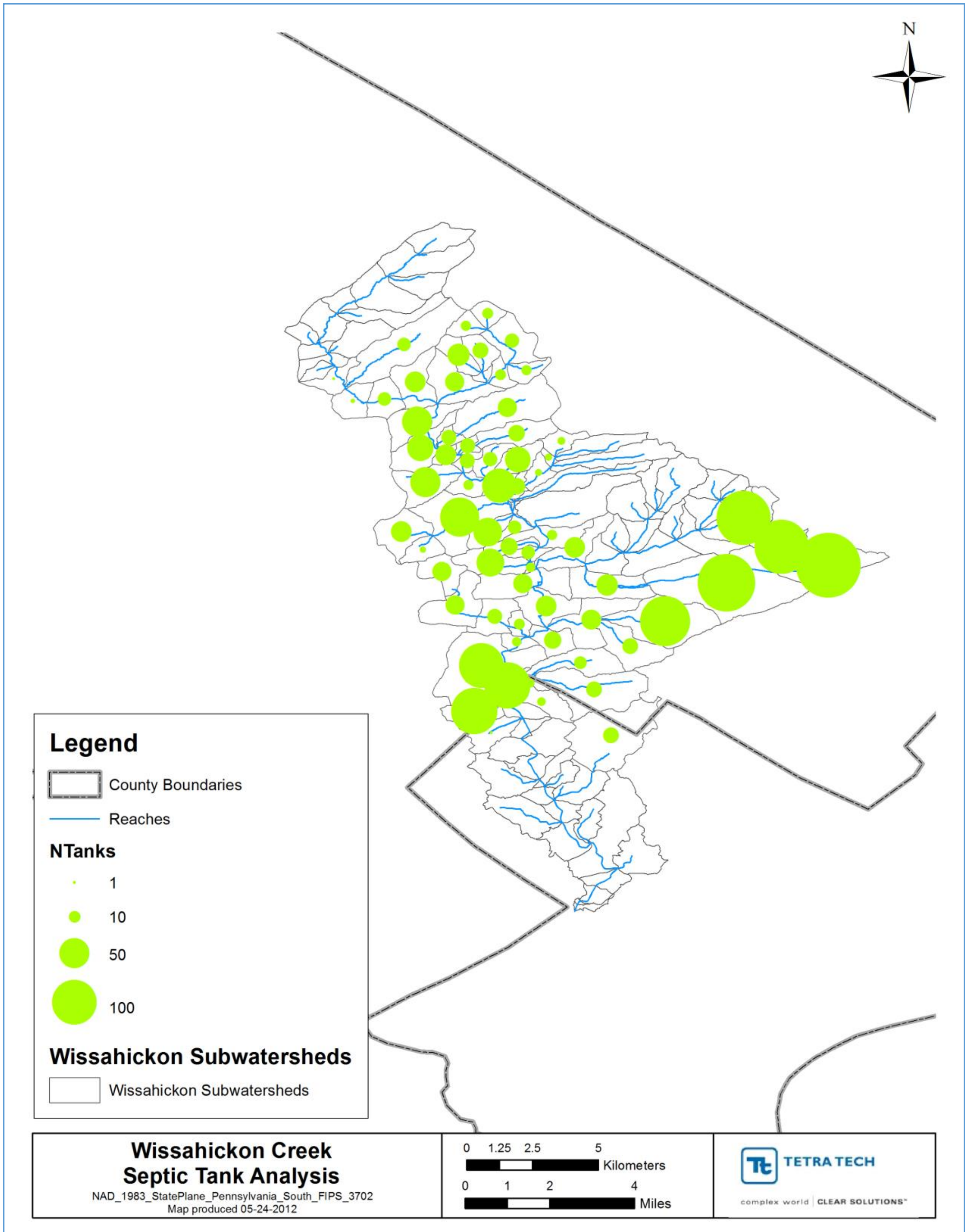

Figure 4-6. Estimated density of septic systems in the Wissahickon Creek Watershed.

4.2 EFDC Receiving Water Model Description and Configuration

EFDC is a general purpose modeling package for simulating three-dimensional flow, transport, and biogeochemical processes in surface water systems including rivers, lakes, estuaries, reservoirs, wetlands, and coastal regions. The EFDC model is a widely tested model and is supported by USEPA. In addition to hydrodynamic and salinity and temperature transport simulation capabilities, EFDC is capable of simulating cohesive and noncohesive sediment transport, near field and far field discharge dilution from multiple sources, eutrophication processes, the transport and fate of toxic contaminants in the water and sediment phases, and the transport and fate of various life stages of finfish and shellfish. Special enhancements to the hydrodynamic portion of the code, including vegetation resistance, drying and wetting, hydraulic structure representation, wave-current boundary layer interaction, and wave-induced currents, allow refined modeling of wetland marsh systems, controlled flow systems, and near-shore wave induced currents and sediment transport. The EFDC model has been extensively tested and documented. The model is presently being used by a number of organizations including universities, governmental agencies, and environmental consulting firms.

The structure of the EFDC model includes four major modules (Figure 4-7): (1) a hydrodynamic model, (2) a water quality model, (3) a sediment transport model, and (4) a toxics model. For Wissahickon Creek, the hydrodynamic and water quality modules are used; the sediment and toxics modules are not used. The EFDC hydrodynamic module is composed of six transport modules including dynamics, dye, temperature, salinity, near field plume, and drifter. Various products of the dynamics module (i.e., water depth, velocity, and mixing) are directly coupled to the water quality, sediment transport, and toxics models. A schematic diagram for the hydrodynamics model and water quality model is included in Figure 4-8.

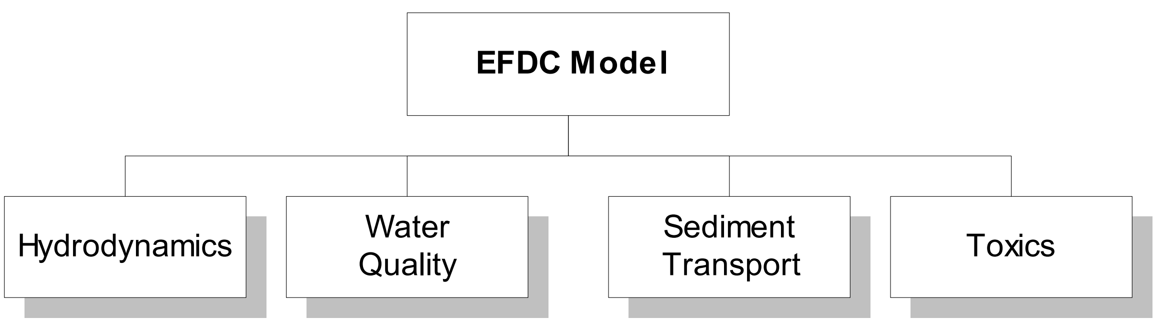

Figure 4-7. EFDC model structure.

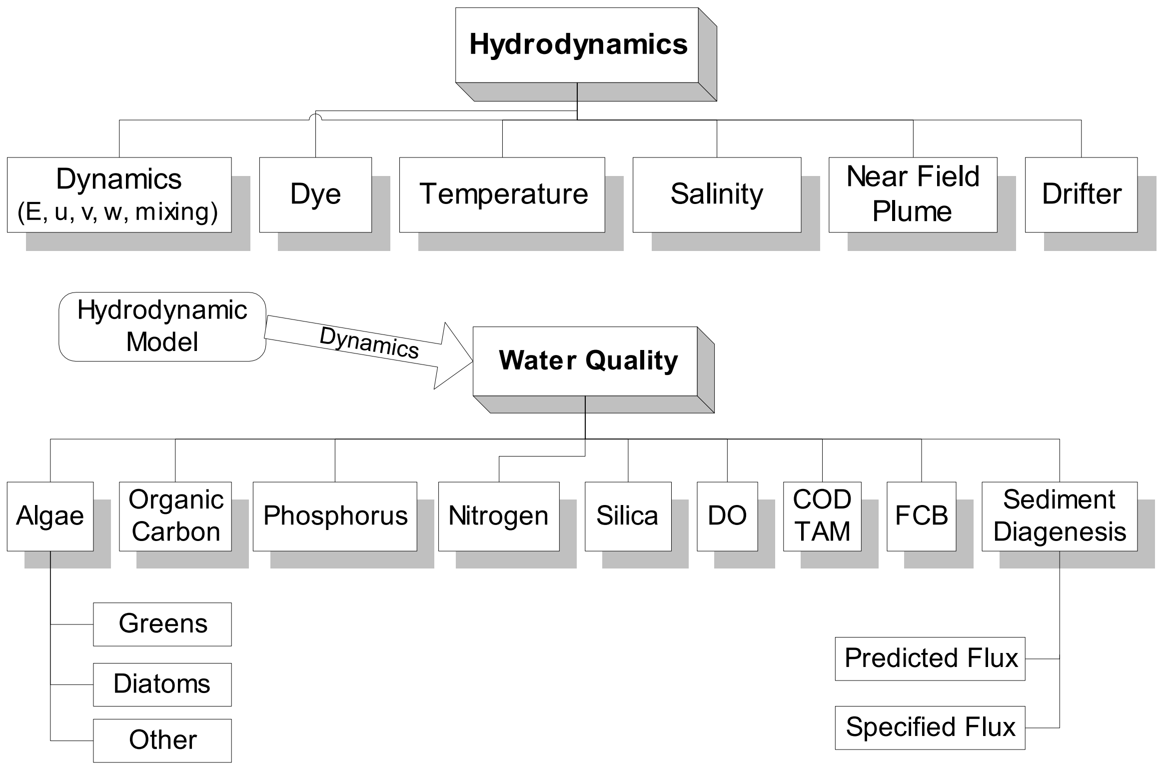

Figure 4-8. EFDC hydrodynamic and water quality module structure.

The EFDC code includes a eutrophication submodel for water quality simulation (Park et al. 1995), which is functionally equivalent to the CE-QUAL-ICM or Chesapeake Bay Water Quality model (Cerco and Cole 1993). The water column eutrophication models are coupled to a functionally equivalent implementation of the CE-QUAL-ICM biogeochemical processes model (DiToro and Fitzpatrick 1993). Figure 4-8 shows the schematic diagram. In addition to the phytoplankton, benthic algae or macroalgae can be simulated in EFDC. The eutrophication models can be executed simultaneously with the hydrodynamic component of EFDC. EFDC accepts an arbitrary number of point and nonpoint source loadings as well as atmospheric and ground water loadings.

Configuration of the EFDC receiving water model involved processing bathymetric/cross-sectional data, developing a model grid, assigning initial hydrodynamic and water quality conditions in the water column, defining boundary conditions at the water surface, and linkage to the watershed model for up-stream and lateral inputs. The following discussion provides more detail regarding model configuration and application.

4.2.1 Grid Generation

The first step to configure EFDC for Wissahickon Creek was to discretize the waterbody into a computational grid, in order to solve the model's governing equations for hydrodynamics and water quality in a spatial context. A two-dimensional grid was developed to most truly represent the shape of the mainstem and tributaries of Wissahickon Creek. Significant hydraulic features (including watershed inflows, dams, and major bathymetric variability) and their locations were considered in preparing the grid. Low head dams were characterized in the EFDC model as explicit hydraulic structures. The grid consists of 120 grid cells. Each cell is represented by a single vertical layer. It should be noted that this grid was developed and refined through an iterative process wherein model resolution, accuracy, and simulation time were optimized.

4.2.2 Periphyton Representation

In order to more accurately represent the complex chemical and biological interactions exhibited by Wissahickon Creek, and periphyton influence in particular, a detailed water quality framework was instituted. The EFDC model was configured to represent the limiting effects of different nutrients, the interactions between algal species, filamentous and other periphyton types, and nutrient fate and transport within the water column and between the water column and sediment. Two types of periphyton algal groups and multiple forms of nitrogen, phosphorus, and carbon were simulated, as well as their combined impact on dissolved oxygen and nutrient levels.

To enhance the existing EFDC modeling framework, an additional module was developed and incorporated into the source code to specifically allow for more precise representation of periphyton dynamics. Comments on the 2003 TMDL recommended to group the periphyton in Wissahickon into two broader groups: one group mainly representative of filamentous periphyton species with a high half saturation nutrient concentration, and a second group representing periphyton with a low half saturation coefficient. The rates were initially based on the recommendation from the PADEP biology staff, and were adjusted through the calibration. This modification allows for representation of competition for nutrient uptake and density limitations. The parameter requirements and values for each periphyton class are shown in Table 4-2 below.

Table 4-2. Periphyton parameterization in EFDC.

	Filimentous (model species #1)	Non-filimentous (model species #2)	Literature min	Literature max
Growth (1/d)	0.7	0.7	0.62	4
Respiration (1/day)	0.03	0.03	0.02	0.2
Grazing (1/d)	0.035	0.035	0.005	0.1
P half-saturation (mg/L)	0.125	0.005	0.001	0.5

4.3 Model Calibration

After the models were configured, calibration was performed at two locations in the Wissahickon Creek Watershed. Calibration refers to the adjustment or fine-tuning of modeling parameters to reproduce observations. Model calibration is necessary to ensure physically realistic model prediction. For the Wissahickon Creek Watershed, model calibration focused on two main areas: hydrology and water quality.

The first step in the model calibration process was to select an appropriate time period. The main consideration when choosing the time period was ambient water quality data availability. January 2005 through December 2005 was chosen because it had the most abundant series of data, including ambient water quality data, high-frequency dissolved oxygen data, macrophyte data, and WWTP discharge data.

The next step was to determine a set of parameters, or variables, that best describe the hydrologic and water quality processes in the Wissahickon Creek Watershed. The parameters were then used by the model to help replicate the physical processes occurring in the watershed and streams.

Finally, model performance was evaluated following each water quality simulation by comparing modeled results with observed data at various locations throughout the watershed. If the modeled results did not adequately represent the trends, relationships, and magnitudes of the observed data, model parameters were adjusted (i.e. calibrated) to improve model performance. This process continued until the observed data was well-represented by the model.

Graphical results for the calibration of each location were too numerous to display in the main report, but are available in Appendices C and D.

4.3.1 LSPC Model Calibration

Hydrology

The LSPC model was run with the previously described configuration for a simulation period beginning January 1, 2005 and ending December 31, 2005. Results from the uncalibrated, default model were checked for continuity by comparing total modeled flow volume with observed flow volume at the mouth of Wissahickon Creek. This assessment helps highlight (1) potential problems with representation of climate data (precipitation, potential evapotranspiration, etc.), and (2) continuity errors in the reach routing network.

Calibration began by setting the infiltration index (INFILT) consistent with values suggested based on HSG (USEPA 2000). Although the HRUs were classified largely as HSG-B and HSG-C, evaluation of storm hydrographs showed systematic under prediction. INFILT was therefore set slightly below the default recommendations for HSG-B and HSG-C. This approach is consistent with previous modeling efforts by PWD (PWD 2007).

After INFILT was set to reasonably replicate the peaks of storm hydrographs, the next step in the hydrology calibration process focused on two parameters that control the behavior of groundwater in the system (1) the base groundwater recession rate (AGWRC), and (2) variable groundwater recession rate (KVARY). The base groundwater recession rate (AGWRC) mathematically is the ratio of current groundwater discharge to groundwater discharge from the previous 24 hours. It describes how quickly groundwater outflow is changing. The variable groundwater recession rate (KVARY) is a hydrology parameter used in conjunction with AGWRC to adjust for non-linear seasonal variation in groundwater flow patterns. KVARY is typically one of the last parameters adjusted during hydrology calibration and only if varying seasonal groundwater patterns are evident in the observed data. AGWRC was set within the typically accepted range using higher values for naturally vegetated HRUs and lower values for human-distributed HRUs.

BASINS Technical Note 6 recommends initially setting lower zone storage (LZSN) as a function of annual precipitation. While at the upper end of typical values, the calibrated value of 8 inches is consistent with this guidance (USEPA 2000). DEEPFR, the fraction of LZSN lost to deep groundwater aquifers, was set at 0.08 to reflect a basin-wide consumptive water loss equal to approximately 8 percent of annual average streamflow (USGS 2005). Although the consumptive water loss is not physically lost to aquifers, it was a convenient and reasonable way to physically represent this withdrawal-loss activity in the model. BASETP, the fraction of evaporation satisfied from baseflow, was set at 0.03 in an attempt to reflect observed groundwater trends consistent with a "losing stream" believed to be related to groundwater withdrawals in nearby watersheds (PWD 2007). Descriptions and calibrated values of 11 key hydrology parameters are presented below in Table 4-3.

Table 4-3. Calibrated model hydrology parameters

Parameter	Description	Units	Typical Range	Calibrated Values
INFILT	Index to infiltration capacity	in./hr	0.01 – 0.25	0.025 – 0.1
LZSN	Lower zone storage	in.	3.0 – 8.0	8.0
AGWRC	Base groundwater recession constant	none	0.92 – 0.99	0.965 – 0.985
KVARY	Variable groundwater recession	1/in.	0.0 – 3.0	0.0
UZSN	Upper zone storage	in.	0.1 – 1.0	0.8 – 0.96
CESPEC	Interception storage	in.	0.03 – 0.2	0.05 – 0.25
INFTW	Interflow Inflow Parameter	none	1.0 – 5.0	1.0
IRC	Interflow Recession Constant	none	0.3 – 0.7	0.3
LZETP	Lower zone evapotranspiration parameter	none	0.2 – 0.7	0.2 – 0.7
DEEPFR	Fraction of groundwater flow to deep recharge	none	0.0 – 0.2	0.08
BASETP	Fraction of remaining evapotranspiration from baseflow	none	0.0 – 0.05	0.0 – 0.03

Watershed model calibration was assessed using data from two USGS streamflow gages: USGS 01474000 Wissahickon Creek at Mouth, Philadelphia, PA, and USGS 01473900 Wissahickon Creek near Fort Washington. The initial evaluation focused on the period from 1/1/2005 through 12/31/2005 as this period has the finest-scale, most complete point source discharge records for the 5 major WWTPs. Figures 4-9 and 4-10 present modeled versus observed flow duration curves at the two USGS streamflow gages.

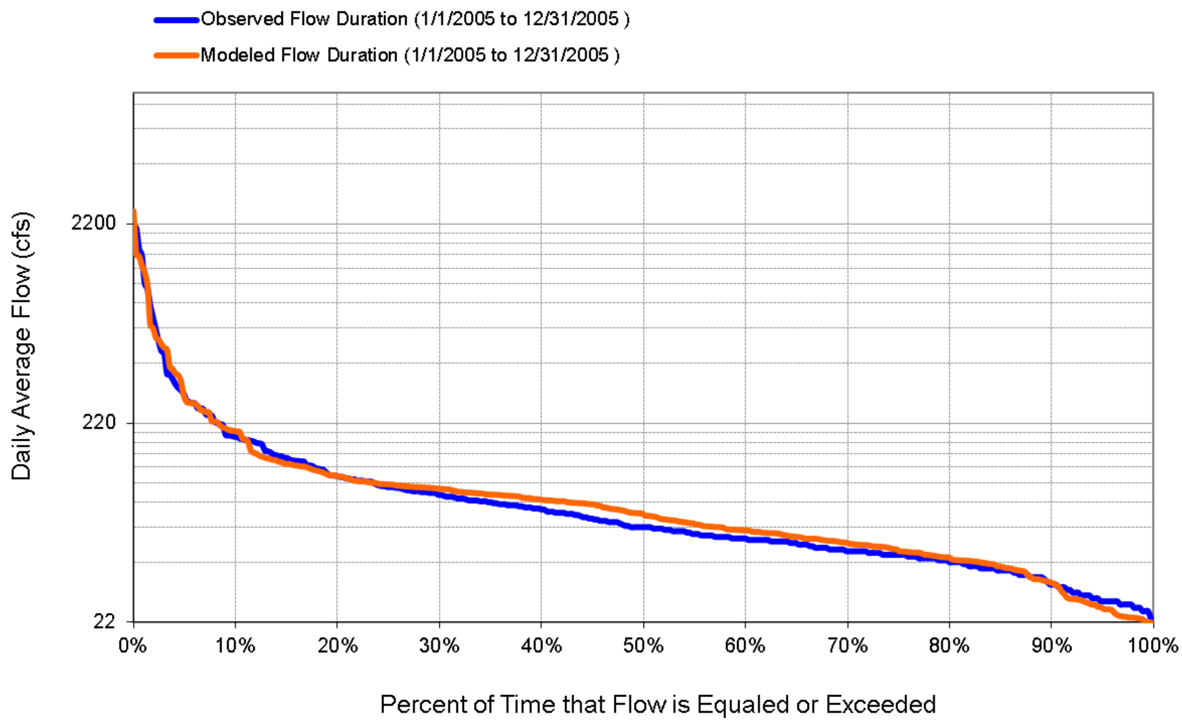

Figure 4-9. Plot of observed vs. modeled flow duration USGS 01474000 Wissahickon Creek at Mouth, Philadelphia, PA (1/1/2005 through 12/30/2005).

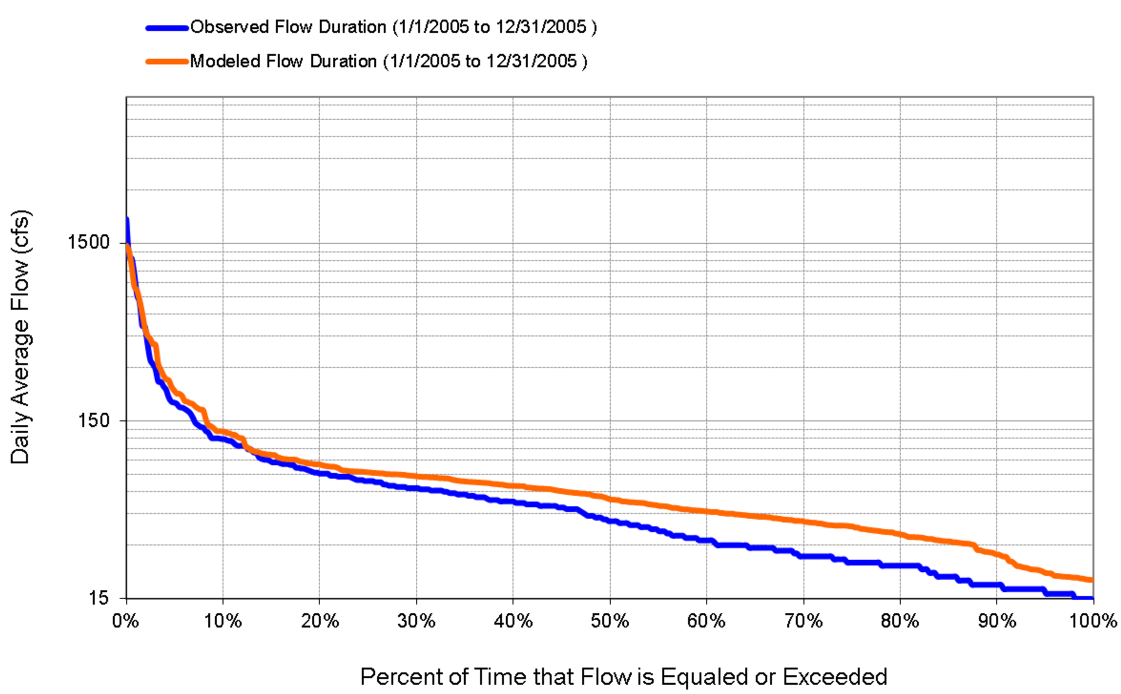

Figure 4-10. Plot of observed vs. modeled flow duration USGS 01473900 Wissahickon Creek at Fort Washington, PA (1/1/2005 through 12/30/2005).

An additional assessment was performed to verify that the monthly and seasonal observed flow patterns are being accurately represented by the model. This assessment focuses on replication of the gross monthly flow pattern. The exact magnitude of individual months can be refined through calibration; however, seasonal prediction of high and low flows is highly dependent on climate data inputs. This analysis can provide further insight into the quality of climate data used to drive the model. Figure 4-11 and 4-12 present plots of monthly modeled flows vs. monthly observed flows from January 1, 2005 through December 31, 2005.

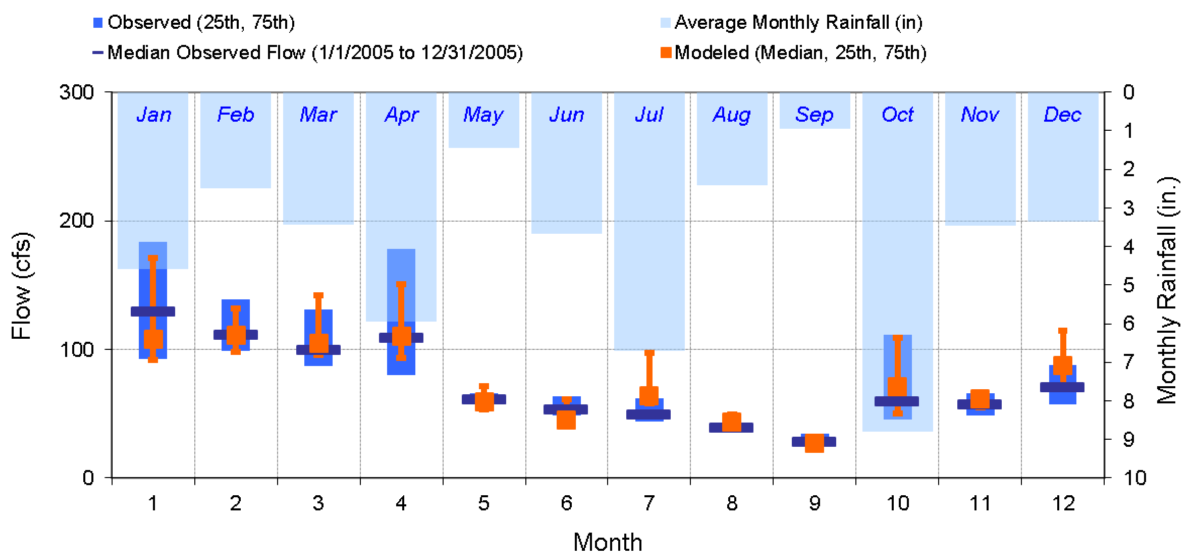

Figure 4-11. Plot of observed vs. modeled flow volume USGS 01474000 Wissahickon Creek at Mouth, Philadelphia, PA (1/1/2005 through 12/30/2005).

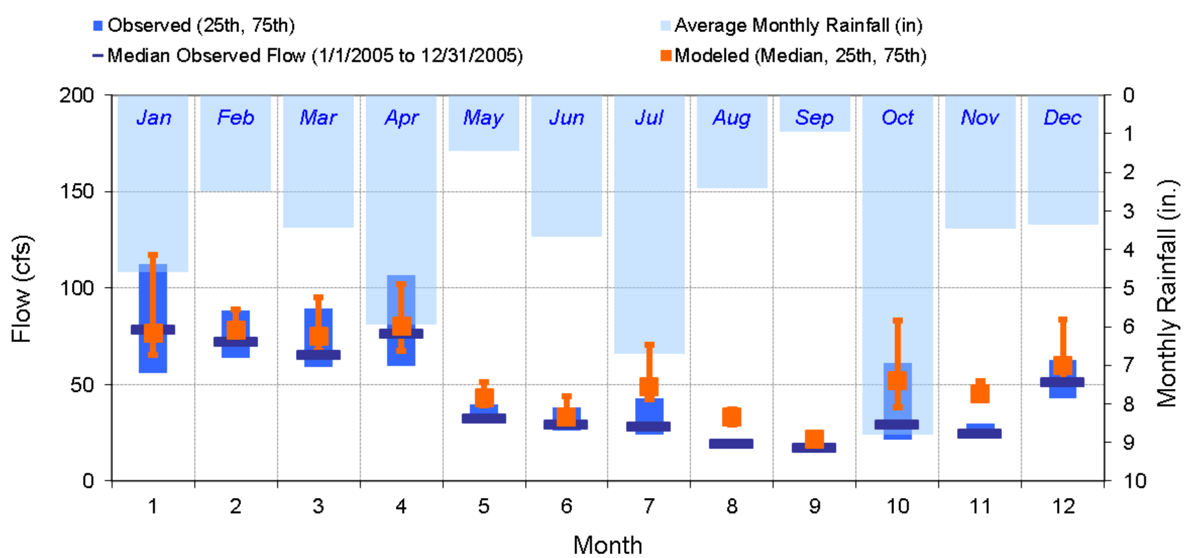

Figure 4-12. Plot of observed vs. modeled flow volume USGS 01473900 Wissahickon Creek at Fort Washington, PA (1/1/2005 through 12/30/2005).

Figures 4-11 and 4-12 suggest a good match between modeled and observed monthly flows with a slight over-prediction during the late summer and early fall, most noticeably at the upstream USGS gage at Fort Washington (Figure 4-12).

Water Quality

Water quality calibration of nutrients and dissolved oxygen was performed at eight locations in the watershed. Calibration at one of the locations will be described here. The WS076 station was also used in hydrology calibration, and will illustrate model performance at that location. It is located along the lower portion of Wissahickon Creek, downstream of the major WWTP facilities, and provides an assessment of how the model represents the aggregate of pollutant sources in the lower portion of the watershed. The remainder of the calibrations are presented in Appendix C.

The model results are compared to instantaneous water quality samples in Figures 4-13 and 4-14. Figure 4-13 illustrates modeled phosphorus concentrations (mg/L) compared to observed grab samples taken at the WS076 station. The LSPC model represents the fluctuations in phosphorus concentrations well, and follows seasonal trends and storm effects as evidenced by acute drops in phosphorus in July and October, 2005.

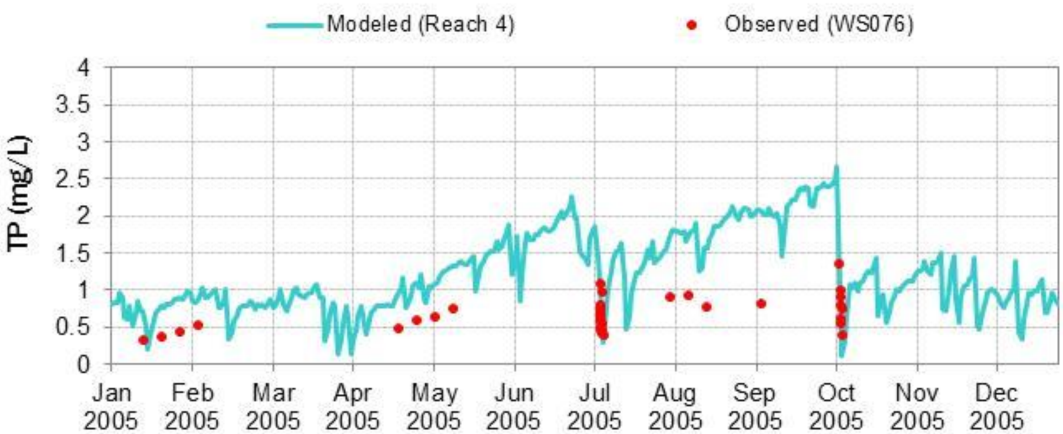

Figure 4-13. LSPC Phosphorus calibration at WS076, near the mouth of Wissahickon Creek.

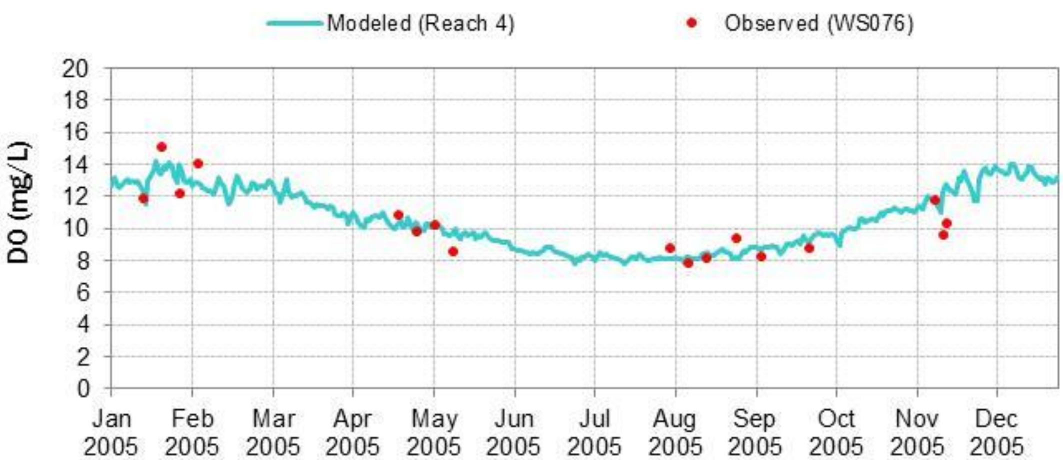

Figure 4-14. LSPC Dissolved oxygen calibration at WS076, near the mouth of Wissahickon Creek.

Figure 4-14 illustrates modeled dissolved oxygen concentrations (mg/L) compared to observed grab samples taken at the WS076 station. The LSPC model represents the fluctuations in dissolved oxygen well and follows typical seasonal trends of lower dissolved oxygen levels in the warmer months and increases in dissolved oxygen when water temperatures decrease.

LSPC Model Assumptions

- No significant vertical stratification is assumed in the stream reaches.
- Each LSPC reach is assumed to be completely mixed for water quality parameters.
- LSPC is a spatially lumped model and does not represent the spatial orientation of individual land uses in a subwatershed.
- Land uses and stream channel cross sections are fixed and constant throughout the modeling period.
- Stratification effects cannot be simulated because of representation as a completely mixed system. Lateral spatial gradients in the main channel or in tributaries cannot be represented.

4.3.2 EFDC Model Calibration

Once calibrated, the LSPC model results were used as boundary conditions for the EFDC receiving water model. The main parameters subjected to calibration included: algal and periphyton growth rates, respiration rates, and death rates; CBOD decay rate; sediment oxygen demand (SOD); nitrification and denitrification rates; nitrogen and phosphorus recycling rates from dead algae; and carrying capacity of periphyton, substrate availability for periphyton growth, and local solar radiation shading coefficient; and recreation equation coefficients. The calibration process involved a stepwise adjustment of these parameters, within reasonable and acceptable ranges, until the model adequately reproduced the observed data.

Model results were compared to instantaneous water quality samples in Figures 4-15 and 4-16. Figure 4-15 illustrates modeled phosphorus concentrations (mg/L) compared to observed grab samples taken at the WS076 station. It is important to note that this station was also used in calibrating the LSPC watershed model. The station was used to assess LSPC model performance prior to linking the LSPC watershed model to the EFDC receiving water model. LSPC results were then used to drive the EFDC water quality routines, which represent more complex in-stream processes and provide a better calibration. This is clearly evidenced when comparing Figure 4-15 to Figure 4-13. The EFDC model represents the fluctuations in phosphorus concentrations much better than the LSPC model, and follows seasonal trends and storm effects as evidenced by acute drops in phosphorus in July and October 2005.

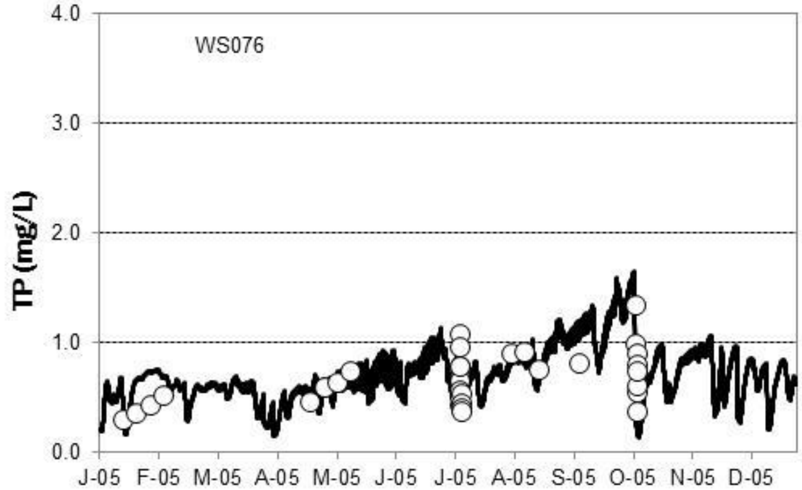

Figure 4-15. EFDC Phosphorus calibration at WS076, near the mouth of Wissahickon Creek.

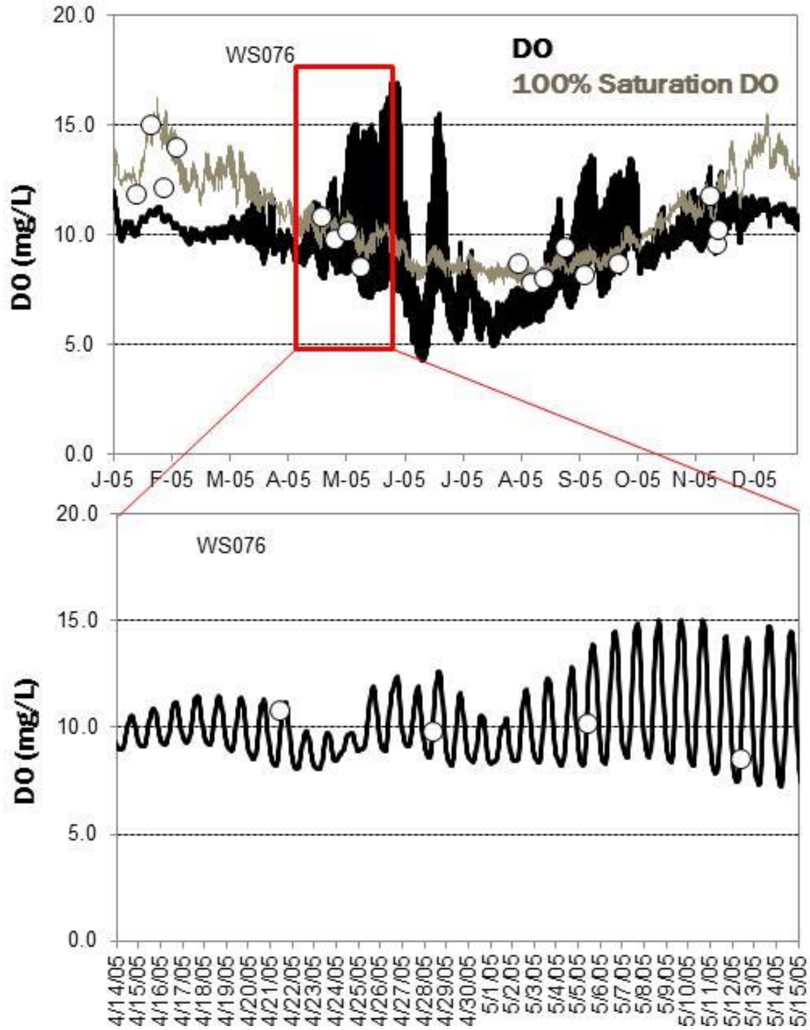

Figure 4-16. EFDC Dissolved oxygen calibration at WS076, near the mouth of Wissahickon Creek.

Figure 4-16 illustrates modeled dissolved oxygen concentrations (mg/L) compared to observed grab samples taken at the WS076 station. Similarly to the phosphorus comparison, the EFDC model represents the fluctuations in dissolved oxygen concentrations much better than the LSPC representation, and follows seasonal trends and storm effects.

Figure 4-16 also shows a detailed look at the April 2005 time frame where both the model and observed data show supersaturated oxygen levels in Wissahickon Creek. The frequency of grab samples is low compared to model output, and model results should optimally encompass the range of observed values. Therefore, an additional dataset was obtained through the use of in-situ data sondes.

The in-situ data sondes were used to collect data along the central portion of Wissahickon Creek. Figure 4-17 shows the data from one data sonde that recorded 15-minute dissolved oxygen data at the WS1210 station. The data provides insight to the diurnal fluctuations occurring at that location. The WS1210 station is along the mainstem of Wissahickon Creek, just downstream of the Morris Road bridge.

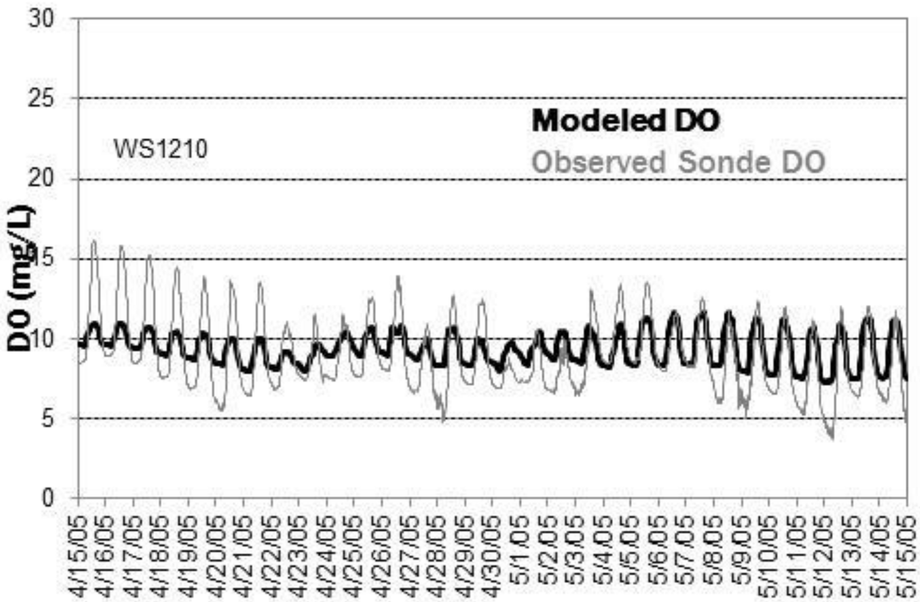

Figure 4-17. EFDC Dissolved oxygen calibration at WS1201, near the Morris Road bridge.

Figure 4-17 also shows the EFDC model output at the WS1210 station. The EFDC model is able to simulate diurnal DO fluctuations well, which are dependent on a number of complex climatological and biochemical factors. Increases and decreases in oxygen levels are represented very well in terms of peak timing, and moderately well with respect to amplitude. Although a limited number of calibration locations is shown here, Appendix D will show that the model also reproduced the spatial distribution of water quality very well, particularly in the vicinity of point source discharge locations. In addition, the DO fluctuation, as simulated with the diurnal module, matched the observed data reasonably well, as described and shown above.

The capability of the model to reproduce the variations in phosphorus, dissolved oxygen, and other water quality constituents is important when assessing the calibration, and a characteristic that will allow changes in loading rates to be considered fully. The model responses demonstrated in the calibration provide confidence that influential environmental and biological factors are being adequately considered.

5. ALLOCATION ANALYSIS AND TMDLS

A TMDL is the total amount of pollutant that can be assimilated by the receiving water body while still achieving water quality standards or goals. It is composed of the sum of individual waste load allocations (WLA) for point sources and load allocations (LA) for nonpoint sources and natural background levels. In addition, the TMDL must include a margin of safety (MOS), implicitly or explicitly, to account for the uncertainty in the relationship between pollutant loads and the quality of the receiving water body. Conceptually, this definition is represented by the following equation:

$$\text{TMDL} = \Sigma WLAs + \Sigma LAs + MOS$$

In TMDL development, allowable loadings from each pollutant source are summed to a cumulative TMDL threshold, thus providing a quantitative basis for establishing water quality-based controls. TMDLs can be expressed as a mass loading over time (e.g., grams of pollutant per day) or as a concentration in accordance with 40 CFR 130.2(l).

5.1 Baseline Conditions

The first step in the allocation process is to determine the baseline conditions. Baseline conditions allow for an evaluation of instream water quality under the highest expected loading conditions. For nonpoint sources and MS4s, the baseline conditions represent existing loadings which were determined using the LSPC model. For the WWTPs, baseline conditions were calculated using observed phosphorus data from discharge monitoring reports (DMRs) and effluent discharge rate. Effluent discharge rate is the flow used to determine effluent limitations for an NPDES permit. Effluent discharge rate was available for all of the WWTPs except for North Wales. Therefore, the baseline conditions for North Wales were calculated using observed flow and phosphorus data from DMRs. Table 5-1 shows the flow and phosphorus data used to calculate the baseline conditions for the five WWTPs.

Table 5-1. Flow and phosphorus data used to calculate the baseline conditions for the five WWTPs. Effluent discharge rate and average monthly observed phosphorus were used to calculate the baseline conditions at Abington, Ambler, Upper Dublin, and Upper Gwynedd. Average monthly observed flow and phosphorus were used to calculate baseline conditions at North Wales.

Time	Abington (PA0026867)		Ambler (PA0026603)		North Wales (PA0022586)		Upper Dublin (PA0029441)		Upper Gwynedd (PA0023256)	
	Flow (MGD)	Avg TP (mg/L)	Flow (MGD)	Avg TP (mg/L)	Flow (MGD)	Avg TP (mg/L)	Flow (MGD)	Avg TP (mg/L)	Flow (MGD)	Avg TP (mg/L)
Jan-05	3.91	3.3	6.5	3.4	0.7	1.8	1.1	3.1*	5.7	2.2
Feb-05	3.91	3.2	6.5	3.3	0.6	2.5	1.1	3.1*	5.7	2.0
Mar-05	3.91	3.2	6.5	3.0	0.7	1.6	1.1	3.1*	5.7	2.2
Apr-05	3.91	2.8	6.5	3.5	0.7	1.7	1.1	3.1*	5.7	3.0
May-05	3.91	3.8	6.5	4.7	0.3	3.3	1.1	2.6*	5.7	3.6
Jun-05	3.91	4.5	6.5	5.2	0.3	3.8	1.1	2.7*	5.7	3.5
Jul-05	3.91	3.9	6.5	5.1	0.4	3.5	1.1	3.2*	5.7	3.1
Aug-05	3.91	3.9	6.5	5.3	0.2	4.2	1.1	3.5*	5.7	3.4
Sep-05	3.91	4.2	6.5	4.7	0.2	4.5	1.1	2.7*	5.7	2.1
Oct-05	3.91	3.9	6.5	4.5	0.5	3.2	1.1	2.8*	5.7	1.8
Nov-05	3.91	4.3	6.5	4.9	0.4	3.2	1.1	2.4*	5.7	1.5
Dec-05	3.91	3.9	6.5	4.1	0.5	2.4	1.1	2.4*	5.7	1.5
Jan-06	3.91	3.6	6.5	3.1	0.8	1.9	1.1	3.1*	5.7	2.0
Feb-06	3.91	3.5	6.5	3.1	0.6	2.4	1.1	3.1*	5.7	2.6
Mar-06	3.91	4.2	6.5	3.6	0.3	4.0	1.1	3.1*	5.7	3.5
Apr-06	3.91	4.4	6.5	3.9	0.4	4.4	1.1	3.1*	5.7	3.0
May-06	3.91	4.8	6.5	4.2	0.3	3.7	1.1	2.6*	5.7	2.8
Jun-06	3.91	4.0	6.5	3.8	0.5	3.6	1.1	2.7	5.7	2.9
Jul-06	3.91	3.9	6.5	4.3	0.5	2.1	1.1	3.2+	5.7	2.8
Aug-06	3.91	4.2	6.5	4.5	0.3	3.7	1.1	3.7	5.7	3.1
Sep-06	3.91	3.7	6.5	4.4	0.7	2.2	1.1	2.6	5.7	2.9
Oct-06	3.91	3.7	6.5	4.0	0.5	2.8	1.1	2.8	5.7	2.9
Nov-06	3.91	3.5	6.5	3.7	0.8	1.6	1.1	2.3	5.7	2.3
Dec-06	3.91	3.8	6.5	4.1	0.5	2.7	1.1	2.4	5.7	2.7

*TP Calculated based on observed ORP DMR values
+ Interpolated value between June and August 2006. No DMR data available for TP or ORP.

5.2 Allocation Strategy

EPA used LSPC and EFDC models to inform its TMDL allocation decisions on how to attain the water quality endpoints for TP in the Wissahickon Creek Watershed. Source allocations were developed for all modeled subwatersheds because they all contribute to the impaired streams in the Wissahickon Creek Watershed. Loading contributions were reduced from baseline conditions at all applicable sources until the TMDL water quality endpoints for TP were attained at the outlet of each subwatershed. The loading contributions from the upstream subwatershed were then routed through downstream water bodies. The simulated allocation period covered from April 1, 2005, through October 31, 2005.

5.2.1 Subwatershed Groupings

To effectively display the detailed source allocations associated with successful TMDL scenarios, the 118 modeled Wissahickon Creek subwatersheds were aggregated into 6 regions representing separate hydrologic units (Figure 5-1). The 6 regions provide a basis for georeferencing the source allocations, and are referred to as Allocation Groups.

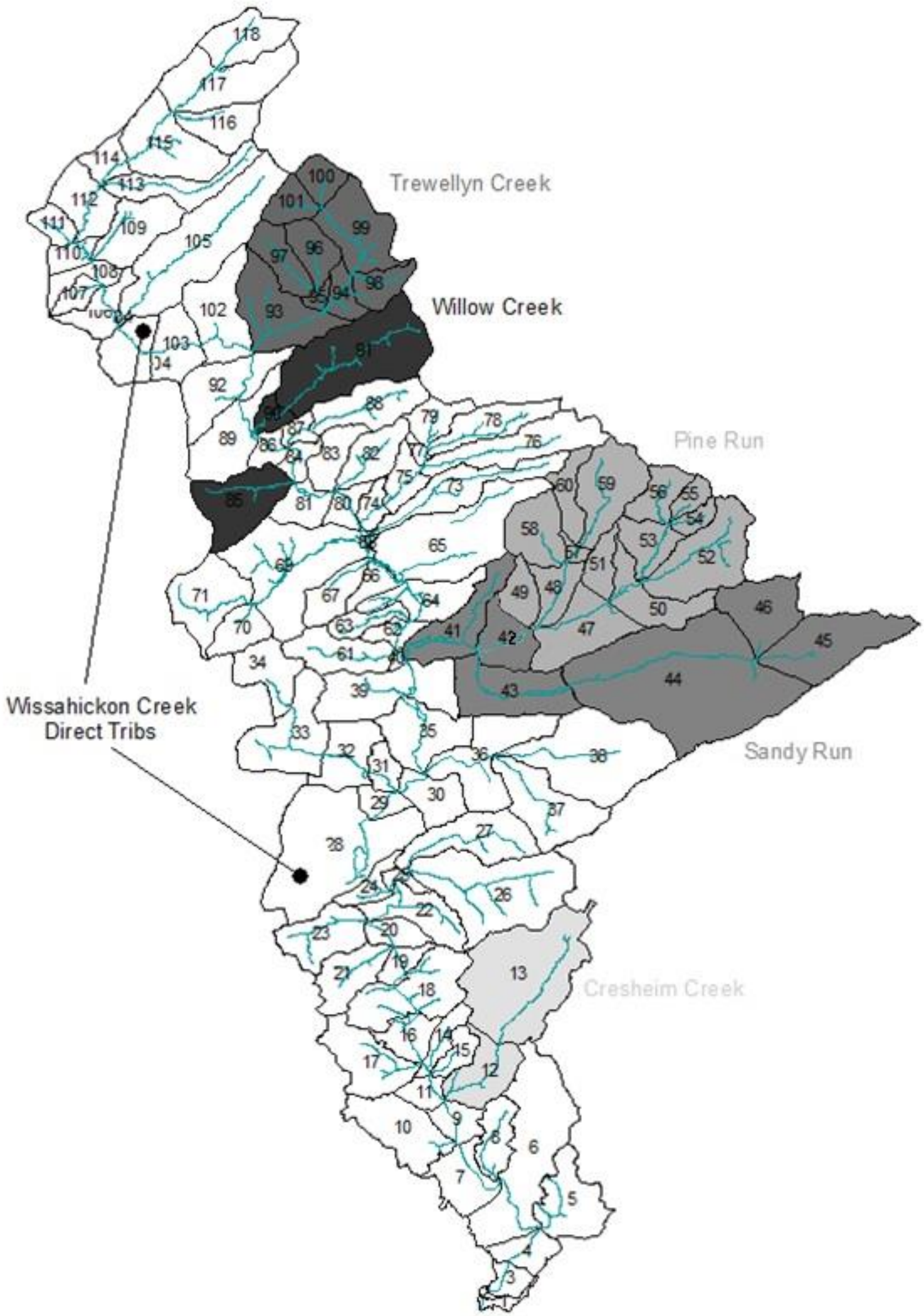

Figure 5-1. Wissahickon Creek Watershed broken up into Allocation Groups (shaded areas).

5.2.2 Allocation Process

The allocation process applied a top-down reduction methodology. This methodology entails a subwatershed by subwatershed application of TP reductions (starting with headwaters) to achieve the water quality endpoint for TP at the end of each subwatershed, until waters in all subwatersheds meet the TMDL endpoint. LSPC output for baseline conditions was compared directly with the phosphorus TMDL endpoints. If predicted phosphorus concentrations exceeded the TMDL endpoint in a given subwatershed, the phosphorus sources represented in LSPC required additional reductions.

The LSPC-EFDC linked modeling system represented all sources of phosphorus (e.g WWTPs, failed septic systems, stormwater contributions) so that allocations could be applied in the modeling environment. Existing sources of TP are shown in Figure 5-2 by Allocation Group, which are mapped in Figure 5-1. The total annual load is shown at the top of each column to illustrate the relative contributions from each Allocation Group. The watershed-wide distribution of TP sources is shown in the left-most bar ("Wissahickon Creek- All"). TP sources by tributary within the system are shown in the six remaining bars.

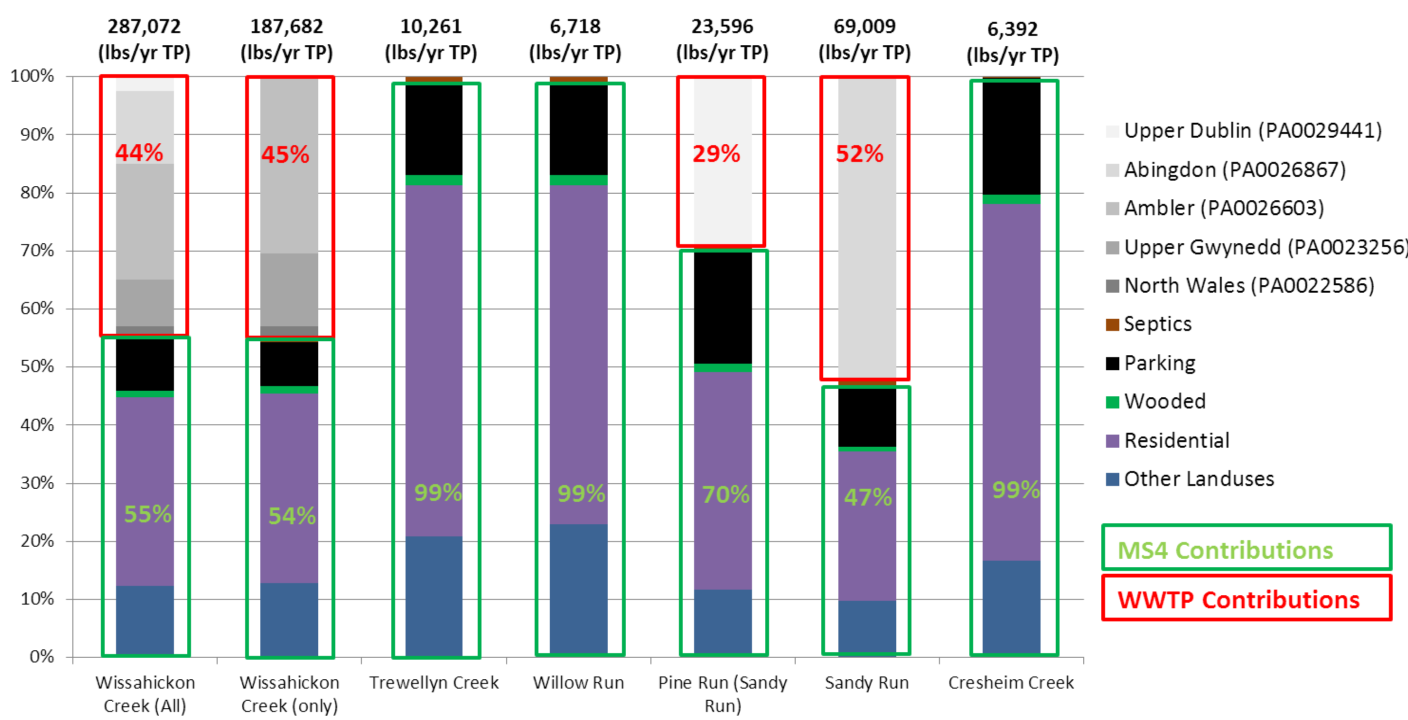

Figure 5-2. Distribution of existing TP loads by source and Allocation Group.

For the allocation process, the WWTP flows were increased to their effluent discharge rate (except North Wales WWTP– see Table 5-1), and all other sources were kept at the existing condition, which defines the "baseline condition." The baseline conditions were reduced in the modeling environment until the 40 μg/L TP endpoint was met at each of the outlets of the LSPC model, and in all segments of the EFDC model. Discrete LSPC sources (e.g land uses, septics) upstream of the interface locations were explicitly reduced between 46 and 98%.

Septic systems discharging directly to Wissahickon Creek were reduced uniformly by 88%, which is equivalent to the average reduction made to the aggregate tributary loads. The remaining reductions were applied to point sources, which ranged from 90 to over 99%.

It should be emphasized that although TP was the only pollutant reduced during the allocation process, other nutrients were simulated and calibrated during the model development process to ensure best possible representation of the watershed.

5.2.3 Load Allocations

Septic contributions to the overall nonpoint source load are not as significant as land surface loads, but represent the only component of the load allocation (LA) in Wissahickon Creek. Source-based LA reductions were achieved by iteratively reducing nonpoint source loads by subwatershed until phosphorus concentrations in that segment met the TMDL endpoints above. Table 5-2 shows the TP LAs by Allocation Group for the Wissahickon Creek Watershed.

Table 5-2. Annual TP LAs

Allocation Group	Wissahickon Creek Direct Tributaries TP LA	Cresheim Creek TP LA	Sandy Run TP LA	Willow Creek TP LA	Trewellyn Creek TP LA	Pine Run TP LA	Total TP LA
	lbs/year	lbs/year	lbs/year	lbs/year	lbs/year	lbs/year	lbs/year
Septics	161.86	2.13	67.33	11.03	14.67	17.68	274.69

5.2.4 Waste Load Allocations

Federal regulations (40 CFR 130.7) require TMDLs to include waste load allocations (WLAs) for each point source. There are two types of WLA included in the Wissahickon Creek Watershed TMDL: NPDES permitted point sources and the loads discharged from areas within the jurisdictions responsible for implementing MS4s in the watershed. The components of the WLA are summarized below.

WLA: MS4 Municipalities

EPA's stormwater permitting regulations require certain municipalities to obtain permit coverage for all stormwater discharges from urban MS4s. A November 12, 2010, EPA Memorandum (http://water.epa.gov/polwaste/npdes/stormwater/upload/sw_tmdlwla_comments.pdf) clarified existing regulatory requirements for MS4s connected with TMDLs. The key points are the following:

- NPDES-regulated MS4 discharges must be included in the WLA of the TMDL and may not be addressed by the LA component of the TMDL.
- The stormwater allotment can be a gross allotment and does not need to be apportioned to specific outfalls.

- Industrial stormwater permits need to reflect technology-based and water quality-based requirements.

In accordance with this memorandum, MS4s were treated as point sources for the TMDL and NPDES permitting purposes, and the phosphorus loading generated within the boundary of an MS4 area was assigned a WLA. Stormwater phosphorus loads in the MS4 regulated area are covered under the Phase II NPDES Stormwater Program. Runoff from urban areas during storm events can be a significant phosphorus source, delivering nutrients to the water body. EPA's stormwater permitting regulations require public entities to obtain NPDES permit coverage for stormwater discharges from MS4s in specified urbanized areas.

Because all of the municipalities with the Wissahickon watershed are MS4s, and because EPA was able to obtain only very limited data on the MS4 sewershed and MS4 discharge of TP, EPA represented the entire Wissahickon Creek Watershed as subject to MS4 permitting. See Section 3.1.2 above for more detailed discussion. Lacking sewershed maps of the MS4s, EPA based the boundaries of the MS4s on a GIS shapefile of municipal boundaries for Pennsylvania. To determine the loading associated with each MS4, the township boundary GIS layer was overlaid with the watershed boundaries, and EPA proportionally assigned the land-based WLA to each MS4 on the basis of area. Table 5-3 provides the aggregate TP WLAs for MS4s.

Table 5-3. Annual aggregate TP WLAs for MS4s.

MS4 Township	Total Area (acres)	Baseline TP Load (lbs/year)	Allocated TP WLA (lbs/year)	Percent Reduction (%)
ABINGTON	2296.92	9574.45	209.60	97.8
AMBLER	542.60	2707.77	79.37	97.1
CHELTENHAM	173.37	576.99	27.82	95.2
HORSHAM	68.56	563.86	15.28	97.3
LANSDALE	438.62	1912.30	26.03	98.6
LOWER GWYNEDD	5281.20	23505.76	1458.61	93.8
MONTGOMERY	987.08	5143.51	119.85	97.7
NORTH WALES	369.35	1639.47	27.01	98.4
PHILADELPHIA	6793.22	24799.61	2404.14	90.3
SPRINGFIELD	4123.43	15038.23	641.87	95.7
UPPER DUBLIN	7689.35	30535.65	1587.65	94.8
UPPER GWYNEDD	3196.09	12149.69	458.51	96.2
UPPER MORELAND	26.78	156.50	1.78	98.9
WHITEMARSH	5242.69	16595.84	1373.25	91.7
WHITPAIN	3339.29	12295.91	784.40	93.6
WORCESTER	62.54	314.64	9.82	96.9
Total MS4 WLA	**40631.09**	**157510.18**	**9224.99**	**94.1**

As discussed in Section 3.1.2, the entire watershed is within the MS4 political boundaries, and there are no additional lands beyond those political boundaries for characterization. Without the sewershed maps, EPA had no way to separate the nonpoint and point source discharges. Thus, for this modeling effort, all lands within the political boundaries were assumed to be within the MS4 jurisdiction. Therefore, all land surface loads are a designated component of the WLA. Table 5-4 shows the TP loading associated with the specific land uses for Wissahickon Creek Watershed (along with the area for each land use) and includes all lands inside the MS4 boundaries. EPA then determined the WLA for each MS4 by taking the sum of all the loadings for each land use land use category.

Table 5-4. Aggregate TP WLA for MS4s and component TP loadings by land use for all MS4s.

Modeled Landuse	Modeled Landuse Code	Summarized Group	Total Area (acres)	Baseline TP Load (lbs/year)	Allocated TP Load (lbs/year)	Percent Reduction (%)
Agriculture	AG_B	Ag	768.73	1130.94	46.99	95.8
Agriculture	AG_C	Ag	1939.61	4967.27	116.35	97.7
Commercial	COM_IMP	Impervious Developed	1307.99	1280.63	230.15	82.0
Community Services	COM_SER	Pervious Developed	1377.05	6969.14	161.68	97.7
Golf	GOLF	Golf	1482.15	2904.69	43.18	98.5
Light Industrial	IND_IMP	Impervious Developed	579.12	559.93	25.70	95.4
Mining	MINING	Pervious Developed	119.81	241.88	129.57	46.4
Parking: Agriculture	PK_AG	Pervious Developed	5.56	26.27	10.36	60.6
Parking: Community Services	PK_COMSER	Pervious Developed	646.68	1040.90	262.03	74.8
All other Parking	PK_IMP	Impervious Developed	574.86	24277.63	573.56	97.6
Recreation	REC_B	Pervious Developed	1058.53	3604.91	326.75	90.9
Recreation	REC_C	Pervious Developed	525.23	3585.32	185.15	94.8
Residential: Multi-family	RES_MUL	Residential	1994.15	13858.35	406.77	97.1
Residential: Row Home	RES_ROW	Residential	210.64	1468.62	103.47	93.0
Residential: Single_Family Detached	RES_SIN_B	Residential	14358.04	49313.23	932.29	98.1
Residential: Single_Family Detached	RES_SIN_C	Residential	4219.97	28798.41	495.94	98.3
Transportation	TRAN_IMP	Impervious Developed	512.09	499.16	182.22	63.5
Utility	UTL	Pervious Developed	333.94	1639.75	59.70	96.4
Vacant	VAC	Pervious Developed	1327.09	6627.30	217.27	96.7
Water	WATER	Background	303.34	1473.43	1473.43	0.0
Wooded	WOOD_B	Background	4364.72	1869.07	1869.07	0.0
Wooded	WOOD_C	Background	2621.79	1373.34	1373.34	0.0
Total Aggregate MS4 WLA			**40631.09**	**157510.17**	**9224.97**	**94.1**

The WLAs can be broken down in a similar way for individual MS4s. Figure 5-3 shows a map of land uses for the City of Philadelphia MS4 that are within the Wissahickon Creek Watershed. Table 5-5 shows the WLAs for each of those land uses. Appendix E provides the same information for the other fourteen MS4s located in the Wissahickon Creek Watershed.

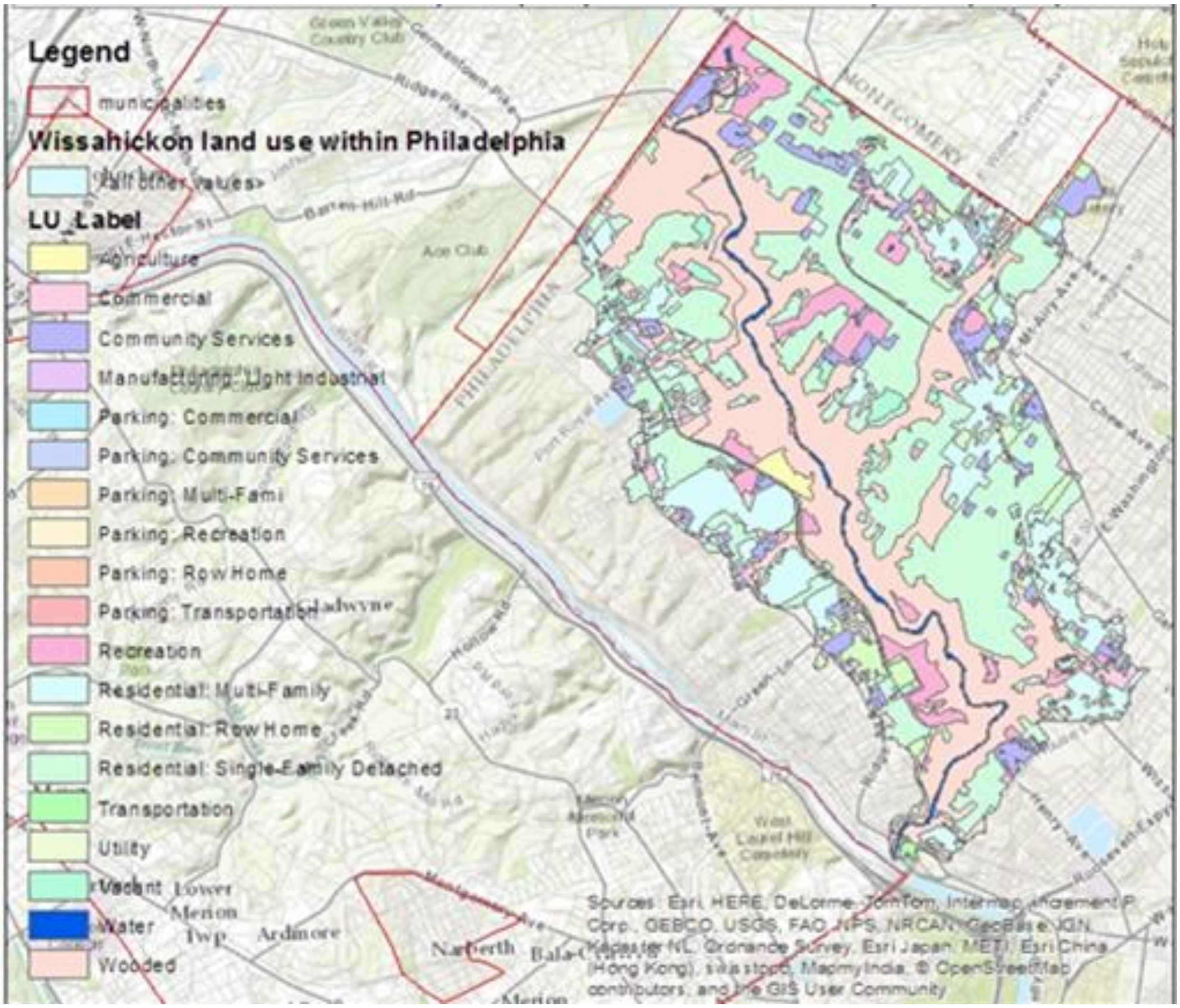

Figure 5-3. Land uses for the portion of the City of Philadelphia MS4 that lies within the Wissahickon Creek Watershed.

Table 5-5. Annual TP WLA and component TP loadings by land use for the portion of the City of Philadelphia MS4 that lies within the Wissahickon Creek Watershed.

Modeled Land Use: Philadelphia	Acres	Percent Area (%)	Summarized Group	Baseline TP Load (lbs/year)	Allocated TP Load (lbs/year)	Percent Reduction (%)
Agriculture	34.94	0.51	Agriculture	60.41	2.24	96.3
Residential: Multi-Family	897.70	13.22	Residential	15391.04	613.22	96.0
Residential: Row Home	185.41	2.73	Residential			
Residential: Single-Family Detached	2183.93	32.15	Residential			
Commercial	194.02	2.86	Impervious Developed	3964.41	209.53	94.7
Manufacturing: Light Industrial	1.47	0.02	Impervious Developed			
All other parking	155.74	2.29	Impervious Developed			
Transportation	42.66	0.63	Impervious Developed			
Recreation	378.05	5.57	Pervious Developed	4053.91	249.31	93.9
Parking: Community Services	47.89	0.70	Pervious Developed			
Community Services	328.10	4.83	Pervious Developed			
Utility	12.20	0.18	Pervious Developed			
Vacant	130.63	1.92	Pervious Developed			
Water	82.58	1.22	Background	1329.84	1329.84	0.0
Wooded	2117.47	31.17	Background			
Total Aggregate MS4 WLA for City of Philadelphia				**24799.61**	**2404.14**	**90.3**

WLA: Industrial and Private/Public Sewerage Permitted Facilities

For four of the selected NPDES permitted facilities in the Wissahickon Creek Watershed, the phosphorus WLAs were defined by the facilities' effluent discharge rate in 2005-2006, and loads were reduced to provide assimilative capacity for additional sources. The North Wales WWTP was characterized by observed DMR data for both flow and TP, as effluent discharge rate for the 2005-2006 time period was not available. Table 5-6 shows the baseline and TMDL concentrations and loads for each facility.

Table 5-6. Annual WWTP baseline conditions and allocations.

Permit	Facility	Baseline TP concentration (µg/L)	Allocated TP Concentration (µg/L)	Baseline TP Load (lbs/year)	Allocated TP WLA (lbs/year)	Percent Reduction (%)
PA0029441	Upper Dublin	2877.2	71.9	9634.00	171.47	98.2
PA0026867	Abington	3842.6	38.4	45734.00	361.45	99.2
PA0026603	Ambler	4099.3	57.4	81115.00	798.63	99.0
PA0023256	Upper Gwynedd	2726.7	32.7	47311.00	282.58	99.4
PA0022586	North Wales	2932.6	35.2	3976.08	47.71	98.8
Total WLA for WWTPs				**187770.08**	**1661.84**	**99.1**

For the other existing point sources which did not have NPDES phosphorus effluent limitations (including total phosphorus and orthophosphate), EPA determined that such facilities were not substantive sources of nutrients. EPA did not explicitly represent them in the modeling or allocation tables. The *de minimis* TP loading associated with such sources is contained in the background loading and accounted for in the model calibration and assumptions of the TMDL. The assumption of this TMDL for the *de minimis* point sources is that the loading does not exceed or increase from the 2005-2006 levels. A list of such point sources with *de minimis* discharges of TP appears in Appendix B.

5.3 Margin of Safety (MOS)

The MOS is the portion of the pollutant loading reserved to account for uncertainty in the TMDL development process, specifically to account for the uncertainty in the relationship between pollutant loads and the water quality of the receiving water body. The MOS may be implicit or explicit. This TMDL employs an implicit MOS due to conservative assumptions used in the modeling process.

For the Wissahickon Creek Watershed TMDL, an implicit MOS was based on several conservative assumptions. The allocation scenario that meets the TMDL target of 0.04 mg/L TP was developed so that the target is met at all modeled locations in the watershed. The EFDC model consists of 120 grid cells, with multiple cells representing each reach segment along the mainstem and tributaries of Wissahickon Creek. The allocation scenario was developed to meet the TMDL target at each cell that compose the tributaries. The high resolution of the allocation scenario requires a more stringent allocation result, as opposed to gross reductions for each tributary that do not consider that level of spatial resolution. In addition, several refinements were made to address comments received in the 2003 TMDL. These refinements include the simulation of the competition of multiple algal species, individual interactions with nutrients and substrate (e.g. flood scour effects), and other factors such as temperature and light availability (e.g. seasonal changes in tree canopy).

Furthermore, the models used to develop the TMDL were run continuously over a two year period. This means the TMDL takes into account high, low, and average flow conditions, thus providing a more accurate representation of loadings from both point and nonpoint sources.

5.4 Critical Conditions and Seasonal Variations

Federal regulations (40 CFR 130.7(c)(1)) require TMDLs to consider critical conditions for streamflow, loading, and water quality parameters. Critical conditions are the set of environmental conditions, which, if met, will ensure attainment of objectives for all other conditions. This is typically the period in which the impaired water body exhibits the most vulnerability. EPA selected the critical condition to be all flow conditions during the growing season (April 1 through October 31). Nonpoint source and MS4 loadings are typically precipitation-driven; thus, in-stream impacts can occur during wet weather in which storm events cause surface runoff to carry pollutants to water bodies. Under low-flow conditions, non-precipitation-driven point sources dominate phosphorus loading with their more constant flow and pollutant loading. Low flow conditions in Wissahickon Creek are critical where permitted discharges represent the majority of tributary flows. Figure 5-4 shows the distribution of TP loadings during low flow conditions in May 2005. WWTP contributions can clearly be seen as a significant source of phosphorus, and represent approximately 80% of the TP contributions to Wissahickon Creek during low flow conditions.

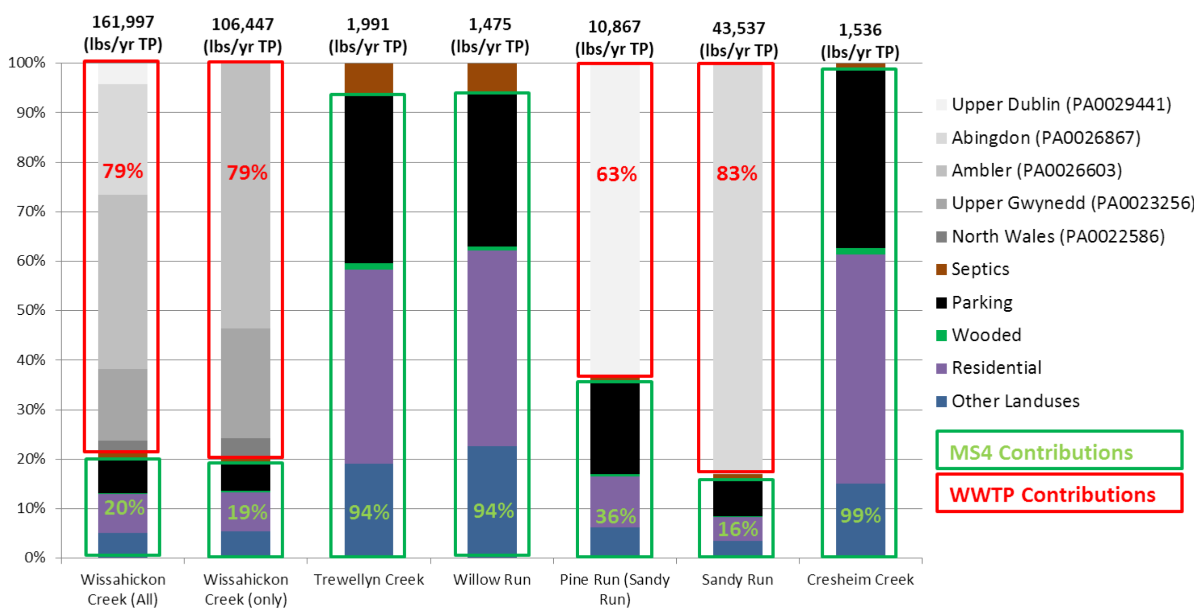

Figure 5-4. Distribution of TP loads by source and Allocation Group during low flow conditions in May 2005.

High concentrations of pollutants are also observed during wet conditions, when stormwater flows transport TP to the surface waters of Wissahickon Creek. The Wissahickon Creek Watershed TMDL adequately addresses critical conditions for flow through the use of a dynamic model and analysis of all flow conditions in the watershed.

The TMDL was developed using continuous simulation (modeling over a period of several years that captured precipitation extremes), which inherently considers seasonal hydrologic and source loading variability. The LSPC model simulates seasonal precipitation variability throughout the watershed as represented by the meteorological time-series used to drive the model covering a range of hydrologic conditions, including the critical conditions. Seasonal variation is also captured in the time variable simulation, which represents seasonal precipitation on a year-to-year basis.

5.5 TMDLs

As described in Section 5.3.1, the 118 modeled Wissahickon Creek subwatersheds were aggregated into 6 Allocation Groups representing separate hydrologic units (Figure 19): Wissahickon Creek and direct tributaries, Sandy Run, Cresheim Creek, Willow Creek, Trewellyn Creek, and Pine Run. The TMDLs were developed for each Allocation Group to provide more detailed source allocation information. The TMDLs are presented as annual loads, despite having a seasonal endpoint. This is because total phosphorus that enters the Wissahickon Creek and its tributaries during the non-growing season gets deposited into the sediment and can get reintroduced during the growing season. Tables 5-7 through 5-14 present the annual TMDLs for each of the Allocation Groups and the sum of all of the Allocation Groups. The annual loads were then divided by 365 to provide the average daily loads for each of the Allocation Groups. The average daily loads are presented in Tables 5-16 through 5-20.

Table 5-7. Annual TMDL loads for Wissahickon Creek and direct tributaries.

Source Group	Allocation Type	Source	Baseline TP Load (lbs/year)	Allocated TP Load (lbs/year)	Percent Reduction (%)
Point Sources: WWTP	WLA	Upper Dublin (PA0029441)	0.00	0.00	0.0
		Abington (PA0026867)	0.00	0.00	0.0
		Ambler (PA0026603)	81115.00	798.63	99.0
		Upper Gwynedd (PA0023256)	47311.00	282.58	99.4
		North Wales (PA0022586)	3976.08	47.71	98.8
Point Sources: MS4	WLA	Abington (PAG130012)	757.03	39.17	94.8
		Ambler (PAG130036)	2707.77	79.37	97.1
		Cheltenham (PAG130054)	576.99	27.82	95.2
		Horsham (PAG130157)	0.00	0.00	0.0
		Lansdale (PAG130038)	1912.30	26.03	98.6
		Lower Gwynedd (PAG130072)	9936.80	809.78	91.9
		Montgomery (PAG130016)	3882.06	85.05	97.8
		North Wales (PAG130005)	1639.47	27.01	98.4
		Philadelphia (PA0054712)	19846.40	2035.37	89.7
		Springfield (PAG130130)	13013.43	492.85	96.2
		Upper Dublin (PAG130075)	9675.10	583.18	94.0
		Upper Gwynedd (PAG130031)	12149.69	458.51	96.2
		Upper Moreland (PAG130019)	0.00	0.00	0.0
		Whitemarsh (PAG130103)	14744.90	1205.58	91.8
		Whitpain (PAG130137)	10900.98	693.92	93.6
		Worcester (PAG130026)	314.64	9.82	96.9
Nonpoint Sources	LA	Septics	1348.81	161.86	88.0
Total Point Sources: WWTP			**132402.08**	**1128.92**	**99.1**
Total Point Sources: MS4			**102057.56**	**6573.46**	**93.6**
Total Nonpoint Sources			**1348.81**	**161.86**	**88.0**
Total			**235808.45**	**7864.24**	**96.7**

Table 5-8. Annual TMDL loads for Sandy Run.

Source Group	Allocation Type	Source	Baseline TP Load (lbs/year)	Allocated TP Load (lbs/year)	Percent Reduction (%)
Point Sources: WWTP	WLA	Upper Dublin (PA0029441)	9634.00	171.47	98.2
		Abington (PA0026867)	45734.00	361.45	99.2
		Ambler (PA0026603)	0.00	0.00	0.0
		Upper Gwynedd (PA0023256)	0.00	0.00	0.0
		North Wales (PA0022586)	0.00	0.00	0.0
Point Sources: MS4	WLA	Abington (PAG130012)	8812.17	170.39	98.1
		Ambler (PAG130036)	0.00	0.00	0.0
		Cheltenham (PAG130054)	0.00	0.00	0.0
		Horsham (PAG130157)	0.00	0.00	0.0
		Lansdale (PAG130038)	0.00	0.00	0.0
		Lower Gwynedd (PAG130072)	0.00	0.00	0.0
		Montgomery (PAG130016)	0.00	0.00	0.0
		North Wales (PAG130005)	0.00	0.00	0.0
		Philadelphia (PA0054712)	0.00	0.00	0.0
		Springfield (PAG130130)	603.88	73.91	87.8
		Upper Dublin (PAG130075)	5417.20	242.32	95.5
		Upper Gwynedd (PAG130031)	0.00	0.00	0.0
		Upper Moreland (PAG130019)	75.45	0.97	98.7
		Whitemarsh (PAG130103)	1850.94	167.66	90.9
		Whitpain (PAG130137)	0.00	0.00	0.0
		Worcester (PAG130026)	0.00	0.00	0.0
Nonpoint Sources	LA	Septics	561.05	67.33	88.0
Total Point Sources: WWTP			**55368.00**	**532.92**	**99.0**
Total Point Sources: MS4			**16759.64**	**655.25**	**96.1**
Total Nonpoint Sources			**561.05**	**67.33**	**88.0**
Total			**72688.69**	**1255.50**	**98.3**

Table 5-9. Annual TMDL loads for Cresheim Creek.

Source Group	Allocation Type	Source	Baseline TP Load (lbs/year)	Allocated TP Load (lbs/year)	Percent Reduction (%)
Point Sources: WWTP	WLA	Upper Dublin (PA0029441)	0.00	0.00	0.0
		Abington (PA0026867)	0.00	0.00	0.0
		Ambler (PA0026603)	0.00	0.00	0.0
		Upper Gwynedd (PA0023256)	0.00	0.00	0.0
		North Wales (PA0022586)	0.00	0.00	0.0
Point Sources: MS4	WLA	Abington (PAG130012)	0.00	0.00	0.0
		Ambler (PAG130036)	0.00	0.00	0.0
		Cheltenham (PAG130054)	0.00	0.00	0.0
		Horsham (PAG130157)	0.00	0.00	0.0
		Lansdale (PAG130038)	0.00	0.00	0.0
		Lower Gwynedd (PAG130072)	0.00	0.00	0.0
		Montgomery (PAG130016)	0.00	0.00	0.0
		North Wales (PAG130005)	0.00	0.00	0.0
		Philadelphia (PA0054712)	4953.21	368.77	92.6
		Springfield (PAG130130)	1420.92	74.03	94.8
		Upper Dublin (PAG130075)	0.00	0.00	0.0
		Upper Gwynedd (PAG130031)	0.00	0.00	0.0
		Upper Moreland (PAG130019)	0.00	0.00	0.0
		Whitemarsh (PAG130103)	0.00	0.00	0.0
		Whitpain (PAG130137)	0.00	0.00	0.0
		Worcester (PAG130026)	0.00	0.00	0.0
Nonpoint Sources	LA	Septics	17.76	2.13	88.0
Total Point Sources: WWTP			**0.00**	**0.00**	**0.0**
Total Point Sources: MS4			**6374.13**	**442.80**	**93.1**
Total Nonpoint Sources			**17.76**	**2.13**	**88.0**
Total			**6391.89**	**444.93**	**93.0**

Table 5-10. Annual TMDL loads for Willow Creek.

Source Group	Allocation Type	Source	Baseline TP Load (lbs/year)	Allocated TP Load (lbs/year)	Percent Reduction (%)
Point Sources: WWTP	WLA	Upper Dublin (PA0029441)	0.00	0.00	0.0
		Abington (PA0026867)	0.00	0.00	0.0
		Ambler (PA0026603)	0.00	0.00	0.0
		Upper Gwynedd (PA0023256)	0.00	0.00	0.0
		North Wales (PA0022586)	0.00	0.00	0.0
Point Sources: MS4	WLA	Abington (PAG130012)	0.00	0.00	0.0
		Ambler (PAG130036)	0.00	0.00	0.0
		Cheltenham (PAG130054)	0.00	0.00	0.0
		Horsham (PAG130157)	0.00	0.00	0.0
		Lansdale (PAG130038)	0.00	0.00	0.0
		Lower Gwynedd (PAG130072)	5231.27	221.37	95.8
		Montgomery (PAG130016)	0.00	0.00	0.0
		North Wales (PAG130005)	0.00	0.00	0.0
		Philadelphia (PA0054712)	0.00	0.00	0.0
		Springfield (PAG130130)	0.00	0.00	0.0
		Upper Dublin (PAG130075)	0.00	0.00	0.0
		Upper Gwynedd (PAG130031)	0.00	0.00	0.0
		Upper Moreland (PAG130019)	0.00	0.00	0.0
		Whitemarsh (PAG130103)	0.00	0.00	0.0
		Whitpain (PAG130137)	1394.93	90.48	93.5
		Worcester (PAG130026)	0.00	0.00	0.0
Nonpoint Sources	LA	Septics	91.94	11.03	88.0
Total Point Sources: WWTP			**0.00**	**0.00**	**0.0**
Total Point Sources: MS4			**6626.20**	**311.85**	**95.3**
Total Nonpoint Sources			**91.94**	**11.03**	**88.0**
Total			**6718.14**	**322.88**	**95.2**

Table 5-11. Annual TMDL loads for Trewellyn Creek.

Source Group	Allocation Type	Source	Baseline TP Load (lbs/year)	Allocated TP Load (lbs/year)	Percent Reduction (%)
Point Sources: WWTP	WLA	Upper Dublin (PA0029441)	0.00	0.00	0.0
		Abington (PA0026867)	0.00	0.00	0.0
		Ambler (PA0026603)	0.00	0.00	0.0
		Upper Gwynedd (PA0023256)	0.00	0.00	0.0
		North Wales (PA0022586)	0.00	0.00	0.0
Point Sources: MS4	WLA	Abington (PAG130012)	0.00	0.00	0.0
		Ambler (PAG130036)	0.00	0.00	0.0
		Cheltenham (PAG130054)	0.00	0.00	0.0
		Horsham (PAG130157)	539.28	11.33	97.9
		Lansdale (PAG130038)	0.00	0.00	0.0
		Lower Gwynedd (PAG130072)	8337.69	427.47	94.9
		Montgomery (PAG130016)	1261.45	34.80	97.2
		North Wales (PAG130005)	0.00	0.00	0.0
		Philadelphia (PA0054712)	0.00	0.00	0.0
		Springfield (PAG130130)	0.00	0.00	0.0
		Upper Dublin (PAG130075)	0.00	0.00	0.0
		Upper Gwynedd (PAG130031)	0.00	0.00	0.0
		Upper Moreland (PAG130019)	0.00	0.00	0.0
		Whitemarsh (PAG130103)	0.00	0.00	0.0
		Whitpain (PAG130137)	0.00	0.00	0.0
		Worcester (PAG130026)	0.00	0.00	0.0
Nonpoint Sources	LA	Septics	122.24	14.67	88.0
Total Point Sources: WWTP			**0.00**	**0.00**	**0.0**
Total Point Sources: MS4			**10138.42**	**473.60**	**95.3**
Total Nonpoint Sources			**122.24**	**14.67**	**88.0**
Total			**10260.66**	**488.27**	**95.2**

Table 5-12. Annual TMDL load for Pine Run.

Source Group	Allocation Type	Source	Baseline TP Load (lbs/year)	Allocated TP Load (lbs/year)	Percent Reduction (%)
Point Sources: WWTP	WLA	Upper Dublin (PA0029441)	0.00	0.00	0.0
		Abington (PA0026867)	0.00	0.00	0.0
		Ambler (PA0026603)	0.00	0.00	0.0
		Upper Gwynedd (PA0023256)	0.00	0.00	0.0
		North Wales (PA0022586)	0.00	0.00	0.0
Point Sources: MS4	WLA	Abington (PAG130012)	5.24	0.05	99.0
		Ambler (PAG130036)	0.00	0.00	0.0
		Cheltenham (PAG130054)	0.00	0.00	0.0
		Horsham (PAG130157)	24.59	3.95	83.9
		Lansdale (PAG130038)	0.00	0.00	0.0
		Lower Gwynedd (PAG130072)	0.00	0.00	0.0
		Montgomery (PAG130016)	0.00	0.00	0.0
		North Wales (PAG130005)	0.00	0.00	0.0
		Philadelphia (PA0054712)	0.00	0.00	0.0
		Springfield (PAG130130)	0.00	0.00	0.0
		Upper Dublin (PAG130075)	15443.36	752.58	95.1
		Upper Gwynedd (PAG130031)	0.00	0.00	0.0
		Upper Moreland (PAG130019)	81.06	0.81	99.0
		Whitemarsh (PAG130103)	0.00	0.00	0.0
		Whitpain (PAG130137)	0.00	0.00	0.0
		Worcester (PAG130026)	0.00	0.00	0.0
Nonpoint Sources	LA	Septics	147.31	17.68	88.0
Total Point Sources: WWTP			**0.00**	**0.00**	**0.0**
Total Point Sources: MS4			**15554.25**	**757.39**	**95.1**
Total Nonpoint Sources			**147.31**	**17.68**	**88.0**
Total			**15701.56**	**775.07**	**95.1**

Table 5-13. Annual TMDL loads for Wissahickon Creek and all of its tributaries (all six Allocation Groups).

Source Group	Allocation Type	Source	Baseline TP Load (lbs/year)	Allocated TP Load (lbs/year)	Percent Reduction (%)
Point Sources: WWTP	WLA	Upper Dublin (PA0029441)	9634.00	171.47	98.2
		Abington (PA0026867)	45734.00	361.45	99.2
		Ambler (PA0026603)	81115.00	798.63	99.0
		Upper Gwynedd (PA0023256)	47311.00	282.58	99.4
		North Wales (PA0022586)	3976.08	47.71	98.8
Point Sources: MS4	WLA	Abington (PAG130012)	9574.45	209.60	97.8
		Ambler (PAG130036)	2707.77	79.37	97.1
		Cheltenham (PAG130054)	576.99	27.82	95.2
		Horsham (PAG130157)	563.86	15.28	97.3
		Lansdale (PAG130038)	1912.30	26.03	98.6
		Lower Gwynedd (PAG130072)	23505.76	1458.61	93.8
		Montgomery (PAG130016)	5143.51	119.85	97.7
		North Wales (PAG130005)	1639.47	27.01	98.4
		Philadelphia (PA0054712)	24799.61	2404.14	90.3
		Springfield (PAG130130)	15038.23	641.87	95.7
		Upper Dublin (PAG130075)	30535.65	1587.65	94.8
		Upper Gwynedd (PAG130031)	12149.69	458.51	96.2
		Upper Moreland (PAG130019)	156.50	1.78	98.9
		Whitemarsh (PAG130103)	16595.84	1373.25	91.7
		Whitpain (PAG130137)	12295.91	784.40	93.6
		Worcester (PAG130026)	314.64	9.82	96.9
Nonpoint Sources	LA	Septics	2289.11	274.69	88.0
Total Point Sources: WWTP			**187770.08**	**1661.84**	**99.1**
Total Point Sources: MS4			**157510.18**	**9224.99**	**94.1**
Total Nonpoint Sources			**2289.11**	**274.69**	**88.0**
Total			**347569.37**	**11161.52**	**96.8**

Table 5-14. Average daily TMDL loads for Wissahickon Creek and its direct tributaries.

Source Group	Allocation Type	Source	Baseline TP Load (lbs/day)	Allocated TP Load (lbs/day)	Percent Reduction (%)
Point Sources: WWTP	WLA	Upper Dublin (PA0029441)	0.00	0.00	0.0
		Abington (PA0026867)	0.00	0.00	0.0
		Ambler (PA0026603)	222.23	2.19	99.0
		Upper Gwynedd (PA0023256)	129.62	0.77	99.4
		North Wales (PA002586)	10.89	0.13	98.8
Point Sources: MS4	WLA	Abington (PAG130012)	2.07	0.11	94.8
		Ambler (PAG130036)	7.42	0.22	97.1
		Cheltenham (PAG130054)	1.58	0.08	95.2
		Horsham (PAG130157)	0.00	0.00	0.0
		Lansdale (PAG130038)	5.24	0.07	98.6
		Lower Gwynedd (PAG130072)	27.22	2.22	91.9
		Montgomery (PAG130016)	10.64	0.23	97.8
		North Wales (PAG130005)	4.49	0.07	98.4
		Philadelphia (PA0054712)	54.37	5.58	89.7
		Springfield (PAG130130)	35.65	1.35	96.2
		Upper Dublin (PAG130075)	26.51	1.60	94.0
		Upper Gwynedd (PAG130031)	33.29	1.26	96.2
		Upper Moreland (PAG130019)	0.00	0.00	0.0
		Whitemarsh (PAG130103)	40.40	3.30	91.8
		Whitpain (PAG130137)	29.87	1.90	93.6
		Worcester (PAG130026)	0.86	0.03	96.9
Nonpoint Sources	LA	Septics	3.70	0.44	88.0
Total Point Sources: WWTP			**362.75**	**3.09**	**99.1**
Total Point Sources: MS4			**279.61**	**18.01**	**93.4**
Total Nonpoint Sources			**3.70**	**0.44**	**88.0**
Total			**646.05**	**21.55**	**96.7**

Table 5-15. Average daily TMDL loads for Sandy Run.

Source Group	Allocation Type	Source	Baseline TP Load (lbs/day)	Allocated TP Load (lbs/day)	Percent Reduction (%)
Point Sources: WWTP	WLA	Upper Dublin (PA0029441)	26.39	0.47	0.0
		Abington (PA0026867)	125.30	0.99	99.2
		Ambler (PA0026603)	0.00	0.00	0.0
		Upper Gwynedd (PA0023256)	0.00	0.00	0.0
		North Wales (PA0022586)	0.00	0.00	0.0
Point Sources: MS4	WLA	Abington (PAG130012)	24.14	0.47	98.1
		Ambler (PAG130036)	0.00	0.00	0.0
		Cheltenham (PAG130054)	0.00	0.00	0.0
		Horsham (PAG130157)	0.00	0.00	0.0
		Lansdale (PAG130038)	0.00	0.00	0.0
		Lower Gwynedd (PAG130072)	0.00	0.00	0.0
		Montgomery (PAG130016)	0.00	0.00	0.0
		North Wales (PAG130005)	0.00	0.00	0.0
		Philadelphia (PA0054712)	0.00	0.00	0.0
		Springfield (PAG130130)	1.65	0.21	87.8
		Upper Dublin (PAG130075)	14.84	0.66	95.5
		Upper Gwynedd (PAG130031)	0.00	0.00	0.0
		Upper Moreland (PAG130019)	0.21	0.003	98.7
		Whitemarsh (PAG130103)	5.07	0.46	90.9
		Whitpain (PAG130137)	0.00	0.00	0.0
		Worcester (PAG130026)	0.00	0.00	0.0
Nonpoint Sources	LA	Septics	1.54	0.18	88.0
Total Point Sources: WWTP			**151.69**	**1.46**	**99.0**
Total Point Sources: MS4			**45.9**	**1.80**	**96.1**
Total Nonpoint Sources			**1.54**	**0.18**	**88.0**
Total			**199.15**	**3.43**	**98.3**

Table 5-16. Average daily TMDL loads for Cresheim Creek.

Source Group	Allocation Type	Source	Baseline TP Load (lbs/day)	Allocated TP Load (lbs/day)	Percent Reduction (%)
Point Sources: WWTP	WLA	Upper Dublin (PA0029441)	0.00	0.00	0.0
		Abington (PA0026867)	0.00	0.00	0.0
		Ambler (PA0026603)	0.00	0.00	0.0
		Upper Gwynedd (PA0023256)	0.00	0.00	0.0
		North Wales (PA0022586)	0.00	0.00	0.0
Point Sources: MS4	WLA	Abington (PAG130012)	0.00	0.00	0.0
		Ambler (PAG130036)	0.00	0.00	0.0
		Cheltenham (PAG130054)	0.00	0.00	0.0
		Horsham (PAG130157)	0.00	0.00	0.0
		Lansdale (PAG130038)	0.00	0.00	0.0
		Lower Gwynedd (PAG130072)	0.00	0.00	0.0
		Montgomery (PAG130016)	0.00	0.00	0.0
		North Wales (PAG130005)	0.00	0.00	0.0
		Philadelphia (PA0054712)	13.57	1.01	92.6
		Springfield (PAG130130)	3.89	0.20	94.8
		Upper Dublin (PAG130075)	0.00	0.00	0.0
		Upper Gwynedd (PAG130031)	0.00	0.00	0.0
		Upper Moreland (PAG130019)	0.00	0.00	0.0
		Whitemarsh (PAG130103)	0.00	0.00	0.0
		Whitpain (PAG130137)	0.00	0.00	0.0
		Worcester (PAG130026)	0.00	0.00	0.0
Nonpoint Sources	LA	Septics	0.05	0.01	88.0
Total Point Sources: WWTP			**0.00**	**0.00**	**0.0**
Total Point Sources: MS4			**17.46**	**1.21**	**93.1**
Total Nonpoint Sources			**0.05**	**0.01**	**88.0**
Total			**17.51**	**1.22**	**93.0**

Table 5-17. Average daily TMDL loads for Willow Creek.

Source Group	Allocation Type	Source	Baseline TP Load (lbs/day)	Allocated TP Load (lbs/day)	Percent Reduction (%)
Point Sources: WWTP	WLA	Upper Dublin (PA0029441)	0.00	0.00	0.0
		Abington (PA0026867)	0.00	0.00	0.0
		Ambler (PA0026603)	0.00	0.00	0.0
		Upper Gwynedd (PA0023256)	0.00	0.00	0.0
		North Wales (PA0022586)	0.00	0.00	0.0
Point Sources: MS4	WLA	Abington (PAG130012)	0.00	0.00	0.0
		Ambler (PAG130036)	0.00	0.00	0.0
		Cheltenham (PAG130054)	0.00	0.00	0.0
		Horsham (PAG130157)	0.00	0.00	0.0
		Lansdale (PAG130038)	0.00	0.00	0.0
		Lower Gwynedd (PAG130072)	14.33	0.61	95.8
		Montgomery (PAG130016)	0.00	0.00	0.0
		North Wales (PAG130005)	0.00	0.00	0.0
		Philadelphia (PA0054712)	0.00	0.00	0.0
		Springfield (PAG130130)	0.00	0.00	0.0
		Upper Dublin (PAG130075)	0.00	0.00	0.0
		Upper Gwynedd (PAG130031)	0.00	0.00	0.0
		Upper Moreland (PAG130019)	0.00	0.00	0.0
		Whitemarsh (PAG130103)	0.00	0.00	0.0
		Whitpain (PAG130137)	3.82	0.25	93.5
		Worcester (PAG130026)	0.00	0.00	0.0
Nonpoint Sources	LA	Septics	0.25	0.03	88.0
Total Point Sources: WWTP			**0.00**	**0.00**	**0.0**
Total Point Sources: MS4			**18.15**	**0.85**	**95.3**
Total Nonpoint Sources			**0.25**	**0.03**	**88.0**
Total			**18.41**	**0.88**	**95.2**

Table 5-18. Average daily TMDL loads for Trewellyn Creek.

Source Group	Allocation Type	Source	Baseline TP Load (lbs/day)	Allocated TP Load (lbs/day)	Percent Reduction (%)
Point Sources: WWTP	WLA	Upper Dublin (PA0029441)	0.00	0.00	0.0
		Abington (PA0026867)	0.00	0.00	0.0
		Ambler (PA0026603)	0.00	0.00	0.0
		Upper Gwynedd (PA0023256)	0.00	0.00	0.0
		North Wales (PA0022586)	0.00	0.00	0.0
Point Sources: MS4	WLA	Abington (PAG130012)	0.00	0.00	0.0
		Ambler (PAG130036)	0.00	0.00	0.0
		Cheltenham (PAG130054)	0.00	0.00	0.0
		Horsham (PAG130157)	1.48	0.03	97.9
		Lansdale (PAG130038)	0.00	0.00	0.0
		Lower Gwynedd (PAG130072)	22.84	1.17	94.9
		Montgomery (PAG130016)	3.46	0.10	97.2
		North Wales (PAG130005)	0.00	0.00	0.0
		Philadelphia (PA0054712)	0.00	0.00	0.0
		Springfield (PAG130130)	0.00	0.00	0.0
		Upper Dublin (PAG130075)	0.00	0.00	0.0
		Upper Gwynedd (PAG130031)	0.00	0.00	0.0
		Upper Moreland (PAG130019)	0.00	0.00	0.0
		Whitemarsh (PAG130103)	0.00	0.00	0.0
		Whitpain (PAG130137)	0.00	0.00	0.0
		Worcester (PAG130026)	0.00	0.00	0.0
Nonpoint Sources	LA	Septics	0.33	0.04	88.0
Total Point Sources: WWTP			**0.00**	**0.00**	**0.0**
Total Point Sources: MS4			**27.78**	**1.30**	**95.3**
Total Nonpoint Sources			**0.33**	**0.04**	**88.0**
Total			**28.11**	**1.34**	**95.2**

Table 5-19. Average daily TMDL loads for Pine Run.

Source Group	Allocation Type	Source	Baseline TP Load (lbs/day)	Allocated TP Load (lbs/day)	Percent Reduction (%)
Point Sources: WWTP	WLA	Upper Dublin (PA0029441)	0.00	0.00	0.0
		Abington (PA0026867)	0.00	0.00	0.0
		Ambler (PA0026603)	0.00	0.00	0.0
		Upper Gwynedd (PA0023256)	0.00	0.00	0.0
		North Wales (PA0022586)	0.00	0.00	0.0
Point Sources: MS4	WLA	Abington (PAG130012)	0.01	0.0001	99.0
		Ambler (PAG130036)	0.00	0.00	0.0
		Cheltenham (PAG130054)	0.00	0.00	0.0
		Horsham (PAG130157)	0.07	0.01	83.9
		Lansdale (PAG130038)	0.00	0.00	0.0
		Lower Gwynedd (PAG130072)	0.00	0.00	0.0
		Montgomery (PAG130016)	0.00	0.00	0.0
		North Wales (PAG130005)	0.00	0.00	0.0
		Philadelphia (PA0054712)	0.00	0.00	0.0
		Springfield (PAG130130)	0.00	0.00	0.0
		Upper Dublin (PAG130075)	42.31	2.06	95.0
		Upper Gwynedd (PAG130031)	0.00	0.00	0.0
		Upper Moreland (PAG130019)	0.22	0.002	99.0
		Whitemarsh (PAG130103)	0.00	0.00	92.8
		Whitpain (PAG130137)	0.00	0.00	0.0
		Worcester (PAG130026)	0.00	0.00	0.0
Nonpoint Sources	LA	Septics	0.40	0.05	88.0
Total Point Sources: WWTP			**0.00**	**0.00**	**0.0**
Total Point Sources: MS4			**42.61**	**2.08**	**95.1**
Total Nonpoint Sources			**0.40**	**0.05**	**88.0**
Total			**43.02**	**2.12**	**95.1**

Table 5-20. Average daily TMDL loads for Wissahickon Creek and all of its tributaries (all six Allocation Groups).

Source Group	Allocation Type	Source	Baseline TP Load (lbs/day)	Allocated TP Load (lbs/day)	Percent Reduction (%)
Point Sources: WWTP	WLA	Upper Dublin (PA0029441)	26.39	0.47	98.2
		Abington (PA0026867)	125.30	0.99	99.2
		Ambler (PA0026603)	222.23	2.19	99.0
		Upper Gwynedd (PA0023256)	129.62	0.77	99.4
		North Wales (PA0022586)	10.89	0.13	98.8
Point Sources: MS4	WLA	Abington (PAG130012)	26.23	0.57	97.8
		Ambler (PAG130036)	7.42	0.22	97.1
		Cheltenham (PAG130054)	1.58	0.08	95.2
		Horsham (PAG130157)	1.54	0.04	97.3
		Lansdale (PAG130038)	5.24	0.07	98.6
		Lower Gwynedd (PAG130072)	64.40	4.00	93.8
		Montgomery (PAG130016)	14.09	0.33	97.7
		North Wales (PAG130005)	4.49	0.07	98.4
		Philadelphia (PA0054712)	67.94	6.59	90.3
		Springfield (PAG130130)	41.20	1.76	95.7
		Upper Dublin (PAG130075)	83.66	4.35	94.8
		Upper Gwynedd (PAG130031)	33.29	1.26	96.2
		Upper Moreland (PAG130019)	0.43	0.01	98.9
		Whitemarsh (PAG130103)	45.47	3.76	91.7
		Whitpain (PAG130137)	33.69	2.15	93.6
		Worcester (PAG130026)	0.86	0.03	96.9
Nonpoint Sources	LA	Septics	6.27	0.75	88.0
Total Point Sources: WWTP			**514.44**	**4.55**	**99.1**
Total Point Sources: MS4			**431.53**	**25.27**	**94.1**
Total Nonpoint Sources			**6.27**	**0.75**	**88.0**
Total			**952.24**	**30.58**	**96.8**

5.6 Future TMDL Modifications and Growth

EPA has established the Wissahickon TMDL, including its component WLAs, LAs, and implicit MOS, based on the applicable WQS and the totality of the information available concerning water quality and hydrology, and present and anticipated pollutant sources and loadings. EPA recognizes, however, that neither the world at large, nor the watershed, is static. In a dynamic environment, change is inevitable. Much change can be generated during TMDL implementation and could include new monitoring data, installation of best management practices (BMPs) and land use changes.

It is possible to accommodate some of those changes in the existing TMDL without the need to revise it in whole, or in part. For example, EPA's permitting regulations at 122.44(d)(1)(vii)(B) require that permit WQBELs be "consistent with the assumptions and requirements of any available wasteload allocation for the discharge" in the TMDL. As the EPA Environmental Appeals Board has recognized, "WLAs are not permit limits per se; rather they still require translation into permit limits." *In re City of Moscow*, NPDES Appeal No. 00-10 (July 27, 2001). In providing such translation, the Environmental Appeals Board said that "[w]hile the governing regulations require consistency, they do not require that the permit limitations that will finally be adopted in a final NPDES permit be identical to any of the WLAs that may be provided in a TMDL." Id. Accordingly, depending on the facts of a situation, Pennsylvania may write a permit limit that is consistent with (but not identical to) a given WLA without revising that WLA (either increasing or decreasing a specific WLA), provided the permit limit is consistent with the operative *assumptions* (e.g., about the applicable WQS, the sum of the delivered point source loads, the sufficiency of reasonable assurance) that informed the decision to establish that particular WLA. It is an assumption of this TMDL that any new or expanded wastewater treatment plant could discharge into the watershed at 40 μg/L end of pipe without a TMDL revision.

There might, however, be circumstances with the degree to which a permit limit might deviate from a WLA in the TMDL such that one or more WLAs and LAs in the TMDL would need to be revised. In such cases, it might be appropriate for EPA to revise the TMDL (or portions of it). EPA would consider a request made by the public or PADEP to revise the TMDL. Alternatively, PADEP could propose to revise a portion(s) of the TMDL (including specific WLAs and LAs) and submit those revisions to EPA for approval. A proposed WLA can be made available for public comment concurrent with the associated permits revision/reissuance public notice. If EPA approved any such revisions, those revisions would replace their respective parts in the EPA-established TMDL. In approving any such revisions or in making its own revisions, EPA would ensure that the revisions themselves met all the statutory and regulatory requirements for TMDL approval and did not result in any component of the original TMDL not meeting applicable WQS.

6. Reasonable Assurance for TMDL Implementation

When a TMDL is developed for waters impaired by both point and nonpoint sources, and the WLA is based on an assumption that nonpoint source load reductions will occur, the TMDL must provide reasonable assurances that nonpoint source control measures will achieve the expected load reductions. For point sources, such as MS4s and WWTPs, it is expected that the TMDL will be implemented through the NPDES program. NPDES permits must be consistent with the assumptions and requirements of the WLAs in the TMDL.

The Wissahickon Creek Watershed TMDL does not direct or require implementation of any specific set of actions or selection of controls. It is expected that the TMDL will be implemented through a variety of regulatory and non-regulatory programs operating under federal, state, and local law. Implementation may occur through a staged approach using a variety of tools, such as compliance schedules, permit requirements, and/or monitoring towards progress. EPA is sensitive to the fact that the WLAs set forth in this TMDL may take time to achieve. It may also be appropriate to set priorities in order to secure larger reductions early on, recognizing that final compliance by all permittees may take some time. PADEP has already initiated discussions with stakeholders regarding a watershed-wide collaborative effort to develop a plan for restoring water quality in the Wissahickon Creek Watershed. EPA looks forward to engaging PADEP, the public, and stakeholders in further developing an appropriate implementation framework.

The issuance of NPDES permits provides the reasonable assurance that the WLAs assigned to point sources in the Wissahickon Creek Watershed TMDL will be achieved. This is because 40 CFR 122.44(d)(1)(vii)(B) requires that effluent limits in permits be consistent with “the assumptions and requirements of any available wasteload allocation” in an EPA-approved TMDL. Furthermore, EPA has the authority to object to the issuance of an NPDES permit that is inconsistent with WLAs established for that point source.

Further reasonable assurance for the achievement of the MS4 WLA reductions comes from a variety of state and local watershed implementation plans already in place. PWD’s Green City, Clean Waters initiative is investing over $2 billion to protect and enhance Philadelphia’s surrounding watersheds by managing stormwater with green infrastructure. An Act 167 stormwater management plan, developed by several local entities, aims to improve water quality in the Wissahickon Creek Watershed through the use of stormwater control measures. The William Penn Foundation awarded Friends of the Wissahickon, a non-profit organization, $440,000 to increase watershed protection through reduced stormwater runoff, public education and outreach, and volunteer maintenance activities.

The implementation of pollutant reductions from nonpoint sources (LA) relies heavily on incentive-based programs. Pennsylvania has a number of funding programs in place to ensure that the LAs assigned to nonpoint sources in the Wissahickon Creek Watershed TMDL can be achieved. Some of the potential sources of funding for LA implementation are EPA’s Section 319 funds, Pennsylvania’s State Revolving Loan Program (also available for permitted activities), and landowner contributions.

PADEP provides technical assistance on the operation and maintenance of septic systems. Financial assistance is available to home owners with failing septic systems through low-interest loans and grants. EPA has determined that these programs provide sufficient reasonable assurance to achieve the necessary load reductions.

7. PUBLIC PARTICIPATION

Public participation is a necessary step in the TMDL development process. Each state must provide for public participation consistent with its own continuing planning process and public participation requirements. However, EPA is establishing this TP TMDL upon the request made by PADEP. When EPA establishes a TMDL, EPA regulations require EPA to publish a notice seeking public comment pursuant to 40 C.F.R. §130.7(d)(2). EPA believes there should be full and meaningful public participation in the TMDL development process. This section describes the public participation for this TMDL development process.

To date, EPA has held three informational meetings during the course of the TMDL development process. On July 10, 2012, EPA held its first public meeting to discuss revisions to the 2003 nutrient TMDL for the Wissahickon Creek Watershed. The meeting was held at the Upper Gwynedd Township building in North Wales, Pennsylvania. On July 25, 2012, EPA presented stakeholders with the selected TMDL endpoint and methodology used to derive the endpoint, as well as the models used to develop the TMDL. The meeting was held at the EPA Region III office in Philadelphia, Pennsylvania. The third meeting was held on November 14, 2014 at PADEP's Southeast Regional office in Norristown, Pennsylvania. EPA provided stakeholders with updates on the progress of the TMDL and discussed the models used to develop the TMDL.

This section of the document will be updated prior to finalization to reflect the public participation during the public comment period. The public notice follows on the next page.

PUBLIC NOTICE

EPA Proposes Total Phosphorus TMDL for the Wissahickon Creek Watershed—Notice of Availability, Solicitation of Public Comment

The U.S. Environmental Protection Agency, Region III (EPA) plans to establish a Total Maximum Daily Load (TMDL) for total phosphorus in the Wissahickon Creek Watershed. The TMDL will establish reductions necessary to address the poor stream health caused by excessive total phosphorus from wastewater treatment plants, stormwater runoff, and other sources. The Wissahickon Creek drains approximately 64 square miles in Montgomery and Philadelphia Counties in Pennsylvania. Major tributaries of Wissahickon Creek include Cresheim Creek, Sandy Run, Willow Creek, Trewellyn Creek, and Pine Run. Municipalities impacted by this action include Abington, Ambler, Cheltenham, Horsham, Lansdale, Lower Gwynedd, Montgomery, North Wales, Philadelphia, Springfield, Upper Dublin, Upper Gwynedd, Upper Moreland, Whitemarsh, Whitpain, and Worcester.

EPA welcomes input from the public and interested parties regarding the proposed TMDL. A draft of the *Total Phosphorus TMDL for the Wissahickon Creek Watershed, Pennsylvania* is available on EPA's website at http://www.epa.gov/reg3wapd/tmdl/. Hard copies of the draft TMDL report can also be requested. Please direct questions to Ms. Ashley Toy at (215) 814-2774 or toy.ashley@epa.gov. Written comments will be accepted through July 4, 2015. *The end of the comment period falls on a holiday, so all comments postmarked by the following business day, July 6, 2015, will be accepted.* All written comments should be sent to Ms. Lenka Berlin (contact information below). Please reference "Wissahickon Creek TMDL" on all submitted comments.

Ms. Lenka Berlin
US EPA Region III, 3WP30
1650 Arch Street
Philadelphia, PA 19103
berlin.lenka@epa.gov

EPA will hold a public meeting to present the details and answer questions regarding the proposed TMDL on June 10, 2015 at 7:00 pm. The meeting will be held at Temple University Ambler Campus, Ambler Learning Center Room 202, 580 Meetinghouse Road, Ambler, PA 19002.

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