Long Term 2 Enhanced Surface Water Treatment Rule Watershed Control Plan Update

For the Queen Lane and Baxter Drinking Water Treatment Plant Intakes on the Schuylkill and Delaware Rivers, in Philadelphia, PA

Philadelphia Water Department Office of Watersheds October 2020

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Philadelphia Water Department

Office of Watersheds | Source Water Protection Program

1101 Market Street, 4th FL

Philadelphia, PA 19107

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Executive Summary

Introduction and Objective

The Philadelphia Water Department's Source Water Protection Program is a multi-faceted program that is primarily responsible for ensuring the safety and quality of Philadelphia's drinking water. A critical component of the program's mission is to fulfill all source water protection regulatory requirements. On January 5th, 2006, the EPA promulgated the first drinking water regulation based on source water quality under the Long Term 2 Enhanced Surface Water Treatment Rule (LT2). The LT2 serves as a series of amendments to the Safe Drinking Water Act and aims to protect public health from illness due to *Cryptosporidium* and other microbial pathogens in drinking water.

A bin classification system forms the basis of the EPA's risk-targeted approach to reducing *Cryptosporidium* in drinking water sources. Filtered public water systems (PWSs) are classified in one of four bins based on results from a two-year-long source water monitoring program. PWD's three drinking water treatment plants have been monitoring for *Cryptosporidium* in conjunction with the LT2 since 2001. Based on the results from the Round 1 monitoring, the Baxter and Belmont intakes were classified as Bin 1, which required no additional treatment. Results from the Queen Lane intake, however, indicated a slightly higher average oocyst concentration and resulted in Bin 2 classification. Conventional treatment plants, such as Queen Lane, that are placed in Bin 2 require an additional 1-log treatment credit. To achieve this credit, PWD implemented two treatment performance options for combined filter effluent (CFE) and individual filter effluent (IFE), which in combination will achieve 1-log removal. To ensure compliance with the regulation, PWD also chose to develop a Watershed Control Plan (WCP) to achieve an additional 0.5-log backup treatment credit. The WCP achieved the planned watershed load reductions in the initial 5-year implementation timeline.

From April 2015 through March 2017, LT2 Round 2 monitoring occurred. Results from this sampling period classified the Queen Lane WTP as Bin 1. However, the ongoing initiatives outlined in the plan as well as annual status reporting and triennial Watershed Sanitary Survey updates are being continued to maintain the 0.5-log backup treatment credit. PWD results from Round 2 sampling reclassified the Baxter Water Treatment Plant on the Delaware River as a Bin 2 facility. PWD treatment is selecting the same IFE and CFE filter performance options as selected for the Queen Lane WTP for an additional 1-log treatment credit. Additionally, this document expands ongoing WCP for the Queen Lane Intake to include priority areas influencing the Baxter intake to achieve a 0.5-log backup credit to ensure Baxter's compliance with LT2 regulation.

Scope of Work

To fulfill the EPA's requirements for a WCP, PWD must designate an area of influence, which is defined as the area outside of which the likelihood of *Cryptosporidium* contamination affecting the treatment plant intake is not significant. PWD has designated the entire Schuylkill River watershed as the area of influence due to several factors, including the extended survival of

Cryptosporidium oocysts, the pathogen's potential to travel long distances downstream before significant die-off, the high degree of removal required by drinking water treatment, and *Cryptosporidium's* extremely low infectious doses.

Different planning considerations warranted a slightly different approach to define the area of influence for the Baxter intake. The Delaware River Watershed is greater than 13,000 square miles, extending over four states, 42 counties, and 838 municipalities. As a result, a watershed-scale WCP presents clear logistical challenges for data collection and project implementation. To mitigate these limitations, specific target areas of the Delaware River Watershed are selected for incorporation into the combined area of influence to expand the geographic scope of the WCP.

The Schuylkill Watershed remains the area of influence for the Queen Lane intake. The Baxter intake's area of influence includes the Lehigh sub-basin as well as the Pennsylvania sides of the Upper Estuary, Lower Central, and Upper Central sub-basins of the Delaware River Basin. Designating the entire Schuylkill River watershed and the middle and lower regions of the Delaware River Basin as the combined area of influence presents many challenges regarding *Cryptosporidium* source prioritization and the implementation of watershed control plan measures.

The WCP is composed of the following elements, which aim to address these watershed-wide challenges and identify feasible action items for reducing *Cryptosporidium* contamination:

- identification of potential and actual sources of *Cryptosporidium* within the area of influence;
- an analysis of control measures to mitigate sources of *Cryptosporidium*;
- a vulnerability assessment for high priority sources of *Cryptosporidium*;
- a statement of goals and specific actions that PWD will undertake to reduce source water vulnerability to *Cryptosporidium* contamination and a description of how actions are expected to contribute to specific goals;
- identification of partners and their roles, PWD's resource requirements and commitments, and a schedule for plan implementation; and,
- a means by which to maintain the 0.5 log removal credit that will include submittal of an annual status report to the PADEP.

PWD's extensive Source Water Protection Program forms the basis for the LT2 Watershed Control Plan Program. The plan's scope encompasses a series of ongoing, proposed, and future initiatives to address priority sources of *Cryptosporidium* in the watershed. Initiatives to be included in the plan implementation process fall into one of four categories: wastewater dischargers and compliance, agricultural land use and runoff, animal vectors, and education and outreach.

PWD's ongoing initiatives include the following: *Cryptosporidium* source tracking studies in collaboration with regional universities; partnership work, particularly involving the Schuylkill Action Network (SAN); action items outlined in the City's Combined Sewer and Stormwater Management Plans; the Delaware Valley Early Warning System (EWS); and the City's extensive education and outreach efforts that encompass both in-city and watershed-wide projects and partnerships.

Future initiatives that have been identified to further reduce the risk of *Cryptosporidium* contamination throughout Philadelphia's source watersheds and at the Queen Lane and Baxter intakes are summarized below for each implementation category.

WWTP Dischargers:

- Through participation in the SAN Pathogens and Point Sources Workgroup, ensure that high-priority sources are identified and addressed.
- Coordinate with SAN to provide or promote wet weather and high flow management education to WPCP operators.
- Continue to identify and inventory WPCP dischargers through the Watershed Sanitary Survey triennial reporting.
- Track the installation of treatment upgrades at wastewater utilities through Chapter 94 reporting and participation in the Dissolved Oxygen (DO) Partnership.
- Support future research initiatives surrounding the impact of WPCP effluent on *Cryptosporidium* surface water concentrations.

Agricultural Land Use & Runoff:

- Provide nutrient management planning and Act 38 training for internal PWD staff to improve outreach and assistance to local agricultural operations.
- Develop and distribute educational resources for agriculture Best Management Practices (BMPs) installed both within Philadelphia and throughout the watershed.
- Coordinate with the Philadelphia School District and other agency and non-profit partners to implement BMPs at Walter B. Saul High School in the Wissahickon watershed, Manatawna Farm in the Schuylkill River watershed and Fox Chase Farm in the Pennypack watershed.
- Identify, inventory, and assess CAFOs located in the Schuylkill River watershed and parts of the Delaware River watershed.
- Track research related to the impact of agricultural sources on *Cryptosporidium* surface water concentrations.

- Work with the Schuylkill Action Network and other partner organizations to prioritize farmland for agricultural BMP installation.
- Continue to contribute to the Schuylkill River Restoration Fund and serve on the grant advisory committee to help fund priority agricultural BMP projects in the Schuylkill River watershed.

Animal Vectors:

- Continue implementation of waterfowl management programs at Fairmount Park properties, including Peter's Island, and at the Queen Lane, Belmont, and Baxter WTPs, as well as PWD's three WPCPs.
- Raise awareness throughout the watershed as to the threat animal vectors pose to source water quality (e.g., installation of educational signage, education campaigns, and/or special events).
- Promote the establishment of no-mow areas, meadows, and/or riparian buffers to deter Canada geese.

Education & Outreach:

- Maintain and expand in-city and watershed-wide partnership work and education and outreach initiatives.
- Explore partnership opportunities with local vocational schools and universities with specialization in agricultural sciences and/or environmental sciences.
- Participate in the development of Urban Agriculture Curriculum at Lincoln High School in the Pennypack watershed.

The above initiatives are included in the Watershed Control Plan Update because they address priority sources of *Cryptosporidium* in the Schuylkill and parts of the Delaware River watersheds, which serve as the WCP's area of influence. In addition to qualitatively assessing the impact of priority sources and identifying appropriate control measures, PWD also attempted a quantitative assessment of *Cryptosporidium* in the area of influence. The quantitative assessment involves a series of calculations that aim to: 1) provide an estimate of the total load attributable to priority sources and 2) provide estimates of the reduction in load achieved through the implementation of source water protection initiatives. A first attempt was also made to define a benchmark or target reduction for the estimated total load of oocysts in the area of influence.

Observations

According to the Source Water Assessment's *Cryptosporidium* source prioritization, National Pollutant Discharge Elimination System (NPDES) dischargers—particularly WPCPs and runoff from subwatersheds associated with agricultural land use—are the primary point and non-point sources, respectively, of *Cryptosporidium* contamination in both the Delaware and Schuylkill watersheds.

In addition to the Source Water Assessment's source prioritization results, PWD classifies raw sewage discharges resulting from upstream combined sewer overflows (CSOs), defective laterals, wildcat sewers, separate sewer overflows (SSOs), and inadequate or failing sewer infrastructure as priority sources of *Cryptosporidium*.

Source tracking studies in collaboration with Lehigh University reveal that certain animals, particularly geese, can serve as vectors, transferring viable and human-infectious oocysts from original hosts to Philadelphia's source waters.

In-city and watershed-wide vulnerability assessments reveal that all high priority sources, which include WPCP effluent, agricultural runoff, raw sewage discharges, and animal vectors, are still potential threats to *Cryptosporidium* contamination at Philadelphia's drinking water intakes.

PWD has identified in-city and watershed-wide ongoing and proposed initiatives to address high priority sources of *Cryptosporidium*. In-city initiatives address raw sewage discharges, animal vectors, and agricultural runoff. WPCP effluent cannot be managed or mitigated directly by PWD since no City-owned plants are located upstream of the Queen Lane and Baxter intakes.

Quantitatively estimating the impact of different sources of *Cryptosporidium* is only possible using a presumptive approach that relies heavily on values found in literature. Moving forward, expanding data collection and research opportunities will be necessary to develop a better understanding of the sources of *Cryptosporidium* and the effectiveness of source water protection initiatives.

Watershed control plan initiatives that address priority sources of *Cryptosporidium* on a watershed-wide scale will require collaboration and cooperation between PWD and its upstream partners. Certain initiatives will also require support from state and federal regulatory authorities. One of PWD's most influential partners in the Schuylkill River Watershed, and one which will be a critical component of WCP implementation, is the Schuylkill Action Network (SAN). SAN strives to improve the water resources of the Schuylkill River watershed by transcending regulatory and jurisdictional boundaries in the strategic implementation of partnership-based protection measures.

Conclusions

PWD believes it is necessary to examine the potential sources of *Cryptosporidium*, its vectors throughout the watershed, and its movement through the City's source waters in order to reduce the levels of *Cryptosporidium* that require treatment upon reaching Philadelphia's drinking water intakes. Through this approach, PWD's ultimate goal is to reduce the presence of *Cryptosporidium* at Philadelphia's intakes. However, the success of the watershed control plan should not focus on sampling and water quality analyses. At this point in time, *Cryptosporidium* monitoring is not an adequate means of assessing changes in the oocyst watershed load, or the number of oocysts that ultimately reach the intake. Despite the challenges associated with quantitatively assessing the watershed control plan's impact, PWD recognizes that no single action item will guarantee lower *Cryptosporidium* concentrations at the intake, highlighting the importance of a comprehensive implementation approach that addresses all priority sources and emphasizes cooperation and collaboration with watershed partnerships and regulatory agencies.

Although coordinating source water protection efforts over such a large area of influence is a challenge, PWD's Source Water Protection Program has already successfully developed a holistic watershed approach to drinking water protection that will form the basis of the WCP implementation process. The program's approach recognizes the interconnectedness between source water protection concerns, upstream land and water use, partnership development, and the need to maintain a healthy aquatic ecosystem. Following implementation of this watershed control plan, pathogen contamination risks will not only be reduced from a drinking water perspective, but also in regard to human infection risks associated with river-based recreational activities. In order to lower *Cryptosporidium* concentrations and reduce the risk of pathogen contamination, PWD will continue to work with upstream partners, such as the Schuylkill Action Network, to communicate and consult on regulatory issues, funding opportunities, and watershed-wide initiatives.

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AFO	animal feeding operation
ALPP	agricultural land preservation program
AMD	abandoned mine drainage
APHIS	Animal and Plant Health Inspection Services
ARRA	American Recovery and Reinvestment Act
AST	aboveground storage tank
BCC	Berks County Conservancy
BCCD	Berks County Conservation District
BMP	best management practices
CAC	Citizens Advisory Council
CAFO	concentrated animal feeding operation
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CERCLIS	Comprehensive Environmental Response, Compensation and Liability Act Information System
COA	consent order & agreement
CRP	Conservation Reserve Program
CSO	combined sewer overflow
CWA	Clean Water Act
DMR	discharge monitoring report
DRBC	Delaware River Basin Commission
DWTP	Drinking Water Treatment Plant
ECHO	Enforcement and Compliance History Online
EMC	event mean concentration
EPA	U.S. Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
EWS	Early Warning System
FISH	fluorescent in-situ hybridization
FPC	Fairmount Park Commission
FWWIC	Fairmount Waterworks Interpretive Center
IESWTR	Interim Enhanced Surface Water Treatment Rule
IWMP	Integrated Watershed Management Plan
IWU	Industrial Waste Unit
MGD	million gallons per day
MS4	Municipal Separate Storm Sewer System
LT2ESWTR	Long Term 2 Enhance Surface Water Treatment Rule
LTCP	Long Term Control Plan
NLCD	National Land Cover Dataset
NLT	National Lands Trust
NMP	Nutrient Management Plan
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
OLDS	on-lot sewage disposal systems

PADEP	Pennsylvania Department of Environmental Protection
PCR	polymerase chain reaction
PCS	Permit Compliance System
PDE	Partnership for the Delaware Estuary
PEACCE	Pennsylvania Environmental Agricultural Conservation Certification of Excellence
PEC	Pennsylvania Environmental Council
POTW	publicly owned treatment works
PWD	Philadelphia Water Department
PWS	Public Water System
RAWA	Reading Area Water Authority
RCRA	Resource Conservation and Recovery Act
RCRIS	Resource Conservation and Recovery Act Information System
SAN	Schuylkill Action Network
SAP	Sewer Assessment Program
SDWA	Safe Drinking Water Act
SPILL	Sewage Pollution Incident and Location Log
SRLM	Schuylkill River Loading Model
SRRF	Schuylkill River Restoration Fund
SSO	separate sewer overflow
STP	sewage treatment plant
SWA	Source Water Assessment
SWIG	Schuylkill Watershed Initiative Grant
SWMM	Storm Water Management Model
SWPP	Source Water Protection Plan
TMDL	Total Maximum Daily Load
TRI	Toxic Release Inventory
TSS	total suspended solids
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WCP	Watershed Control Plan
WPCP	water pollution control plant
WQC	Water Quality Council
WRT	Waterways Restoration Team
WS	Wildlife Services
WTP	water treatment plant
WWTP	wastewater treatment plant

1 Introduction

On January 5th, 2006, the EPA promulgated the Long Term 2 Enhanced Surface Water Treatment Rule (LT2). The LT2 serves as a series of amendments to the Safe Drinking Water Act and is the first drinking water regulation based on source water quality. The LT2 serves to protect public health from illness due to *Cryptosporidium* and other microbial pathogens in drinking water and to address risk trade-offs with the control of disinfection byproducts. Key provisions of the regulation that pertain to the Philadelphia Water Department (PWD) include the following: source water monitoring for *Cryptosporidium*; risk-targeted *Cryptosporidium* treatment by filtered systems; and criteria for the use of *Cryptosporidium* treatment and control processes. The following Watershed Control Plan (WCP) presents a comprehensive source water protection approach to reducing levels of infectious *Cryptosporidium* in finished drinking water (US EPA 2006). The elements within this plan will be achieved through previously established frameworks and ongoing efforts of PWD's Source Water Protection Program. Primary elements of the plan concern the identification of *Cryptosporidium* sources in the delineated area of influence, prioritization of the identified sources, development of control measures to address the prioritized sources, and a plan for the continuation of these efforts in the future. By implementing the following WCP, an effective approach to reducing *Cryptosporidium* in Philadelphia's source water, and thereby finished drinking water, can be achieved and dependency on treatment removal processes can be reduced.

1.1 Background

The amendments found in the LT2 rule supplement existing microbial treatment regulations and target public water systems (PWSs) with a higher potential risk from *Cryptosporidium* (US EPA 2006, 40 CFR Parts 9, 141, 142). The LT2 rule focuses on *Cryptosporidium* because it has been identified as the cause of several waterborne disease outbreaks in the United States by means of an infectious and potentially severe gastrointestinal illness termed cryptosporidiosis. *Cryptosporidium* is credited as causing the largest waterborne disease outbreak in United States history, infecting nearly 400,000 people in Milwaukee, Wisconsin during March and April of 1993.

The LT2's proposed amendments apply to all PWSs supplied by a surface water source and PWSs supplied by a ground water source under the direct influence of surface water. A bin classification system forms the basis of the EPA's risk-targeted approach to reducing *Cryptosporidium* in these drinking source waters, *see* Figure 1-1. Filtered PWSs are classified in one of four bins based on results from a two-year-long source water monitoring program. PWSs classified in the lowest bin, Bin 1, are subject to no additional treatment requirements, whereas PWSs assigned to higher bins must reduce *Cryptosporidium* levels beyond IESWTR and LT1ESWTR requirements. The total *Cryptosporidium* treatment required for plants in Bins 2, 3, and 4 is 4.0-log, 5.0-log, and 5.5-log, respectively.

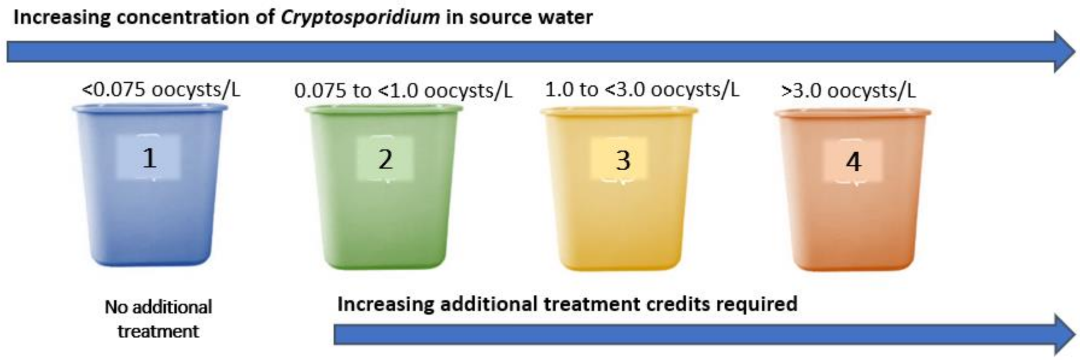


FIGURE 1-1: LT2 SURFACE WATER TREATMENT RULE BIN CLASSIFICATION SYSTEM

The majority of plants, including PWD's three drinking water treatment plants, treat surface water using conventional treatment, which is defined in 40 CFR 141.2 as coagulation, flocculation, sedimentation, and filtration. The EPA has estimated that conventional treatment plants in compliance with the IESWTR or LT1ESWTR typically achieve a *Cryptosporidium* removal efficiency of approximately 3-log, implying that an additional 1-log, 1.5-log, or 2-log treatment credit(s) is required depending upon bin classification. In order to achieve these credits, today's rule outlines a variety of treatment and control options collectively termed the "microbial toolbox." Options for credit include source protection and management programs, pre-filtration processes, treatment performance programs, additional filtration components, and inactivation technologies.

PWD's three drinking water treatment plants (DWTPs) started monitoring for *Cryptosporidium* in conjunction with the LT2 in 2001. PWD maintains two trained *Giardia*/*Cryptosporidium* analysts at its Bureau of Laboratory Services (BLS), who provide in-house expertise and are actively involved in methods improvement. This team provided the data for PWD's first and second rounds of *Cryptosporidium* LT2 compliance.

Philadelphia's drinking water treatment plants provide approximately 250 million gallons of water per day to nearly 1.6 million customers in Philadelphia, *see* Figure 1-2. Two of Philadelphia's DWTPs, Queen Lane and Belmont, rely on surface water from the Schuylkill River to provide an average of 110 million gallons per day (MGD) of potable drinking water to nearly 400,000 customers in Philadelphia. Both plants are located within 12 miles upstream of the Schuylkill River's confluence with the Delaware River. The Queen Lane DWTP is located immediately downstream of the confluence of the Wissahickon Creek and Schuylkill River in the East Falls neighborhood of Philadelphia. The Belmont DWTP intake is located two miles downstream of Queen Lane. PWD's third DWTP, Baxter, is located on the Delaware River in the Torresdale neighborhood and provides approximately 60% of the drinking water to Philadelphia (PWD 2009d).

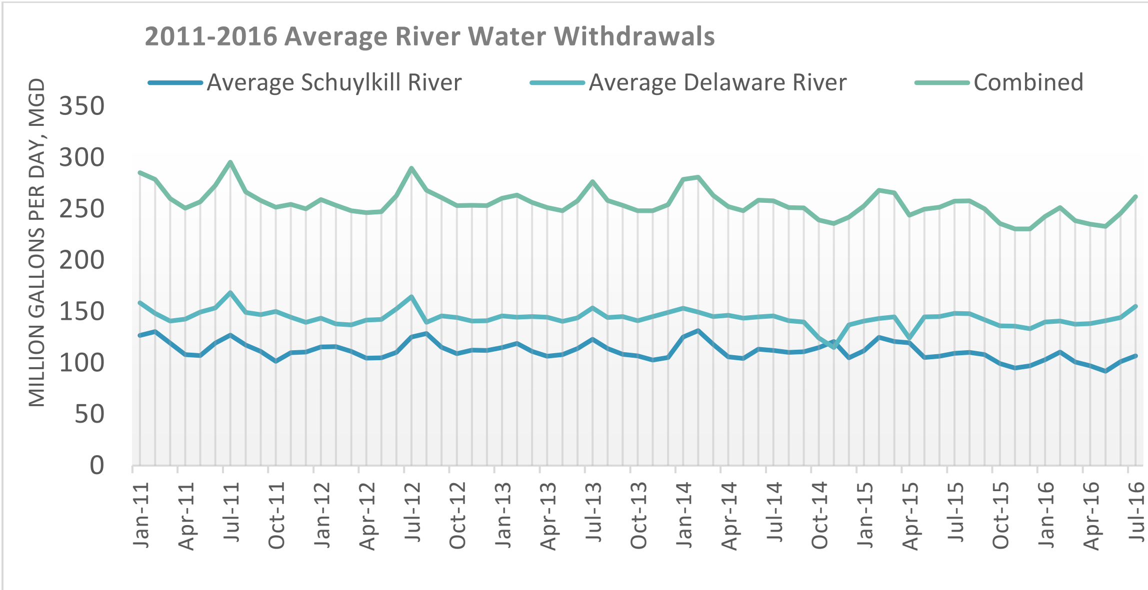


Figure 1-2: Average PWD River Withdrawals for Drinking Water Treatment, 2011-2016

In compliance with LT2 regulations, PWD analyzed its Round 1 monitoring results and classified each treatment plant in one of four bins. It was determined that Baxter and Belmont have average *Cryptosporidium* levels below 0.075 oocysts/L, classifying the plants in Bin 1, with no additional treatment necessary. Round 1 results from Queen Lane, however, indicated a slightly higher average oocyst concentration of 0.076 oocysts/L that resulted in a Bin 2 classification. As illustrated in Figure 1-1, Bin 2 is characterized by treatment plants whose average oocyst concentration is 0.075 oocysts/L or higher but less than 1.0 oocysts/L. Since all of PWD's drinking water treatment plants use conventional treatment methods, they are automatically awarded 3-log treatment credit toward *Cryptosporidium* removal. Round 1 results indicate that Queen Lane requires an additional 1-log removal credit to achieve the 4-log removal required of plants classified as Bin 2. From the regulation's associated microbial toolbox options for additional treatment credits, PWD selected the combined and individual filter effluent performance requirements to achieve a total of 1-log additional treatment credit. The Watershed Control Plan was developed to provide a 0.5-log back-up credit to ensure the goal of an additional 1-log removal.

Following results of Round 2 monitoring, which occurred from April 2015 through March 2017, the Baxter Treatment Plant was re-classified as a Bin 2 facility. Microbial toolbox options selected for compliance at the Baxter Treatment Plant will be the same as those selected for the Queen Lane Treatment Plant. Additionally, the ongoing Watershed Control Plan for Queen Lane is expanded to include priority geographic areas in Baxter Water Treatment Plant's contributing drainage area.

The Watershed Control Plan (WCP) is comprised of the following elements:

- designation of an area of influence;
- identification of both potential and actual sources of *Cryptosporidium;*

- an analysis of control measures to mitigate the sources of *Cryptosporidium;*
- a statement of goals and specific actions PWD will undertake to reduce source water *Cryptosporidium* levels and a description of how actions are expected to contribute to specific goals;
- identification of partners and their roles, PWD's resource requirements and commitments, and a schedule for plan implementation; and,
- a means by which to maintain the credit that will include an annual status report and a triennial watershed sanitary survey to track and document watershed sources.

Although the WCP is a secondary treatment credit option in Pennsylvania, the PWD Source Water Protection Program recognizes that the successful control of *Cryptosporidium* is not only dependent on physical removal processes such as filtration, but also on an understanding of the sources and vectors that enable the pathogen to reach the City's drinking water intakes.

In 2018, PWD completed a comprehensive 25-year Drinking Water Master Plan strategy to identify the highest priority capital improvements needed to ensure resilient, robust, and dependable infrastructure into the future. The resulting key facility upgrades increase level of service and decrease operational and public health risks. The strategy identified approximately 400 individual projects with an estimated cost of $2.5 billion over the next 25 years. The Water Master Plan identified 10 key projects, *see* Figure 6-2. The treatment technology upgrades at each PWD water treatment plant include UV disinfection, which is effective at inactivating *Cryptosporidium* oocysts during the treatment process.

This strategy will be updated every five years to accommodate changing priorities, emerging research, and regulatory developments. Regardless of the status of the UV disinfection installation at each drinking water treatment plant, PWD will continue to implement the WCP and other control strategies to protect the quality and quantity of drinking water at Philadelphia's intakes through the work of the Source Water Protection Program.

1.2 Source Water Protection Program Overview

PWD's decision to employ a Watershed Control Plan to control *Cryptosporidium* reflects the Source Water Protection Program's multi-barrier approach to ensuring the safety and quality of Philadelphia's drinking water. A holistic approach to water quality protection has been used since the program's inception in 1998 with the formation of the Office of Watersheds. Over the years, the program has developed a thorough understanding of the City's water supply characteristics, including ambient water quality conditions, major sources of actual and potential contamination, water availability, flow patterns and management practices, and tidal and reservoir impacts. As with other water quality concerns, the Source Water Protection Program deems it appropriate to identify *Cryptosporidium* as a watershed-wide issue requiring a watershed-wide approach. Only through an examination of the potential sources of *Cryptosporidium,* its vectors throughout the watershed, and its movement through the City's water sources will it be possible to reduce the levels of *Cryptosporidium* that require treatment upon reaching Philadelphia's drinking water intakes.

The success of the Source Water Protection Program's organized and comprehensive approach is essential to the integrity of the Delaware and Schuylkill Rivers as drinking water supplies. In order for the program to meet its high standards, PWD employs a wide range of tools, including research projects, regional partnerships, outreach and education, advanced technologies, and on-the-ground implementation and monitoring to achieve, if not exceed, source water goals. Forming the basis of PWD's various source water protection efforts are the Source Water Assessments (SWAs) and Source Water Protection Plans (SWPPs), both of which are publicly available. Completed in 2002 for all three intakes, the SWAs were created in response to the 1996 Safe Drinking Water Act Amendments, which call for the assessment of all source water supplies across the U.S. to identify potential sources of contamination. PWD, along with its project partners, conducted a watershed-based, multi-phase assessment that identified and prioritized potential and existing sources of contamination and evaluated the vulnerability of the water supply to these contaminant sources. The SWPP establishes a set of priority actions to address threats to the water supply identified during the assessment phase. The plan's recommended action items are based on a holistic watershed approach that recognizes the interconnectedness between source water protection concerns, upstream land and water use, and the need to maintain a healthy aquatic ecosystem. Upon completion of the protection plan, PWD became one of the first water suppliers in the state to meet all steps outlined in the Pennsylvania Department of Environmental Protection's (PADEP) minimum criteria for a Source Water Protection Program.

The Source Water Assessments and Protection Plans are fundamental elements of the PWD Source Water Protection Program. However, the program itself encompasses a much wider range of projects related to research, on-the-ground implementation, partnership workgroups, and in-city initiatives. An example of project work relevant to this Watershed Control Plan is PWD's involvement in research to identify and mitigate pathogen levels in the City's source waters. In collaboration with Lehigh University, PWD participated in source tracking projects to identify the primary sources and vectors of *Cryptosporidium* in Philadelphia's watersheds. The results of completed research are discussed in detail later in this plan. Successful research initiatives within the Source Water Protection Program have also led to on-the-ground project implementation, as is evident with the launching of several projects, including the Delaware Valley Early Warning System (EWS). The EWS, which has been fully operational since 2004, is an integrated monitoring, notification and communication system that provides water suppliers with advanced warning of water quality contamination events. Other implementation efforts include the installation of best management practices (BMPs) throughout the watershed that have reduced water contamination from stormwater runoff, agricultural runoff, and abandoned mine drainage (AMD).

Since the city of Philadelphia represents only a small fraction of its total source watershed area, PWD's partnerships have proved imperative to implementation of many watershed projects. The largest, and perhaps most influential, of these partnerships is the Schuylkill Action Network (SAN). SAN has worked to improve the water resources of the Schuylkill River watershed by transcending regulatory and jurisdictional boundaries in the strategic implementation of partnership-based protection measures (SWIG 2009). Recognizing the value of this partnership network in achieving source water protection goals, the PWD has consistently funded and supported the SAN since its inception. SAN has supported projects ranging from the installation of stormwater BMPs to the promotion of education and outreach activities aimed at connecting residents to water quality concerns and solutions. Since 2006, the public-private grant partnership of the Schuylkill River Restoration Fund has provided the opportunity to fund environmental projects in the Schuylkill River Watershed to address key source water protection needs. Administered by Schuylkill River Greenways and funded by SAN partners, including PWD, the grant program has awarded more than $4 million since its inception with an additional $5.4 million in leveraged funding.

In addition to collaborating with educational institutions and various other agencies, organizations, and watershed partnerships, PWD has developed several of its own source water protection initiatives to mitigate the risk of pathogens in the water supplies. Examples of some of PWD's in-city initiatives include PWD's stormwater permit and stormwater ordinance, the City's Defective Lateral Abatement Program, and Wildlife Management Program. The City's stormwater permit is a required permit under the National Pollutant Discharge Elimination System in compliance with the provisions of the Clean Water Act (CWA), 33 U.S.C. Section 1251 et seq. (the "Act"), 25 Pa. Code Chapter 92, and Pennsylvania's Clean Streams Law, as amended, 35 P.S. Section 691.1 et seq. The City has also enacted a stormwater ordinance in compliance with Pennsylvania's Stormwater Management Act (Act 167). The City's stormwater permit provides the State with an overview of stormwater pollution control measures and measures to control flooding problems. One such issue tracked in annual stormwater permit reports is the progress of defective lateral identification and abatement efforts to protect Philadelphia's source water quality. PWD's Defective Lateral Detection and Abatement Program focuses on identifying defective laterals within the city and correcting the cross connections, thereby reducing bacterial loadings to the river. The City's Wildlife Management Program is also aimed at reducing bacterial contamination of Philadelphia's source waters through a reduction in the population of geese near drinking water intakes. Geese are an effective vector for the transport of bacteria and protozoa, and a considerable source of these pathogenic microorganisms.

It should also be noted that in conjunction with all of PWD's source water protection efforts, the City of Philadelphia's Department of Public Health has made cryptosporidiosis a reportable disease, meaning that Philadelphia monitors disease rates and tracks the source of disease outbreaks through enhanced case study forms. Therefore, if Philadelphia were to experience a breakthrough of treatment barriers that allowed viable and infectious *Cryptosporidium* into its drinking water, the Department of Public Health would be able to track the outbreak. The number of reported cases of cryptosporidiosis in Philadelphia from 2008-2018 ranged from 14 to 58 annually, none of which were associated with drinking water. In fact, after more than two decades of public health surveillance, no relationship between cryptosporidiosis outbreaks and drinking water has been found.

PWD's SWPP takes a multi-faceted approach to protecting and improving source water quality throughout the Schuylkill and Delaware River watersheds. The program has a thorough understanding of the threats to Philadelphia's water supply and the level of coordination and collaboration that will be necessary to continue to identify regional protection priorities and implement protection initiatives. Collectively, PWD's source water protection efforts form the basis of a comprehensive and effective Watershed Control Plan.

2 Delineation of Area of Influence

An accurate assessment of the impact of *Cryptosporidium* at the Queen Lane intake requires the identification of what the EPA terms the "area of influence." The area of influence is defined as the area outside of which there is not a significant likelihood of *Cryptosporidium* or fecal contamination affecting a drinking water intake. Several methods can be used to establish the boundaries of the area of influence. Some of these methods include: characterization of watershed hydrology, modeling *Cryptosporidium* time of travel, or, when sufficient data exists, it can be useful to assess such factors as fate and/or die-off/inactivation times in natural waters. The EPA states that a public water system can use one or more of these methods, or it can use methods that do not include any of the above, as long as the State considers the results sufficient to establish the boundaries of the area of influence.

2.1 Queen Lane Intake

PWD has identified the area of influence using the delineation method set forth in the Source Water Assessment described below. Research involving the fate and transport of *Cryptosporidium,* and the potential effects of future development on pathogen levels in Philadelphia's water supply, is also referenced to provide additional information regarding the presence and persistence of *Cryptosporidium* throughout the watershed.

PWD's Source Water Assessment delineation methodology specifies three zones of influence: Zones A, B, and C. Together, these zones encompass the entire Schuylkill River watershed, or the entire drainage area with the potential to influence water quality conditions at the Queen Lane intake. The A, B and C time of travel zones are defined in the PADEP's Source Water Assessment Program Plan. The zones used for PWD's assessment were calculated and provided by the USGS and approved for use by the PADEP. They are based on average flow conditions and USGS estimates of flow-velocity relationships.

Zone A includes 73.7 square miles of the Schuylkill River watershed and represents the area within a 5-hour time of travel of the Queen Lane intake. Since proximity to the water supply intake results in reduced response times and potential lower dilution and attenuation of a contaminant, Zone A represents a critical area of highest potential impact on the Queen Lane intake (PWD 2002B). Zone A continues upstream of the intake to river mile 31 at Valley Forge and consists of almost the entire Wissahickon Creek watershed and the direct drainages to the Schuylkill River, to directly upstream and including portions of Valley Creek.

Zone B encompasses 1,271 square miles of the Schuylkill River watershed and represents the area between the 5-hour and 25-hour time of travel of the Queen Lane intake with a two-mile-wide boundary on either side of the river or stream. The delineated zone extends upstream of the intake to river mile 108, near Auburn, PA. Zone B includes all tributaries below the Maiden and Tulpehocken Creeks, about half of the Maiden Creek watershed, part of the Tulpehocken Creek watershed below Blue Marsh Reservoir, and part of the Little Schuylkill River up to Greenawald, PA.

Zone C consists of the remaining 655.3 square miles within the Schuylkill River watershed that has a time of travel greater than 25 hours. This zone encompasses the remainder of the Schuylkill River watershed, primarily including the headwaters of the Schuylkill River, most of the Little Schuylkill River, the majority of the Tulpehocken Creek watershed, and the headwaters of Maiden Creek watershed.

Figure 2-1 illustrates Zones A, B, and C within the Schuylkill River watershed, as well as the location of the Queen Lane and Belmont drinking water intakes.

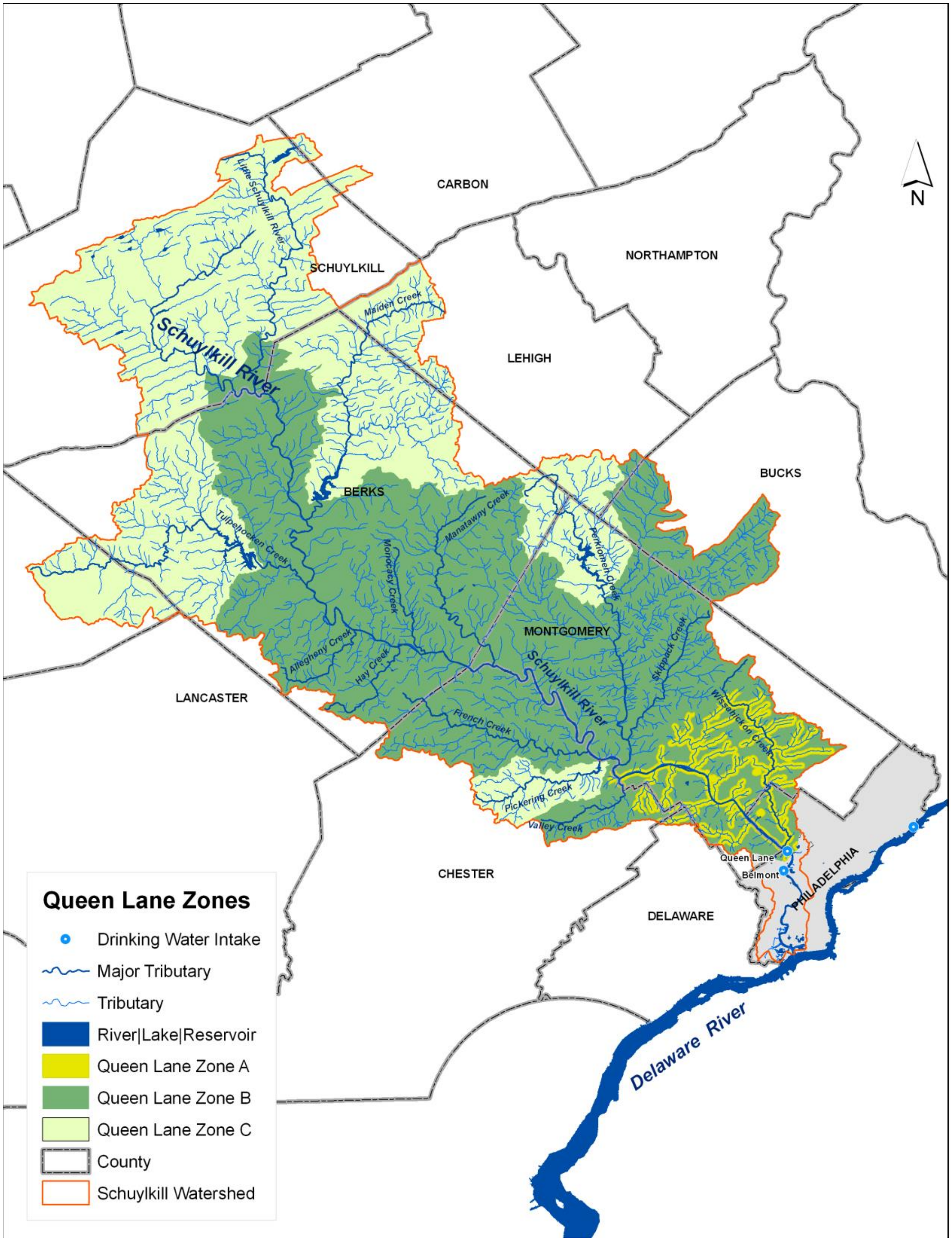


FIGURE 2-1: ZONES A, B AND C AND PWD'S QUEEN LANE AND BELMONT INTAKES (ADAPTED FROM PWD 2002B)

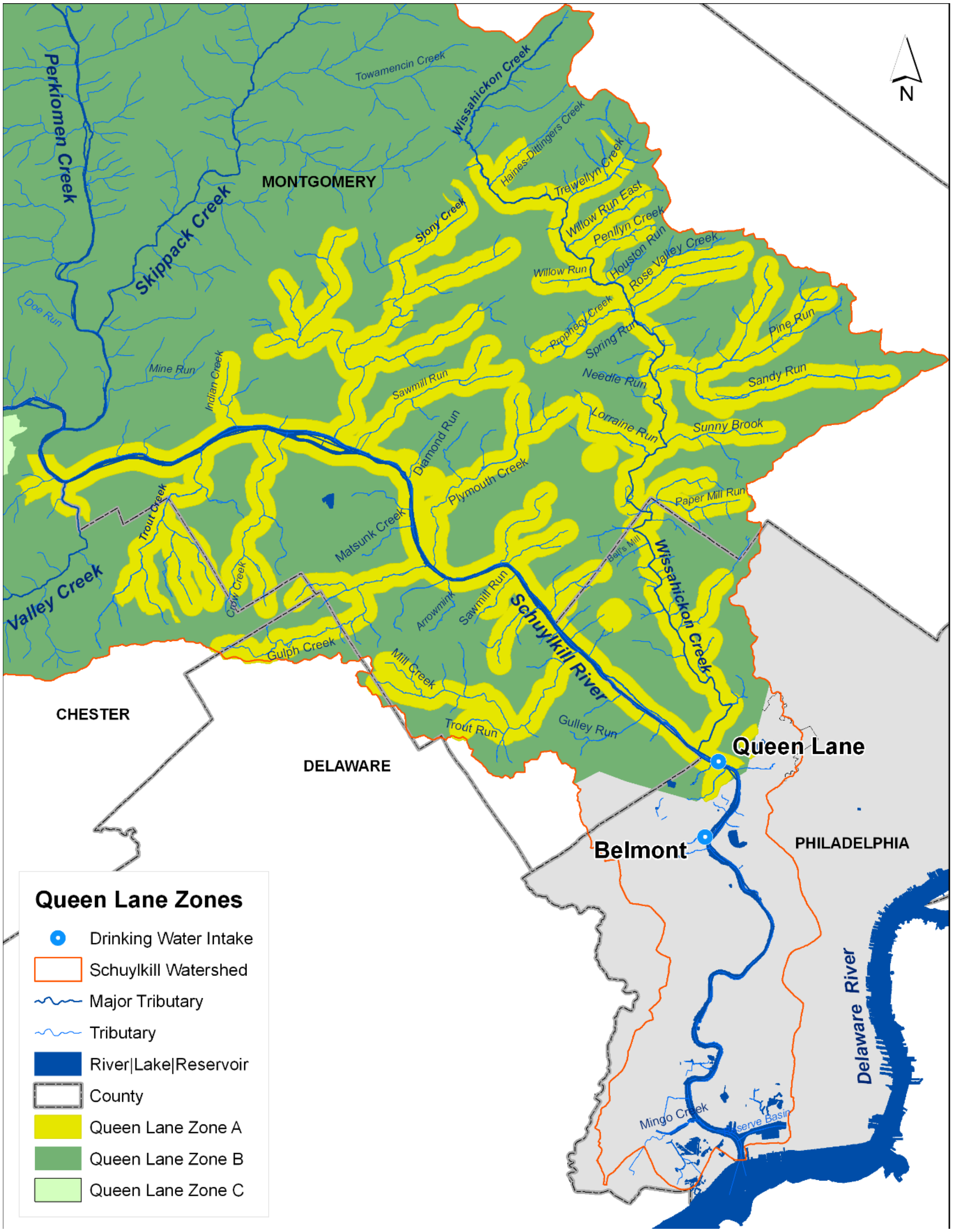


Figure 2-2: Schuylkill River Source Water Protection Zone A Relative to the Queen Lane and Belmont Intakes (Adapted from PWD 2002b)

Figure 2-2 provides a more detailed look at Zone A, the zone of highest priority relative to the Queen Lane intake. Results from the zone delineation process were used to create a ranking of all potential point and non-point sources, as well as a series of source prioritization rankings by contaminant category. The results from the prioritization of *Cryptosporidium* sources will be discussed later in this plan. Additional information regarding the transport of *Cryptosporidium* is available in *The Role of Wastewater Treatment in Protecting Water Supplies against Emerging Pathogens* (Crockett 2007). By focusing on the fate and transport of *Cryptosporidium* in wastewater treatment plant effluent, the research presented in this paper reveals that *Cryptosporidium* has the potential to travel throughout a large portion of the watershed, or area of influence, while maintaining its viability. The study first establishes that wastewater effluent can contain significant amounts of infectious and viable pathogens in its discharge while meeting regulatory permit standards. Upon reaching receiving waters, *Cryptosporidium* can survive from 30 to 176 days with upwards of 30 to 70% of the oocysts remaining viable beyond 100 days at temperatures of 21 and 4 degrees C, respectively. In addition, it was concluded that *Cryptosporidium* oocysts in wastewater discharge can travel 160 km, or 100 mi, in less than 7 days, retaining their viability upon withdrawal at a downstream water intake. Considering the extended survival of *Cryptosporidium*, the pathogen's potential to travel long distances downstream before significant die-off, the high degree of removal required by drinking water treatment, and *Cryptosporidium's* extremely low infectious doses, it is clearly evident that the entire Schuylkill River watershed should be considered an area of influence.

Designating the entire Schuylkill River watershed as the area of influence presents many challenges in regard to *Cryptosporidium* source prioritization and the implementation of watershed control plan measures. Several areas within the watershed have already been identified as sources of *Cryptosporidium,* especially the Wissahickon Creek subwatershed, which is located in Zone A. The Wissahickon Creek flows into the Schuylkill River approximately 1,200 feet upstream of the Queen Lane intake on the east side of the Schuylkill River (Marengo & Weggle 1999). The creek itself is almost entirely WWTP effluent discharge during dry weather conditions, and it is also the receiving waters for stormwater runoff and discharges from industrial and farming operations. Due to the Wissahickon's close proximity to the intake and the characteristics of its watershed, this plan will take an in-depth look at the creek's influence on *Cryptosporidium* levels at Queen Lane. Although control measures are needed in the Wissahickon, the creek's watershed is not entirely located within Philadelphia's City boundaries. In fact, only 2.4% of the entire Schuylkill River watershed is located within the City. In order to implement watershed control plan measures, PWD will need to rely largely on stakeholder collaboration and its Schuylkill River watershed partnerships. Due to these circumstances, the Source Water Protection Program has placed a strong emphasis over the years on developing partnerships with upstream communities to achieve common goals while leveraging outside funds (Sham et al 2010). The specific partnerships that will be utilized during implementation of this WCP will be discussed in the following sections.

Since Philadelphia comprises such a small percentage of the Schuylkill River watershed, PWD has already begun to consider the potential impacts of upstream land use changes on water quality at the Queen Lane intake. PWD's Source Water Assessment characterizes existing land uses in the Schuylkill River watershed using the National Land Cover Dataset, which originated in the early-mid 1990s, and updated data from the 2000 Census. To assess potential future land use changes, the Source Water Protection Plan developed and simulated a build-out scenario. The build-out analysis utilizes the U.S. EPA's Stormwater Management Model (SWMM) to estimate potential changes in runoff pollutant loads throughout the watershed. Available zoning data obtained on the county level were used to aid in projecting land cover changes. Where zoning was available, the remaining lands were developed to the maximum capacity provided in the zoning regulations. When zoning was not available, a rural low-density residential development was assumed for available open space (PWD 2006). Development restrictions such as delineated wetlands, preserved open space, and steep slopes were also considered in creating the build-out scenario.

Results from the build-out analysis reveal that the percentage of developed land (land used for residential, commercial, industrial, or institutional purposes) will increase from about 15% to as much as 68% under current zoning. Based on modeling estimates of percent imperviousness associated with each land use, the percent impervious land surface is estimated to increase from 10% at existing conditions to 18% at full build-out. It should be noted that the approach used to perform the build-out scenario will tend to overestimate development because all developable agricultural and forested lands were assumed to convert to low-density residential in the absence of zoning guidelines. The scenario also predicts a drastic increase in the percentage of developed areas, because zoning would allow the high-density residential classification to more than triple and commercial/industrial/transportation land uses to more than double.

As a result of projected changes in land use and impervious cover, the annual pollutant loading of *Cryptosporidium* is estimated to increase by approximately 24% (PWD 2006). This increase in *Cryptosporidium* loading does not consider additional pollutant loads from point sources associated with the build-out scenario. Assuming that the new development occurs along with the construction of sewage collection and treatment systems, additional point source loads for *Cryptosporidium* could occur through the discharge of treated wastewater. Based on rough extrapolations of housing unit trends and population trends from the last few decades, it could take anywhere from 50 to 150 years for this “worst-case” build-out scenario to occur if recent trends continue indefinitely (PWD 2006). The potential impact of future development on *Cryptosporidium* loading further stresses the importance of PWD's partnerships and the department's ability to collaborate with upstream partners when making land use planning decisions and identifying effective control measures.

2.2 Baxter Intake

PWD has identified the area of influence using a combination of the delineation method set forth in the Source Water Assessment, with adaptations made for feasibility of plan implementation. PWD's Source Water Assessment delineation methodology specifies three zones of influence: Zones A, B, and C, in order of source water protection priority based on estimated contaminant time of travel to Philadelphia's intakes. Together, these zones encompass 8,100 square miles and comprise the entire contributing drainage area with the potential to influence water quality conditions at the Baxter intake.

The source water protection zones for Baxter were developed with consideration of the fact that the intake is located in the tidal portion of the Delaware River. In tidal rivers and estuaries, tidal current oscillations can transport contaminants in an upstream direction during the flood portion of the tidal cycle. For this reason, the source water protection zones for the Baxter intake consider potential contaminant source areas both upstream and downstream of the intake. For tidal areas, zone delineations were determined through the application of a 3-D time variable hydrodynamic model. For non-tidal zone delineation, high flow condition velocities are assumed. The final zone delineations combine tidal zone results from the hydrodynamic modeling with upstream USGS zone delineation based on high flow stream velocities that were calculated and provided by the USGS and approved for use by the PADEP.

Zone A, the most critical area of highest potential impact on the water supply, encompasses 206 square miles and continues upstream of the intake to river mile 131 at Trenton, NJ and Morrisville, PA. Zone A delineation assumes a contaminant time of travel less than or equal to five hours and an area one-quarter mile wide on either side of the impacted streams/rivers. The final Zone A delineation includes main tributaries such as: Tacony Creek Watershed, Pennypack Creek Watershed, Cooper River, Pennsauken Creek, large portions of the Rancocas Creek Watershed, and lower portions of the Neshaminy Creek Watershed, Mill Creek and Assiscunk Creek.

Zone B designates the second highest priority areas for water supply protection. Zone B encompasses an area of 2,060 square miles and assumes a contaminant time of travel greater than five hours and less than 25 hours, with a two-mile-wide boundary on either side of the river/stream. Zone B extends upstream to river mile 208, including all tributaries below the Lehigh River.

Zone C encompasses the remaining watershed area, approximately 5,834 square miles, consisting primarily of the headwaters of the Delaware River and the remainder of the Lehigh River.

The Baxter intake receives water from a total drainage area of approximately 8,100 square miles. Please note that due to program constraints described in subsequent text, only Baxter's source water protection zones A and B were considered for incorporation into the area of influence. Figure 2-4 illustrates Zones A and B within the Delaware River Watershed, as well as the relative location of the Baxter drinking water intake.

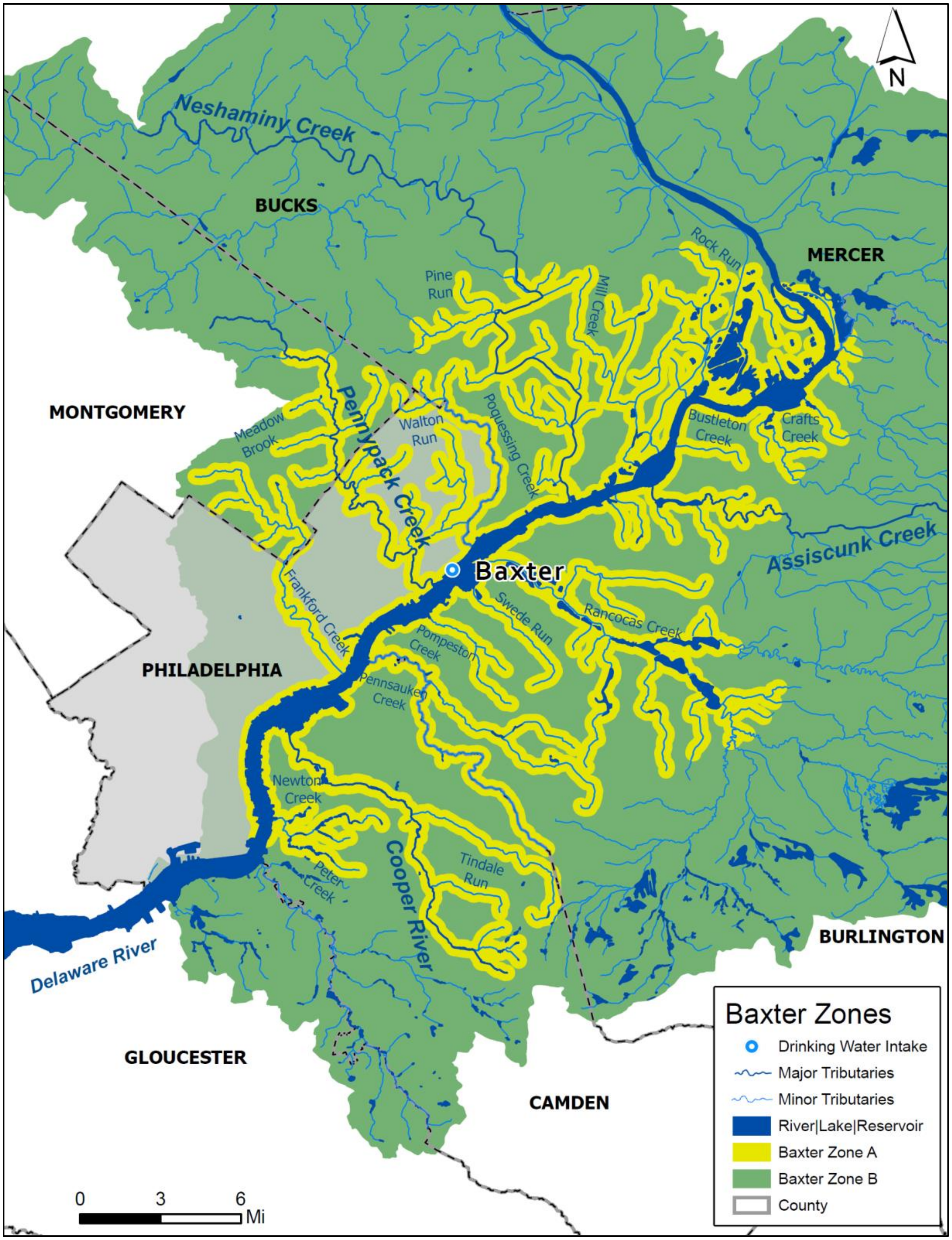


FIGURE 2-3: DELAWARE RIVER SOURCE WATER PROTECTION ZONE A RELATIVE TO THE BAXTER INTAKE (ADAPTED FROM PWD 2002A)

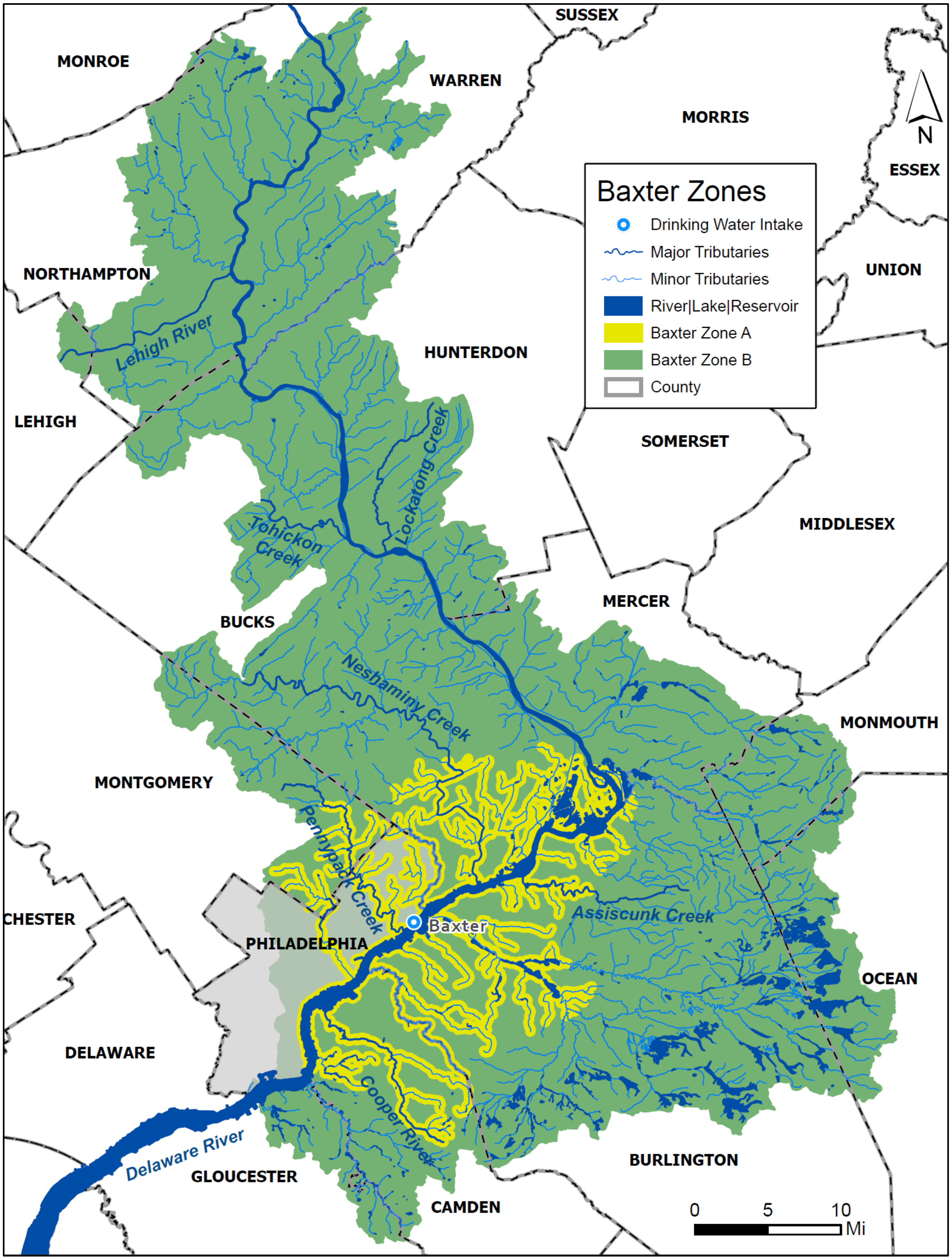


FIGURE 2-4: DELAWARE RIVER SOURCE WATER PROTECTION ZONES A AND B RELATIVE TO THE BAXTER INTAKE (PWD 2002A)

Results from the source water zone delineation process were used to create a ranking of all potential point and non-point sources, as well as a series of source prioritization rankings by contaminant category. The results from the prioritization of *Cryptosporidium* sources will be discussed later in this plan. Upon reaching receiving waters, *Cryptosporidium* can survive from 30 to 176 days with upwards of 30 to 70% of the oocysts remaining viable beyond 100 days at temperatures of 21 and 4 degrees C, respectively. Additionally, *Cryptosporidium* oocysts in wastewater discharge can travel 160 km, or 100 mi, in less than 7 days, retaining their viability upon withdrawal at a downstream water intake. Considering the extended survival of *Cryptosporidium*, the pathogen's potential to travel long distances downstream before significant die-off, the high degree of removal required by drinking water treatment, and *Cryptosporidium's* extremely low infectious doses, it is evident that in the absence of constraints, a watershed scale should be considered an area of influence for the WCP in the absence of implementation constraints.

Incorporating the entire upstream area of the Delaware River Watershed, or all of Baxter's source water protection zones, into the area of influence would present many challenges in regard to *Cryptosporidium* source prioritization and the implementation of watershed control plan measures. The majority of developed land in the Delaware River Watershed is located within the southern portion of the watershed between Lehigh and Philadelphia counties. Findings from past PWD studies indicate that concentrations of *Cryptosporidium* and Giardia in the Lower Delaware River Basin stem primarily from runoff and sewage discharges. The 2002 Source Water Assessment also noted that *Cryptosporidium* and turbidity loadings were higher from agricultural areas, which aligns with previous assumptions of the 2011 WCP for priority sources of *Cryptosporidium* in the Schuylkill River Watershed.

Philadelphia has the highest population density of any county within the watershed. More than 60% of Philadelphia County in located within the Delaware River Watershed. However, only 0.7% of the entire Delaware River Watershed is located within the City. In order to implement watershed control plan measures, PWD will need to rely largely on stakeholder collaboration and watershed partnerships. The 2011 WCP was largely successful due to the existing watershed coordination mechanism, the Schuylkill Action Network. Without the existence of such a critical partnership mechanism, WCP implementation across large areas crossing multiple jurisdictions and state regulatory authorities will be challenging. PWD will explore existing partnership opportunities and evaluate the feasibility of creating a mechanism similar to the SAN for the Delaware River Watershed to assist in current and future watershed protection efforts. PWD will work with the Partnership for the Delaware Estuary to develop a stakeholder engagement strategy. Specific partnerships that will be utilized during implementation of this WCP will be discussed in the following sections.

In total, the Delaware River Watershed is greater than 13,500 square miles, extending over four states, 42 counties, and 838 municipalities (DRBC 2020). As a result, a watershed-scale WCP would present clear logistical challenges for data collection, project implementation, and compliance enforcement. Given that the priority *Cryptosporidium* sources are agricultural runoff, urban stormwater runoff, and treated wastewater effluent, the Upper Delaware River Watershed, which includes the watersheds of the East-West Branch, Lackawaxen, and Neversink-Mongaup sub-basins, does not warrant inclusion in the area of influence. These sub-basins of the Delaware River Basin are also in Source Water Protection Zone C, with an estimated time of travel of 25 or more hours to the Baxter Water Treatment Plant intake. Additionally, cross-channel transport models suggest that contaminants on one bank of the Delaware are not likely to reach the other bank of the Delaware River, justifying the omission of priority *Cryptosporidium* sources in New Jersey (Duzinski 2010). Locational advantages include that this area is under the jurisdiction of one state department of environmental protection and one regional office of the EPA, which facilitates oversight of plan implementation and data collection efforts.

For this Watershed Control Plan, the Baxter Area of Influence will include the Lehigh, Upper Central, Lower Central, and Upper Estuary sub-basins of the Delaware River Watershed limited to the Commonwealth of Pennsylvania (*see* Figure 2-5). The Upper Estuary sub-basin is clipped on the Southernmost side to the boundary of Source Water Protection Zone B. Shown in gray in Figure 2-5 are the areas of the Delaware River Basin that are not designated as part of Baxter's area of influence.

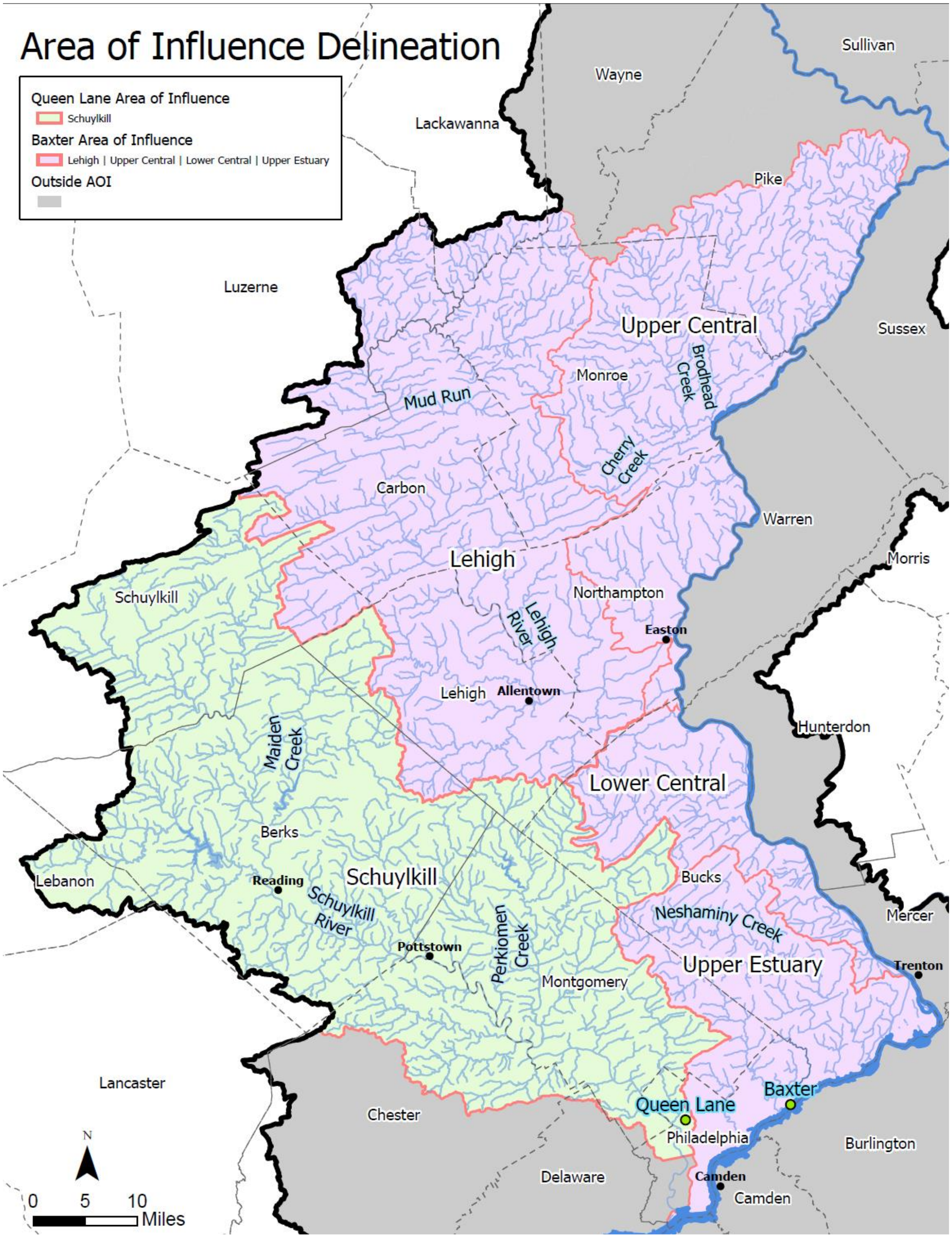


FIGURE 2-5: AREA OF INFLUENCE DELINEATION FOR BAXTER AND QUEEN LANE INTAKES

2.3 Area of Influence Description

The Schuylkill River Watershed is approximately 1,900 square miles encompassing portions of 11 counties with almost 3 million residents (PWD 2002b). The entire Schuylkill River Watershed, defined as the area of influence for the Queen Lane intake in the 2011 WCP, remains the selected area of influence for that intake. Additionally, this update to the WCP delineates an area of influence in the Delaware River Basin to better protect the Baxter intake.

The Delaware River Basin has a population of more than 8.3 million people and occupies approximately 13,000 square miles of land area divided among five states: Delaware (8%), New York (20%), New Jersey (23%), Pennsylvania (49%), and Maryland (<1%) (Somers et al., 2017). The Delaware Bay is not used for Philadelphia's source water and is outside the scope of this plan. This plan discusses three major regions comprising approximately 11,400 square miles of the Delaware River Basin as the Upper, Central, and Lower Regions in terms of the likelihood of contributing *Cryptosporidium* load to the Baxter intake.

The non-tidal Upper Region of the Delaware River Basin, includes the East-West Branch, Lackawaxen and Neversink-Mongaup sub-basins. This 3,442 square mile region ranging from southern New York to parts of northeast Pennsylvania and northwest New Jersey is excluded from the area of influence due to a low probability of *Cryptosporidium* occurrence impacting water quality at the Baxter intake. This is due to a number of factors limiting the occurrence and influence of *Cryptosporidium* in the Upper Region including an abundance of forested land (79.8% of the Upper Region), low urban development (1.8% of the Upper Region), less agricultural development (12.4% of the Upper Region), *Special Protection Water* (SPW) designation, and an estimated time-of-travel of more than 25 hours to Philadelphia's Baxter intake. These characteristics make *Cryptosporidium* loads from priority sources such as wastewater effluent, urban stormwater, agriculture insignificant relative to the other regions defined in the area of influence.

The non-tidal Central Region includes Upper Central, Lehigh, and Lower Central sub-basins. Land use in the central region is 56% forested, 22.8% agriculture, and 12.1% developed (Homsey et al., 2017a). Both the Upper and Central Regions of the Delaware River Basin are designated by the Delaware River Basin Commission (DRBC) as *Special Protection Waters* (SPW). The DRBC designated the drainage area to the 197-mile non-tidal stretch of the Delaware River from Hancock, New York to Trenton, New Jersey as SPW as an additional protection measure to ensure the preservation of water quality. This anti-degradation policy requires DRBC approval for new and expanding of industrial and municipal wastewater treatment plants for proposed facilities discharging a 0.01 MGD or more. The regulations discourage new or increased wastewater discharges by requiring applicants demonstrate that there will be no measurable change to existing water quality and requiring the evaluation of natural and load reduction alternatives. Additionally, DRBC's regulations require that the wastewater discharges to the Special Protection Waters be Best Demonstrable Technology. For municipal wastewater facilities Best Demonstrable Technology equates to compliance with effluent criteria for seven parameters and the use of UV disinfection. The requirement of UV disinfection, and its known ability to inactivate *Cryptosporidium* oocysts, mitigates potential risk of *Cryptosporidium* contamination from treated wastewater effluent in the non-tidal SPW of the Delaware River Basin.

The Lower Region includes the drainage areas of the tidal Delaware River below Trenton, New Jersey. The Lower Region consists of the Schuylkill, Upper Estuary, and Lower Estuary sub-basins. The Lower Region accounts for 36% of the Delaware River Basin's land area and is the most heavily developed and populated area of the basin. Approximately 32% of the region is developed land and 30% is agricultural (Homsey et al., 2017a). The Schuylkill sub-basin is already included in the area of influence for the Queen Lane intake and is not included in the AOI delineation for the Baxter intake. The Lower Estuary is in Source Water Protection Zone C and is also not included in the Baxter area of influence delineation. The Upper Estuary sub-basin is considered in the area of influence for those areas that overlap with Source Water Protection Zone B.

The sub-basins in the Central Region, in combination with the tidal Upper Estuary sub-basin in the Lower Region, comprise the Baxter intake area of influence. The sections that follow describe the characteristics of the Baxter intake area of influence by sub-basin.

2.3.1 Lehigh

The Lehigh sub-basin contains 10 counties and covers 1,362 square miles or approximately 41% of the Central Region and 11% of the entire Delaware River Basin. The Lehigh sub-basin has a population of roughly 700,000 people. The Lehigh River is the second largest tributary to the Delaware River, running approximately 103 miles from its origin in the Pocono Plateau in southern Wayne County to its confluence in Easton, Pennsylvania. The Tobyhanna Creek meets with the Lehigh River to form two forks of the headwater region, characterized by protected forests, exceptional water quality and stream habitat. The river then flows southwest to White Haven for 30 miles through an undeveloped area including two state parks. Water quality in this reach of the river has been impacted by abandoned mine drainage in four tributary streams originating from the Eastern Middle and Southern coalfields. The Lehigh then flows through Jim Thorpe, Lehighton, and Palmerton before making its way through the Kittatinny Ridge and entering the Lehigh Valley. The Lehigh Valley has more developed land, including urban and suburban areas. Tributaries in the Lehigh Valley have headwaters in agricultural and woodland landscapes and meet the main stem in the highly developed areas in the vicinity of Allentown, Bethlehem, and Easton. A total of 79 stream miles (4% of the watershed) are characterized as being impaired due to agricultural nonpoint source pollution. These impacted streams include several tributaries in the Lehigh Valley including Monocacy, Jordan, Coplay, Saucon, and Little Lehigh. Over the 15-year period from 2000 to 2015 the Upper Lehigh Watershed, area lying above Lehighton, observed the greatest population growth (27.8%) in the watershed (Somers et al., 2017). Over the same 15-year period population growth in the Middle Lehigh Watershed, above Jim Thorpe, and the Lower Lehigh Watershed, above Bethlehem, increased by approximately 12% and 11%, respectively (Somers et al., 2017).

2.3.2 Upper Central

The non-tidal Upper Central sub-basin consists of 1,524 square miles in both Pennsylvania and New Jersey, comprising 46% of the land area of the Central Region. However only the

Pennsylvania side of the Upper Central region is included in Baxter's area of influence since hydrodynamic modelling shows that water quality constituents, like *Cryptosporidium*, cannot move across the Delaware River from one bank to another. The Upper Central sub-basin in the area of influence includes parts of Monroe, Pike, and Northampton counties in Pennsylvania. This area has a population of approximately 250,000, increasing 20.4% over the 15-year period from 2000 to 2015 (Somers et al., 2017).

Major watersheds in the Upper Central sub-basin include the Broadhead Creek watershed. The Broadhead Creek drainage area encompasses 285 square miles, encompassing 17 municipalities in Monroe County, and part of Greene Township in Pike County. The Broadhead Creek empties into the Delaware River at the southern end of the Delaware Water Gap National Recreation Area and includes major tributaries of Marshalls, McMichael, Paradise, and Pocono Creeks. The Broadhead Creek watershed includes 15 exceptional value streams and 563 miles of streams.

2.3.3 Lower Central

The non-tidal Lower Central sub-basin consists of 454 square miles in Pennsylvania and New Jersey, comprising 14% of the Central Region's land area. Due to the inability for cross-channel transport in the main stem of the Delaware River, only the Pennsylvania side of the Lower Central region is included in Baxter's area of influence. The Pennsylvania side of the Lower Central sub-basin includes a large portion of Bucks County, in southeastern Pennsylvania. The Pennsylvania side of the Lower Central sub-basin has a population of approximately 110,000, increasing 6.1% from 2000 through 2015 (Somers et al., 2017). Major watersheds in this area include the Upper, Middle, and Lower Tohickon Creek watersheds.

The Tohickon Creek Watershed, located in southeastern Pennsylvania, spans 112 square miles and encompasses portions of Bedminster, East Rockhill, Haycock, Hilltown, Milford, Nockamixon, Plumstead, Richland, Springfield, Tinicum, and West Rockhill Townships in Bucks County, Pennsylvania. Included within its borders are the Boroughs of Dublin, Perkasie, Richlandtown, Trumbauersville, and Quakertown. The Tohickon Creek runs approximately 30 miles from the Nockamixon Dam to its confluence with the Delaware River. The Tohickon Creek is part of the Lower Delaware National Wild and Scenic River system as a partnership river with management oversight through a partnership of adjacent communities, state governments and the National Park Service.

2.3.4 Upper Estuary

The Lower Region consists of the Schuylkill, Upper Estuary, and Lower Estuary sub-basins which comprise 41%, 37%, and 22% of the region's land area, respectively (Homsey et al., 2017a). From 1996 and 2010, the sub-basins of the Lower Region experienced the greatest increases in development (7% to 31%) and the largest loss of forest (3% to 5%) and agricultural lands (2% to 8%) (Homsey et al., 2017b).

The Upper Estuary sub-basin is included in the Baxter intake area of influence. The land cover of the Upper Estuary is 45% developed, 19% agriculture, and 19% forested (Homsey et al., 2017b). Due to the inability for cross-channel transport in the Delaware River, only the Pennsylvania side of the Upper Estuary is included in Baxter's area of influence. The Upper Estuary sub-basin within southeast Pennsylvania includes parts of Philadelphia, Bucks, Montgomery, Delaware, and Chester Counties. The Pennsylvania side of the Upper Estuary has a population over 2.5 million, experiencing 2% growth between 2010 and 2015 (Somers et al., 2017).

Baxter's Source Water Assessment established the southernmost boundary to Zone B in Philadelphia at the HUC12 Petty Island-Delaware River Watershed (020402020405), which drains directly into the Delaware River. The area of Upper Estuary on the Pennsylvania side that overlaps with Source Water Protection Zone B is included in the Baxter area of influence delineation.

2.3.4.1 Pennypack Creek Subwatershed

The Pennypack Creek Subwatershed covers a 55.8 square mile drainage area of southeastern Pennsylvania. The headwaters of the Pennypack Creek rise from springs and wetlands located in Horsham and Warminster Townships within Montgomery and Bucks Counties, respectively. The Pennypack then travels roughly 25 miles through 12 municipalities to its confluence with the Delaware River in Philadelphia. Numerous tributaries flow into the Pennypack Creek, and the total number of stream miles in the subwatershed is estimated to be more than 120. More than half of the land cover in the watershed is residential. Approximately 31.4% of the Pennypack Creek watershed lies within Philadelphia's jurisdiction. An estimated 33% of the watershed is impervious cover, and within Philadelphia 41.8% is impervious (PWD 2009b). Almost the entire Pennypack Creek Watershed is included in Source Water Protection 'Zone A.'

2.3.4.2 Poquessing Creek Subwatershed

The Poquessing Creek Subwatershed is the smallest of Philadelphia's watersheds, draining only approximately 21.8 square miles. The Poquessing Creek's headwaters rise from tributary streams in Lower Moreland and Lower Southampton Townships of Montgomery and Bucks counties, respectively. The Poquessing Creek then flows roughly 9 miles before reaching its confluence with the Delaware River. For most of its length, the Poquessing Creek serves as an approximate dividing line between the City of Philadelphia and Bucks County. Approximately 60% of the Poquessing Creek's drainage area lies within the City of Philadelphia, while 35% is in Bucks County and less than 5% is in Montgomery County. The watershed is more than 40% residential and approximately 38% of it is impervious cover (PWD 2010b). The entire Poquessing Creek Watershed is included in Source Water Protection 'Zone A.'

2.3.4.3 Neshaminy Creek Subwatershed

The Neshaminy Creek Watershed occupies an area of 233 square miles, 86% of which is located in central and lower Bucks County, with the remaining 14% in Montgomery County. The headwaters of the Neshaminy Creek flow from its West Branch in the vicinity of Lansdale and Hatfield to its North Branch, northeast of Doylestown. The Neshaminy Creek flows approximately 50 miles in a southeasterly direction to its confluence with the Delaware River.

The West Branch of the Neshaminy Creek is one of two branches feeding into the mainstem of the Neshaminy Creek. The West Branch flows for approximately 8 miles before converging with the North Branch to form the Neshaminy Creek. The West Branch of the Neshaminy drainage area covers 25 square miles encompassing parts of Montgomery and Bucks counties. The West

Branch watershed includes Franconia, Souderton, Hatfield, Montgomery, and Towamencin townships as well as Hatfield and Lansdale boroughs. The headwaters of the West Branch of the Neshaminy Creek watershed are highly developed.

The North Branch of the Neshaminy Creek emerges in Plumsted Township, Bucks County traveling through the Borough of Chalfont and New Britain Townships. Its main tributary is Pine Run, which flows 7.8 miles from an unnamed pond in Plumstead Township southwest through Buckingham and New Britain Townships until it meets its confluence with the North Branch in the Borough of Chalfont. The Pine Run watershed drains approximately 12 square miles. The major land use of both the North Branch and Pine Run watersheds is agriculture with some areas of developed land.

The Lower Neshaminy Creek watershed encompasses approximately 40 square miles within Bucks County including Northampton, Middletown, Upper Southampton, Lower Southampton townships and Hulmeville, Langhorne, Langhorne Manor and Penndel boroughs. The majority of land use in this area is developed medium density residential.

The DRBC's Southeastern Pennsylvania Groundwater Protected Area (GPA) includes 1,200 square miles, encompassing the entire Neshaminy Creek Watershed. In the designated GPA more stringent regulations apply to groundwater withdrawals than in other areas of the basin to prevent groundwater depletion.

2.3.4.3.1 LITTLE NESHAMINY CREEK SUBWATERSHED

The Little Neshaminy Creek is a 43 square mile subwatershed in the Upper Estuary covering parts of southeast Montgomery County and southwest Bucks County. From its headwaters in Montgomery Township, the Little Neshaminy flows approximately 16 miles to its confluence with the main stem of the Neshaminy Creek. Park Creek is the major tributary to the Little Neshaminy and flows from its headwaters in Lower Gwynedd and Upper Dublin townships eastward through Horsham Township for approximately 6 miles until its confluence with the Little Neshaminy in Warrington. The Little Neshaminy Creek subwatershed includes Horsham, Lower Gwynedd, Montgomery, and Upper Dublin townships in Montgomery County and Ivyland Borough, Northampton, Warminster, Warrington, and Warwick townships in Bucks County. The plurality of the land cover in this subwatershed is low density.

3 Potential and Actual Sources of *Cryptosporidium*

3.1 Source Water Assessment Methodology (2002)

Identifying potential and actual sources of *Cryptosporidium* in the area of influence is the initial step in determining what control measures will prove most effective. Using various methods, PWD has identified several sources that affect *Cryptosporidium* levels at the intakes. Methods of source identification and prioritization include the approaches outlined in PWD's Source Water Assessments (SWA), source tracking research projects in collaboration with Lehigh University, a Schuylkill Action Network (SAN) survey focusing on the impacts of WPCP effluent, and the development and implementation of in-City defective lateral abatement programs. Through these various approaches, PWD has developed a thorough understanding of its highest priority sources and the control measures that will most effectively reduce oocyst levels at the Philadelphia intakes.

PWD's SWA identified point and non-point sources of *Cryptosporidium* that are most likely to influence water quality conditions at Philadelphia's intakes. All potential sources were first inventoried, then screened and ranked. Two types of rankings were conducted. The first prioritized sources across 10 priority contaminants, including *Cryptosporidium*. The second, and more relevant ranking for this Watershed Control Plan, prioritized sources for each contaminant. The second contaminant-based method of prioritization consisted of the three steps described below:

3.1.1 Step 1: Point Source Inventory and Screening

Point source data was compiled from various State and Federal databases available online, as well as from self-assessment data provided by water suppliers. The following Federal databases were accessed to determine point sources in the Schuylkill River Watershed:

- Permit Compliance System (PCS);
- Resource Conservation and Recovery Act Information System (RCRIS);
- Comprehensive Environmental Response, Compensation, and Liability Act Information System (CERCLIS); and,
- Toxic Release Inventory (TRI).

Regulated aboveground storage tanks (ASTs) were also compiled from the PADEP Storage Tank Program to supplement available RCRA data. For the Schuylkill River Watershed, the inventory contains more than 3,000 potential point sources within the 1,900 square mile watershed and includes information on the most common types of sources and the zones in which they are concentrated (PWD 2002b). For the Delaware River Watershed, the inventory contained more than 1,500 aboveground storage sites prior to additional impact screening (PWD 2002a).

Sources that are not located within Zones A and B were eliminated. Individual site contaminants were downloaded, where available, for all remaining facilities. *Cryptosporidium* calculations for point source facilities were based on estimated values from literature. Each contaminant was associated with one of 10 categories. These categories, including *Cryptosporidium*, were generally based on contaminant groups described in the PADEP SWAP guidance document.

Following the geographic screening, point sources were further screened to produce the following universe of sites for *Cryptosporidium*:

2002 Database*	Schuylkill R. Watershed SWA	Delaware R. Watershed SWA
PCS	~50 sites (all dischargers greater than 1 MGD)	50 sites (including all major dischargers)
RCRA	11 sites (all sites located within a floodplain)	20 sites (all sites located within a floodplain)
TRI and AST	20 sites each	20 sites each
CERCLA	No sites selected	Included in narrative results (63 sites within a floodplain in Zone A)

**Databases may have since changed names or may have been replaced or improved since the analysis was completed in 2002*

Due to the large number of potential point sources in the Delaware River Watershed, a process of successive screenings was applied, including the use of a threshold value. For *Cryptosporidium*, a threshold value of 1 oocyst per liter was selected based on potential health impacts. Additionally, two different methods for time of travel estimation were applied to account for the tidal dynamics observed upstream of Trenton, NJ.

3.1.2 Step 2: Non-Point Source Inventory and Screening

3.1.2.1 Schuylkill River Watershed

A non-point source runoff screening process was also performed prior to the final ranking of *Cryptosporidium* sources. In order to identify those non-point sources that were to be included in a final ranking, a Runoff Loading Summary was developed to estimate storm runoff loadings to the river for all 10 pollutant categories, excluding volatile organic compounds, throughout the watershed (PWD 2002B). The Schuylkill River SWA Partnership developed the Schuylkill River Runoff Loading Model (SRLM) in order to estimate the pollutant loads from rainfall runoff. SWMM, EPA's Stormwater Management Model, was used to simulate rainfall runoff quantities and quality at specified inlet locations. For each subwatershed, the surface runoff volume from a particular land use predicted by SWMM was multiplied by an Event Mean Concentration (EMC) to yield a loading rate for each land use type. Land use categories were based on the USGS's National Land Cover Dataset and updated with 2000 Census data for residential and commercial areas.

Results of the loading calculations for *Cryptosporidium* within Zones A and B indicate that the highest pollutant loads are from the Perkiomen and Upper Schuylkill watersheds, through which the mainstem Schuylkill River flows. The Wissahickon and Middle Schuylkill watersheds also have high estimates of *Cryptosporidium* loads from runoff. The Tulpehocken and Upper

Schuylkill watersheds have the highest daily loads per unit area. Both subwatersheds encompass a relatively small area, and a high percentage of the land area is characterized as pasture or hay, which has the highest EMC for *Cryptosporidium* (PWD 2002b).

Following the runoff loading analysis, subwatersheds were ranked for *Cryptosporidium* according to the potential concentration of the contaminant at the intake from that source. The 30 highest-ranked subwatersheds passed through to the final ranking.

3.1.2.2 Delaware River Watershed

Similar screening and prioritization procedures were applied to identify potential non-point sources in the Baxter Source Water Assessment to include in the final ranking. The Delaware River Runoff Loading Model was developed by the Delaware River Source Water Assessment Partnership to estimate contaminant loadings to the river for all 10 pollutant categories, excluding volatile organic compounds (PWD 2002A). The model considers physical characteristics of the subwatersheds, meteorological data, land use, and event mean concentrations for the contaminant groups of interest to estimate average daily loadings.

The Zone A delineated area for an intake is defined as the area within a five-hour time of travel of the water supply intake, including one-quarter mile downstream and within a one-quarter mile wide area on either side of the stream from the intake. For the contaminant loads from rainfall-runoff, Zone A includes parts of the Neshaminy, tidal PA Bucks, Crosswicks, tidal PA Philadelphia, tidal NJ Upper, tidal NJ Lower and Rancocas subwatersheds.

Zone B for PWD’s Baxter Intake encompasses Zone A and area farther upstream in the Delaware Watershed including the NJ Mercer direct, PA Bucks direct, Tohickon, Middle Delaware and Lehigh subwatersheds. Since Zone B encompasses a larger area, the pollutant loads are greater for Zone B than for Zone A. The area contained in the Zone B delineation is about 23% impervious surfaces. Results from all contaminant categories indicated that the subwatersheds with the greater pollutant loads tend to be distributed both within Zone B delineation and along the major hydrologic features.

Results of the loading calculations for *Cryptosporidium* within Zones A and B indicated that the highest pollutant estimates are located in the Middle Delaware and Lehigh Subwatersheds. On a per acre basis, the highest load intensity occurs in the Tidal PA Bucks and Tohickon Subwatersheds.

In total, 30 potential non-point sources were selected for the final EVAMIX source ranking from an initial list of 440 subwatersheds, none of which resulted in a priority ranking of “Highest – A” or “Moderately High – B” (PWD 2002a).

3.1.3 Step 3: Final Combined Point and Non-Point Source Ranking

The final prioritization of point and non-point sources used the six criteria listed below.

- Relative Impact at Intake (weight 40%) – This criterion is based on the concentration of contamination potentially caused by the source at the intake.

- Time of Travel (weight 5%) – This is a criterion calculated as the time of travel from source to intake, based on high flow velocity.
- Potential for Release/Controls (weight 20%) – This is a qualitative criterion based on "Very High" to "Very Low" scoring.
- Violation Type/Frequency (weight 15%) – This is a qualitative criterion based on "Low" to "High" scoring.
- Location (weight 5%) – This is a qualitative criterion based on GIS analysis of the following categories:
    - In the Floodplain – 3 points
    - In Zone A – 2 points
    - In Zone B – 1 point

Final ranking results were broken down into six major categories according to the PADEP's SWA Plan. These categories are designated A through F, with A representing sources of highest protection priority and F representing sources of lowest protection priority. Potentially significant sources of contamination fall into categories A through C.

Table 3-1 below shows the results of the ranking for estimated sources of *Cryptosporidium* in the Schuylkill River watershed classified as "Highest Priority - A" or "Moderately High – B." The table indicates that priority sources of *Cryptosporidium* are NPDES dischargers. Stormwater runoff from agricultural or urbanized watersheds, if prioritized, resulted in a ranking of "Moderate – C." Most sources appear to be relatively minor contributors. Geographically, a large number of Schuylkill River Watershed sources are from relatively far upstream, in the Reading and Berks County areas. This list is not identical to that in the SWA as it has been revised to correct errata. Rows shaded in grey are proposed for reprioritization due to changes in status or operations that are detailed in subsequent text.

Analogous procedures were used for Baxter's Source Water Assessment contaminant prioritization. Results from the Delaware River EVAMIX analysis for *Cryptosporidium* classified as "Highest Priority – A" are summarized in Table 3-2. It's worth noting that higher priority sources of *Cryptosporidium* were located along the mainstem of the Delaware, the Lehigh River, and the Rancocas and Neshaminy Creeks. Advances in the hydrodynamic modeling capabilities have since improved and; as a result, several point sources formerly ranked as highest priority were reclassified with a lower prioritization. Additionally, this list has been modified to correct errata identified in the SWA. Rows shaded in grey are proposed for reprioritization due to changes in status or operations that are detailed in subsequent text.

TABLE 3-1: SCHUYLKILL RIVER WATERSHED PRIORITY CONTAMINANT CATEGORY A AND B RANKINGS FOR *CRYPTOSPORIDIUM, ADAPTED FROM* PWD 2002B

Source ID	Source Name	Source Type	Subwatershed	Zone	Time of Travel*	Relative Impact (%)	Priority
781	Montgomery County Sewer Authority	POINT	Perkiomen Creek	Floodplain	10.5	0.009	Highest - A
1613	Upper Gwynedd Twp	POINT	Wissahickon Creek	Floodplain	12.5	0.009	Highest - A
465	Whitemarsh Twp Sew Auth	POINT	Schuylkill River	Zone A	3.5	0.009	Highest - A
666	Norristown Municipal Waste Authority	POINT	Schuylkill River	Floodplain	5.5	0.009	Highest - A
795	Abington Twp WWTP	POINT	Sandy Run	Zone A	11.3	0.009	Highest - A
664	E. Norritown/Plymouth/ Whitpain Joint Sewer Auth	POINT	Schuylkill River	Floodplain	5.5	0.009	Highest - A
2503	Berks Montgomery Municipal Authority	POINT	Swamp Creek	Floodplain	23.1	0.009	Highest - A
821	Ambler Borough WWTP	POINT	Wissahickon Creek	Zone A	8.7	0.009	Highest - A
2491	Reading City	POINT	Schuylkill River	Zone B	29.5	0.009	Highest - A
464	Conshohocken STP	POINT	Schuylkill River	Zone A	3.5	0.009	Highest - A
2470	Birdsboro Borough Municipal Authority	POINT	Schuylkill River	Floodplain	24.8	0.009	Highest - A
2455	Pottstown Borough	POINT	Schuylkill River	Zone B	19.5	0.009	Highest - A
2509	Wyomissing Valley JMA	POINT	Wyomissing Creek	Zone B	31	0.009	Highest – A
665	Upper Merion Municipal Utility Authority	POINT	Trout Creek	Zone A	8	0.009	Highest – A

535	Upper Merion Twp Authority - Matsunk WPCC	POINT	Schuylkill River	Zone B	5	0.009	Highest – A
2574	Hamburg Municipal Authority	POINT	Schuylkill River	Zone B	41.8	0.009	Highest – A
2453	Upper Gwynedd-Towamencin Municipal Authority	POINT	Towamencin Creek	Zone B	16.5	0.009	Highest – A
792	Phoenixville Borough STP	POINT	Schuylkill River	Zone B	11.5	0.009	Highest – A
2521	Pennridge Wastewater Treatment Authority	POINT	East Branch Perkiomen	Floodplain	25.4	0.009	Highest – A
1614	Limerick Twp Municipal Authority	POINT	Schuylkill River	Floodplain	15	0.009	Highest – A
2474	Exeter Twp WWTP	POINT	Schuylkill River	Floodplain	25.7	0.009	Highest – A
780	Valley Forge Sewer Authority	POINT	Schuylkill River	Zone B	10	0.009	Highest – A
2485	Borough of Souderton	POINT	Skippack Creek	Zone B	18.5	0.009	Moderately High - B
2752	120 Old Philadelphia	POINT	Schuylkill River	Floodplain	22.8	0.009	Moderately High - B
2510	Antietam Valley Municipal Authority	POINT	Antietam Creek	Zone B	28.6	0.009	Moderately High - B

2516	Spring Twp Municipal Authority	POINT	Cacoosing Creek	Zone B	35.3	0.009	Moderately High - B
2473	Lower Frederick Township Treatment Plant	POINT	Perkiomen Creek	Floodplain	16.6	0.001	Moderately High - B
2723	Sinking Spring Borough Municipal Authority	POINT	Cacoosing Creek	Floodplain	36	0.009	Moderately High - B
1734	Borough of North Wales	POINT	Wissahickon Creek	Floodplain	13.2	0.001	Moderately High - B
2747	Leesport Borough Authority	POINT	Schuylkill River	Floodplain	37.1	0.001	Moderately High - B
2460	Schwenksville Borough Authority	POINT	Perkiomen Creek	Floodplain	16.1	0.001	Moderately High - B
2677	Spring City Borough Sewage Plant	POINT	Schuylkill River	Floodplain	14.5	0.001	Moderately High - B
622	Bridgeport Borough	POINT	Schuylkill River	Floodplain	5.5	0.001	Moderately High - B
2454	North Coventry Municipal Authority STP	POINT	Schuylkill River	Floodplain	19.5	0.001	Moderately High - B
2536	Oley Township Municipal Authority	POINT	Manatawny Creek	Floodplain	29.8	0.001	Moderately High - B
2476	Allegheny E. Conf. Assoc. 7th Day Adventists	POINT	Allegheny**	NA**	NA**	NA**	NA**
2556	Maidencreek Township Authority	POINT	Willow Creek	Zone B	37.6	0.001	Moderately High - B

2720	Fleetwood Borough Authority	POINT	Willow Creek	Zone B	40.7	0.001	Moderately High - B
2626	Lower Salford Twp Authority	POINT	Indian Creek	Zone B	20.5	0.001	Moderately High - B
2639	Lower Salford Twp Authority	POINT	West Branch Skippack Creek	Floodplain	16.5	0.001	Moderately High - B
2631	Telford Borough Authority	POINT	Indian Creek	Zone B	23.6	0.001	Moderately High - B

** Time of Travel based on PWD estimate of stream velocity. Estimates were made independent of the study to establish zone.*

***Corrected following the publication of the 2002 SWA.*

Notes: 1) Rows marked in grey are proposed for removal from the priority source list A.

2) Industrial dischargers were removed from the table as they are not priority sources of *Cryptosporidium*

Source: PWD (2002b). Schuylkill River Watershed Source Water Assessment.

TABLE 3-2: DELAWARE RIVER WATERSHED HIGHEST PRIORITY CONTAMINANT CATEGORY RANKING FOR *CRYPTOSPORIDIUM, ADAPTED FROM* PWD 2002A

Source ID	Source Name	Source Type	Subwatershed	Zone	Time of Travel*	Relative Impact (%)	Priority
1463	Mt. Laurel Twp MUA	POINT	Rancocas Creek	Zone A	1.5	1.33E-04	Highest-A
1443	Burlington City STP	POINT	Delaware Direct	Zone A	1.5	1.33E-04	Highest-A
1332	Delran Sewerage Authority	POINT	Delaware Direct	Floodplain	0.2	1.33E-04	Highest-A
1401	Black's Creek WWTP	POINT	Unnamed Tributary	Zone A	3.5	1.33E-04	Highest-A
1295	Ewing-Lawrence SA	POINT	Assunpink Creek**	Zone B	5.4	1.33E-04	Highest-A
1528	Pemberton	POINT	Rancocas Creek	Floodplain	4.6	1.33E-04	Highest-A
1330	Riverside STP	POINT	Rancocas Creek	Floodplain	0.2	1.33E-04	Highest-A
1255	Chalfont-New Britain Twp Joint	POINT	Neshaminy Creek	Zone B	7.9	1.33E-04	Highest-A
1447	Beverly Sewage Authority	POINT	Delaware Direct	Zone A	0.7	1.33E-04	Highest-A
1177	Easton City	POINT	Delaware Direct	Zone B	17.4	1.33E-04	Highest-A
1323	Warminster Twp. Municipal Authority	POINT	Little Neshaminy Creek	Zone B	4.8	1.33E-04	Highest-A
1350	Cinnaminson STP	POINT	Delaware Direct	Floodplain	0.0	1.33E-04	Highest-A
1186	Catasauqua Borough Authority	POINT	Lehigh River	Floodplain	23.8	1.33E-04	Highest-A
1371	Hamilton Township WPCF	POINT	Crosswicks Creek	Zone B	4.0	1.33E-04	Highest-A
1197	Bethlehem City	POINT	Lehigh River	Floodplain	21.4	1.33E-04	Highest-A
1434	Bristol Twp WP Control Plant	POINT	Delaware Direct	Zone A	1.1	1.33E-04	Highest-A
1467	Mount Holly Sewerage Authority	POINT	Rancocas Creek	Floodplain	2.6	1.33E-04	Highest-A
1413	Florence Township STP	POINT	Delaware Direct	Zone A	2.0	1.33E-04	Highest-A

1352	USATC & Fort Dix (Wastewater)	POINT	Rancocas Creek	Zone B	5.9	1.33E-04	Highest-A

** Time of Travel based on PWD estimate of stream velocity. Estimates were made independent of the study to establish zones.*

***Corrected following the publication of the 2002 SWA.*

Notes: 1) Rows marked in grey are proposed for removal from the priority source list A, see Table 3-3 for justification.

2) Three rows were deleted in its entirety due to improvements made to time of travel estimates since the original model run. These point sources include Northeast Monmouth County Regional Sewer Authority, Lambertville Municipal Utilities Authority, and Monmouth County Bayshore Outfall Authority.

3) Industrial dischargers were removed from the table as they are not priority sources of *Cryptosporidium*

Source: PWD (2002a). Delaware River Watershed Source Water Assessment.

3.2 Updates to Source Water Assessment Methodology

The contaminant category ranking for *Cryptosporidium* point and non-point sources is based on information that was gathered and evaluated prior to 2002, when the SWA was published. In order to update the methodology originally set forth in the SWA, a series of steps were taken to confirm the status of A and B priority point source dischargers. A plan to re-evaluate the original prioritization of non-point sources is also presented in this section.

3.2.1 High-Priority Point Sources

Updating the original ranking of priority dischargers in the Schuylkill River watershed, Zones A and B, required the following steps: identifying those dischargers that no longer exist or have changed names or ownership; compiling information regarding updates or improvements made to existing high-priority dischargers; and identifying recently proposed or constructed permitted facilities within the watershed. Information pertaining to NPDES permits in the Schuylkill River watershed is accessible through several databases. The following sources were used for this analysis:

- PADEP’s eFacts database;
- EPA’s Envirofacts database, including the Multi-system, PCS, and Enforcement Compliance History Online (ECHO) queries;
- PWD database containing all dischargers to the Schuylkill River; and,
- Chapter 94 Annual Reports file reviews at PADEP Southeast Regional Office.

Information concerning improvements made to existing facilities and planning initiatives for new facilities was primarily obtained from the PENNVEST and news releases. Additional information was gathered from the Schuylkill Action Network (SAN) Pathogen and Point Sources Workgroup. Through careful comparison of the information included in the above sources, several tables were created to provide an overview of relevant updates and changes made to priority point sources within the Schuylkill and Delaware River Watersheds. Beginning with Table 3-3, several NPDES dischargers have undergone significant changes in status since the original SWA prioritization. These changes in status relate to either a change in ownership, a termination of plant or company operations, or a treatment upgrade that would effectively inactivate *Cryptosporidium*.

TABLE 3-3: CHANGES IN STATUS OF A & B PRIORITY DISCHARGERS OF *CRYPTOSPORIDIUM* IN THE SCHUYLKILL RIVER WATERSHED AND A PRIORITY DISCHARGERS IN THE DELAWARE RIVER WATERSHED

Facility	Owner	Watershed	Subwatershed	Status	Description of Status Update	Priority Designation	Proposed for Removal (Y/N)
120 Old Philadelphia	Unknown	Schuylkill	Schuylkill River	Unknown	Could not be identified	Moderately High - B	Y
Laurel Lake STP	Allegheny East Conference	*Allegheny***	*Straight Run***	Active	Outside of Schuylkill River Watershed	NA**	Y
Ambler Municipal STP	Borough of Ambler	Schuylkill	Wissahickon Creek	Active	UV disinfection installation in 1999	Highest - A	Y
North Wales Borough WWTP	Borough of North Wales	Schuylkill	Wissahickon Creek	Decommissioned	Combined with Upper Gwynedd in 2011/2012 and plant was decommissioned, dissembled, and remediated	Moderately High - B	Y
CNBTJSA Advanced Wastewater Treatment Facility	Chalfont New Britain Township Joint Sewage Authority	Delaware	Neshaminy Creek	Active	UV Disinfection Installation in 1999; new UV disinfection facility installed in 2011	Highest-A	Y
Delran Township WWTP	Delran Township	Delaware	Delaware Direct	Active	Delran Sewerage Authority dissolved July 2010, when Delran Township established Sewer Department responsible for the assets, service, and liabilities	Highest-A	N
E. Norriton/Plymouth/Whitpain JSA	Aqua America (Essential Utilities)	Schuylkill	Schuylkill River	Active	Aqua Pennsylvania Inc. acquired East Norriton Township sewage system in November 2018	Highest - A	N
Exeter Twp WWTP	Pennsylvania American Water Company	Schuylkill	Schuylkill River	Active	Acquired by American Water Company in October 2019	Highest - A	N
Fleetwood Sewage Treatment Plant	Pennsylvania American Water Company	Schuylkill	Willow Creek	Active	UV Disinfection Installation in 2013	Moderately High - B	Y
Limerick Township WWTP	Aqua America (Essential Utilities)	Schuylkill	Schuylkill River	Active	Acquired by Aqua America in July 2018	Highest - A	N
Indian Creek STP	Lower Salford Twp Authority	Schuylkill	Indian Creek	Decommissioned	Flows diverted to Mainland STP in MontCo and plant was removed from service in October 2012	Moderately High - B	Y

Pemberton Twp Wastewater Treatment Plant	Pemberton Twp	Delaware	Rancocas Creek	Active	Municipal Authority dissolved in October 2019, now owned by Pemberton Township; treatment process includes UV disinfection prior to discharge	Highest-A	Y
Upper Gwynedd Township Wastewater Treatment Facility	Upper Gwynedd Twp	Schuylkill	Wissahickon Creek	Active	UV Disinfection Installation in 2013	Highest - A	Y
TMA Wastewater Treatment Facility	Towamencin Municipal Authority	Schuylkill	Towamencin Creek	Active	Name changed to Towamencin Municipal Authority in March 2015 after Upper Gwynedd withdrew shared ownership	Highest - A	N
Joint Base McGuire-Dix-Lakehurst WWTP	US Armed Forces	Delaware	Rancocas Creek	Active	Two outdated treatment plants on the McGuire and Fort Dix bases were replaced by the 1996 construction of a tertiary wastewater treatment facility at Joint Base McGuire-Dix-Lakehurst; Plant is capable of handling 4.6 MGD through total effluent recharge to aquifer	Highest-A	Y
Log College Sewage Treatment Plant	Warminister Municipal Authority	Delaware	Little Neshaminy Creek	Active	Possibility of change of ownership; received offers from several potential buyers in 2019	Highest-A	N

***Corrected following the publication of the 2002 Source Water Assessments*
Sources: PADEP eFacts, EPA ECHO 2020 Database, facility websites, news releases, and other internet sources accessed in 2020

In addition to the changes listed in Table 3-3, several originally prioritized NPDES dischargers have either undergone, or are approved to undergo, upgrades and improvements to their treatment facilities. A majority of these improvements are funded by recently approved PENNVEST loans. A detailed list containing update and improvement information is presented below in Table 3-4, for the Schuylkill and Delaware River Watersheds.

TABLE 3-4: PLANNED UPGRADES AND IMPROVEMENTS TO THE SCHUYLKILL AND DELAWARE RIVER SOURCE WATER ASSESSMENT'S PRIORITY DISCHARGERS OF *CRYPTOSPORIDIUM*

Facility	Owner	Watershed	Subwatershed	Priority	System Improvements
Conshohocken Borough STP	Borough of Conshohocken	Schuylkill	Schuylkill River	Highest - A	• Improvements to plant, pump stations and collection system outlined in 5-year capital improvement plan • In 2018 awarded CFA grant of $341,559 to help rehabilitate the Regional Sanitary Sewer Interceptor • Replacement of rotating biological contractor units 1-9 planned for FY2023; belt filter press replacement planned for FY2026
Lower Perkiomen Valley Regional Sewer Authority	Montgomery County Sewer Authority	Schuylkill	Perkiomen Creek	Highest - A	• The Perkiomen Middle Interceptor project is the final phase of the Regional Act 537 Plan approved by PaDEP in 2004 • Includes the installation of ~17,300 ft of sanitary sewer main
Fritz Island Wastewater Treatment Plant	City of Reading	Schuylkill	Schuylkill River	Highest - A	• The Reading Wastewater Treatment plant is working with an engineering firm on a $100 million upgrade project needed to accommodate capacities determined in an Act 537 special study and the City's Consent Decree with the Department of Justice
Sinking Spring Borough STP	Municipal Authority of the Borough of Sinking Spring	Schuylkill	Cacoosing Creek	Moderately High - B	• $1.7M PA Infrastructure Investment Authority loan to replace 2,950 ft of sanitary sewer line and eliminate raw sewage discharges into Cacoosing Creek
Upper Gwynedd Township Wastewater Treatment Facility	Upper Gwynedd Twp	Schuylkill	Wissahickon Creek	Highest - A	• Currently implementing Wastewater Improvement Program • WIP will expand the sewer infrastructure to allow UGT the ability to divert the wastewater currently being sent to the Towamencin Municipal Authority back to Upper Gwynedd Township's Wastewater Treatment Plant – reducing SSOs and allowing rate payer money to be invested in the township.

TMA Wastewater Treatment Facility	Towamencin Municipal Authority	Schuylkill	Towamencin Creek	Highest - A	• Awarded $200,000 in CFA funding in March 2019 for a Biosolids Process Transformation and Optimization Planning Study, leading to the adoption of a sustainable biosolids treatment, handling and disposal process within 5 yrs
Whitemarsh WPCC	Whitemarsh Township Authority	Schuylkill	Schuylkill River	Highest – A	• In 2018 awarded CFA grant of $323,000 to assist with the rehabilitation of the wastewater treatment plant
Morrisville STP	Morrisville Borough Municipal Authority	Delaware	Delaware Direct	Moderately High - B	• Completed feasibility study in 2015, is in the process of completing the Act 537 report and has undertaken an economic study, all to evaluate the best alternative(s) for replacing the existing Sewer Plant • New plant is estimated to cost $100M or $80M depending on option selected (2018)

Note: This is not an exhaustive list of all planned facility upgrades in the area of interest

As a final step, EPA's ECHO database was reviewed for any possible violations at the SWA's highest-priority NPDES dischargers. Dischargers with either a significant violation or a violation requiring formal enforcement action within the last five years were identified. Table 3-5 lists which dischargers met either one or both criteria at the time the ECHO database was queried. The City of Reading is not included in the table as they no longer report compliance information to the database and are under a consent decree with the United States Department of Justice.

TABLE 3-5: VIOLATIONS AND ENFORCEMENT ACTIONS AGAINST PRIORITY DISCHARGERS

Priority Discharger	Watershed	Alleged Current Significant Violations [1]	Quarters with Noncompliance (3 years) [1]	Formal Enforcement Action (5 years) [1]
Abington Twp WWTP	Schuylkill	No	1	1
Swamp Creek STP (Berks Montgomery Municipal Authority)	Schuylkill	No	9	0
Bethlehem City*	Delaware	No	4	0
Beverly Sewage Authority	Delaware	No	8	0
Birdsboro Borough MA	Schuylkill	No	5	0
Bordentown Sewerage Authority*	Delaware	No	0	0
Bristol Township Sewerage Treatment Plant*	Delaware	No	7	1
Burlington City STP*	Delaware	No	11	0
Catasaqua Borough Authority	Delaware	No	2	1
Cinnaminson Township Sewerage Authority*	Delaware	No	9	0
Conshohocken STP*	Schuylkill	No	3	0
Delran Sewerage Authority	Delaware	No	11	0
E. Norriton/Plymouth/Whitpain JSA*	Schuylkill	No	6	0
Easton City*	Delaware	No	6	0
Ewing-Lawrence SA*	Delaware	No	11	1
Exeter Twp STP*	Schuylkill	No	7	3
Florence Township STP*	Delaware	No	6	0
Hamburg Boro Wastewater Treatment Plant	Schuylkill	No	3	1
Hamilton Township WPCF*	Delaware	No	8	0
Limerick Twp Municipal Authority*	Schuylkill	No	1	1
Montgomery County Sewer Authority*	Schuylkill	No	12	0
Mount Holly Municipal Utilities Authority *	Delaware	No	11	0
Mt. Laurel Municipal Utilities Authority*	Delaware	No	8	0
Norristown Municipal STP	Schuylkill	No	6	0
Pennridge Wastewater Treatment Authority*	Schuylkill	No	2	1
Phoenixville Borough STP	Schuylkill	No	0	0
Pottstown Borough*	Schuylkill	No	10	0
Riverside Township Sewerage Authority*	Delaware	No	11	0
Sinking Spring Borough Municipal Authority*	Schuylkill	No	1	0
Upper Gwynedd-Towamencin Municipal Authority	Schuylkill	No	5	1
Upper Merion Municipal Utility Authority*	Schuylkill	No	4	0
Upper Merion Twp Authority- Matsunk WPCC	Schuylkill	No	2	0
Valley Forge Sewer Authority*	Schuylkill	No	3	0
Warminster Twp Municipal Authority*	Delaware	No	1	0
Whitemarsh Twp SA	Schuylkill	No	10	0
Antietam Valley Municipal Authority	Schuylkill	No	2	0
Borough of Souderton	Schuylkill	No	3	0
Bridgeport Borough	Schuylkill	No	1	0
Lower Frederick Township Treatment Plant	Schuylkill	No	4	1

Lower Salford Twp Authority (West Branch Skippack Creek)	Schuylkill	No	1	0
Maidencreek Township Authority	Schuylkill	No	0	0
North Coventry Municipal Authority STP	Schuylkill	No	3	0
Oley Township Municipal Authority	Schuylkill	No	3	0
Schwenksville Borough Authority	Schuylkill	No	7	0
Spring City Borough Sewage Plant	Schuylkill	No	8	0
Telford Borough Authority	Schuylkill	No	4	0
Spring TWP MA	Schuylkill	No	2	0
Wyomissing Valley JMA	Schuylkill	No	1	0

[1] Statistics are representative of the current compliance status when the EPA ECHO database was queried in August 2020. Quarters with noncompliance goes back three years prior to the date of the query, while formal enforcement actions go back 5 years from the date the database was queried.
[2] Description from quarter 12 results. Quarter 13 was in draft/unofficial form and was not fully quality assured at the time of this compilation.
[3] Statistics from EPA ECHO's Effluent Exceedances Report at the time of compilation for date range September 2019 through August 2020. Note Records identified as potential outliers or data errors are not counted.
Multiple CWA NPDES permits listed for this facility; permit number shown reflect the major NPDES individual permit
Source: EPA (2020). ECHO Database, accessed August 2020.

The current significant violations column indicates violations by a point source discharger of sufficient magnitude or duration to be a regulatory priority (US EPA 2010c). Significant violations may include reporting violation and/or effluent violations. Notably, none of the priority dischargers in the area of interest had an alleged significant violation at the time the database was queried. The fifth column displayed in Table 3-4, formal enforcement action, indicates the number of enforcement actions that have been taken against a facility within the last five years. It should be noted that not all violations receive formal enforcement action. Minor violations, or violations that are short in duration or quickly corrected by the facility, may not warrant formal action. Those dischargers that are listed as receiving formal enforcement action but do not have any listed significant violations were all found to have at least one quarter in non-compliance status during the last three years. For more detailed information on specific violations and enforcement actions, the EPA ECHO database can be accessed at https://echo.epa.gov/. Information on the database is updated regularly.

In the Delaware Watershed, Bristol Township, Catasaqua Borough Authority, and Ewing-Lawrence Sewerage Authority all had at least one formal enforcement action over the last five years. Of the Schuylkill River Watershed dischargers, Abington Township, Exeter Township, Hamburg Borough, Limerick Township, Pennridge Wastewater Treatment Authority, Upper Gwynedd-Towamencin Municipal Authority, and Lower Frederick Township Treatment Plant all had at least one formal enforcement action over the last five years. Exeter Township had three formal enforcement actions within the last five years, which is more than any of the other priority dischargers that were reporting data to the ECHO database. Exeter Township, Bristol Township, and Ewing-Lawrence Sewerage Authority also had the most quarters with non-compliance. Exeter and Bristol each had 7 out of 12 quarters in noncompliance while Ewing-Lawrence had 11 out of 12 in non-compliance.

According to Table 3-4 above, no additional upgrades or improvements are planned at these facilities. However, the Exeter Township WWTP was acquired by American Water in October 2019, which plans to commit resources to improving environmental compliance and increasing reliability of operations.

3.2.2 High-Priority Non-Point Sources

Although the majority of priority dischargers in Zones A and B consist of NPDES facilities, the SWA's runoff loading analysis revealed that runoff from several Schuylkill River subwatersheds is a potentially significant source of *Cryptosporidium.* As previously explained, the loading analysis is based on two variables: the event mean concentration (EMC) and the subwatershed's land use category. Land use categories were identified for each subwatershed using the USGS's National Land Cover Dataset (NLCD) and were updated with 2000 Census data for residential and commercial areas (PWD 2002b). Assuming that the EMC remains constant, an update of non-point priority sources would involve a re-evaluation of land use within the Schuylkill River watershed. The observations made about watershed land use from the 2000 estimates in the SWA will be used in this analysis. Direct comparison between the 1992 NLCD and 2001 NLCD has been discouraged by USGS, leading PWD to consider alternate approaches that would avoid the uncertainty and possible inaccuracy associated with projecting changes in land use since the SWA.

PWD chose an alternate approach that focuses on changes in the numbers of certain livestock in each county located within the watershed. This approach was deemed appropriate since contamination from animal feces is the primary source of *Cryptosporidium* in agricultural runoff. In fact, an infected calf or lamb is capable of producing more oocysts per day than 1,000 infected immuno-compromised people (Crockett & Haas 1997). PWD's simple quantitative analysis focuses on updating the numbers of cows/calves, sheep/lambs, and hogs/pigs over the course of three decades, from 1987 to 2017. The data from each county's animal inventory was multiplied by the percentage of the county area physically located within the watershed to provide a more accurate estimation of the number of animals within the Schuylkill River watershed. The percentage of the land area from each county is shown in Table 3-6 for reference. The livestock inventory data used for this analysis was provided by the USDA's Census of Agriculture, which is published every five years.

The livestock data are displayed in Table 3-7 for the Schuylkill River Watershed only. The table presents the data by county and includes the percent differences from the most recent census year, from 2012 to 2017, and overall percent change from 1987 to 2017. It should be noted that Berks and Montgomery counties each contain more than 80% of their land area within the Schuylkill River Watershed, and together they constitute more than 60% of the entire watershed.

TABLE 3-6: LAND AREA DISTRIBUTION OF THE SCHUYLKILL RIVER WATERSHED, BY COUNTY

County	% County Land Area in Schuylkill Watershed	% Schuylkill Watershed in County
Berks	87.2%	39.5%
Bucks	11.9%	3.9%
Carbon	1.9%	0.4%
Chester	22.9%	9.1%
Delaware	1.3%	0.1%
Lancaster	0.01%	0.01%
Lebanon	14.7%	2.8%
Lehigh	20.2%	3.7%
Montgomery	82.8%	21.1%
Philadelphia	32.2%	2.4%
Schuylkill	41.5%	17.0%

TABLE 3-7: SUMMARY OF CERTAIN GROUPS OF LIVESTOCK FOR COUNTIES LOCATED IN THE SCHUYLKILL RIVER WATERSHED, 1987-2017

County	Cattle and Calves							% Change 2012 to 2017	% Change 1987 to 2017
	1987	1992	1997	2002	2007	2012	2017		
Berks	60,149	56,892	55,066	52,481	58,368	69,132	74,596	7.9%	24.0%
Bucks	1,421	1,191	1,189	917	769	832	1,160	39.4%	-18.4%
Carbon	24	24	31	19	20	27	28	1.7%	15.0%
Chester	12,475	11,635	11,603	9,592	9,322	9,031	10,876	20.4%	-12.8%
Delaware	16	5	6	1	--	--	--	--	--
Lancaster	--	--	33	33	35	37	33	-9.2%	--
Lebanon	7,058	7,168	7,688	7,731	8,345	8,698	9,488	9.1%	34.4%
Lehigh	1,116	803	967	737	721	780	817	4.8%	-26.8%
Montgomery	9,650	6,447	7,550	5,915	3,523	2,743	3,540	29.0%	-63.3%
Philadelphia	--	--	--	--	--	--	--	--	--
Schuylkill	4,463	5,171	5,640	4,469	4,985	5,293	5,472	3.4%	22.6%
Total	96,372	89,336	89,773	81,895	86,087	96,572	106,011	9.8%	10.0%

County	Hogs/Pigs							% Change 2012 to 2017	% Change 1987 to 2017
	1987	1992	1997	2002	2007	2012	2017		
Berks	41,095	54,973	56,062	53,631	62,072	58,083	68,149	17.3%	65.8%
Bucks	553	204	83	185	47	63	92	45.1%	-83.4%
Carbon	24	23	18	5	3	1	2	61.5%	-91.8%
Chester	2,980	2,715	540	2,946	4,198	6,286	4,934	-21.5%	65.6%
Delaware	--	--	0	--	--	--	--	--	--
Lancaster	42	48	45	49	45	48	42	-12.7%	--
Lebanon	7,257	10,973	13,529	16,575	14,691	14,973	13,280	-11.3%	83.0%
Lehigh	2,424	1,693	1,367	585	833	427	--	--	--
Montgomery	8,050	5,571	7,633	3,974	6,536	2,419	879	-63.7%	-89.1%
Philadelphia	--	--	--	--	--	--	7	--	--
Schuylkill	5,978	9,609	8,073	9,079	8,356	9,839	4,313	-56.2%	-27.9%
Total	68,405	85,809	87,349	87,028	96,782	92,139	91,697	-0.5%	34.1%

County	Sheep/Lambs							% Change 2012 to 2017	% Change 1987 to 2017
	1987	1992	1997	2002	2007	2012	2017		
Berks	2,377	2,100	1,671	1,725	2,165	2,007	2,869	42.9%	20.7%
Bucks	208	307	173	229	276	228	193	-15.3%	-7.2%
Carbon	5	4	10	5	11	4	6	35.2%	14.9%
Chester	702	784	493	654	694	623	406	-35.0%	-42.2%
Delaware	--	2	--	1	2	2	1	-26.7%	--
Lancaster	1	1	1	1	1	1	1	17.4%	--
Lebanon	335	273	184	240	259	297	371	24.8%	10.6%
Lehigh	202	235	187	208	250	144	151	--	--
Montgomery	607	653	662	1,400	802	884	589	-33.4%	-3.0%
Philadelphia	--	--	--	--	6	--	--	--	--
Schuylkill	395	208	51	129	179	124	171	38.6%	-56.6%
Total	4,833	4,566	3,432	4,593	4,645	4,313	4,757	10.3%	-1.6%

County	Horses/Ponies							% Change 2012 to 2017	% Change 1987 to 2017
	1987	1992	1997	2002	2007	2012	2017		
Berks	1,249	933	1,302	1,988	2,251	2,570	1,747	14.2%	39.8%
Bucks	187	154	177	302	356	386	235	8.3%	25.9%
Carbon	2	2	2	4	3	2	4	-24.5%	81.0%
Chester	1,122	991	1,212	1,968	1,791	2,060	1,635	15.0%	45.8%
Delaware	5	3	3	2	4	4	4	3.3%	-26.2%
Lancaster	1	1	1	2	2	2	2	5.1%	34.5%
Lebanon	107	132	135	257	309	314	227	1.4%	112.4%
Lehigh	151	114	150	288	160	241	365	50.3%	141.2%
Montgomery	694	1,020	844	1,439	1,465	1,745	159	19.1%	-77.1%
Philadelphia	--	--	19	--	31	38	71	0	--
Schuylkill	124	178	209	434	370	337	378	-8.8%	203.3%
Total	3,643	3,528	4,054	6,684	6,742	7,699	4,827	14.2%	32.5%

Source: USDA (2019). Tables 11, 12, 13, and 18. Census of Agriculture [for 1987 through 2017]. Available at https://www.nass.usda.gov/AgCensus/index.php.

Trends in animal inventory data vary greatly depending on the group of animals being considered. Cattle/calves, which are the greatest known sources of *Cryptosporidium* oocysts (Crockett & Haas 1997), have increased in number in the watershed by approximately 10%. Sheep/lambs are the only group of animals demonstrating a slight decrease in number throughout the entire watershed, with an estimated decrease of 1% from 1987 to 2017. Cattle/calves have increased in number in Berks County (25%) but have decreased in Montgomery County by 63%. Sheep/lambs have increased in Berks County by 21% but have decreased in Montgomery County over the past three decades by 3%.

Figure 3-1 summarizes the results for each group of livestock in the Schuylkill River Watershed for the 1987 through 2017 USDA Census of Agriculture.

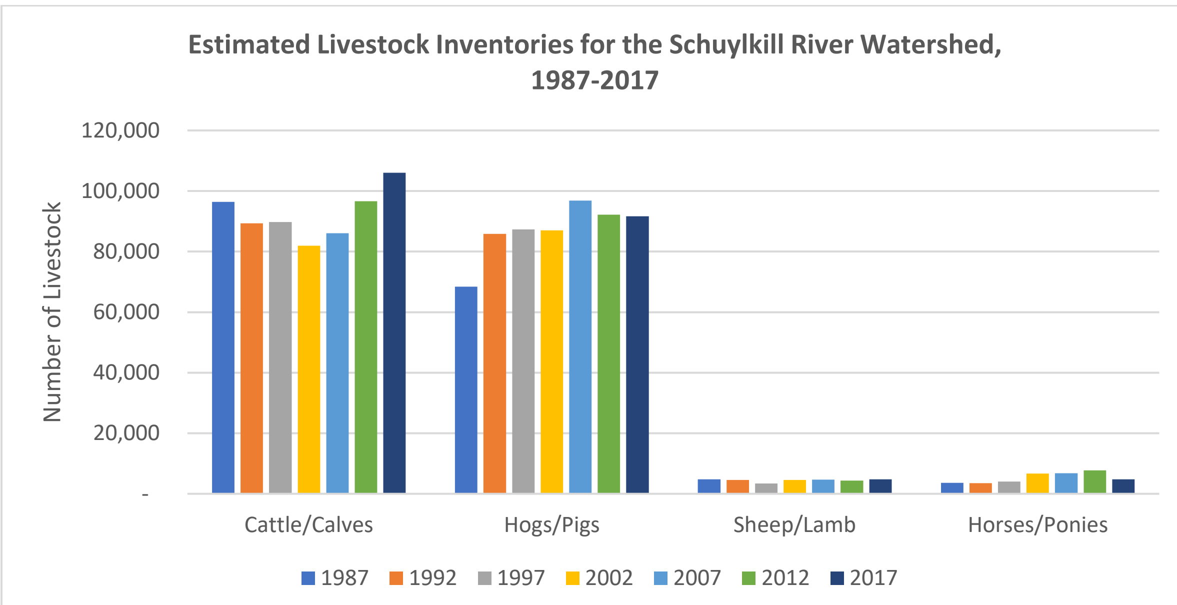


FIGURE 3-1: NUMBER OF LIVESTOCK BY YEAR IN THE SCHUYLKILL RIVER WATERSHED, DATA SOURCE USDA CENSUS OF AGRICULTURE.

Results from the USDA animal inventories broadly indicate that agricultural activity is either remaining relatively constant or is increasing throughout the watershed. Cattle/calves, which are perhaps the most important animals to consider when accounting for sources of *Cryptosporidium* contamination, have been increasing in number in the last two decades. In addition, land use data analyzed for the SWA estimates that developed lands in the Schuylkill River watershed have increased by more than 30% from 1982 to 1997 (PWD 2002b). During that time period, agricultural lands decreased by 14% and forested lands decreased by 5%. It is clear that control measures aimed at reducing the impact of livestock and agricultural lands on *Cryptosporidium* levels are of primary importance. However, there is reasonable evidence to conclude that agricultural activity, and the threat it poses to our waterways, has decreased as development has increased.

Agricultural activity in regard to Animal Feeding Operations, AFOs, is a concern in regard to pathogen contamination due to the potentially high number of livestock that can be housed at these facilities. EPA defines an AFO as a facility where animals are confined for 45 days or more per year and where no vegetation grows in the area of confinement (US EPA 2008). AFOs are considered Concentrated Animal Feeding Operations (CAFOs) when a certain number of a specified animal type is confined or stabled. For example, an AFO would be considered a large CAFO if 700 mature dairy cows or more are stabled or confined at the farm site. Currently, the EPA requires all CAFOs that either discharge or propose to discharge apply for a NPDES permit. Permitted CAFOs must also develop Nutrient Management Plans (NMPs) to address manure handling, storage, and land application. An NMP may include plans to ensure adequate manure storage, install riparian buffers where manure is applied, and limit the manure land application rate. While these plans focus on the implementation of BMPs that will reduce phosphorus and nitrate contamination, the same management practices can also reduce the risk of *Cryptosporidium* contamination (US EPA 2008).

According to PADEP data from October 2019, a total of 36 CAFOs exist in the Schuylkill River watershed, representing a total of more than 25,200 animal equivalent units (AEUs, 1 AEU = 1,000 lbs of animal weight). The type of livestock varies by farm, and includes beef and dairy cattle, swine, chicken and other poultry (PADEP, personal communication, October 2019). These totals mark a slight increase from PADEP's 2018 data, during which 32 CAFOs representing more than 22,700 AEUs existed in the Schuylkill River watershed.

3.2.3 Source Tracking Project Results

3.2.3.1 Wissahickon Creek, May 2005-April 2008

The SWA's source prioritization methodology is only one of several approaches employed by PWD to identify actual and potential sources of *Cryptosporidium.* Recent source tracking projects have improved PWD's understanding of not only the sources but also the vectors of oocyst contamination throughout the watershed. These projects were led by Lehigh University, with PWD providing support in terms of sampling and general project management.

The first of two extensive source tracking projects focused on *Cryptosporidium* sources within the Wissahickon watershed. Objectives of the project included "…determining the frequency of *Cryptosporidium* presence in the Wissahickon Creek, determining the genotypes and likely sources of *Cryptosporidium* in the watershed, and identifying the times of year when oocysts, particularly those genotypes associated with human disease, are prevalent in the Wissahickon Creek" (Jellison et al 2009). Given that the Wissahickon Creek flows into the Schuylkill River less than 0.5 miles upstream of the intake, Wissahickon water quality characteristics can heavily influence conditions at Queen Lane.

Throughout the duration of the study, from May 2005 to April 2008, 129 samples were analyzed from Wissahickon Creek, 83 samples were analyzed from wastewater treatment plants, and 240 fecal droppings were analyzed from throughout the watershed. Samples were taken from two locations in Wissahickon Creek, WISS 410 and WISS 140, and from three treated WWTP effluents. WISS 410 is heavily impacted by five WWTP dischargers. WISS 140, which is located farther downstream than WISS 410, is within city limits and is located downstream of Fairmount

Park. Results from the study indicate that oocysts were detected in 22% of Wissahickon Creek samples, 5% of WWTP samples, and 7% of fecal samples. Outcomes from the study also reveal that oocysts were detected year round, independent of wet-weather events and with no apparent seasonal trend (Jellison et al 2009). Figure 3-2 illustrates the location of WISS 140, WISS 410, and the three WWTP sampling locations in relation to the Queen Lane intake.

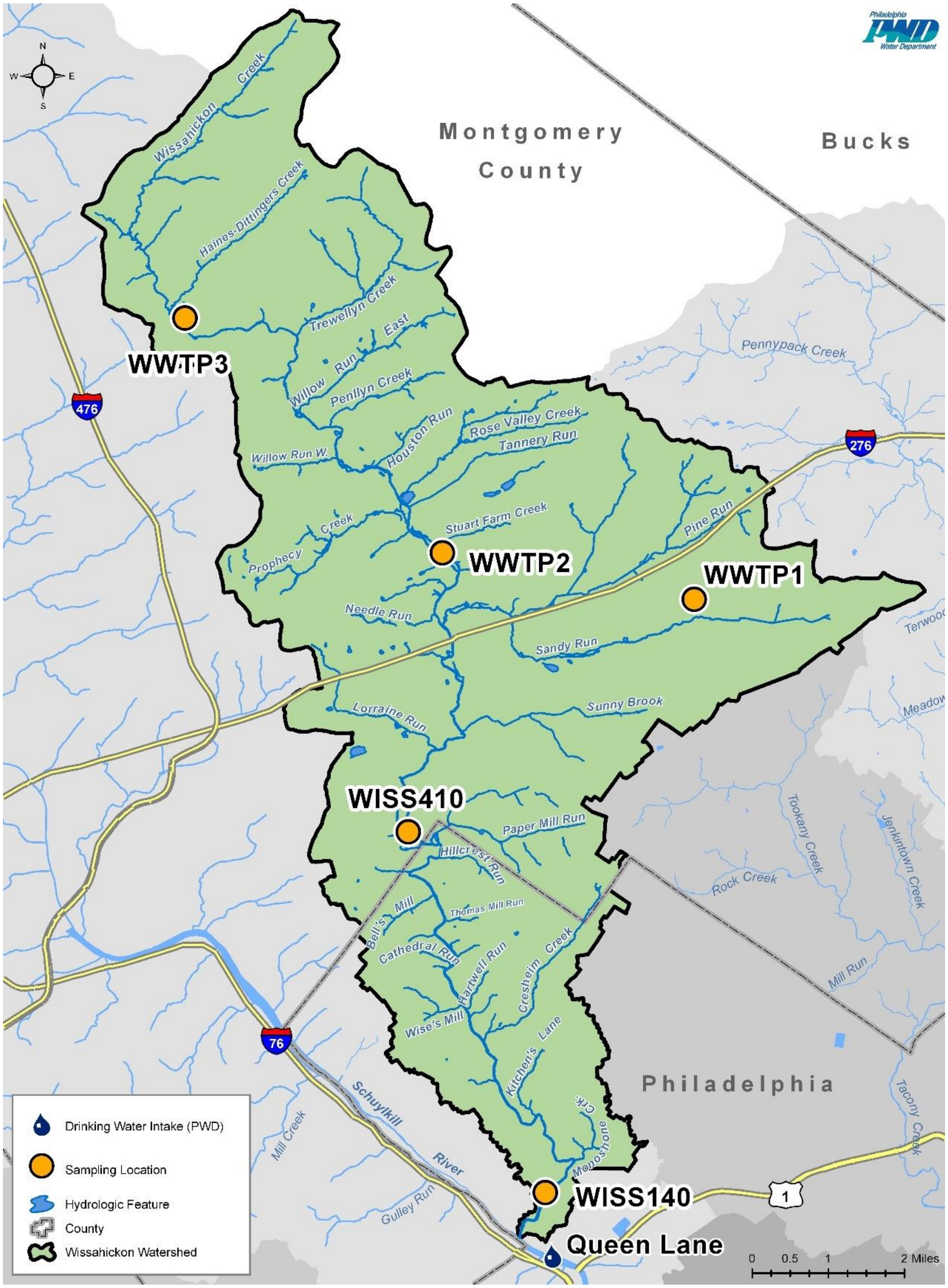


FIGURE 3-2: CRYPTOSPORIDIUM SOURCE TRACKING SAMPLING LOCATIONS IN THE WISSAHICKON WATERSHED

The *Cryptosporidium* genotypes in each sample were identified using the polymerase chain reaction (PCR) method. Human infectious genotypes were identified in 65%, 88%, and 64% of the *Cryptosporidium* sequences collected from Wissahickon Creek, WWTP, and fecal samples, respectively (Jellison et al 2009). A slightly higher percentage of human-infectious genotypes were found at WISS 410 than at WISS 140, implying that human health risk may be reduced as water travels downstream through the lower watershed. In addition, the genotypes detected in the WWTP effluent samples were closely related to those genotypes detected in Wissahickon Creek, suggesting that WWTPs are a source of *Cryptosporidium* oocysts. In regard to fecal sampling results, several genotypes were detected in a single deer or goose fecal sample, and multiple unusual genotypes, including *C. parvum* and a *C. hominis*-like genotype, were detected across numerous positive samples.

3.2.3.2 Queen Lane and WISS 140, September 2008-May 2010

To expand upon the results of the Wissahickon Creek source tracking study, Lehigh University and PWD collaborated on a second *Cryptosporidium* detection and genotyping study, which ran from September 2008 to May 2010. The objectives of this second study focus on water quality conditions at the Queen Lane Intake. Goals include identifying the frequency of *Cryptosporidium* at Queen Lane and WISS 140 and determining the public health risk associated with the detected genotypes (Jellison 2010a). This study also included a genotyping analysis of goose feces collected from the Philadelphia area (Pennypack Creek, Valley Green and Kelly Drive) and the Lehigh area (Monocacy Creek and Saucon Valley Park). Unlike the Philadelphia area, the Monocacy Creek is negligibly impacted by treated wastewater. Samples from both areas were compared to determine if geese generally transmit human-infectious *Cryptosporidium* spp. genotypes, or if geese are serving as vectors of human-infectious genotypes that originate from WWTP effluent.

Two detection methods were used in this study: PCR and Fluorescent *in-situ* hybridization (FISH). The primary difference between the PCR and FISH methods is that FISH detects, but does not differentiate between, two species of viable, human-infectious oocysts, *C. hominis* and *C. parvum*. PCR will detect and differentiate any species or genotype of *Cryptosporidium* in a sample but will not differentiate between viable and nonviable oocysts. In addition, FISH provides a quantitative oocyst count while the PCR method only provides information on oocyst presence/absence (Jellison 2010b).

Results from this study indicate that oocysts were detected at the Queen Lane intake on 5 (16.1%) of 31 days since September 2008 and at WISS 140 on 2 (20.0%) of 10 days since September 2009 (Jellison 2010a). The detection frequency for this study is very similar to the detection frequency in the previously described Wissahickon Creek study that ran from May 2005-April 2008. However, the phylogenetic analysis shows that the *Cryptosporidium* sequences removed from the Queen Lane intake samples were not identical to the sequences recovered from the Wissahickon Creek, indicating that sources outside of the Wissahickon Creek watershed are contributing to oocyst levels at the intake. Both of the *Cryptosporidium* genotypes detected at the intake, *C. hominis* and *C. parvum*, are human-infectious genotypes that may pose a public health risk.

Oocyst detection during this study was not identical among filters collected on the same day at a specified sampling location (Jellison 2010a). Discrepancies were also present between the results of the PCR genotyping analysis and the FISH assay. FISH results yielded a significantly higher rate of oocyst detection, suggesting that viable human-infectious oocysts may be present at the intake more frequently than previously indicated by the genotyping analysis.

In addition to sampling at the intake and WISS 140, a total of 217 goose fecal samples were analyzed for this study since July 2008. No oocysts were detected in the goose samples from the Lehigh area. Conversely, 11 (7.5%) of the 147 goose samples from the Philadelphia area (including Pennypack Creek, Valley Green, and Kelly Drive), which is influenced by WWTP effluent, were positive for *Cryptosporidium*. *C. parvum* and *C. hominis*-like genotypes were detected in 8 of 11 geese. *C. parvum* and *C. hominis* are the primary genotypes associated with human illness (Nichols 2008).

3.2.3.3 Schuylkill Watershed Genotyping, October 2015 to April 2017

In 2015, PWD and Lehigh University embarked on a research monitoring program to characterize the Schuylkill River watershed for *Cryptosporidium*. The project compared the *Cryptosporidium* species present in subwatersheds of the Schuylkill River, and documented and analyzed upstream watershed conditions at the time the *Cryptosporidium* sample was collected.

There were two objectives of the study. The first objective was to identify and compare detection of *Cryptosporidium* species at different locations within the Schuylkill River watershed. The second objective was to collect water quality and watershed data to analyze for correlations with *Cryptosporidium* detection and watershed conditions.

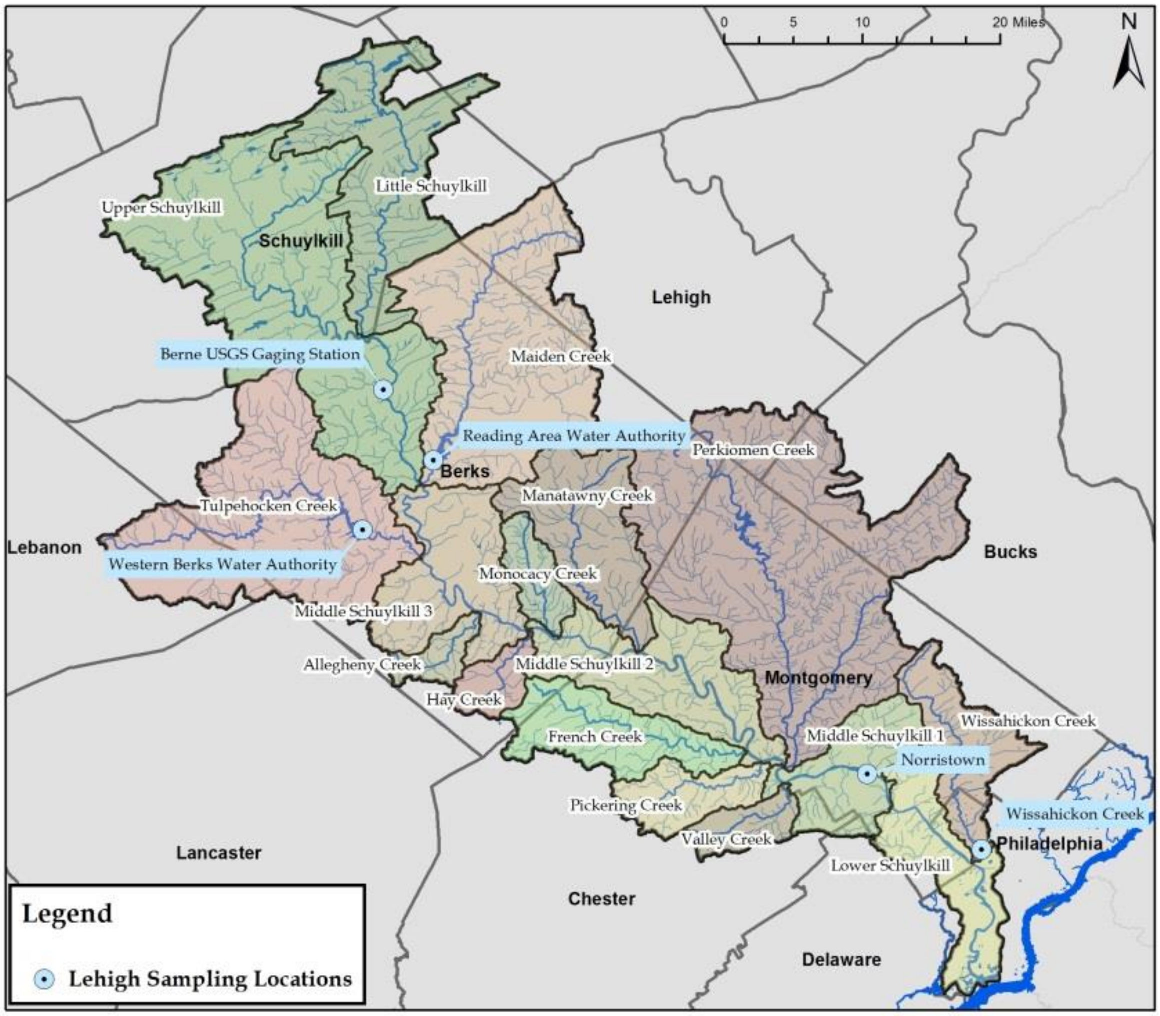


FIGURE 3-3: SCHUYLKILL RIVER WATERSHED SAMPLE COLLECTION LOCATION MAP FOR 2015-2017 STUDY

Five locations in the Schuylkill River watershed were selected for *Cryptosporidium* sample collection and are shown in Figure 3-3 and detailed in Table 3-8. The Lehigh University team collected samples from the sites at Reading Area Water Authority on Lake Ontelaunee, Western Berks Water Authority on the Tulpehocken Creek and the USGS gage station on the Schuylkill River at Berne, PA, collectively referred to as the "Upper Watershed." The PWD team collected samples from the Schuylkill River at Norristown and the Wissahickon Creek in Philadelphia, collectively referred to as the "Lower Watershed." Monitoring began in October 2015 and samples were collected twice per month. Two sample collection methods were used: biofilm samplers and filtration.

Table 3-8: Site Description and Sample Collection Method, 2015-2017 Source Tracking Study

Site ID	Site Description	Sample Collection Method
Berne	USGS gage station on the Schuylkill River at Berne	Filter and biofilm
RAWA	Reading Area Water Authority, Lake Ontelaunee	Biofilm
WBWA	Western Berks Water Authority, Tulpehocken Creek downstream of Blue Marsh Reservoir	Biofilm
Norristown	Schuylkill River at Dekalb Bridge, Bridgeport, PA side	Filter
Wissahickon Creek	Wissahickon Creek, 330 yards below Monoshone confluence in Philadelphia	Filter

At each of the five sites, one or both sample collection methods were used. Biofilm samplers are devices machined from plastic that hold up to twelve glass microscope slides. The biofilm samplers are weighted with gravel-filled PVC pipes and have 0.20-inch x 0.30-inch mesh sides to protect the slides from large debris. The biofilm samplers are placed in stream for a period of two to three weeks, during which time a biofilm forms on the glass microscope slide. *Cryptosporidium* attach to this biofilm (Jellison, 2010). On each sample date, the microscope slides are collected from all biofilm samplers and replaced with clean slides. For sample collection by filtration, the Pall Envirochek HV capsule filters approved under EPA Method 1623 for collection of *Cryptosporidium* samples were used. Although samples are collected using the EPA-approved filters, this research effort does not follow Method 1623. The method of sample collection at each site is listed in Table 3-8.

All samples were analyzed at Lehigh University and processed through immunomagnetic separation (IMS), DNA extraction, and nested polymerase chain reaction (PCR). Samples that tested positive for *Cryptosporidium* by PCR are sequenced and genotyped to identify the species of *Cryptosporidium* detected.

Due to quality control issues early in the study, samples collected in October and early November were eliminated from analysis. Additionally, samples collected on 4/18/16 and 5/2/16 were eliminated from analysis due to contamination during laboratory analysis. Only data from samples with oocyst detection that was confirmed positive from genetic sequencing collected from 10/13/15 through 3/28/17 are included in the detection frequencies.

Frequency of oocyst detection was 8.3% (2 of 24) at RAWA; 0% (0 of 26) at WBWA; 8.7% (2 of 23) at Berne-biofilm; 4.3% (1 of 23) at Berne-filter; 36% (9 of 25) at Norristown and 20% (5 of 25) at Wissahickon. Oocysts were detected more frequently in the lower watershed sampling locations (20% and 36%) than the upper Schuylkill Watershed sampling locations (0-8.7%). Oocyst detection followed a seasonal pattern: the highest detection rates occurred during the winter months, a slightly lower detection rate in the fall, and no detections in the spring and summer meteorological seasons.

At Berne, the only site where both filtration and biofilm samplers are used concurrently, the percent frequency of oocyst detection was comparable by both methods (8.7% by biofilms compared with 4.3% by filtration). The results are summarized in Table 3-9.

TABLE 3-9: SUMMARY OF SOURCE TRACKING RESEARCH RESULTS FROM NOVEMBER 2015-MARCH 2017

Site ID	Sample Type	Samples Taken	Confirmed Positive Samples	Percent Positive Samples
RAWA	Biofilm	25	2	8.3%
WBWA	Biofilm	26	0	0.0%
Berne	Biofilm	23	2	8.7%
Berne	Filter	24	1	4.3%
Norristown	Filter	26	9	36.0%
Wissahickon	Filter	26	5	20.0%

The positive samples for *Cryptosporidium* have been genotyped and the results for all five sites are summarized in Table 3-10-10. Analysis of the positive samples shows that *C. andersoni* was the only *Cryptosporidium* species detected in the upper watershed at Berne and RAWA. *C. andersoni* is primarily found in cattle, although there have been a number of reports of *C. andersoni* in human infections (Leoni et al. 2006; Morse et al. 2007; Waldron et al. 2011; Agholi et al. 2013; Liu et al. 2014). *C. andersoni* was also detected at Norristown, but not at Wissahickon.

The genotype profiles detected in the lower watershed are more varied, with a mixture of human- and wildlife-associated *Cryptosporidium* species and genotypes detected at the Norristown and Wissahickon sites. *C. hominis* was found in four samples at Norristown and three samples at Wissahickon. *C. parvum* was not found at any sampling location. *C. hominis* and *C. parvum* are the two *Cryptosporidium* species most commonly associated with human disease.

From these data, it is possible that the *Cryptosporidium* profiles in the upper watershed are impacting the lower watershed as the *C. andersoni* genotypes detected in the upper watershed closely match those detected at Norristown. Additionally, other influences (both wildlife and human) are contributing to the genotype profiles observed in the lower watershed. Of the wildlife-associated genotypes detected in the lower watershed, *C. ubiquitum* (Fayer et al. 2010; Elwin et al. 2012) and the skunk genotype (Robinson et al. 2008) have both been reported in human infections.

TABLE 3-10: GENOTYPES DETECTED AT EACH SAMPLING LOCATION

Site ID	Genotypes Detected (# samples)	Dates Detected	Major Host	Reported in Humans
Berne	*C. andersoni* (3)	1/18/16; 2/1/16; 3/13/17	Cattle	Yes
RAWA	*C. andersoni* (2)	1/5/16; 2/22/16	Cattle	Yes

WBWA	---	---		
Norristown	*C. andersoni* (5)	1/5/16; 1/18/16; 2/1/16; 2/22/16; 3/7/16	Cattle	Yes
	C. hominis (4)	2/1/16; 10/17/16; 11/14/16;	Humans	Yes
	C. ubiquitum (1)	11/30/15	Ruminants, Rodents, Primates	Yes
	Avian genotype III (1)	1/18/16	Birds	No
Wissahickon	*C. hominis* (3)	11/30/15; 1/18/16; 2/22/16	Humans	Yes
	C. ubiquitum (2)	1/18/16; 2/1/16	Ruminants, Rodents, Primates	Yes
	C. ubiquitum-like (1)	1/18/16	--	--
	Skunk genotype (2)	11/30/15; 1/18/16	Skunk, Raccoon	Yes
	Deer mouse	11/30/15; 1/18/16; 2/1/16	Rodents	No
	Goose genotype II (1)	1/9/17	Geese	No
	Duck genotype b (1)	2/1/16	Birds	No

Water quality parameter measurements (i.e., temperature, pH, conductivity, dissolved oxygen (DO), turbidity, and chloride) were taken at each sampling location. Those data, along with ancillary watershed data (i.e., average ambient temperature, average discharge, and total precipitation accumulation) were analyzed for correlations to *Cryptosporidium* detection. A significant relationship between both water temperature and positive oocyst detection was observed in the lower watershed sites and Berne-biofilm, with detections more frequent in colder temperatures. At the lower watershed sites, positive detections also correlated with higher dissolved oxygen. DO is a temperature dependent parameter with higher solubility of oxygen in colder waters. Colder ambient temperatures were also significantly correlated to positive detections in the lower watershed sites. These correlations support the observed seasonal pattern of detections only occurring in the winter and fall throughout the duration of the project.

3.2.4 SAN Cryptosporidium Survey - Results

The results from the source tracking studies clearly indicate that there are multiple sources of *Cryptosporidium* impacting conditions at the Queen Lane intake. The most constant of these sources is WWTP effluent. During dry weather conditions, discharges from WWTPs can make up 65-90% of the flow of the Wissahickon Creek, which, as previously stated, directly affects conditions at the intake (Crockett & Haas 1997).

To further investigate the influence of WWTP effluent on *Cryptosporidium* levels in the Schuylkill River, the Schuylkill Action Network (SAN) Pathogens Workgroup conducted a *Cryptosporidium* monitoring program in 2006 and 2007. The monitoring program took one sample per facility per year, between May and June at 71 sewage treatment plants and one duck CAFO. The effluent samples captured at each facility were analyzed by Clancy Environmental Consultant (CEC) labs.

In addition to the two-year monitoring program, a plant operator survey was conducted at 69 facilities in 2007 to identify the range of treatment technologies and other operational characteristics of each plant (Duzinski 2008).

The SAN sampling program intended to provide a reference of *Cryptosporidium* concentrations in wastewater treatment plant discharges across the Schuylkill River watershed in order to inform how future sampling programs should be designed. Although not a comprehensive study of *Cryptosporidium* in wastewater discharge, the SAN sampling program observed that *Cryptosporidium* levels varied widely between the two years, with oocysts detected at 8 of the 71 plants in 2006, and 22 of the 71 plants in 2007. The results of the plant operator survey found that 54 plants use some form of chlorination disinfection, while only 14 plants employ UV disinfection. Sixty-one plants are designed for secondary treatment only, and 5 plants include tertiary treatment.

3.2.5 Defective Laterals

Another potential source of *Cryptosporidium* is the untreated sewage released by defective laterals. To address this problem, the City of Philadelphia has effectively implemented a Defective Lateral Detection and Abatement Program. The program was developed under the City's Municipal Separate Storm Sewer System (MS4) permit initially signed in 1995 and further refined under a Consent Order & Agreement (COA) reached with the Pennsylvania Department of Environmental Protection (PADEP).

The program is comprised of several initiatives that aim to detect, investigate, and prevent illicit discharges. The prevention of illicit discharges is primarily achieved through sewer and lateral inspections. Investigative aspects of the program included ranking MS4 outfalls according to their priority for corrective actions and investigating dry weather flows to identify sewer lateral defects. Outfalls were ranked using information from the City's stormwater outfall monitoring system.

PWD maintains a stormwater outfall monitoring system in compliance with the MS4 permit issued by the PADEP. Outfalls are inspected at least once per permit term. Samples are collected for outfalls that have dry weather flow and analyzed for fecal coliform and fluoride. Priority outfalls have been established through the 1998 Stormwater Consent Order and Agreement and internally, additional areas of focus have been added to maintain progress in the screening, testing and abating program and for efficient crew deployment. Priority Outfalls are sampled on a quarterly basis.

The Philadelphia Water Department submits a quarterly Defective Lateral Connection Status Report to the PADEP as part of the reporting requirements of the City of Philadelphia NPDES Storm Water Management Permit No. PA0054712. The report describes recent activities of the City within the 1998 COA Priority Outfall areas and at other significant outfalls on the Stormwater Outfall Priority Score list. Reports are included in the appendices of the Philadelphia's Wet Weather Management Programs Stormwater Management Program Annual Report, made publicly available on http://water.phila.gov/reporting/.

When citizens call the PWD's hotline, 215.685.6300, to report potential illicit dischargers or dry weather flow, all calls and follow up actions are tracked in PWD's work management system. The City investigates all reports of potential illicit discharges from the stormwater system through either the Industrial Waste Unit or the Sewer Maintenance Unit.

3.3 Qualitative Assessment of the Relative Impact of Contamination Sources

3.3.1 PWD's SWA & SWPP- Implications

Results from the SWA prioritization indicate that NPDES dischargers and runoff from non-point sources, or subwatersheds, have the greatest potential to impact *Cryptosporidium* levels at the Queen Lane intake. Many of these priority sources are located relatively far upstream, in the Reading and Berks County areas. To further confirm the impact which these two primary sources have on *Cryptosporidium* levels not only at the intake but throughout the entire watershed, a qualitative loading analysis was completed for the SWA.

The SWA's qualitative loading analysis is only meant to provide some very general indications about the impacts of various sources of contaminants. Each type of source was rated in the loading analysis as having either low, medium, or high impact on ambient river concentrations (PWD 2002b). The qualitative loading data used to determine the impact ratings were then compared with actual water quality data from research studies. For *Cryptosporidium*, the comparison of data suggests that during storm events, elevated levels of oocysts are most likely due to stormwater runoff (PWD 2002b). During non-rainfall periods, however, it appears that NPDES discharges, in particular from WWTPs, are the main source of daily concentrations observed in the Schuylkill River. Therefore, the implications of results from both the SWA prioritization and the qualitative loading analysis signify that efforts to reduce mean daily concentrations of *Cryptosporidium* in the river should focus on reducing the impacts from wastewater discharge, while efforts to reduce peak concentrations should focus on mitigating stormwater runoff. Background concentrations of *Cryptosporidium* can also develop when oocysts accumulate in riverbed sediment and become re-suspended during storm events. The re-suspension of oocysts is discussed in further detail later in this section.

According to the SWA, runoff from agricultural land characterized as pasture/hay has an EMC of 1 oocysts/100 mL, the highest EMC compared to all other land uses. Agricultural runoff is of particular concern in the Wissahickon watershed, where there are two farms located along the lower reaches of the tributary. Erdenheim Farm, the larger of the two farms, encompasses 450 acres and has more than 100 cattle, including calves, and sheep. In addition, a park system surrounds a large portion of the Wissahickon Creek and contains wildlife that could be sources of protozoa. Implementing control measures in the Wissahickon watershed will very likely reduce peak concentrations of *Cryptosporidium* at the Queen Lane intake.

PWD's Source Water Protection Plan (SWPP) expands upon the SWA's prioritization method by re-examining the highest-ranked sources and further prioritizing them according to their impact on the entire watershed (PWD 2006). The SWPP found that high-priority sources for

Cryptosporidium are located primarily along the mainstem of the Schuylkill River, between Reading and Norristown, with a large cluster of priority sources located just downstream of Norristown. The high-priority non-point source subwatersheds are located in the Lower and Middle Schuylkill subwatersheds and in the Tulpehocken and Maiden Creek subwatersheds.

Results from the SWPP's prioritization process also support conclusions from the SWA, which indicate that *Cryptosporidium* is found in both point source discharges and runoff. In regard to agricultural land uses, *Cryptosporidium* is directly linked to the waste of young animals, especially calves.

3.3.2 Source Tracking Projects – Implications

3.3.2.1 Lehigh University Collaboration

The source tracking projects led by Lehigh University provide valuable information about the sources and vectors of *Cryptosporidium* in the Schuylkill River Watershed. Oocysts were detected across all types of samples, including creek, WWTP, and fecal samples. The 2005-2008 Wissahickon study found that the distribution of oocysts and oocyst genotypes can vary between sample locations within the same watershed, as was the case with the oocysts detected at WISS 410 and WISS 140. Previous studies focusing on the distribution of *Cryptosporidium* genotypes in several New York watersheds (Jiang et al 2005) and the Potomac River watershed (Yang et al 2008) attributed this variance in distribution to different land uses within the same watershed. The implications of land use are apparent in the Lehigh University study as well, where five WWTPs discharge upstream of WISS 410, while the land upstream of WISS 140 is wooded and designated for wildlife and recreational uses. Results from the Wissahickon source tracking project also found that multiple oocyst genotypes can be present in a single sample, suggesting that more than one source can impact a single location, and a single source, such as WWTP effluent or an animal host, can release multiple oocyst genotypes into the environment (Jellison 2009). Consequently, WWTPs and animal hosts such as deer and geese are appropriate targets for source water protection in the Wissahickon Watershed. If, as this study suggests, animal hosts serve as the primary vectors of *Cryptosporidium* oocysts, then further identification and control of the vectors that transfer oocysts from host to water sources may prove to be just as important as the identification and control of original oocyst sources.

The Queen Lane and WISS 140 source tracking study, which served as a follow-up to the Wissahickon study, had various implications concerning the contamination sources affecting the intake. Oocysts were detected in 16.1% of the Queen Lane samples since September 2008 and in 20.0% of WISS 140 samples since September 2009 (Jellison 2010a). Although oocyst detection frequencies were similar between the two studies, the sequences recovered from the Queen Lane intake samples were not identical to any of the sequences recovered from the Wissahickon study. Therefore, sources outside of the Wissahickon watershed are impacting *Cryptosporidium* levels at the Queen Lane intake. It should also be noted that all the sequences detected at Queen Lane, WISS 140, and from geese have primarily been associated with human infection and may represent a potential public health risk.

A total of 217 goose fecal samples were analyzed for this study since July 2008 (Jellison 2010a). Analysis of these samples revealed important information regarding the influence of WWTP effluent on the intake's water quality. *C. parvum* and *C. hominis*-like genotypes were detected in 8 of the 11 positive goose fecal samples in the Philadelphia area. No positive samples were detected from the geese samples from the Lehigh area, which is negligibly influenced by WWTP effluent. Two conclusions can be drawn from these sampling results: 1) geese are not the primary sources of *C. parvum* and *C. hominis*, but instead serve as vectors of human-infectious genotypes, and 2) it is very likely that human infectious genotypes are originating from other point sources, specifically, treated WWTP effluent and watershed wildlife. Findings from this study support the conclusion from not only the Wissahickon study, but also the SWA and SWPP, that WWTP effluent and animal hosts are primary sources of *Cryptosporidium* at the Queen Lane intake. Source water and goose sampling in other watersheds upstream of the intake would further validate this hypothesis.

Results from the 2015-2017 study, performed concurrently with Round 2 LT2 monitoring, further confirmed the significance of cattle as priority sources. Additionally, results indicated a potential pattern in seasonal occurrence of *Cryptosporidium*, which upon further research, may help inform planning for watershed control measures.

3.3.3 SAN Cryptosporidium Survey – Implications

The SAN monitoring program provides further evidence that WWTP effluent is a consistent source of *Cryptosporidium* oocysts within the Schuylkill River watershed. Future monitoring programs with more frequent sampling would be necessary to determine which particular WWTPs regularly release the highest levels of *Cryptosporidium.*

The survey portion of the SAN study indicated that the majority of WWTPs in the watershed are capable of secondary treatment only. Secondary treatment may achieve 0.7-2.0 log removal, as opposed to tertiary treatment systems, which can achieve a log removal of 2.4-3.3 (Crockett 2007). These numbers reflect the high likelihood that WWTPs using traditional, secondary treatment processes will pass *Cryptosporidium* oocysts into receiving waters. In addition, disinfection processes such as chlorination and UV disinfection simply deactivate oocysts, without physically removing them from treated water. The viable and non-viable oocysts are then both accounted for when determining detection rates using EPA method 1623, as is required by LT2 regulations. Therefore, drinking water providers such as PWD are faced with the challenge of reducing *Cryptosporidium* at their intakes when it is known that the treatment processes at WWTPs do not always effectively remove the pathogen.

3.4 Role of Fate and Transport

It is critical to consider the role of fate and transport when determining what sources are capable of influencing *Cryptosporidium* levels at Philadelphia's intake. The SWA methodology identifies the highest-priority sources as those located in Zones A and B, within a 5-hour and 25-hour time of travel of both the Delaware and Schuylkill intakes, respectively. This Watershed Control Plan assumes that sources within Zones A through C have the potential to impact conditions at Philadelphia's intakes. Zone C includes the area beyond the 25-hour time of travel of the intake and incorporates the remainder of the watershed area for both the Schuylkill and Delaware River Watersheds.

It is necessary to include the entire Schuylkill River Watershed in the area of influence due to the observed survivability of viable oocysts. It has been found that oocysts can survive in river waters from 30 to 176 days with upwards of 30% and 70% of oocysts remaining viable after 100 days at temperatures of 21ºC and 4ºC, respectively (Sattar et al 1999). Using travel time estimates, it has also been concluded that *Cryptosporidium* oocysts can travel 160 km, or 100 miles, in less than 7 days, at which point they will remain viable upon withdrawal at a downstream intake (Crockett 2007). The entire length of the mainstem Schuylkill River, running from Pottsville to Philadelphia, is only 128 miles. *Cryptosporidium* oocysts initially introduced to the river from point or non-point sources can also accumulate in high concentrations in riverbed and streambed sediment. These oocysts are re-suspended during hydrologic or physical disturbances and can have a significant effect on water quality that may not always be observed during low-flow periods (Crockett 2004). The conditions found on a riverbed may also lengthen the survival time of oocysts. Pathogens, even bacteria that generally die off by more than 50 to 90% within only 1 to 3 days in the environment, can survive up to several weeks if they are attached to particulate matter and exposed to colder water or shielded from sunlight (Novotny & Olem 1994; Thomann & Mueller 1987).

It is clear that several factors, including *Cryptosporidium's* extended survival periods and its potential to remain viable after traveling long distances downstream, confirm that point and non-point sources throughout the entire Schuylkill River Watershed need to be considered when assessing water quality at Queen Lane.

Similar fate and transport principles and assumptions are applied to the Delaware River Watershed with geographic limitations placed on the Area of Influence as described in Section 2.

4 Analysis of Control Measures

Section 3 identifies NPDES discharges, particularly WWTPs, and runoff from subwatersheds associated with agricultural land use, as the primary point and non-point sources, respectively, of *Cryptosporidium* contamination at Philadelphia's intakes. Extensive research efforts have also revealed that certain animals can serve as vectors, transferring viable oocysts from original hosts to Philadelphia's source waters. Efforts to reduce mean daily concentrations of *Cryptosporidium* in the river should therefore focus on reducing the impacts from wastewater discharge, while efforts to reduce peak concentrations should focus on mitigating agricultural runoff. In addition, further identification of animals that serve as mechanical vectors is imperative to fully understand and control sources of oocyst contamination. The objective of this section is to identify those control measures that will prove most effective at reducing *Cryptosporidium* contamination in the area of influence, with the ultimate goal of lowering oocyst levels at the intakes. The feasibility of implementing control measures on a watershed-wide basis is also discussed.

4.1 Potential Control Measures

4.1.1 Point Sources

Treated WWTP effluent from NPDES discharges is the highest priority point source for *Cryptosporidium* in the area of influence. Subsequently, the most effective point source control measures will involve treatment process modifications that achieve a higher level of removal and/or inactivation of *Cryptosporidium* oocysts. As stated in Section 3, a majority of WWTPs in the Schuylkill and Delaware River watersheds use secondary treatment. While secondary treatment may only achieve a log removal of 0.7-2.0, plants employing tertiary treatment can potentially achieve 2.4-3.3 log removal (Crockett 2007). It has been estimated that through the use of alternative treatment technologies, such as UV light disinfection and filtration, wastewater dischargers may be able to achieve 6 log combined removal and inactivation of emerging pathogens (Crockett 2007). Modifying treatment disinfection processes with alternative technologies like UV will not only improve pathogen removal/inactivation but will also create the opportunity to reduce risks associated with disinfection byproduct formation. The appropriateness of implementing UV disinfection for *Cryptosporidium* removal/inactivation should be evaluated by balancing the costs and overall effectiveness against other potential watershed control plan measures.

Additional control measures and management practices are necessary to address discharges of raw sewage resulting from inadequate or failing sewerage systems and septic systems. During wet weather, separate sewer overflows (SSOs) and combined sewer overflows (CSOs) release untreated sewage upstream of Queen Lane. SSOs are often the result of infiltration and/or inflow. Sources of infiltration can include cracked pipes, loose joints, cracked or open pipes or manholes in stream, and root intrusion (SAN 2010b). Inflow can result from loose, open or perforated manholes, direct downspout and sump pump connections, and a cross connection of a stormwater pipe to a sewer pipe. During wet weather, CSOs result when the combined sewer system becomes overloaded, releasing a combination of sewage and stormwater into receiving waterways. Dry weather overflows can be caused by blockages (tree roots, grease, etc.) due to poor collection system maintenance, or by defective sewer lateral connections. Wildcat sewers, illegal sewers that discharge raw sewage directly to the river, have also been identified throughout the Schuylkill River Watershed. PWD's Schuylkill River Source Water Assessment concludes that sewer system capacity and integrity, as well as treatment plant capacity during wet weather periods, represent the greatest and most difficult sewerage-related issues in the watershed (PWD 2002B).

Control measures that address issues contributing to inadequate or improperly managed sewerage systems include the following:

- infrastructure improvements and modifications specifically related to collection system and plant capacity expansions;
- identification and abatement of defective lateral connections and wildcat sewers; and,
- regular enforcement activities throughout the watershed that ensure proper functioning and maintenance of sewerage and septic systems.

PWD and its watershed partners have already started to address several of these issues through various programs and initiatives, which will be discussed in further detail in Section 5. By addressing sewerage-related issues on a watershed-wide scale, the Schuylkill River may see considerable reductions in pathogen loadings. Please note that wastewater infrastructure impacting the Poquessing and Pennypack Watersheds, selected for inclusion in the area of influence, is primarily owned and operated by the City of Philadelphia. Relevant program updates and infrastructure improvements will be included in Annual Status Reports.

4.1.2 Non-Point Sources

Stormwater runoff is a regular non-point source of water pollution that introduces *Cryptosporidium* and a host of other contaminants into Philadelphia's source waters. Agricultural runoff is of particular concern when considering pathogen contamination. As previously described, runoff from pasture lands has the highest event mean concentration (EMC) for *Cryptosporidium* of all land use types in the watershed. It can therefore be inferred that *Cryptosporidium* loadings in runoff will be reduced through the implementation of agricultural best management practices (BMPs). Examples of BMPs that may effectively reduce oocyst levels in the Schuylkill River and its tributaries are listed below.

- stream bank fencing for livestock containment
- stream crossings for livestock
- manure containment sites
- fencing and re-vegetation for the control and containment of animal vectors (especially geese)

- riparian buffers
- other BMPs, such as stormwater wetlands, that are located on or near agricultural land and have the potential to divert and filter contaminated stormwater flow

The above-listed BMPs serve to reduce impacts from livestock activity and pasture runoff on the Schuylkill River. In addition to mitigating the potential for pathogen contamination, agriculture BMPs also reduce nutrient and sediment loadings, which are additional causes of stream impairment in the Schuylkill River watershed. Section 5 will discuss the specific projects and initiatives that PWD has undertaken to address *Cryptosporidium* contamination from non-point sources throughout the watershed.

4.2 Relative Effectiveness of Control Measures

PWD's ability to reduce *Cryptosporidium* levels at the intake will depend on both the feasibility and long-term effectiveness of the control measures that are selected for implementation. A primary component of effective BMP implementation is location. The most effective control measures will be those that address *Cryptosporidium* contamination directly at its source, whether that source is located within close proximity to or relatively far upstream of the intake. PWD's assessment methods and research initiatives outlined in Section 3.3 provide substantial evidence as to what sources of contamination need to be addressed. Section 6 will provide additional information as to where, based on the Source Water Assessment land use analysis, certain BMPs should be located.

4.2.1 Point Sources

Treatment process modifications at priority NPDES dischargers have the potential to greatly reduce routine releases of *Cryptosporidium* to the area of influence. PWD's Source Water Protection Plan estimates that of the total *Cryptosporidium* loading to the Schuylkill River, 83% is from NPDES dischargers and the remaining 17% is from non-point sources. As stated earlier in this section, upgrading a plant from secondary to tertiary treatment will increase oocyst removal by approximately 1 log. Modifications made to improve the filtration and disinfection processes of a treatment system will also increase a plant's ability to effectively remove or inactivate *Cryptosporidium* oocysts. For example, a secondary treatment plant employing UV could achieve a *Cryptosporidium* combined log inactivation/removal of > 6, whereas under the plant's current operation without the use of UV, it may only achieve a log removal of 2 (Crockett 2007). Plants should consider what combination of treatment processes will achieve maximum oocyst removal for public health protection while also effectively addressing competing environmental regulatory requirements (Crockett 2007).

Additional control measures and management practices are necessary to reduce discharges of untreated sewage to the Schuylkill River. Infrastructure improvements for adequate wastewater collection and treatment systems are needed to address system capacity issues, such as overloading caused by infiltration and inflow. Addressing hydraulic overloads will reduce the frequency of raw sewage events, such as overflowing manholes into downstream water supplies (PWD 2002B). The identification and abatement of defective lateral connections and wildcat sewers are also effective means of reducing the frequency of raw sewage discharges. By using these control measures to minimize the discharge of untreated sewage, public health risks associated with pathogen contamination will be effectively reduced.

4.2.2 Non-Point Sources

Agriculture is one of the leading causes of impaired stream miles in the Schuylkill River watershed. More than 70% of agriculturally impaired stream miles are located within Berks County, the state's fifth-leading county in agricultural production at the time of the land use characterization for the Source Water Assessment (PWD 2002b). Despite the potential for significant negative water quality impacts by agricultural activities, agricultural lands also represent some of the simplest and most cost-effective areas for reducing *Cryptosporidium* contamination. It should be noted that only agriculture projects, not urban stormwater projects, are included in the scope of implementation for the Watershed Control Plan. This decision is based on the fact that agriculture BMPs that address high-impact sources are easier to implement, less expensive, and have a greater probability of reducing watershed loads than urban stormwater BMPs. Stormwater projects are also already implemented through a variety of other programs, including on the local level through stormwater ordinances and MS4 permits.

A number of farms in the Schuylkill River watershed have already installed agriculture BMPs, including specially designed cattle crossings and streambank fencing, to reduce the impacts of cattle on streams. Other farms have established riparian buffers to protect streambanks and to filter out harmful contaminants. The specific agriculture projects PWD has been involved with will be outlined in Section 5.2.

While agricultural BMPs directly address known sources of *Cryptosporidium*, very little performance monitoring has occurred to quantify the efficacy of BMPs at removing pathogens from runoff. Lack of performance monitoring can be attributed to the high cost of *Cryptosporidium* monitoring, as well as the limited availability of certified lab technicians trained in the analytical techniques used to process samples.

Although BMPs in the Schuylkill River watershed have not been monitored for *Cryptosporidium* removal, studies elsewhere in the nation have attempted to quantify the oocyst removal capabilities of certain BMPs. Vegetated buffer strips, in particular, are advocated by the U.S. Department of Agriculture for pathogen removal. A study published in 2002 entitled *Transport of Cryptosporidium parvum Oocysts through Vegetated Buffer Strips and Estimated Filtration Efficiency* aims to provide basic design criteria for on-farm vegetated buffers that can remove > 99.9% (> 3 log) of *Cryptosporidium parvum* oocysts from agricultural runoff (Atwill et al 2002). At the time of this study, optimal design criteria for on-farm vegetated buffer strips did not exist for removing pathogens. Based on the study's observations and data analysis, vegetated buffer strips of soils with bulk densities between 0.6 and 1.7 g/cm^3, < 20% slope, and with a width of at least 3 meters should achieve 3 log removal of *C. parvum* oocysts from stormwater flow generated during events with an intensity less than 4 cm/hr. These design criteria assume that the vegetated buffer strips are properly maintained over time.

The study also points to other factors that can increase the efficacy of BMPs, including maintaining a large distance between livestock activity (i.e. feedlots, calf housing, etc.) and source waters. It was also found that as the bulk density of soils is decreased, a greater number of oocysts are removed from the surface flow passing through a buffer strip. These results imply that land practices that compact soil and reduce its porosity subsequently increase the number of oocysts transported to surface waters by reducing the infiltration capacity of runoff.

A second study performed in the Tomales Bay watershed in California in 2008 assessed the performance of several agricultural BMPs at 35 cattle lots on five dairy farms over a two-year period. This study expands upon the results of the previously described study by implementing vegetated buffers in a working farm setting. The goals of the California study were to "1) evaluate factors associated with *Cryptosporidium* oocysts in runoff from dairy high use areas and 2) evaluate the efficacy of BMPs to reduce the *Cryptosporidium* load in storm runoff from treated dry lots compared to adjacent control dry lot sites" (Miller et al 2008). Sampling over the two-year period, between November 2002 and March 2004, produced a total of 350 stormwater samples. *Cryptosporidium* oocysts were detected at four of the five dairy farms, however, only oocysts resembling *C. parvum* were used in the analysis.

The study found that cattle age class, cumulative seasonal precipitation, and 24-hour precipitation all significantly affected oocyst levels in stormwater runoff, as did the implementation of straw mulch and vegetated buffer strips on land used for cattle activity (Miller et al 2008). *Cryptosporidium* concentrations and loading rates revealed that the oocyst levels in runoff from areas housing young calves were 2100 and 728 times greater, respectively, than oocyst levels in runoff from areas housing adult cows. These findings suggest that implementing BMPs that directly address calf areas may be an extremely effective way to reduce oocyst concentrations in runoff. The impact of cattle, especially calves, is evident in the estimated human shedding equivalent. A human shedding equivalent is defined as the number of people shedding oocysts equivalent to the same number of organisms per day from a particular animal or source (Crockett & Haas 1997). One infected calf or lamb can shed more oocysts per day than 1,000 immuno-compromised people. In comparison, a 10 MGD discharge of raw sewage into a stream or river is comparable to the loading of approximately 200 immuno-compromised people shedding *Cryptosporidium* oocysts.

Oocyst concentrations were also found to be highest early in a storm event and even early in the storm season, when runoff is first contaminated with accumulated fecal matter. In terms of BMP implementation, both vegetated buffers and straw mulch application were found to act as barriers capable of trapping oocysts and removing them from runoff. Based on the study's results, "…each 10% increase in straw mulch application to dairy high-use areas resulted in the oocyst concentration decreasing by a factor of 0.73" (Miller et al 2008). Each additional meter of vegetated buffer strip decreased the oocyst concentration by a factor of 0.97. The efficiency of oocyst removal in buffer strips was notably lower than the results from the previous study, a difference which may be attributable to several factors including soil type, storm intensity, buffer composition, and the hydrologic behavior of runoff—factors that can be controlled in an experimental setting.

The results from the two abovementioned studies suggest that certain agricultural BMPs effectively trap oocysts in runoff before they contaminate surface waters. The degree to which BMPs are effective appears to be a combination of environmental factors and the design and placement of the BMP itself. As PWD and other partnerships and organizations move forward with implementing agricultural BMPs in the watershed, the results of research studies should be considered, and careful consideration should be given to the location and method of BMP construction.

4.3 Feasibility of Control Measures

PWD's ability to implement any watershed-wide plan depends largely on the level of cooperation and collaboration that can be achieved between Philadelphia and its upstream partners. As stated in Section 2, the entire Schuylkill River watershed as well as parts of the Delaware River watershed are considered part of the area of influence for *Cryptosporidium* contamination at Philadelphia's intakes. Philadelphia's jurisdiction encompasses a very small portion of the entire watershed—a little more than 2%. The degree to which Philadelphia can influence water quality conditions at both intakes while only acting within the city's jurisdictional boundaries is quite limited. For this reason, PWD has expended considerable effort developing partnerships with a diverse group of watershed organizations, government agencies, academic institutions, and businesses. PWD's commitment to watershed-wide collaboration is evident in the seven objectives outlined in the Schuylkill River Source Water Protection Plan. These objectives, listed below, allow PWD to ensure the integrity and affordability of the region's water supply.

1. Establish and fund the Schuylkill Action Network (SAN) as a permanent watershed-wide organization charged with identifying problems and prioritizing projects and funding sources to bring about real improvement in water quality throughout the Schuylkill River watershed
2. Create a long-term, sustainable fund to support restoration, protection, and education projects in the Schuylkill River watershed
3. Increase awareness of the regional importance of the Schuylkill River as drinking water source.
4. Initiate changes in policies and decision-making that balance and integrate the priorities of both the Safe Drinking Water Act and the Clean Water Act.
5. Establish and fund the operations, ongoing development and maintenance of the Early Warning System as a regional information sharing resource and promote its capabilities for water quality monitoring and improving emergency communication.
6. Reduce point source impacts to water quality.
7. Reduce non-point source impacts to water quality.

Both the Schuylkill Action Network and the Schuylkill River Restoration Fund have been critical mechanisms for implementing the Queen Lane Watershed Control Plan. With the addition of areas of the Delaware River Watershed in the 2020 Plan Update, the focus will be on evaluating the interest and ability to establish similar mechanisms specific to the Delaware River Watershed. PWD will work with partners to explore the feasibility of establishing a water utility coordination group in the Delaware River Watershed. Additionally, PWD intends to explore the feasibility of establishing such a funding mechanism for the Delaware River Watershed.

The following section will discuss in detail the projects that PWD has implemented to achieve the objectives listed above, and the importance of watershed partnerships as the City works toward fulfilling its source water protection goals.

5 Statement of Goals and Specific Actions

5.1 Goals

PWD fully recognizes its responsibility to protect the water quality for residents within its source watersheds. Within the City's jurisdictional boundaries, PWD can directly implement source water protection measures. Outside of Philadelphia, PWD enables source water protection through the watershed-wide initiatives of various partnerships. Addressing potential and actual sources of *Cryptosporidium* and reducing oocyst levels at Philadelphia's intakes will require a collaborative effort between PWD and its partners. Regardless of whether or not contaminative threats originate from a nearby source to Philadelphia's intakes or are located farther upstream, potential sources need to be addressed throughout the entire expanded area of influence.

Within City limits, PWD's goal is to adequately address all high priority sources of *Cryptosporidium*. Extensive control measures and management practices have already been implemented within Philadelphia to minimize the risk of pathogen contamination. PWD has implemented several agricultural projects to divert and detain contaminated runoff before it reaches surface waters. The City is also working to reduce raw sewage discharges through innovative combined sewer overflow (CSO) and stormwater management techniques. PWD has made it a priority to educate city residents as to various source water protection issues, including pathogen contamination, and to support research initiatives that will further develop PWD's understanding of the role of animal vectors in the fate and transport of *Cryptosporidium* throughout its source watersheds. WWTP effluent, the *Cryptosporidium* point source of highest concern according to the Source Water Assessment's prioritization, cannot be directly addressed by Philadelphia since PWD's WWTPs are not located upstream of the intakes.

In addition to meeting pathogen reduction goals within the city, PWD is committed to supporting and helping ensure the realization of this goal throughout the entire area of influence. PWD recognizes that in a watershed of this magnitude, partnerships are necessary so that the combined expertise of various organizations and stakeholders can be used to achieve cumulative water quality improvements. High priority protection areas for improving overall water quality conditions at Queen Lane include the mainstem of the Schuylkill River between Reading and Philadelphia, the Wissahickon Creek, and the Perkiomen Creek. The Valley Creek, French Creek, and Tulpehocken Creek have secondary protection priority (PWD 2002B). For the Delaware River Watershed, priority protection areas include the mainstem between Camden and Trenton (PWD 2007). Table 5-1 outlines the location of priority sources for *Cryptosporidium* contamination at Queen Lane and Baxter Water Treatment Plants.

TABLE 5-1: GENERAL LOCATIONS OF PRIORITY *CRYPTOSPORIDIUM* SOURCES

	Priority Areas	
Priority Source	**Schuylkill**	**Delaware**
Treated Sewage	Reading to Philadelphia	Camden to Trenton
Untreated Sewage	Bridgeport, Norristown, and Schuylkill County	Camden to Trenton
Urban/Residential Runoff	Reading to Philadelphia	Watershed-wide
Agricultural Runoff	Perkiomen Creek & Tulpehocken Creek	Watershed-wide

Sources: PWD (2006). Schuylkill Source Water Protection Plan; PWD (2007). Delaware Source Water Protection Plan.

As is evident from the locations listed above, priority point and non-point *Cryptosporidium* sources are located outside of Philadelphia. The specific partnerships and organizations that PWD works closely with to address these sources will be described in more detail later in this section.

Through PWD's Source Water Protection Program, significant strides have been made to reduce the risk of pathogen contamination. The City's commitment to maintain existing control measures is equally as important as the commitment to develop future initiatives and management practices. The proceeding section will identify those action items already implemented by PWD through an assessment of both in-city and watershed scale projects. This comprehensive project assessment will reveal what vulnerabilities remain when all existing and proposed control measures are considered. The remaining vulnerabilities will provide a framework for moving forward with implementation of this plan as PWD strives to minimize the threat of *Cryptosporidium* contamination at Philadelphia's intakes.

5.2 Existing Actions and Their Contributions to Specific Goals

The Source Water Assessments and Source Water Protection Plans emphasize Philadelphia's need to look farther upstream to protect source water quality and to educate, engage, and involve members of upstream communities as well as its own residents. PWD's Source Water Protection Program objectives for Queen Lane relate to a series of initiatives and projects that are primarily led and funded by PWD and its largest watershed partner organization, the Schuylkill Action Network (SAN).

In-city PWD projects that address priority sources of pathogens in Philadelphia fall into the categories of wastewater discharges/compliance, agricultural land use/runoff, animal vector control, and education and outreach. While some projects directly address known sources of *Cryptosporidium*, others act as preventive measures to address potential contaminative threats before they become a reality. Table 5-2 below outlines the in-city PWD projects.

TABLE 5-2: IN-CITY PROJECT ASSESSMENT BY CATEGORY

Wastewater Discharges/Compliance			
Project	**Sub-basin (watershed)**	**Status**	**Primary Partners**
Cryptosporidium and Microbial Source Tracking Studies	Various	Ongoing	PWD and/or Regional Universities
Defective Lateral Detection and Abatement Program	Various	Completed; monitoring ongoing	PWD
Monoshone Assessment	Schuylkill (Wissahickon)	Completed	PWD
Main and Shurs Elimination (Venice Island)	Schuylkill	Completed; maintenance ongoing	PWD
State Road Relief Sewer	Upper Estuary	Completed; monitoring ongoing	PWD, Bensalem Township/Bucks County
PWD's Combined Sewer Management Program	Various	Ongoing	PWD
PWD's Stormwater Management Program	Various	Ongoing	PWD
Delaware Valley Early Warning System Reporting	Various	Completed; ongoing reporting/monitoring	PWD, DRBC, EWS subscribers (water utilities and industrial users)
River Road Properties Sewer Connection	Schuylkill	Ongoing	PWD, Philadelphia Streets Dept., PADEP
Agricultural Land Use/Runoff			
Project	**Sub-basin (Watershed)**	**Status**	**Primary Partners**
Northwestern Stables Stormwater Management	Schuylkill (Wissahickon)	Complete	SAN/SRRF, NRCS, Northwestern Stables, PWD

Northwestern Stables Manure Containment	Schuylkill (Wissahickon)	Completed	PWD, PADEP, USDA, Resource Conservation & Development Council, City of Philadelphia Public Properties
Belmont Stables	Schuylkill	Completed	PWD, PADEP, USDA, Resource Conservation & Development Council
Courtesy Stables Runoff Treatment Project	Schuylkill (Wissahickon)	Completed; maintenance ongoing	PWD, Friends of the Wissahickon (FOW), Philadelphia Parks and Recreation, Natural Resources Conservation Service, Delaware Estuary Grant from National Fish & Wildlife Foundation
Monastery Stables Stormwater Diversion and Detention Project	Schuylkill (Wissahickon)	Completed	PWD, FOW, Philadelphia Parks and Recreation, Boarders and Stewards of Monastery (BSM), Philadelphia Saddle Club (PSC)
W.B. Saul High School Bioswale	Schuylkill (Wissahickon)	Completed	PWD, Philadelphia Parks and Recreation, EPA, Philadelphia School District, PADEP
W.B. Saul High School Agricultural Best Management Practices	Schuylkill (Wissahickon)	Ongoing	PWD, Philadelphia Parks and Recreation, EPA, Philadelphia School District, PADEP
Animal Vectors			
Project	**Sub-basin (Watershed)**	**Status**	**Primary Partners**
Belmont Meadow Extension/Intake Project	Schuylkill	Completed	PWD, Philadelphia Parks and Recreation, EPA, Drexel University, Philadelphia University, US Fish & Wildlife Service
Goose Control Programs	Various	Ongoing	PWD, USDA
Education/Outreach			
Project	**Sub-basin (Watershed)**	**Status**	**Primary Partners**

Philly RiverCast	Schuylkill	Ongoing	PWD, EPA
Expanded Annual Water Quality Report	Various	Ongoing	PWD
Fairmount Water Works Interpretive Center (FWWIC)	Schuylkill	Ongoing	PWD, Philadelphia Parks and Recreation, PDE, DRBC, PADEP, PEC, EPA, PA Department of Conservation and Natural Resources, and others listed at www.fairmountwaterworks.org
Dog Waste Control Program	Various	Ongoing	PWD, PDE

5.2.1 In-City Initiatives

5.2.1.1 Wastewater Discharge/Compliance

5.2.1.1.1 *CRYPTOSPORIDIUM* AND MICROBIAL SOURCE TRACKING STUDIES

Recent source tracking projects have improved PWD's understanding of both the sources and vectors of oocyst contamination throughout the watershed. These projects have been led by Lehigh University, with PWD providing support in terms of funding, sampling, elution and project management and oversight. Following necessary budgetary adjustments being made due to the COVID-19 pandemic, the research contract with Lehigh University was discontinued in July 2020. PWD's Aquatic Biology Laboratory is developing the necessary analytic capabilities (e.g. PCR) so that these studies can be continued in-house at a later time. See Section 3.2.3 for a detailed description of the Wissahickon Creek and Queen Lane *Cryptosporidium* source tracking studies.

5.2.1.1.2 DEFECTIVE LATERAL DETECTION AND ABATEMENT PROGRAM

Philadelphia's Defective Lateral Detection and Abatement program was developed under the City's initial Municipal Separate Storm Sewer System (MS4) permit signed in 1995 and further refined under a Consent Order & Agreement (COA) reached with the PADEP on June 30th, 1998. The City successfully complied with the terms of the agreement and many of the COA requirements have now been incorporated into the City's 2005 MS4 permit.

The Defective Lateral Detection and Abatement Program is comprised of several initiatives that aim to detect, investigate, and prevent illicit discharges. The prevention of illicit discharges is primarily achieved through sewer and lateral inspections. Investigative aspects of the program include ranking MS4 outfalls according to their priority for corrective actions and investigating dry weather flows to identify sewer lateral defects. The City also investigates all potential reports of illicit discharges from the stormwater system through either the Industrial Waste Unit or the Sewer Maintenance Unit.

5.2.1.1.3 MONOSHONE ASSESSMENT

In conjunction with the Defective Lateral Detection and Abatement Program, in FY 2006 PWD conducted and completed an analysis of 82 defective lateral abatements and sewer relining work performed in the sewer-shed of outfall W-068-04/05, which discharges to the Monoshone Creek in the Wissahickon Creek Watershed. The purpose of this analysis was to determine the water quality improvements achieved as a result of the abatement and relining work and to compare this improvement with the additional water quality benefits anticipated from the Saylor Grove Wetland BMP, also located in the Monoshone.

It was found that significant reductions were achieved in fecal coliform concentrations and loadings in outfall W-068-04/05 as a result of defective lateral abatements, sewer relining, and the Saylor Grove Stormwater Wetland BMP (PWD 2009c).

5.2.1.1.4 MAIN AND SHURS ELIMINATION

The Main Interceptor Sewer, which is located along the Schuylkill River adjacent to the Manayunk Canal in the northwest section of Philadelphia, conveys sewage from collection systems that serve the northwest section of the City. During extreme wet weather events, the Main Interceptor Sewer exceeds its capacity and overflows occur at a relief point into a storm sewer upstream of stormwater outfall S-052-5. To abate the hydraulic overload conditions in the Main Interceptor Sewer, PWD completed construction of a 3-million-gallon offline storage tank in 2014. This storage system captures and stores excess flows, thereby eliminating surcharges and preventing overflow conditions at the relief point. The storage tank accommodates SSO/CSOs that once averaged approximately 10 million gallons of untreated wastewater each year and returns it to PWD's Southeast WPCP (PWD 2009c). Routine maintenance of the storage tank is performed by PWD's Green Stormwater Operations group.

5.2.1.1.5 PWD'S WET WEATHER MANAGEMENT PROGRAMS

There are several initiatives and projects under Philadelphia's wet weather management programs, which consist of the combined sewer management program and the stormwater management program, that reflect PWD's commitment to maintaining and ensuring the adequacy of the City's sewer infrastructure. These programs fulfill the requirements of the City's CSO and Stormwater Permits. Although Philadelphia does not have any CSO outfalls upstream of the Queen Lane intake, the CSO management program's monitoring and maintenance procedures serve as sewerage-related control measures. The CSO Management measures occur both in the combined sewer areas and in the separate sewer areas of Philadelphia. Listed below are aspects of the CSO and Stormwater Management programs that are considered pertinent to this plan.

5.2.1.1.6 COMBINED SEWER MANAGEMENT PROGRAM

5.2.1.1.6.1 SEWER ASSESSMENT PROGRAM (SAP)

PWD has implemented a comprehensive sewer assessment program (SAP) to provide for continued inspection and maintenance of the collection system using closed circuit television (CCTV). The SAP program was developed by PWD and consultants and was finalized in March 2006. The SAP is one of the tools used to identify and remediate areas of infiltration and inflow (I & I) as well as guide the capital improvement program to ensure that the existing sewer systems are adequately maintained, rehabilitated, and reconstructed. Any infiltration that is observed during the on-going CCTV sewer inspection is categorized based on a range of 5 levels: weepers, drippers, light runners, heavy runners, or gushers. All occurrences of top two leak intensity categories are immediately reported to PWD's Water Conveyance Leak Detection Unit for investigation.

5.2.1.1.6.2 COMPREHENSIVE MONITORING AND MODELING PROGRAM

PWD maintains an extensive monitoring network through the combined sewer system, a majority of the separate sewer system, rain gauges, pump stations and connections from all adjacent outlying communities (PWD 2009c). The monitoring network in conjunction with the US EPA's Storm Water Management Model (SWMM) was used to develop a watershed-scale model for the PWD combined sewer system. The identification and quantification of rainfall dependent inflow/infiltration (RDII) into sanitary sewers contributing to the City of Philadelphia's service area is a key component of this program.

PWD also actively conducts infrastructure assessments to inventory and prioritize sewage infrastructure potentially affected by either infiltration or exfiltration through spatial data collection for all points that either hydraulically alter the flow of the creek or infrastructure points that are affected by stream migration. Corrective actions are taken when points of concern are identified (PWD 2009c).

5.2.1.1.6.3 EVALUATION OF THE COLLECTION SYSTEM TO ENSURE ADEQUATE TRANSPORT CAPACITY FOR DRY AND WET WEATHER FLOW

System-wide hydrologic and hydraulic models have been developed in support of the City's Long Term Control Plan Update (LTCPU). Models are used to evaluate the system performance benefits of various system improvements. PWD has analyzed the utilization of in-system storage and storm flood relief through various in-City projects and continues to evaluate the collection system to ensure adequate transport capacity for dry and wet weather flows (PWD 2009c).

5.2.1.1.6.4 INTERCEPTOR RELINING

Planning and design is underway for relining several segments of interceptor within Philadelphia. Benefits of sewer relining include: decreased pollutant loads to surface water by decreased exfiltration; decreased flow in sewer system by decreased inflow/infiltration; and increased efficiency of the sewer system (PWD 2009c).

5.2.1.1.7 STORMWATER PROGRAM

5.2.1.1.7.1 POLLUTION MIGRATION/INFILTRATION TO THE MS4 SYSTEM

The Industrial Waste Unit (IWU) within PWD responds to all citizen complaints of liquid, solid, or gaseous pollutants within Philadelphia, and continues to be the lead organization for inspecting and enforcing pollution discharges to the separate storm sewer system (PWD 2009c). The IWU coordinates with neighboring communities in the event that a pollutant may drain into the Philadelphia MS4 system. Using a variety of pollution sensing, testing, and removal techniques, the IWU mitigates the impacts of spills to the MS4 system, combined system, and receiving waters.

5.2.1.1.8 SANITARY INFILTRATION CONTROLS

5.2.1.1.8.1 INVESTIGATE, REMEDIATE AND REPORT SANITARY INFILTRATION

As part of the City's Stormwater Permit, PWD employs interventions that prevent the degradation of surface and groundwater by the inadequate treatment of sewage or site runoff, provides oversight for the construction and operation of individual On-Lot Sewage Disposal Systems (OLDS), and provides an immediate response to all reports of unintentional spills to prevent their entrance into surface or ground water. Inspection, education and consultative services as well as review of citizen reports of degraded water quality issues are managed (PWD 2009c).

In addition, the Collector System within PWD maintains and manages a database called the Sewage Pollution Incident & Location Log (SPILL), which reports information about unintentional sanitary discharges including date reported, problem location, spill type, description, and abatement date.

5.2.1.1.8.2 INSPECTION AND REMEDIATION OF ON-LOT SEPTIC/DISPOSAL SYSTEMS

The On-Lot Sewage Disposal System program allows for the supervision of the design and installation of new systems to prevent sewage from being discharged onto the ground and also entails the identification, evaluation, and recommendation of remedial actions where available to homeowners with malfunctioning systems. This program also enables permitting and monitoring of storage tanks and portable toilets. A liaison is maintained with the PADEP, PWD and City Planning Commission concerning the prevalence of malfunctions within certain geographical areas in the City. An extension of the municipal sewerage system is recommended to PWD for those areas where homes are experiencing malfunctions and no practical means are available for their correction (PWD 2009c).

The Source Water Protection Program's 2009 Water Budget Report estimates that the total discharge to septic systems in the Schuylkill River Watershed, which is the summation of the public water supply discharge to septic systems and the private domestic supply discharge to septic systems, is approximately 17.4 MGD. A majority of the daily discharge to septic systems, 15.6 MGD, is from private domestic supply (PWD 2009d).

5.2.1.1.9 DELAWARE VALLEY EARLY WARNING SYSTEM

The Early Warning System (EWS) is a web and telephone system that facilitates communication among water suppliers and industrial intakes about spills and other incidents in the Schuylkill and Delaware watersheds.

EWS is designed to improve the safety of the drinking water supply by providing real time water quality monitoring results and event notification to regional users. Features include a notification system, a time of travel model, the Spill Model Analysis Tool, real-time water quality data and a central website where users can access event information, analysis tools, and data. As of 2019, the EWS user base consists of more than 450 registered users from 55 organizations.

PWD continues to develop and enhance the EWS Tidal Spill Trajectory Tool. The Tidal Spill Trajectory Tool was developed using a $295,000 grant awarded to PWD by the Maritime Exchange for the Delaware River and Bay. The tool was launched in 2014 and expanded EWS capabilities to include predicting a contaminant spill path and contaminant plume arrival times at tidal intakes in the lower Delaware River. In 2015, the EWS was honored with the Governor's Award for Environmental Excellence due to the integration of the advanced spill modeling capabilities.

In September 2016, EWS was nationally recognized by EPA Water Security Division as a case study published in *Online Source Water Quality Monitoring for Water Quality Surveillance and Response System*. The EWS was also featured as part of the Philadelphia Water Department case study in the 2017 publication of the American Water Works Association (AWWA) entitled *Operational Guide to AWWA Standard G300: Source Water Protection*, 2nd Edition.

In 2020, PWD implemented significant updates to the EWS user interface. Notable improvements include full mobile device (smartphone) functionality for the EWS web site and improved mapping and notification features. These updates will be presented to EWS users through a series of regional trainings and conferences.

5.2.1.1.10 RIVER ROAD PROPERTIES

River Road in northwest Philadelphia runs along the Schuylkill River directly upstream of two PWD treatment plant intakes. Sitting at a low elevation, the stretch of residential road is prone to flooding during rain events. Both the city and PADEP have been concerned about the on-lot septic systems of many River Road residential properties sitting in the Schuylkill River's floodplain, but the existing septic systems cannot be replaced as they do not meet current regulations. PWD began the design for sewer installation and hosted public meetings in 2007, permits and approval for the project were obtained from PADEP in 2008 and 2009, and the road's residents agreed to move forward following more public meetings in 2017.

The approximately mile-long new sanitary sewer will provide service for 42 properties along River Road from Port Royal Avenue to County Line Road. A sewage pumping station will be constructed on the river side and sewage collected from the sewer will be pumped to the nearby Nixon Street sewer. Construction began in early 2019 and is expected to be completed by the end of 2020.

5.2.1.2 Agricultural Land Use/Runoff

5.2.1.2.1 NORTHWESTERN STABLES

At Northwestern Stables in Fairmount Park, an uncontained manure pile was located behind the barn, contributing manure-laden stormwater runoff to the nearby Wissahickon Creek. The contaminated runoff was addressed through construction of a reinforced concrete manure containment pad; installation of bollards to protect the concrete walls and barn; excavation of a basin and drainage swale to capture any runoff from the containment pad; and construction of roll curbing and a 10-foot infiltration trench. The containment facility now confines the manure pile to a small area and prevents nutrients and pathogens from entering the Wissahickon Creek. Roll curbing and an infiltration trench capture and divert runoff that would formerly have flowed into the barn.

5.2.1.2.2 BELMONT STABLES

A manure storage area beside the barn at Belmont Stables in Fairmount Park was contributing manure-laden stormwater runoff directly into a tributary of the Schuylkill River. Stormwater was also forming a large puddle in the parking area behind the barn. These problems were addressed through construction of a reinforced concrete manure containment pad; installation of bollards to protect the concrete walls; excavation of a basin and diversion swale; and construction of a protective post and rail fence around the basin. The containment facility confines the manure pile to a small area and prevents nutrients and pathogens from entering the Schuylkill River. The diversion swale and basin capture, divert, and infiltrate storm flows that would have otherwise formed a puddle in the parking lot.

5.2.1.2.3 COURTESY STABLES RUNOFF TREATMENT PROJECT

This project's aim was to correct a suite of problems contributing to contaminated stormwater that flows from the barnyard at Courtesy Stables through an adjacent wetland and into a tributary of the Wissahickon Creek. Stormwater was rerouted from the barnyard and surrounding area into a grassed waterway/filter strip where nutrients and sediment are now removed, and a portion of the water is infiltrated into the ground before reaching the wetland. Flow from a springhouse was rerouted directly to the wetland, serving as a continuous source of clean water, rather than through the riding ring, where it adsorbs nutrients and creates muddy conditions. Invasive plant species onsite were removed and replaced with Philadelphia-native trees and shrubs and educational signage was erected, linking the nutrient runoff reduction to the improvement of the Delaware Estuary.

5.2.1.2.4 MONASTERY STABLES STORMWATER DIVERSION AND DETENTION PROJECT

PWD partnered with the City's Department of Parks and Recreation, previously known as the Fairmount Park Commission (FPC), to address stormwater and agricultural runoff at this FPC property along the Wissahickon Creek. Lack of proper stormwater management controls, a sloping topography towards the bordering creek, and the intensity of horse activity on the site make Monastery Stables a source of contamination to the Wissahickon watershed. Before implementation, rainfall collected in the paddocks and discharged toward the Wissahickon Creek through several eroded gullies, carrying sediment, nutrients, and harmful pathogens. The project introduced stormwater management controls, including subsurface storage tanks and vegetated swales to increase stormwater infiltration and direct and treat stormwater runoff, thereby reducing sediment, nutrient, and harmful pathogen loadings to the Wissahickon Creek.

5.2.1.2.5 W.B. SAUL HIGH SCHOOL BIOSWALE

In FY 2004, PWD utilized a PADEP Growing Greener Technical Assistance Grant to complete a conceptual design to implement stormwater BMPs at this Agricultural High School in the Wissahickon watershed. The W.B. Saul High School project combines urban stormwater and agricultural BMPs to reduce the harmful impact of the school's runoff on the water quality of the Wissahickon Creek. Prior to discharging into the storm sewer, which then flows to the Wissahickon, agricultural runoff from the livestock and farming practices, as well as stormwater runoff from the school's roofs and parking lots, is now captured and treated through a series of long pools connected by wetland swales. This project also adds an educational component to the curriculum of Saul High School, already one of the nation's premier agricultural high schools, by demonstrating proper management of agricultural runoff.

5.2.1.2.6 W.B. SAUL HIGH SCHOOL AGRICULTURAL BEST MANAGEMENT PRACTICES

In 2016, Saul High School created a 501(c)(3) as a mechanism to acquire funding for projects identified in their school master plan. PWD began collaborating with Saul and other stakeholders in 2018 to facilitate the implementation of BMPs to reduce sediment, pathogen, and nutrient loading in the Schuylkill watershed. Construction of BMPs at Saul began in 2019, when the construction of a swale and culvert diverting runoff from the adjacent Henry Avenue was completed. The diversion system connects to a highway inlet at the top of the Saul High School access drive and conveys diverted flow below pastureland adjacent to the Wissahickon Valley Park.

PWD continues to coordinate internally to determine resources available to support projects to manage stormwater and protect source water on the Saul Agricultural High School campus. Planned BMPs still to be implemented include the construction of a new concrete heavy use area, manure transfer system, and roofed barn area.

5.2.1.3 Animal Vectors

5.2.1.3.1 GEESE CONTROL AT PWD INTAKES

PWD's Belmont intake is located on the Schuylkill River downstream from several parking lots in Fairmount Park. The parking lots have historically been places where humans feed the large population of non-migratory Canada Geese. Consequently, the stretch of riverside parkland has been severely eroded and Belmont's source water quality negatively impacted by the presence of these geese.

The goal of the Belmont Meadow Project, which took place in two phases, was to deter non-native Canada geese from dwelling and feeding around the Belmont intake. This was achieved by installing fencing along Peter's Island, installing educational signage, and planting trees, shrubs, and two meadows. The new plantings create an inhospitable environment by obstructing the geese's sight and increasing their fear of predators, while also serving as a buffer zone to filter polluted runoff from the parking area. The project began in 1999 with the implementation of the Phase I meadow and was completed in 2004 with the Phase II extension meadow.

Results from the project indicate significant reductions in the number and impact of geese on land and water quality near the intake. The average number of geese observed in Project Area I, or the Phase I area, has been reduced by 97%, from 17 to less than one goose per site visit. Project Area II has resulted in goose populations decreasing from 35 per visit in 2000 to less than five per visit in 2005, indicating a reduction of 88%. It has been estimated that each year, 25 tons of goose manure are diverted from the immediate park area above the intake as a result of Phase I and Phase II, reducing the threat of *Cryptosporidium* contamination in the Schuylkill River. Educational signs have also successfully reduced feeding and encouraged the relocation of the local goose population to downstream of the intake. Approximately $35,000 in capital funds have been invested in the Belmont Goose Project to achieve the present fecal removal rate. At this time, there remains a need to address the goose nesting problem on Peter's Island, where the fencing proved to be ineffective (PWD 2007). Peter's Island is a priority site on the collaborative wildlife management program with USDA APHIS, as described below.

5.2.1.3.2 WILDLIFE MANAGEMENT

PWD has entered into a cooperative services agreement with the USDA's Animal and Plant Health Inspection Services (APHIS) to implement an integrated waterfowl management program to reduce and prevent damages caused by Canada geese to PWD's drinking water treatment and wastewater treatment plants. The program includes the components listed below. The USDA's Wildlife Services (WS) will provide oversight and instructional assistance in the application of visual and audible deterrents and chemical repellents and the implementation of habitat modification and exclusion measures.

- PWD will institute a no feeding of wildlife policy and actively enforce the policy.
- APHIS will conduct treatment of nests and eggs of Canada geese at approximately 7-10 day intervals for the 8-week nesting season. Nests and eggs will be collected and disposed of following the 28-30 day incubation period.

- APHIS will conduct non-lethal waterfowl harassment (i.e., visual deterrents, use of lasers, chasing with remote controlled vehicles, pyrotechnics, recorded distress calls, etc.) at PWD facilities when deemed necessary.

- APHIS may conduct Canada goose round-ups at PWD where deemed necessary by APHIS and provided for through permitting of the PA Game Commission. PWD will be responsible for providing documented proof that a direct threat to human health and safety exists on PWD facilities where round-ups are requested. Should the round-ups take place, Canada geese will be humanely captured, euthanized, and processed for human consumption.

- APHIS will review landscaping/habitat modification plans at the request of PWD to ensure that long-term habitat modifications are appropriate for an integrated waterfowl damage management program.

PWD has implemented the USDA program at the Queen Lane, Belmont and Baxter Drinking Water Treatment Plants, as well as PWD's three Water Pollution Control Plants. The program is also being implemented on public lands throughout the city including Pleasant Hill Park, Peter's Island, Franklin Delano Roosevelt Park and Concourse/Centennial Lake. An ongoing wildlife management program provides the greatest practical level of protection associated with wildlife damage at these sites.

5.2.1.4 Education/Outreach

The in-city Education and Outreach components of PWD's source water protection program serve several main objectives:

- communicating the risk of pathogen ingestion to all customers, particularly those most vulnerable from a health perspective, and explaining how to decrease potential exposure to *Cryptosporidium*;

- communicating PWD's research and implementation of watershed protection strategies to help the public better understand and mitigate the threat of *Cryptosporidium* contamination; and,

- promoting public awareness and engaging support for source water protection measures that can be practiced on various scales, including on an individual basis.

Although Philadelphia can fulfill these objectives within the City, PWD's upstream partners enable the City to fulfill the same objectives on a watershed scale. Consequently, building relationships with upstream partners to ensure that source water protection measures are implemented throughout the watershed is an imperative aspect of PWD's education and outreach efforts. Specific watershed partners will be discussed in the watershed-wide project assessment. The following initiatives occur within Philadelphia and support one or more of PWD's education and outreach goals.

5.2.1.4.1 PHILLY RIVERCAST

RiverCast is the first operable web-based recreational warning system in the United States. Using real-time flow, precipitation, and turbidity data, RiverCast predicts bacteria levels within a section of the Schuylkill River heavily used by the public for swimming, rowing and boating. RiverCast translates the predicted bacteria levels into one of three ratings, each of which corresponds to suggested guidelines for recreation. High bacteria levels, for example, translate to a “red” rating, in which RiverCast advises against any direct or indirect contact with the river. Nearly 1.5 million users have visited RiverCast since it became operable in June 2005 (PWD 2020). The site, which can be accessed at www.phillyrivercast.org, enables PWD to promote public awareness of water quality concerns and indirectly engages support for source water protection measures.

5.2.1.4.2 EXPANDED ANNUAL WATER QUALITY REPORT

PWD publishes an annual drinking water quality report. The report is mailed to every city resident and contains a wealth of information regarding the source, safety and contents of the City’s drinking water. Annual water quality reports, or consumer confidence reports, are mandated by the 1996 Safe Drinking Water Act amendments. According to the EPA, the information contained in a water quality report should raise consumers’ awareness of their drinking water sources, describe the process by which safe drinking water is delivered to their homes on a daily basis, and educate consumers about the importance of source water protection measures to protect their drinking water supply (US EPA 2010b). PWD’s annual water quality report is a comprehensive document that includes an educational statement for vulnerable populations about avoiding *Cryptosporidium* and details the monitoring and research work that PWD has undertaken to ensure a safe drinking water supply. The report also outlines numerous other source water protection efforts, including: PWD’s collaboration with upstream communities and the state of PA to ensure regulations are enforced at wastewater treatment plants; management of the Early Warning System (EWS); and implementation of the City’s goose control measures. Consumers are also made aware of actions they can take to help protect source water, such as conserving water, keeping trash out of storm drains, and avoiding feeding geese and other wildlife, especially near waterways. Information concerning PWD’s Source Water Assessment and Source Water Protection Plan is also provided in the report, which is available year-round at the City’s website, www.phila.gov/water. Because the water quality report is distributed throughout the entire City of Philadelphia, it is an ideal document for communicating the risks associated with *Cryptosporidium* contamination and PWD’s efforts to reduce these risks.

5.2.1.4.3 FAIRMOUNT WATER WORKS INTERPRETIVE CENTER (FWWIC)

The FWWIC is PWD’s renowned education center, located on the banks of the Schuylkill River in Philadelphia. The mission of the center is to “educate citizens to understand their community and environment, especially the urban watershed, know how to guide the community and environment in the future, and understand the connections between daily life and the natural environment.” “Water in our World” is the theme that unites the innovative exhibits and interactive educational programs at the Fairmount Water Works. These exhibits and programs meld the history, technology and science of providing water to a regional urban watershed, while illustrating the impacts of human actions on our water supply. The center is able to emphasize the importance of source water protection through hands-on learning and various school and life-long learning programs. The center’s exhibits serve the entire Philadelphia region, and the Interpretive Center has been recognized by the PADEP as the Delaware River Basin's official Watershed Education Center (PWD 2009c).

5.2.1.4.4 DOG WASTE CONTROL PROGRAM

Through a pilot project in Delaware, the Partnership for the Delaware Estuary (PDE) found that most dog owners are completely unaware of the connection of dog waste to water pollution. A similar project has been initiated by PWD, where 5,000 "Bags on Board" and educational tip cards were produced and purchased for distribution at the Fairmount Water Works Interpretive Center (FWWIC) and various public events in 2007. "Bags on Board" is a roll of 15 dog-waste collection bags that conveniently clips onto a dog leash. The educational tip card not only explains the effects of dog waste on local waterways, but also provides a list of other daily actions that can be modified slightly to reduce stormwater runoff pollution (PWD 2009c).

PWD's Public Affairs team is actively working to educate residents on the impacts of pet waste to water quality and have created several education and community engagement programs including 'spokesdog' competitions, social media campaigns, educational guides, and tip cards. These efforts aim to communicate how pet waste can negatively affect our waterways and what pet owners can do to clean up and dispose of the waste.

5.2.2 Watershed-Wide Initiatives

In addition to PWD's extensive list of in-city projects, Philadelphia has been involved in numerous other projects and initiatives elsewhere in the Schuylkill River watershed. The Schuylkill Action Network (SAN) is a particularly important partner in PWD's watershed control plan approach to reducing *Cryptosporidium* at Queen Lane. SAN's mission, as stated on the partnership's website, www.schuylkillwaters.org, is to improve the water resources of the Schuylkill River watershed by working with state agencies, local watershed organizations, businesses, academics, water suppliers, local and state governments, regional agencies, and the federal government to transcend regulatory and jurisdictional boundaries in the strategic implementation of protection measures. The SAN seeks to achieve this mission through the objectives listed below.

- Support existing efforts and implement actions to restore and protect water quality in the Schuylkill River watershed.
- Promote the long-term coordinated stewardship and restoration of the watershed and educate others regarding their roles in protecting the watershed and water supplies.
- Transfer the experience and lessons learned to other communities.
- Enhance intergovernmental communication and coordination by working together on the identification and resolution of environmental issues with shared regulatory responsibility.

SAN's objectives are achieved through several workgroups consisting of a collaboration of stakeholders, including federal and state agencies, water suppliers, local officials, conservation districts, community members, academics and industries (SAN 2008). PWD continues to be an active participant in each workgroup, helping to address water quality issues of high concern in the watershed. The following list outlines the general, overarching goal of each SAN workgroup.

Abandoned Mine Drainage Workgroup

Goal: To maximize reduction and/or treatment of abandoned mine drainage (AMD). AMD is the leading cause of pollution in the Schuylkill River headwaters, producing metal-laden and sometimes highly acidic discharges in telltale orange and silver plumes, easily visible in the surface waters. Acidity and metals interfere with vegetative growth, aquatic life, and both ground and surface drinking water resources.

Agriculture Workgroup

Goal: To maximize reduction and/or prevention of agricultural impacts to water quality. According to a federal report, agricultural runoff is now considered the primary source of pollutants in streams and rivers in the U.S. Approximately 37% of land use in the Schuylkill Watershed is agricultural, and 258 miles of streams are considered agriculture-impaired.

Education and Outreach Workgroup

Goal: To improve public support for watershed protection actions. SAN believes that an educated public can be the most valuable resource tool in restoring the health of an entire watershed. Ideally, education efforts foster an appreciation and awareness of local water resources, inspiring stewardship and meaningful changes in daily actions.

Pathogens and Point Sources Workgroup

Goal: To prevent drinking water related outbreaks of gastrointestinal illness by improving NPDES compliance and reducing discharges from un-sewered communities.

Storm Water Workgroup

Goal: To maximize reduction and/or prevention of stormwater runoff pollution. Stormwater runoff contains chemicals, fertilizers, pesticides, bacteria, road salt, engine fluids, eroded soils, and debris, and creates 30% of all water quality impairments in the Schuylkill watershed.

Watershed Land Protection Workgroup

Goal: To promote a sustainable landscape in the Schuylkill River watershed through strategic conservation and efficient land resource use to protect the integrity of water supplies for future generations.

In addition to partnering with SAN, PWD is actively involved in a number of Schuylkill River watershed partnerships, including the Wissahickon Clean Water Partnership. A more detailed description of the Wissahickon Clean Water Partnership is provided later in this section.

5.2.2.1 The Schuylkill Watershed Initiative Grant (SWIG) and Other Funding Sources for Watershed Projects

Partnerships such as SAN enable PWD to facilitate implementation of projects upstream of Queen Lane and outside Philadelphia's jurisdictional boundaries. Project implementation is only feasible, however, when the partnerships can secure adequate funding. Many SAN initiatives were implemented with funding from the US EPA's Targeted Watershed Initiative Program. This EPA program seeks to demonstrate how water pollution can be managed on a watershed basis through the use of studies, demonstrations, and education/outreach activities. PWD received a $1.15 million grant, the Schuylkill River Watershed Initiative Targeted Watershed Grant (SWIG), in 2005 as part of this program. The funding enabled PWD and the Partnership for the Delaware Estuary (PDE) to initiate more than 40 individual projects to improve water quality in the Schuylkill River. From 2005 to 2008, PDE and PWD worked with more than a dozen partners to complete seven suites of projects that address the issues from each major SAN workgroup: abandoned mine drainage, agricultural runoff, stormwater runoff, and education of key constituents and audiences. In addition to the SWIG, PWD and its partners have received funding for project implementation from several other sources, which include the following: EPA, Pennsylvania's Growing Greener program, Exelon and the Schuylkill River Restoration Fund, and the William Penn Foundation. Funds for agricultural projects have also been leveraged from other agencies, including Berks County Conservation (BCC) and the Natural Resources Conservation Service (NRCS).

NRCS funding in Philadelphia's source watersheds is provided through conservation programs under the 2008 Farm Bill, which builds on the conservation gains made in the 1985, 1996 and 2002 Farm Bills. Two specific NRCS programs, the Environmental Quality Incentives Program (EQIP) and the Conservation Reserve Program (CRP), have already funded several projects in the Schuylkill River watershed. These programs address issues related to cropland conservation, water quality improvement and wildlife management. The water quality improvement goals of the EQIP program, for example, are focused on reducing non-point source pollution, including nutrients, sediment and pesticides, as well as reducing point source pollution, such as contamination from animal feeding operations (PA NRCS 2010). Agricultural BMP projects funded under these programs may include livestock exclusion, riparian buffers, streambank protection and manure containment structures. Many of the BMPs that are funded to improve water quality also serve as drinking water protection control measures that will simultaneously reduce pathogen contamination. Projects funded under these programs serve many benefits and present the opportunity for drinking water protection to become a high priority issue for funding allocation.

Table 5-3 provides an inventory of projects that PWD has partnered on in the Schuylkill River Watershed, with funding provided by a combination of the sources described above. The projects, which all address pathogen contamination, fall under the categories of Wastewater Discharges/Compliance, Agricultural Land Use/Runoff and Education/Outreach. A brief description of each project is provided below in Table 5-3.

TABLE 5-3: WATERSHED-WIDE PROJECT ASSESSMENT BY CATEGORY

Wastewater Discharges/Compliance		
Project	**Status**	**Primary Partners**
Infectivity/Viability Study	Completed	PWD, Clancy Environmental
Sewage Facilities Self-Assessment Program	Ongoing	PWD, SAN, EPA, municipalities
Delaware Valley Early Warning System Reporting	Ongoing	PWD, DRBC, EWS subscribers (water utilities and industrial users)
Act 537 Planning Workshops	Ongoing	PADEP, SAN, EPA, municipalities
Schuylkill River Water Quantity Analysis	Completed	PWD
Identification and Abatement of Wildcat Sewers	Ongoing	SAN
Agricultural Land Use/Runoff		
Project	**Status**	**Primary Partners**
Conservation Plans	Completed	SAN, Berks County Conservation District
Parcel Prioritization, Riparian Buffer Planting, Streambank Fencing & Cattle Crossings	Completed; maintenance ongoing	SAN, Berks County Conservation District (BCCD), USDA, farming community, Berks County Conservancy (BCC)
Education/Outreach		
Project	**Status**	**Primary Partners**
SAN Website	Ongoing	SAN, Partnership for the Delaware Estuary
SAN Pathogens Workgroup	Ongoing	PADEP, EPA, PWD

SAN Agricultural Workgroup	Ongoing	PWD, PADEP, EPA, BCCD, BCC
Schuylkill River Restoration Fund	Ongoing	Schuylkill River Heritage Area, PDE, Exelon, DRBC, EPA, PADEP
Wissahickon Clean Watershed Partnership	Ongoing	PWD, PADEP, Wissahickon Valley Watershed Association (WVWA), PEC, Friends of Wissahickon, various townships
Partnership for the Delaware Estuary	Ongoing	PDE, PWD, additional partners listed at www.delawareestuary.org

5.2.2.1 Wastewater Discharges/Compliance

5.2.2.1.1 INFECTIVITY/VIABILITY STUDY

In 2004, PWD undertook a study to evaluate the potential effectiveness of ultraviolet light disinfection to inactivate *Cryptosporidium* in wastewater. Influent and effluent samples following UV treatment were collected on a monthly basis at the Abington WWTP from February to June 2004. Samples for *Cryptosporidium* were sent to Clancy Environmental for processing and analysis.

Results from the study do not provide adequate evidence of the correlation between UV disinfection and oocyst inactivation. The study's inconclusive results indicate the need to perform additional monitoring at WWTPs upstream of the Philadelphia's intakes. In regard to the efficacy of UV disinfection, peer-reviewed literature establishes a concrete correlation between UV disinfection doses and *Cryptosporidium* inactivation (Crockett 2007). The benefits of UV disinfection justify future development of strategies to upgrade upstream WWTPs with UV machines.

5.2.2.1.2 SEWAGE FACILITIES SELF-ASSESSMENT PROGRAM

EPA led this project through the SAN Pathogens and Point Sources Workgroup to identify municipal dischargers for a voluntary capacity management self-assessment project. Dischargers were provided with a self-assessment form to answer questions about their facility regarding sewer collection capacity, maintenance, operation, and management. The assessment took place on a subwatershed basis, and the Pathogens and Point Sources Workgroup used the results to obtain a better understanding of how sewage facility operations impact the water quality of the Schuylkill River (PWD 2006). Through the Pathogens and Point

Sources Workgroup, additional information regarding treatment capacity and technology is collected and compiled.

5.2.2.1.3 DELAWARE VALLEY EARLY WARNING SYSTEM (EWS)

For a description of PWD's Delaware Valley Early Warning System, please refer to section 5.2.1.1.9.

5.2.2.1.4 SCHUYLKILL RIVER WATER QUANTITY ANALYSIS

The Schuylkill River Water Quantity Analysis is a continuation of the Source Water Assessment and Protection Planning processes. The analysis specifically focuses on the factors that influence the water budget of the Schuylkill River (PWD 2009d). The project's aim is to identify the sustainable yield of the Schuylkill River as a drinking water source to the Queen Lane and Belmont WTPs. Schuylkill River water quantity is examined by calculating water budgets using multiple methods and analyzing how the results inform Philadelphia water supply sustainability and regional water resource management. This analysis will identify how, where, and in what amounts water is used throughout the watershed. The study also identifies periods of low flow when the percentage of flow comprised of WWTP discharge is more than 50%. Due to the downstream location of Philadelphia, it is critical that PWD can relate how water is used upstream to the amount of water needed for Philadelphia drinking water, industries and assimilative capacity.

The analysis indicates the degree to which WWTP effluent can affect Philadelphia's source waters based on the percentage of flow comprised of WWTP discharge. This is an important consideration when implementing LT2 control measures, since WWTP effluent has been identified as a high-priority source of *Cryptosporidium*.

5.2.2.1.5 IDENTIFICATION AND ABATEMENT OF WILDCAT SEWERS

SAN's Pathogen and Point Sources Workgroup has led efforts to identify and abate wildcat sewers within the Schuylkill River watershed, many of which are in Schuylkill County. A wildcat sewer system collects wastewater but has no treatment facilities. The raw sewage is discharged into streams or abandoned mine areas. As a result of the partnership's efforts, 29 wildcat sewers have been successfully abated to date.

5.2.2.2 Agricultural Land Use/Runoff

5.2.2.2.1 CONSERVATION PLANS

The Berks County Conservation District (BCCD) and the SAN Agriculture Workgroup partnered on an initiative to draft 44 conservation plans at cooperating farms in the watershed. Conservation plans identify strategies for proper manure management, identify optimized use of fertilizer and prevention of farm erosion and runoff to streams, and allow farms to become eligible for Federal funding to implement the tenets outlined in the plan. Using the results of a farm prioritization process, farms were targeted for conservation planning assistance from the BCCD, with the goal of following up with the installations of BMPs by the Berks County Conservancy (BCC).

The SWIG conservation planning process included coordination with the BCC on initial outreach to farmers and development of a Conservation and/or Nutrient Management Plan by a qualified technical service provider, with assistance, oversight and approval by the BCCD. A nutrient management plan, as defined by the NRCS, documents the strategies and practices utilized by livestock operations to address natural resource concerns related to soil erosion, livestock manure and disposal of organic by-products (PA NRCS 2010). As part of the planning process, BCCD completed several activities, including those listed below.

- Led the cooperation of agencies/organizations through the SAN Agriculture Workgroup for priority farmer contact.
- Developed a landowner information packet for dissemination to priority farms with potential interest in BMPs.
- Developed an agreement with the Reading Area Water Authority (RAWA) to provide participant farms with invasive removal assistance in fenced buffer areas and worked with RAWA to train staff on proper removal of invasive plants on BMP project farms.
- Provided planning/design consultation to the BCC for fencing, animal crossings, and buffer plantings on AG-2 project farms.
- Met with RAWA to submit grant request for Growing Greener funds to develop an Integrated Source Water Protection plan for the Maiden Creek/Lake Ontelaunee watershed and surrounding areas.

The BCCD, through the combination of SWIG and Growing Greener funds, was able to complete a total of 44 plans for farms in the Schuylkill River watershed, covering more than 3,000 acres and including 37 conservation plans, 2 nutrient management plans and 5 combination conservation and nutrient management plans.

5.2.2.2.2 PARCEL PRIORITIZATION, RIPARIAN BUFFER PLANTING, STREAMBANK FENCING, & CATTLE CROSSINGS

This project was designed as a two-phase study to examine the effectiveness of a coordinated prioritization approach to directing the implementation of a series of agricultural BMPs. The first phase was for the SAN Workgroup to establish a set of criteria and weightings that, when entered into a complex formula generated by EVAMIX software, determined the highest priority farms in the Schuylkill watershed (i.e., farms contributing most to agriculture impairments). The second phase was for primary partners to conduct outreach to farms and install BMPs, including stream bank fencing, cattle crossings, and riparian buffers at 15 of the highest priority farms determined during the parcel prioritization process. The highest priority farms are located on three clusters in two subwatersheds: Lower Maiden Creek and Upper Maiden Creek (SWIG 2009).

As a result of the parcel prioritization process, BMPs were installed on 19 farms in the watershed, including three major clusters (Seidel, Hill, and Adams farms), where upstream and downstream monitoring data was collected (SWIG 2009). BMP implementation was possible on four additional farms from the original 15 highest priority due to the availability of additional SWIG funding. The 19 farms with BMPs are detailed below in Table 5-4.

TABLE 5-4: SUMMARY OF SWIG AGRICULTURAL BMPS, 2005-2009

Farm	Farm Acreage	Acreage Fenced	Fencing (ft)	Stream Length Restored (ft)	Trees	Shrubs	Crossings
R. Seidel	78.6	1	1956	978	109	185	2
C. Seidel (2)	121.2	6.7	8746	4373	184	335	4
D. Woolf	53	2.1	4017	2008	95	178	2
Adam	105.8	10.1	5270	2635	560	0	5
Dreibelbis	177	82	1465	835	-	-	1
B. Hill	44.8	0.4	653	326	10	0	1
J.Hill	26.1	0.5	852	426	36	0	1
Junge	174	1	1534	767	90	0	1
Epting	30.2	1.0	1978	1030	6	0	3
Atkinson	77.7	2.0	2685	1095	36	24	2
Derstine	200.9	-	-	300	25	0	0
Lesher	126.4	3.9	2045	125	-	-	1
Luft	203.5	3.3	1656	750	60	0	1
Schroeder	138.3	5.6	3350	3350	140	0	3
Rabenold	209.6	1.3	3012	1506	0	0	2
Smith	92.6	2.9	4478	2239	0	0	3
Guntz	126.1	10	3210	2240	16	0	2
Hoch	183.3	0	0	2150	0	0	0

Source: The Schuylkill River Watershed Initiative Targeted Watershed Grant Final Report, 2009

Figure 5-1 below illustrates modifications made at the Seidel Farm through stream bank fencing and planting.

FIGURE 5-1: SEIDEL FARM STREAM BANK FENCING PROJECT - LEFT, 2004 BEFORE STREAM BANK FENCING; AND RIGHT, 2006 AFTER STREAM BANK FENCING

In order to begin gauging the success of the SAN agricultural BMPs, water quality, biological and visual monitoring assessments were performed at the three project location clusters: Adams, Hill, and Seidel Farms. At each farm parcel location, benthic/habitat monitoring and dry weather water quality monitoring were performed above and below each parcel, and each parcel was visually assessed both pre- and post-implementation (SWIG 2009). Monitoring was performed for the following water quality parameters: TSS, nitrate, nitrite, ammonia, total nitrogen, total phosphorus, conductivity, pH, temperature, and fecal coliform. Due to the relatively short time frame between project implementation (some projects were completed as recently as fall 2008) and sampling, the data collected were insufficient to demonstrate any water quality changes resulting from BMP implementation. However, to preliminarily gauge the success of the BMPs, expected loading reductions were modeled for sediment, total phosphorus, and total nitrogen. For example, at Adams Farm, Hill Farm, and the Seidel Farm, sediment loadings were estimated to be reduced by 132 tons/year, 47 tons/year, and 181 tons/year, respectively, through the implementation of riparian buffers.

5.2.2.2.3 SCHUYLKILL RIVER RESTORATION FUND

In 2006, Exelon, SAN, and the Schuylkill River Greenways National Heritage Area (SRG NHA) established the Exelon Restoration Fund, now named the SRRF. The SRRF provides grants to support projects that improve and protect water quality throughout the Schuylkill River watershed. Initially, Exelon provided all the funding to fulfill a requirement in their DRBC docket for the Wadesville Mine Demonstration Project. Beginning in 2009, PWD became the second annual contributor to the SRRF. Partnership for the Delaware Estuary (PDE) became a member and contributor in 2010 and Aqua PA followed in 2012. Additionally, MOM's Organic Market contributed to the SRRF 2014 through 2016, and Coca-Cola contributed in 2015. Members of the SAN serve as technical experts in the grant selection process to support the review of project applications for their benefit to the Schuylkill River watershed. SRG NHA oversees the SRRF and distributes grant money.

PWD now contributes approximately $100,000 to the SRRF each year. Priority projects are selected for the implementation of agricultural best management practices to support WCP

Cryptosporidium control objectives. During the first seven years of the WCP, PWD has supported the construction of either manure storage basins or vegetated buffers at 11 separate agricultural operations in the watershed through its participation in and annual contribution to the SRRF. SRRF projects that have received PWD grant funding in the past five years are listed in Table 5-5 below.

TABLE 5-5: ADDITIONAL SCHUYLKILL RIVER RESTORATION FUND AGRICULTURE PROJECTS

Farm	Subwatershed	Award Year	BMP Work Completed or In Progress
Grube Farm	Irish Creek	2020	Liquid manure storage basin, manure transfer system, roof dry stack manure storage, heavy use area stabilization, exclusionary fencing, barnyard controls and rain gutters
Kunkel Farm	Manor Creek	2020	Manure storage basin, roofed heavy use area, and barnyard stormwater controls
Love Farm	Hay Creek	2019	Dry manure storage basin, rain gutters and lined outlets, water pipeline to pasture, and animal stream crossing
Northwestern Stables	Wissahickon	2019	Stabilization of 41,000 square foot heavy use paddocks, 12,000 square feet of vegetated buffers and rain gardens, underground pipe system to collect and divert flow from paddocks, and improvements to existing roof drainage
A. Burkholder Farm	Saucony Creek	2018	Dry roofed manure storage area, water pipeline to pasture, animal stream crossing, and rain gutters and other barnyard controls
Brown Farm	Maiden Creek	2018	Manure storage basin, stream bank and wetland exclusion fencing, water supply well establishment, automatic drinker installation, and rain gutter improvements
Youse Farm	Manatawny Creek	2017	Manure storage basin, rain gutters and lined outlets, and other barnyard controls
Maidenford Farm	Irish Creek	2017	350 feet of streambank restoration and planting of vegetation, protection of 1.4 acres of forested riparian buffer and 1.3 acres of marginal pastureland wildlife habitat buffer, and 700 feet of livestock exclusion fencing
Zettlemoyer Farms	Upper Maiden Creek	2016	Two manure storage areas, rain gutters and other barnyard controls, establishment and planting of a riparian buffer with stream fencing, and implementation of rotational grazing
Rice Farm	Maiden Creek	2015	Two dry manure storage areas, rain gutters and lined outlets, and other barnyard controls

5.2.2.2.4 NRCS AGRICULTURE BMPS

The Natural Resources Conservation Service (NRCS) is also involved in the implementation of agriculture BMPs throughout the Schuylkill and Delaware River watersheds. Many agriculture best management projects are funded in part through contributions from NRCS funding programs such as the Environmental Quality Incentive Program (EQIP). NRCS also often provides in-kind technical assistance, including engineering and design services. With frequent help from NRCS and other SAN partners, hundreds of improvements have been implemented in the Schuylkill River Watershed since the inception of the SAN in 2003, including: the construction of 175 manure storage facilities; 185 barnyard and heavy use area upgrades; 89 stream crossings; and 494 acres of riparian buffers on agricultural lands (SAN 2018; SAN 2019).

5.2.2.3 Education/Outreach

On a watershed-wide scale, PWD's Education and Outreach initiatives serve many of the same objectives as those initiatives implemented within the City. The extensive size of the Schuylkill River watershed highlights the importance of partners that share the same source water protection goals, and will work to further the City's objectives, specifically in regard to pathogens reduction. Moving forward with plan implementation, PWD's partners may provide valuable feedback for this watershed control plan based on their various perspectives and diverse knowledge of the watershed. The initiatives below occur or have occurred in the Schuylkill River watershed and support one or more of PWD's education and outreach goals.

5.2.2.3.1 SAN PATHOGENS AND POINT SOURCES WORKGROUP

The Pathogens and Point Sources Workgroup of SAN is primarily comprised of water utilities, regulatory agencies, conservation districts, and non-profit organizations working together to address emerging water quality issues in the Schuylkill Watershed. The workgroup forum also enables PWD to raise important concerns with state and federal regulators regarding the impacts of upstream WWTP discharges on drinking water treatment. This forum provides a valuable context for bringing attention to drinking water treatment concerns, including LT2 compliance, as they relate to WWTP policies. Improved compliance efforts upstream ensure greater protection against pathogens in Philadelphia rivers.

5.2.2.3.2 SAN AGRICULTURE WORKGROUP

The goal of the SAN Agriculture Workgroup is to maximize the reduction and/or prevention of agricultural impacts to water quality. Meetings are held quarterly between EPA, PADEP, PWD, NRCS, and other conservancy and conservation district groups. The workgroup helps plan, implement and track agricultural BMPs in the Schuylkill River watershed, and plays an important role in the implementation of this watershed control plan.

5.2.2.3.3 WISSAHICKON CLEAN WATER PARTNERSHIP

In summer 2016, The City of Philadelphia joined 13 Wissahickon Creek watershed municipalities and four wastewater treatment plant operators to form a Wissahickon Clean Water Partnership (WCWP). The WCWP seeks to collaboratively develop an alternative TMDL for nutrients that would better address aquatic life impairments in the Wissahickon Watershed. The municipal participants represent over 98% of the watershed area, which provides a powerful stakeholder group that is uniquely positioned to develop a coordinated plan to improve water quality in the watershed. The project was funded in part by The William Penn Foundation through the Pennsylvania Environmental Council. Technical work was performed by Temple University. PWD is also a key participant in the effort providing technical support and important historical water quality information about the Wissahickon Creek.

With encouragement from PADEP and EPA, the WCWP is preparing a comprehensive Water Quality Improvement Plan for this highly-visible urbanized watershed that will include a long-term program to achieve significant water quality improvements through an adaptive management process. Specified projects and/or treatment upgrades may reduce pathogens in addition to nutrients as well as establishing a partnership framework for future collaborative efforts. In 2020, the Water Resources Association of the Delaware River Basin selected the WCWP to receive its prestigious Government Award (Blanton 2020).

5.2.2.3.4 PARTNERSHIP FOR THE DELAWARE ESTUARY

The Partnership for the Delaware Estuary (PDE), established in 1996, is a non-profit organization dedicated to protecting and enhancing the Delaware Estuary. The organization is one of 28 congressionally designated National Estuary Programs throughout the coastal United States. PDE partners with other Pennsylvania organizations to increase awareness, understanding, and scientific knowledge about the estuary, while protecting and enhancing the estuary and its tributaries for future generations (PDE 2010).

PWD and PDE work closely together in several partnerships, including the Schuylkill Action Network (SAN). PDE currently facilitates Water Quality Council Meetings and has worked with Philadelphia to provide education and outreach to communities in the watershed. An example of one outreach initiative was the publication of a student activity book, "Let's Learn about Water," that develops the concepts of a watershed, impact of non-point source pollution, and personal responsibility for protecting our water supply. The curriculum has already been used in a number of middle schools to meet state required science-based credits (PWD 2009c). Other PDE initiatives include a dog waste control program, piloted in Delaware and adopted by PWD, and development of stormwater inlet labeling.

5.2.2.3.5 WATERSHED PARTNERS AND THEIR ROLES

Please refer to the information presented in the above in-city and watershed-wide assessments for a description of PWD's primary watershed partners and how their work relates to PWD's source water protection efforts.

5.2.2.4 Other Accomplishments in Philadelphia's Source Watersheds

5.2.2.4.1 COMPLIANCE & AGENCY PARTNERSHIPS

PWD's commitment to reducing the risk of pathogen contamination in the watershed, and supporting its partners in this effort, is evident through the extensive list of projects above. Enforcement efforts on the part of municipal, county, state and federal regulators are also a critical component of PWD's goal to ensure a safe drinking water source for the City of Philadelphia.

The SAN Pathogens and Point Sources Workgroup tracks state highlights and accomplishments. These accomplishments demonstrate the workgroup is fulfilling its mission to address pathogen contributions in the watershed through the following action items: improving reporting of sewage overflows; promoting self-assessment by local municipalities of sewer collection system capacity, maintenance, operation and management; and ensuring compliance with combined system regulation/requirements, targeted inspections, compliance assistance, and appropriate enforcement.

Enforcement efforts to reduce the risk of *Cryptosporidium* contamination extend beyond the accomplishments achieved through SAN initiatives. For example, Pennsylvania's conservation districts work in partnership with state and federal agencies to implement effective, locally-led conservation programs. Conservation districts play a multi-faceted role in the watershed, from assisting county and municipal governments in land reviews and stormwater management plans to conducting educational programs related to soil and water conservation (PACD 2010). Within the Schuylkill River watershed, conservation district representatives participate in key partnerships, including SAN and partners in the Wissahickon Watershed, to aid in project implementation, education and outreach.

On a municipal level, effective management of publicly owned treatment works (POTWs) upstream of Philadelphia's intakes has contributed to the success of source water protection efforts. POTWs must manage all aspects of their treatment system and processes in order to meet NPDES permit requirements. Developing pretreatment standards and implementing wet weather management procedures are just two examples of POTW management practices.

State and federal-level enforcement play a critical role in ensuring the adequacy of wastewater collection systems and treatment plants. Many wastewater-related issues are not within Philadelphia's jurisdiction to address; therefore, the State's efforts to oversee permit compliance at upstream communities are crucial to protecting water quality conditions, including *Cryptosporidium* levels, at Philadelphia's downstream intakes. The elimination/reduction of combined sewer overflows (CSOs) upstream of the intake is one such example. The implementation and enforcement of Long-Term Control Plans (LTCPs) is critical to managing and reducing or eliminating combined sewer overflows.

The Schuylkill River Source Water Assessment identifies 11 upstream CSOs that represent sources of contamination at the Queen Lane intake. Two of these CSO communities, Bridgeport and Norristown, are located in Zone B and represent high-priority sources. Both communities are implementing Long Term Control Plans (LTCPs). Norristown's LTCP was approved in March 2002, with the plan of eliminating CSOs through system separation. The sewer separation plan was completed in August 2007, which helped to decrease wet weather flows and eliminate one CSO area. Infiltration and inflow still need to be addressed to eliminate the remaining CSO area and treatment plant overloading (CDM 2009). Bridgeport's LTCP was approved in May 2004, with plans to address CSOs through presumptive measures and a partial separation of the system. Bridgeport completed construction of new Front Street Interceptor in 2012, eliminating the original CSO outfalls and adding approximately 0.5 MG of wet weather storage to their collection system. As of 2020, the number of CSOs in the Schuylkill River Watershed upstream of the Queen Lane intake has decreased to 6 CSOs.

PWD's Source Water Protection Plan for the Delaware River identified increasing development upstream of the Baxter intake and discharges within Zone A of the Delaware River as the two main concerns regarding stormwater and combined sewer overflows. The assessment found 91 CSOs and 329 stormwater outfalls in the Zone A portion of Philadelphia County that either drain into the Delaware River directly or through tributaries before reaching the river. Of the 91 CSOs, 55 drain directly to the Delaware while 31 drain to the Tacony/Frankford Creek and 5 to the Pennypack Creek. PWD holds one stormwater permit and three CSO permits with the National Pollution Discharge Elimination System (NPDES) that govern all these 91 outfalls, with each permit representing multiple outfalls. PWD's Office of Watersheds manages the permit requirements through its Combined Sewer and Stormwater Management Program. The goal of the programs is to not only fulfill permit requirements, but also to prevent and mitigate the damage to water quality and to streams from these drainages by reducing the amount of stormwater reaching the drains (PWD 2007). In addition to these in-city CSOs, PWD's Source Water Assessment for the Delaware River identifies several communities directly upstream of the Baxter intake as having CSO discharges. These communities include Bethlehem, Allentown, Easton, Gloucester, and Camden (PWD 2002a). Additionally, the Lansdale Borough has two CSO outfalls that both discharge to tributary streams of the West Branch of the Neshaminy Creek. Reports to PaDEP from the Borough indicate that there have not been discharges from either CSO since 2014.

Additional issues requiring State-level enforcement are wet weather management and infrastructure maintenance. The state's efforts under the Act 537 program and 25 PA Code Chapter 94 address many sewerage-related issues that pose a threat to water quality in the watershed. The major provisions under the Act 537 program, or sewage facilities program, serve to correct existing sewage disposal problems and prevent future problems from occurring at both large, municipally owned sewage treatment plants and individual on-lot sewage disposal systems (OLDS). The Act requires proper planning of all types of sewage facilities, permitting of individual and community OLDS, as well as uniform standards for designing OLDS (PADEP 2008).

Chapter 94, Wasteload Management, encompasses both collection system capacity and plant capacity issues (PA Code 2011). The goal of Chapter 94 compliance is to reduce wastewater volume and pollutant mass loadings through the application of pollution prevention practices to avoid hydraulic, organic and industrial wastewater overloads at sewerage facilities. The chapter specifically states the following objectives:

- Prevent the occurrence of overloaded sewerage facilities.
- Limit additional extensions and connections to an overloaded sewer system or a sewer system tributary to an overloaded plan.
- Improve opportunities to prevent or reduce the volume and toxicity of industrial wastes generated and discharged to sewerage facilities and where prevention and reduction opportunities have been maximized, and to recycle and reuse municipal and industrial wastewaters and sludges.

PADEP reviews Chapter 94 reports annually to track treatment plants and sewer collection systems that regularly experience hydraulic overloads. The causes behind frequent hydraulic overloads, such as SSOs due to infiltration/inflow, are assessed and actions are taken to resolve these issues. PWD strongly values these enforcement efforts and plans to continue its work with government agencies, utilities and other organizations to continue to identify and address sources of pathogen contamination to aid in the enforcement process.

5.2.2.4.2 POLICY CHANGES

In addition to Pennsylvania's enforcement actions, the state has developed policy changes that further address source water protection issues. An example of recent policy development includes the revisions made to Title 25 Pa. Code Chapter 102: Erosion and Sediment Control and Stormwater Management. According to the State, Chapter 102 serves to protect surface waters of the Commonwealth through the utilization of Best Management Practices (BMPs) that minimize accelerated erosion and sedimentation during earth disturbance activities and manage post-construction stormwater runoff after earth disturbance activities. A final-form rulemaking amended the existing regulation to achieve several objectives including: the incorporation of

NPDES permit requirements for stormwater discharge from construction activities, long-term operations and maintenance requirements for post-construction management stormwater BMPs, revisions to the agricultural planning and implementation requirements, updated erosion and sediment control requirements, and provisions for riparian buffers and riparian forest buffers (CWA 2010).

The revisions particularly relevant to this watershed control plan include those changes made to the agricultural section (Section 102.4 (a)). The regulations now call for an E&S plan to be developed for animal heavy use areas, in addition to the original requirement for agricultural plowing and tilling. The E&S plan must identify appropriate BMPs to minimize erosion and sedimentation. The new regulations under Chapter 102 may help reduce the impact of agricultural and livestock activity on water quality, including pathogen concentrations.

Another notable policy change is the 2008 EPA-issued rule on requirements for CAFOs that are applying for a NPDES permit (US EPA 2008). The final rule includes two main revisions. The first revision pertains to CAFO permitting and asserts that only those CAFOs that discharge or propose to discharge must apply for permits. The revision requires a case-by-case evaluation of the CAFO's design, construction, operation and maintenance to determine whether the CAFO will discharge from its production site or land application area. The second revision adds a new requirement for permitted CAFOs. CAFOs that require permitting must now submit a Nutrient Management Plan (NMP) at the time of permit application, and the NMP must be incorporated into the CAFO's NPDES permit conditions. In addition, following review of the NMPs by the permitting authorities, the public must be provided with the opportunity for public review and comment (US EPA 2008).

6 Recommended Future Actions

By assessing the comprehensive list of projects and initiatives that contribute to reducing the risk of pathogen contamination in Philadelphia's source waters, PWD can evaluate areas of vulnerability that still exist. Listed in Table 6-1 below is a general evaluation of priority sources and an indication of whether or not they are adequately being addressed based on assessments of work within the City of Philadelphia and throughout the entire area of influence. The extent to which specific in-city and watershed-wide initiatives throughout the entire area of influence address priority sources of *Cryptosporidium* are described in detail in section 5.2.

TABLE 6-1: GENERAL VULNERABILITY ASSESSMENT OF PRIORITY *CRYPTOSPORIDIUM* SOURCES

Priority *Cryptosporidium* Sources	Currently Being Addressed	
	In-City	Throughout Entire AOI
Treated WPCP Effluent	NA	No*
Raw Sewage Discharges	Yes	Variable°
CSOs	Yes±	Variable°
Defective Laterals	Yes	Variable°
Wildcat Sewers	Yes	Variable°
SSOs	Yes	Variable°
Infrastructure Inspection/Main.	Yes	Variable°
Agricultural Runoff	Yes	Yes
Animal Vectors (specifically geese)	Yes	No*

AOI= Area of Interest

*When a priority source is listed as "No," not being addressed, there may exist select sites where the issues is currently being addressed, however, on a larger scale the source still represents a considerable vulnerability.

° "Variable" indicates a source that is generally addressed through regulatory requirements and permit issuances. Whether or not these sources are adequately being addressed depends on the specific municipality or utility and the level of enforcement action in that area.

± Actions to reduce Philadelphia's CSOs are part of a 25-year stormwater and wastewater infrastructure improvement program that are outside the scope of the Watershed Control Plan Update

Throughout the expanded area of influence, vulnerabilities still exist in the areas of treated WWTP effluent, raw sewage discharges and animal vectors. Agricultural runoff is being addressed both in-city and throughout the watershed; however, PWD encourages expanding these efforts to further minimize the threat of oocyst contamination at Philadelphia's intakes.

PWD proposes the following action items for the area of influence, with the hopes of achieving each initiative through the implementation of the Watershed Control Plan. Future initiatives are presented by control strategy category. The general control strategy categories are as follows:

1. ***Capital Improvements at Philadelphia's Water Treatment Plants*** – Includes the planning, design, and construction of UV disinfection upgrades to enhance drinking water treatment abilities and microbial protections
2. ***Watershed Protection Initiatives*** – Consists of various research, coordination, and on-the-ground projects to address priority sources of *Cryptosporidium*
3. ***Education and Outreach*** – Includes tasks to support the goal of raising awareness of source water protection issues throughout the area of influence
4. ***Stakeholder Engagement and Partnership Building*** – Outlines tasks associated with the feasibility evaluation of a Delaware River Watershed collaborative and/or funding mechanism

6.1.1 Capital Improvements at Philadelphia's Water Treatment Plants

Since the submission of the first iteration of the Watershed Control Plan in 2011, the Philadelphia Water Department has developed a comprehensive Drinking Water Master Plan that reviews existing drinking water treatment, pumping, distribution, and supply infrastructure in the context of anticipated regulatory and environmental drivers. The objective of the plan is to develop a strategic, long-term capital improvement plan that anticipates the capacity, treatment, and resiliency needs of the future.

PWD's completed Drinking Water Master Plan strategy identifies the highest priority capital improvements over the next 25 years that are needed to ensure resilient, robust, and dependable infrastructure. In total, the strategy identified approximately 400 individual projects with a projected total cost of $2.5 billion. All prioritized projects will result in reduced operational and public health risks and improved drinking water service. The 10 key projects identified in the plan are shown in Figure 6-2. Of these projects, the top three priority improvements include treatment upgrades at all three drinking water treatment plants, which include the installation of UV disinfection. UV disinfection is effective at inactivating *Cryptosporidium* oocysts and other microbials during the treatment process while reducing the production of harmful disinfection byproducts.

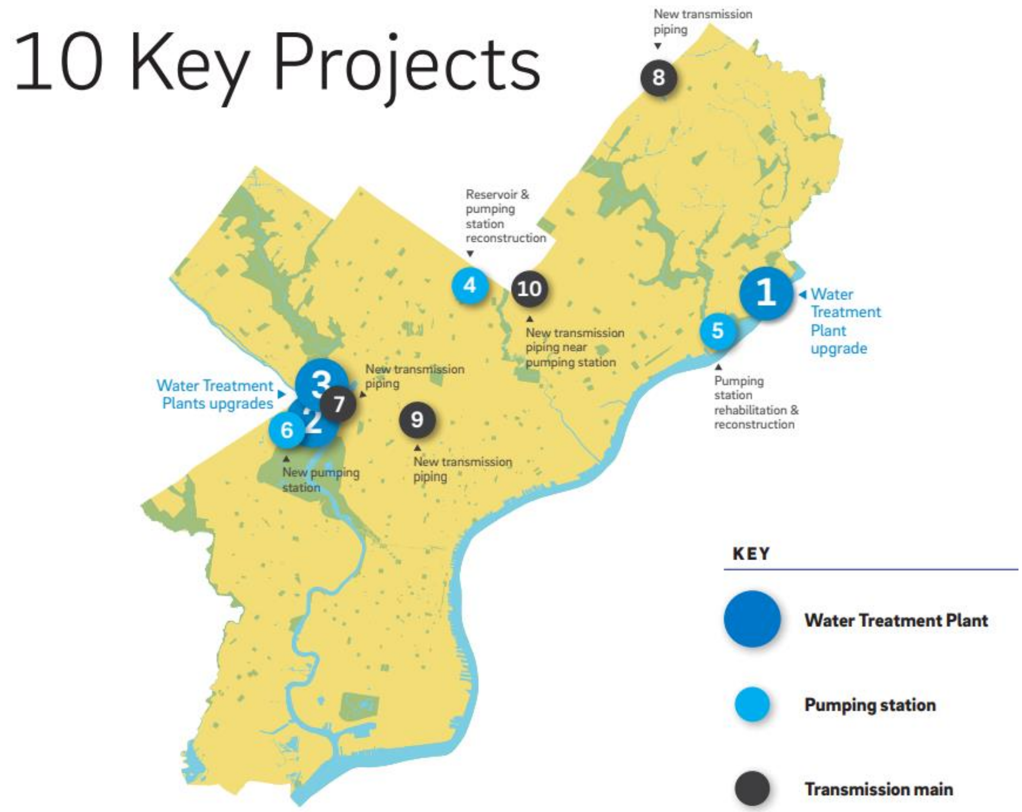
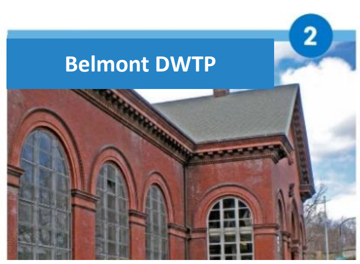


FIGURE 6-2: PWD DRINKING WATER MASTER PLAN 10 KEY PROJECTS

The Drinking Water Master Plan's top three key projects include the following:

Key Component: UV treatment addition

Benefit: long term regulatory compliance and drinking water quality



Key Component: Additional treatment capacity and UV treatment addition
Benefit: long term regulatory compliance, drinking water quality, and supply redundancy

Key Component: Reconstruction of entire plant with additional capacity and UV treatment
Benefit: Increased reliability and modularity and supply redundancy

The Watershed Control Plan will continue to track the status of these treatment upgrades and include updates and/or plan modifications in the WCP annual status reports.

More information on the Drinking Water Master Plan can be found here.

6.1.2 Watershed Protection Initiatives

Philadelphia's Watershed Protection Program champions a multi-barrier approach to protecting Philadelphia's water supplies. Key program components include emergency preparedness systems, public and private communication networks, computer modeling systems, laboratories, regional and national partnerships, and the development and implementation of formal plans to inform watershed management decisions. The initiatives in this section are organized by the priority source of *Cryptosporidium* addressed (i.e., wastewater discharge compliance, agricultural land use, and animal vectors). Additionally, a section explaining existing efforts to reduce urban and residential runoff is included.

6.1.2.1 Priority Source - Wastewater Dischargers/Compliance

Treated effluent is a consistent source of *Cryptosporidium* contamination that is largely outside of PWD's role and jurisdictional rights to address. The following PWD initiatives aim to reduce the risk of *Cryptosporidium* contamination from treated WWTP effluent while minimizing the occurrence of raw sewage discharges.

6.1.2.1.1 ONGOING INITIATIVES:

In-City

- Continue to support *Cryptosporidium* source tracking studies when possible, either through collaboration or in-house sampling efforts.
- Continue to regularly review and update Philadelphia's Act 537 Plan. The plan was last updated on February 27, 2009.
- Continue to implement the initiatives outlined in the annual Combined Sewer Management and Stormwater Management Plans in order to fulfill the City's Stormwater and CSO permits. Ongoing initiatives include monitoring as part of the Defective Lateral Detection and Abatement Program, maintenance of the Main and Shurs Elimination (Venice Island) project, and SSO monitoring of the State Road relief sewer.
- Continue to maximize usage for the Delaware Valley Early Warning System while maintaining the system's ongoing operations and maintenance needs.

Expanded Area of Influence

- Continue to support efforts of the SAN Pathogens and Point Sources Workgroup. The following strategies for the 2020 SAN Pathogens and Point Sources Workplan are as follows:
  1) Strengthen communication between and provide educational resources to wastewater and drinking water utilities to improve source water protection efforts,
  2) facilitate date and information sharing to document wastewater treatment,

3) investigate evolving source water issues, such as unregulated contaminants, and develop a better understanding of what these issues mean for water suppliers' source water protection strategies, and

4) engage and educate the public about pathogen water quality issues and solutions (SAN 2020a).

- Continue to support SAN in its efforts to identify and abate wildcat sewers throughout the Schuylkill River watershed.

6.1.2.1.2 PROPOSED INITIATIVES:

In-City

- Update discharger information from Source Water Assessments to reassess vulnerability from upstream dischargers
- Continue to strengthen relationships with upstream wastewater dischargers through partnerships like the Dissolved Oxygen (DO) Partnership

Expanded Area of Influence

- Re-delineate source water protection zones in the Delaware River Watershed using advanced hydrodynamic tidal modelling and update priority dischargers accordingly
- Track installation of wastewater treatment upgrades upstream of Philadelphia's intakes
- Work with professional organizations and industry groups (NACWA, WaterRF, et al.) to support related research and advocacy efforts

6.1.2.2 Priority Source - Agricultural Land Use & Runoff

Within the City of Philadelphia, PWD has addressed agricultural runoff through the projects listed in the in-city assessment. The expanse of agricultural land within the city is obviously minimal, so future agricultural BMP efforts should be focused elsewhere in the watershed. The following initiatives aim to reduce the impact of agricultural activities on water quality in the expanded area of influence.

6.1.2.2.1 ONGOING INITIATIVES:

In-City

- Coordinate with watershed partners to develop Comprehensive Nutrient Management Plans for WB Saul High School, Fox Chase Farm, and Manatawna Farm.
- Work with USDA/NRCS, PA Dept of Agriculture and the Philadelphia School District to implement best management practices at WB Saul High School.

- Reassess land use in the Schuylkill River Watershed, with each update of the National Land Cover Database (NLCD)
- Reassess land use in the Poquessing and Pennypack Watersheds with most recent NLCD

Expanded Area of Influence

- Actively participate in the SAN Agricultural Workgroup and support initiatives outlined in the Annual Workplans

6.1.2.2.2 PROPOSED INITIATIVES:

In-City

- Develop maintenance plans or MOUs for PWD's in-city agricultural BMPs
- Work with USDA/NRCS, PA Dept of Agriculture and the Philadelphia School District to implement best management practices at Fox Chase Farm
- Work with Northwestern Stables, Courtesy Stables, and Monastery Stables to implement conservation planning practices
- Work with Fox Chase Farms in the Pennypack Watershed, WB Saul High School Farm in the Wissahickon Watershed, and Manatawna Farm in the Schuylkill River Watershed to improve management and help teach the next generation of farmers best management practices.
- Reassess land use in the Schuylkill River watershed with the most recent National Land Cover Database (NLCD)

Expanded Area of Influence

- Reassess land use in Baxter’s area of influence with the 2016 National Land Cover Database (NLCD)
- PWD will explore the possibility of partnering with academic institutions on *Cryptosporidium*-related research and education initiatives, targeting those institutions with established agricultural sciences education. Relevant research may include monitoring to better characterize the sources of *Cryptosporidium* in Philadelphia’s source water.
- Identify priority projects and available funding sources; work with SAN partners to best utilize Farm Bill funds.
- Through the SAN Agriculture Workgroup, PWD will work with partners to identify CAFOs located in the Schuylkill River watershed and assess the status of their NPDES permits.
- Promote drinking water protection in existing funding programs.

- Reassess completed agricultural projects from early 2000s and use the assessment to inform revisions to the SAN agricultural monitoring plans
- Participate in State Conservation Commission nutrient management trainings and conferences to further develop expertise and enhance liaison role to Philadelphia's agricultural properties

6.1.2.3 Priority Source - Animal Vectors

Wild animals throughout the watershed can serve as mechanical vectors of *Cryptosporidium,* transferring viable oocysts from original hosts to Philadelphia's source waters. Geese in particular were identified as vectors in past source tracking studies. The following initiatives aim to reduce the impacts of geese near PWD's intakes and expand the implementation of animal vector control measures throughout the area of influence.

6.1.2.3.1 ONGOING INITIATIVES

In-City

- Work with the USDA APHIS wildlife services to implement waterfowl management programs at Philadelphia Water Department facilities
- Work with the USDA APHIS wildlife services to implement goose control measures on Fairmount Park Properties, including Peter's Island

Expanded Area of Influence

- Continue to support source tracking research to further identify and understand the animals that serve as mechanical vectors of *Cryptosporidium* in the watershed.

6.1.2.3.2 PROPOSED INITIATIVES

In-City

- Redesign and install "Do Not Feed Geese" educational signage in priority locations

Expanded Area of Influence

- Support efforts to publish scientific journal article to raise awareness and contribute to the state of the science

6.1.2.4 Priority Source - Urban & Residential Runoff

Although urban and residential runoff is not as significant a source of *Cryptosporidium* as agriculture runoff and WWTP effluent in Philadelphia's source watersheds, Philadelphia is addressing urban runoff through the City's 2009 Long Term Control Plan Update (PWD 2009a). On September 1st, 2009, PWD submitted the Green City, Clean Waters plan to the PADEP and EPA detailing how PWD would invest approximately $1.6 billion over the following 25 years to substantially reduce CSOs. To ensure this public investment not only results in clean and beautiful waterways but also provides tangible, additional benefits to our citizens, PWD is dedicating a large portion of this plan to a green stormwater infrastructure approach. PWD's definition of green stormwater infrastructure includes a range of soil-water-plant systems that intercept stormwater, infiltrate a portion of it into the ground, evaporate a portion of it into the air and, in some cases, release a portion of it slowly back into the sewer system. As a result, less stormwater enters the combined sewer system, ultimately reducing CSOs and the risk of pathogen contamination associated with these overflows. Integrating green stormwater infrastructure into a highly developed area like Philadelphia requires a decentralized and creative approach to planning and design. Various tools can be implemented to accomplish this feat, including stormwater planters, rain gardens, and green roofs. Implementing innovative green stormwater infrastructure throughout our City can maximize economic, social, and environmental benefits for Philadelphia. The following benefits have been associated with green infrastructure implementation in the City:

- Reduced CSOs
- Enhanced groundwater recharge
- Additional habitat and recreation space
- Increased carbon sequestration
- Improved air quality
- Reduced energy and fuel demand
- Mitigation of urban heat island effect
- Higher property values

PWD encourages the use of innovative stormwater management in upstream communities to achieve similar benefits. Philadelphia is implementing green infrastructure on a relatively large scale, but even small-scale green infrastructure projects can have positive water quality impacts. PWD will continue its outreach efforts to educate communities on the innovative designs that can be used to address stormwater management.

Along with the focus on green stormwater infrastructure, PWD has been working on upgrades to traditional infrastructure throughout our wastewater collection and treatment systems to increase system capacity and better manage stormwater. Traditional infrastructure improvements include relining and replacing sewers, improving capacity within our collection system, and improving our three water pollution control plants.

Stormwater BMPs are not within the scope of this watershed control plan. Therefore, the effectiveness of green infrastructure at reducing *Cryptosporidium* surface water contamination is not evaluated in this plan. Urban stormwater BMPs are usually not installed with the primary intention to capture pathogens in runoff. However, the benefits achieved in terms of nutrient and sediment reduction may produce ancillary benefits related to pathogen removal. The 2006 Pennsylvania Stormwater Best Management Practices Manual indicates that vegetated filter strips have a TSS removal efficiency of approximately 30%. Riparian buffer restoration can achieve a pollutant removal efficiency of approximately 65% (PADEP 2006). Turbidity can serve as an indicator of TSS, and the relationship between *Cryptosporidium* and turbidity is made explicit in the EPA LT2 regulations. Therefore, it is reasonable to conclude that the removal of sediment through the implementation of stormwater BMPs that infiltrate runoff may also reduce pathogen levels, including *Cryptosporidium*, in runoff.

6.1.3 Education and Outreach

Education and outreach initiatives are a critical component of PWD's Source Water Protection Program since point source discharges and land uses throughout the entire expanded area of influence are capable of impacting water quality conditions near Philadelphia's drinking water intakes. Many education and outreach initiatives are implemented through PWD's watershed partnerships. Therefore, a primary PWD goal is to maintain its watershed partnerships and continue to promote the importance of source water protection. PWD is committed to seeking opportunities that will expand partnership development and strengthen source water protection throughout the expanded area of influence.

6.1.3.1 Ongoing Initiatives

In-City

- Continue to submit a comprehensive annual water quality report that emphasizes critical source water issues and, in particular, educates customers as to the research initiatives and implementation strategies PWD is using to reduce the risk of *Cryptosporidium* contamination
- Continue to maintain the Fairmount Water Works Interpretive Center and promote source water protection through the center's various exhibits and learning programs
- Continue to operate and maintain Philly RiverCast and promote the web-based recreational warning system
- Continue to implement a pet waste education programs in the City of Philadelphia
- Continue to work with watershed partners to implement in-city stormwater education programs

Expanded Area of Influence

- Continue to participate in the SAN workgroups and support initiatives outlined in each group's workplan
- Continue to collaborate with the Partnership for the Delaware Estuary on various education and outreach initiatives, including the publication of guidance materials and organization of public programs and meetings surrounding water quality concerns
- Continue to promote the use of the Delaware Valley Early Warning System among industries, wastewater dischargers, and water suppliers

- Continue to support the Schuylkill River Restoration Fund to achieve implementation of best management practices at high-priority sites in the watershed

6.1.3.2 Proposed Initiatives

In-City

- Work with Philadelphia and regional schools to identify opportunities to enhance conservation practice education in the curriculum

Expanded Area of Influence

- Work with Bucks County Partners to explore opportunities for collaboration on educational campaigns and programming for surrounding community
- Work with Bucks County Conservation District to identify education and outreach opportunities as they relate to source water protection

6.1.4 Stakeholder Engagement and Partnership Building

The existing coordination and funding mechanisms in the Schuylkill River Watershed made the first iteration of the Watershed Control Plan possible. Without these mechanisms available in the Delaware River Watershed, the coordination and funding needs in these areas will be fully identified and the feasibility of addressing these needs will be explored to create a framework for improved environmental management in the expanded area of influence.

6.1.4.1 Ongoing

In-City

- Promote the Schuylkill River Restoration Fund to potential applicants where appropriate
- Remain an active participant in watershed partnerships and reinvigorate Philadelphia Watershed partnerships, e.g. Friends of the Pennypack and Friends of Fox Chase Farm

Expanded Area of Influence

- Continue to support the Schuylkill River Restoration Fund to achieve implementation of priority projects
- Champion the Schuylkill River Restoration Fund and work with SAN partners to draw in more funders

6.1.4.2 Proposed

In-City

- Engage Philadelphia stables in the implementation of erosion and sediment control measures

Expanded Area of Influence

- Identify and engage water utility partners in the Delaware River Watershed and host various coordination meetings to establish and maintain a dialogue among area water utilities
- Organize planning forums and identify coordination priorities with water utility stakeholders
- Explore the needs and feasibility of creating a partnership-based coordination mechanism for the Delaware River Watershed
- Explore stakeholder interest and opportunities for collaborative funding and/or a grant program.

7 Quantitative Assessment of the Relative Impact of Contamination Sources

The initiatives outlined in Section 6 are included in this plan because they each have the potential to either directly or indirectly contribute to a reduction in the total *Cryptosporidium* watershed load. In order to quantitatively assess the impact of PWD projects and their potential to reduce the total *Cryptosporidium* load in the Schuylkill River watershed, a series of calculations were performed to:

1. Provide an estimate of the total watershed load that is comprised of contributions from the priority sources outlined earlier in this plan, and

2. Provide estimates of the reduction in watershed load achieved through implementation of PWD projects.

Upon determining a total watershed load, a first attempt was made to establish a target reduction by comparing the observed average concentration of 0.076 oocysts/L at the Queen Lane intake during the LT2 Round 1 monitoring period (2001-2003) to a desired Bin 1 concentration of 0.074 oocysts/L. An analogous calculation was performed for the 0.087 oocysts/L at the Baxter intake during LT2 Round 2 monitoring period (2015-2017).

It should be emphasized that the calculations described below serve as a preliminary step in developing a quantitative method to assess *Cryptosporidium* loads from priority sources in the area of influence. The method outlined below is based on assumptions and values found in literature. Due to a lack of data and information available to support quantitative assessments of *Cryptosporidium* sources, the accuracy of this method cannot be determined, and the results should not be used to make any absolute conclusions. The uncertainties associated with quantifying *Cryptosporidium* loads and the impact of priority projects only highlight the need for continued and expanded research.

The following summary provides a brief description of the quantitative approach used to determine both the watershed load and the project impact estimates. An explanation is also provided regarding the development of a target reduction for the watershed load.

7.1.1 Total Cryptosporidium Load

A total watershed load was calculated based on the potential contribution from *Cryptosporidium* sources in the delineated area of influence for both the Queen Lane and Baxter intakes. The watershed load is comprised of loading estimates for agricultural land use/runoff, WWTP effluent and stormwater runoff. Brief descriptions of the calculation method(s) used for each source are outlined below.

7.1.1.1 Agricultural Land Use/Runoff

Two different calculation methods were used to determine the contribution from agricultural land use/runoff to the total watershed load. The first method is similar to the approach used in the Source Water Assessment (SWA), in which a land use analysis, runoff volumes, and a *Cryptosporidium* event mean concentration (EMC) are used to calculate a total *Cryptosporidium* watershed load. The second method utilizes estimated infected livestock populations for the entire Schuylkill River watershed, as well as oocyst shedding rates for each category of livestock (C. Crockett, personal communication, December 2010).

7.1.1.2 WWTP Effluent

The method for calculating the contribution from WWTP effluent takes into account the treatment level (secondary or tertiary) of plants in the area of influence, as well as estimates for secondary effluent oocyst concentrations based on various sources of literature. The oocyst concentrations were each multiplied by the average daily flow rate at each WWTP to determine a total daily load. For the Schuylkill River watershed, that includes 94 municipal WWTPs and 35 non-municipal WWTPs. Treated wastewater effluent *Cryptosporidium* load in the Baxter intake area of influence includes 79 municipal WWTPs and 86 non-municipal WWTPs; 67 WWTPs in the Lehigh sub-basin, 27 WWTPs in the Lower Central (PA Only) sub-basin, 41 WWTPs in the Upper Central (PA Only) sub-basin, and 30 WWTPs in the Upper Estuary (PA Only) sub-basin. For the plants that have tertiary treatment systems, an additional 1 log, or 90% removal, was assumed for effluent oocyst concentrations. The UV disinfection dose for wastewater and reuse applications has traditionally ranged from 40-100mJ/cm^2, with up to 4-log inactivation achieved at a dose of 40 mJ/cm^2 (CH2MHill 2009). Assuming a conservative 3 log removal/inactivation for the three plants with UV disinfection, inactivated load was estimated and removed from sub-basin *Cryptosporidium* load totals.

7.1.1.3 Urban/Developed Stormwater Runoff

To calculate an estimate for the annual oocyst load from stormwater runoff, an EMC/land use method was used. Land use categories and EMCs that encompass urban/developed lands were selected from the 2002 Schuylkill and Delaware River Source Water Assessments for these calculations.

7.1.1.4 *Cryptosporidium* Load from Expanded Area of Interest[1]

Results of the loading estimates for each source described above are displayed in Table 7-1 below.

TABLE 7-1: ANNUAL WATERSHED LOADS FOR *CRYPTOSPORIDIUM* SOURCES IN THE AREA OF INFLUENCE

	Delaware River Basin Sub-Basins				
	Baxter AOI				Queen Lane AOI
Load Estimate (oocysts/yr)	Lehigh Valley	Lower Central	Upper Central	Upper Estuary	Schuylkill
Agricultural Runoff (Land Use/EMC)	1E+12	7E+11	4E+11	4E+11	2E+12
Agricultural Runoff (Animal Population)	7E+13	9E+13	1E+13	6E+13	8E+14
Urban Stormwater Runoff	3E+11	3E+10	9E+10	6E+11	5E+11
Wastewater Effluent	1E+08	1E+07	3E+07	4E+07	3E+07
Sub-basin Crypto Load Estimates					
Min Estimate (oocysts/yr)	1E+12	7E+11	5E+11	1E+12	3E+12
Max Estimate (oocysts/yr)	7E+13	9E+13	1E+13	7E+13	8E+14

Summing the contributions from the sources listed in Table 7-1 yields the total *Cryptosporidium* loads for each sub-basin in Table 7-2 below. Since two methods are used to calculate the

[1] Note: Calculated *Cryptosporidium* loads may differ slightly due to rounding

agriculture component (land use vs. animal population), there are two different total load estimations that create an estimated range.

TABLE 7-2: ESTIMATES FOR THE ANNUAL TOTAL LOAD OF *CRYPTOSPORIDIUM* IN THE AREA OF INFLUENCE (OOCYSTS/YEAR)

		Annual Load Estimation (oocysts/year)	
	Sub-basin	*Land Use Method*	*Animal Population Method*
Baxter intake AOI	Lehigh	1E+12	7E+13
	Lower Central	7E+11	9E+13
	Upper Central	5E+11	1E+13
	Upper Estuary	1E+12	7E+13
		3E+12	*2E+14*
Queen Lane intake AOI	Schuylkill	3E+12	8E+14
	Total (oocysts/yr)	**6E+12**	**1E+15**

7.1.2 Target Reduction[2]

The estimated *Cryptosporidium* watershed loads were used to develop a benchmark or target reduction number. There is no way to guarantee that achieving a target reduction will subsequently lower the oocyst concentration at the intake. However, a benchmark reduction still helps define a quantitative target for reducing the watershed load and provides a means to evaluate the impact of source water protection initiatives.

7.1.2.1 Queen Lane Intake

To calculate a benchmark reduction, the ratio of 0.074 oocysts/L, or a maximum Bin 1 concentration, to 0.076 oocysts/L, or the observed concentration at the intake, was used:

$$\frac{0.076\ \mathrm{oocysts/L} - 0.074\ \mathrm{oocysts/L}}{0.076\ oocysts/L} = 0.02$$

Multiplying the 0.02 by the larger of the two estimates for the total Schuylkill load listed above in Table 7-2 (8E+14 oocysts/year), yields a target total watershed load of 2E+13 oocysts/year. For a 5-year project implementation timeline, the target reduction is therefore 4E+12 oocysts/year, or the equivalent of a 2.7% reduction in the existing Schuylkill River watershed annual load.

The higher of the two watershed load estimates is used to calculate the target reduction for several reasons. The higher watershed load is most likely an overestimate of the number of oocysts that reach surface waters in the Schuylkill River watershed. The overestimate is due to several assumptions made during the loading calculations for the individual sources. By overestimating the watershed load, a factor of safety is incorporated into the target reduction. Using a conservative target reduction is desired so that the impacts of additional factors are taken into account, including inconsistent sources of *Cryptosporidium* that are not included in

[2] Note: Calculated *Cryptosporidium* loads may differ slightly due to rounding

the total watershed load, the existence of unknown delivery ratios that represent the number of oocysts that make it from source to stream, and the amplification of these and other influences over such a large area as the Schuylkill River watershed.

7.1.2.2 Baxter Intake

An analogous method was used to calculate a benchmark reduction at the Baxter intake. The ratio of 0.074 oocysts/L, or a maximum Bin 1 concentration, to 0.087 oocysts/L, or the observed concentration at the intake during Round 2 sampling, was used as follows:

$$\frac{0.087 \text{ oocysts/L} - 0.074 \text{ oocysts/L}}{0.087\ oocysts/L} = 0.149$$

In other words, a 14.9% reduction in observed concentration would allow Baxter to fall under Bin 1 cutoff value. Multiplying the larger of the two estimates for the AOI loading listed above in Table 7-2 (2E+14 oocysts/year) by 14.9% yields a target load reduction of 4E+13 oocysts/year. The target reduction over a 5-year timeline is therefore 7E+12 oocysts/year, or the equivalent of a 14.9% reduction in the existing load. The target percentage reduction applied to both Queen Lane and Baxter AOIs yields a target load reduction of 3E+13 oocysts each year for every year within the five-year implementation timeline.

7.1.3 Project Impact Estimates

As projects are implemented under the LT2 watershed control plan, their impact can be assessed using the same presumptive approaches used to estimate the total load. The impact, or potential for reducing the total load, can then be compared to the target reduction that is established above. As an example of the potential for source water protection initiatives to influence the *Cryptosporidium* watershed load, an analysis was performed involving WWTPs in the Wissahickon watershed. A total of five WWTPs (Upper Gwynedd, Abington, Ambler, North Wales and Upper Dublin) currently discharge into the Wissahickon watershed. Of these plants, Abington and Ambler already employ UV disinfection, while Upper Dublin currently uses CL_2 gas. Upper Gwynedd has used UV disinfection since 2013. North Wales closed in 2012, and all of the plant's flow will be re-routed to Upper Gwynedd. Therefore, for these calculations, the average daily flow rate from North Wales is accounted for in the average daily flow rate for Upper Gwynedd. Computing the total average daily loads from WWTP effluent in the Wissahickon watershed, the percent potential reduction/inactivation of *Cryptosporidium* oocysts from treated effluent was calculated as follows:

- Upper Gwynedd, Abington, and Upper Dublin were assumed to discharge with secondary treatment, while Ambler was assumed to discharge with tertiary treatment, in accordance with treatment level data from the 2008 SAN *Cryptosporidium* Survey. All four plants were assumed to discharge with secondary or tertiary treatment only (no UV disinfection) as the baseline.
- UV disinfection was then applied to the flows at Abington, Ambler and Upper Gwynedd, with each plant assumed to achieve an additional 3 log inactivation due to UV disinfection.
- Upper Dublin was assumed to remain at baseline conditions.

The UV disinfection dose for wastewater and reuse applications has traditionally ranged from 40-100mJ/cm^2, with up to 4 log inactivation achieved at a dose of 40 mJ/cm^2 (CH2MHill 2009). Assuming a conservative 3 log removal/inactivation for the three plants with UV disinfection, the number of infectious oocysts in the total flow from WWTPs in the Wissahickon is reduced from baseline conditions by approximately 95% through the use of UV. In order to compare the inactivation number to the target Schuylkill sub-basin reduction, the difference between the average load from the three plants before and after taking UV disinfection into account was calculated. Approximately 3E+07 oocysts/year are inactivated when UV is employed at Upper Gwynedd, Ambler and Abington, highlighting the potentially large public health impacts if more WWTPs upgrade to UV in the Schuylkill River watershed. It should be emphasized that although UV disinfection inactivates *Cryptosporidium* oocysts, it does not physically remove oocysts in WWTP effluent. Therefore, although public health risks are substantially reduced through oocyst inactivation, non-viable oocysts or empty oocyst shells will not be differentiated from viable and infectious oocysts under the current EPA monitoring and analysis methods used at drinking water intakes.

Project reduction estimates were also calculated for the agricultural BMPs installed throughout Philadelphia's source watersheds. Only the WWTP reduction calculations, however, are included in this plan because the accuracy of the agricultural project reduction estimates is still largely unclear. WWTPs discharge directly to the river, implying that it is unnecessary to account for an overland delivery ratio. For both agriculture and stormwater projects, the reductions from implemented projects are difficult to estimate because the delivery ratio, or the percentage of "controlled" *Cryptosporidium* that never reaches a stream, is not known.

7.1.4 Conclusions Regarding the Quantitative Approach

Several conclusions can be drawn from the quantitative approaches developed for the LT2 Watershed Control Plan.

1. Estimating the impact of different sources of *Cryptosporidium* is only possible using a presumptive approach that relies heavily on values found in literature. The accuracy of this approach is unclear and most likely results in an overestimate of the number of *Cryptosporidium* oocysts that reach surface waters within the expanded area of influence.

2. The expanded area of influence is a large area to consider. While sources of *Cryptosporidium* throughout the entire watershed should be taken into account, the factors that affect the impact of contamination sources and the delivery ratio, or the percent of oocysts that travel from source to surface waters, are amplified many times over such a large area.

3. Evaluation of program success should continue to focus on tracking the implementation of the source water initiatives outlined earlier in this plan. Any quantitative approach used to measure program success should focus on updating relevant calculations and modeling results as changes to priority point and non-point sources are identified and additional research is performed. A comparison of results from Round 1 to Round 2 does not provide a full picture.

4. Moving forward, expanding data collection and research opportunities will be necessary to develop a better understanding of the sources of *Cryptosporidium* and the effectiveness of source water protection initiatives. PWD proposes several research initiatives for increasing the understanding of agriculture and WWTP effluent sources of *Cryptosporidium*. These initiatives are listed below in Section 8.

8 Future Research Initiatives

The quantitative approaches used to calculate *Cryptosporidium* loads clearly indicate that more research is needed to not only improve the accuracy of future quantitative assessments, but also to increase PWD's understanding of the impact of specific *Cryptosporidium* sources on surface water concentrations at Philadelphia's intakes.

It has been established that agricultural runoff and WWTP effluent both have a direct impact on source water concentrations of *Cryptosporidium*. PWD proposes several research initiatives that aim to improve the understanding of *Cryptosporidium* surface water contamination as it relates to agriculture sources and WWTP effluent. The proposed research initiatives and the mechanisms through which research and monitoring can be performed are described below.

8.1.1 Agriculture Related Research

Section 4, *Analysis of Control Measures*, describes projects elsewhere in the nation that attempt to quantify the oocyst removal capabilities of agriculture BMPs. The presumptive approach described above relies heavily on values from literature to provide quantitative estimates for the prevalence of infection in livestock populations and oocyst shedding rates. Although existing data are helpful in developing a general understanding of the impact of agriculture sources and the effectiveness of select control measures, many of these results are site-specific and not necessarily directly applicable to farms in Philadelphia's source watersheds.

In order to increase the understanding of agriculture impacts in Philadelphia's source watersheds, PWD proposes localized, long-term research efforts that focus on farms that have the potential to contribute to surface water contamination at Philadelphia intakes. Future focused research efforts may include the following components:

- Increased monitoring at farm BMP sites
- Increased monitoring upstream and downstream of farms in the expanded area of influence
- Assessing, in greater depth, agricultural sources of contamination in the subwatersheds listed in the Source Water Assessment's prioritization of *Cryptosporidium* sources.
- Evaluating farms within the expanded area of influence and developing site-specific farm management practices that will reduce the risk of *Cryptosporidium* surface water contamination. Management practices could include containment and manure management of potentially infected calf populations.

Through research efforts similar to those listed above, PWD and its watershed partners may be able to gain a better understanding of the water quality impacts of specific agriculture sources as well as the most effective practices available to reduce these impacts within Philadelphia's source watersheds.

8.1.2 WWTP Related Research

Treated WWTP effluent is generally a concern when it comes to protecting drinking water supplies; *Cryptosporidium* being one aspect of this concern. Using a presumptive approach based on results from pooled literature sources, PWD was able to estimate *Cryptosporidium* loads attributable to WWTP effluent in the area of influence. Moving forward, monitoring downstream of WWTPs in the area of influence will increase PWD's understanding of the relationship between treated effluent and *Cryptosporidium* surface water concentrations.

In collaboration with Lehigh University, PWD has explored possible research areas involving the impact of WWTP effluent. Lehigh has evaluated the efficacy of biofilms in capturing the presence of oocysts in surface waters. One research initiative explored in collaboration with Lehigh University involves the use of biofilm samplers to capture the impact of WWTP effluent by installing samplers both upstream and downstream of WWTPs. In addition to focusing on the impact of WWTPs, this study explored the use of biofilms as a significantly cheaper monitoring alternative to *Cryptosporidium* filters. Identifying new and less costly *Cryptosporidium* monitoring methods is an important area of research that, if expanded upon, could potentially increase the feasibility of collecting and analyzing *Cryptosporidium* monitoring data over larger areas of study and for longer periods of time.

8.1.3 Seasonal Occurrence Research

Following completion of LT2 Round 2 monitoring (2015-2017), PWD scientists and engineers observed higher oocyst concentrations and more frequent detections in the colder months. PWD further examined Round 2 compliance data to investigate seasonal clustering of positive detections. Considering the potential sources of *Cryptosporidium* and their respective control mechanisms listed in Table 8-1, it was hypothesized that more *Cryptosporidium* oocysts wash into the waterways during the time of year when vegetated and riparian buffers are dormant.

TABLE 8-1: *CRYPTOSPORIDIUM* SOURCE AND CONTROL MECHANISM CONSIDERATIONS FOR SEASONAL ANALYSIS

Source	Control Mechanism	Seasonal Dependency
Wastewater Effluent	UV disinfection	Loading to waterways and treatment type is not seasonally dependent
Agricultural Runoff	Agricultural BMPs e.g., manure management, riparian and vegetated buffers	Seasonal components to manure management practices
Wildlife Impacted Runoff	Stormwater BMPs e.g., Riparian and vegetated buffers	Seasonal changes in vegetated buffers

**Possibly a higher percentage of WWTP effluent in source waters during low flows, but treatment is not seasonal and does not affect Cryptosporidium detections via EPA Method 1632*

PWD Round 2 compliance data were further examined by its occurrence in the vegetated and dormant seasons. For the purposes of analysis, the vegetated season was defined as the time period between the last frost in the spring and the first frost in the fall while the dormant season was defined as the first frost in the fall and the last frost in the spring. Season definitions for this analysis were based on the median first and last frost dates (28°F) from nearby weather stations. The weather stations and dates determined to define the "seasons" of this analysis are shown in Table 8-2.

TABLE 8-2: DEFINING VEGETATED AND DORMANT SEASONS TO ANALYZE PWD LT2 ROUND 2 COMPLIANCE DATA

PWD Intake (Watershed)	Weather Station	Last Frost (28°F)	First Frost (28°F)
Baxter (Delaware)	Philadelphia NE Airport	March 29	November 13
Belmont (Schuylkill)	Franklin Institute	March 19	November 17
Queen Lane (Schuylkill)	Franklin Institute	March 19	November 17

PWD's LT2 Round 2 monitoring data was then visualized with the seasonal cutoffs, see Figure 8-1. The "dormant" season is highlighted in yellow while the "vegetated" season is highlighted in green for each PWD drinking water intake. A pattern of increased frequency and concentration can be observed in the dormant season.

FIGURE 8-1: PRELIMINARY ANALYSIS OF SEASONAL TRENDS IN PWD LT2 ROUND 2 COMPLIANCE DATA

The detections were then examined on a percentage basis by intake, as shown in Figure 8-2. The percent of positive detections in the vegetated season ranged from 10% to 19% at PWD's Schuylkill River intakes while the percent of positive detections in the dormant season ranged from 15% to 25%. The percent of positive detections during the vegetated and dormant seasons at the Baxter intake were 15% and 28%, respectively. Negatives, or non-detections, are represented by the grey areas and range from 56% (Queen Lane and Baxter) to 75% (Belmont) of samples.

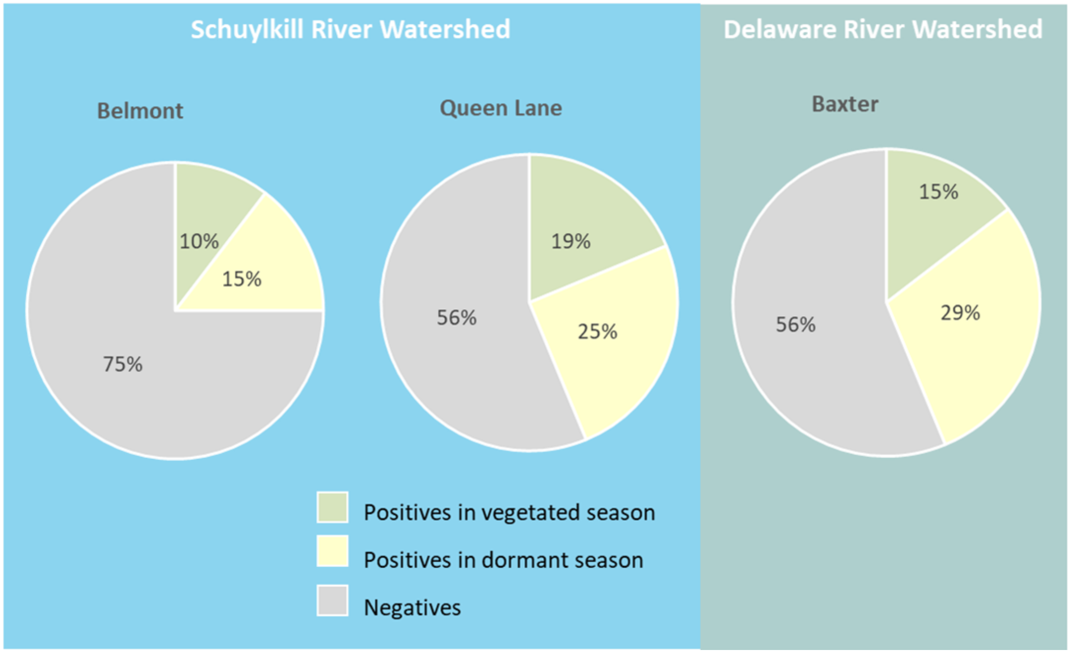


FIGURE 8-2: PRELIMINARY SEASONAL OCCURRENCE ANALYSIS OF PWD'S LT2 ROUND 2 COMPLIANCE DATA

Further examination of publicly available data of other water supply intakes in Philadelphia's source watersheds showed a greater percentage of negative samples relative to positive samples in both the Schuylkill and Delaware River intakes. Of the seven water supply intakes examined on the Schuylkill River Watershed, a greater percentage of positive samples occurred during the dormant season as opposed to the vegetated season. Out of the eight water supply intakes examined in the Delaware River Watershed, six had a greater percent of positive detections in the dormant season. One Delaware River intake had equal percentage positive samples in the vegetated and dormant seasons and one intake had a greater percentage of positive detections during the vegetated season. When looking at the *Cryptosporidium* oocysts concentrations detected, five out of eight Delaware River Watershed intakes had a higher average concentration in the dormant season as opposed to the vegetated season. Five out of seven Schuylkill River Watershed intakes had a higher average oocyst concentration in the dormant season as opposed to the vegetated season.

Based on these preliminary observations, it appears that more positive detections occur in the dormant season; however within this observed pattern there are several sources of variability. Potential sources of variability include but are not limited to the analytical laboratory processing the samples, rainfall location and intensity, human and animal outbreaks, and fate and transport mechanisms of *Cryptosporidium*. It may not be feasible to target management strategies towards variability; however, it is reasonable to target the observed occurrence pattern. For the vegetated season, buffers are appropriate control mechanisms for streams and areas draining into storm sewers. For the dormant season, wildlife management and multi-barrier approaches to agricultural runoff may be more effective.

Although this is only a preliminary analysis based on limited data, it shows the need for further research into the seasonal trends of *Cryptosporidium* occurrence on a watershed scale as they may influence the effectiveness of control mechanisms and better inform management strategies.

8.1.4 Additional Research Opportunities and Mechanisms

PWD's partnerships with water research organizations and academic institutions create an opportunity to further *Cryptosporidium*-related research in the watershed. Water industry organizations such as the Water Research Foundation (WaterRF) and the American Water Resources Association (AWRA) could be instrumental in leading *Cryptosporidium* research studies. PWD, as an active member of these organizations, can help identify priority research areas and support project planning efforts. In addition, PWD could expand its opportunities to partner with academic institutions as priority projects are identified.

In order to identify the highest priority research needs relating to *Cryptosporidium* and the threat it poses to our nation's drinking water supplies, PWD proposes the creation of a forum or working group. The working group could consist of research organizations, utilities, regulators, and leading researchers in the field of *Cryptosporidium* and source water contamination. The knowledge base and varying perspectives of workgroup participants would help identify areas most in need of continued research, while also providing utilities, such as PWD, with a better understanding of how they may interpret and utilize existing research results. As part of PWD's feasibility assessment of a utility-based Delaware River Watershed coordination group, *Cryptosporidium* research needs and planning priorities will be discussed along with the identification of appropriate partners to include in the effort.

In addition to forming a working group, PWD believes it would be beneficial to create a literature database that captures and organizes the results from both ongoing and completed research studies. A research database could be extremely useful in assessing existing projects, gaps in research, and also to serve as a tool for utilities to evaluate what research is applicable to their watershed and what research is strictly site-specific. This is a project that PWD could initiate, with eventual support and project management coming from the *Cryptosporidium* working group.

9 Timeline for Implementation

The watershed control program implementation plan is based on an approximately five-year timeline. The status of each initiative will be reported on in the plan's status reports, which PWD will continue to submit to PADEP on an annual basis. The *Cryptosporidium* control strategies within the WCP include the following broader categories:

- ***UV Inactivation at PWD Drinking Water Treatment Plants*** – Includes the planning, design, and construction of treatment upgrades to enhance drinking water treatment abilities (*see Table 9-1*)
- ***Watershed Protection Initiatives*** – Consists of various research, coordination, and on-the-ground projects to address priority sources of *Cryptosporidium* (*see Table 9-2*)
- ***Education and Outreach*** – Includes tasks to support the goal of raising awareness of source water protection issues *(see Table 9-3).*
- ***Stakeholder Engagement and Partnership*** *Building* – Outlines tasks associated with the feasibility evaluation of a Delaware River Watershed Collaborative and/or funding mechanism (*see Table 9-4*).

The projects outlined in the watershed control plan will be implemented according to the proposed timelines in the tables that follow. Please note that these timelines are for planning purposes and may be altered or modified due to any number of different variables. Should any changes to the proposed project implementation schedule occur, PWD will report each change and the subsequent reasons for altering the schedule in the annual status report submitted to the PADEP.

9.1 Capital Improvements at Philadelphia's Water Treatment Plants

The Philadelphia Water Department recently completed a 25-year drinking water master plan to identify the highest priority capital improvements needed to ensure a resilient, robust, and dependable infrastructure. Key projects were identified to decrease operational and public health risks as well as enhance PWD's level of service. The strategy identified approximately 400 individual projects with an estimated total cost of $2.5 billion. Although this planning process is cyclical and is formally updated every 5 years, the timeline in Table 9-1 below represents the planned implementation of UV inactivation at Philadelphia's three drinking water treatment plants. Any changes to this timeline will be reported in subsequent annual status reports. Although the nature of these projects does not lend itself to a 5-year timeline, the projects have been included in the plan due to their relevance to the goal of controlling pathogens in drinking water. The installation of UV disinfection will provide inactivation of *Cryptosporidium* and other microbial contaminants, in addition to reducing the formation of disinfection byproducts during the treatment process.

Table 9-1: LT2 Watershed Control Plan Implementation Schedule – UV Inactivation at PWD DWTPs

Control Strategy: UV Inactivation at PWD Water Treatment Plants						
Planned Capital Project**	Planning		Design		Construction	
	Start	End	Start	End	Start	End
Installation of UV treatment system at Baxter WTP on Delaware River*	2019	2022	2022	2025	2026	2030
Installation of UV treatment system at Belmont WTP on Schuylkill River*	2019	2021	2021	2024	2025	2029
Installation of UV treatment system at Queen Lane WTP on Schuylkill River*	2021	2024	2024	2031	2031	2038

**and other treatment process upgrades*

***Dates are subject to changes due to many different factors. Updates to the timeline will be included in the Annual Status Reports*

9.2 Watershed Protection Initiatives

The Philadelphia Water Department has a robust Watershed Protection Program that includes source water protection, climate change adaptation planning, and water quality modeling focus areas. The Watershed Protection Program uses a multi-barrier approach that includes emergency preparedness systems, public and private communication networks, computer modeling systems, laboratories, regional and national partnerships, and the development and implementation of formal plans to achieve watershed protection goals. Table 9-2 outlines planned watershed protection projects and tasks aimed to support the goal of pathogen reduction. These efforts are grouped by the priority source of *Cryptosporidium* that they address (e.g., wastewater discharger compliance, agricultural land use, and animal vectors).

Table 9-2: LT2 Watershed Control Plan Implementation Schedule – Watershed Protection Control Strategy

Control Strategy: Watershed Protection			
Priority Source - Wastewater Discharger Compliance			
Initiatives	Target Sub-basin(s)	Target Completion Date	Priority Source Addressed
Collaborate on *Cryptosporidium* source tracking studies	Various	Ongoing	Wastewater Discharges
Continue to regularly review and update Philadelphia's Act 537 Plan	Upper Estuary	Ongoing	Wastewater Discharges
Implement initiatives outlined in the annual Combined Sewer Management and Stormwater Management report	Upper Estuary	Ongoing	Wastewater Discharges
Maximize usage for the Delaware Valley Early Warning System while maintaining the system's ongoing O&M needs	Various	Ongoing	Wastewater Discharges

Continue to support efforts identified in the SAN Pathogens/Compliance Workgroup's Annual Workplans	Schuylkill	Ongoing	Wastewater Discharges
Re-delineate source water protection zones in the Delaware River Watershed using advanced hydrodynamic tidal modelling and update priority dischargers accordingly	Upper Estuary, Lower Central, Upper Central, Lehigh	2023	Wastewater Discharges
Update discharger information from Source Water Assessments to reassess vulnerability from upstream dischargers	Schuylkill, Upper Estuary, Lower Central, Upper Central, Lehigh	Ongoing	Wastewater Discharges
Track installation of wastewater treatment upgrades upstream of Philadelphia's intakes	Schuylkill, Upper Estuary, Lower Central, Upper Central, Lehigh	Ongoing	Wastewater Discharges
Work with professional organizations and industry groups, e.g. NACWA, WaterRF, et al., to support related research and advocacy efforts	Various	Ongoing	Wastewater Discharges
Continue to strengthen relationships with upstream wastewater dischargers through the DO Partnership	Upper Estuary, Lower Central, Upper Central	Ongoing	Wastewater Discharges

Priority Source - Agricultural Land Use			
Initiatives	**Target Sub-basin(s)**	**Target Completion Date**	**Priority Source Addressed**
Develop maintenance plans or MOUs for PWD's in-city agricultural BMPs	Schuylkill, Upper Estuary	2024	Agriculture
Coordinate with watershed partners to develop Comprehensive Nutrient Management Plans for WB Saul High School, Fox Chase Farm, and Manatawna Farm.	Schuylkill, Upper Estuary	2021	Agriculture
Work with USDA/NRCS, PA Dept of Agriculture and the Philadelphia School District to implement best management practices at WB Saul High School.	Schuylkill	2025	Agriculture
Work with USDA/NRCS, PA Dept of Agriculture and the Philadelphia School District to implement best management practices at Fox Chase Farm	Upper Estuary	2025	Agriculture
Work with Northwestern, Courtesy Stables, and Monastery Stables to implement conservation planning practices	Schuylkill, Upper Estuary	2021/2022	Agriculture

Reassess land use in the Schuylkill River Watershed with the 2016 National Land Cover Database (NLCD) and each subsequent update of the NLCD	Schuylkill	2021	Agriculture
Reassess land use in the Baxter AOI with the 2016 National Land Cover Database (NLCD) and each subsequent update of the NLCD	Upper Estuary, Lower Central, Upper Central, Lehigh	2021	Agriculture
Actively participate in the SAN Agricultural Workgroup and support initiatives outlined in the Annual Workplans	Schuylkill	Ongoing	Agriculture
Identify priority projects and available funding sources; work with SAN partners to best utilize Farm Bill funds	Schuylkill	Ongoing	Agriculture
Assess status of CAFO NPDES permits in the Schuylkill River watershed	Schuylkill	Ongoing	Agriculture
Promote drinking water protection in existing funding programs	Schuylkill, Upper Estuary, Lower Central, Upper Central, Lehigh	Ongoing	Agriculture
Reassess agricultural projects from early 2000s and use assessment to inform the revision of SAN agricultural monitoring plans	Schuylkill	2020	Agriculture
Participate in State Conservation Commission nutrient management trainings and conferences to further develop expertise and enhance liaison role to Philadelphia's agricultural properties	Schuylkill, Upper Estuary	Ongoing	Agriculture

Priority Source - Animal Vectors			
Initiatives	**Target Sub-basin(s)**	**Target Completion Date**	**Priority Source Addressed**
Implement goose control measures on Fairmount Park Properties, including Peter's Island	Schuylkill, Upper Estuary	Ongoing	Animal Vectors
Implement waterfowl management programs at Philadelphia Water Department Facilities	Schuylkill, Upper Estuary	Ongoing	Animal Vectors
Continue to support source tracking research	Various	Ongoing	Animal Vectors
Support efforts to publish scientific journal article to raise awareness and contribute to the state of the science	Various	Ongoing	Animal Vectors
Redesign and install "Do-Not-Feed Geese" educational signage in priority locations	Upper Estuary, Schuylkill	2023	Animal Vectors

9.3 Education and Outreach

The objectives and tasks outlined in Table 9-3 aim to raise awareness of source water protection issues both within the city and throughout Philadelphia's source watersheds.

TABLE 9-3: LT2 WATERSHED CONTROL PLAN IMPLEMENTATION SCHEDULE – EDUCATION & OUTREACH

Control Strategy: Education and Outreach		
Goal -Continue to raise awareness of source water protection issues in Philadelphia		
Objectives and Tasks	Target Sub-basin(s)	Target Completion Date
Continue to submit a comprehensive annual water quality report that emphasizes critical source water issues	Schuylkill and Upper Estuary	Ongoing (Annually)
Continue to maintain the FWWIC and promote source water protection through the center's exhibits and programs	Schuylkill and Upper Estuary	Ongoing
Continue to operate and maintain Philly RiverCast and promote the web-based recreational warning system	Schuylkill and Upper Estuary	Ongoing (Seasonal)
Implement in-City stormwater education programs	Schuylkill and Upper Estuary	Ongoing
Continue to implement pet waste education program in the City of Philadelphia	Schuylkill and Upper Estuary	Ongoing
Goal -Raise awareness of source water protection issues throughout Philadelphia's source watersheds		
Objectives and Tasks	Target Sub-basin(s)	Target Completion Date
Continue to participate in the SAN workgroups and support initiatives outlined in each group's workplan	Schuylkill	Ongoing
Continue to collaborate with the PDE on various education and outreach initiatives	Schuylkill and Upper Estuary	Ongoing
Continue to promote the use of the Delaware Valley Early Warning System among industries, wastewater dischargers, and water suppliers	Schuylkill, Lehigh, Lower Central, Upper Estuary	Ongoing
Work with Bucks County Partners to explore opportunities for collaboration on educational campaigns and programming for surrounding community	Upper Estuary	2023
Work with Bucks County Conservation District to identify education and outreach opportunities as they relate to source water protection	Upper Estuary	2022

Continue to convene the Water Quality Council (WQC) to address water quality issues on a holistic basis	Upper Estuary	Ongoing (Monthly)
Work with Philadelphia and regional schools to identify opportunities to enhance conservation practice education in the curriculum	Upper Estuary, Lower Schuylkill	2022

9.4 Stakeholder Engagement and Partnership Building

Stakeholder engagement and partnerships are intended to support the following goals:

1) Maintain and strengthen existing watershed partnerships, and
2) Develop a framework for a Delaware River Watershed Collaborative.

The first goal focuses primarily on existing Schuylkill River Watershed partnerships and reinvigorating Philadelphia's in-city watershed partnerships. The second goal is to identify and assess the gaps in collaborative efforts to protect and preserve the Delaware River Watershed. Associated objectives and tasks are outlined in Table 9-4.

TABLE 9-4: LT2 WATERSHED CONTROL PLAN IMPLEMENTATION SCHEDULE – STAKEHOLDER ENGAGEMENT AND PARTNERSHIP BUILDING

Control Strategy: Stakeholder Engagement and Partnership Building		
Goal - Continue to strengthen existing partnerships		
Objectives and Tasks	Target Sub-basin	Target Completion Date
Continue to support the Schuylkill River Restoration Fund to achieve implementation of priority projects	Schuylkill	Ongoing
Champion the Schuylkill River Restoration Fund and work with SAN partners to draw in more funders	Schuylkill	Ongoing
Promote the Schuylkill River Restoration Fund to potential applicants where appropriate	Schuylkill	Ongoing
Remain an active participant in watershed partnerships and reinvigorate Philadelphia Watershed partnerships, e.g. Friends of the Pennypack and Friends of Fox Chase Farm	Upper Estuary	Ongoing
Engage Philadelphia stables in the implementation erosion and sediment control measures	Upper Estuary	Ongoing
Goal -Develop a Delaware River Watershed Collaborative Framework		
Objectives and Tasks	Target Sub-basin	Target Completion Date
• Identify and Engage Water Utility Partners	Upper Estuary, Lower Central	2021
• Organize Planning Forums and Identify Coordination Priorities with Water Utility Stakeholders	Upper Estuary, Lower Central	2022
• Host Kick-off Meeting with Identified Stakeholders • Determine Workgroups (if needed), Workgroup Chairs, and Workplans • Hold First Workgroup Meetings (if applicable)	Upper Estuary, Lower Central	2023
• Host Second Annual Water Utility Coordination Meeting • Begin to Explore Opportunities for Collaborative Funding Grant Program	Upper Estuary, Lower Central	2024
• Host Third Annual Water Utility Coordination Meeting • Continue to Explore Opportunities for Collaborative Funding Grant Program • Develop Strategic Plan for Future of Collaborative	Upper Estuary, Lower Central	2025

10 Future Actions for Maintaining WCP Treatment Credit

In order to maintain the 0.5-log backup treatment credit for the Watershed Control Plan at both Queen Lane and Baxter intakes, PWD will comply with all State-mandated regulations throughout the plan implementation process. The following three action items are required once the 2020 Watershed Control Plan Update is approved:

1) Submit an annual watershed control program status report to the State;
2) Undergo a watershed sanitary survey every three years for community systems; and,
3) Make the watershed control plan, annual status reports, and watershed sanitary survey reports available to the public upon request.

This section outlines the State's watershed control plan regulations and PWD's corresponding future actions.

10.1 *Annual Watershed Control Program Status Report*

The focus of the annual status report will be to describe the system's implementation of the approved plan and assess the adequacy of the plan to meet its goals. Implementation of the watershed control plan will involve two main components: maintaining ongoing initiatives for both the City and entire watershed and moving forward with implementation of the proposed/future initiatives. Both aspects of implementation will be assessed in the watershed program status report that PWD will submit to the State on an annual basis. The status of each initiative will be assessed, and evaluations made as to the perceived benefits and overall effectiveness or ineffectiveness for all implemented initiatives. The progress made with implementing future initiatives will be compared to the original timeline. Upon assessing both current/ongoing initiatives and proposed initiatives, PWD will address any shortcomings in plan implementation, including those previously identified by the State or as a result of the watershed survey conducted as part of the implementation process (US EPA 2006). If shortcomings do exist in the plan implementation process, the status report will explain how PWD plans to address these shortcomings.

In addition, the regulations state that the annual status report must include a description of any significant changes that have occurred in the watershed since the last watershed sanitary survey. PWD will submit a watershed sanitary survey to the State every three years, in accordance with the State's regulatory requirements, and will provide information on any significant watershed changes, should they arise, in the annual status reports that are submitted following each watershed sanitary survey.

PWD will also immediately inform the State if significant changes to the approved watershed control plan are deemed necessary, prior to making any such change. If any changes in the watershed control plan reduce the level of source water protection originally outlined in the plan, PWD will identify actions that will be taken to mitigate the effect of these changes.

10.2 *Triennial Watershed Sanitary Survey*

As part of the plan implementation process, PWD will submit a watershed sanitary survey every three years. The State requires that the survey be conducted according to State guidelines and by persons the State approves. Specific criteria for the sanitary survey are as follows:

1) The watershed sanitary survey must meet the following criteria: encompass the region identified in the State-approved watershed control plan as the area of influence; assess the implementation of actions to reduce source water *Cryptosporidium* levels; and identify any significant new sources of *Cryptosporidium*.
2) If the State determines that significant changes may have occurred in the watershed since the previous watershed sanitary survey, systems must undergo another watershed sanitary survey by a date the State requires, which may be earlier than the regular date.

In accordance with the zone delineations in the Source Water Assessment, PWD has identified the entire Schuylkill and Lehigh sub-basins as well as the Pennsylvania sides of the Upper Central, Lower Central, and Upper Estuary sub-basins as the AOI for Philadelphia's intakes. PWD will continue to work to evaluate the status of potential sources within the AOI. The first Schuylkill River Watershed Sanitary Survey was completed in 2015 and most recently updated in 2018. Following approval of this plan, the watershed sanitary surveys will reflect the addition of the Baxter intake's area of influence.

To assess the implementation of actions to reduce source water *Cryptosporidium* levels, PWD will evaluate the status of ongoing and future initiatives through the annual watershed control plan status report. The Annual Watershed Control Plan Status Reports have been submitted every year since 2013. As stated above, each initiative will be evaluated in terms of its implementation progress and the initiative's observed benefits and overall effectiveness at supporting PWD's source water protection goals.

PWD's Schuylkill River Source Water Assessment (SWA) will serve as the baseline for subsequent sanitary surveys that are completed during the watershed control plan implementation process. Within the SWA, and outlined in Section 3 of this plan, PWD identifies the highest priority point and non-point sources for *Cryptosporidium* contamination at the Queen Lane and Baxter intakes. Updating the original ranking of priority dischargers in the Schuylkill and Delaware River watersheds required the following steps: identifying those dischargers that no longer exist or have changes in name or ownership; compiling information regarding updates or improvements made to existing high-priority dischargers; and identifying recently proposed or constructed permitted facilities within the watershed. Section 3 outlines the results of this update. PWD will continue to track the status of these sources for each sanitary survey following approval of the watershed control plan. New facilities that are identified through the status updates will be assessed in terms of their potential impact at the intake, accounting for such factors as time of travel from source to intake, the geographical location, and the frequency and/or potential for release.

In an effort to improve the accuracy and comprehensiveness of the status updates, PWD will expand its evaluation of wastewater-related changes in the watershed by continuing to work with the Schuylkill Action Network (SAN) to identify new sources and persistent areas of concern in regard to pathogen contamination. There are multiple approaches to tracking the progress of wastewater conveyance and treatment system improvements; tracking that is needed to reduce the contaminative risk associated with malfunctioning or hydraulically overloaded systems. Tracking approaches may include working with the State to identify areas of concern through the coordination of 25 PA Code Chapter 94 and Act 537 enforcement. Systematic tracking of these changes will help identify the presence of new priority sources in addition to those identified in this plan.

PWD will also continue to evaluate the threat posed by non-point sources, specifically, runoff from agricultural land. Section 3 aims to establish a link between pasture/livestock numbers and the prevalence of agricultural activities in the area of influence. The results broadly indicate that agricultural activity is either remaining relatively constant or decreasing throughout the watershed. Ideally, PWD would like to update the land use assessment results described in the Source Water Assessment to gain a better understanding of high-priority subwatersheds with regard to agricultural activities. The Source Water Assessment identified land use categories for each subwatershed using the 1992 USGS National Land Cover Dataset (NLCD), and updated information from the 2000 Census data for residential and commercial areas. Since direct comparison of the 1992 NLCD and the 2001 National Land Cover Database is not encouraged by the USGS, PWD was not able to directly compare changes in land use between the two datasets. Future efforts to reassess land use on a subwatershed scale would use the more recent 2001 National Land Cover Database, updated with 2010 Census data, when it becomes available. Both 2011 and 2016 NLCD have been released and displayed in previous WCP Annual Status Reports. When future updates to the dataset becomes available, PWD will reassess land use and communicate results accordingly in annual reports.

10.3 Availability of Documents

The State mandates that all reports must be in a plain language style and include criteria by which to evaluate the success of the program in achieving plan goals. The State may approve systems to withhold from the public portions of the annual status report, watershed control plan, and watershed sanitary survey based on water supply security considerations.

PWD will post a copy of the plan online at, http://water.phila.gov/reporting/ should members of the public wish to review the plan. Subsequent annual status reports and watershed sanitary surveys are also available for the public to access. In addition, PWD will include on its website a brief overview of how PWD is achieving LT2 compliance, including a summary of action items addressed in the watershed control plan. This summary of information is accessible at the following link: https://www.phila.gov/water/sustainability/protectingwaterways/.

Pending approval of the 2020 Watershed Control Plan Update, the following dates should be noted for continued compliance under the LT2 regulation.

TABLE 10-1: IMPORTANT DATES FOR THE 2020 LT2 WATERSHED CONTROL PLAN UPDATE

Action Item	Due Date
WCP Update Due to State	October 2020
State Approval of WCP Update Due	October 2021
First Annual Report on the WCP Update Due to State	October 2022*
First Sanitary Survey on the WCP Update Due to State	October 2024*

**May vary pending 2020 WCP Update approval date*

10.4 Concluding Statement

PWD's ultimate goal is to lower *Cryptosporidium* concentrations at Queen Lane and Baxter water treatment plant intakes. It is very likely that there is no single action item that will guarantee lower *Cryptosporidium* concentrations at the intakes; therefore, a comprehensive implementation approach is necessary. PWD's comprehensive approach, as indicated by the in-city and watershed-wide action items outlined in Section 6, includes strategies to address wastewater discharges and compliance, agriculture land use and runoff, animal vectors, and continued and expanded education and outreach. For the watershed control plan approach to be successful, PWD will need to rely on the collaboration and cooperation of watershed partnerships. In addition, certain initiatives, such as the incorporation of *Cryptosporidium* monitoring results into monthly DMRs, will require support from state and federal regulatory authorities. Watershed-wide cooperation is needed not only in terms of planning support, but in regard to funding support as well. PWD feels that certain funding programs, such as the USDA/NRCS water quality improvement programs, can more directly support source water projects located above drinking water intakes in the watershed. Although it is a challenge to coordinate source water protection efforts for pathogen contamination on such a large scale, doing so will not only make this watershed control program a success, but will reduce the risks associated with pathogen contamination throughout a large portion of the Schuylkill and Delaware River watersheds.

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