Advance Restoration Plan for the

Knight Run Subwatershed

Chester County, Pennsylvania

Prepared by The Cadmus Group LLC for
U.S. Environmental Protection Agency Region 3

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Cover Photos: Octoraro Reservoir (top; Anita Martin, Chester Water Authority) and Knight Run at Ross Fording Road (bottom; Mike Morris, Pennsylvania Department of Environmental Protection)

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1 Introduction

The Knight Run subwatershed is located in western Chester County, Pennsylvania and spans 9.1 square miles (Figure 1). It is within the Muddy-Run-East Branch Octoraro Creek Subwatershed (Hydrologic Unit Code 020503061403).[1] Knight Run is a tributary of East Branch Octoraro Creek, which flows into Octoraro Reservoir, a drinking water source for over 40,000 customers served by Chester Water Authority. Outflow from the Octoraro Reservoir enters Octoraro Creek, which flows southwest into Cecil County, Maryland, where it joins the Susquehanna River and ultimately drains into the Chesapeake Bay.

Several water quality issues have been identified in the Knight Run subwatershed and in downstream waters:

- All streams in Knight Run are listed as impaired in Pennsylvania's 2024 Integrated Water Quality Report (PADEP 2024) because they do not meet water quality goals for protecting aquatic life. These waters are on Pennsylvania's Clean Water Act Section 303(d) list because there is no Total Maximum Daily Load (TMDL) in place. Habitat for fish and other aquatic species is degraded due to siltation (smothering or burial by grains of soil and other small particles).
- Sediment and nutrient (nitrogen and phosphorus) loads in Knight Run contribute to downstream water quality problems, including nonattainment of the water quality goals for protecting the potable water supply use in the East Branch Octoraro Creek and Octoraro Reservoir due to high nitrate concentrations and nonattainment of the aquatic life use in East Branch Octoraro Creek due to siltation and nutrients.

This Advance Restoration Plan (ARP) is a near-term plan for addressing the above water quality problems in the Knight Run subwatershed. It describes land management actions that, if implemented, would reduce siltation to levels that would no longer impair aquatic life. The plan includes a schedule and milestones for implementing these actions in approximately 10 years. The recommended actions would also help reduce nitrate concentrations downstream in Octoraro Reservoir to protect human health and help reduce phosphorus concentrations downstream in East Branch Octoraro Creek to limit algal growth. Certain land management actions may reduce annual pollutant loads in the near term while others may take longer to reach their full level of effectiveness. There is also an anticipated lag time for ecological recovery once water quality targets reach a level that would support aquatic life. The ARP includes monitoring activities to observe changes in water quality and biological conditions over time. Monitoring should continue beyond the BMP implementation timeline to evaluate pollutant reductions achieved and ecological recovery. The ARP timeframe is 10-15 years to account for unforeseen delays and lag-time in ecological recovery. The ARP schedule includes annual progress reporting with periodic reviews of the ARP for revisions.

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[1] HUCs are identified by the U.S. Geological Survey in the Watershed Boundary Dataset which is a nationally consistent watershed boundary dataset that is subdivided into 8 levels as described on USGS's Hydrologic Units of the United States webpage. A 12-digit HUC is typically referred to as a subwatershed. The project area is a smaller portion of the Muddy-Run-East Branch Octoraro Creek Subwatershed.

Many land management actions are voluntary for landowners of agricultural lands. Farmers benefit from having local stakeholders with expertise in agriculture assist them in developing a variety of options tailored to the specific operation that balance productivity and pollutant reductions. Pennsylvania farmers are required by law to operate within regulatory compliance by implementing the applicable requirements outlined in the Pennsylvania Clean Streams Law, Title 25 Environmental Protection, Part I Department of Environmental Protection, Subpart C Protection of Natural Resources, Article II Water Resources, Chapters: § 91.36 Pollution control and prevention at agricultural operations, § 92a.29 CAFO and § 102.4 Erosion and sediment control requirements. Agricultural regulations are designed to reduce the amount of sediment and nutrients reaching the streams and groundwater in a watershed.

The Octoraro Source Water Collaborative (OSWC) partners and other stakeholders can use this plan to:

- Understand the sources of water pollution in the Knight Run subwatershed and how they affect aquatic life and drinking water.
- Learn what water quality targets should be achieved in the Knight Run subwatershed to restore and protect aquatic life, and to support improvement of downstream water quality in Octoraro Reservoir and East Branch Octoraro Creek.
- Identify best management practices (BMPs) to implement in the Knight Run subwatershed and milestones for BMP implementation to achieve water quality targets.
- Learn about potential funding sources for implementing BMPs.
- Identify monitoring needs to measure and track water quality responses to BMPs.
- Educate community members about water quality in Knight Run and its relevance to protecting Octoraro Reservoir.

This plan is intended to support ongoing efforts by the OSWC to improve and protect water quality in Octoraro Reservoir. The collaborative is a partnership of local stakeholders, environmental and non-profit organizations, agency and municipal officers, and farmers, including the Lancaster and Chester County Conservation Districts, Chester Water Authority, and Pennsylvania Department of Environmental Protection (PADEP). In its Strategic Plan, the OSWC set a goal to “improve water quality by reducing nutrient and sediment loading in the Upper Octoraro through increased BMP implementation, identifying and accessing funding, monitoring and documenting changes, and sharing successes and lessons learned” (OSWC 2022). This ARP document provides a roadmap stakeholders can use to reduce pollutant loading in Knight Run in support of the Octoraro Source Water Collaborative Strategic Plan. Several components of this document were developed with input from collaborative members.

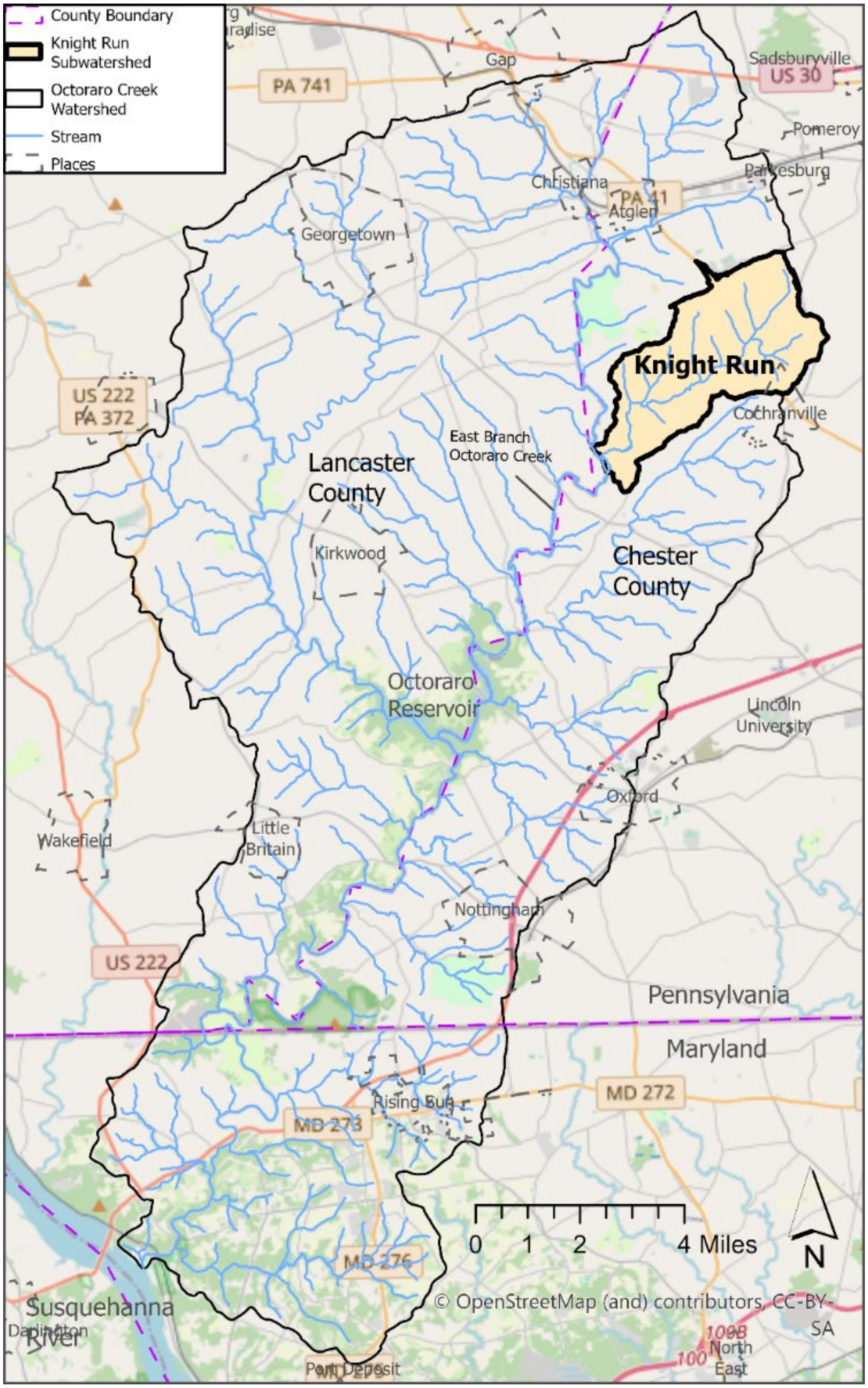

Figure 1. Location of the Knight Run subwatershed in the Octoraro Creek Watershed.

2 ARP Scope and Approach

This ARP was developed to guide water quality improvement activities in the Knight Run subwatershed. The pollutants addressed are sediment, nitrogen, and phosphorus. Load reductions for these pollutants are established for sources in the Knight Run subwatershed, and potential BMPs to achieve the reductions are discussed.

The overall goal of this ARP is to present a plan to:

- **Restore Knight Run streams so that siltation is no longer listed as a cause of impairment under the Clean Water Act in the subwatershed within approximately 10-15 years**.
- **Support improved water quality downstream in Octoraro Reservoir and East Branch Octoraro Creek by reducing nitrogen, phosphorus, and sediment loading contributions from Knight Run**.

Table 1 summarizes the organization and content of this document.

Table 1. Summary of remaining sections of this Advance Restoration Plan (ARP) document.

Section Number	Section Name	Content
3	Water Quality Impairments	Describes Clean Water Act impairments in Knight Run, East Branch Octoraro Creek, and Octoraro Reservoir.
4	Subwatershed Characterization	Describes the Knight Run subwatershed, including land use, available water quality data, pollution sources, and existing pollutant loads.
5	Calculation of Allowable Loading Rates	Describes water quality goals for this ARP, target pollutant loads needed to achieve the goals, and how target loads were calculated.
6	Load Reductions Needed by Source Sector	Presents load reductions needed for each different type of pollution source in the Knight Run subwatershed.
7	Analysis of BMPs to Achieve Load Reductions	Describes possible BMPs to achieve target pollutant loads, including the quantity of BMPs needed and costs.
8	ARP Implementation Strategy	A detailed strategy for implementing the ARP, including roles and responsibilities, funding sources, a schedule and milestones, effectiveness evaluation methods and criteria, and educational activities.

An ARP is one approach that a state can use to restore waters listed as impaired under the Clean Water Act (USEPA 2025). The U.S. Environmental Protection Agency (EPA) reviews ARPs but does not take action to approve or disapprove them. If the BMPs recommended in this ARP are not implemented or do not restore siltation impairments in Knight Run within the planned 10-15-year timeframe, PADEP may consider a different approach to guiding water quality improvement, such as developing a total maximum daily load (TMDL). [2]

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[2] States are required to develop Total Maximum Daily Loads (TMDLs) for waters on the 303(d) list pursuant to Section 303(d) of the Clean Water Act. The 303(d) list is represented in Pennsylvania's 2024 Integrated Water Quality Report (PADEP 2024) as those waters listed in Category 5. However, states have the inherent authority under the Clean Water Act to prioritize waters for TMDL development with their limited resources. ARPs are advantageous as a planning tool to make near-term water quality improvements in advance of a TMDL; hence the term "advance" restoration plan. States may pursue other alternative approaches to address water quality problems as part of their state Water Quality Management Plan. Waters that reach attainment status are removed from the 303(d) list.

This ARP uses the Octoraro Watershed Model and associated Scenario Application Manager (SAM) Tool to estimate existing pollutant loads from sources in the Knight Run subwatershed, load reductions needed to achieve water quality goals, and possible BMPs to reduce pollutant loading to target levels. The Octoraro Watershed Model and SAM Tool are referenced throughout this document and are described below:

- The **Octoraro Watershed Model** uses the Hydrologic Simulation Program—FORTRAN (HSPF) to simulate hydrology and water quality in the Octoraro Watershed. The model divided the Octoraro Watershed into 60 distinct subwatersheds, including Knight Run. For each subwatershed, the model estimates nitrogen, phosphorus and sediment loads during 2013 to 2021 based on land use, weather, and other watershed characteristics. The model was calibrated and validated by comparing predicted and observed streamflow and pollutant concentration data at multiple locations throughout the watershed.
- The **SAM Tool** is a standalone software application that allows users to design a BMP implementation scenario by selecting BMPs to simulate and specifying the number of acres treated, pollutant reduction efficiencies, and unit-area costs per BMP. The SAM Tool then applies the Octoraro Watershed Model to simulate pollutant load reductions and other water quality benefits provided by the BMPs included in the scenario.

A detailed description of Octoraro Watershed Model and SAM Tool development and past applications is provided in *Water Quality Modeling to Support Source Water and Aquatic Life Protection, Octoraro Creek, Pennsylvania and Maryland - Final Modeling Report (*Attachment 1).

The Knight Run subwatershed was selected for ARP development following engagement with the OSWC and an evaluation of subwatersheds across the Octoraro Watershed to identify priorities for watershed planning. Appendix D summarizes the stakeholder engagement and subwatershed evaluation activities completed as part of the process of selecting Knight Run for ARP development.

3 Water Quality Impairments

3.1 Background

Pennsylvania Water Quality Standards (WQS)[3] are state regulations that establish goals for water quality in streams, rivers, lakes, reservoirs, and other surface waters in the state. They designate beneficial uses of water bodies related to aquatic life, water supply, recreation, and fish consumption, and they define water quality criteria that correspond to protection of those designated uses. Pennsylvania WQS also specify the water bodies where each use must be protected. While Pennsylvania does not have numeric water quality criteria for sediment, it does have applicable narrative criteria:

> *Water may not contain substances attributable to point or nonpoint source discharges in concentration or amounts sufficient to be inimical or harmful to the water uses to be protected or to human, animal, plant or aquatic life. (25 PA Code Chapter 93.6 (a)); and,*
>
> *In addition to other substances listed within or addressed by this chapter, specific substances to be controlled include, but are not limited to, floating materials, oil, grease, scum and substances which produce color, tastes, odors, turbidity or settle to form deposits. (25 PA Code, Chapter 93.6 (b))*.

To assess if water quality in an individual water body segment supports its designated uses, PADEP applies methods and criteria described in *Water Quality Assessment Methodology for Surface Waters* (PADEP 2023a). For example, to evaluate if nitrate plus nitrite concentrations impair a water body that is used as a drinking water source (such as Octoraro Reservoir), PADEP compares nitrate plus nitrite monitoring data to the criterion of 10 mg N/L defined in Pennsylvania WQS. If a designated use is not supported, the designated use is considered 'impaired'.

PADEP documents the results of water quality assessments in a biennial Integrated Water Quality Report. As part of water quality assessment and reporting, PADEP divides surface water bodies into segments, called assessment units. The Integrated Water Quality Report lists assessment units that PADEP has classified as impaired. For each impaired assessment unit, one or more causes of impairment (e.g., nutrients, siltation) and associated pollution sources (e.g., agriculture, mining, point sources) are reported based on protocols specified in PADEP's assessment methodology (PADEP 2023a).

Table 2 summarizes impairments from Pennsylvania's 2024 Integrated Water Quality Report for the Knight Run subwatershed and downstream in East Branch Octoraro Creek and Octoraro Reservoir (PADEP 2024). This ARP was designed to address the 'Siltation' and 'Nutrients' impairments in Table 2. It does not directly address the 'Cause Unknown' and 'Habitat Alteration' impairments. However, land management actions proposed for addressing the siltation and nutrient impairments, such as installing riparian buffers and other BMPs on agricultural lands, may help address the remaining impairments. Further, implementation of

[3] Pennsylvania's WQS are published in Title 25 Chapter 93 of the Pennsylvania Code.

this ARP in combination with other water quality restoration and protection actions throughout the upper Octoraro Watershed will be needed to fully address the downstream impairments in Table 2.

Table 2. Water quality impairments in the Knight Run subwatershed and downstream, based on Pennsylvania's 2024 Integrated Water Quality Report (PADEP 2024). A detailed list of individual impaired assessment units is provided in Appendix A.

Water Body	Designated Use	Cause	Source
Knight Run Streams[1]	Trout Stocking	Siltation	Agriculture
		Cause Unknown[3]	Agriculture
		Habitat Alterations[4]	Habitat Modification-Other than Hydromodification
East Branch Octoraro Creek[2] (downstream)	Trout Stocking	Siltation	Agriculture
		Cause Unknown[3]	Agriculture
		Habitat Alterations[4]	Habitat Modification-Other than Hydromodification
	Potable Water Supply	Nutrients	Agriculture
Octoraro Reservoir (downstream)	Warm Water Fishes	Nutrients	Agriculture
	Potable Water Supply	Nutrients	Agriculture

[1] All stream assessment units in Knight Run have the same impairment causes and sources.

[2] All stream assessment units in East Branch Octoraro Creek downstream of Knight Run have the same impairment causes and sources, except for two small assessment units where Trout Stocking is impaired but potable water supply is not (PA-SCR-57468143, PA-SCR-57468155).

[3] Cause Unknown is "used when the cause of the impairment cannot be identified." (PADEP 2015b).

[4] Habitat alterations is a non-pollutant form of pollution that causes an impairment. Pollution is a "man-made or man-induced alteration of the chemical, physical, biological, and radiological integrity of water." (Section 502 (19)). This type of impairment is not on the state's 303(d) list of impaired waters requiring a TMDL but is included in a state's integrated report under Category 4c pursuant to CWA Section 305. (EPA Citation needed)

Together, the impairment listings for Knight Run and downstream waters formed the basis for selecting the pollutants addressed in this ARP (sediment, nitrogen, and phosphorus) and provided a foundation for evaluating target pollutant load reductions. The following sections provide more details on these impairments. Section 4 includes a discussion of available water quality monitoring data related to the impairments. The analysis of target pollutant load reductions is presented in Section 5.

3.2 Knight Run Impairments

In Pennsylvania's 2024 Integrated Water Quality Report, streams in Knight Run are divided into 42 unique stream assessment units. All 42 stream assessment units are listed as impaired due to nonattainment of the aquatic life use for Trout Stocking (Table 2). The Trout Stocking use is defined as "the maintenance of stocked trout from February 15 to July 31 and maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat" (25 PA Code Section 93.3).

Impairment determinations for the Knight Run subwatershed were made by PADEP based on available water quality monitoring data, including findings from field surveys of stream habitat and biological conditions, which indicated that applicable narrative water quality criteria defined in Pennsylvania WQS were not met. Siltation is identified as a cause of the aquatic life use impairment (Table 2). Siltation is the accumulation of fine sediments on the stream bed in excess of what can be transported naturally, which results in smothering of habitat used by fish and other biological communities, thereby inhibiting the growth or survival of the communities. Siltation occurs when excess sediment from the landscape enters a stream system. The identification of siltation as a cause of impairment highlights the need for reduced sediment input to Knight Run streams from the surrounding landscape to improve conditions for fish and other aquatic life.

3.3 Downstream Impairments

Knight Run flows into East Branch Octoraro Creek, which subsequently drains to Octoraro Reservoir (Figure 1). East Branch Octoraro Creek and Octoraro Reservoir are designated as potable water supply use waters, defined in Pennsylvania WQS as a water supply used by the public "after conventional treatment, for drinking, culinary and other domestic purposes, such as inclusion into foods, either directly or indirectly" (25 PA Code Section 93.3). Potable water supply is listed as impaired for both East Branch Octoraro Creek and Octoraro Reservoir in the 2024 Integrated Water Quality Report due to excess nutrients from agriculture (Table 2). Nutrients include nitrogen and phosphorus compounds. They are essential for the growth of people, plants, and wildlife but also carry risks to human health when present at high levels. For example, ingesting drinking water with high levels of nitrate can disrupt the ability of red blood cells in the human body to carry oxygen. This can cause a serious health condition due to lack of oxygen known as "blue baby syndrome" in babies and at-risk children or adults. Emerging science also indicates long-term exposure to high nitrate in drinking water may be associated with increased risk of thyroid disease, colorectal cancer, and certain birth defects (Ward et al. 2018).

As indicated by the potable water supply impairment listings, reduced nutrient levels in East Branch Octoraro Creek and Octoraro Reservoir are needed to protect human health. This need is further demonstrated by Chester Water Authority monitoring data for treated drinking water and associated treatment operations. Chester Water Authority treats and distributes water from Octoraro Reservoir to their customers. When levels of nitrate or other pollutants in the reservoir are too high, Chester Water Authority draws from the Susquehanna River to blend with or replace water from Octoraro Reservoir to maintain compliance with federal drinking water standards. Pumping water from the Susquehanna River to the water treatment plant increases energy consumption and operational costs for Chester Water Authority. Maximum nitrate concentrations reported by Chester Water Authority between 2021 to 2024 in treated water delivered to customers were 8 to 9 mg N/L (CWA 2021; 2022; 2023; 2024). These concentrations approach the federal drinking water standard for nitrate of 10 mg N/L.

Other impairment listings for East Branch Octoraro Creek and Octoraro Reservoir in the 2024 Integrated Water Quality Report are related to aquatic life (Table 2). Like Knight Run, Trout Stocking in East Branch Octoraro Creek is reported to be impaired by siltation, indicating that excess sediment loading from the landscape is a significant contributor to degraded conditions for aquatic species. In Octoraro Reservoir, the Warm Water Fishes use is impaired due to nutrients (Table 2). In addition to carrying human health risks, excess nutrients can also harm fish and other aquatic life. For example, nitrogen and phosphorus feed dense algae blooms, which can block sunlight for underwater organisms and deplete oxygen levels available to fish.

4 Subwatershed Characterization

4.1 Subwatershed Description

The Knight Run subwatershed spans 9.1 square miles in Highland and West Fallowfield Townships within Chester County. The subwatershed has a rural agricultural setting. Population estimates from the 2020 U.S. census indicate that approximately 1,000 people reside in the subwatershed. Elevation ranges from approximately 350 to 700 feet above sea level.

Nearly 70% of the subwatershed area is agricultural land (cropland, hay fields, or pasture) (Figure 2). The primary crops grown are corn, soybeans, and pasture/hay crops such as alfalfa (Table 3). Dairy farms are also present, and land is used for livestock grazing. Typical landscape and agricultural field conditions in the Knight Run subwatershed are shown in Figure 3. Crop and soil management techniques vary across the landscape. Some fields have exposed soils without conservation tillage or cover crops (photos D through F in Figure 3). Soils in the subwatershed are generally deep and well-drained and were formed from weathered schist from underlying Peters Creek Schist bedrock. They include soils in the Chester, Gleneig and Manor soil series (PADEP 2013).

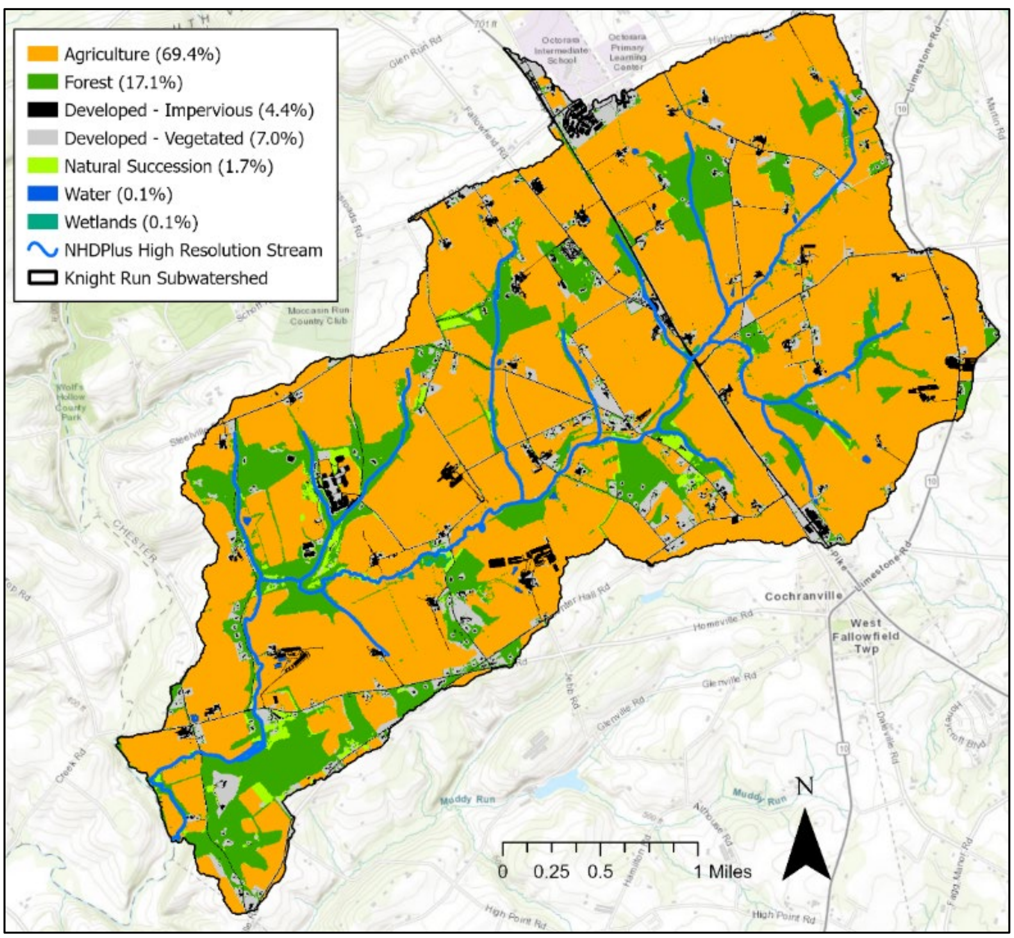


Figure 2. Land cover in the Knight Run subwatershed in 2021/2022 from the [Chesapeake Bay Land Use and Land Cover Database (2024 Edition)](#).

Table 3. Land use summary for the Knight Run subwatershed, calculated by averaging land use areas in 2020 through 2024 Cropland Data Layers accessed from the U.S. Department of Agriculture [*CropScape*]() tool*. Categories that make up less than 1% of subwatershed area are not shown.*

Land Use Category	% of Knight Run Subwatershed (2020-2024 Average)
Corn	27%
Grass/Pasture	22%
Forest	14%
Soybeans	9%
Developed Open Space	6%
Winter Wheat/Soybeans Double Crop	5%
Alfalfa	4%
Rye	2%
Other Hay (Non Alfalfa)	2%
Developed Low Intensity	2%
Winter Wheat	1%
Triticale/Corn Double Crop	2%
Developed Medium Intensity	1%

Knight Run and the broader Octoraro Creek watershed are part of the Lower Susquehanna River subbasin and the Chesapeake Bay basin. Knight Run contains 17.1 stream miles and drains into East Branch Octoraro Creek, which subsequently flows into Octoraro Reservoir. The Knight Run mainstem is a second order stream, and tributaries are first order streams draining through cropland and some small patches of forest (Figure 2). Based on limited available field measurements, typical streamflow in the mainstem ranges from 2 to 10 cubic feet per second.

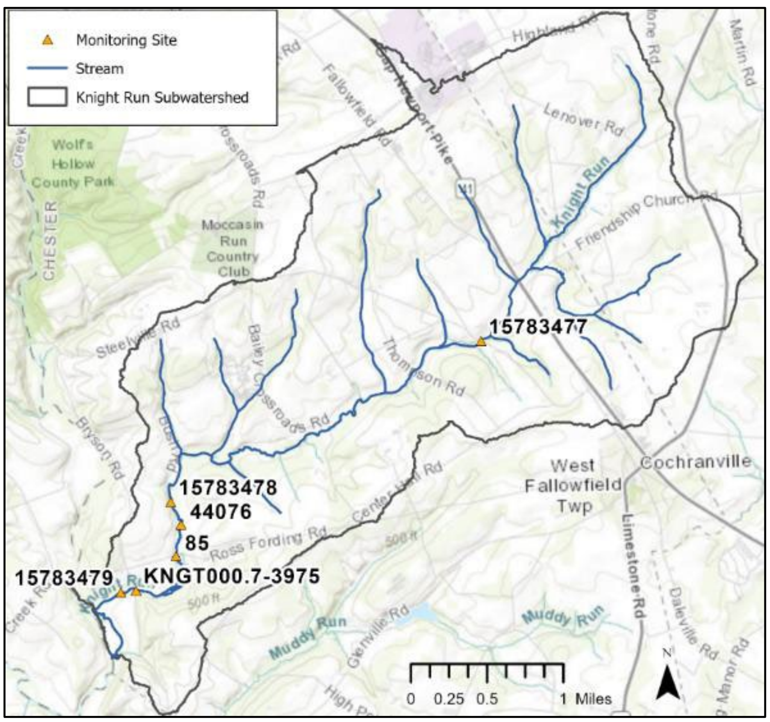
Limited information is available about fish species present in Knight Run. In April 2025, the Pennsylvania Fish and Boat Commission stocked East Branch Octoraro Creek with Brown Trout and Rainbow Trout (PA Fish and Boat Commission 2025). These species may occur in Knight Run along with other fish species. The Chesapeake Longperch (*Percina bimaculata*) is classified as 'Threatened' in Pennsylvania (58 PA Code Section 75.2) and has been documented downstream of Knight Run in East Branch Octoraro Creek (PA Fish and Boat Commission 2023). Limited information is available about the abundance, ecology and life history of this species, but degraded water quality and habitat may be factors contributing to its threatened status (PA Fish and Boat Commission 2023).

Figure 3. Example landscapes and field conditions, including fields with exposed soils, in the Knight Run subwatershed. Image source: Mike Morris, PADEP, May 2025.

4.2 Summary of Existing Water Quality Conditions

This section summarizes water quality conditions in the Knight Run subwatershed based on available water monitoring data, modeling results, and field visits. It focuses on parameters related to the water quality impairments that PADEP has identified in Knight Run or downstream – siltation, nutrients, and habitat alterations (Table 2). For each water quality parameter, the subsections below summarize available information, key patterns, and important data gaps relevant to ARP implementation.

Several organizations have collected monitoring data in Knight Run, including the Octoraro Watershed Association (OWA), Susquehanna River Basin Commission (SRBC), PADEP, and the U.S. Geological Survey (USGS) (Figure 4). Other relevant sources of information cited in this section include a groundwater nitrate transport model developed for the Octoraro Watershed (Guiseppe et al. 2012; PADEP 2013), the Octoraro Watershed Model, and visual observations of Knight Run streams by PADEP during a May 2025 drive-through of the subwatershed.



Organization	Site ID	Latitude	Longitude	Sample Events	Time Period	N	P	DO	Bioassessment
USGS	015783477	39.90428	-75.94047	1	2017	X	X	X	
USGS	015783479	39.88111	-75.98556	5	2000-2020	X	X	X	
USGS	015783478	39.88959	-75.97919	2	2023	X	X	X	
PADEP	44076	39.887436	-75.977971	1	2014				X
SRBC	KNGT000.7-3975	39.88125	-75.983694	7	2008-2010	X	X		
OWA	85	39.88447	-75.978668	53	2020-2025	X	X	X	

Figure 4. Summary of monitoring sites with nitrogen (N), phosphorus (P), dissolved oxygen (DO), and bioassessment (macroinvertebrate and stream habitat) data in the Knight Run subwatershed. Note that the specific constituents available for each parameter are not the same across sites (e.g., total phosphorus may be sampled at one site versus phosphate at another site).

4.2.1 Nitrate

Summary of Available Monitoring Data

Available monitoring data for nitrate is displayed in Figure 5 for both Knight Run and East Branch Octoraro Creek. Nitrate concentrations in Knight Run frequently approach and exceed PADEP water quality criteria established for nitrate plus nitrite to protect the potable water supply use (10 mg N/L). For East Branch Octoraro Creek, monitoring conducted since 1998 at a site just upstream of the Knight Run confluence shows that nitrate concentrations are frequently near 8 mg N/L, but do not exceed 10 mg/L. These data indicate that Knight Run contributes to the high nitrate concentrations and potable water supply use impairments downstream in East Branch Octoraro Creek and Octoraro Reservoir.

Legacy nitrogen stored in groundwater is likely to contribute to the high observed nitrate concentrations in Knight Run. A groundwater model developed for the Octoraro Watershed estimated that some areas have groundwater travel times of 10-35 years (Guiseppe 2012; PADEP 2013). This significant travel time presents an opportunity for nitrogen from the landscape to accumulate in groundwater before it is discharged to springs or streams. The consistently high nitrate concentrations measured in Knight Run (Figure 5) suggest there are high background levels during baseflow conditions, reflecting elevated groundwater concentrations and legacy nitrogen stored in the watershed.

Nitrate Export to Downstream Waters

The Octoraro Watershed Model also points to Knight Run as a significant source of nitrate to downstream waters. The model estimated that pollutant sources in Knight Run accounted for 7% of the average annual nitrate plus nitrate load generated by all sources upstream of Octoraro Reservoir during 2013 through 2021, and 12% of the average annual nitrate plus nitrite load entering Octoraro Reservoir from East Branch Octoraro Creek originated from Knight Run. Among the 37 model subwatersheds upstream of Octoraro Reservoir, Knight Run was the second-highest ranked subwatershed contributing to total nitrate plus nitrite loading. The model results underscore the need to reduce nitrate levels in Knight Run to help address the potable water supply impairments downstream in East Branch Octoraro Creek and Octoraro Reservoir.

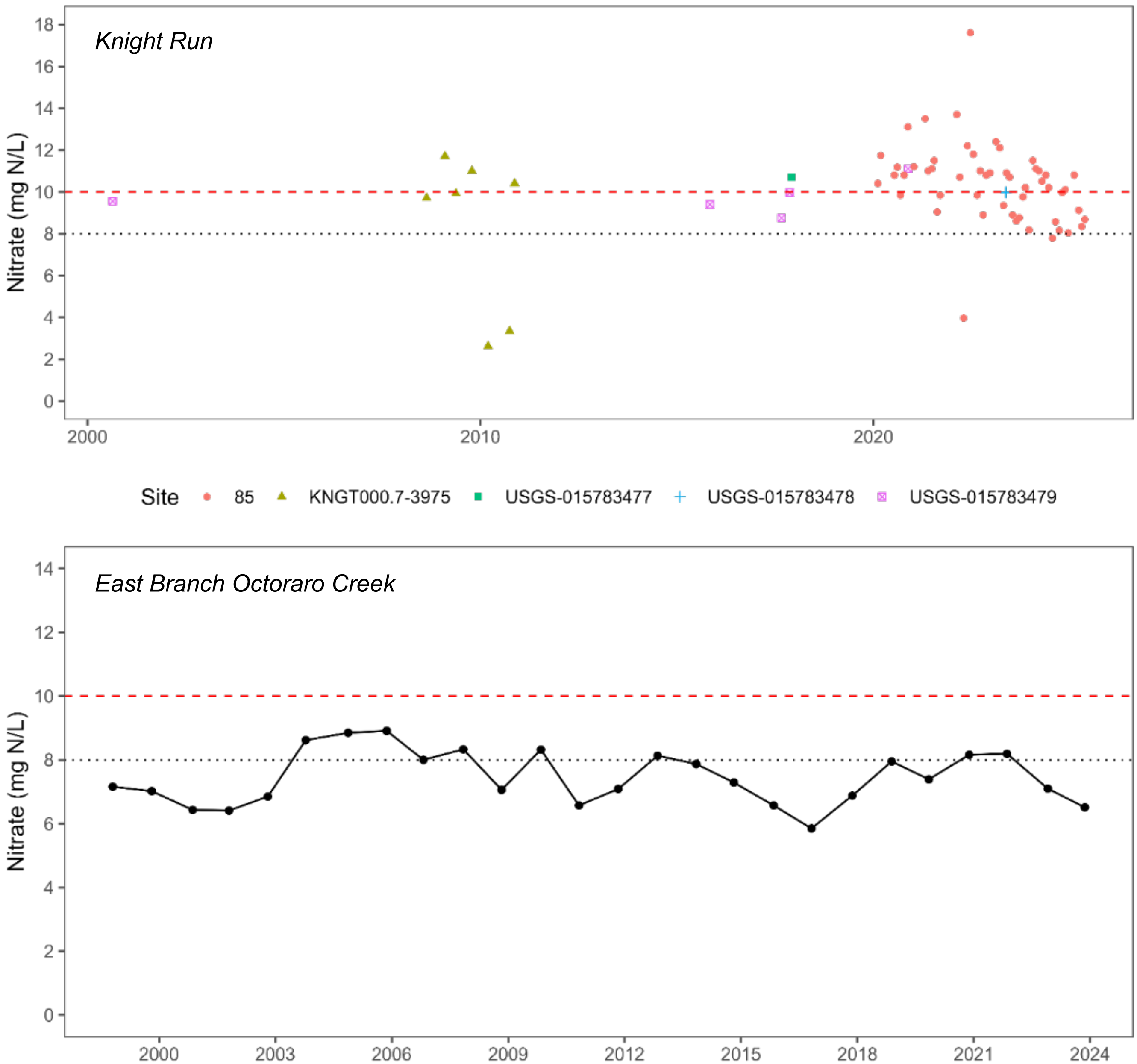


Figure 5. Nitrate concentrations measured at stream monitoring sites in Knight Run (top) and East Branch Octoraro Creek near Steelville (USGS site 01578347; located just upstream of the confluence with Knight Run) (bottom). See Figure 4 for monitoring site locations. The dashed red line is Pennsylvania's surface water quality criterion for nitrate plus nitrite for protecting potable water supply (10 mg N/L) and the dotted line (8 mg N/L) is proposed in this ARP as a benchmark for nitrate plus nitrite to evaluate plan effectiveness.

4.2.2 Siltation

Summary of Available Monitoring Data

Stream segments in the Knight Run subwatershed are at risk for high turbidity and excess accumulation of fine sediment on the streambed, especially segments with slow moving water that are surrounded by agricultural land use. Observations of Knight Run streams by PADEP staff during the May 2025 site visit documented significant fine sediment accumulation in such stream segments. PADEP staff took photos and visually evaluated conditions in several Knight Run segments near the subwatershed outlet (Figure 6) and in segments along the upper mainstem and tributaries (Figure 7). In general, swiftly flowing riffle and run reaches were rocky with limited fine sediment deposition (photo A in Figure 6; photos C and D in Figure 7), but heavy fine sediment deposition was apparent in pools (photos B through D in Figure 6; photos A and B in Figure 7).

Figure 6. Conditions in Knight Run near the subwatershed outlet. Photos show typical conditions in swifter flowing riffles and runs (A) and pools (B-D). Photo source: Michael Morris, PADEP.

Figure 7. Stream conditions within the upper mainstem and tributaries of Knight Run, including pools surrounded by agricultural landscapes (A and B) and swifter flowing reaches (C and D). Photo source: Michael Morris, PADEP.

Siltation impairment listings for streams in Pennsylvania are generally based on field surveys of stream habitat conditions. For wadable streams, PADEP recommends combining two habitat condition metrics that are scored as part of habitat surveys to inform decisions on whether siltation impairs aquatic life (PADEP 2023a):

- **Sediment deposition scores** reflect the degree of sediment accumulation on the streambed and in pools, and associated effects on the formation of islands and point bars.
- **Embeddedness scores** evaluate whether rocks on the streambed are exposed versus covered and sunken into silt, sand, and mud.

High deposition and embeddedness scores indicate that a reach receives fine sediment at a rate that exceeds its natural capacity to transport sediment downstream, which can result in degraded biological communities in the reach. Additional information on these metrics is available in PADEP's *Water Quality Monitoring Protocols for Surface Waters* (PADEP 2023b).

In January 2014, PADEP conducted a stream habitat survey at one site on the Knight Run mainstem (site 44076 in Figure 4). PADEP assessment methods require the sum of embeddedness plus sediment deposition scores for high-gradient wadable streams like those in Knight Run to be greater than 24 (PADEP 2023a). The sum of embeddedness and sediment deposition scores for Knight Run was 16, which does not reach PADEP's benchmark for attainment. Heavy siltation is clear from recent photos of Knight Run stream segments (Figure 6 and Figure 7) . Further, macroinvertebrate data collected from Knight Run at the same location and time (January 2014) as the habitat survey did not meet reference biological condition benchmarks defined in PADEP assessment methods. The macroinvertebrate Index of Biotic Integrity (IBI) score for Knight Run was 34, below the benchmark score of 50. Because certain types of macroinvertebrates are highly sensitive to pollution, they are a good indicator of habitat condition and overall stream health. Macroinvertebrates are also an important food source for fish and other aquatic life. The IBI score reflects multiple macroinvertebrate community condition metrics, including the total number of taxa present and the percent of taxa in a sample that are sensitive to pollution. Since the IBI and sum of embeddedness plus sediment deposition benchmarks were not achieved, PADEP considered aquatic life to be impaired in Knight Run due to siltation.

Sediment Export to Downstream Waters

The Octoraro Watershed model indicates that Knight Run is a significant source of sediment to downstream waters. The model estimated that Knight Run accounted for 8% of the total sediment load generated from sources upstream of Octoraro Reservoir during 2013 through 2021, more than any other subwatershed upstream of the reservoir. Sediment export from Knight Run also represented 12% of the average annual sediment load at the outlet of East Branch Octoraro Creek. These results show that reducing sediment input to Knight Run will not only improve local stream conditions but will also be critical for addressing the siltation impairment downstream in East Branch Octoraro Creek.

4.2.3 Habitat Alteration

Summary of Available Monitoring Data

Stream habitat alteration includes physical changes to the stream channel due to bank erosion, removal or lack of riparian vegetation, or the presence of concrete channels or streambeds (PADEP 2023a). Bank erosion and lack of riparian vegetation can have multiple negative effects on water quality. Eroding streambanks can be a source of sediment to the stream network, resulting in increased fine sediment accumulation downstream. Riparian vegetation helps prevent streambank erosion by slowing surface runoff, and the root systems of trees and other plants stabilize soils. Riparian vegetation also plays an important role in intercepting and filtering pollutants in runoff from adjacent upland areas.

Field measurements of bank erosion and riparian vegetation conditions were not available for Knight Run at the time this document was developed. However, eroded and incised stream banks are apparent in photos from the May 2025 site visit completed by PADEP for this ARP (Figure 8). During the site visit, PADEP also noted that many stream segments lacked riparian buffers, in some cases because streamside areas were used as livestock pasture (Figure 8). An analysis of land cover data completed for this ARP further identified the prevalence of stream segments that lack forest buffers in the subwatershed (see Section 7.3.1).

Figure 8. Examples of stream segments in Knight Run without riparian buffers (A-D), including eroding streambanks in pasture (A) and an incised stream channel (D).

4.2.4 Phosphorus and Dissolved Oxygen

Summary of Available Monitoring Data

Both nitrogen and phosphorus can stimulate the growth of algae and aquatic plants in a water body, driving a process called 'eutrophication'. Eutrophication occurs when excess nutrients fuel plant and algae growth at levels that degrade conditions for fish and other aquatic life. In freshwater streams, phosphorus is more typically the primary driver of algal growth and associated eutrophication effects.

Several water quality indicators can be used to evaluate the presence and severity of eutrophication issues in a water body, including concentrations of the nutrient that drives eutrophication (phosphorus or nitrogen) and parameters that measure the water body's response to nutrient loading. Since a critical symptom of eutrophication is the depletion of oxygen levels in the water body, dissolved oxygen is often monitored. Dissolved oxygen can be measured as a concentration or a 'percent saturation' value, which expresses the actual dissolved oxygen concentration in the water body relative to the maximum concentration that could be present based on water temperature, pressure, and salinity.

Figure 9 displays available phosphorus and dissolved oxygen monitoring data for Knight Run. Overall, the data are sparse and too limited to draw conclusions about eutrophication in the Knight Run subwatershed. Among the four parameters displayed in Figure 9, PADEP has established numeric benchmarks for dissolved oxygen percent saturation to determine if aquatic life in a stream is impaired due to eutrophication. The benchmarks for dissolved oxygen percent saturation vary by stream type and sampling month (PADEP 2023c). Evaluating whether the benchmarks are met requires continuous monitoring, where a sensor is installed to measure dissolved oxygen at regular intervals (such as every 30 minutes) across the growing season. An example of continuous dissolved oxygen data for East Branch Octoraro Creek is provided in Figure 10. Collecting continuous dissolved oxygen percent saturation data and additional phosphorus data in Knight Run during ARP implementation would enable an evaluation of the presence of elevated nutrient concentrations and associated eutrophication effects.

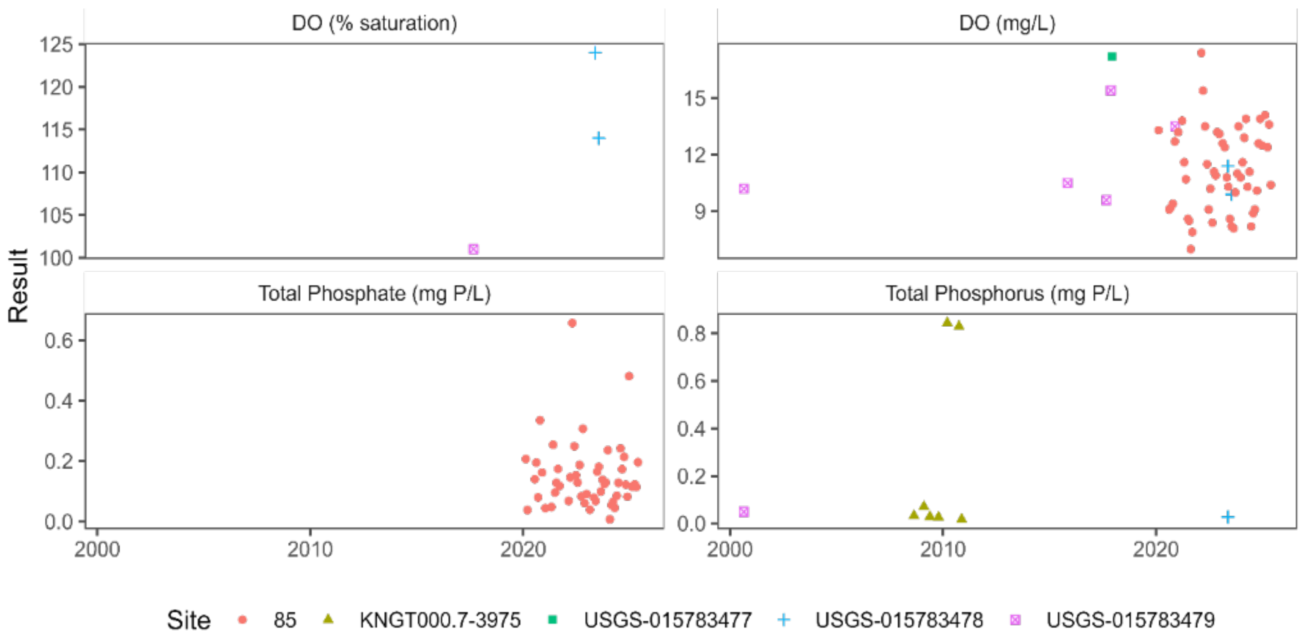


Figure 9. Available dissolved oxygen (DO) and phosphorus monitoring data for stream sites in Knight Run. See Figure 4 for site locations.

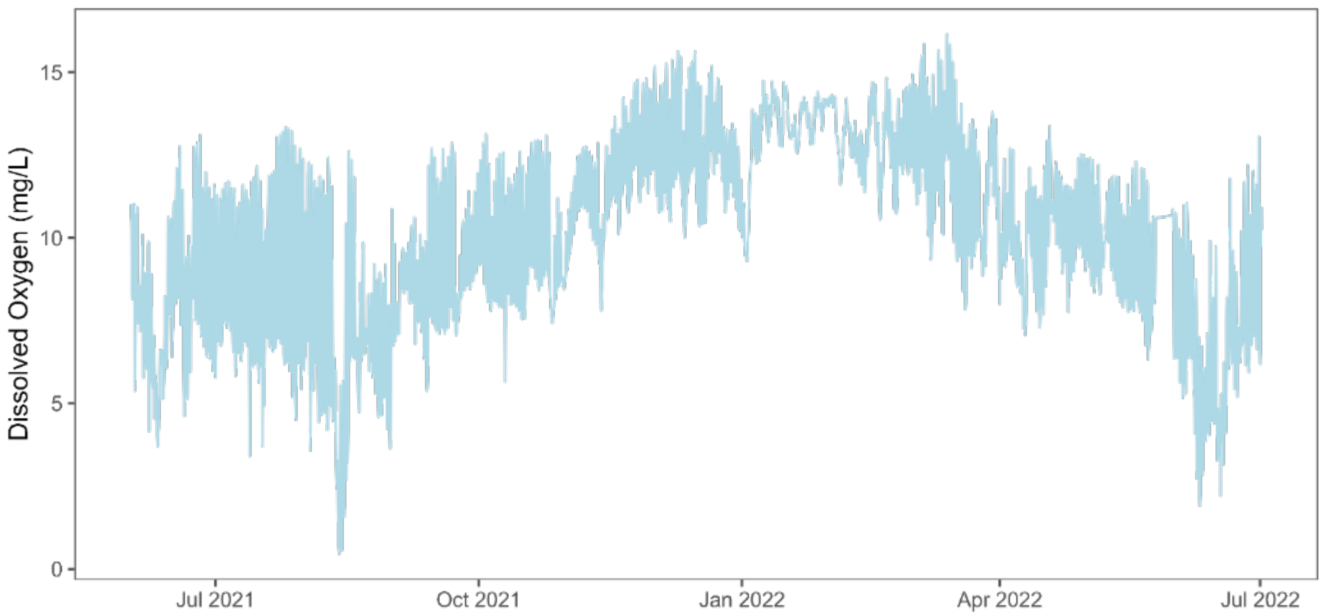


Figure 10. Example of continuous dissolved oxygen concentration data, measured by Stroud Water Research Center in East Branch Octoraro Creek (39.87012, -76.004).

Phosphorus Export to Downstream Waters

The Octoraro Watershed model suggests that Knight Run is a significant source of phosphorus to downstream waters. The model estimated that pollutant sources in Knight Run account for 7% of the total phosphorus load generated by all sources upstream of Octoraro Reservoir during 2013 through 2021. Among the 37 subwatersheds upstream of Octoraro Reservoir, only one other subwatershed accounted higher phosphorus loading than Knight Run. Phosphorus exported from Knight Run represented 11% of the average annual phosphorus load entering Octoraro Reservoir through East Branch Octoraro Creek. Similar to other pollutants discussed previously in this section, the model results point to Knight Run as a key subwatershed contributing to water quality issues in East Branch Octoraro Creek and Octoraro Reservoir, and indicate that phosphorus reductions in Knight Run can have a meaningful impact on eutrophication impairments downstream.

4.3 Pollution Sources

4.3.1 Types of Pollution Sources

Sources of water pollution can be classified as either point sources or nonpoint sources based on whether they are regulated under the National Pollutant Discharge Elimination System (NPDES) program. Point sources of pollution are regulated by state and federal agencies through NPDES permitting. In general, point sources use discrete conveyances such as pipes or ditches to discharge polluted material into surface waters. Examples include treated effluent from a municipal wastewater treatment facility or wastewater generated by an industrial faciltiy that is discharged through a pipe or other conveyance into a lake or stream. NPDES permits establish limits on how much pollution a point source can discharge.

Nonpoint sources of pollution include any sources other than point sources. Nonpoint sources are diffuse and generally do not enter surface water through one specific location. Nonpoint source pollution can occur through many different processes, including surface runoff, groundwater inputs, direct input of pollutants by precipitation, wind-blown dust, livestock, or wildlife, and alteration of stream channels or streamflow. Nonpoint source pollution is not regulated through NPDES permitting. Human activity can contribute to nonpoint source pollution issues by increasing the amount of pollution in the environment that is available for transport into water bodies or by enhancing pathways for pollutant transport. Examples include applying fertilizer or livestock manure to agricultural lands; constructing impervious surfaces; using malfunctioning or faulty septic systems; or exposing bare soils on construction sites.

The subsections below describe nonpoint sources and point sources of pollution in the Knight Run subwatershed. Section 4.4 provides estimates of the relative contribution of each source to total sediment, nitrogen, and phosphorus loading in the Knight Run subwatershed based on results of the Octoraro Watershed Model.

4.3.2 Description of Nonpoint Sources

Agricultural Runoff

Runoff from agricultural lands can contain high concentrations of sediment and nutrients. Fields where crops are grown often have exposed soils or low vegetative cover and are therefore prone to erosion during runoff events. Croplands also receive chemical fertilizer and animal manure applications, both of which contain elevated levels of nitrogen and phosphorus. These nutrients can dissolve into surface or subsurface runoff and wash into nearby waterbodies. Furthermore, phosphorus can bind to soil particles and be transported into streams along with eroded sediment.

In addition to cropland, nutrient and sediment loading occurs from areas where livestock are raised. For example, livestock waste that is held in open storage areas can be washed into waterbodies with surface runoff, while waste stored in lagoons systems can leach into the subsurface and flow into waterbodies with groundwater discharge. Animals that graze on pastures can deposit waste directly into stream channels or onto the landscape where it can be washed into waterways. Runoff from feedlots and barnyards can have high levels of sediment and nutrients due to the prevalence of exposed soils and deposited manure.

Runoff from Developed Lands

Developed lands include residential, commercial, industrial, or other related land use types. Runoff from developed lands can be referred to as stormwater and typically has high nutrient and sediment concentrations. For example, runoff from areas with high impervious surface cover tends to have high sediment and nutrient concentrations because any dust, plant debris, pet/wildlife waste, or other material deposited on the surface is carried into nearby waters without being filtered through soil. Roads, driveways, rooftops, parking lots, and other paved areas therefore all act as nutrient and sediment sources.

Other unpaved areas with disturbed soils (gravel or dirt roads, trails, paths, construction sites, etc.) also contribute high levels of sediment and attached phosphorus to surface waters. Vegetated spaces such as lawns and parks typically have lower nutrient and sediment loading than impervious areas since soil particles are held in place by plant roots and precipitation can infiltrate the soil. However, loading from these areas is generally still higher than undisturbed natural lands because of lower canopy densities and a minimal plant litter layer. Nutrient loads can be particularly high from vegetated developed lands where plant fertilizers are applied.

Septic Systems

Septic systems are an additional source of nutrients in developed areas that lack a centralized system for sanitary sewage disposal. Septic systems are located underground and function by receiving domestic sewage in a holding tank that allows solids to settle out of suspension and for an initial breakdown of organic material. Liquid sewage exits the tank into a drain field. The drain field is typically two to five feet below the soil surface in the unsaturated zone and is comprised of multiple rows of perforated pipes. As the liquid sewage percolates through the soil, nutrients are reduced as they bind to soil particles or are taken up by plants before reaching groundwater.

Excess nutrient loading to surface waters can occur when sewage pools on the land surface and is transported in runoff during precipitation events; when sewage is not adequately treated by soil before reaching groundwater; and when liquid sewage ‘short-circuits’ groundwater and is instead routed to a nearby water body with minimal soil contact time. These issues can be significant with aging or improperly sited septic systems or with extreme rainfall events. EPA’s How Septic Systems Work and Penn State Extension’s Septic System Basics webpages provide more information about septic systems.

Instream Erosion

Under natural conditions, the dimensions of a stream reach (width, depth, and slope) are generally stable over time, with any bed or bank erosion balanced by the same amount of deposition of sediment from upstream sources. Significant changes only occur periodically, for example during an extreme flow event. In watersheds with developed and agricultural lands, the balance between channel erosion and deposition is disrupted due to altered streamflow, high sediment loading, or direct channel modifications. These can accelerate channel downcutting and widening, two instream erosion processes that can contribute sediment and attached phosphorus to downstream waters.

Other Nonpoint Sources

Nitrogen and phosphorus are naturally occurring compounds that are present in rocks, plant material, soils, and wildlife waste. Nutrient loading is therefore expected from undisturbed forests, wetlands, and other natural areas. However, these areas contribute significantly lower loads per acre than agricultural and developed areas since runoff volumes and nutrient concentrations are reduced with a more extensive plant canopy, leaf litter layer, and soil infiltration and percolation. In addition, these areas are not fertilized. These same factors also reduce soil erosion and sediment loading from undeveloped vegetated lands.

An additional background source of nutrient and sediment loading to open waterbodies is atmospheric deposition. Dust and plant material in the atmosphere can be deposited to the water surface from the wind during dry periods or carried by precipitation. In agricultural and developed watersheds, this typically represents a small fraction of nutrient and sediment loading.

4.3.3 Description of Point Sources

PADEP is authorized to administer the National Pollutant Discharge Elimination System (NPDES) Program, which, among other duties, includes issuing NPDES permits to existing or futures point sources subject to the NPDES program and enforcing those permits when appropriate. Point sources in the Knight Run subwatershed with NPDES permits as of July 2025 are shown in Table 4. Permitted point sources include the Octorara Area Elementary School sewage treatment plant, one dairy farm with a general permit to operate a confined animal feeding operation (CAFO) and a general permit for discharges associated with construction activities, and another property with a general permit for discharges associated with construction activities.

Table 4. National Pollution Discharge Elimination System (NPDES) permits in the Knight Run subwatershed as of July 2025.

NPDES Permit ID	Facility	Description	Permit Status	Latitude	Longitude
PA0042889	Octorara Area Elementary School	Sewage treatment plant authorized to discharge continuously	Expired 1/31/2025	39.925	-75.939722
PAC150390	2,5, and 8 Herb Drive	General permit for discharges associated with construction activities	Effective	39.901472	-75.9275
PAC150257	Walton Farm	General permit for discharges associated with construction activities	Expired	39.891534	-75.951161
PAG123808	Walton Farm	General permit for operation of a confined area feeding operation (CAFO)	Expired	39.891534	-75.951161

The NPDES permit for the Octorara Area Elementary School specifies discharge limitations and monitoring requirements for parameters related to sediment and nutrients such as total suspended solids[4], total phosphorus and various nitrogen constituents (PADEP 2025a). The facility discharges treated effluent to a

[4] A parameter that is similar to sediment that may settle to form deposits or may remain suspended in the water column.

channel that drains into an unnamed tributary of Knight Run (assessment unit PA-SCR-57465977). The facility's NPDES permit expired in 2025 and was reissued with an effective date of July 1, 2025. The permit includes effluent limits expressed as monthly averages for total suspended solids (7.5 pounds/day), total phosphorus (0.5 pounds/day), and ammonia-nitrogen (1.5 pounds/day between November 1 to April 30; 0.5 pounds/day between May 1 to October 31). The average is calculated based on a minimum of two composite samples. It also includes monitoring and reporting requirements for nitrate plus nitrate and Total Kjeldahl nitrogen. The facility's pollutant discharges have exceeded permit limits on multiple occasions, including limits for ammonia-nitrogen (EPA 2025). As described below in Section 4.4, discharges from this facility were included in the Octoraro Watershed Model and accounted for less than 1% of average annual nitrogen, phosphorus, and sediment loading to Knight Run.

The NPDES general permits in Table 4 for construction activities do not contain numeric limits for discharge of sediment, nutrients, or other pollutants. The permits instead require permittees to implement BMPs to protect water quality, including BMPs specified in site-specific Erosion and Sediment Control Plans and Post-Construction Stormwater Management plans that must be submitted as part of permit issuance.

The NPDES general permit in Table 4 for operating a regulated CAFO prohibits any discharge of pollutants from livestock production areas (e.g., barns, feedlots, or manure storage areas) to surface waters except in compliance with an NPDES permit. The permittee may not discharge pollutants from production areas to waters of the Commonwealth except when a storm event(s) causes an overflow of manure from a facility designed, constructed, operated and maintained to contain all process-generated manure plus the runoff from the design storm at the location of the facility. The applicable design storms for a dairy operation is a 25-year/24-hour storm. For dairy farms, very large storm events are defined as 25-year/24-hour storms. These storms have a 24-hour rainfall total that occurs on average once every 25 years. The permit also specifies several requirements that the operation must follow to protect water quality in other parts of the farm, such as adhering to a site-specific Nutrient Management Plan when applying livestock manure to crops or adhering to a site-specific Erosion and Sediment Control Plan for plowed or tilled fields. The agricultural stormwater exemption provided for under the Clean Water Act covers stormwater discharges from fields under the ownership and control of a regulated CAFO when manure is applied in compliance with a Nutrient Management Plan.

This document presents readily available information about existing point sources. This document should not be construed as a determination by EPA or PADEP that there are no other point sources that are subject to the NPDES program. Sources with expired or terminated permits may no longer be in operation or the operation may no longer be subject to the NPDES program. The state is responsible for ensuring future permits comply with the Clean Water Act and its implementing regulations.

4.4 Baseline Pollutant Loads

In this report, 'baseline' pollutant loads refer to estimates of existing average annual pollutant loads in Knight Run before ARP implementation. The Octoraro Watershed Model was used to estimate baseline loads for sediment, total nitrogen, and total phosphorus over 2013 through 2021 for individual source categories. The source categories defined for baseline load calculations align with the sources described above and include:

- Cropland - Agricultural fields used to grow row crops such as corn and soybeans.
- Pasture/Hay – Agricultural fields used for livestock grazing and growing hay, or other livestock production areas such as barnyards or feedlots.
- Developed – Roads, buildings, or other impervious surfaces and adjacent turf grass, or other low vegetation in residential, commercial, industrial, and recreational areas.
- Natural lands – Forests, wetlands, or natural herbaceous lands.
- Stream Beds/Banks – Erosion of material from stream channels.
- Septic Systems – Small wastewater disposal systems, typically installed to treat wastewater from a single household.
- Atmospheric Deposition – The transfer of pollutants from the air (gases or particles) to the land surface.
- Point Sources – Discharge of pollutants from the Octorara Area Elementary School (NPDES permit PA0042889). Other point sources in Table 4 were not explicitly represented in the Octoraro Watershed Model. Loads from these sources are accounted for in their related source categories (cropland and pasture/hay for the CAFO permit; developed for the construction permits).

The Octoraro Watershed Model provides estimates of pollutant source loads that flow *into* Knight Run and the instream load at the Knight Run *outlet*. After pollutant loads enter Knight Run, instream water quality processes such as pollutant settling, uptake by aquatic life, and chemical transformations reduce the amount of pollution that reaches the outlet. Since the target pollutant loads for this ARP are instream loads at the Knight Run outlet (Section 5), the baseline loads presented in this section are also expressed as loads routed to the Knight Run outlet. This required adjusting the modeled source loads to account for instream routing. Separate adjustments were made by pollutant, based on the difference between the modeled average annual load at the Knight Run outlet and the sum total of modeled average annual loads for all sources in Knight Run. This analysis showed that instream routing reduced source loads by approximately 11% for sediment, 2% for total nitrogen, and 3% for total phosphorus. Modeled loads for each source category were reduced by these percentages to calculate baseline loads.

Baseline loads for sediment, nitrogen, and phosphorus are shown in Figure 11. Agricultural sources (cropland and pasture/hay) account for 83% of the baseline sediment load, 89% of the baseline total nitrogen load, and 93% of the baseline total phosphorus load. Developed areas rank as the second largest contributor for all pollutants, ranging from approximately 4% (total phosphorus) to 11% (total nitrogen) of total loading. Discharge from the Octorara Area Elementary School (labeled as 'point source' in Figure 11) accounted for less than 1% of total loading across all three pollutants.

As shown in Figure 11, stream bed/bank erosion accounts for less than 1% of the total baseline sediment load. When interpreting this value, it is important to understand that it reflects the amount of sediment delivered to the Knight Run outlet that originates from stream bed/bank erosion, based on results of the Octoraro Watershed Model. Although the magnitude of the bed/bank load is relatively low compared to other sources, bed/bank erosion may still be significant in individual stream reaches in the subwatershed (for example, see Figure 8 in Section 4.2.3). In such cases, eroded bed/bank sediment may not be delivered to the subwatershed outlet because it settles out of the water column and contributes to heavy sediment deposition in pools or other slow-moving reaches. Further, while the Octoraro Watershed Model was calibrated to Total Suspended Solids (TSS) monitoring data from the watershed, a lack of physical channel erosion measurements for calibration contributes to uncertainty in model results. These modeling limitations can be considered when planning BMPs to address sediment impairments in specific reaches (see Section 7.1 for further discussion of potential BMPs to achieve load reductions).

Pollutant	Total Baseline Load
Sediment	1,313 tons/year
Total Nitrogen	203,334 pounds/year
Total Phosphorus	9,238 pounds/year

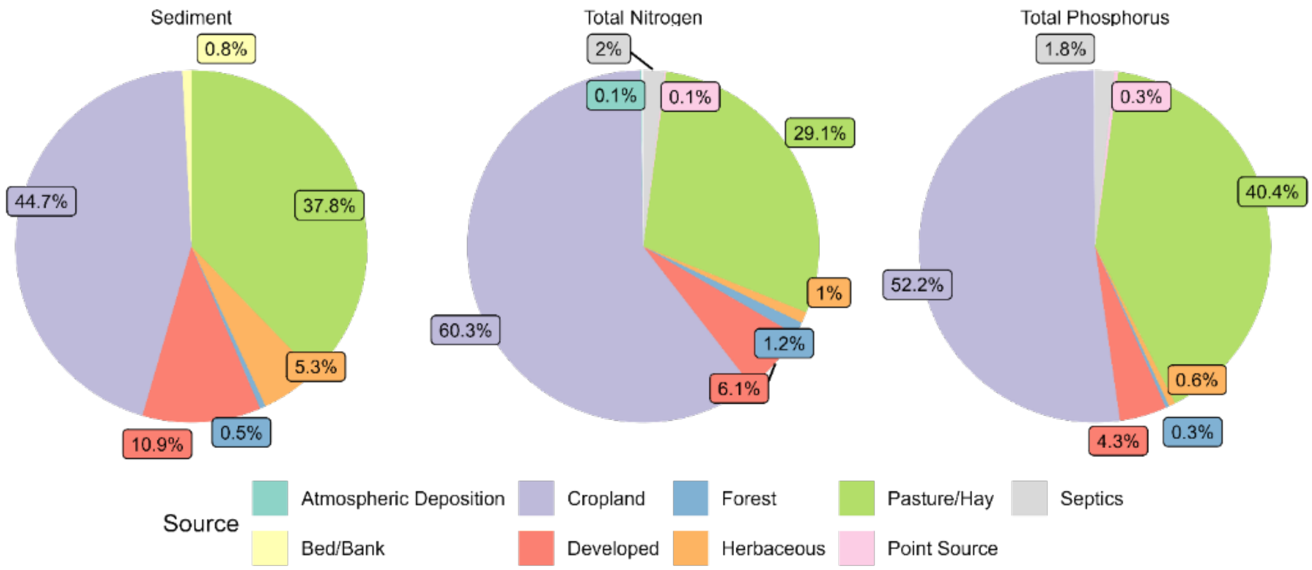


Figure 11. Summary of total baseline loads in Knight Run and contributions by source category. Baseline loads were calculated from 2013 through 2021 Octoraro Watershed Model results and represent average annual pollutant loads in Knight Run before ARP implementation.

5 Calculation of Allowable Loading Rates

5.1 Overview of Water Quality Goals and Target Pollutant Loads

This section presents target pollutant loads for the Knight Run subwatershed and reductions needed to meet the target loads. The general process for determining target sediment, nitrogen, and phosphorus loads consisted of the following steps:

1. **Define water quality goals**. Water quality goals are narrative statements on desired water quality conditions and outcomes for streams in the Knight Run subwatershed and for downstream waters.

   The water quality goals selected for this ARP are listed in Table 5. Water quality goals include a local component (i.e., goals for Knight Run) and a downstream component for Octoraro Reservoir or East Branch Octoraro Creek. Goals for downstream waters reflect the broader efforts of the Octoraro Source Water Collaborative (OSWC) to protect water quality across the upper Octoraro Watershed.

2. **Select water quality endpoints**. Water quality endpoints are numeric values of pollutants or related parameters in Knight Run or in downstream waters that correspond to attainment of water quality goals. The water quality endpoints selected for this ARP are listed in Table 5 and Table 6. Each water quality endpoint is described further in Sections 5.2 through 5.4.

3. **Run BMP scenarios in the SAM Tool to calculate target pollutant loads for Knight Run.** Target loads for sediment, nitrogen, and phosphorus are listed in Table 7. They are desired levels of pollutant loading needed to achieve water quality endpoints. For downstream water quality endpoints, target loads for Knight Run will achieve the endpoints when loads from other subwatersheds in the upper Octoraro Watershed are also reduced. The modeling approaches used to calculate target loads are described in Sections 5.2 through 5.4.

Table 5. Water quality goals and numeric water quality endpoints selected for this ARP.

Pollutant	Local Goal	Downstream Goal
Sediment	Delist siltation as a cause of aquatic life use impairment in the Knight Run subwatershed.	Delist siltation as a cause of aquatic life use impairment downstream in East Branch Octoraro Creek. *Water Quality Endpoint: Average Annual Sediment Load ≤ 178 pounds per acre at the outlet of East Branch Octoraro Creek*
Nitrogen	Reduce nitrogen export from Knight Run to Octoraro Reservoir and East Branch Octoraro Creek to restore and protect drinking water quality.	Delist nutrients as a cause of potable water supply impairment downstream in East Branch Octoraro Creek and Octoraro Reservoir. *Water Quality Endpoint: Maximum Nitrate Plus Nitrite Concentration ≤ 8 mg/L throughout Octoraro Reservoir*
Phosphorus	Reduce phosphorus loads in Knight Run to achieve dissolved oxygen percent saturation benchmarks established by PADEP for protecting aquatic life. *Water Quality Endpoint: See dissolved oxygen saturation endpoints in Table 6*	Delist nutrients as a cause of aquatic life use impairment downstream in East Branch Octoraro Creek and Octoraro Reservoir.

Table 6. Water quality endpoints for dissolved oxygen saturation at the Knight Run outlet.

Metric	April	May & October	June & September	July & August
75^{th} Percentile of Daily Range in Dissolved Oxygen Percent Saturation	29.84%	26.26%	27.42%	34.91%
25^{th} Percentile of Daily Minimum Dissolved Oxygen Percent Saturation	87.15%	83.87%	80.07%	80.36%

Table 7. Target pollutant loads and reductions for sediment, nitrogen, and phosphorus. Values represent desired average annual loads at the Knight Run outlet needed to achieve water quality endpoints.

Pollutant	Baseline Load	Target Load	Target Load Reduction	Target Load Reduction (%)
Sediment	1,313 tons/year	546 tons/year	767 tons/year	58%
Total Nitrogen	203,334 lbs/year	161,969 lbs/year	41,365 lbs/year	20%
Total Phosphorus	9,238 lbs/year	5,543 lbs/year	3,695 lbs/year	40%

5.2 Target Sediment Load

The target sediment load for Knight Run is an average annual load of 546 tons per year, equivalent to a 58% reduction from the baseline load (Table 7). The target load was calculated with the SAM Tool by developing a BMP scenario focused on sediment reduction for the entire Octoraro Watershed. For Knight Run and other subwatersheds draining to East Branch Octoraro Creek, the SAM Tool was configured to simulate BMPs and associated sediment loading reductions needed to achieve the sediment endpoint selected for this ARP (average annual load of 178 pounds per acre at the outlet of East Branch Octoraro Creek). Figure 12 displays the scenario results. As illustrated in Figure 12, achieving the sediment endpoint at the outlet of East Branch Octoraro Creek requires sediment load reductions of approximately 50% to 60% from all upstream subwatersheds, including the target reduction of 58% for Knight Run.

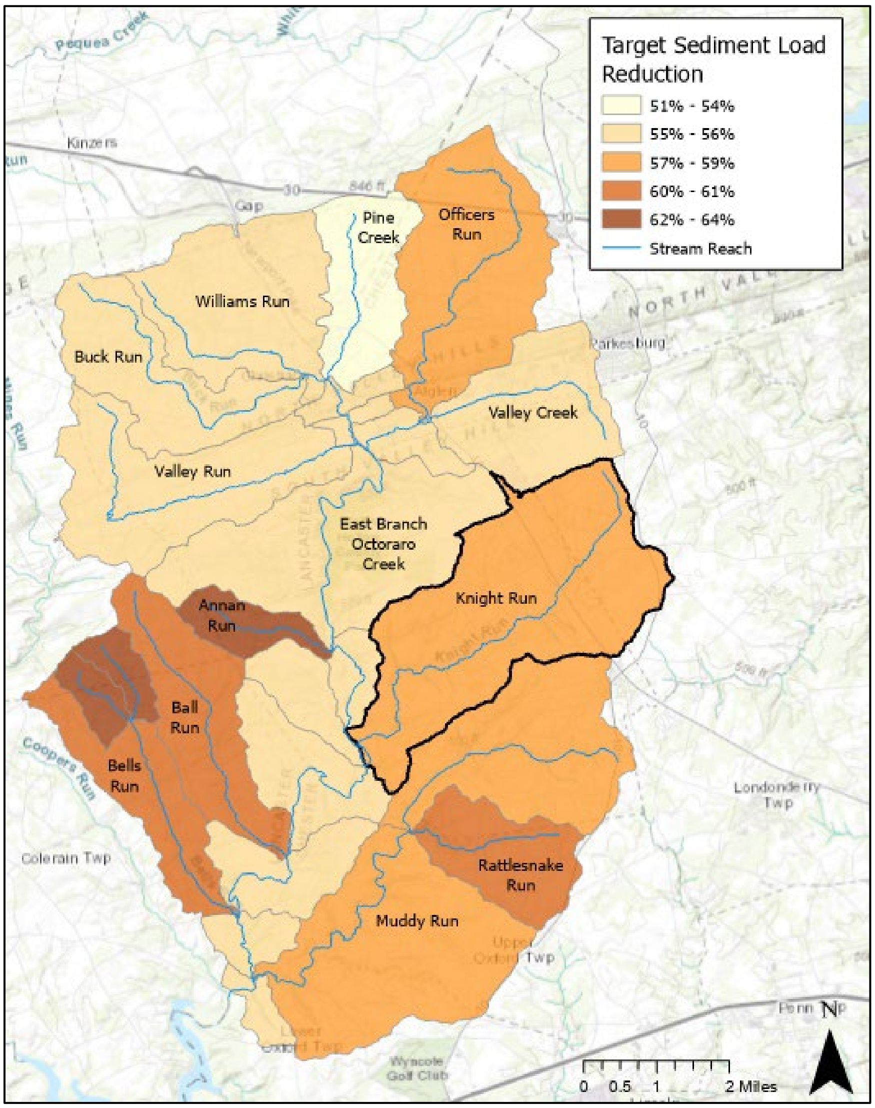


Figure 12. Sediment load reductions simulated by the SAM Tool for East Branch Octoraro Creek and tributary subwatersheds to attain the sediment endpoint of 178 pounds per acre at the outlet of East Branch Octoraro Creek.

The sediment endpoint selected for this ARP was derived by evaluating the distribution of sediment loads reported in SRBC (2019) for 27 stream monitoring sites in the Susquehanna River Basin. Figure 13 displays average annual sediment loads for the 27 sites and the percentile rank for each site. The endpoint selected for this ARP of 178 pounds per acre falls in the bottom 10th percentile of sites and is below values reported for all six sites designated as reference sites. SRBC (2019) required reference sites to have: (a) an upstream drainage area of less than 500 square miles; and (b) a siltation impairment rate of less than 25% in the upstream drainage area (i.e., less than 25% of streams above the monitoring site had siltation impairments). The endpoint for this ARP was set below the minimum reference site load to help achieve a lower siltation impairment rate in the East Branch Octoraro Creek drainage area and because of uncertainty in the level of comparability between Octoraro Watershed Model estimates of sediment loading and the data used in SRBC (2019).

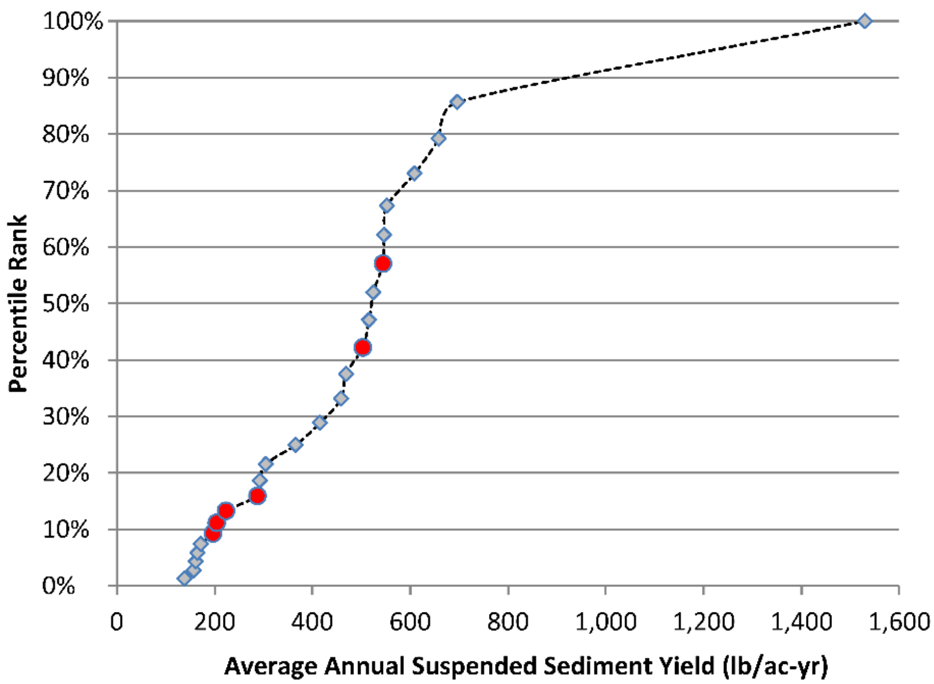


Figure 13. Distribution of average annual sediment loads for 27 stream monitoring sites in the Susquehanna River Basin calculated from 2005 through 2015 monitoring data. Adapted from SRBC (2019). Red points are reference sites, defined in SRBC (2019) as sites with: (a) upstream drainage area less than 500 square miles; and (b) a siltation impairment rate of less than 25% in the upstream drainage area. Since the siltation impairment is based on a narrative water quality standard, this is a conservative interpretation of the narrative into a numeric target for planning purposes and is protective of the water quality standard. Delisting of Knight Run will ultimately be determined by PADEP through their established assessment methodologies. If the state conducts a stream habitat survey and determines the sum of embeddedness plus sediment deposition has improved to be greater than 24 (PADEP's current benchmark for attainment), then the state may delist before full implementation of the ARP.

5.3 Target Nitrogen Load

The target total nitrogen load for Knight Run is an average annual load of 161,969 pounds per year, equivalent to a 20% reduction from the baseline load (Table 7). The target load for Knight Run was calculated with the SAM Tool by developing a BMP scenario for the entire Octoraro Watershed focused on nitrogen reduction. For Knight Run and other subwatersheds draining to Octoraro Reservoir, the SAM Tool was configured to simulate BMPs and associated nitrogen loading reductions needed to maintain nitrate plus nitrite concentrations in Octoraro Reservoir below 8 mg N/L. This water quality endpoint is less than the 10 mg N/L water quality criterion used by PADEP to assess potable water supply use attainment. It was selected as a conservative value based on Chester Water Authority's action level to use secondary source and provides an additional level of protection to help ensure that the Octoraro Reservoir does not exceed the water quality criterion.

Figure 14 displays the nitrogen scenario results from the SAM Tool. As illustrated in Figure 14, achieving the nitrogen endpoint in Octoraro Reservoir requires total nitrogen load reductions of approximately 15% to 25% from all upstream subwatersheds, including the 20% target load reduction for Knight Run.

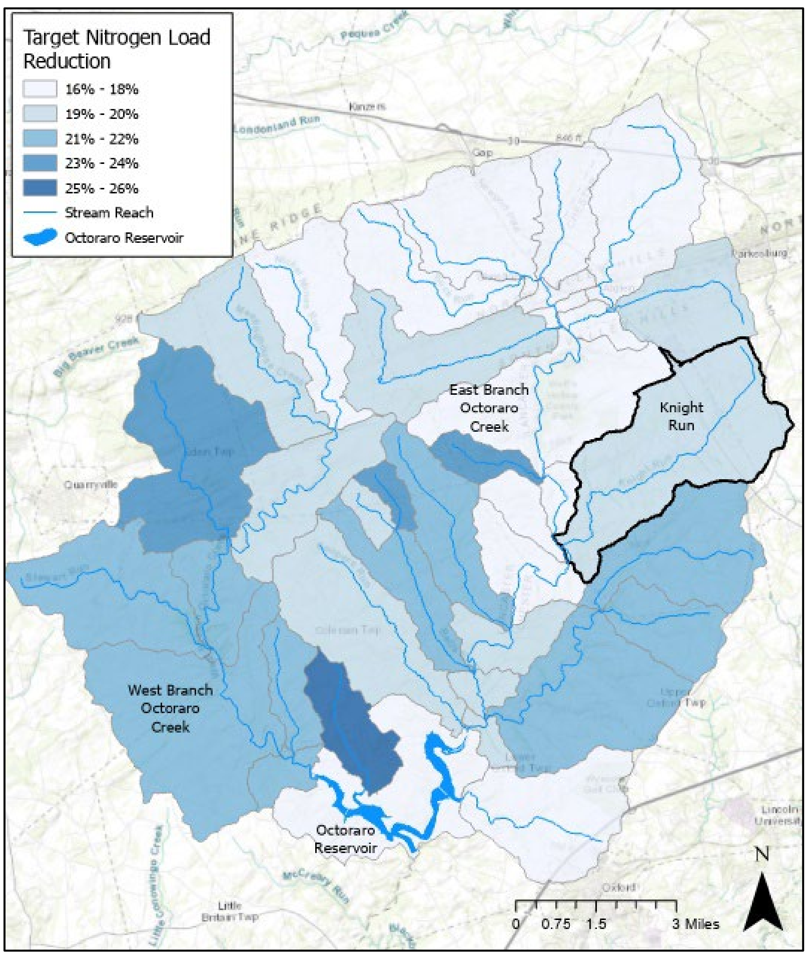


Figure 14. Total nitrogen load reductions simulated by the SAM Tool for upper Octoraro subwatersheds to attain the nitrogen endpoint of maintaining Octoraro Reservoir nitrate plus nitrite concentrations below 8 mg N/L.

5.4 Target Phosphorus Load

The target phosphorus load for Knight Run is an average annual load of 5,543 pounds per year, equivalent to a 40% reduction from the baseline load (Table 7). The target load was calculated with the SAM Tool by developing a BMP scenario for the Knight Run subwatershed to evaluate phosphorus load reductions needed to achieve the dissolved oxygen saturation endpoints listed in Table 6 at the Knight Run outlet. To determine the phosphorus load needed to meet the endpoints, an iterative approach was applied. Phosphorus loads simulated by the SAM Tool were iteratively reduced from baseline levels by adding BMPs until the modeled daily dissolved oxygen percent saturation patterns at the outlet of Knight Run met both endpoints listed in Table 6 during all growing season months (April through October). The resulting phosphorus load simulated by the SAM Tool was used as the target load for this ARP.

The dissolved oxygen percent saturation endpoints selected for this ARP are benchmarks that have been proposed by PADEP for determining if aquatic life in a stream is impaired due to eutrophication (PADEP 2023c)[5]. As described in Section 4.2.4 of this report, excess phosphorus in streams can cause eutrophication and deplete oxygen levels available for aquatic life. Dissolved oxygen percent saturation characterizes the amount of dissolved oxygen present in a water body relative to the maximum potential concentration. The benchmarks proposed by PADEP include metrics for both the minimum and range of dissolved oxygen percent saturation values that occur in a day. Daily minimum benchmarks are established since very low dissolved oxygen levels cannot sustain aquatic life, while daily range benchmarks are established since very large swings in dissolved oxygen over short periods of time can severely stress organisms. Because dissolved oxygen levels in a water body vary naturally by month, the benchmark values vary throughout the growing season (Table 6). Attaining the benchmarks is a strong indicator that phosphorus levels in a stream are not high enough to cause eutrophication and associated aquatic life impacts.

[5] The endpoints are equal to benchmarks listed in PADEP (2023c) for streams with drainage areas less than 38.6 square miles that are located in Pennsylvania eutrophication region B.

6 Load Reductions Needed by Source Sector

This section presents estimates of pollutant load reductions by source category needed to achieve target pollutant loads for Knight Run. The source-specific reductions in this section are suggested objectives and not rigid requirements that must be met. During implementation of this ARP, greater or lesser reductions can be made for each source as long as the overall target load for each pollutant is achieved.

The source categories used in this section were introduced in Section 4.4 and include cropland, pasture/hay, developed, natural lands, stream beds/banks, septic systems, atmospheric deposition, and point sources. The following steps were applied to calculate pollutant load reductions by source category:

1. Summarize baseline loads by source category. Baseline loads for each source category were calculated from Octoraro Watershed Model results as the average annual load that is routed to the Knight Run outlet (see Section 4.4).
2. Identify priority sources for reductions. Prioritization was based on the relative contribution of each source to total loading and priorities of existing water quality restoration and protection initiatives in the upper Octoraro Watershed. The priority sources selected for this ARP are cropland and pasture/hay. These sources together account for approximately 80% to 90% of baseline loading for all three pollutants (Figure 11). Agriculture is also identified as the source of pollution that is causing water quality impairments in Knight Run and downstream waters in Pennsylvania's 2024 Integrated Water Quality Report (Table 2). Furthermore, efforts to reduce loading from agricultural lands are well-established in the region.
3. Calculate load reductions needed from priority sources to achieve the target load for each pollutant. This step applied an equal percent reduction to priority sources to meet the overall target load reduction. No change in baseline loads was assumed for non-priority sources.

This ARP focuses on reductions from agriculture based on the relatively high loads in this sector and complements the on-going efforts of the OSWC partners who specifically work with agricultural landowners. However, progress made in reducing sediment, phosphorus, and nitrogen in other sectors through the County Action Plan to meet Chesapeake Bay TMDLs may reduce the reductions needed from agriculture in this subwatershed.

Load reductions by source category are displayed in Table 8 (sediment), Table 9 (nitrogen), and Table 10 (phosphorus). As described above, reductions are applied to cropland and pasture/hay only since this ARP focuses on managing pollution from agricultural sources. Other sources are not reduced from baseline loading. Section 7 contains a detailed discussion of agricultural BMPs that can be implemented in Knight Run to achieve the reductions.

Table 8. Sediment reductions needed by source category to meet the target load for Knight Run.

Source	Baseline Load (tons/year)	Priority Source?	% Reduction Needed (Priority Sources Only)	Target Load (tons/year)	Target Load Reduction (tons/year)
Cropland	587	Yes	71%	171	416
Pasture/Hay	496			145	351
Developed	143	No	0%	143	0
Forest	7		0%	7	0
Herbaceous	70		0%	70	0
Wetlands	0.2		0%	0.2	0
Septics	0		0%	0	0
Bed/Bank	11		0%	11	0
Atm. Deposition	0		0%	0	0
Point Source	0.1		0%	0.1	0
Total	**1,313**	**-**	**58%**	**546**	**767**

Table 9. Total nitrogen reductions needed by source to meet the target load for Knight Run.

Source	Baseline Load (lbs/year)	Priority Source?	% Reduction Needed (Priority Sources Only)	Target Load (lbs/year)	Target Load Reduction (lbs/year)
Cropland	122,586	Yes	23%	94,675	27,911
Pasture/Hay	59,092			45,638	13,454
Developed	12,493	No	0%	12,493	0
Forest	2,462		0%	2,462	0
Herbaceous	2,065		0%	2,065	0
Wetlands	202		0%	202	0
Septics	3,982		0%	3,982	0
Bed/Bank	0		0%	0	0
Atm. Deposition	208		0%	208	0
Point Source	244		0%	244	0
Total	**203,334**	**-**	**20%**	**161,969**	**41,365**

Table 10. Total phosphorus reductions needed by source to meet the target load for Knight Run.

Source	Baseline Load (lbs/year)	Priority Source?	% Reduction Needed (Priority Sources Only)	Target Load (lbs/year)	Target Load Reduction (lbs/year)
Cropland	4,820	Yes	43%	2,738	2,082
Pasture/Hay	3,733			2,120	1,613
Developed	400	No	0%	400	0
Forest	30		0%	30	0
Herbaceous	55		0%	55	0
Wetlands	4		0%	4	0
Septics	163		0%	163	0
Bed/Bank	0.1		0%	0	0
Atm. Deposition	0		0%	0	0
Point Source	32		0%	32	0
Total	**9,238**	**-**	**40%**	**5,543**	**3,695**

7 Analysis of BMPs to Achieve Load Reductions

7.1 Overview

This section describes BMPs that are estimated to achieve the target sediment, nitrogen, and phosphorus loads selected for this ARP. The BMPs were identified and evaluated with the SAM Tool. Two BMP scenarios are presented:

- An 'interim' scenario that achieves target loads for nitrogen and phosphorus only. The SAM Tool indicates target loads for nitrogen and phosphorus can be met with a lower level of BMP implementation compared to sediment. Target loads for nitrogen and phosphorus therefore serve as key interim milestones that could be achieved before the sediment target is met. The interim scenario provides an understanding of BMPs needed to reach target nitrogen and phosphorus loads, and the associated level of progress toward meeting the target sediment load.
- A 'final' scenario that also achieves the target sediment load. Because sediment requires the greatest load reduction (relative to nitrogen and phosphorus), this scenario includes a higher level of BMP implementation compared to the interim scenario.

The BMP scenarios were initially designed using the optimization function of the SAM Tool to identify a group of BMPs that could achieve load reduction targets at the lowest cost. The scenarios were then refined based on additional analysis of BMP opportunities in the subwatershed and feedback from local stakeholders. The information in this section is intended to provide a starting point for guiding ARP implementation. There are likely additional BMP opportunities in the Knight Run subwatershed beyond what is listed here, and what is ultimately implemented will largely be dependent on landowner preferences, knowledge gained during implementation, and findings of ARP effectiveness evaluations.

The paragraphs below summarize the interim and final BMP scenarios developed for this ARP and highlight key concepts relevant to ARP implementation. Additional details of BMP scenario settings and assumptions are provided in Appendix B.

Types of BMPs

Table 11 lists the set of BMPs included in the interim and final scenarios. Because this ARP focuses on addressing agricultural sources of pollution, all BMPs in the scenarios address pollutant loading from cropland or pasture/hay. BMPs for other sources of pollution were not considered in the analysis. The scenarios include both physical BMPs such as riparian buffers, and operational BMPs such as nutrient management and conservation tillage.

The BMPs included in the scenarios (Table 11) align with agricultural BMPs identified in Chester County's Countywide Action Plan (Chester County 2021) designed to help meet statewide goals for reducing pollutant loading to Chesapeake Bay. The Countywide Action Plan specifies target implementation rates for nearly all BMPs included in the scenarios (the exception is Agricultural Stormwater Management). However, additional implementation of BMPs in the Knight Run subwatershed beyond rates specified in the Countywide Action Plan will likely be needed to achieve load reduction targets defined for this ARP, as previous applications of the SAM Tool indicated that the Countywide Action Plans would be insufficient to restore water quality impairments in the Octoraro Watershed related to sediment and phosphorus (see Attachment 1).

During implementation of this ARP, technical assistance providers should ensure that BMPs follow applicable state or federal standards, such as standards from the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Field Office Technical Guide for Pennsylvania.

BMP Areas

Table 11 also reports the number of acres treated by each BMP in the interim and final scenarios. These values represent 'new' areas where BMPs need to be implemented to achieve target pollutant loads in Knight Run. The SAM Tool uses the Octoraro Watershed Model to simulate the magnitude of pollutant load reductions that the BMPs provide, with reductions calculated relative to baseline pollutant loads. Because the Octoraro Watershed Model was calibrated to water quality monitoring data from 2013 through 2021, baseline loads already account for existing BMPs in place during that time span. The BMP scenarios summarized in Table 11 therefore represent additional BMP implementation needed beyond baseline 2013 through 2021 conditions.

Load Reductions

Table 12 displays pollutant load reductions achieved in the interim and final scenarios compared to target reductions. In addition to confirming that targets are achieved, these values also provide insight into the relative level of effort needed to achieve each pollutant-specific target. For example, the sediment load reduction in the final scenario (58%) is equal to the sediment reduction target for this ARP. In contrast, phosphorus and nitrogen loads in the final scenario are reduced far beyond their respective targets. This illustrates that the sediment target is the most difficult target to achieve and the primary factor driving BMP implementation in the final scenario. Fewer BMPs are needed to achieve nitrogen and phosphorus targets.

Figure 15 illustrates the relative contribution of each BMP to total load reductions in the interim and final scenarios. BMPs with the highest reductions could potentially be prioritized during implementation of this ARP. In general, grass buffers provide the highest load reductions for all three pollutants, while agricultural stormwater management and feeding space management provide the lowest reductions. Other top-ranking BMPs vary by pollutant and include conservation tillage, Agricultural Erosion and Sediment Control Plans, and nutrient management.

BMP Costs

Table 13 and Table 14 present cost information for the scenarios. Costs to implement BMPs in the final scenario include total capital costs of approximately $2.1 million, approximately $1.3 million in opportunity costs for converting farmland to buffers and restored wetlands, and ongoing operations and maintenance (O&M) costs of approximately $70,000 annually. Table 14 also displays an annualized cost for each BMP and the total annualized cost for each scenario. Annualized costs combine the three cost categories (capital, opportunity, and O&M) into a single overall dollar amount per BMP and per scenario. Annualized costs can be useful for comparing BMPs to one another, for comparing the scenarios developed for this ARP to each other, and for comparing the interim and final scenarios to additional refined scenarios that may be developed in the future as ARP implementation gets underway. Annualized costs should not be interpreted as the actual cost per year to implement the scenario. In practice, actual costs and associated funding needed per year will depend on the type and quantity of BMPs installed or adopted, and characteristics of individual BMP projects.

Figure 16 illustrates the relative cost-effectiveness of BMPs in the final scenario, calculated from the annualized cost of the BMP and the corresponding load reduction provided by the BMP. Conservation tillage is the most cost-effective BMP across all three pollutants and provides significant load reductions. Other top-ranking BMPs for cost-effectiveness include forest and grass buffers (without livestock fencing), nutrient management, and pasture management. BMPs that are less cost-effective are agricultural stormwater management, feeding space management, and wetland restoration. The interim scenario had similar cost-effectiveness rankings. The purpose of cost-effectiveness data in Figure 16 is not to recommend against particular BMPs, but rather to provide information that may be considered during ARP implementation. There may be good reason to implement BMPs that are less cost-effective on a given farm.

Other BMPs

Additional BMPs beyond those simulated in the scenarios may offer significant pollutant load reductions and can be considered during ARP implementation. For example:

- **Stream and Floodplain Restoration**. Projects that directly address bed/bank erosion and sediment deposition issues through stream restoration and floodplain restoration could support efforts to address sediment impairments. As discussed in Section 4.4, bed/bank erosion may be an important contributor to sediment impairments in some stream segments despite the relatively low contribution of bed/bank erosion to overall sediment loading at the subwatershed outlet.

  Bed/bank erosion can be especially prominent in reaches affected by mill dams. Mill dams were commonly installed on Pennsylvania streams following European settlement and resulted in significant deposition of sediment above the dam in the stream channel and adjacent floodplains (Walter et al. 2007). As mill dams were abandoned over time, this sediment (referred to as 'legacy sediment'), has been prone to erosion. The buildup of legacy sediment also disrupted key hydrologic and geomorphic processes, resulting in disconnection of streams from natural floodplains that would otherwise attenuate sediment during high flow periods. PADEP maintains an online map layer of known mill dams. While the map does not show any dams in the Knight Run subwatershed or downstream on East Branch Octoraro Creek (as of February 2026), it likely captures only a fraction of mill dams that were historically in place. The map shows that mill dams have been identified upstream of Knight Run on East Branch Octoraro Creek and its tributaries, indicating that mill dams were present in the area and the potential for unidentified mill dams in Knight Run.

  Field surveys of channel erosion, mill dams, legacy sediment, disconnected floodplains, and related downstream impacts throughout the Knight Run subwatershed could highlight reaches where stream restoration or floodplain restoration projects may be needed. If issues related to mill dams and legacy sediment are identified, remaining accumulations of legacy sediment could be excavated to prevent future erosion and to restore floodplain connectivity. In such areas, activities to address legacy sediment should be completed before implementing any riparian buffers, wetland restoration activities, or related BMPs. If legacy sediment is not addressed, stream channels may continue to rapidly erode, resulting in failure of the newly established buffers or wetlands.

- **Animal Waste Management Systems**. Livestock waste storage impoundments, containment structures, treatment lagoons, and related structures (hereafter referred to as 'Animal Waste Management Systems') can be considered for animal feeding operations where such systems are not already present or are inadequate. Animal Waste Management Systems that are properly designed and maintained can help reduce nutrient export from feedlots, barnyards, or other areas where livestock are held or confined. However, Animal Waste Management Systems alone will have limited effects on total nutrient loading in the subwatershed unless they are paired with: (a) proper nutrient management practices to ensure the stored waste is applied to fields in a manner that minimizes water quality impacts; (b) manure transport out of the subwatershed; or (c) manure processing technologies. Further discussion of manure transport and manure processing technologies is provided below. Additional information on Animal Waste Management Systems is available in Chesapeake Bay Program (2016).

- **Manure Transport and Manure Processing Technologies**. Manure transport and manure processing technologies could be considered for reducing nutrient loading to Knight Run streams. Manure processing technologies include biochar facilities or anaerobic digesters, which convert manure into end-products (e.g., livestock bedding, soil amendments, or fertilizers) and also produce biogas that can be used for energy production. The end-products generated by these technologies are typically less prone to nutrient loss in runoff and groundwater when applied to agricultural lands compared to raw manure and can help retain existing nutrients on the landscape for plant uptake. Depending on the specific technology used, the nutrient content of end-products may be lower than the manure used as input. Manure or end-products of manure processing technologies could be sold or otherwise transported for use outside of Knight Run to reduce the total amount of nutrients applied to lands in the subwatershed. As a first step, a manure balance for the subwatershed could be completed to determine if manure is generated in excess of amounts needed to meet planned crop yields.

- **Comprehensive Nutrient Management Plans**. A Comprehensive Nutrient Management Plan (CNMP) is a site-specific plan for an animal feeding operation that outlines management practices to minimize the impacts of nutrients and manure across animal production areas (e.g., feedlots or barnyards), raw material storage areas, waste handling containment or storage areas, and land treatment areas (e.g., fields where manure is land applied). Whereas Nutrient Management Plans developed under NRCS practice standard 590 focus on land treatment areas only, a CNMP takes a 'whole farm' perspective to more thoroughly address and prevent impacts of livestock waste. For additional information, refer to USDA NRCS (2022).

Table 11. List of all agricultural BMPs available in the SAM Tool and BMPs included in the scenarios developed for this ARP. The number of acres treated represents 'new' areas where BMPs need to be implemented to achieve target pollutant load reductions in Knight Run.

BMP Name	Sources Treated by BMP	BMP Included in Scenario?	Acres Treated by BMP in Scenario	
			Interim Scenario	Final Scenario
Agricultural Stormwater Management	Pasture (Feeding Space)	✓ (Final Scenario Only)	0 acres	15 acres
Agricultural Erosion and Sediment Control Plans	Cropland, Pasture, and Hay	✓	1,633 acres	3,102 acres
Conservation Tillage	Cropland	✓	670 acres	1,158 acres
Cover Crops	Cropland	-	-	-
Crop Irrigation Management	Cropland	-	-	-
Feeding Space Management	Pasture (Feeding Space)	✓ (Final Scenario Only)	0 acres	6 acres
Forest Buffers	Cropland	✓	184 acres	331 acres
Forest Buffers with Livestock Fencing	Pasture	✓	73 acres	131 acres
Grass Buffers	Cropland & Hay	✓	1,281 acres	2,433 acres
Grass Buffers with Livestock Fencing	Pasture	✓	383 acres	689 acres
Manure Incorporation	Cropland with Manure Application	-	-	-
Nutrient Management	Cropland, Pasture, and Hay	✓	1,507 acres	2,411 acres
Off-Stream Livestock Watering	Pasture	-	-	-
Pasture Management	Pasture	✓	361 acres	687 acres
Water Control Structures	Cropland, Pasture, and Hay	-	-	-
Wetland Creation	Cropland, Pasture, and Hay	-	-	-
Wetland Restoration	Cropland, Pasture, and Hay	✓	215 acres	387 acres

Table 12. Pollutant load reductions provided by each BMP in the interim (top) and final (bottom) scenarios developed for this ARP. Percent reductions are expressed relative to baseline loads.

Interim Scenario						
BMP Name	Sediment Load Reduction		Nitrogen Load Reduction		Phosphorus Load Reduction	
	% of Total	Tons/Year	% of Total	Pounds/Year	% of Total	Pounds/Year
Ag. Erosion and Sediment Control Plans	16%	79	8%	4,719	11%	394
Conservation Tillage	22%	112	8%	4,718	23%	865
Forest Buffers	5%	26	11%	6,212	4%	156
Forest Buffers with Livestock Fencing	3%	13	2%	1,354	2%	79
Grass Buffers	33%	165	41%	23,795	28%	1,019
Grass Buffers with Livestock Fencing	13%	66	9%	4,955	11%	414
Nutrient Management	0%	0	12%	6,721	13%	471
Pasture Management	4%	21	2%	1,063	4%	146
Wetland Restoration	3%	15	7%	4,032	4%	162
Total Load Reduction in Scenario	**496 tons/year**		**57,569 tons/year**		**3,705 tons/year**	
Total % Reduction in Scenario	**38%**		**28%**		**40%**	
Target % Reduction	**58%**		**20%**		**40%**	
Target % Reduction Achieved?	⃠		✓		✓	

Final Scenario						
BMP Name	Sediment Load Reduction		Nitrogen Load Reduction		Phosphorus Load Reduction	
	% of Total	Tons/Year	% of Total	Pounds/Year	% of Total	Pounds/Year
Ag. Erosion and Sediment Control Plans	16%	124	8%	7,960	11%	629
Conservation Tillage	21%	160	8%	7,237	22%	1,258
Forest Buffers	5%	38	10%	9,930	4%	236
Forest Buffers with Livestock Fencing	2%	19	2%	2,163	2%	119
Grass Buffers	34%	260	42%	40,134	28%	1,628
Grass Buffers with Livestock Fencing	13%	99	8%	7,917	11%	624
Nutrient Management	0%	0	10%	9,548	11%	633
Pasture Management	4%	34	2%	1,793	4%	233
Wetland Restoration	3%	23	7%	6,450	4%	245
Agricultural Stormwater Management	0.6%	5	2.6%	2,529	2.0%	115
Feeding Space Management	0.2%	1	1%	603	0.3%	18
Total Load Reduction in Scenario	**762 tons/year**		**96,264 pounds per year**		**5,738 pounds per year**	
Total % Reduction in Scenario	**58%**		**47%**		**62%**	
Target % Reduction	**58%**		**20%**		**40%**	
Target % Reduction Achieved?	✓		✓		✓	

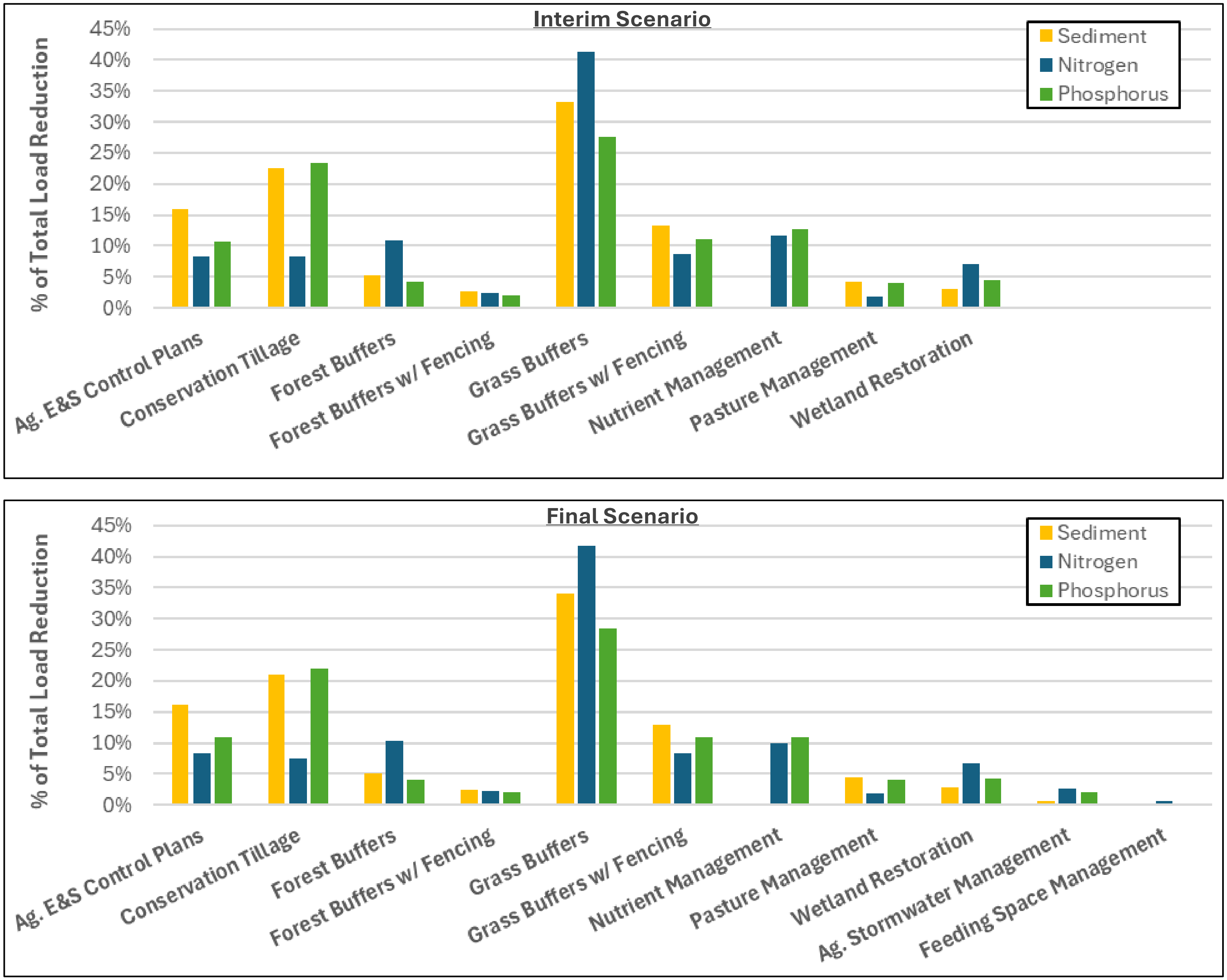


Figure 15. Pollutant load reductions provided by each BMP in the interim (top) and final (bottom) scenarios developed for this ARP.

Table 13. Cost assumptions for the BMP scenarios developed for this ARP. Costs are estimated in 2018 dollars.

BMP Name	Capital Cost[1] ($/ Treated Acre)	Opportunity Cost[2] ($/Treated Acre)	O&M Cost[3] ($/Treated Acre/ Year)	BMP Lifespan	Annualized Cost[4] ($/Treated Acre/Year)
Ag. Erosion and Sediment Control Plans	$26.55	$0.00	$0.00	1	$26.55
Conservation Tillage	$0.00	$0.00	$0.00	1	$0.00
Forest Buffers	$724.99	$361.58	$14.50	40	$74.83
Forest Buffers with Livestock Fencing	$1,538.93	$136.82	$60.69	30	$148.02
Grass Buffers	$160.70	$361.59	$6.43	10	$45.32
Grass Buffers with Livestock Fencing	$899.02	$140.21	$42.03	18	$121.96
Nutrient Management	$6.23	$0.00	$0.00	1	$6.23
Pasture Management	$44.89	$0.00	$0.00	1	$47.13
Wetland Restoration	$981.38	$521.67	$17.37	15	$138.00
Agricultural Stormwater Management	$9,734.85	$0.00	$389.39	10	$1,650.10
Feeding Space Management	$6,012.98	$0.00	$0.60	15	$579.90

[1]Capital costs are one-time expenses needed to plan, construct, install, develop, or otherwise adopt a BMP.

[2]Opportunity costs represent lost revenue from converting agricultural land to buffers or restored wetlands.

[3]Operations and maintenance (O&M) costs are ongoing annual costs needed ensure a BMP continues to function as intended.

[4]Annualized costs were calculated following methods used by the Chesapeake Assessment and Scenario Tool (CAST) (CBP 2024), with capital and opportunity costs amortized over the lifespan of the BMP with a 5% interest rate and added to annual O&M costs.

Table 14. Estimated costs needed to implement BMPs in the interim (top) and final (bottom) scenarios developed for this ARP. Costs are estimated in 2018 dollars.

Interim Scenario				
BMP Name	**Capital Cost[1] ($)**	**Opportunity Cost[2] ($)**	**O&M Cost[3] ($/Year)**	**Annualized Cost[4] ($/Year)**
Ag. Erosion and Sediment Control Plans	$43,356	$0	$0	$43,356
Conservation Tillage	$0	$0	$0	$0
Forest Buffers	$133,398	$66,531	$2,668	$13,769
Forest Buffers with Livestock Fencing	$112,342	$9,988	$4,430	$10,805
Grass Buffers	$205,857	$463,197	$8,237	$58,055
Grass Buffers with Livestock Fencing	$344,325	$53,700	$16,097	$46,711
Nutrient Management	$9,389	$0	$0	$9,389
Pasture Management	$16,205	$0	$0	$17,014
Wetland Restoration	$210,996	$112,159	$3,735	$29,670
Total	**$1,075,867**	**$705,575**	**$35,167**	**$228,768**

Final Scenario				
BMP Name	**Capital Cost[1] ($)**	**Opportunity Cost[2] ($)**	**O&M Cost[3] ($/Year)**	**Annualized Cost[4] ($/Year)**
Ag. Erosion and Sediment Control Plans	$82,358	$0	$0	$82,358
Conservation Tillage	$0	$0	$0	$0
Forest Buffers	$239,972	$119,683	$4,800	$24,769
Forest Buffers with Livestock Fencing	$201,600	$17,923	$7,950	$19,391
Grass Buffers	$390,983	$879,748	$15,644	$110,264
Grass Buffers with Livestock Fencing	$619,425	$96,605	$28,959	$84,030
Nutrient Management	$15,021	$0	$0	$15,021
Pasture Management	$30,839	$0	$0	$32,378
Wetland Restoration	$379,793	$201,886	$6,722	$53,406
Agricultural Stormwater Management	$146,023	$0	$5,841	$24,752
Feeding Space Management	$36,078	$0	$4	$3,479
Total	**$2,142,091**	**$1,315,846**	**$69,919**	**$449,847**

[1]Capital costs are one-time expenses needed to plan, construct, install, develop, or otherwise adopt a BMP.

[2]Opportunity costs represent lost revenue from converting agricultural land to buffers or restored wetlands.

[3]Operations and maintenance (O&M) costs are ongoing annual costs needed ensure a BMP continues to function as intended.

[4]Annualized costs were calculated following methods used by the Chesapeake Assessment and Scenario Tool (CAST) (CBP 2024), with capital and opportunity costs amortized over the lifespan of the BMP with a 5% interest rate and added to annual O&M costs.

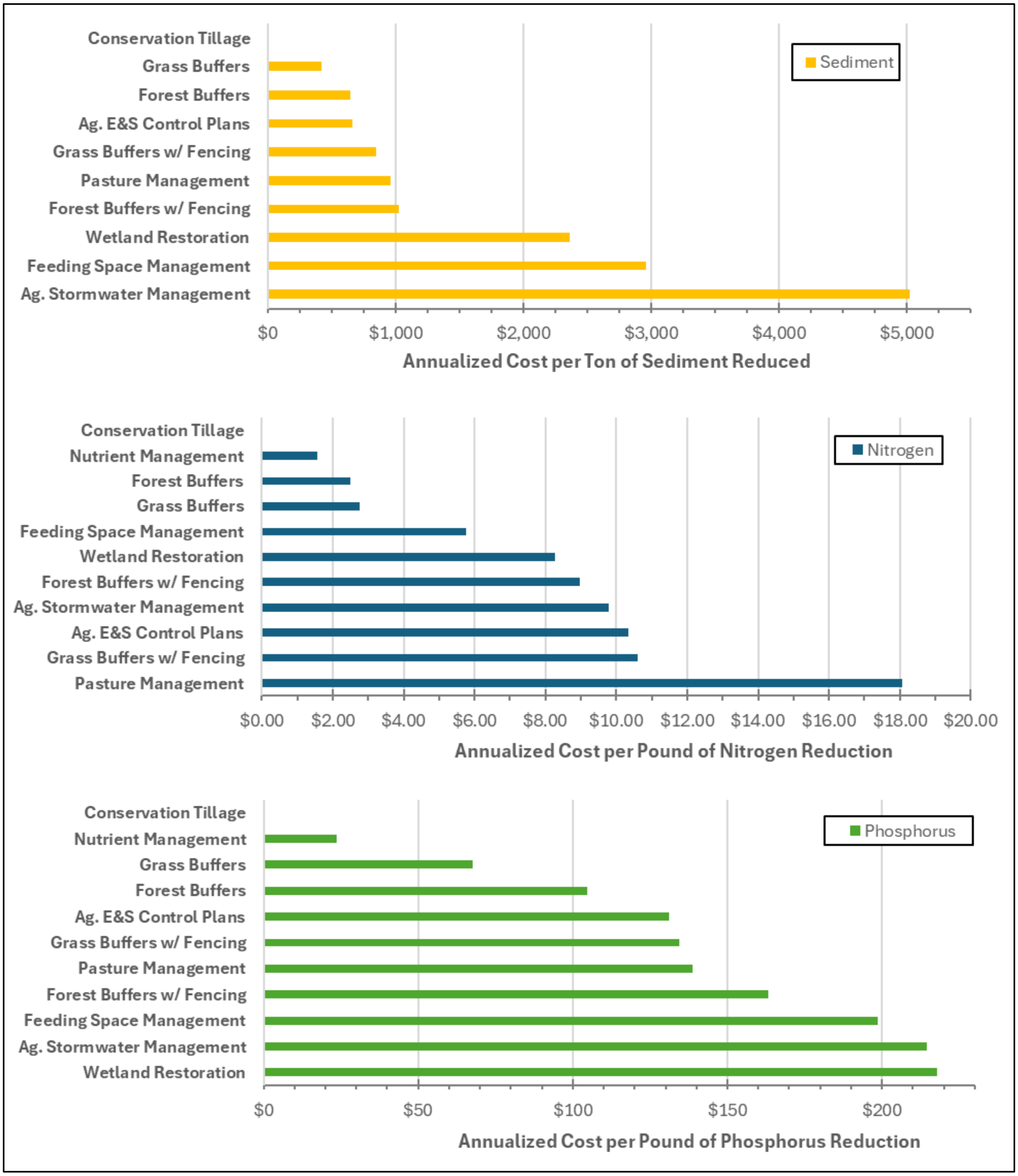


Figure 16. Cost efficiencies for BMPs in the final scenario developed for this ARP.

7.2 BMP Descriptions and Scenario Assumptions

The sections below describe each BMP included in the scenarios developed to achieve load reduction targets and summarize key assumptions related to pollutant sources treated by the BMP and pollutant load reduction efficiencies. Additional details of BMP scenario settings and assumptions are provided in Appendix B.

7.2.1 Forest and Grass Buffers

Forest buffers are linear vegetated areas adjacent to stream channels that are dominated by trees and have dense canopy cover. Grass buffers are dominated by herbaceous vegetation. Grass buffers can be located adjacent to stream channels, along concentrated flowpaths (small ephemeral streams or gullies where runoff accumulates on the landscape before flowing into larger streams), or on the edge of farm fields. Depending on their location and design, grass buffers may also be referred to by other terms such as filter strips, field borders, or grass waterways.

Forest and grass buffers are planted to filter pollutants in surface runoff or shallow subsurface flow from adjacent upland areas. As polluted water passes through the buffer, sediment and nutrient levels are reduced due to processes such as physical settling and biological uptake.

Forest and grass buffers treat pollutant loads from cropland, pasture, and hay fields in the BMP scenarios developed for this ARP. Four categories of buffers are included in the scenarios: (1) forest buffers; (2) forest buffers with livestock fencing; (3) grass buffers; and (4) grass buffers with livestock fencing. Each category has distinct pollutant reduction efficiencies or costs. Reduction efficiencies and costs were derived from values in the Chesapeake Assessment and Scenario Tool (CAST), which reflect the following key assumptions:

- Buffers are installed on existing cropland, pasture, or hay fields. Pollutant reduction is achieved through converting cropland or pasture to forest or grass within the buffer area and through treatment of runoff from upland cropland, pasture, or hay fields that drain to the buffer.
- Buffers that treat pasture loading include livestock exclusion fencing installed along the length of the buffer to prevent livestock from grazing, trampling, and depositing manure in the buffer and to prevent livestock stream access.
- Minimum buffer width is 35 feet. For buffers along streams, buffer width is measured separately on each side of the stream channel (i.e., if buffers are installed on both sides of the stream, then the minimum buffer width across both sides is 70 feet).

Figure 17 displays land cover in the 100-foot buffer around each side of streams in Knight Run based on 2021/2022 land cover data in the Chesapeake Bay Land Use and Land Cover Database (2024 Edition). While patches of forest exist throughout the subwatershed, agricultural cover is present in 38% of the buffer area, indicating there is significant opportunity to install forest buffers along streams to improve water quality. Further discussion of potential areas in the Knight Run subwatershed for forest and grass buffers is provided in Section 7.3.

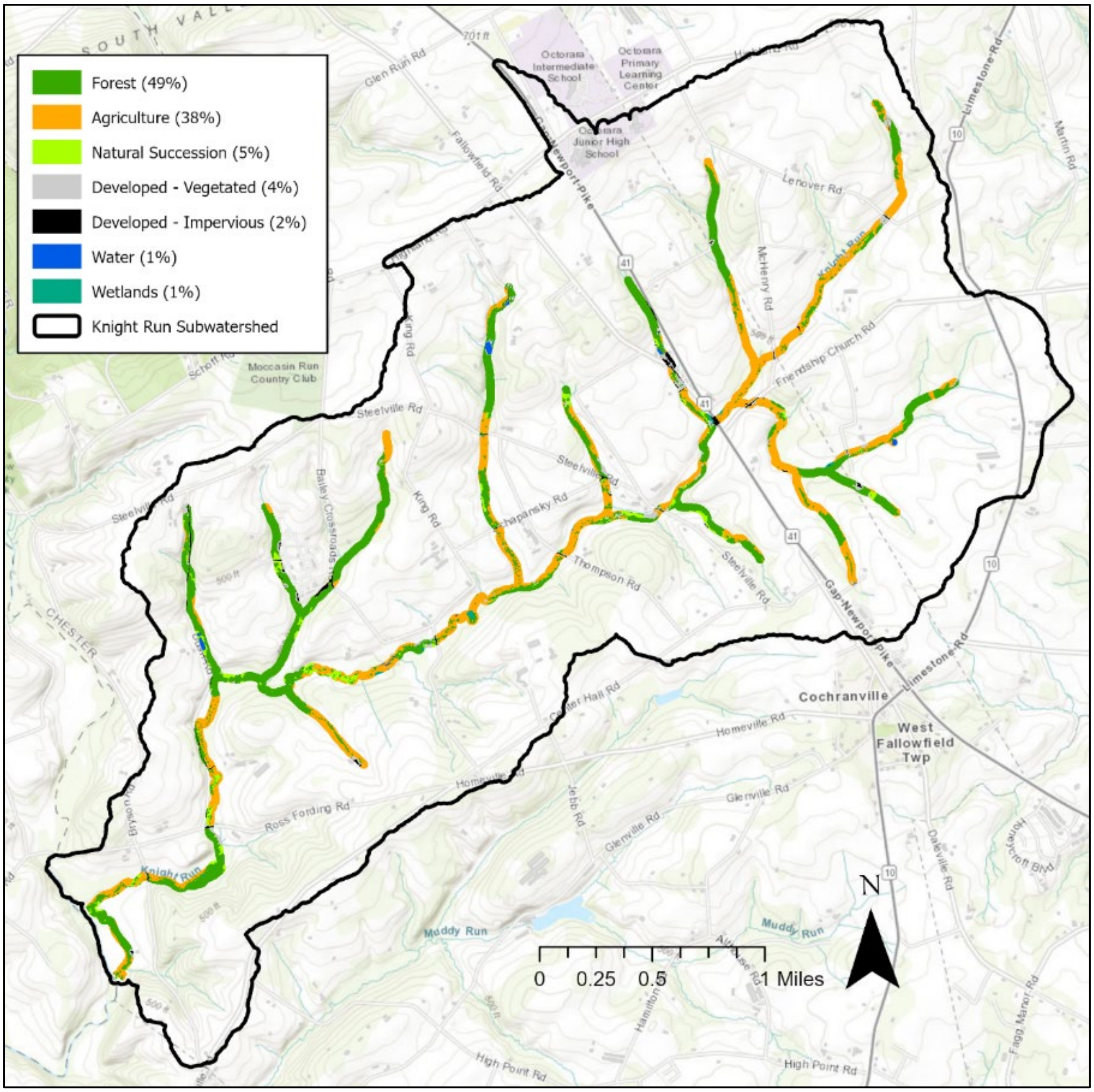


Figure 17. Land cover in the 100-foot buffer around each side of streams in 2021/2022 from the [Chesapeake Bay Land Use and Land Cover Database (2024 Edition)](#).

7.2.2 Agricultural Erosion and Sediment Control Plans

An Erosion and Sediment Control Plan is a written document that is developed and implemented for any earth disturbance activity to protect land and water resources against accelerated erosion and sediment transport with BMPs. In Pennsylvania, agricultural plowing or tilling activities (including no-till) and animal heavy use areas are required to develop an Agricultural Erosion and Sediment Control Plan. The PADEP Agriculture Erosion and Sediment Control webpage contains resources for writing and implementing Agricultural Erosion and Sediment Control Plans, including a manual and fillable template.

Agricultural Erosion and Sediment Control Plans are used to treat cropland, pasture, and hay fields in the BMP scenarios developed for this ARP. The pollutant reduction efficiencies and costs were set to CAST values for the CAST Soil Conservation and Water Quality Plans BMP. The reduction efficiencies and costs account for practices that benefit water quality through Agricultural Erosion and Sediment Control Plan implementation which are not already accounted for in other modeled BMPs, such as conservation tillage or pasture management.

7.2.3 Conservation Tillage

Conservation tillage includes any practices that reduce soil disturbance and exposure of bare soils on cropland as part of planting or harvest activities. Under a conventional tillage routine, soils are intensively tilled before planting or after harvest, resulting in very little remaining crop residue on the land surface and significant exposed soil. Conservation tillage aims to prepare soils in a manner that reduces soil disturbance and maintain a higher level of crop residue. Conservation tillage can improve soil health and crop yields while reducing erosion and nutrient loading.

Conservation tillage is used to treat cropland in the BMP scenarios developed for this ARP. Pollutant reduction efficiencies and costs for conservation tillage were derived from values in CAST as part of SAM Tool development (Attachment 1). CAST includes distinct reduction efficiencies and costs for three different subcategories of tillage practices: low residue tillage (15%-29% crop residue maintained after planting); conservation tillage (30%-59% crop residue maintained after planting); and high residue tillage (at least 60% crop residue maintained after planting). A weighted average of CAST reduction efficiencies and costs for the three tillage subcategories was calculated and entered in the SAM Tool, with subcategories weighted according to historical levels of implementation in the Octoraro Watershed from CAST BMP tracking data. The pollutant reduction efficiencies in the SAM Tool most closely align with the high residue tillage routine (at least 60% of crop residue remaining).

Opportunities for increased adoption of conservation tillage in Knight Run are evident in crop residue data generated through visual surveys of agricultural fields across the Chesapeake Bay Basin as part of bay restoration efforts. During the surveys, field staff drive specified road routes through counties at the time of crop planting to observe and record crop field conditions such as the presence or absence of crops, crop type grown, whether cover crops were used, and crop residue levels. Data for counties in the upper Octoraro Watershed (Chester County and Lancaster County) are displayed in Figure 18[6]. The use of conventional tillage versus conservation tillage varies from year-to-year and no clear trend is evident. Variation is likely due to year-to-year differences in crops planted and farm operations. As noted above, the pollutant reduction efficiencies for conservation tillage in the BMP scenarios developed for this ARP most closely align with the high residue tillage routine (at least 60% of crop residue remaining). The survey data in Figure 18 indicate that on average high residue tillage is used on only 21% of fields in the upper Octoraro Watershed, suggesting there is potential to significantly increase high residue tillage adoption in Knight Run.

[6] Only Lancaster County was surveyed in 2016 and 2020. Data from these years is still assumed to be representative of upper Octoraro Watershed tillage practices. The multi-year average proportion of each tillage class does not change significantly if 2016 and 2020 data are excluded from average calculations.

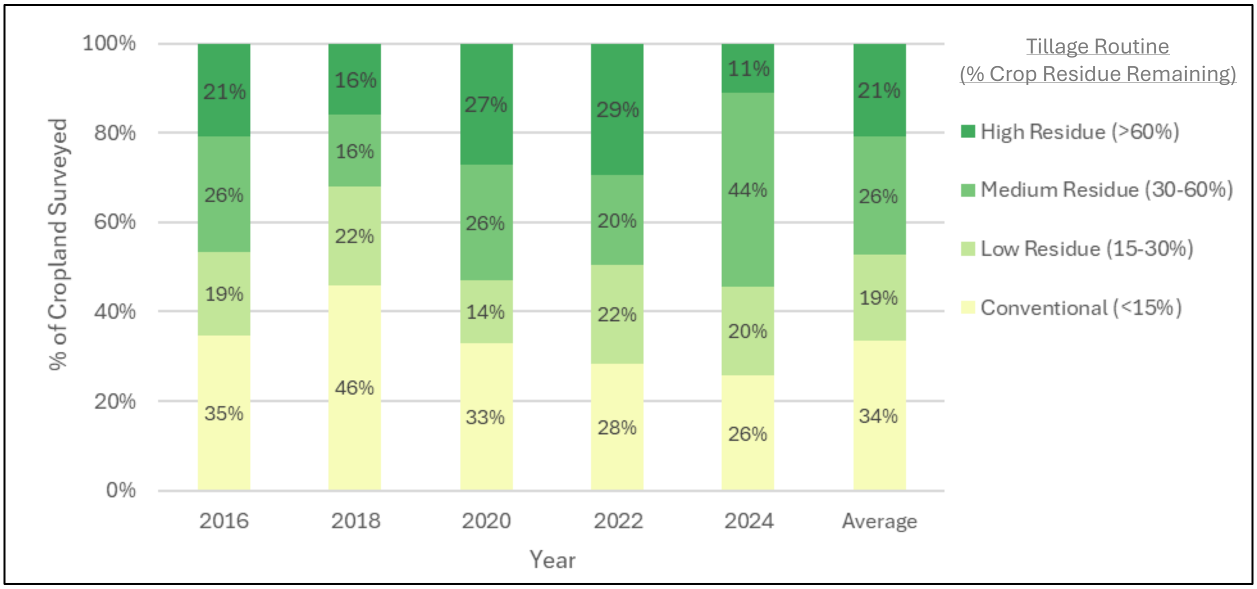


Figure 18. Summary of tillage survey data for Chester County and Lancaster County provided by PADEP. Only Lancaster County was sampled in 2016 and 2020. Sample sizes ranged from 66 observations in 2020 to 137 observations in 2022.

7.2.4 Nutrient Management

Nutrient management is the strategic application of nitrogen and phosphorus to agricultural lands to optimize crop growth and environmental health. Nutrient management involves:

- Assessing existing soil nutrient levels and crop-specific needs at the field level;
- Identifying the best-fit nutrient source for a given application need (for example, synthetic fertilizer, livestock manure, or organic-by-products);
- Planning optimal nutrient application rates, timing, and placement;
- Executing nutrient applications according to plan by using proper equipment and operations; and
- Tracking nutrient applications and other management activities over time.

Nutrient management treats pollutant loads from cropland, pasture, and hay fields in the BMP scenarios developed for this ARP. The pollutant reduction efficiencies and costs were calculated as part of SAM Tool development and are based on values from CAST. However, CAST includes multiple subcategories of nutrient management practices, each with distinct water quality benefits and costs that also vary by crop type treated. Subcategories of nutrient management include: (a) core practices that are assumed to be implemented on any lands with nutrient management; and (b) supplemental practices that further benefit water quality (CBP 2022). For the SAM Tool, a single set of reduction efficiencies and costs were assumed for nutrient management which reflect a blend of CAST values, based on typical crops grown and historical levels of nutrient management subcategory implementation in the Octoraro Watershed in CAST tracking data.

7.2.5 Pasture Management

Pasture management refers to techniques to strategically manage livestock grazing on pasture lands to reduce overgrazing and associated loss of vegetative cover, soil erosion, and nutrient runoff. It is also referred to as rotational or prescribed grazing. Under pasture management, livestock are systematically moved to fresh pasture while other areas are rested. When effectively implemented, pasture management can increase pasture yields and support healthier livestock while also providing water quality benefits.

Pollutant reduction efficiencies and costs for pasture management in the BMP scenarios developed for this ARP were set to CAST values for the CAST Precision Intensive Rotational/Prescribed Grazing BMP. The reduction efficiencies assume that lands with pasture management are outside of the stream corridor (at least 35 feet from the top of a stream bank) and are maintained to have vegetative cover of 60% or greater.

7.2.6 Wetland Restoration

Wetlands contribute to improved water quality by filtering and treating surface runoff and groundwater from upland areas. As water flows through a wetland, several physical, chemical, and biological processes can occur that reduce pollutant levels. These include physical settling, adsorption to soil particles, and plant uptake. Wetlands also promote the removal of nitrogen from the landscape through denitrification. Denitrification is the conversion of some nitrogen compounds (including nitrate and nitrite) to nitrogen gas. Under the anoxic or anaerobic conditions that develop when wetland soils are saturated with water, certain bacteria naturally present in the environment perform denitrification.

Wetland restoration is the manipulation of a former wetland site to restore natural hydrologic conditions, vegetation, and water quality functions. In the BMP scenarios developed for this ARP, restored wetlands treat pollutant loads from cropland, pasture, and hay fields. Pollutant reduction efficiencies and costs were set to values in CAST for the CAST headwater wetland restoration BMP. Similar to buffers, reduction efficiencies and costs assume that restored wetlands are installed on existing cropland, pasture, or hay fields. Pollutant reduction is therefore achieved by converting agricultural land to a wetland and treatment of runoff from upland cropland, pasture, or hay fields that drain to the restored wetland.

7.2.7 Agricultural Stormwater Management

Agricultural stormwater management refers to the design and construction of stormwater infrastructure to treat stormwater generated from confined animal production areas (e.g., from livestock structures or paved areas). Example stormwater infrastructure could include detention ponds, constructed wetlands, rain gardens, or vegetated swales. These and other practices capture stormwater and reduce pollutant levels through processes such as physical settling, infiltration into the subsurface, and vegetation uptake.

In the BMP scenarios developed for this ARP, pollutant reduction efficiencies and costs for agricultural stormwater management are set to values from CAST. The CAST reduction efficiencies and costs assume that agricultural stormwater management practices are designed and constructed according to engineering criteria and specifications outlined in state urban stormwater design manuals.

Note that the Octoraro Watershed Model and SAM Tool do not explicitly simulate pollutant loading from confined animal production areas. Therefore, agricultural stormwater management treats pollutant loads from pasture in the SAM Tool. However, the SAM Tool assumes that pasture lands that are treated with agricultural stormwater management have elevated pre-treatment pollutant loads compared to other pasture areas. The SAM Tool applies pollutant loading multipliers to pasture lands with agricultural stormwater management to calculate the pre-treatment loads before applying pollutant reduction efficiencies.

7.2.8 Feeding Space Management

Feeding space management refers to any practices that prevent stormwater or other runoff from entering barnyard areas where livestock are held or confined, and practices that prevent runoff from leaving the barnyard. For example, this could include diverting stormwater generated on roofs or impervious areas away from a barnyard. Unlike agricultural stormwater management, feeding space management focuses on preventing water from entering or leaving a barnyard, it does not involve the treatment of runoff using stormwater infrastructure.

In the BMP scenarios developed for this ARP, pollutant reduction efficiencies and costs for feeding space management are set to CAST values for the CAST Barnyard Runoff Control BMP. The CAST reduction efficiencies and costs assume that feeding space management practices are designed and constructed according to applicable state or federal standards (if practices are funded through state or federal programs), or otherwise meet criteria for barnyard clean water diversion defined in the *Chesapeake Bay Program Resource Improvement Practice Definitions and Verification Visual Indicators Report* (CBP 2014).

Because the Octoraro Watershed Model and SAM Tool do not explicitly simulate pollutant loading from barnyards, feeding space management treats pollutant loads from pasture in the SAM Tool. Similar to agricultural stormwater management, the SAM Tool assumes that pasture lands that are treated with feeding space management have elevated pre-treatment pollutant loads compared to other pasture areas. Pollutant loading multipliers are applied to pasture lands with feeding space management to calculate elevated pre-treatment loads before applying pollutant reduction efficiencies.

7.3 Potential Priority Areas for BMP Implementation

This section contains maps of potential locations in the Knight Run subwatershed for prioritizing BMP implementation. The maps are intended to provide a starting point for identifying critical areas for BMPs as stakeholders begin to implement this ARP.

The maps in this section include a layer that divides the Knight Run subwatershed into four smaller drainage units called planning catchments. The proposed planning catchments are displayed in Figure 19 and were developed to support ARP implementation. Alternately, the NHDPlus catchments could be used which would break the watershed into nine smaller drainage units or drainage units may be delineated based on selected monitoring locations. The implementation strategy for this ARP (Section 8) suggests organizing landowner outreach and BMP implementation around catchments, with activities focused on one catchment at a time. The planning catchments in Figure 19 are provided as suggestions only, other delineations may be used instead during ARP implementation. Detailed discussion of ARP implementation is provided in Section 8.

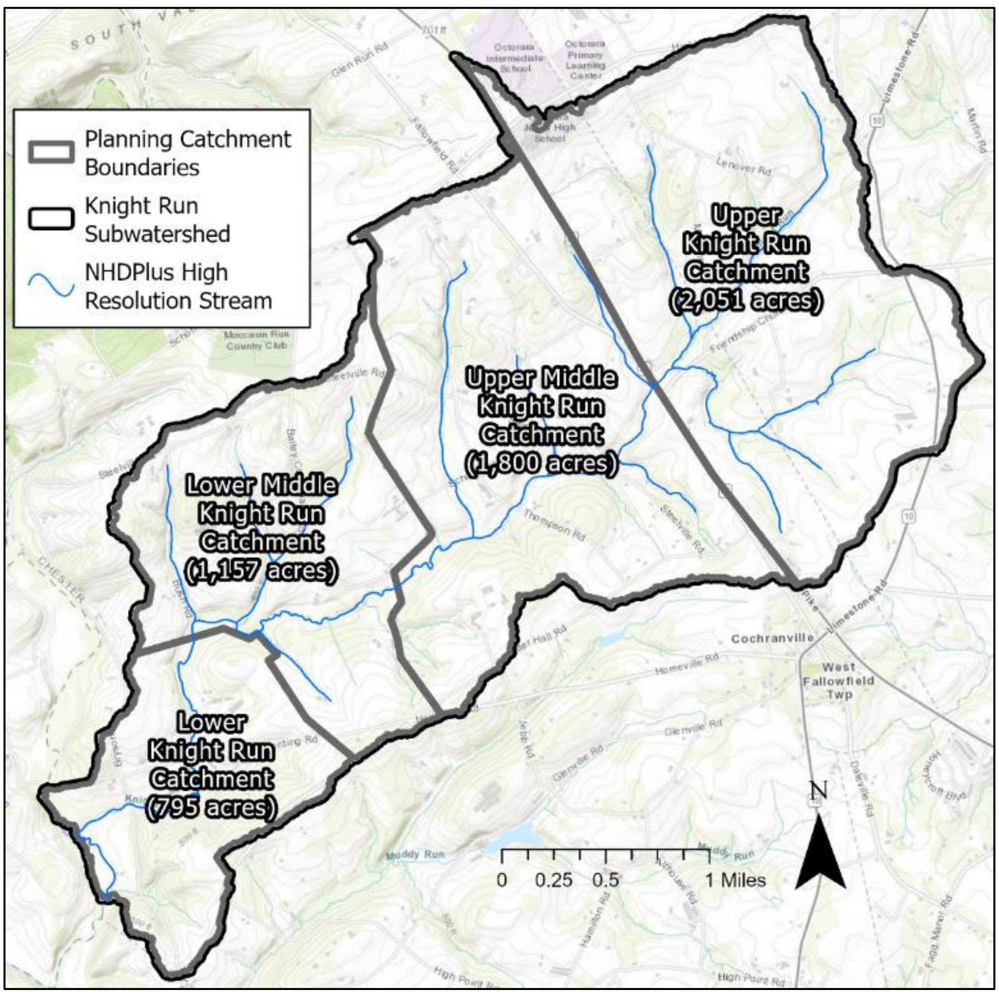


Figure 19. Planning catchments for the Knight Run subwatershed. Planning catchments divide the subwatershed into four smaller drainage units and were developed to support implementation of this ARP. Planning catchments are included in maps of potential BMP locations throughout this section.

7.3.1 Potential Priority Areas for Forest and Grass Buffers

Figure 20 displays potential locations in the Knight Run subwatershed where forest and grass buffer implementation could be prioritized. Potential areas for forest buffers are located along stream corridors that lack dense forest cover. Potential grass buffers are located along concentrated flowpaths (small ephemeral channels or gullies where water accumulates before flowing into larger streams) on agricultural fields.

Studies of forest buffers along streams have found that their ability to reduce pollutant loads can be limited when concentrated flowpaths are present in adjacent uplands and in the stream corridor (Wallace et al. 2018). In these cases, polluted runoff from upland areas 'short-circuits' the forest buffer, moving quickly through concentrated flowpaths into streams with little filtering. Implementing grass buffers along concentrated flowpaths on agricultural lands can provide additional filtering and reduce flow velocity before runoff reaches a forest buffer, so that remaining pollutants that enter the forest buffer can be more effectively filtered (Knight et al. 2009). Installing and maintaining both types of buffers in areas displayed in Figure 20 (or alternative areas identified during ARP implementation) can support improved water quality, with forest and grass buffers working in tandem to reduce agricultural sediment and nutrient loading.

The following paragraphs describe methods applied to identify potential buffer locations in Knight Run.

<u>Forest Buffer Delineation Methods</u>

Potential forest buffer locations were identified by: delineating a 100-foot wide corridor on each side of stream segments in the NHDPlus High Resolution hydrography dataset published by the U.S. Geologic Survey (USGS); visually reviewing aerial imagery and 2021/2022 land cover data from the Chesapeake Bay Land Use and Land Cover Database (2024 Edition) in the stream corridor; and sectioning the corridor into high, moderate, or low priority areas for forest buffers based on the extent of forest cover. High priority sections had little to no existing forest cover; moderate priority sections had some forest cover, but increased tree density could potentially benefit water quality; low priority sections already had forest cover across all or most of the corridor.

<u>Grass Buffer Delineation Methods</u>

Potential grass buffer locations were identified by first delineating concentrated flowpaths in the Knight Run subwatershed using a high-resolution Digital Elevation Model (DEM) map layer generated by the Chesapeake Conservancy as part of land cover mapping. The DEM map layer reports the elevation of every 1-meter by 1-meter grid cell in the dataset. Geoprocessing tools in ArcGIS Pro software were applied to analyze the DEM to identify concentrated flowpaths. A minimum flowpath drainage area of four acres was used for the analysis. Smaller drainage area thresholds resulted in flowpaths that were too detailed for the scope of the analysis, while larger thresholds produced flowpaths that were too coarse.

After mapping the concentrated flowpaths, potential grass buffer locations were identified by: delineating a 17.5-foot-wide corridor on each side of the flowpaths (35-foot total buffer width); visually reviewing aerial imagery and the 2022 Chesapeake Bay Land Use and Land Cover Database in the flowpath corridor; and sectioning the flowpaths into high, moderate, or low potential for grass buffers based on land cover and flowpath length. High priority sections were located on agricultural lands and were generally at least 500 feet long; moderate priority sections had shorter lengths but were still located on agricultural lands; low priority sections were located on non-agricultural lands or had very short lengths.

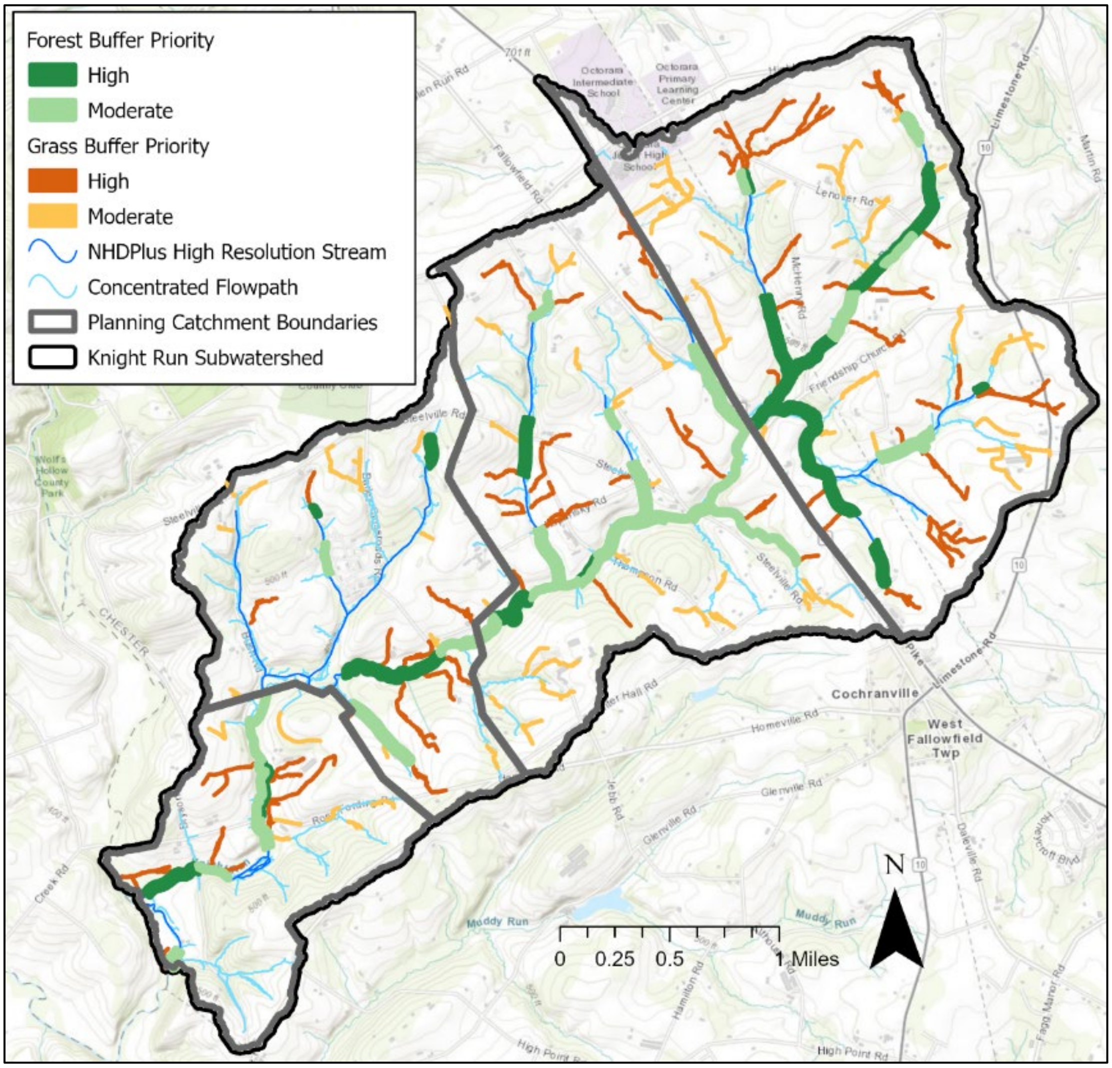


Figure 20. Potential locations for prioritizing forest and grass buffer installation. Forest buffers are proposed along the corridor of stream segments in the NHDPlus High Resolution dataset that lack dense forest cover. Grass buffers are proposed along concentrated flowpaths located on agricultural lands.

7.3.2 Potential Priority Areas for Wetland Restoration

Figure 21 displays areas in the Knight Run subwatershed that have been identified as suitable for wetland restoration by the EPA Watershed Resources Registry for Pennsylvania. The Watershed Resources Registry consists of a series of map layers that depict potential areas for restoring and protecting riparian buffers, wetlands, and other natural areas that provide treatment of polluted runoff. The map layers were developed through a collaborative process that included input from stakeholders such as the EPA, PADEP, the U.S. Army Corps of Engineers, Pennsylvania Department of Conservation and Natural Resources, Pennsylvania Department of Transportation, and the U.S. Fish and Wildlife Service. Areas suitable for wetland restoration were determined from soils data that indicated the presence of poorly drained or very poorly drained soils. Suitable areas were then assigned scores based on several factors associated with the need for wetland restoration and potential benefits that wetland restoration would provide.

Suitable areas with high scores in Figure 21 could be prioritized for site-specific investigations of the potential to restore wetlands that will capture and treat runoff from adjacent agricultural lands.

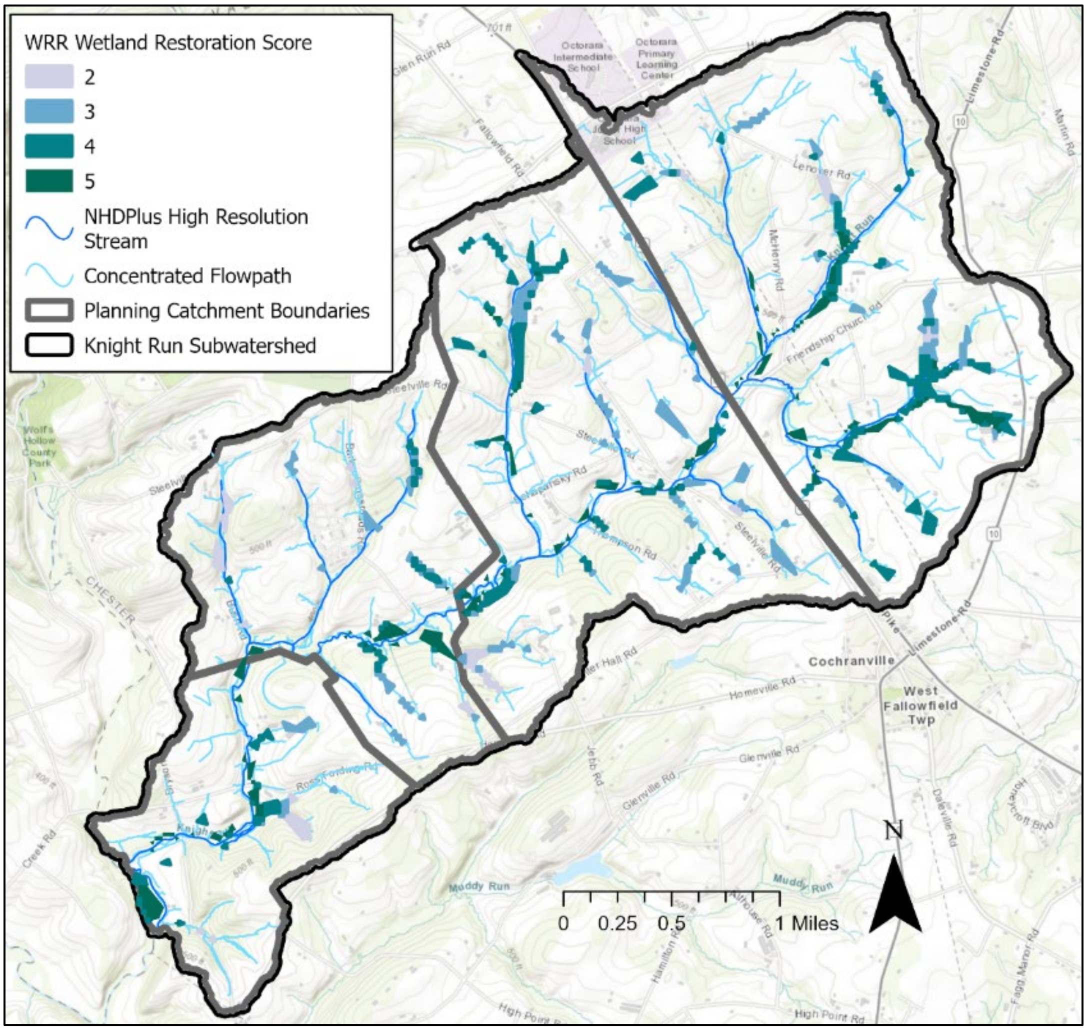


Figure 21. Suitable areas for wetland restoration in the Knight Run subwatershed and suitability scores from the [EPA Watershed Resources Registry (WRR) for Pennsylvania](#).

7.3.3 Potential Priority Areas for Other BMPs

Figure 22 displays potential areas for prioritizing implementation of the remaining BMPs described in this ARP (e.g., Agricultural Erosion and Sediment Control Plans and conservation tillage). For these BMPs, implementation could focus on agricultural lands within the Priority Drainage Areas shown in Figure 22. The Priority Drainage Areas represent lands that may be contributing relatively high sediment and nutrient loads to Knight Run because of a lack of forest buffers or due to the presence of concentrated flowpaths. BMP implementation in the Priority Drainage Areas could be more effective at improving water quality conditions in Knight Run compared to other areas.

The Priority Drainage Areas in Figure 22 consist of: (1) direct drainage areas of stream segments that are designated as a high priority for forest buffer implementation; and (2) areas draining to concentrated flowpaths that are designated as a high priority for grass buffer implementation. Priority Drainage Areas were delineated with geoprocessing tools in ArcGIS Pro software from the same high-resolution DEM map layer that was used to delineate concentrated flowpaths (see Section 7.3.1). After identifying high priority locations for forest and grass buffers (also described in Section 7.3.1), a map layer of outlet points for Priority Drainage Areas (i.e., 'pourpoints') was created by manually setting outlet points at locations along streams and flowpaths. The outlet points were positioned to capture drainage areas for high priority forest and grass buffer locations. The ArcGIS Pro Watershed Tool was then run to delineate the drainage area upstream of each outlet point to create the Priority Drainage Area boundaries.

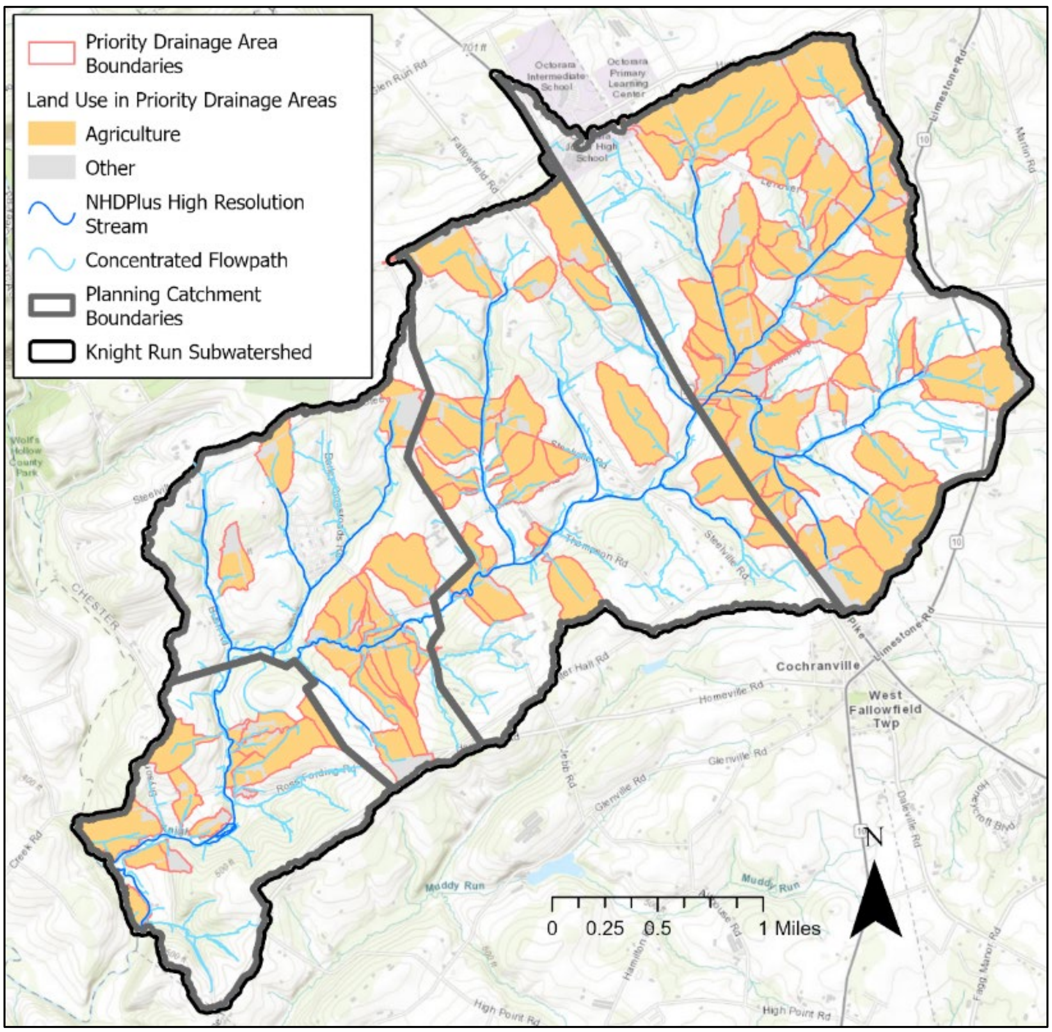


Figure 22. Potential priority areas for implementing Agricultural Erosion and Sediment Control Plans, conservation tillage, nutrient management, pasture management, agricultural stormwater management, and feeding space management.

8 ARP Implementation Strategy

8.1 Overview

This section describes a strategy for implementing this ARP. It presents key information for turning the plan into action. The implementation strategy was designed to achieve local water quality goals for Knight Run described in Section 5.1. Achieving local water quality goals will reduce pollutant loads exported downstream and therefore also make progress toward achieving the downstream goals in Section 5.1.

This ARP implementation strategy was modeled after the Chesapeake Conservancy Rapid Stream Delisting Strategy (the "RSD" Strategy), which has a goal of restoring streams within a timeframe of approximately 10 years. The RSD Strategy targets streams impaired by agricultural nonpoint source pollution for accelerated BMP implementation and monitoring. The program targets efforts in small areas called catchments (typically 1,000 to 2,000 acres in size). It focuses on catchments where landowner interest in installing BMPs is expected to be high and where water quality indicators are relatively close to achieving goals. This ARP builds off this approach by utilizing the same partnership coordination structure and applies a catchment targeted approach to address the subwatershed as a whole. Partners involved in BMP implementation may target one catchment at a time, starting with headwater catchment and moving downstream. One or more monitoring sites are also established in each catchment, so that data are available to evaluate and track the effects of local implementation efforts on water quality.

Concentrating BMP implementation efforts within a single catchment at a time and prioritizing headwater catchments have several benefits. Working in a single catchment focuses limited resources by reducing the number of property owners to engage for outreach and implementation. Headwater segments also generally have greater potential for short-term water quality improvement and impairment delisting compared to streams with larger, more complex drainage areas. Success in headwaters can also galvanize stakeholders and promote successful restoration downstream. If a headwater catchment is successfully restored, downstream catchments may then have greater potential for improvement.

At the time this ARP was developed, there were several catchments within the Octoraro Creek Watershed where the RSD Strategy was already being implemented. For example, the approach was already being implemented in the headwaters of Nickel Mines Run, another impaired subwatershed upstream of Octoraro Reservoir targeted for ARP development. Because some partners participating in the Nickel Mines Run effort are also active in Knight Run restoration efforts, institutional knowledge from the Nickel Mines Run effort can help inform and guide implementation of this ARP. Using an established approach familiar to local organizations will also help ensure that partners 'hit the ground running'.

An overview of the implementation process for this ARP is shown in Figure 23. Key elements of the process are described below.

- **Participants and Roles**. Implementation will be carried out by an ARP Implementation Coordinator and partners (the 'Implementation Team'). Section 8.2 contains a description of team members and roles.

- **Phase I Tasks**. In Phase I of the process completed during the first year, the Implementation Team will identify and map priority areas for BMP implementation, divide Knight Run into catchments, assign priority rankings to catchments, establish monitoring sites in each catchment, and begin monitoring.

  Section 7.3 of this report contains maps of potential priority areas for BMP implementation and potential catchment delineations for Knight Run. These maps could be used directly for Phase I of ARP implementation or refined by the Implementation Team to reflect additional local knowledge.

- **Phase II Tasks**. In Phase II of the process, the Implementation Team will focus landowner outreach and BMP implementation activities within one catchment at a time, starting with the highest priority catchment identified in Phase I. For each catchment, the Implementation Team will identify priority parcels, and further direct landowner outreach and BMP implementation activities toward those parcels. Routine monitoring will continue in all catchments.
- **Progress Tracking**. To help organize on-the-ground activities and track progress, the ARP Implementation Coordinator will maintain a parcel inventory spreadsheet. The spreadsheet will contain key information for land parcels in each catchment, including landowner contacts, acres of BMP priority areas in the parcel, and BMPs implemented in the parcel. Chester County maintains an online mapping tool with parcel data and offers a parcel map layer for download. Parcel inventories already maintained by Chesapeake Conservancy for RSD Strategy catchments can serve as templates for tracking implementation in Knight Run.
- **Progress Reporting**. The ARP Implementation Coordinator will report ARP implementation progress to OSWC on an annual basis. Annual reporting will include a summary of tracking data from the parcel inventory spreadsheet. The SAM Tool can support progress reporting by simulating BMPs implemented since the start of ARP implementation to quantify modeled pollutant load reductions and associated instream water quality improvements. As water quality monitoring data becomes available, water quality patterns will also be reported based on analysis completed by PADEP or other partners with monitoring expertise to evaluate whether water quality is improving and if local water quality goals defined in Section 5.1 have been achieved.
- **Adaptive Management**. The implementation strategy will be refined over time. For example, landowner outreach or property visits may reveal additional priority parcels for BMP implementation that were not identified during the first step of Phase II. If this occurs, these additional priority parcels could be added to the parcel inventory. Annual progress evaluations may also uncover the need to revise or refine implementation approaches. For example, progress evaluations may point to the need for additional or alternative landowner outreach methods or highlight specific BMPs that are effective and popular with landowners which could be targeted for enhanced implementation. This ARP should be reviewed and updated periodically based on the progress evaluations to adapt to changes in the BMPs selected and changes in pollutant sources.

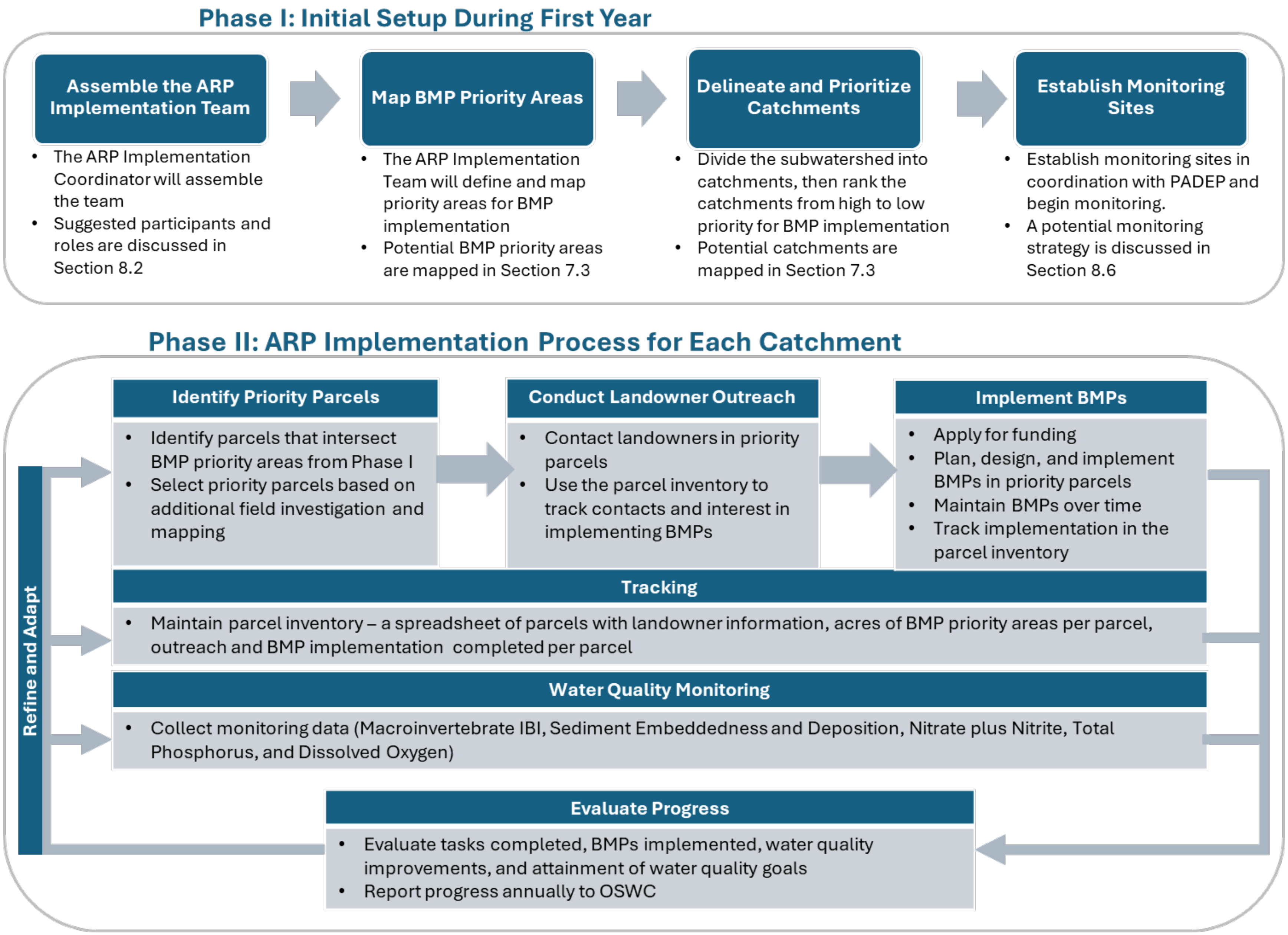


Figure 23. Overview of the ARP implementation process for Knight Run.

8.2 Tasks, Roles, and Responsibilities

ARP implementation tasks and responsible parties are summarized in Table 15. A key role is the ARP Implementation Coordinator. As shown in Table 15, the Octoraro Watershed Restoration Coordinator within the Chester County Conservation District is anticipated to serve as the ARP Implementation Coordinator. In this role, they will guide and track ARP implementation by the various partners. Partners will include local technical providers that work with landowners to plan, design, and install BMPs, and other stakeholders. The ARP Implementation Coordinator and partners will work together to carry out the process and tasks described in Figure 23 and Table 15.

Technical providers that will likely be involved with Knight Run ARP implementation are those already part of the Octoraro Source Water Collaborative (OSWC). These partners may include the Chester County Conservation District, Alliance for the Chesapeake Bay, USDA NRCS, Stroud Water Research Center, Team Ag, Mowery Environmental LLC, and Weaver Environmental Consulting, among others. Other stakeholders expected to be involved include the Chester Water Authority, Chester County Water Resources Authority, the OSWC monitoring and agricultural workgroups, Octoraro Watershed Association, PADEP, and EPA Region 3. This is not an exhaustive list of potential partners, and partner involvement may change over time.

The ARP Implementation Coordinator and technical providers are assigned key tasks related to planning, documenting, and tracking BMP implementation (Table 15). The ARP Implementation Coordinator will maintain a parcel inventory spreadsheet that documents acres of BMP priority areas for each priority parcel by catchment. Technical providers will target priority parcels for outreach and implementation. For each priority parcel, technical providers will determine what BMPs are best-suited using maps of BMP priority areas, technical provider expertise, on-the-ground information, and landowner input.

Consistent with the RSD Strategy process, technical providers will assess and determine when BMP implementation is complete within each parcel. Technical providers may rate implementation as complete when all targeted BMPs have been implemented in the parcel, or if all possible BMP implementation is complete within voluntary landowner participation constraints. Technical providers will periodically report the percentage of BMP implementation that is complete in the parcel, the types of BMPs implemented, and the acres treated by the BMP type to the ARP Implementation Coordinator, who will record this information in the parcel inventory. The ARP Implementation Coordinator will compile parcel-level tracking information to summarize BMP implementation progress at the catchment scale to the ARP Implementation Team and OSWC on an annual basis.

The roles and responsibilities in Table 15 are suggestions based on the RSD Strategy approach and stakeholder input. These are not requirements and may change as ARP implementation proceeds. The specific personnel working on each task will ultimately depend on staffing availability and may be affected by changing resources, funding, and organizational strategies. The ARP Implementation Coordinator is responsible for coordinating with partners to identify personnel who can serve as responsible parties for each task if personnel availability changes or tasks evolve over time.

Table 15. Suggested tasks and responsible parties for ARP implementation.

Task	Task Description	Responsible Parties
Coordinate ARP Implementation	The ARP Implementation Coordinator will guide and track ARP implementation, including organizing and leading meetings, recruiting partners, and identifying resources needed. They will also be responsible for tracking and reporting ARP progress. The Octoraro Watershed Restoration Coordinator within the Chester County Conservation District is anticipated to serve in this role.	ARP Implementation Coordinator
Map BMP Priority Areas	Use land cover data, aerial imagery, and local knowledge to identify areas to target for BMP implementation. Maps of potential BMP locations in Section 7.3 can be a starting point and refined as needed based on local knowledge and property visits.	ARP Implementation Coordinator, Technical Providers
Delineate & Prioritize Catchments	Divide the Knight Run subwatershed into smaller catchments. Planning catchments in Figure 19 can be used as a starting point. Then, rank catchments from high to low priority and begin implementation in the highest ranked catchment.	ARP Implementation Coordinator, Technical Providers
Identify Priority Parcels	Select parcels for prioritizing landowner outreach and BMP implementation. Parcels that overlap BMP priority areas can be initial candidates, with priorities refined based on additional field investigation and mapping.	ARP Implementation Coordinator & Technical Providers
Maintain a Parcel Inventory	Maintain a spreadsheet of land parcels. For each parcel, document landowner information, acres of BMP priority areas, and BMP needs.	ARP Implementation Coordinator
Conduct Landowner Outreach	Contact priority parcel landowners to educate them about water quality issues and assess their interest in voluntary BMP implementation. Record contacts and interest in the parcel inventory.	Technical Providers
Implement BMPs	For parcels with willing landowners, plan and design BMPs, apply for funding, and implement BMPs in cooperation with the landowner. Ensure BMPs are maintained over time to sustain performance.	Technical Providers
Track BMP Implementation	In the parcel inventory, record completed BMP implementation activities by parcel. For example, the types of BMPs implemented, acres treated by the BMP type, and approximate percent of BMP implementation completed. When sharing this information, respect landowner privacy as required by funding sources or landowner requests.	ARP Implementation Coordinator, Technical Providers
Conduct Water Quality Monitoring	Establish monitoring sites in each catchment in coordination with PADEP. Monitoring sites should be established in all catchments and near the subwatershed outlet. Monitoring should begin as soon as possible to collect baseline data. As needed, educate partners on water quality monitoring and data analysis protocols.	ARP Implementation Coordinator, OSWC Monitoring Workgroup, PADEP
Assess Water Quality Conditions	Partners with water quality monitoring expertise will periodically assess if local water quality indicators show improvement and achieve benchmarks listed in Section 8.6. PADEP will make final determinations of water quality standards attainment.	PADEP, OSWC Monitoring Workgroup
Conduct Education Campaign	Educate landowners and technical providers about local water quality issues and benefits of BMP implementation. Examples include distributing flyers included in Attachment 2 and organizing BMP demonstration tours or other events.	ARP Implementation Coordinator, OSWC, Technical Providers
Evaluate and Document Progress	Communicate ARP implementation progress to the OSWC annually. Summarize progress using the evaluation methods and criteria described in Section 8.5. Also report progress to funding sources and other entities as required. Findings from progress evaluations should be used to revise and refine ARP implementation over time.	ARP Implementation Coordinator

8.3 Schedule and Milestones

The proposed schedule and milestones for implementing this ARP are presented in Table 16. The schedule was designed around the two-phase process shown in Figure 23, beginning with a one-year period for completing Phase I. The remainder of Table 16 assumes the planning catchments shown in Figure 19 will be used for implementation, starting with Upper Knight Run. If different catchment delineations are used, or if a different planning catchment is selected as the top priority, then the Implementation Team should update the schedule and milestones.

The schedule targets completing BMP implementation in each catchment within five years of starting catchment-specific activities. The ARP Implementation Coordinator and technical providers will determine when BMP implementation is considered complete for individual parcels and catchments. In general, implementation could be considered complete in a catchment if appropriate BMPs have been installed or adopted in all priority parcels, or if all possible implementation has occurred within landowner participation constraints.

Local water quality goals in each catchment are targeted to be achieved within eight years of starting catchment-specific outreach and implementation. A lag between completing BMP implementation and achieving local water quality goals is built into the schedule because of environmental factors (for example, recovery time of biological communities) and to provide time for analysis of post-implementation monitoring data. Final determinations of water quality standards attainment and impairment delistings will be made by PADEP. However, interim analysis can be completed by partners with appropriate expertise to assess if water quality is improving. The Implementation Team can use PADEP assessments and interim analysis to determine if local water quality goals are achieved within a catchment. If local water quality goals are not achieved, then adaptive management can be applied to refine the implementation approach.

The schedule assumes the ARP Implementation Team will apply for funding as they work in each catchment. PADEP's Section 319 Nonpoint Source program prioritizes projects designed to achieve water quality standards within five to ten years (PADEP 2025b). Developing funding applications for each catchment individually will align the planned timeline for achieving water quality goals in the catchment with Section 319 priorities and help ensure the projects listed in funding applications are 'shovel ready'. It also enables partners to showcase success stories and lessons learned from the initial catchment to create more competitive funding applications for subsequent catchments.

The schedule and milestones in Table 16 are not requirements. Actual progress may be faster or slower depending on staffing, funding, landowner participation, and environmental factors affecting BMP performance and stream response. Often, landowner participation is limited initially but increases after successful demonstration projects. Further, while the schedule indicates activities should be completed separately by catchment, the ARP Implementation Team can be flexible and work across multiple catchments if certain tasks are more efficient to complete over larger areas or if high-quality BMP opportunities arise in lower priority catchments. In combination with methods and criteria for evaluating progress (Section 8.5), the schedule and milestones offer a reference for the ARP Implementation Team to determine if the pace of ARP implementation is adequate, or if adjustments are needed.

Table 16. ARP implementation schedule and milestones. [1] Water quality indicators and evaluation benchmarks are detailed in Section 8.6.

Milestone	2026	2027	2028	2029	2030	2030	2031	2032	2033	2034	2035	2036	2037-2041
Phase I													
Initial Setup Tasks													
Assemble implementation team, map BMP priority areas, delineate and prioritize catchments, establish monitoring sites and schedule													
Phase II													
Upper Knight Run Catchment													
Identify priority parcels and outreach to landowners													
Apply for funding													
BMP implementation in priority parcels													
Upper Middle Knight Run Catchment													
Identify priority parcels and outreach to landowners													
Apply for funding													
BMP implementation in priority parcels													
Lower Middle Knight Run Catchment													
Identify priority parcels and outreach													
Apply for funding													
BMP implementation in priority parcels													
Lower Knight Run Catchment													
Identify priority parcels and outreach													
Apply for funding													
BMP implementation in priority parcels													
Water Quality Monitoring													
Upper Knight Run Catchment (sediment & phosphorus indicators)													
Upper Middle Knight Run Catchment (sed & phosphorus indicators)													
Lower Middle Knight Run Catchment (sed & phosphorus indicators)													
Lower Knight Run Catchment (sediment & phosphorus indicators)													
Evaluate IBI benchmarks (B = Baseline, I = Interim, F=Final)		B			I			I			I		F
Lower Knight Run Catchment (nitrogen indicators)													
Tracking, Evaluation, and Reporting													
Maintain parcel inventory													
Evaluate progress													
Report on progress annually to OSWC													
Review and update ARP periodically with SAM Tool													
Petition PADEP to reassess													

8.4 Education

Educating landowners, technical providers, and implementation partners is critical for successful ARP implementation. Anticipated ARP-related education efforts can be grouped into four categories:

1. **Watershed-wide education and outreach to all stakeholders and residents in the Octoraro Watershed**. The OSWC and ARP Implementation Coordinator are anticipated to participate in watershed-wide efforts to educate stakeholders and residents about the importance of water quality protection. The OSWC Strategic Plan already defines specific objectives, tasks, and milestones for educating landowners and community leaders in the Octoraro Watershed (OSWC 2022). For example, the plan includes objectives to "*engage, collaborate, or communicate with at least 100 farmers through appropriate outreach and educational events,*" "*engage community leaders from different groups and identify those willing to speak on behalf of the Octoraro Source Water Collaborative,*", and "*conduct outreach to the general public through developing materials specifically targeted towards the general public and attending and hosting community outreach events for the public*". The ARP Implementation Coordinator will collaborate with OSWC to ensure that watershed-wide education activities reach audiences in Knight Run in addition to other parts of the Octoraro Watershed.
2. **One-on-one education of landowners in the Knight Run subwatershed**. The ARP Implementation Coordinator and technical providers will conduct targeted outreach to priority parcel landowners in the Knight Run subwatershed to educate them about potential impacts of agricultural operations on water quality, specific BMPs that can be implemented on their lands to reduce pollutant loading, and potential funding sources to support BMP implementation.
3. **Knowledge sharing between OSWC members**. OSWC meetings, workgroups, and other events will provide a venue for members to learn from each other and stay informed about water quality issues in Knight Run and other parts of the Octoraro Watershed. Educating OSWC members about the Knight Run ARP will ensure they are strong advocates for ARP implementation. Knowledge sharing can also include training on monitoring data collection and analysis protocols to help build a roster of stakeholders with the right expertise to generate and analyze data to support evaluations of ARP effectiveness.
4. **Distribution of the outreach and education materials in Attachment 2**. The materials consist of a trifold designed for farmers and a fact sheet for technical providers on water quality issues in the Octoraro Watershed. The ARP Implementation Coordinator and OSWC members can distribute these materials as part of the education initiatives described above.

8.5 Evaluation Methods and Criteria

Table 17 lists proposed progress measures and associated evaluation questions to inform evaluations of ARP effectiveness. The progress measures address four topics (implementation tasks, BMP implementation, water quality improvement, and achievement of water quality goals). The evaluation questions are intended to guide decisions on whether progress is adequate for each topic.

Progress will be reported annually by the ARP Implementation Coordinator to OSWC. Reporting can answer the evaluation questions in Table 17 and discuss whether progress is adequate for each measure or if adjustments to the implementation approach are needed. The SAM Tool can also support progress reporting by simulating BMPs implemented since the start of ARP implementation to quantify modeled pollutant load reductions and associated instream water quality improvements. The purpose of Table 17 is to support a standardized approach for evaluating progress. Positive progress across all questions in Table 17 is not expected every year, especially during the initial years of ARP implementation. Measures #3-4 can only be evaluated after necessary monitoring data have been collected and analyzed. Decisions on whether progress is 'adequate' in a single year and cumulatively over time can be based on evaluation question responses along with relevant context such as landowner attitudes and participation levels, environmental events such as major floods, and changing levels of funding and staffing resources.

Table 17. Proposed progress measures and associated evaluation questions (check boxes).

Measure #1: Are ARP Implementation Tasks Moving Forward or Stalled? (Evaluate Annually)	
☐ 1.1. Did all tasks in Table 15 have activity in the last year (excluding tasks that are already complete)?	
☐ 1.2. Were tasks completed on schedule based on Table 16?	
☐ 1.3. Did any tasks not progress or progress slowly because of staffing or funding limitations, low landowner participation, implementation delays (e.g. permitting, weather, etc.), or other factors?	
Measure #2: Has BMP Implementation Increased in Priority Parcels? (Evaluate Annually)	
☐ 2.1. For each active catchment, has the total number of priority parcels with any level of BMP implementation increased?	
☐ 2.2. For each active catchment, has the number of priority parcels where BMP implementation is considered 'complete' increased?	
Measure #3: Do Water Quality Indicators Show Improvement? (Evaluate Once Data Are Available)	
For each monitoring site with available data, have there been improvements in:	
☐ 3.1. Sediment embeddedness plus deposition scores?	☐ 3.4. Dissolved oxygen saturation?
☐ 3.2. Macroinvertebrate Index of Biotic Integrity (IBI) scores[1]?	☐ 3.5. Nitrate plus nitrite concentrations?
☐ 3.3. Total phosphorus concentrations?	☐ 3.6. Nitrate plus nitrite loads?
Measure # 4: Are Local Water Quality Goals Achieved? (Evaluate Once Data Are Available)	
For each monitoring site with available data, does the most recent data achieve evaluation benchmarks:	
☐ 4.1. Does the sediment embeddedness plus deposition score achieve the PADEP benchmark for assessing water quality standards attainment (score ≤ 24)?	
☐ 4.2. Does the macroinvertebrate IBI score achieve the PADEP benchmark for assessing water quality standards attainment (score ≥ 50)?	
☐ 4.3. Do dissolved oxygen saturation measurements achieve PADEP benchmarks for assessing water quality standards attainment (see Table 6)?	
☐ 4.4. Is the maximum nitrate plus nitrite concentration below 8 mg N/L?	

[1] Shull (2017) reported that macroinvertebrate score changes greater than 10 points represent discernable changes rather than noise. This guideline can be considered when evaluating improvement over time.

8.6 Effectiveness Monitoring

Table 18 summarizes the proposed monitoring strategy designed to generate data to support evaluations of ARP effectiveness. The table includes proposed monitoring locations and timing, water quality indicators to monitor, and evaluation benchmarks. The evaluation benchmarks are threshold values of water quality indicators that align with successful achievement of local water quality goals for this ARP.

Table 18 includes two types of effectiveness monitoring: catchment-specific monitoring and monitoring near the Knight Run outlet. Monitoring conducted in each catchment will generate data to determine if the catchment is attaining benchmarks used by PADEP to assess siltation and eutrophication impairments, and for understanding interim water quality improvements. Catchment-specific monitoring may include measurement of total phosphorus concentrations, sediment embeddedness and deposition scores, and baseline/final macroinvertebrate IBI scores. Ideally, dissolved oxygen percent saturation and flow could be monitored continuously with in-situ sensor, if available.

Monitoring near the Knight Run outlet will generate data to determine if nitrogen export downstream to East Branch Octoraro Creek and Octoraro Reservoir is decreasing over time. Monitoring will include sampling of nitrate plus nitrite concentrations with paired streamflow measurements. Table 18 targets summer baseflow sampling for evaluating nitrate plus nitrite trends over time. Summer baseflow conditions can provide an understanding of nitrogen levels in water with longer residence times in the subwatershed, primarily groundwater. The presence of a decreasing trend during summer baseflow periods can be a strong indicator of ARP effectiveness. In contrast, high flow periods (e.g., during spring or following storm events) generally exhibit greater variability in water quality, making trends harder to detect and interpret.

Alternatively, the EPA, USGS, and NRCS have collaborated on a monitoring approach described on USGS's Monitoring the Effectiveness of Conservation Practices in Small Agricultural Watersheds webpage which might serve as a model, if funding is available. This approach involves installation of a stream gage at the outlet of Knight Run for continuous water level and flow data. A 'super gage' would also include continuous water quality parameters, such as turbidity, temperature, conductivity, dissolved oxygen, and nitrate measured every 15 or 30 minutes by water quality sensors. If a stream gage or super gage is installed, protocols for integrating the data into ARP effectiveness evaluations will need to be developed by the ARP Implementation Team. Methods applied by the USGS to statistically analyze changes in pollutant loads over time require at least 10 years of continuous flow data and multiple years of water quality data (Hirsch and De Cicco 2015; Oelsner et al. 2017). However, patterns observed at gage sites on shorter timescales may still be useful as one line of evidence for evaluating if water quality is improving. Gage data can also document short-term water quality responses to specific hydrologic events such as floods or drought and be a useful tool for educating landowners and technical providers about local water quality patterns.

Monitoring site selection and initial data collection should begin as soon as possible after ARP implementation starts. Where available, existing monitoring sites can be used for ARP effectiveness monitoring (see Figure 4). However, sites and monitoring strategy should be selected in coordination with OSWC monitoring workgroup (which includes EPA, PADEP, SRBC, and OWA as partners) to ensure they are representative of upstream assessment units and can be used to assess attainment of water quality standards throughout the Knight Run subwatershed. Monitoring data collected by individuals or groups may provide data to PADEP which is categorized as into three tiers (Tier 1, Tier 2, Tier 3) as described on PADEP's Existing and Readily Available Data webpage. For assessment purposes, Tier 3 data must have been collected following an approved Quality Assurance Project Plan, appropriate study designs, and PADEP water quality monitoring protocols for surface waters. Individuals seeking to provide PADEP with Tier 3 data must also be audited by PADEP staff in PADEP water quality monitoring protocols for surface waters before submitting data.

Table 18. Proposed monitoring locations, timing, indicators, and evaluation benchmarks for ARP effectiveness monitoring.

Monitoring Location(s)	Monitoring Schedule	Pollutant	Indicator(s) to Monitor	Sampling Frequency (During Active Sampling Years)	Sampling Timing	Evaluation Benchmark
One reach per catchment[1]	Rotate between catchments[2]	Sediment	Sum of Sediment Embeddedness and Deposition Score	Once per year	November - May	>24
			Macroinvertebrate Index of Biotic Integrity Score	Twice (baseline and final)		≥ 50
		Phosphorus	Total Phosphorus Concentration	Monthly	Entire calendar year	Informational only
			Dissolved Oxygen Percent Saturation	Continuous measurement with in-situ sensor		See Table 6
Knight Run near outlet at Bryson Rd Crossing[3]	Begin in year 1 of ARP implementation and continue every year	Nitrogen	Nitrate Plus Nitrite Concentration	Monthly	Summer baseflow	Declining nitrate plus nitrite load; Maximum concentration < 8 mg N/L
			Streamflow	Monthly (measured at same time as nitrate plus nitrite)		

[1] Reach selection for catchment-specific monitoring can consider active or historic monitoring locations (see Figure 4). Reaches should be selected in coordination with PADEP to ensure they are representative of upstream assessment units.

[2] The proposed schedule for catchment-specific monitoring is shown in Table 16.

[3] Location is the same as USGS-015783479 and KNGT000.7-3975 in Figure 4; historic nitrate plus nitrite monitoring data is available at this location (Figure 4).

8.7 Potential Funding Sources

Agricultural BMPs often require substantial funding to cover costs related to site-scale planning, materials, installation, and long-term maintenance. While some landowners may self-finance these projects, most rely on grants, loans, or tax credits. Technical providers typically collaborate with landowners to prepare funding applications. Because funding eligibility and application requirements can be complex and vary by funding source and BMP type, local technical providers such as conservation districts are often best positioned to identify the most suitable funding opportunity for each project.

Section 7 identifies riparian forest buffers and other types of BMPs needed to achieve load reduction targets for the Knight Run subwatershed. An inventory of conservation programs with financial incentives for installing riparian buffers is available through *A Landowner's Guide to Conservation Buffer Incentive Programs in Pennsylvania* (Talbert 2009). Other types of BMPs can be funded through various programs administered by government agencies and nonprofit organizations. Table 19 lists potential resources for funding ARP implementation activities. The table is intended as a starting point for investigating potential funding opportunities rather than an exhaustive list of all potential funding sources. Across the funding sources listed, eligibility requirements, application period, and the current availability of funds varies. Funding availability may change over time as ARP implementation proceeds. As stated above, local technical providers have expertise needed to determine the best-fit funding sources for a particular project.

This ARP was written with the goal to make BMP implementation projects in Knight Run eligible for Clean Water Act Section 319 Nonpoint Source Management grant funding. It was structured to include elements that EPA requires in Watershed Implementation Plans (WIPs) for Clean Water Act Section 319 grant funding eligibility. When allocating Section 319 grant funding, PADEP gives priority to BMP implementation needs identified in an existing WIP. PADEP also prioritizes grant funding for updates or revisions to existing WIPs that are at least eight years old (PADEP 2025b). At the time this ARP was developed, PADEP's Section 319 program did not accept new WIPs. However, when the program accepts WIPs again in the future, this ARP could be submitted to PADEP to make BMP implementation projects in the Knight Run subwatershed eligible for Section 319 funding.

Table 19. Potential resources for funding ARP implementation activities.

Organization	Resource	Description
PADEP	Section 319 Nonpoint Source Management Grants	Funding to develop and implement nonpoint source management plans. Funding must address sources of nonpoint source pollution in Pennsylvania's Nonpoint Source Management Plan.
	Growing Greener Plus Grants	Issues grants from the Environmental Stewardship Fund to help protect and restore Pennsylvania's waters from nonpoint source pollution.
	County Action Plan (CAP) Implementation Block Grant	Funds the implementation of CAPs to achieve nutrient and sediment reduction

Organization	Resource	Description
		goals established as part of Pennsylvania's Phase 3 Watershed Implementation Plan.
Pennsylvania Department of Agriculture	Agriculture Conservation Assistance Program	Provides financial and technical assistance to implement BMPs on agricultural operations.
	Resource Enhancement & Protection (REAP) Program	Enables landowners to earn state income tax credits to offset the cost of implementing conservation practices that reduce nutrient and sediment pollution.
Pennsylvania Department of Agriculture and Department of Treasury	Agriculture Linked Investment Program	Issues low-interest loans designed to help fund BMP implementation for agricultural operations.
Pennsylvania Department of Community and Economic Development	Watershed Restoration and Protection Program (WRPP)	Grants to restore and maintain stream reaches impaired by nonpoint source pollution.
PENNVEST	Financing for Agricultural Best Management Practices	Offers financing to conservation districts and landowners for installing agricultural BMPs.
PENNVEST & PADEP	Clean Water State Revolving Fund (CWSRF), Drinking Water State Revolving Fund (DWSRF)	The CWSRF provides low-interest loans to eligible for projects addressing municipal wastewater facilities, nonpoint source pollution, septic systems, stormwater runoff, green infrastructure, estuary protection, or water reuse. The DWSRF provides low-interest loans for projects addressing drinking water quality and supply.
Chesapeake Bay Program	Small Watershed Grants Program	Grants for community-based projects to improve local watershed conditions while building stewardship among residents.
	Innovative Nutrient and Sediment Reduction Grants	Grant awarded to support innovative, sustainable, and cost-effective approaches to reduce sediment and nutrient pollution within the Chesapeake Bay watershed.
Chesapeake Bay Trust	Watershed Assistance Grant Program	Grants for watershed restoration project designs and permitting, watershed planning, and programmatic development. Eligible areas for funding include the Octoraro Watershed.
Southeastern Partnership for Forests & Water	Funding resources inventory	Inventory of funding sources for source water protection, forestry initiatives, and landscape conservation.
National Fish and Wildlife Foundation	Chesapeake Watershed Investments for Landscape Defense (WILD) Grants	Grants to support efforts to conserve, steward, and enhance fish and wildlife habitats and related conservation values in the Chesapeake Bay watershed.

Organization	Resource	Description
	Pennsylvania Most Effective Basins	Grants to fund projects that accelerate implementation of cost-effective agricultural BMPs in selected basins of the Chesapeake Bay watershed of Pennsylvania.
USDA NRCS	Multiple programs, including funding for agricultural conservation and source water protection. http://www.nrcs.usda.gov/programs-initiatives	Multiple NRCS funding programs are available, including but not limited to the Environmental Quality Incentives Program (EQIP) to develop and implement farm conservation plans, and Agricultural Conservation Easement Program for protecting and restoring wetlands.
USDA Farm Service Agency	Conservation Reserve Enhancement Program (CREP)	CREP offers annual rental payments for conservation lands, cost-share assistance for establishing conservation practices, and other financial incentives for agricultural conservation.
U.S. Forest Service (USFS)	Cooperative forestry programs for private lands	USFS has multiple programs that provide funding or technical assistance for managing private forest lands.
Wright Foundation for Sustainability and Innovation	Grant programs for tree canopy improvement and regenerative agriculture	The canopy improvement program supports tree planting; the regenerative agriculture grant supports agriculture practices that address water quality.
National Oceanic and Atmospheric Administration	Chesapeake Bay – Watershed Education and Training Program grants	Grants for environmental education programs targeting students and teachers.

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Appendix A. Impaired Assessment Units: Knight Run, East Branch Octoraro Creek, and Octoraro Reservoir

Table A-1. Assessment units in Knight Run with aquatic life use impairments from the 2024 Pennsylvania Integrated Water Quality Report. This ARP only addresses the siltation impairments.

ATTAINS ID	Stream Name	Length (miles)	Assessed Use Category	Impairment Source	Impairment Cause
PA-SCR-57465945	Unnamed Tributary to Knight Run	0.03	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57465975	Knight Run	1.5	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57465977	Unnamed Tributary to Knight Run	0.98	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57466009	Unnamed Tributary to Knight Run	0.27	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57466035	Unnamed Tributary to Knight Run	0.06	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57466053	Knight Run	0.17	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57466067	Unnamed Tributary to Knight Run	0.38	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57466071	Knight Run	0.01	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57466079	Knight Run	0.01	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57466107	Knight Run	0.14	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - Other Than Hydromodification	Habitat alterations
PA-SCR-57466109	Unnamed Tributary to Knight Run	0.76	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57466175	Unnamed Tributary to Knight Run	0.32	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57466183	Unnamed Tributary to Knight Run	0.14	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57466185	Unnamed Tributary to Knight Run	0.61	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations

ATTAINS ID	Stream Name	Length (miles)	Assessed Use Category	Impairment Source	Impairment Cause
PA-SCR-57466211	Unnamed Tributary to Knight Run	0.36	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57466269	Knight Run	0.42	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57466307	Unnamed Tributary to Knight Run	0.64	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57466309	Knight Run	0.37	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57466325	Unnamed Tributary to Knight Run	0.5	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57466343	Unnamed Tributary to Knight Run	0.58	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57466521	Knight Run	0.51	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57466523	Unnamed Tributary to Knight Run	1.1	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57466545	Unnamed Tributary to Knight Run	0.21	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57466561	Unnamed Tributary to Knight Run	0.04	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57466691	Unnamed Tributary to Knight Run	0.97	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57466693	Unnamed Tributary to Knight Run	0.27	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57466787	Unnamed Tributary to Knight Run	0.61	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57466809	Unnamed Tributary to Knight Run	0.06	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57466843	Unnamed Tributary to Knight Run	0.35	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57466849	Knight Run	1.43	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57466855	Knight Run	0.2	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57466857	Unnamed Tributary to Knight Run	0.13	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57466867	Knight Run	0.16	Aquatic Life	Agriculture	Cause unknown, Siltation

ATTAINS ID	Stream Name	Length (miles)	Assessed Use Category	Impairment Source	Impairment Cause
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57466949	Unnamed Tributary to Knight Run	0.48	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57467203	Knight Run	0.95	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57467205	Knight Run	0.01	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57467255	Knight Run	0.11	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57467257	Knight Run	0.11	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57467273	Knight Run	0.06	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57467275	Knight Run	0.18	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57467451	Knight Run	0.96	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57467459	Knight Run	0.01	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations

Table A-2. Assessment units in East Branch Octoraro Creek downstream of Knight Run with aquatic life and potable water supply use impairments from the 2024 Pennsylvania Integrated Water Quality Report. This ARP only addresses the siltation and nutrients impairments.

ATTAINS ID	Stream Name	Length (miles)	Assessed Use Category	Impairment Source	Impairment Cause
PA-SCR-57467675	East Branch Octoraro Creek	0.35	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
			Potable Water Supply	Agriculture	Nutrients
PA-SCR-57467743	East Branch Octoraro Creek	1.24	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
			Potable Water Supply	Agriculture	Nutrients
PA-SCR-57467931	East Branch Octoraro Creek	0.58	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
			Potable Water Supply	Agriculture	Nutrients
PA-SCR-57467947	East Branch Octoraro Creek	0.03	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
			Potable Water Supply	Agriculture	Nutrients
PA-SCR-57467987	East Branch Octoraro Creek	0.14	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
			Potable Water Supply	Agriculture	Nutrients
PA-SCR-57468123	East Branch Octoraro Creek	0.39	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
			Potable Water Supply	Agriculture	Nutrients
PA-SCR-57468143	East Branch Octoraro Creek	0.02	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57468153	East Branch Octoraro Creek	0.04	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
			Potable Water Supply	Agriculture	Nutrients
PA-SCR-57468155	East Branch Octoraro Creek	0.02	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
PA-SCR-57468169	East Branch Octoraro Creek	0.02	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
			Potable Water Supply	Agriculture	Nutrients
PA-SCR-57468237	East Branch Octoraro Creek	0.13	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
			Potable Water Supply	Agriculture	Nutrients
PA-SCR-57468545	East Branch Octoraro Creek	1.7	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
			Potable Water Supply	Agriculture	Nutrients

ATTAINS ID	Stream Name	Length (miles)	Assessed Use Category	Impairment Source	Impairment Cause
PA-SCR-57468791	East Branch Octoraro Creek	1.14	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
			Potable Water Supply	Agriculture	Nutrients
PA-SCR-57468829	East Branch Octoraro Creek	0.13	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
			Potable Water Supply	Agriculture	Nutrients
PA-SCR-57468855	East Branch Octoraro Creek	0.28	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
			Potable Water Supply	Agriculture	Nutrients
PA-SCR-57468891	East Branch Octoraro Creek	0.1	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
			Potable Water Supply	Agriculture	Nutrients
PA-SCR-57468995	East Branch Octoraro Creek	0.24	Aquatic Life	Agriculture	Cause unknown, Siltation
				Habitat modification - other than hydromodification	Habitat alterations
			Potable Water Supply	Agriculture	Nutrients

Table A-3. Octoraro Reservoir assessment units with aquatic life and potable water supply use impairments from the 2024 Pennsylvania Integrated Water Quality Report.

ATTAINS ID	Lake Name	Area (acres)	Assessed Use Category	Impairment Source	Impairment Cause
PA-LRP-02050306002281	Octoraro Lake	622.750812	Aquatic Life	Agriculture	Nutrients
			Potable Water Supply	Agriculture	Nutrients

Appendix B. BMP Scenario Setup and Assumptions

B1 Background

This appendix supplements Section 7 by providing additional details on the BMP scenarios developed for this ARP. The scenarios were configured and run in the SAM Tool. The SAM Tool includes a BMP database customized for the Octoraro Watershed with 25 pre-defined BMPs. For each BMP, the BMP database stores default values of the following parameters needed to simulate water quality benefits and costs:

1. **Pollutant reduction efficiencies for total nitrogen, total phosphorus, and sediment**. Reduction efficiencies quantify the relative reduction in pollutant loads exported from the area treated by a BMP. Reduction efficiencies range from 0 to 1, a value of 0 corresponds to no reduction in exported loads from the treated area, a value of 1 corresponds to 100% reduction. Refer to Section 6.1.2 of Attachment 1 for additional information on reduction efficiencies and default values in the Octoraro Watershed BMP database.
2. **Model land use treated by the BMP**. Some BMPs are assigned to treat multiple model land use types (for example, all agricultural land uses), while other BMPs treat one specific model land use (for example, cropland with manure application). When running a BMP scenario, the SAM Tool will only reduce pollutant loads from model land use types that are assigned to the BMP. Refer to Section 6.1.4 of Attachment 1 for additional information on default model land uses assigned to BMPs in the Octoraro Watershed BMP database.
3. **Suitable load factors.** Certain BMPs are intended to target specific sources within the model land use assigned to the BMP. The suitable load factor accounts for pollutant loading differences between the model land use that is assigned to the BMP and the specific source targeted for treatment.

   For example, the Agricultural Stormwater Management BMP is intended to target loading from stormwater generated on confined animal feeding areas. However, the Octoraro Watershed Model does not explicitly simulate pollutant loading from confined animal feeding areas as a model land use. Agricultural Stormwater Management is therefore assigned to treat loading from the pasture/hay model land use, and suitable load factors for the BMP account for additional pollutant loads available for reduction from confined animal feeding areas compared to average pasture/hay loading. If a BMP scenario included treatment of five acres of pasture/hay by Agricultural Stormwater Management, then pollutant loads from those five acres would be increased using suitable load factors as part of load reduction calculations. Refer to Table 6-5 of Attachment 1 for default suitable load factors assigned to BMPs in the Octoraro Watershed BMP database.
4. **Suitable area percentages.** For BMPs that treat specific sources within a model land use, the BMP database includes a default suitable area percentage for the BMP. These values quantify the percentage of model land use area that is suitable for the BMP. As part of

developing the Octoraro Watershed BMP database, suitable area percentages were calculated from Chesapeake Assessment Scenario Tool (CAST) pollutant source areas reported for 12-digit hydrologic units (HUC12s). CAST reports areas for detailed pollutant source categories. For example, separate areas for feedlot, pasture, and hay are reported and these values were used to estimate suitability percentages for the Agricultural Stormwater Management and Feeding Space Management BMPs, which are assigned the pasture/hay model land use but are only suitable for treating confined animal feeding areas.

Suitability percentages were calculated for each HUC12 in the Octoraro Watershed. Values were then assigned to model subwatersheds located in each HUC12. Refer to Section 6.1.4 of Attachment 1 for additional information on suitable areas in the Octoraro Watershed BMP database.

5. **Available area percentages.** All BMPs include default availability estimates that reflect the percentage of model land use available for the BMP. Availability is defined as the suitable area minus the area already treated by the BMP during the time period covered by the Octoraro Watershed Model (2013 through 2021). Default available area percentages were calculated during development of the Octoraro Watershed BMP database from CAST BMP tracking data reported for HUC12s during 2013 through 2021. Available area percentages were calculated for each HUC12 in the Octoraro Watershed. Values were then assigned to model subwatersheds located in each HUC12. Refer to Section 6.1.4 of Attachment 1 for additional information on available areas in the Octoraro Watershed BMP database.

6. **Cost per treated acre.** BMP costs in the Octoraro Watershed BMP database are quantified using a similar approach as CAST and are calculated from CAST cost profiles. Costs in the Octoraro Watershed BMP database are expressed as a total annualized dollar amount per treated acre that combines one-time costs (capital costs and opportunity costs) and annual operations and maintenance (O&M) costs into a single value. Like CAST, BMP costs are reported in 2018 dollars and the assumed interest rate for annualizing capital and opportunity costs is 5%.

   Note that CAST expresses costs for each BMP as a dollar amount *per acre of BMP implemented*, while the SAM Tool expresses costs *per acre treated by the BMP*. For most BMPs, these areas are equal. However, for BMPs like buffers or wetlands that receive and treat pollution from adjacent upland areas, the treated area includes the area where the BMP is installed (the implemented area) plus the upland area. For these BMPs, CAST costs were adjusted during development of the Octoraro Watershed BMP database using a treated area factor that accounts for the difference between the implemented area and the treated area. Refer to Section 6.1.3 of Attachment 1 for additional information on default costs assigned to BMPs in the Octoraro Watershed BMP database.

B2 Scenario Set Up

The BMP scenarios developed for this ARP were created by setting up initial scenarios in the SAM Tool that achieved target load reductions at a minimized cost, then revising the scenarios based on additional analysis of BMP opportunities in the Knight Run subwatershed and stakeholder input. A key user input in the SAM Tool is the landowner participation rate for each BMP. The SAM Tool combines landowner participation rates entered by the user with available areas for the selected BMPs to calculate the area treated by each BMP in the scenario. In the BMP scenarios developed for this ARP, landowner participation rates were set to 50%-55% for the interim scenario and 80%-95% for the final scenario. These levels of participation were needed to achieve target load reductions for nitrogen and phosphorus in the interim scenario, and the target sediment load reduction in the final scenario.

The BMP scenarios generally used pre-defined BMPs from the Octoraro Watershed BMP database and default BMP parameter values. Exceptions are described below.

- **Customization 1: Forest Buffers and Forest Buffers with Livestock Fencing**. The area of cropland available for treatment by forest buffers, and the area of pasture available for treatment by forest buffers with livestock fencing, were both customized for the BMP scenarios. Custom values were calculated through an analysis of land use in the stream corridor of the Knight Run subwatershed. The analysis method included the following steps:
    a. Delineate a 100-foot-wide corridor on each side of stream segments in the NHDPlus High Resolution hydrography dataset published by the U.S. Geologic Survey (USGS).
    b. Calculate the area of agricultural land in the stream corridor with the 2017/2018 Chesapeake Bay Land Use and Land Cover Database (2022 Edition): 171 acres. This value represented the total area in the stream corridor that could be converted from agriculture to forest buffers. Note that 2017/2018 land use conditions were analyzed to align with the baseline 2013 through 2021 modeling period.
    c. Calculate the area of agricultural land available for treatment by forest buffers: 513 acres. This step used the area of agriculture in the stream corridor from step (b), and assumed that every 1 acre of agriculture in the stream corridor converted to a forest buffer would treat pollution from that area plus an additional 2 acres of upland agriculture. The assumption of 2 upland acres treated aligns with CAST assumptions for forest buffers. CAST assumes that 1 acre of forest buffer will treat an additional 2 upland acres for sediment and phosphorus, and 4 upland acres for nitrogen (CBP 2022). The selection of 2 upland acres for this analysis represents a conservative assumption. In practice the upland area treated by a forest buffer will depend on site-specific drainage patterns and buffer design and could exceed the 2 acres assumed for this analysis.
    d. Partition the total area of agricultural land available for treatment from step (c) between cropland and pasture land uses: 368 acres of cropland available for

treatment by forest buffers and 145 acres of pasture available for treatment by forest buffers with livestock exclusion fencing. This step assumed that the relative distribution of cropland versus pasture in the available area matched the distribution of each source area for the entire subwatershed.

- **Customization 2: Wetland Restoration**. The area of agriculture available for treatment by restored wetlands was customized for the BMP scenarios. The custom value was calculated through an analysis of land use in portions of the Knight Run subwatershed that have been identified as potential wetland restoration sites by the EPA Watershed Resources Registry for Pennsylvania. The analysis method included the following steps:

    a. Map potential wetland restoration sites in Knight Run using the wetland restoration layer from the EPA Watershed Resources Registry for Pennsylvania.

    b. Calculate the area of agricultural land in potential wetland restoration sites with the 2017/2018 Chesapeake Bay Land Use and Land Cover Database (2022 Edition): 143.5 acres. This value represented the total area in the subwatershed that could be converted from agriculture to a restored wetland. Note that 2017/2018 land use conditions were analyzed to align with the baseline 2013 through 2021 modeling period.

    c. Calculate the area of agricultural land available for treatment by a restored wetland: 430 acres. This step used the area of agriculture land in potential wetland restoration sites from step (b) and assumed that every 1 acre of agriculture converted to a restored wetland would treat pollution from that area plus an additional 2 acres of upland agriculture. The assumption of 2 upland acres treated is equal to the value used in CAST for restored wetlands in headwater areas (CBP 2022)[1]. Similar to forest buffers, this represents a conservative assumption since the upland area treated could exceed 2 acres depending on site-specific drainage patterns and BMP design.

  The annualized cost of wetland restoration was also customized for the BMP scenarios. The default cost of wetland restoration in the Octoraro Watershed BMP database was based on CAST cost estimates for the CAST 'Wetland Restoration – Floodplain' BMP, which represents wetland restoration efforts in floodplain areas. Since the Knight Run subwatershed is located in the headwaters of the Octoraro Watershed, CAST cost estimates for the 'Wetland Restoration – Headwaters' BMP (CBP 2024)[2] were instead used to calculate the cost of wetland restoration for the BMP scenarios.

- **Customization 3: Grass Buffers**. A custom grass buffer BMP was created for the scenarios to treat pollutant loads from hay fields. This resulted in three separate grass buffer BMPs being included in the scenarios: (1) the pre-defined grass buffer to treat cropland; (2) the

[1] CAST assumptions for the upland area treated by restored wetlands vary by hydrogeomorphic region (HGMR). The Octoraro Watershed is in the Piedmont Crystalline HGMR.
[2] Wetland restoration costs from the CAST 'Watershed Average' BMP cost profile were used for the scenarios.

pre-defined grass buffer with livestock fencing to treat pasture; and (3) the custom grass buffer to treat hay. Parameter values for the custom BMP are listed in Table B-1. Parameters were based on values for the two pre-defined grass buffer BMPs in the Octoraro Watershed BMP database and reflect the following assumptions:

a. Any agricultural land not suitable for the two pre-defined grass buffer BMPs was assumed to be suitable for the custom BMP (1,185 acres).

b. A portion of the suitable area was assumed to already be treated by grass buffers during the baseline modeling period and therefore unavailable for implementation in the BMP scenarios. The percentage of suitable area available for the custom BMP was set to the default percentage in the Octoraro Watershed BMP database for the pre-defined grass buffer BMP that treats cropland (81.9%).

c. The annualized cost per treated acre for the custom BMP was set to the default cost for the pre-defined grass buffer BMP that treats cropland ($45.32).

d. As a conservative assumption, pollutant reduction efficiencies for the custom BMP were set to CAST values for grass buffers (CBP 2022), with no additional reduction to account for land conversion from hay to grass cover.

Table B-1. BMP parameters for the custom grass buffer BMP.

Model Land Use Treated	Area Suitable for Treatment	Area Available for Treatment	Annualized Cost per Treated Acre	Pollutant Reduction Efficiency		
				TN	TP	Sediment
Pasture/Hay	1,185 acres	971 acres	$45.32	0.39	0.52	0.56

B3 Supplemental Tables

The tables below display information to support stakeholders as they interpret the BMP scenarios and evaluate BMP needs as part of ARP implementation.

- Table B-2 lists the model land uses and sources treated by BMPs included in the scenarios, and displays suitable areas, available areas, and landowner participation rates used in each scenario.
- Table B-3 lists pollutant reduction efficiencies used in the scenarios.
- Table B-4 provides a crosswalk between BMP names used in this report and BMP names used in the SAM Tool and CAST. It also lists names and identification numbers for USDA NRCS practices in the Field Office Technical Guide for Pennsylvania that correspond to each BMP.

Table B-2. Summary of suitable areas, available areas, and participation rates for BMPs included in the scenarios developed for this ARP.

BMP Name	Model Land Use(s) Treated by BMP	Source(s) Treated by BMP[1]	Acres of Model Land Use(s)	Acres Suitable for Treatment[1]	Acres Available for Treatment[2]	Interim Scenario		Final Scenario	
						Participation Rate in Scenario	Acres Treated in Scenario[3]	Participation Rate in Scenario	Acres Treated in Scenario[3]
Agricultural Stormwater Management	Pasture/Hay	Feeding Space	1,953	16	16	-	-	90%	15
Ag. Erosion and Sediment Control Plans	Cropland, Pasture, Hay		3,896		3,266	50%	1,633	95%	3,102
Conservation Tillage	Cropland		1,943		1,219	55%	670	95%	1,158
Feeding Space Management	Pasture/Hay	Feeding Space	1,953	16	7	-	-	90%	6
Forest Buffers	Cropland		1,943		368	50%	184	90%	331
Forest Buffers with Livestock Fencing	Pasture/Hay	Pasture	1,953	768	145	50%	73	90%	131
Grass Buffers	Cropland		1,943		1,591	50%	795	95%	1,511
Grass Buffers	Pasture/Hay	Hay	1,953	1,185	971	50%	486	95%	922
Grass Buffers with Livestock Fencing	Pasture/Hay	Pasture	1,953	768	766	50%	383	90%	689
Nutrient Management	Cropland, Pasture, Hay		3,896		3,014	50%	1,507	80%	2,411
Pasture Management	Pasture/Hay	Pasture	1,953	768	723	50%	361	95%	687
Wetland Restoration	Cropland, Pasture, Hay		3,896		430	50%	215	90%	387

[1] Some BMPs are intended to treat specific sources within the assigned model land use. For these BMPs, the 'Source(s) Treated by BMP' column describes the source targeted for treatment and the 'Acres Suitable for Treatment' column denotes the estimated acres of the source in the Knight Run subwatershed.

[2] For most BMPs, the area available for treatment was calculated as the suitable area minus the estimated number of acres already treated by the BMP during the baseline modeling period (2013 through 2021). For 'Forest Buffers' and 'Forest Buffers with Livestock Fencing', the available area was calculated from the stream corridor land use analysis described in this appendix. For 'Wetland Restoration', the available area was calculated from the potential wetland land use analysis described in this appendix.

[3] The number of acres treated in the scenarios reflects 'new' areas where BMPs need to be implemented to reduce pollution and achieve target pollutant loads in Knight Run.

Table B-3. Pollutant reduction efficiencies for BMPs included in the scenarios developed for this ARP.

BMP Name	TN	TP	Sediment
Agricultural Stormwater Management	0.35	0.55	0.7
Ag. Erosion and Sediment Control Plans	0.0704	0.1329	0.2201
Conservation Tillage	0.1271	0.6641	0.6921
Feeding Space Management	0.2	0.2	0.4
Forest Buffers	0.6104	0.4368	0.5824
Forest Buffers with Livestock Fencing	0.6104	0.4368	0.5824
Grass Buffers (Cropland)	0.4251	0.4368	0.5824
Grass Buffers (Hay)	0.39	0.42	0.56
Grass Buffers with Livestock Fencing	0.4251	0.4368	0.5824
Nutrient Management	0.1087	0.1721	0
Pasture Management	0.11	0.2399	0.3002
Wetland Restoration	0.4578	0.416	0.3224

Table B-4. Crosswalk between BMP names used in this report and BMP names used in the SAM Tool and CAST. Also shown are names and identification numbers for USDA NRCS practices in the Field Office Technical Guide for Pennsylvania that correspond to each BMP.

BMP Name in ARP Report	BMP Name in SAM Tool	CAST BMP Name	USDA NRCS Conservation Practice Standard
Agricultural Stormwater Management	Agricultural Stormwater Management	Agricultural Stormwater Management	See instead PADEP Stormwater Best Practices Manual
Agricultural Erosion and Sediment Control Plans	Conservation Plans	Soil Conservation and Water Quality Plans	See instead PADEP Agriculture Erosion and Sediment Control resources
Conservation Tillage	Conservation Tillage	Conservation Tillage; Tillage Management	Residue and Tillage Management, No-Till (329) Residue and Tillage Management, Reduced Till (345)
Cover Crops	Cover Crops	Cover Crops	Cover Crop (340)
Crop Irrigation Management	Crop Irrigation Management	Cropland Irrigation Management	Irrigation Water Management (449)
Feeding Space Management	Feeding Space Management	Barnyard Runoff Control; Loafing Lot Management	Roof runoff structure (558); Diversion (362); Stormwater Runoff Control (570); Trails and Walkways (575)
Forest Buffers	Forest Buffers	Forest Buffer	Riparian Forest Buffer (391)
Forest Buffers with Livestock Fencing	Forest Buffer – Streamside with Exclusion Fencing	Forest Buffer-Streamside with Exclusion Fencing	
Grass Buffers	Grass Buffer	Grass Buffer	Riparian Herbaceous Cover (390); Filter Strip (393); Field Border (386); Grass Waterway (412);
Grass Buffers with Livestock Fencing	Grass Buffer – Streamside with Exclusion Fencing	Grass Buffer-Streamside with Exclusion Fencing	
Manure Incorporation	Manure Incorporation	Manure Incorporation; Manure Injection	Addressed as part of Nutrient Management (590)
Nutrient Management	Nutrient Management	Nutrient Management	Nutrient Management (590)
Off-Stream Livestock Watering	Off Stream Watering Without Fencing	Off Stream Watering Without Fencing	Watering Facility (614)
Pasture Management	Pasture Management	Precision Intensive Rotational/Prescribed Grazing; Horse Pasture Management	Prescribed Grazing (528)
Water Control Structures	Water Control Structures	Water Control Structures	Structure for Water Control (587)
Wetland Creation	Wetland Creation	Wetland Creation	Constructed Wetland (656)
Wetland Restoration	Wetland Restoration	Wetland Restoration	Wetland Restoration (657)

B4 References

Chesapeake Bay Program (CBP). 2022. Quick Reference Guide for Best Management Practices (BMPs): Nonpoint Source BMPs to Reduce Nitrogen, Phosphorus and Sediment Loads to the Chesapeake Bay and its Local Waters. CBP/TRS-323-18. Second edition. https://www.chesapeakebay.net/files/ documents/BMP-Guide_Full.pdf

Chesapeake Bay Program (CBP). 2024. Cost Profiles for Chesapeake Assessment and Scenario Tool (CAST) Version 2023, Phase 6-7.14.3. Chesapeake Bay Program Office. Last accessed July 2025. https://cast.chesapeakebay.net/Documentation/CostProfiles

Appendix C. Rapid Stream Delisting Strategy

C1 Background

At the time this ARP was developed, the Chesapeake Conservancy Rapid Stream Delisting Strategy was already being implemented in the headwaters of Nickel Mines Run. This effort already involves Octoraro Source Water Collaborative (OSWC) partners. This approach is also being used by the Lancaster Clean Water Partners. The RSD Strategy has a goal of restoring streams within a timeframe of approximately 10 years. It targets streams impaired by agricultural nonpoint source pollution for BMP implementation and monitoring with the goal of delisting aquatic life use impairments. The program divides watersheds into several smaller areas called catchments (typically 1,000 to 2,000 acres in size). It focuses on catchments where landowner interest in installing BMPs is expected to be high and where water quality indicators are relatively close to achieving goals. Partners involved in BMP implementation target one catchment at a time, starting with headwater catchments and moving downstream. One or more monitoring sites are also established in each catchment, so that data are available to evaluate and track the effects of local implementation efforts on water quality. This approach is the basis for this ARP to maintain continuity amongst the OSWC partners working in both Lancaster and Chester Counties.

C2 Tracking Spreadsheet

Partners periodically will meet to discuss progress being made by landowners within the planning catchments. The type of information tracked are in Table C-1. This serves only as an example and can be adapted by ARP implementation team.

Table C-1: Catchment and Parcel Information Tracked in the Rapid Stream Delisting Strategy.

Example Information to Collect and Track		
Catchment Information[1]		
Catchment Name	Ag goal progress completed/underway (ac)	Ag goal progress completed/underway (%)
County	Ag goal amenable (ac)	Ag goal amenable (%)
Area (ac)	Ag TBD (ac)	Ag TBD (%)
Ag Impaired Stream (mi)	Buffer goal progress completed/underway (ac)	Buffer goal progress completed/underway (%)
Total Stream (mi)	Buffer goal amenable (ac)	Buffer goal amenable (%)
Parcels in catchment	Buffer TBD (ac)	Buffer TBD (%)
Priority Parcels	AIT progress completed/underway (ac)	SUM_Drain_Area_1
Ag goal (ac)	AIT progress amenable (ac)	Ag acres draining through parcel buffer gaps
AIT Goal (ac)	AIT TBD (ac)	Imp acres draining through parcel buffer gaps
Buffer Goal (ac)	Urban Area Coverage (Yes/No)	Turf acres draining through parcel buffer gaps

Ag ac from Land Use	MEB coverage	Sum ag, imp, turf draining through buffer gaps
Imp ac from Land Use	EJ Area coverage	AIT_ROA
Turf ac from Land Use	Estimated Cost	
AIT ac from Land Use	Township Overlap	
Forested ac from Land Use		
Acres of forest buffer restoration opportunity area		
	Parcel/Landowner Information[2]	
Object ID	Owner Address 1	Full Parcel Acreage
PIN	Owner Address 2	Parcel Acreage within Catchment
Land Use Code	Owner Address 3	Willing to accept federal funding? (Yes/No)
Owner Name	Owner Address City	
Parcel Address	Owner Address State	
	Owner Address Zip	
	Landowner Status[3]	
Completed – maintenance phase	Landowner amenable	Outreach Priority
Underway	No contact/unknown	Planning & design phase
Shovel-Ready - has funding	Not enough resource concerns	Completed – needs verification
Shovel-Ready - needs funding	Resource concerns – LO not amenable	Outreach started, landowner hasn't responded
	Partner Information[2]	
Outreach Contact	Partner Comments	Other Partners

[1]Rapid Stream Delisting Strategy Dashboard

[2]Example spreadsheet maintained by Chesapeake Conservancy

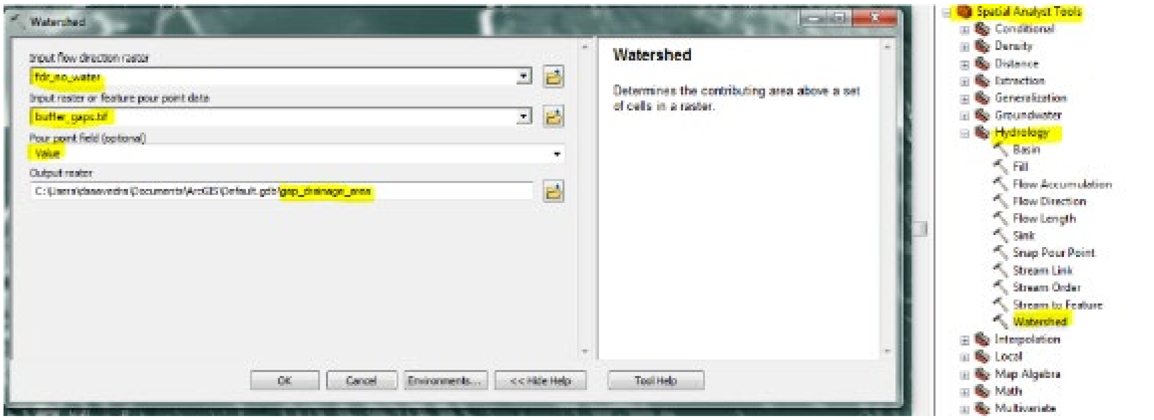
[3]Combination of tracked information from above sources.

C3 Buffer Gap Analysis

The purpose of the buffer gap analysis is to delineate the area of land that drains through each riparian buffer gap. The following steps are taken, as shown in Figure C-1:

- Under Spatial analyst -> Hydrology tools, run the **Watershed** tool, using the flow direction with water removed as the input flow direction raster, and the buffer gaps raster as the input raster pour point data
- Note: before running this tool it may be useful to use the Region Group tool on the gap grid before delineating drainage areas. See upcoming slide "Gaps and drainage areas as features" for more information
- Set Snap Raster environment setting to land cover raster

Figure C-1: Screenshot of Spatial Analyst Tool.



Transparent red areas represent the land area that contributes flow to each riparian buffer gap (dark red). Example is shown Figure C-2.

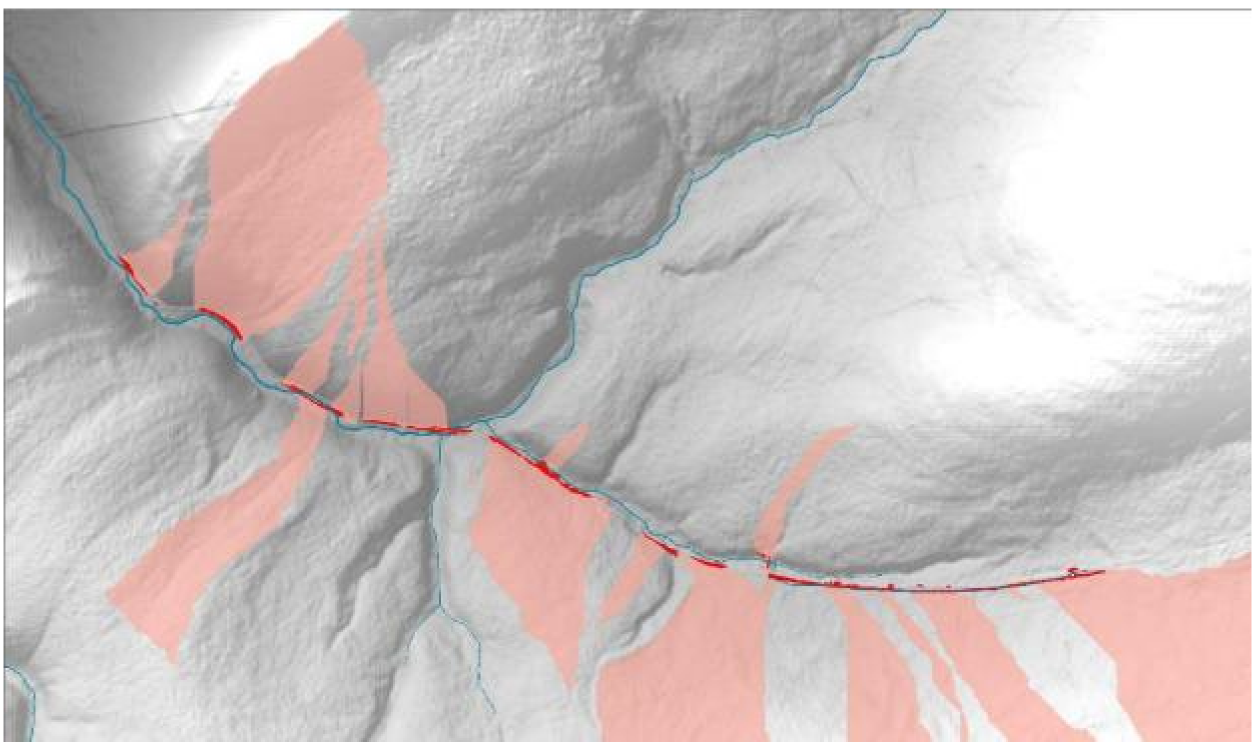


Figure C-2. Screenshot of drainage area flowing through gap in buffers.

For some analyses, it is useful to represent buffer gaps and their corresponding drainage areas as individual features. This allows for selection and analysis of individual gaps and can aid in the prioritization of gaps for restoration.

To represent gaps as individual features, use the following workflow, as shown in Figure C-3:

- After gaps are identified (as rasters), use the **Region Group** tool with the following parameters: *InRaster = buffer gaps, OutRaster = grouped buffer gaps, Number of neighbors = 8, Zone grouping method = WITHIN, Add link field = DISABLE*
- After gaps are grouped, they can be converted to polygon using **Raster to Polygon** tool with the following parameters: *InRaster = grouped buffer gaps, Field = Value, Output Polygon = grouped buffer gaps poly, Simplify polygons = DISABLE*
- *It is helpful to run the **Dissolve** tool using the GRIDCODE field of the buffer gap polygons to ensure that portions of gaps adjacent to each other in the diagonal direction are represented as one contiguous feature and not separate features*

To represent drainage areas as individual features, as shown in Figure C-4:

- Run the **Watershed** tool using the grouped buffer gap raster (from above, step 1) as input
- Run **Raster to Polygon** to convert drainage areas to polygons, disabling the Simplify polygons box
- Run the **Dissolve** tool using the GRIDCODE field of the drainage area polygons

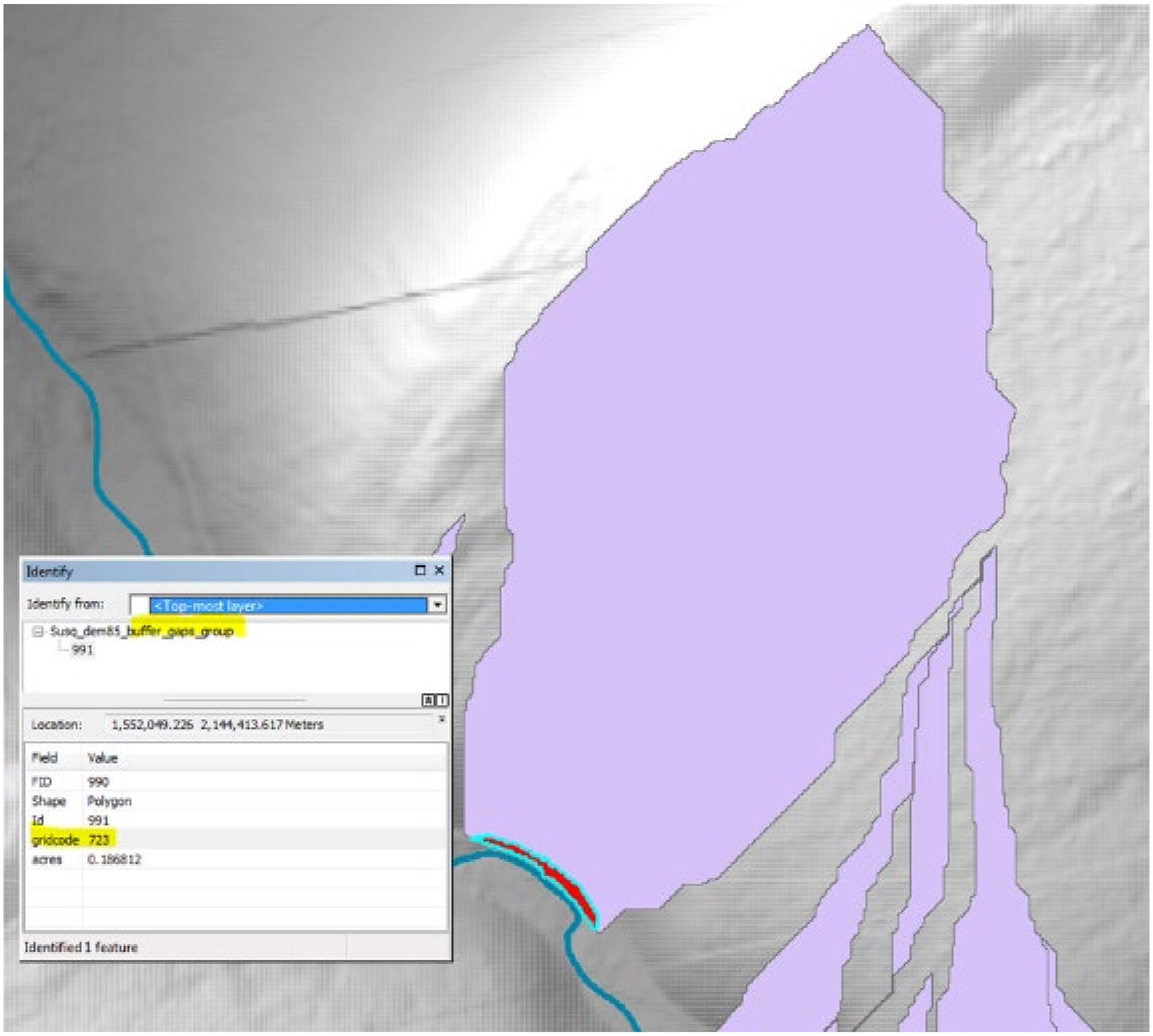


Figure C-3: Buffer gap in dark red as an individual feature.

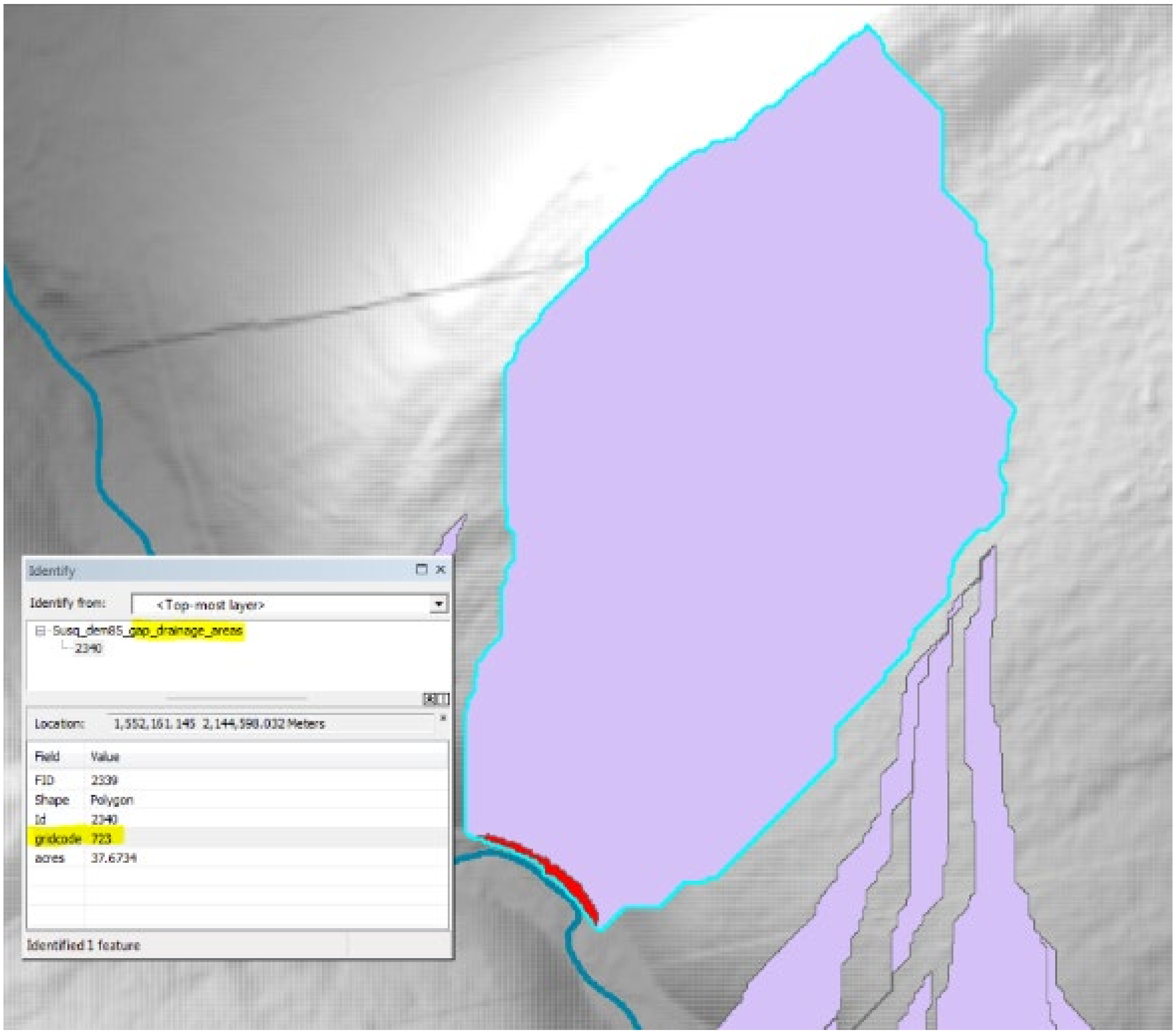


Figure C-4. Drainage area in purple as an individual feature.

Appendix D. Summary of Stakeholder Engagement and Subwatershed Evaluation to Prioritize Watershed Planning

D1 Introduction

This appendix documents the methods and results of an effort to prioritize subwatersheds in the Octoraro Watershed for watershed planning. Results were used to select Knight Run for Advance Restoration Plan (ARP) development. Objectives of the prioritization effort were to:

1. Engage the Octoraro Source Water Collaborative (OSWC) and PADEP to identify critical factors to consider for prioritizing and selecting subwatersheds for ARP development.
2. Develop and apply methods for selecting subwatersheds for ARP development.
3. Document the subwatershed selection methodology and associated data to help inform future restoration and protection prioritization efforts.

D2 Stakeholder Engagement

Identifying Key Factors for Subwatershed Selection

Initial planning of the subwatershed selection methodology was completed through engagement with OSWC members to identify key factors to consider for subwatershed selection. During a breakout session at the November 7, 2024 OSWC Annual Meeting, EPA Region 3 staff facilitated a discussion with OWSC members about factors they consider most important for selecting subwatersheds for ARP development. Attendees were asked to rank seven different factors from most important (Rank #1) to least important (Rank #7). Table D1 lists the seven factors and summarizes results of the ranking activity.

Table D1. Stakeholder ranking results for subwatershed selection factors.

Factor	Number of Votes							Weighted Score[a]
	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Rank 6	Rank 7	
Likelihood of landowner participation	5	2	1	4	2	0	0	74
Potential for large pollutant load reductions	1	7	2	1	1	2	0	70
Potential for reducing nitrate levels in Octoraro Reservoir	3	1	4	1	3	1	1	63
Potential for successful grant funding	3	1	3	2	3	0	1	60
Potential for delisting impaired streams	2	1	2	2	3	4	0	55

Contains areas without existing restoration efforts	0	1	2	2	0	2	6	34
Contains areas with existing restoration efforts	0	1	0	2	2	4	4	32

[a] The weighted score was calculated for each factor by summing the product of the number of votes the factor received and a rank-based weight across all ranks. Weights were set to the inverse of the rank number (e.g., Rank 1 had a weight of 7 and Rank 7 had a weight of 1).

Based on the rankings in Table D1 and discussion with breakout session attendees and PADEP, three critical factors were identified to guide further development of subwatershed selection methods:

- **Source Water Protection.** Breakout session attendees ranked 'potential for reducing nitrate levels in Octoraro Reservoir' as the third most important factor. Protecting source water in Octoraro Reservoir is also a primary goal of the OSWC Strategic Plan (OSWC 2022).
- **Landowner Participation.** Landowner participation is a critical factor because it affects whether the water quality outcomes described in an ARP are achieved. Without landowner participation, Best Management Practices (BMPs) for water quality improvement can be planned but are unlikely to be implemented. Breakout attendees ranked landowner participation as the most important factor for subwatershed selection.
- **Potential for Local Delistings.** The potential for local delistings (i.e., delisting impaired streams located within the subwatersheds selected for ARP development) is considered a critical factor because: (1) achieving local delistings is expected to be a primary goal of the ARPs; and (2) delisting potential affects access to grant funding for ARP implementation. In order for the selected subwatersheds to be eligible for Clean Water Act Section 319 Nonpoint Source Management grant funding, the ARPs must satisfy certain requirements for watershed-based plans, including outlining management practices that are expected to result in attainment of applicable water quality standards *within* the subwatersheds. Furthermore, the EPA Region 3 and PADEP Nonpoint Source programs consider ARPs and other watershed-based plans with short-term delisting potential (e.g., 5 to 10 years after plan approval) to be a priority for Section 319 grant funding (PADEP 2024).

Landowner Participation Potential

As described above, landowner participation was identified by stakeholders as a key factor to consider for selecting subwatersheds for ARP development. As a follow-up stakeholder engagement activity, members of the OSWC Agriculture Workgroup were asked to rank subwatersheds in the Octoraro Watershed based on the potential for landowners in each subwatershed to participate in efforts to improve water quality through implementation BMPs or other related activities. Results of the landowner participation rankings are presented in Section D3 of this appendix.

Chesapeake Conservancy Rapid Stream Delisting Program

The Chesapeake Conservancy Rapid Stream Delisting (RSD) program works to restore streams impaired by agricultural nonpoint source pollution, with a goal of delisting impaired streams included in the program within approximately 10 years of starting restoration efforts. As part of the subwatershed selection effort, EPA Region 3 staff engaged with Chesapeake Conservancy to understand where the RSD program is currently working and how the program selects streams with delisting potential for inclusion in the program. Figure D1 displays catchments in the Octoraro Watershed that are part of the Chesapeake Conservancy RSD program. Example factors used by the Chesapeake Conservancy RSD program to identify suitable streams with delisting potential include stream setting and drainage area (smaller headwater catchments are preferred), landowner interest in installing BMPs, and streams where water quality indicators are already relatively close to achieving goals. These factors were included in the subwatershed selection method described below in Section D3.

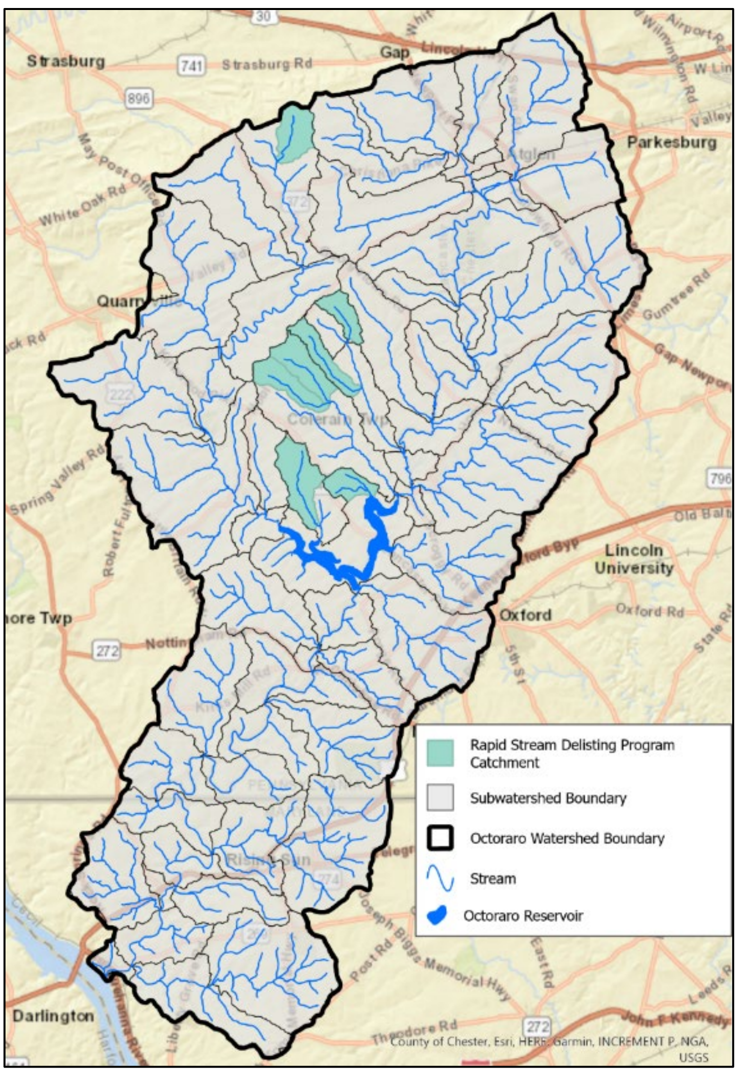


Figure D1. Location of catchments in the Octoraro Watershed that are part of the Chesapeake Conservancy Rapid Stream Delisting program as of February 2026.

Additional Engagement Activities

Other stakeholder engagement activities conducted during the selection of subwatersheds for ARP development included meeting with the Chester County Conservation District to understand their existing watershed management activities and priority areas in the Octoraro Watershed, and meeting with the OSWC Planning Committee to present the draft subwatershed selection methodology, present draft results, and request feedback.

D3 Subwatershed Selection Methods and Results

The critical factors for subwatershed selection described Section D2 were used to guide the development of a three-step method to select subwatersheds for ARP development.

Step 1: Initial Screening

In Step 1, four criteria were applied to identify subwatersheds that meet basic requirements for geographic location within the Octoraro Watershed and the presence of monitoring sites:

1. Subwatersheds were required to be located upstream of Octoraro Reservoir, so that ARP implementation will provide benefits to the local drinking water source.
2. Subwatersheds were required to be a headwater subwatershed because headwaters generally have greater delisting potential than non-headwater streams with larger, more complex drainage areas. Note that for this analysis, Bells Run was considered a headwater subwatershed since it only has two small upstream subwatersheds that total approximately 1.5 miles in size (Figure D2).
3. Subwatersheds were required to have existing PADEP bioassessment monitoring data and water chemistry monitoring sites because these are important for evaluating delisting potential and for documenting existing local water quality conditions to confirm the need for water quality improvement. The presence of monitoring sites also can help justify that sufficient data will be available to evaluate attainment of water quality standards after ARP implementation. Further, existing water quality data enables comparison of pre- and post-implementation monitoring data, which supports analysis of incremental progress and can be a line of evidence for delisting.

Applying the Step 1 criteria yielded 11 candidate subwatersheds for ARP development (Figure D2).

Step 1 Criteria	Basis
Upstream of Octoraro Reservoir	Source water protection
A headwater subwatershed	Delisting potential
Has existing PADEP bioassessment data	Helpful for delisting, effectiveness monitoring
Has existing water quality monitoring data	Helpful for delisting, effectiveness monitoring

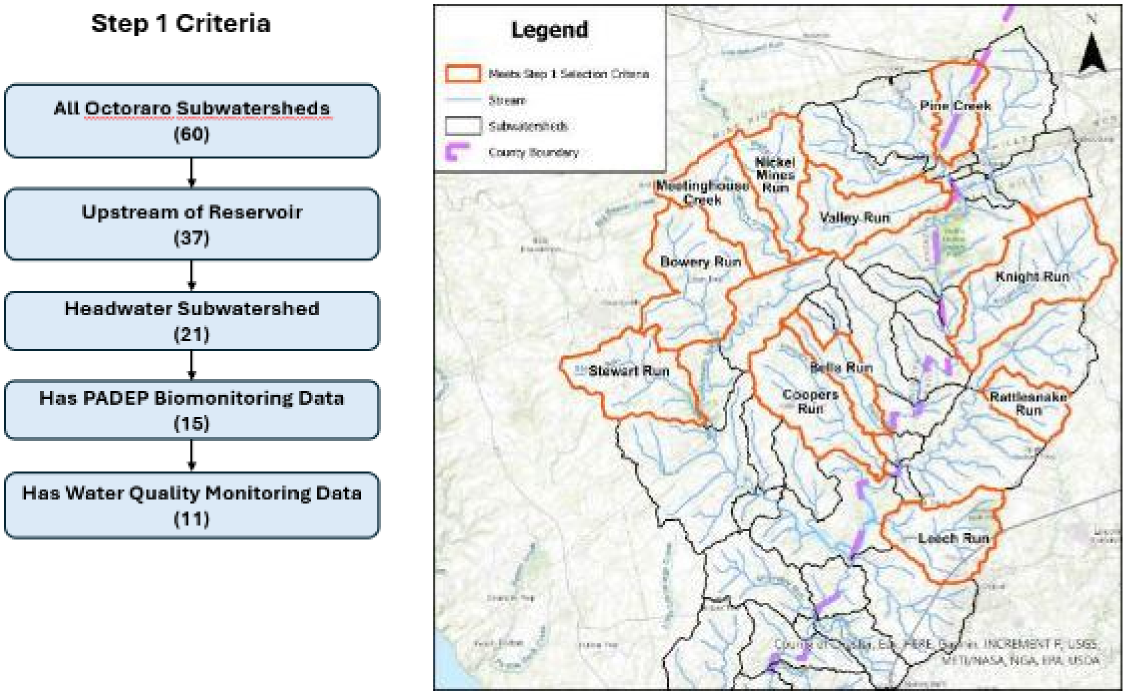


Figure D2. Step 1 subwatershed selection criteria and results.

Step 2: Refined Screening

The purpose of Step 2 was to compare the 11 candidate subwatersheds identified from Step 1 according to characteristics related to source water protection, local delisting potential, and landowner participation. The results of Step 2 were used along with other information from Step 3 to inform final subwatershed selections. The subwatershed characteristics evaluated as part of Step 2 are described below and listed in Table D2.

- **Source Water Protection.** To evaluate the potential for watershed management activities in the 11 candidate subwatersheds to provide source water protection benefits, each subwatershed's relative contribution to Octoraro Reservoir nitrate plus nitrite loading was evaluated using results of the Octoraro Watershed Model. Each subwatershed's relative contribution to the total modeled nitrate plus nitrite load upstream of Octoraro Reservoir was calculated and compared (Table D3). Subwatersheds with higher nitrate plus nitrite contributions were considered to have greater potential to provide source water protection benefits since they offer opportunity for higher load reductions.
- **Potential for Local Sediment and Phosphorus Delistings.** The potential for delisting sediment and phosphorus impairments in each candidate subwatershed was evaluated from results of BMP modeling completed as part of the development of the Octoraro Watershed Model and SAM Tool. As described in Section 6 of Attachment 1, the watershed

modeling project simulated multiple BMP implementation scenarios to meet numeric water quality targets at various points in the Octoraro Watershed.

For this analysis, subwatersheds with modeled sediment loads in the BMP implementation scenarios near or below the target annual load of 178 pounds per acre were assumed to have greater potential for delisting since the model demonstrated that the target load could be achieved. The target sediment load of 178 pounds per acre was selected based on a review of sediment loads for 27 stream monitoring sites in the Susquehanna River Basin (see Section 5.2 of this ARP document). To evaluate phosphorus delisting potential, each candidate subwatershed's lowest modeled phosphorus load in the BMP implementation scenarios was used to compare subwatersheds. Subwatersheds with lower phosphorus loads were assumed to have greater delisting potential. Results of the subwatershed loading evaluation are shown in Table D3.

- **Landowner Participation.** Step 2 also included a comparison among candidate subwatersheds of the potential for landowners to participate in conservation activities to improve water quality. Members of the OSWC Agriculture Workgroup ranked candidate subwatersheds in each county based on the potential for landowner participation. The Chester County Conservation District, Lancaster County Conservation District, Team Ag, and Clean Water Partners provided rankings (Table D4). When submitting rankings, several providers stated they used Pennsylvania Practice Keeper data or other related information to assess existing or historic landowner participation levels. Subwatersheds with the greatest existing or historic participation were ranked highest for landowner participation potential.

Table D2. Step 2 subwatershed selection criteria.

Step 2 Criteria	Basis
Relative contribution of nitrate/nitrite loading to Octoraro Reservoir (prioritize subwatersheds with highest loads)	Source water protection benefits
Modeled sediment load after BMP implementation is near or below target of 178 pounds per acre per year	Sediment delisting potential
Modeled total phosphorus load after BMP implementation (prioritize subwatersheds with lower loads)	Low load suggests greater phosphorus delisting potential
Landowner participation potential	High landowner participation suggests greater delisting potential

Table D3. Results of subwatershed loading evaluation completed as part of Step 2.

Subwatershed	County	Percent of Total Nitrate/Nitrite Load Upstream of Reservoir	Does Modeled Sediment Load after BMP Implementation Achieve ≤ ~178 lbs/acre/year?	Modeled Total Phosphorus Load after BMP Implementation (lbs/acre/year)
Knight Run	Chester	7.0%	Yes (180 lbs/acre/year)	0.65
Bowery Run	Lancaster	6.1%	Yes (100 lbs/acre/year)	0.57
Stewart Run	Lancaster	5.1%	Yes (120 lbs/acre/year)	0.57
Meetinghouse Creek	Lancaster	4.9%	Yes (160 lbs/acre/year)	0.80
Coopers Run	Lancaster	4.9%	No (260 lbs/acre/year)	0.89
Valley Run	Lancaster	4.5%	Yes (140 lbs/acre/year)	0.59
Nickel Mines Run	Lancaster	4.0%	Yes (140 lbs/acre/year)	0.70
Leech Run	Chester	3.5%	No (300 lbs/acre/year)	0.78
Bells Run	Lancaster	3.4%	Yes (146 lbs/acre/year)	0.52
Rattlesnake Run	Chester	1.9%	Yes (160 lbs/acre/year)	0.46
Pine Creek	Both	1.5%	Yes (140 lbs/acre/year)	0.46

Table D4. Landowner participation potential rankings for candidate subwatersheds submitted by members of the OSWC Agriculture Workgroup. A rank of 1 indicates the highest potential for landowner participation in conservation activities to improve water quality.

Rankings for Chester County Subwatersheds		
Rank	Chester County Conservation District	Team Ag
1	Knight Run	Knight Run
2	Rattlesnake Run	Leech Run
3	Leech Run	Rattlesnake Run
4	Pine Creek	Pine Creek

Rankings for Lancaster County Subwatersheds			
Rank	Lancaster County Conservation District	Team Ag	Clean Water Partners
1	Stewart Run	Bowery Run	Bells Run
2	Nickel Mines Run	Bells Run	Nickel Mines Run
3	Meetinghouse Creek	Coopers Run	Stewart Run
4	Bowery Run	Stewart Run	Coopers Run
5	Bells Run	Meetinghouse Creek	Bowery Run
6	Valley Run	Valley Run	Meetinghouse Creek
7	Coopers Run	Nickel Mines Run	Valley Run
8	Pine Creek	Pine Creek	Pine Creek

Step 3: Final Selection

In Step 3, the data compiled during previous steps and additional subwatershed characteristics were evaluated to select one subwatershed in each county for ARP development. The additional subwatershed characteristics considered in Step 3 included:

- PADEP macroinvertebrate IBI and sediment embeddedness scores within each subwatershed and immediately downstream. Scores that were close to PADEP assessment thresholds were assumed to indicate greater potential for improvement and delisting after BMP implementation.

- Whether OSWC stakeholders were currently conducting macroinvertebrate, habitat, and/or water quality monitoring within the subwatershed.
- Whether the Chesapeake Conservancy RSD program was actively working in the subwatershed (see Figure D1).
- Qualitative review of aerial imagery and land cover patterns.

Knight Run was selected as the Chester County subwatershed for ARP development. Knight Run had the highest landowner participation potential ranking among candidate subwatersheds in Chester County (Table D4), offered significant potential for source water protection benefits because it contributed more nitrogen to Octoraro Reservoir than any other candidate subwatershed (Table D3), and had potential for sediment delisting after BMP implementation based on modeling and monitoring data.

D4 References

Octoraro Source Water Collaborative (OSWC). 2022. Octoraro Source Water Collaborative Strategic Plan 2022. https://www.srbc.gov/our-work/what-we-do/docs/lsswpp-octoraro-plan-120922.PDF

Pennsylvania Department of Environmental Protection (PADEP). 2024. Section 319 Nonpoint Source Management Grants Program Guidance. Federal Fiscal Year 2025. https://greenport.pa.gov/elibrary/GetFolder?FolderID=1107628