5.0 WATER QUALITY

5.1 Introduction

Good water quality is essential to the health and productivity of aquatic ecosystems, and to support a variety of human needs including industrial and domestic water supplies, drinking water, and recreation. Input from watershed stakeholders received from the public meetings, the results of the public opinion poll, and review of relevant literature highlighted the following water resource issues of major concern in the Schuylkill River watershed.

- Need for water quality monitoring data
- Urban/suburban development and stormwater runoff
- Non-point source pollution
- Habitat quality
- Acid mine drainage (in the Schuylkill headwaters region)
- Wastewater and other waste discharges
- Water supply

The following sections provide an overview of water quality in the Schuylkill River watershed based on the Pennsylvania Department of Environmental Protection (PA DEP) water quality assessment, available monitoring data, and landscape/water quality modeling. Water quality analyses and discussion focused on issues and problems common throughout the watershed. Recommendations for protecting and improving water quality are summarized for easy reference in **Section 5.2** below and described in detail in **Section 5.6** of this chapter.

A significant amount of water quality related information for the Schuylkill River watershed is available through the Schuylkill River Sourcewater Assessment Partnership (http://www.schuylkillswa.org). For additional information about water quality and environmental protection regulations in Pennsylvania, see the Pennsylvania Code, Title 25, Environmental Protection (http://www.pacode.com/secure/data/025/025toc.html).

5.2 Summary Recommendations

Recommendations for improving the water quality of the Schuylkill River watershed are summarized in the table below. Each recommendation is assigned a unique code number (e.g., **R5.1**) and name, and is cross-referenced to the key water quality issue(s) it addresses. These recommendations are described in more detail in **Section 5.6 Detailed Recommendations from the Water Quality Analysis**, and the page number where the detailed description of that recommendation can be found is listed in the *Page* column of this table.

Recommendations specific to particular water quality issues/analyses also are summarized (by code, name of the recommendation, summary description, and priority implementation areas or target subwatersheds) in a table at the end of each corresponding section in this chapter. For example, summary recommendations specific to water quality monitoring are found in *Section 5.4.1.4 Recommendations for Water Quality Monitoring*, at the end of *Section 5.4 Water Quality Monitoring*.

Code	*Recommendation*	*Summary Description*	*Issues Addressed*	*Page*
R5.1	**Establish a Coordinated, Watershed-wide Monitoring Program with Quality Control Protocols**	EPA, the state and key nonprofits should design a comprehensive watershed-wide monitoring program, providing training for citizen monitoring groups, and with certification protocols to ensure reliable data.	Water quality monitoring	5-21
R5.2	**Implement Urban Best Management Practices to Maximize the Infiltration of Water and Reduce Urban Non-point Source Pollution**	Urban Best Management Practices such as reduction of impervious surfaces, infiltration and sedimentation basins, and street sweeping should be implemented to decrease water quality and other problems associated with stormwater runoff, and to increase groundwater recharge.	Stormwater runoff Non-point source pollution (nutrients, toxics, sediment/erosion) Water supply	5-23
R5.3	**Encourage Homeowners and Small Businesses to Reduce Non-Point Pollution**	Homeowners, small businesses, and individuals should be educated about how their actions influence water quality, and should be encouraged to clean up after pets, properly dispose of yard and household wastes, properly store cars and vehicles, and to take other measures to reduce non-point source pollution.	Non-point source pollution	5-24
R5.4	**Implement Nutrient Management Practices**	Sound Nutrient Management Practices such as soil and manure testing can help minimize the amount of fertilizer entering streams. These practices should also be implemented in suburban and urban areas where fertilizer is used.	Non-point source pollution (nutrients)	5-24
R5.5	**Implement Agricultural Best Management Practices**	Agricultural Best Management Practices such as no-till planting, contour plowing, and stream bank fencing can help reduce the amount of nutrient and sediment pollution entering streams.	Non-point source pollution (nutrients, sediment)	5-25
R5.6	**Implement Timber Harvesting Best Management Practices**	Timber harvesting Best Management Practices such as proper road construction and preservation of riparian buffers should be used to reduce the amount of sediment and nutrients entering streams.	Non-point source pollution (nutrients, sediment)	5-25
R5.7	**Protect and Restore Riparian Forest Buffers**	Riparian buffers function in a variety of ways to maintain the health of stream systems, and should be protected and restored whenever possible.	Non-point source pollution (nutrients, sediment) Habitat quality	5-26
R5.8	**Protect and Restore Wetlands and Areas of Hydric Soils**	Wetlands provide many benefits including the regulation of stormwater runoff, water quality improvements, and unique and important habitat. Efforts should be made to protect and restore wetlands throughout the watershed. Areas of hydric soils may offer the best potential for wetland restoration.	Non-point source pollution (nutrients, sediment) Stormwater runoff Habitat quality	5-27

Code	*Recommendation*	*Summary Description*	*Issues Addressed*	*Page*
R5.9	**Identify and Enforce Sediment and Erosion Control Problems and Violations**	Construction sites contribute a significant amount of sediment to receiving waters. Procedures for monitoring compliance with existing laws should be maintained. Volunteers can be trained to help monitor for existing and potential problems.	Non-point source pollution (sediment/erosion)	5-27
R5.10	**Establish Uniform, Watershed-wide Criteria for Permitted Discharges from Sewage Treatment Plants (STPs)**	Criteria for permitted discharges of pollutants such as fecal coliforms vary among different PA DEP regions within the watershed. Uniform criteria should be developed to help regulate and reduce water quality impairment from sewage treatment plants.	Point source pollution (pathogens/nutrients)	5-28
R5.11	**Monitor Nutrients from All Sewage Treatment Plants**	Sewage treatment plants may not monitor all relevant nutrient levels in their effluent. Establishing uniform discharge criteria and monitoring nutrients at all sewage treatment plants would help to assess nutrient loading to receiving waters.	Point source pollution (nutrients from STPs)	5-28
R5.12	**Promote Tertiary Treatment of Sewage Effluent**	Less than half of the treatment plants in the Schuylkill River watershed provide tertiary treatment of sewage effluent. Where effluent is a problem, plants should be upgraded to provide higher levels of treatment.	Point source pollution (nutrients from STPs)	5-28
R5.13	**Identify and Control Discharges of Untreated Sewage from "Wildcat Systems" and Combined Sewer Overflows (CSOs)**	Discharges of untreated sewage from “wildcat” systems and combined sewer overflows represent a threat to human health and aquatic ecosystems. Wildcat systems should be identified and regulated, and CSOs monitored for compliance with existing regulations.	Point source pollution (nutrients, pathogens)	5-29
R5.14	**Establish Septic Education, Registration, Inspection, and Maintenance Programs**	Septic programs would instruct owners about proper care and maintenance of septic systems, and should provide homeowners with a method for testing their septic systems.	Non-point source pollution (nutrients)	5-29
R5.15	**Size and Maintain Culverts and Bridges to Ensure Minimal Impact to Streams**	Culverts and bridges should be sized and located to adequately convey both low flow and storm events. Structures must also be properly maintained and inspected to prevent obstruction, scour and erosion.	Stormwater runoff Non-point source pollution (sediment/erosion)	5-29

Code	*Recommendation*	*Summary Description*	*Issues Addressed*	*Page*
R5.16	**Conduct Inventories and Studies to Identify and Remove Dams Where Restoration Benefits Outweigh Present Uses and Effects**	Dams can provide benefits, but also cause a broad range of negative ecological impacts. Inventories and studies should be conducted to determine where dams are in the Schuylkill watershed and if they should be removed. The benefits of removal (restoration of stream habitat, fish passage, and water quality) may outweigh present uses and/or effects. Where dam removal does not have overall benefits, construction of fish ladders should be studied and implemented where possible.	Habitat quality Water supply	5-30
R5.17	**Identify Sources and Mitigate Effects of Acid Mine Drainage**	AMD is a significant source of water pollution in the headwaters of the Schuylkill River watershed. In conjunction with other projects, undocumented sources of AMD should be identified and monitored, and a restoration program initiated.	Acid mine drainage	5-30
R5.18	**Monitor and Regulate Existing and Future Groundwater Withdrawals**	When groundwater withdrawals exceed the sustainable yield of aquifers, water supplies can be threatened, streamflow diminished, and aquatic ecosystems degraded. Existing and future groundwater withdrawals should be monitored and regulated to avoid groundwater depletion.	Water supply Habitat quality	5-31
R5.19	**Support PEMA Removal of Structures from Flood Prone Areas**	The Pennsylvania Emergency Management Agency (PEMA) has established a program, which promotes the acquisition and removal of structures from flood-prone areas. Efforts should be made to support this program.	Stormwater runoff Non-point source pollution	5-32
R5.20	**Fund Studies to Document Watershed Condition and Resources**	Watershed management should be based on sound scientific principles and reliable field data. Studies should be conducted to document watershed resources including detailed water budgets, water quality trends, land cover changes, extent of riparian disturbance, wetland disturbance, and other characteristics.	Stormwater runoff Non-point source pollution Point source pollution Habitat quality Water supply	5-32

Code	*Recommendation*	*Summary Description*	*Issues Addressed*	*Page*
R5.21	**Support Studies to Assess the Impacts of Mineral Extraction on Water Quality and Quantity**	For mining operations in the watershed, there may be potential metals and sediment impacts on adjacent streams; when closed down, there may be potential groundwater/hydrology impacts. In order to better understand both water quality and water quantity issues in the watershed, these impacts should be assessed.	Point source pollution Habitat quality Water supply	5-33
R5.22	**Complete Comprehensive Water Budget Studies for the 37 Subwatersheds in the Schuylkill Drainage**	Follow-up studies to the current source water assessment (SWA) should conduct combined surface and ground water studies to generate watershed-based water budgets, so that a prioritized strategic plan of action can be developed to preserve the watershed's water resources. The cumulative impacts of water withdrawal, discharge, transfers out of the watershed and recharge also should be considered.	Stormwater runoff Non-point source pollution Point source pollution Habitat quality Water supply	5-33
R5.23	**Support Cost-Effectiveness Studies on Treating Point Versus Non-Point Source Pollution Impacts**	The current SWA, or follow-up studies, should prioritize which water pollution issues to address first in terms of cost-effectiveness. Subwatershed-based cost-benefit analysis of treating point versus non-point source pollution impacts should direct strategic action on pollution treatment in the watershed.	Stormwater runoff Non-point source pollution Point source pollution Habitat quality Water supply	5-33
R5.24	**Support Cumulative Impact Assessments for Point and Non-point Source Pollution**	The current SWA, or follow-up studies, should assess the cumulative impacts of point and non-point pollution, and if possible, also assess the cumulative water extraction, discharge and recharge effects on a subwatershed basis across the entire watershed.	Stormwater runoff Non-point source pollution Point source pollution Habitat quality Water supply	5-33
R5.25	**Support Outreach Phase for Implementation of the Schuylkill Source Water Assessment (SWA)**	The current SWA should be implemented through a follow-up outreach phase that ensures the guidelines it provides are adopted by municipalities, point-source facilities, nonprofits and citizens where necessary adopted throughout the watershed. This assessment should be done on a subwatershed basis to facilitate implementation.	Stormwater runoff Non-point source pollution Point source pollution Habitat quality Water supply	5-34

5.3 Pennsylvania DEP Water Quality Assessment

The term "water quality" has meaning only in the context of how that water is used. For example, good quality irrigation water might be poor quality drinking water. Use designations for surface waters are set by the State, and are generally assigned according to the type of aquatic communities or human needs supported. **Table 5.1** lists the designated water uses found in the Schuylkill River watershed. Anti-degradation requirements under the Pennsylvania Code, Chapter 93.4a(b), require that the level of water quality necessary to protect existing uses be maintained. Chapter 93.4b of the Pennsylvania Code also establishes criteria for special protection of water designated as High Quality and Exceptional Value waters. High Quality waters include streams with excellent water quality or aquatic communities. Exceptional Value waters include waters of exceptional ecological significance, or waters meeting High Quality criteria that occur in areas such as state or county parks and forests, wildlife refuges, "wilderness trout streams," or that are of exceptional recreational significance. High Quality and Exceptional Value waters are protected under the anti-degradation requirements in Pennsylvania Code, Chapter 93.4a(c) and 93.4a(d), respectively.

Table 5.1 Designated Water Uses in the Schuylkill River Watershed

Abbreviation	***Use***
WWF	Warm Water Fishes
CWF	Cold Water Fishes
MF	Migratory Fishes
TSF	Trout Stocking
EV	Exceptional Value
HQ	High Quality

In the Schuylkill River watershed, the majority of streams are protected either as Cold Water Fisheries (48%), or Warm Water Fisheries (28%). Exceptional Value streams include sections of Valley Creek in Chester County; Sacony, Hay, Pine, and Furnace Creeks in Berks County; Rattling Run in Schuylkill County; and several other small headwater streams throughout the watershed. High Quality streams include the Pickering and French Creeks in Chester/Montgomery Counties. A complete listing of the designated uses of rivers and streams in the Schuylkill River watershed are in **Reference Table 5A: Water Uses Protected in the Schuylkill River Watershed** in the online Reference Documents.

Section 305(b) of the federal Clean Water Act requires that States submit a Water Quality Assessment Report to the US Environmental Protection Agency (US EPA) every two years. The Pennsylvania 305(b) Water Quality Assessment provides a summary of water quality management programs including water quality standards, and point and non-point source pollution control measures. It also presents a summary of waters attaining and not attaining designated aquatic life uses, and the Pennsylvania Department of Environmental Protection's (PA DEP) plan for achieving a comprehensive assessment of flowing waters. Under section 303(d) of the Act, States are required to provide a list of streams or rivers that would not support their designated use even after required water pollution control technologies have been applied, the source and cause of impairment, a priority ranking, and whether a total maximum daily load (TMDL) is required.

A TMDL is a calculation of the maximum amount of a pollutant a water body can receive and still meet its designated use, and an allocation of that amount to various point and non-point pollution sources. The calculation must include a margin of safety to ensure that the water body can meet certain uses designated by the State, and must account for seasonal variation in water quality. Point source TMDLs are implemented through the NPDES permit process, and for non-point sources, Best Management Practices (BMPs) are employed to address the impairment (US EPA 1991; http://www.dep.state.pa.us). In Pennsylvania, the agency responsible for conducting these studies is the Department of Environmental Protection.

The draft Year 2000 Pennsylvania 303(d) impaired waters list is shown graphically in the map: **303(d) Impaired Waters** (adapted from http://www.dep.state.pa.us), and in table format in **Reference Table 5B: Impaired Streams in the Schuylkill River Watershed** in the online Reference Documents. As of December

2000, roughly 70 percent of the streams within the watershed have been assessed. The most common source of impairment in the urban/suburban zone of the southeastern portion of the watershed is urban stormwater runoff leading to problems with pathogens, flow variability, and nutrients. In the northwest portion of the watershed, the major source of impairment is acid mine drainage and metals contamination. Other threats to water quality include agricultural non-point source pollution, wastewater discharges, and toxic leaks and spills.

5.4 Water Quality Monitoring

This section presents a summary of selected water quality monitoring data. An annotated bibliography of other studies and reports addressing water quality issues in the Schuylkill River watershed is included in the online Reference Documents as **Annotated Bibliography of Water Quality References**.

5.4.1 Water Quality Sampling Data

Water quality varies naturally among different streams, at different positions along a single stream, during runoff events, and seasonally during the year. When watersheds are impacted by human activities, water quality can also vary due to point source discharges, non-point source runoff, and general changes in land use and land cover. To accurately assess water quality within a watershed, monitoring networks must capture the full range of spatial and temporal variability. In the Schuylkill River watershed, water quality data are available for a number of locations and parameters, but generally do not adequately reflect the seasonal and/or spatial variability within the watershed.

The majority of publicly available, compiled water quality data for the Schuylkill River watershed are archived in the US EPA STORET (STOrage and RETrieval) database (http://www.epa.gov/storet/). The STORET database contains water quality data from federal, state, and local agencies, and from several non-governmental organizations. The most common parameters sampled in the Schuylkill River watershed are forms of the nutrients nitrogen (N) and phosphorus (P), but other data such as measurements of pH, conductivity, temperature, turbidity, and metals are available in lesser amounts. It should be noted that the quality of STORET data varies with the source agency or group, and that data not properly validated should be considered only as approximate values. Additional water quality data from government agencies, private industries, water providers, and research institutions may exist within the watershed, but are either not publicly accessible, or the data is not entered and compiled in a digital format.

The following sections provide a summary of nitrogen and phosphorus data collected from surface water and groundwater in the Schuylkill River watershed from 1985 to 1998 based on STORET data. Nitrogen and phosphorus are emphasized due to the relatively large amount of these data available, the importance of nutrient loading to stream health throughout the watershed, and because high levels of these parameters are good indicators of other forms of pollution. High nutrient loading is generally associated with point source discharges such as wastewater treatment plants, concentrated nutrient sources such as animal feed lots and leaking septic systems, and non-point source inputs from agricultural fertilizers, urban runoff, and other sources.

High concentrations of nitrogen and phosphorus nutrients in streamflow are not directly harmful to aquatic life, but can promote excessive growth of algae resulting in oxygen depletion, fish kills, and other ecological impacts in lakes and larger rivers. Although there is currently no aquatic life standard for nitrogen or phosphorus, nutrient criteria are being developed by the US EPA. The drinking water standard for nitrate nitrogen is 10 mg/L as N.

In southeastern Pennsylvania, naturally occurring nitrogen concentrations vary considerably among different streams and throughout the year, but dissolved nitrogen concentrations (sum of nitrate, nitrite and ammonium) greater than about 3 to 5 mg/L as N are considered high (Velinsky et al. *unpublished data*). In general, the productivity of most freshwater ecosystems is limited by dissolved phosphorus. Dissolved phosphorus (phosphate) concentrations of approximately 0.05 to 0.10 mg/L as P are likely to stimulate algae growth and eutrophication in lakes and large, slow-moving rivers. Smaller streams with fast currents, rocky sediments, and diverse assemblages of algae-grazing invertebrates can generally withstand higher levels of dissolved phosphorus.

5.4.1.1 Surface Water

The STORET database includes nitrogen and phosphorus samples from a number of streams during the period from 1985 to 1998 but generally the data are not well distributed throughout the watershed or over time. The areas best represented spatially are the French Creek and Valley Creek subwatersheds, yet many of these sites were sampled only 1-2 times during this period. The areas best represented over time are the main tributaries and mainstem Schuylkill River.

Average values for the total nitrogen concentrations for the Schuylkill River subwatersheds are shown graphically in the map: **Stream Nitrate-Nitrogen**, and the map: **Stream Ammonium-Nitrogen**. Values for the minimum, maximum, average, and median nitrogen concentrations as nitrite+nitrate (NO_2+NO_3) and ammonia+ammonium (NH_3+NH_4) for each sampling location are listed in **Reference Table 5C: Stream Nitrogen Concentrations in the Schuylkill River Watershed** in the online Reference Documents. Average ammonia+ammonium concentrations ranged from less than 0.01 mg/L as nitrogen (N) to greater than 1.0 mg/L as N, with the highest concentrations occurring in Valley Creek and the mainstem Schuylkill River. Average nitrite+nitrate concentrations ranged from about 1.5 to 3.0 mg/L as N, with the highest concentrations also in Valley Creek and the mainstem Schuylkill River.

Average values for the total phosphorus concentrations for the Schuylkill River subwatersheds are shown graphically in the map: **Stream Dissolved Phosphorus**. Minimum, maximum, average, and median dissolved phosphorus concentrations values for each sampling location are listed in **Reference Table 5D: Stream Phosphorus Concentrations in the Schuylkill River Watershed** in the online Reference Documents. Average dissolved phosphorus concentrations ranged from less than 0.01 to greater than 0.20 mg/L as P, with the greatest concentrations occurring in the mainstem Schuylkill River. Average total phosphorus concentrations ranged from about 0.02 to greater than 1 mg/L as P, with relatively high concentrations measured at Skippack Creek, Wissahickon Creek, and the mainstem Schuylkill River.

5.4.1.2 Groundwater

Groundwater is an integral part of the water cycle, and should not be considered as separate from surface water. Any contamination of groundwater has the potential to cause contamination of surface waters and degradation of aquatic ecosystems.

The STORET database contains nitrogen and phosphorus samples from a number of wells located throughout the Schuylkill River watershed between 1985 to 1998. Approximately 90 percent of groundwater samples were taken from residential wells, with the remaining samples taken from schools, country clubs, water authorities, and quarries. Similar to surface water, groundwater was not consistently sampled throughout the watershed and over time. Approximately 40 percent of groundwater locations were sampled only 1-2 times, and are of limited value in assessing long term concentrations.

Average values for groundwater nitrogen concentrations in Schuylkill River subwatersheds are shown graphically in the map: **Groundwater Nitrate-Nitrogen**. Minimum, maximum, average, and median concentrations of nitrite+nitrate (NO_2+NO_3) and/or dissolved and total ammonia+ammonium (NH_3+NH_4) values for each well sampling location are listed in **Reference Table 5E: Groundwater Nitrogen Concentrations in the Schuylkill River Watershed** in the online Reference Documents. Average values for dissolved and/or total ammonia+ammonium were generally between 0.01 and 0.10 mg/L as N. Average nitrite+nitrate concentrations ranged from about 0.10 to 10 mg/L as N.

Average values for groundwater phosphorus concentrations in Schuylkill River subwatersheds are shown graphically in the map: **Groundwater Dissolved Phosphorus**. Values for the minimum, maximum, average, and median concentrations of dissolved and total phosphorus concentrations at each well sampling location are listed in **Reference Table 5F: Groundwater Phosphorus Concentrations in the Schuylkill River Watershed** in the online Reference Documents. Average dissolved phosphorus concentrations ranged from 0.02 to 0.14 mg/L as P. Most average total phosphorus concentrations were between about 0.02 and 0.10 mg/L as P, with a only few sites outside this range.

5.4.1.3 Trends in Surface Water Quality

Long-term data are available for only 6 locations on the mainstem Schuylkill River and main tributaries, which have been used to evaluate trends in the various forms of nitrogen, phosphorus, and chloride from 1984 to 1995 (Evans et al. 1996). Trend analyses were conducted for measured concentrations, flow-adjusted concentrations (determined using relationships between concentration and streamflow rates), and daily mass loads.

Results for the mainstem Schuylkill River at Philadelphia and Pottstown indicate that from 1984 to 1995 at both locations there was a significant downward trend with seasonal dependence for total ammonium-nitrogen, a slight upward trend with a strong seasonal dependence for nitrate-nitrogen, and a significant downward trend for total phosphorus (Evans et al. 1996). The decrease in phosphorus levels may be due to the ban on phosphate detergents in the mid- to late 1980s.

Like nitrogen and phosphorus, dissolved chloride concentrations are a good indicator of water quality degradation. Dissolved chloride showed no consistent trend at either of these locations during the period from 1984 to 1988 (Evans et al. 1996). At the Philadelphia location, however, data collected as early as 1842 suggest significant changes in chloride concentrations have occurred over longer periods of time. Chloride concentrations increased from approximately 2-3 mg/L in the middle 1800s to as high as 82 mg/L in 1999 (Keighton 1968; Evans et al. 1996; Velinsky et al. *unpublished data*). The specific causes of elevated chloride concentrations are not known, but are likely to include wastewater and other discharges, agricultural and urban runoff, and the winter application of road salts.

5.4.1.4 Recommendations for Water Quality Monitoring

Code	***Recommendation***	***Summary Description***	***Priority Area/Target Subwatershed***
R5.1	**Establish a Coordinated, Watershed-wide Monitoring Program with Quality Control Protocols**	EPA, the state and key nonprofits should design a comprehensive watershed-wide monitoring program, providing training for citizen monitoring groups, and with certification protocols to ensure reliable data.	All Zones (Refer to **Section 6.5** in *Chapter 6.0* and **Sustainable Landscape Vision** map for a description of Zones)

5.5 Watershed Analysis and Modeling

Water quality is influenced by natural characteristics of the watershed together with human factors such as point and non-point source pollution, land cover changes, the presence of dams, road crossings, and other stream and watershed disturbances. Various landscape, hydrologic, and human influences that affect water quality in the Schuylkill River watershed were characterized using existing spatial data sets and landscape based water quality modeling. The analysis was conducted according to the 37 Schuylkill River subwatersheds shown in the map: **Watershed Orientation**. As discussed in **Section 3.1 Watershed Location** of *Chapter 3.0 Watershed Characterization* of this Plan, these 37 subwatersheds were defined within the Schuylkill River watershed at a scale small enough to allow meaningful comparisons while not exceeding the resolution of the data. The approximate size of each subwatershed is 125 square kilometers or 12,500 hectares (about 31,000 acres). Note that recommendations for the water quality analysis, including those in *Section 5.4* above, make reference to Agricultural, Urban and Suburban Zones as identified in relation to land cover in **Section 6.5 Subwatershed Analysis** *in Chapter 6.0 Promoting a Sustainable Landscape*. These zones also are displayed graphically in the map: **Sustainable Landscape Vision**.

The following sections describe various watershed characteristics that influence water quality in each of the Schuylkill River subwatersheds, and lists recommendations for reducing or minimizing the impacts of each. Results are presented using maps where numerical values or scores for each subwatershed are classified into quintiles (1/5 of the subwatersheds are contained in each category), and each subwatershed is color coded from blue to brown to show relative condition. Note that the nutrient and sediment loading calculations presented for each subwatershed do not include loading from upstream subwatersheds. Accordingly, subwatersheds with low loadings may experience high nutrient or sediment levels if they are downstream of subwatersheds with high loadings. The purpose of this analysis is to provide a watershed-wide assessment to help target areas within the watershed that contribute most to water quality impairment and associated stream degradation. To identify all the known sources and causes of pollution in any given subwatershed, additional research and modeling is required.

5.5.1 Watershed Land Cover

Watershed land cover has a significant influence on the hydrologic characteristics of the watershed, and is the predominant factor influencing non-point source pollution loading. A land cover data layer for the Schuylkill River watershed was compiled and classified by the Multi-Resolution Land Characteristics Interagency Consortium (MRLC) using LANDSAT Thematic Mapper satellite imagery from 1991-1993 (Vogelmann et al. 1998). The satellite imagery has a resolution of 30 meters, meaning that the landscape is aggregated into 900 square meter blocks – i.e., each block or grid cell in the satellite scene contains a single land cover value for an area measuring 30m by 30m. The satellite data layer was classified into fifteen land cover categories following Anderson et al. (1976).

Land cover for the Schuylkill River watershed is displayed in the map: **Regional Land Cover**. Specific percentages of forested land, agricultural land, and urban/residential land for each of the 37 Schuylkill River subwatersheds are listed in **Reference Table 5G: Percent of Land Cover Within Each Subwatershed of the Schuylkill River** in the online Reference Documents. Forested lands are most prevalent in the upper northwestern part of the watershed (West Branch Schuylkill River, Schuylkill River Headwaters, Upper Little Schuylkill River, Lower Little Schuylkill River, and Schuylkill River 8 subwatersheds). This also is the area of highest elevation in the watershed. Agriculture is most concentrated in a band across northern Berks County, and is otherwise dispersed throughout the middle and lower portions of the watershed (Upper Tulpehocken, Little Northkill/Northkill Creek, Schuylkill River Mainstem 7, Middle and Lower Tulpehocken, Lower Maiden Creek, and Sacony Creek subwatersheds). Urban/residential land use is greatest in and around the cities of Reading and Philadelphia. Because the MRLC land cover data was compiled around 1991-1993, while significant development has occurred in many parts of the watershed since then, the percentages for urban/residential land use should be considered lower-end values.

5.5.2 Impervious Cover

5.5.2.1 Background

Impervious cover refers to the area of land covered by roads, rooftops, parking lots, and other surfaces that do not allow the infiltration of water into the soil. Impervious cover has a significant impact on the hydrology of watersheds, and runoff from impervious surfaces can be a significant source of stormwater-related habitat degradation and non-point source pollution. The MRLC land cover data does not directly quantify impervious cover, but includes estimates for the amount of impervious cover within each of the urban/residential land use categories (Anderson et al. 1976). Estimates of the percent impervious cover for each of the Schuylkill River subwatersheds were made by choosing the average percent impervious value for each of the MRLC urban/residential land cover categories, multiplying by the amount of land area in each category, and summing the results. **Table 5.2** shows the estimates for percent impervious cover based on MRLC land cover type. The percent impervious cover for the 37 Schuylkill River subwatersheds is shown graphically in the map: **Impervious Cover**. The map resembles the percent urban/residential land cover because the calculations were based on the MRLC land cover data.[1]

Table 5.2 Estimated Percent Impervious Covers for MRLC Land Cover Categories

MRLC Land Cover Type	*% Impervious Assumed by MRLC*	*% Value Used for Calculations*
Low Intensity Developed	50-80	65
High Intensity Residential	80-100	90
High Intensity Commercial/Industrial	80-100	90

The amount of impervious cover in a watershed has been recognized as a key indicator of stream degradation in urban watersheds (Schueler 1998). As development expands, measures should be taken to control and mitigate the impacts of stormwater runoff and associated non-point source pollution. As a guide to assessing the impacts of urban/suburban development on streams, a "Rapid Watershed Assessment" method has been developed by the Center for Watershed Protection. For more information on this method, see the US EPA and Center for Watershed Protection's web page, *Stormwater Managers Resource Center* (http://www.stormwatercenter.net).

1 MRLC provides the following description of developed land cover classes for areas with a high percentage (>30%) of constructed materials. *Low Intensity Residential* includes areas with a mixture of constructed materials (30-80%) and vegetation (20-70%). *High Intensity Residential* includes highly developed areas with a high percentage of constructed materials (80-100%) and low vegetation cover (20%). *Commercial/Industrial* includes infrastructure and all highly developed areas not classified as High Intensity Residential. For more information: http://www.epa.gov/mrlc/classes.html.

5.5.2.2 Recommendations for Impervious Cover

Code	*Recommendation*	*Summary Description*	*Priority Area/ Target Subwatersheds*
R5.2	**Implement Urban Best Management Practices to Maximize the Infiltration of Water and Reduce Urban Non-point Source Pollution**	Urban Best Management Practices such as reduction of impervious surfaces, infiltration and sedimentation basins, and street sweeping should be implemented to decrease water quality and habitat problems associated with stormwater runoff, and to increase groundwater recharge.	Urban / Suburban Zone Schuylkill River 2 Upper Wissahickon Creek Sandy Run Lower Wissahickon Creek Schuylkill River 1 Schuylkill River Tidal Schuylkill River 6

5.5.3 Runoff as a Percent of Precipitation

5.5.3.1 Background

The amount of runoff produced by a watershed is a function of climate, physiography, vegetation, and human disturbance of the landscape. In general, steep watersheds with shallow soils and sparse vegetation will generate more runoff than less steep watersheds with deep soils and abundant vegetation. Human disturbances such as impervious cover and other soil and vegetation disturbance will result in greater amounts of runoff. Watersheds with high amounts of runoff are generally more susceptible to non-point source pollution, and potentially at greater risk of flooding. As a simple measure of the runoff characteristics of each subwatershed, annual runoff as a percent of annual precipitation was determined by averaging land cover based runoff coefficients within each subwatershed (National Climate Data Center 1998). Results are shown by subwatershed in the map: **Runoff**.

Runoff as a percent of precipitation is greatest in the southeast part of the watershed where impervious coverage is greatest. Significantly lower percentages are indicated for the northern subwatersheds where there is more forest cover, such as Lower Little Schuylkill River and Upper Maiden Creek subwatersheds. The mostly agricultural mid-section of the watershed falls in between these extremes. High amounts of storm runoff can occur from cropland, especially from row crops where infiltration rates may be low due to soil disturbance. As mentioned previously, the effects of increased runoff associated with impervious coverage and stormwater runoff can be a significant source of habitat degradation and non-point source pollution. As the human population increases and development expands within the watershed, measures should be taken to control and mitigate the impacts of stormwater runoff.

5.5.3.2 Recommendations for Runoff as a Percent of Precipitation

Code	*Recommendation*	*Summary Description*	*Priority Area/ Target Subwatersheds*
R5.2	**Implement Urban Best Management Practices to Maximize the Infiltration of Water and Reduce Urban Non-point Pollution**	Urban Best Management Practices such as reduction of impervious surfaces, infiltration and sedimentation basins, and street sweeping should be implemented to decrease water quality and habitat problems associated with stormwater runoff, and to increase groundwater recharge.	Urban/Suburban Zone Schuylkill River 2 Upper Wissahickon Creek Sandy Run Lower Wissahickon Creek Schuylkill River 1 Schuylkill River Tidal Schuylkill River 6

5.5.4 Roads and Road/Stream Crossings

5.5.4.1 Background

Roads and road/stream crossings can have a significant impact on the hydrology and water quality of rivers and streams. Stormwater runoff from roads adjacent to streams can transport contaminants such as sediment, salts, oils, and pesticides used along the road edges. Roads also are corridors where significant amounts of trash and litter accumulate which can be washed into streams during storm events. Where roads cross streams, culverts or bridges can alter the channel size, shape, and/or gradient leading to channel erosion and scour.

As a general measure of stream disturbance due to roads, the number of road/stream crossings was determined for each of the 37 Schuylkill River subwatersheds by overlaying road and stream geographic information system (GIS) data layers. Results of this analysis are shown in the map: **Road/Stream Crossings**. The analysis does not account for the impacts of roads adjacent to but not crossing a stream. To minimize the impacts of roads and road crossings, riparian buffers should be maintained between roads and streams. Culverts and bridges should also be regularly cleaned and maintained, and sized to adequately convey both low flow and storm runoff events.

5.5.4.2 Recommendations for Roads and Road/Stream Crossings

Code	***Recommendation***	***Summary Description***	***Priority Area/ Target Subwatersheds***
R5.7	**Protect and Restore Riparian Forest Buffers**	Riparian buffers function in a variety of ways to maintain the health of stream systems, and should be protected and restored whenever possible.	All Zones
R5.15	**Size and Maintain Culverts and Bridges to Ensure Minimal Impact to Streams**	Culverts and bridges should be sized and located to adequately convey both low flow and storm events. Structures must also be properly maintained and inspected to prevent obstruction, scour and erosion.	All Zones Schuylkill River Headwaters Schuylkill River 8 Ontelaunee/Kistler Creek Sacony Creek Upper Perkiomen Creek East Branch Perkiomen Creek Skippack Creek Schuylkill River 5

5.5.5 Effects of Dams

5.5.5.1 Background

There are approximately 280 dams in the Schuylkill River watershed. Although providing a number of benefits such as flood control and recreation, dams also can cause significant ecological effects (Collier et al. 1996). Dams can adversely affect the health of rivers and streams by altering flow regimes, changing water temperature and chemistry, modifying algae and macroinvertebrate communities, disrupting resident and migratory fish communities, altering channel geomorphology and sediment transport, and impacting physical habitat. In other cases, dams may provide ecological benefits such as trapping sediment or maintaining wetlands.

The number and location dams in the Schuylkill River watershed was obtained from the Pennsylvania DEP Pennsylvania Dams GIS data layer. The number of dams in each Schuylkill River subwatershed is shown in the map: **Number of Dams**. Dam locations are shown in the map: **Dam Locations**. Dam removal should be considered where restoration benefits outweigh present uses and other effects of dams or dam removal.

5.5.5.2 Recommendations for Dams

Code	*Recommendation*	*Summary Description*	*Priority Area/ Target Subwatersheds*
R5.16	**Conduct Inventories and Studies to Identify and Remove Dams Where Restoration Benefits Outweigh Present Uses and Effects**	Dams can provide benefits, but also cause a broad range of negative ecological impacts. Inventories and studies should be conducted to determine where dams are on the Schuylkill River and if they should be removed. The benefits of removal (restoration of stream habitat, fish passage, and water quality) may outweigh present uses and/or effects. Where dam removal does not have overall benefits, construction of fish ladders should be studied and implemented where possible.	All Zones

5.5.6 Nitrogen and Phosphorus from Land Cover

5.5.6.1 Background

The nutrients nitrogen and phosphorus are important regulators of stream productivity. When present in high concentrations, these nutrients can cause over-production and result in harmful algae blooms leading to dissolved oxygen depletion and associated ecological impacts (eutrophication). Stream productivity is particularly sensitive to dissolved phosphorus concentrations. Non-point source nitrogen and phosphorus loads for each subwatershed were calculated using export coefficients based on MRLC land cover types. Export coefficients were chosen based on a literature survey of the most appropriate values for the Schuylkill River watershed (Reckhow et al. 1980; Beaulac and Reckhow 1982; Frink 1991; The Cadmus Group 1998). The use of export coefficients is a simple way to estimate relative nitrogen and phosphorus contributions over large areas. Estimates should not be considered exact values, do not necessarily reflect in-stream concentrations, and should be used only to make relative comparisons of nutrient loading from land cover in different parts of the watershed. The following formula was used for calculating annual nitrogen and phosphorus loads from land cover:

Annual Load (kg/ha) = Land Use within Subwatershed (ha) * Export Coefficient (kg/ha/yr)

The nitrogen and phosphorus export coefficients assigned to each land cover category are shown in **Table 5.3**. Land cover characteristics for each subwatershed were determined from the MRLC land cover data set. See the MRLC website (http://www.epa.gov/mrlc/classes.html) for detailed definitions of these land cover classes.

Table 5.3 Export Coefficients for Nitrogen and Phosphorus

Land Cover	*Nitrogen Export Coefficient (kg/ha/yr)*	*Phosphorus Export Coefficient (kg/ha/yr)*	*Source*
Water	0.00	0.00	Reckhow, et al. 1980
Urban	5.50	1.10	Reckhow, et al. 1980
Hay/Pasture	5.19	0.81	Reckhow, et al. 1980
Row Crops	9.00	2.24	Reckhow, et al. 1980
Lawns/Golf courses	1.52	0.19	Reckhow, et al. 1980
Forest	2.46	0.21	Reckhow, et al. 1980
Wetlands	0.55	0.01	The Cadmus Group 1998
Strip mines/Barren land	8.60	1.50	The Cadmus Group 1998

The estimated nitrogen loads from land cover for each of the 37 Schuylkill River subwatersheds are shown in the map: **Nitrogen from Land Cover**. Subwatersheds with the most agriculture show the highest loadings because of the high export coefficients for agriculture. These subwatersheds are located primarily in the agricultural areas in and around northern Berks County (Upper Tulpehocken, Little Northkill/Northkill Creek, Schuylkill River Mainstem 7, Middle and Lower Tulpehocken, Lower Maiden Creek, and Sacony Creek). The East Branch of the Perkiomen Creek also shows a high level of nitrogen loads. The heavily forested areas in the northwestern part of the watershed show the lowest nitrogen loads due to the low export coefficient associated with forested land cover.

The estimated phosphorous loading from each of the 37 Schuylkill River subwatersheds is shown in the map: **Phosphorus from Land Cover**. Like nitrogen, subwatersheds with high agricultural land cover show relatively high phosphorous loadings, and subwatersheds with more forested land show the lowest phosphorus loadings. Note that results from this analysis reflect only loadings from within a given subwatershed, and do not account for the impact of nitrogen and phosphorus loading from upstream subwatersheds.

5.5.6.2 Recommendations for Nitrogen and Phosphorus from Land Cover

Code	*Recommendation*	*Summary Description*	*Priority Area/ Target Subwatersheds*
R5.2	**Implement Urban Best Management Practices to Maximize the Infiltration of Water and Reduce Urban Non-point Source Pollution**	Urban Best Management Practices such as reduction of impervious surfaces, infiltration and sedimentation basins, and street sweeping should be implemented to decrease water quality and other problems associated with stormwater runoff, and to increase groundwater recharge.	Urban/Suburban Zone Schuylkill River 2 Upper Wissahickon Creek Sandy Run Lower Wissahickon Creek Schuylkill River 1 Schuylkill River Tidal Schuylkill River 6
R5.4	**Implement Nutrient Management Practices**	Sound Nutrient Management Practices such as soil and manure testing can help minimize the amount of fertilizer entering streams. These practices should also be implemented in suburban and urban areas where fertilizer is used.	Agricultural Zone Urban/Suburban Zones Upper Tulpehocken Creek Lower Tulpehocken Creek Little Northkill/Northkill Cr. Schuylkill River 7 Lower Maiden Creek Sacony Creek East Branch Perkiomen Cr.

Code	*Recommendation*	*Summary Description*	*Priority Area/ Target Subwatersheds*
R5.5	**Implement Agricultural Best Management Practices**	Agricultural Best Management Practices such as no-till planting, contour plowing, and stream bank fencing can help reduce the amount of nutrient and sediment pollution entering streams.	Agricultural Zone Upper Tulpehocken Creek Lower Tulpehocken Creek Little Northkill/Northkill Cr. Schuylkill River 7 Lower Maiden Creek Sacony Creek
R5.6	**Implement Timber Harvesting Best Management Practices**	Timber harvesting Best Management Practices such as proper road construction and preservation of riparian buffers should be used to reduce the amount of sediment and nutrients entering streams.	Habitat Zone
R5.7	**Protect and Restore Riparian Forest Buffers**	Riparian buffers function in a variety of ways to maintain the health of stream systems, and should be protected and restored whenever possible.	All Zones
R5.8	**Protect and Restore Wetlands and Areas of Hydric Soils**	Wetlands provide many benefits including the regulation of stormwater runoff, water quality improvements, and unique and important habitat. Efforts should be made to protect and restore wetlands throughout the watershed. Areas of hydric soils may offer the best potential for wetland restoration.	All Zones

5.5.7 Nitrogen from Septic Systems

5.5.7.1 Background

Failing or improperly maintained septic systems can be a significant source of nitrogen loading to streams, and are not included in the estimates of nitrogen loads from land cover based on export coefficients. Nitrogen contributions from septic systems were assessed using the methodology outlined by Nizeyimana et al. (1996) in their statewide analysis of Pennsylvania. U.S. Census data were used to obtain the number of households and number of people within each census tract using septic systems for wastewater disposal. Census data were then combined with information on soil permeability and limitations for septic systems, and the expected annual nitrogen load for each subwatershed from failing septic systems was calculated. Soils data were obtained from the Pennsylvania STATSGO data set, and the analysis was conducted using a GIS. The estimated nitrogen loads from septic systems in each of the Schuylkill River subwatersheds are shown in the map: **Nitrogen from Septic Systems**. Note that results from this analysis reflect only loadings from within a given subwatershed, and do not account for the impact of nitrogen and loadings from septic systems in upstream subwatersheds. Results therefore should be used only to make relative comparisons of nutrient loading from septic systems among different subwatersheds.

5.5.7.2 Recommendations for Nitrogen from Septic Systems

Code	*Recommendation*	*Summary Description*	*Priority Area/ Target Subwatersheds*
R5.14	**Establish Septic Education, Registration, Inspection, and Maintenance Programs**	Septic programs would instruct owners about proper care and maintenance of septic systems, and should provide homeowners with a method for testing their septic systems.	All Zones Unami Creek East Branch Perkiomen Creek Skippack Creek Lower Perkiomen Creek Swamp Creek Lower Manatawny Creek Schuylkill River 3

5.5.8 Sediment from Land Cover

5.5.8.1 Background

Non-point source sediment loading from each subwatershed was calculated using the Universal Soil Loss Equation (USLE) developed by the USDA Agricultural Research Station. This method is widely used to predict the amount of soil loss by surface erosion (Brooks et al. 1991, Wishmeier and Smith, 1978). The basic USLE equation is:

$$\mathbf{A = R * K * (LS) * C * P}$$

where **A** = computed soil loss;
R = rainfall erosivity;
K = soil erodibility factor;
(**LS**) = topographic factor;
C = cropping management factor; and
P = conservation practice factor.

Data for the USLE were compiled from standard R-factor maps in Haan et al. (1994), the state STATSGO soil survey, a digital elevation model (DEM) for the Schuylkill River watershed, and county cropping factors (Hamlett et al. 1992). The conservation practice factor (P) was assumed to be equal to 1 for all subwatersheds. A conservation practice factor of 1 assumes no reduction in soil erosion from agricultural areas due to the use of erosion control techniques. Accordingly, if there are subwatersheds where erosion control techniques are widespread, the USLE estimates may be high for these subwatersheds.

The USLE calculates the total sediment loss from particular parcel of land, but does not account for sediment that may be "trapped" or re-deposited before reaching a stream. Therefore, total sediment loads to streams were calculated using the computed soil loss together with a trapping factor which accounts for the slope of the land, distance to the closest water body, and the type of land cover (Reckhow 1988). The estimated total annual sediment loading to streams from each of the subwatersheds is shown in the map: **Sediment from Land Cover**. Sediment loading is highest in agricultural subwatersheds, and lowest in subwatersheds with the most forested lands. Note that results from this analysis reflect only loadings from within a given subwatershed, and do not account for the impact of sediment loadings from upstream subwatersheds. Results therefore should be used only to make relative comparisons of sediment loading among different subwatersheds.

It is also important to note that sediment loading due to construction and other localized disturbance is not included in these estimates. Sediment loading from soil disturbance at construction sites can contribute considerable amounts of sediment to streams, especially in rapidly developing subwatersheds. The estimates based on USLE also do not account for sediment loading associated with channel bed and bank erosion, which may be significant in developing areas and in areas where riparian vegetation has been disturbed. Accordingly, although not shown in this analysis, sediment loading may be high in subwatersheds where construction, channel bed and bank erosion, or disturbance of riparian vegetation is common.

5.5.8.2 Recommendations for Sediment from Land Cover

Code	*Recommendation*	*Summary Description*	*Priority Area/ Target Subwatersheds*
R5.2	**Implement Urban Best Management Practices to Maximize the Infiltration of Water and Reduce Urban Non-point Source Pollution**	Urban Best Management Practices such as reduction of impervious surfaces, infiltration and sedimentation basins, and street sweeping should be implemented to decrease water quality and habitat problems associated with stormwater runoff, and to increase groundwater recharge.	Urban/Suburban Zone
R5.5	**Implement Agricultural Best Management Practices**	Agricultural Best Management Practices such as no-till planting, contour plowing, and stream bank fencing can help reduce the amount of nutrient and sediment pollution entering streams.	Agricultural Zone Upper Tulpehocken Creek Ontelaunee/Kistler Creek Upper Maiden Creek Sacony Creek
R5.6	**Implement Timber Harvesting Best Management Practices**	Timber harvesting Best Management Practices such as proper road construction and preservation of riparian buffers can reduce the amount of sediment and nutrients entering streams.	All Zones
R5.7	**Protect and Restore Riparian Forest Buffers**	Riparian buffers function in a variety of ways to maintain the health of stream systems, and should be protected and restored whenever possible.	All Zones
R5.8	**Protect and Restore Wetlands and Areas of Hydric Soils**	Wetlands provide many benefits including the regulation of stormwater runoff, water quality improvements, and unique and important habitat. Efforts should be made to protect and restore wetlands throughout the watershed. Areas of hydric soils may offer the best potential for wetland restoration.	All Zones
R5.9	**Identify and Enforce Sediment and Erosion Control Problems and Violations**	Construction sites contribute a significant amount of sediment to receiving waters. Procedures for monitoring compliance with existing laws should be maintained. Volunteers can be trained to help monitor for existing and potential problems.	All Zones

5.5.9 Nitrogen and Phosphorous from Sewage Treatment Plants

5.5.9.1 Background

Sewage treatment plants (STPs) typically receive wastewater, provide treatment, and discharge the treated effluent to nearby streams. Standard treatment methods (primary or secondary treatment) remove most of the suspended solids and pathogens in raw wastewater, but even with secondary treatment less than half of the nitrogen and phosphorous are removed. Higher level or tertiary treatment can effectively remove much of the remaining nutrients, but many STPs do not have the facilities or funding to perform this level of treatment. Although regulated by the EPA National Pollutant Discharge Elimination System (NPDES) permit program, wastewater discharges can impact streams locally below discharge outlets. The influence of STP effluent on streams depends on the volume and concentration of effluent discharged, and the flow characteristics of receiving waters. As wastewater discharges are relatively constant throughout the year, water quality impacts are most pronounced during low flow conditions when insufficient flow is available to dilute the discharge. Nitrogen and phosphorus loadings from 82 major publicly owned sewage treatment plants were estimated for each Schuylkill River subwatershed (see the map: **Public Sewage Treatment Plants**). Loadings were calculated based on estimated effluent discharge volumes, and nutrient concentrations for these plants identified within the Schuylkill River watershed. Discharge volumes could be obtained only for a small percentage of the STPs, and therefore the maximum permitted volumes were used to estimate effluent discharge. Nitrogen and phosphorous concentrations were estimated based on the level of treatment because most plants did not report the nutrient concentrations of their effluent. Of the plants identified, only 29 (35%) treated to the tertiary level, 52 (63%) treated to the secondary level, and one (1%) treated to the primary level. The assumptions made for nutrient concentrations in effluent after different levels of treatment are shown in **Table 5.4** (Thomann 1987).

Table 5.4 Estimated Nutrient Concentrations in Effluent after Different Levels of Treatment

Treatment Level	*Nitrogen Concentration (mg/l)*	*Phosphorous Concentration (mg//l)*
Raw Sewage	40	10
Primary	37	9
Secondary	27	8
Tertiary – Nitrification	26	7
Tertiary - NH3 removal	3	8
Tertiary - P removal	27	1

Annual nitrogen and phosphorus loadings in kg/ha for each subwatershed were calculated by estimating the loads from each STP in kilograms per year, summing within each subwatershed, and dividing by subwatershed area. Results are shown in the map: **Nitrogen from Sewage Treatment Plants**, and the map: **Phosphorus from Sewage Treatment Plants**. Note that results from this analysis reflect only loadings from within a given subwatershed, and do not account for the impact of nitrogen and phosphorus loadings from STPs in upstream subwatersheds. Results should therefore be used only to make relative comparisons of pollution sources among different subwatersheds.

In addition to permitted wastewater discharges, undocumented discharges of raw sewage also are a significant source of nutrients to receiving waters, particularly in the rural headwaters region of the Schuylkill River watershed. These "wildcat" systems should be identified and brought into compliance with existing regulations as quickly as possible. Similarly, combined sewer overflows (CSOs) from urban areas can be a source of nutrient loading. Continuing efforts should be made in the Philadelphia and Reading areas to meet or exceed NPDES requirements, and minimize the frequency and duration of combined sewer overflows. Nutrient loading from undocumented discharges and combined sewer overflows are not quantified in this analysis.

In combination with previously presented data, a rough comparison can be made between nutrient loading from publicly owned sewage treatment plants versus loading from non-point sources (from land cover and septic systems) for each Schuylkill River subwatershed. Because all possible nutrient sources were not quantified in these analyses, comparisons must be considered only as a general indication of the relative contributions from the specific sources mentioned. In general, the data suggest that non-point sources contribute the majority of nitrogen throughout much of the middle watershed, with nitrogen loading from publicly owned sewage treatment plants the predominant source only in the more developed lower watershed areas, including the Upper Wissahickon, Sandy Run, Lower Perkiomen, Schuylkill River 2, Schuylkill River 3, Skippack Creek, and E. Branch of the Perkiomen subwatersheds. Results for phosphorus follow a similar pattern, but with a greater importance associated with inputs from sewage treatment plants throughout the watershed.

5.5.9.2 Recommendations for Nitrogen and Phosphorous from Sewage Treatment Plants

Code	*Recommendation*	*Summary Description*	*Priority Area/ Target Subwatersheds*
R5.10	**Establish Uniform, Watershed-wide Criteria for Permitted Discharges from Sewage Treatment Plants (STPs)**	Criteria for permitted discharges of pollutants such as fecal coliforms vary among different PA DEP regions within the watershed. Uniform criteria should be developed to help regulate and reduce water quality impairment from sewage treatment plants.	All Zones
R5.11	**Monitor Nutrients from All Sewage Treatment Plants**	Sewage treatment plants may not monitor all relevant nutrient levels in their effluent. Establishing uniform discharge criteria and monitoring nutrients at all sewage treatment plants would help to assess nutrient loading to receiving waters.	All Zones Schuylkill River 3 Lower Perkiomen Creek Skippack Creek Upper Wissahickon Creek Sandy Run Schuylkill River 2 Schuylkill River 5
R5.12	**Promote Tertiary Treatment of Sewage Effluent**	Less than half of the treatment plants in the Schuylkill River watershed provide tertiary treatment of sewage effluent. Where effluent is a problem, plants should be upgraded to provide higher levels of treatment.	All Zones
R5.13	**Identify and Control Discharges of Untreated Sewage from “Wildcat Systems” and Combined Sewer Overflows (CSOs)**	Discharges of untreated sewage from “wildcat” systems and combined sewer overflows represent a threat to human health and aquatic ecosystems. Wildcat systems should be identified and regulated, and CSOs monitored for compliance with existing regulations.	All Zones

5.5.10 NPDES Permitted Discharges

Under Section 402 of the Clean Water Act of 1972, all facilities discharging to navigable waters must possess a National Pollutant Discharge Elimination System (NPDES) permit as administered by the US EPA. Facilities permitted for discharge within the Schuylkill River watershed were identified using the EPA’s Better Assessment Science Integrating Point and Non-point Sources (BASINS). The compiled information relies on data from the EPA’s Permit Compliance System (PCS) for the years 1991-1996 and contains entries for facilities holding National Pollutant Discharge Elimination permits. Point source discharge locations are shown in the map: **Point Source Discharge Locations**. A full listing of facilities with NPDES permits listed in the EPA PCS, including information about receiving water, flow rates, and parameters present in discharge, can be found in **Reference Table 5H: Facilities with NPDES Permits Listed with the EPA Permit Compliance System** in the online Reference Documents. Quantitative estimates of nutrient loading from point-source discharges other than publicly owned sewage treatment plants were not made due do limitations of the BASINS data. A more complete and up-to-date compilation of all dischargers within the watershed is available through the Schuylkill River Sourcewater Assessment Partnership (http://www.schuylkillswa.org). Additional information about this data can be obtained from the Philadelphia Water Department, Office of Watersheds.

5.6 Detailed Recommendations from the Water Quality Analysis

This section presents detailed recommendations for protecting water quality in the Schuylkill River watershed. Each recommendation is listed in a table by its code, the name of the recommendation, a representative list of appropriate groups/agencies that might implement or guide the implementation of each recommendation, the key water quality issues addressed, and the water quality analysis section(s) of this chapter to which this recommendation corresponds. Each table is followed by a detailed description of the recommendation.

Code	*Recommendation*	*Appropriate Partners*	*Issues Addressed*	*Sections*
R5.1	**Establish a Coordinated, Watershed-wide Monitoring Program with Quality Control Protocols**	Multi-stakeholder design team including PA DEP, PA DCNR, US EPA, USGS, volunteer monitoring groups, nonprofits, academics and experts	Water quality monitoring	5.4

Description

One of the findings of this water quality modeling effort has been that reliable, updated data for the watershed are needed. Large portions of the watershed are not covered by local groups, and perhaps not even by regional groups, conducting water quality monitoring or research activities. Furthermore there are numerous volunteer-monitoring activities underway throughout the watershed. Efforts should be made to establish a watershed-wide monitoring network to identify current and future water quality problems within the watershed. Coordinating among groups currently sampling in the watershed would facilitate this process, possibly through the water utilities in the Source Water Protection study.

The general lack of consistent water quality data was discussed thoroughly in a recent US GAO report titled *Key EPA and State Decisions Limited by Inconsistent and Incomplete Data* (GAO RCED-00-54). Although some water quality monitoring is in place through state and federal programs, the GAO report reveals that these data are rarely consistent or comprehensive watershed-wide. Yet, these scientific data are essential for any assessment of watershed quality on a local, statewide or national scale, being critical indicators of ecological health. They are also required for fulfilling legal requirements such as the TMDLs required for pollutants in 303(d) waters. Finally, these water quality indicators are the most visible and tangible expression of watershed health in the public eye.

Despite public interest, citizen activism and pressure from watershed groups, monitoring programs are scarce in most states. Thanks to the presence of strong watershed groups and active citizens, the PA DEP has an opportunity to take a leadership role in this area and partner with local organizations as well as the EPA to design an appropriate basin-wide monitoring system. A key challenge to be addressed is convincing funding sources, which may view monitoring as a form of academic research and disqualify it from their grants, of the critical importance of undertaking this program. Proponents of the monitoring plan should undertake education and outreach to funders to identify likely partners, provide strong rationale for funding monitoring, and encourage funders to support a basin-wide monitoring effort. The foundation network could be a useful mechanism for funding the monitoring program (see Recommendation **R7.3** in **Section 7.5** of *Chapter 7.0 Institutional Assessment*).

Role of Volunteers in Monitoring

Volunteer water quality monitors play an important role in looking for and documenting water quality problems throughout the watershed. Volunteer monitoring programs also are an effective way of educating and empowering individuals and communities concerned about the environment. For volunteer monitoring programs to be most effective, volunteers must be trained in the proper sampling methods, and the data collected must be subject to some form of quality control. Programs are already in place to train volunteers in sampling methods. To assure data quality, a professionally managed quality control and data validation program should be established, and all data collected by volunteers given a rating according to quality. This program would ideally involve a respected analytical laboratory, and include volunteer analysis of laboratory standards as well as laboratory analysis of samples previously tested by volunteers. Error estimates should be assigned for each sample based on specified quality control protocols. A less rigorous approach, but easier to implement, would be to coordinate sampling by volunteers and professionals at specific times and places, and to check volunteer sampling results against professionally determined results.

Water Quality Monitoring Program

Based on the need for better quality, more comprehensive water quality data, the number of groups and citizens currently testing water quality, the reliability of citizen monitoring, and issue of data storage, several recommendations on components of a Schuylkill River watershed water quality monitoring program follow.

1. <u>Design a Statistical Sampling Scheme</u>. State and federal agencies, along with key nonprofit and academic groups involved in watershed monitoring and research, should cooperate to design a comprehensive watershed-wide monitoring program. This gathering might take the form of a workshop on monitoring design, bringing together experts from these agencies and other groups to develop agreed-upon monitoring standards and sites. Monitoring data collection should address physical, chemical and biological indicators of watershed health. The monitoring design should incorporate comprehensive statistical sampling across the entire watershed as well as intensive sampling at priority sites for conservation or pollution remediation. The Stroud Water Research Center began regular scientific testing on nineteen different tributaries throughout the Schuylkill River watershed in 1994. This study should be incorporated into any larger sampling program along with other sites which have long-term, reliable data so that the historical information is not lost.

   To generally characterize water quality within the watershed, sampling should focus on the mainstem Schuylkill River and mouths of major tributaries. If possible, sampling also should be extended upwards to the mouths of successively smaller tributaries throughout the watershed. Samples should be collected from each location at least four times a year to account for seasonal variation in water quality, and should include at least one sample during the annual low flow in late summer or fall. In addition, samples should be collected periodically during storm runoff events (rainstorms) to monitor water quality changes associated with non-point source loading. At a minimum, sampling should include temperature, pH, conductivity, turbidity, nitrogen, and phosphorus. Other parameters including dissolved metals, toxic organic materials, and pathogens should be sampled where contamination is suspected or to address local issues and concerns. The resulting data should be available on a user-friendly website allowing people to access and use the data. Monitoring could be coordinated with USGS gauging stations to create a network throughout the watershed.

   Long term, continuous streamflow data is another important need within the watershed. Efforts should be made to help prevent the closure of existing USGS streamflow gages, and if possible additional streamflow gauging stations should be installed on tributaries throughout the watershed.

2. <u>Use Available Watershed Resources with Quality Control Protocols or Certification Program</u>. In order to better engage public participation and to incorporate the substantial monitoring activities of citizen groups, a training and certification program to promote the newly-formed monitoring design should be sponsored by interested state and

federal agencies. This training for citizen monitors might include a workshop on the standardized monitoring program, enrollment of citizen activists in collection of monitoring data, and a "certification" that identifies the participant as an active member of the watershed monitoring system. Certified volunteers and participants could participate in multiple levels of monitoring system construction, implementation and data collection. As part of the citizen effort, water quality testing kits will need to be funded and provided to participants. The Stroud Water Research Center has an established citizen water quality training program, named *Stream School*, that could be the critical starting point for creating training programs; additionally, the Schuylkill Riverkeeper, a program of the Delaware Riverkeeper Network, has organized annual Citizen Monitoring Workshops, which could link the designed program to the needed citizen monitors.

One example of a citizen training program is the Citizens Volunteer Monitoring (CVM) Program offered by the PA DEP. This program offers CVM Clinics that are designed for groups of up to 3 people who have sufficient watershed knowledge and technical expertise to design monitoring programs. While the Clinics offer critical technical assistance to watershed groups with some expertise, groups with less expertise and citizens who are interested in participating in a wider monitoring program also should receive training as suggested above. For more information see the US EPA website: http://www.epa.gov/OWOW/monitoring/volunteer/epavm.html.

3. Centralized Data Repository. The development of a monitoring system should provide for a data repository, probably a centralized database, with a designated staff member responsible for data compilation, updating and quality control. The monitoring design also should provide for participant and monitoring staff discussion, for periodic reevaluation of the program using indicators of success, for re-training and training of new participants, for public data access, and use of the data by other agencies and groups in water quality reporting. Ideally, by creating a consistent set of monitoring goals, by accessing and incorporating grassroots resources, and by creating a watershed data repository, the result would be a highly consistent data set that could be used by the state in reporting water quality to the US EPA, or by nonprofits in determining where restoration and remediation efforts need to be focused. This basin-wide monitoring program would make the Schuylkill River a leader in watershed monitoring, providing an example to watersheds in Pennsylvania and beyond.

Code	*Recommendation*	*Appropriate Partners*	*Issues Addressed*	*Sections*
R5.2	**Implement Urban Best Management Practices to Maximize the Infiltration of Water and Reduce Urban Non-point Source Pollution**	PA DEP, US EPA, municipalities, nonprofit watershed groups	Stormwater runoff Non-point source pollution (nutrients, toxics, sediment, erosion) Water supply	5.5.2 5.5.3 5.5.6 5.5.8

Description

A variety of best management practices (BMPs) can help prevent and mitigate the effects of stormwater runoff and related non-point source pollution in urban and urbanizing areas. The basic objective of most urban BMPs is to increase the infiltration of water into the soil, thereby reducing stormwater runoff volumes, reducing non-point pollution, and increasing groundwater recharge. In areas currently under development, runoff prevention is an important strategy. Prevention practices include encouraging new planning and zoning to allow urban BMPs, minimizing impervious cover, cluster development/alternative lot configuration, minimizing disturbance during construction, reducing setbacks (distance from the house to the road), decreasing road widths and lengths, installing porous pavement in parking areas, shared parking areas, and installing sidewalks on only one side of the street.

Other methods of encouraging water infiltration include infiltration basins, infiltration trenches/dry wells, and porous pavement (US EPA 1993). Infiltration basins require well-drained soils and groundwater tables at least 2-4 feet below the bottom of the basin, to allow slow percolation of water from the basin through the soil. Infiltration trenches may be used on a smaller scale to infiltrate stormwater runoff. Porous pavement may be used in place of traditional concrete or asphalt, and is well suited to parking areas that receive light use. Vegetated filter strips, grassed swales, terraces and specially graded areas, reforestation/revegetation, and sedimentation and retention basins also can be used to infiltrate water and reduce non-point pollution. The above practices are suitable for areas undergoing new development as well as those with existing infrastructure.

Many excellent sources of information about urban BMPs are available (Schueler 1987; US EPA 1993; DNREC and Brandywine Conservancy 1997). The EPA and Center for Watershed Protection's web page, *Stormwater Managers Resource Center* (http://www.stormwatercenter.net) also has good information on the impacts of urban development on streams, and stormwater related BMPs.

Code	*Recommendation*	*Appropriate Partners*	*Issues Addressed*	*Sections*
R5.3	**Encourage Homeowners and Small Businesses to Reduce Non-Point Pollution**	PA DEP, PA DCNR, County Conservation Districts, nonprofit watershed groups, schools	Non-point source pollution	General

Description

Homeowners, small businesses, and individual citizens play an important role in protecting water quality and general stream health. Though the impact of any one person or business on water quality may be small, the cumulative effects from a large number of people can be substantial. This is particularly important for people living or working adjacent to rivers, stream, ponds and other water bodies. Educational tools and programs should be developed and used to educate people about the impacts of their daily actions on water quality, and how they can reduce non-point source pollution by properly applying lawn fertilizer and chemicals, cleaning up after pets, properly disposing of household wastes, properly storing cars and other vehicles which may leak oil and gasoline, and not dumping trash and yard waste into streams.

Code	*Recommendation*	*Appropriate Partners*	*Issues Addressed*	*Sections*
R5.4	**Implement Nutrient Management Practices**	County Conservation Districts, PA DEP, USDA NRCS, County Extension, Penn State University Extension	Non-point source pollution (nutrients)	5.5.6

Description

Non-point source loading of nitrogen and phosphorous from agricultural lands can impact water quality and degrade stream health. Nutrient management practices (NMPs) are designed to help farmers optimize crop growth while minimizing the impact on the environment through careful management of nutrient applications. The Cadmus Group (1998) in their Lake Ontelaunee Watershed report, list the main components of a sound agricultural nutrient management plan as:

Soil testing
Determining nutrient levels in manure
Crediting of residual nitrogen from previous crops
Determining how and when to apply manure
Calibrating the manure spreader
Determining any additional fertilizer needs
Considering erosion and runoff
Conducting a yearly review

Efforts should be made to implement nutrient management practices wherever possible, and particularly in subwatersheds where nutrient loading is a problem. Assistance with the development of nutrient management practices is available from County Conservation Districts, extension services (Penn State University Extension, County Extension), the USDA Natural Resources Conservation Service (http://www.nrcs.usda.gov), and PA DEP (http://www.dep.state.pa.us).

Nutrient management practices should also be encouraged in urban and suburban areas where fertilizer is applied to golf courses, parks and lawns. Landowners, landscapers, and professional groundskeepers should be educated concerning the proper use and application of fertilizers to minimize nutrient runoff associated with over fertilization. Similar programs should be implemented for the urban/suburban use of pesticides and herbicides. A related issue common throughout the watershed is high nutrient and pathogen loading from large resident populations of geese in public parks and other open space. Efforts should be made to reduce the congregation of geese, especially in areas directly adjacent to water bodies, by proper design and planting vegetation to break sightlines, and discouraging the public from feeding geese.

Code	*Recommendation*	*Appropriate Partners*	*Issues Addressed*	*Sections*
R5.5	**Implement Agricultural Best Management Practices**	County Conservation Districts, PA DEP, USDA NRCS, County Extension, Penn State University Extension	Non-point source pollution (nutrients, sediment)	5.5.6 5.5.8

Description

In addition to the nutrient management practices mentioned above, many other methods exist to reduce the amount of non-point source sediment and nutrient pollution from agriculture. Examples of agricultural best management practices include:

Conservation tillage
Contouring
Contour strip cropping
Graded rows
Grassed outlets
Improved soil fertility
Meadowless rotations
No-till plant in prior crop residues
Plow plant systems
Ridge planting
Sod-based rotation
Stream bank fencing
Terraces
Timing of field operations
Winter cover crops

Other agricultural BMPs include establishing and protecting riparian buffers, fencing to control access of livestock and other animals to streams and other water bodies, and controlling runoff from animal feedlots and barnyards. Sources of information that provide additional information and guidance in implementing agricultural best management practices include: PA DEP (*BMP Manual for Livestock and Poultry Operations*); County Conservation Districts; Penn State University Extension; USDA NRCS (http://www.nrcs.usda.gov); and the *Handbook of Non-point Pollution: Sources and Prevention* (Novotony and Chesters 1981). Cost sharing programs are often available to aid farmers in funding implementation of BMPs.

Code	*Recommendation*	*Appropriate Partners*	*Issues Addressed*	*Sections*
R5.6	**Implement Timber Harvesting Best Management Practices**	County Conservation Districts, PA DCNR, County Extension, Penn State University Extension	Non-point source pollution (nutrients, sediment)	5.5.6 5.5.8

Description

Timber harvesting operations can be a significant cause of increased sediment and nutrient loading to rivers and streams. Sediment loading associated with logging roads is an especially important problem. To minimize the impacts of timber harvesting operations within the Schuylkill River watershed, best management practices should be employed including implementation of erosion and sedimentation plans, proper road design, no cutting on steep slopes, and maintenance of riparian buffers along all water bodies. For more detail on the function and benefits of riparian buffers see Recommendation **R5.7** below and **R6.6** in **Section 6.8** of *Chapter 6*.

Additional information and guidance in implementing timber harvesting best management practices can be obtained from PA DCNR Bureau of Forestry, County Conservation Districts, County Extension, and Penn State University Extension.

Code	*Recommendation*	*Appropriate Partners*	*Issues Addressed*	*Sections*
R5.7	**Protect and Restore Riparian Forest Buffers**	PA DEP (Growing Greener, Stream Releaf), PA DCNR, nonprofit watershed groups, municipalities, PA Fish and Boat Commission	Non-point source pollution (nutrients, sediment) Habitat quality	5.5.4 5.5.6 5.5.8

Description

Streamside or "riparian" forests are important to protecting and improving water resources and aquatic ecosystems throughout the Schuylkill River watershed. Riparian forests are complex ecosystems that help provide high quality food and habitat for stream communities. These forests shade streams, providing optimum light and temperature conditions for aquatic life, and are an important source of leaf litter, large woody debris, and organic matter food to streams (Welsch 1991). Riparian forests also serve as filters or "buffers," mitigating or controlling non-point source pollution by stabilizing stream banks and filtering runoff before it reaches the stream. Used as a component of an integrated management system that includes nutrient management and sediment and erosion control practices, riparian forest buffers can be effective in removing excess nutrients and sediment from surface runoff and shallow groundwater.

Throughout the Schuylkill River watershed, riparian disturbance associated with agricultural and urban development has greatly reduced the area of streambank protected by riparian forests. Riparian disturbance is most common in the agricultural and urban zones of the middle and lower watershed, and in valley bottoms where agriculture and urban development typically occur. Smaller streams (first and second order) are particularly susceptible to riparian disturbance, which can lead to significant impacts on water resources and ecosystem health downstream. The health of a large stream such as the Schuylkill River at Philadelphia is directly related to the health of its many smaller tributaries throughout the watershed.

In order to protect and enhance water resources and aquatic ecosystems, remaining riparian forests within the Schuylkill River watershed should be preserved and extended. In areas where riparian forests have been disturbed, native riparian communities should be re-established wherever possible, especially along sensitive first and second order streams. The protection and restoration of riparian forests is particularly important in areas: where non-point source pollution is a problem; where shallow soils, steep slopes, or land disturbance results in large amounts of storm runoff; where sensitive species or ecosystems exist; and, where significant amounts of riparian forest have been disturbed within a watershed. Riparian buffer protection ordinances are encouraged to protect existing riparian habitats.

Riparian forest buffers will be most effective when used as part of a comprehensive land management program addressing stormwater runoff, nutrient management, and sediment and erosion control practices. Riparian forest buffers should be designed using a 3-zone approach: a zone of undisturbed forest approximately 15 feet wide adjacent to the waters edge; a zone of managed forest about 60 feet wide contiguous with the undisturbed forest zone; and a zone where runoff is controlled contiguous with the managed forest zone. The recommended width for forested buffers varies between about 75 and 150 feet based on soil characteristics, adjacent land-use, and project goals (Welsch 1991). Where the recommended width is not possible, smaller buffers should still be established. Where forested buffers are not desired by landowners, vegetative grass or shrub buffers should be established at a minimum.

There are currently several groups and programs in the Schuylkill River watershed addressing riparian reforestation, and resources are available for further information about planning and implementing a reforestation project. The Heritage Conservancy will complete a detailed inventory of the condition of riparian buffers for all streams in the Perkiomen and Valley Creek Watersheds in spring 2001 (http://www.heritageconservancy.org). The Heritage Conservancy will complete riparian buffer inventories for other streams in the Schuylkill River watershed over the next several years. Efforts should be made through these and other programs to protect and restore riparian buffers wherever possible in the watershed.

For general information on riparian reforestation see Welsch (1991) or Federal Interagency Stream Restoration Working Group (1998). For Pennsylvania, contact the PA DEP Bureau of Watershed Conservation Stream ReLeaf program (http://www.dep.state.pa.us) and the Pennsylvania Riparian Buffer Initiative Implementation Plan (PA DEP 1999), the PA DCNR (http://www.dcnr.state.pa.us), the PA Fish and Boat Commission (http://www.fish.state.pa.us), or local watershed conservation groups for resources on riparian forest buffers. For discussion of the importance of riparian buffers as green space corridors see Recommendation **R6.6** in **Section 6.8** of *Chapter 6*.

Code	*Recommendation*	*Appropriate Partners*	*Issues Addressed*	*Sections*
R5.8	**Protect and Restore Wetlands and Areas of Hydric Soils**	PA DEP, PA DCNR, nonprofit watershed groups	Non-point source pollution (nutrients, sediment) Stormwater runoff Habitat quality	5.5.6 5.5.8

Description

Wetlands play a critical role in regulating the movement of water, nutrients, and other materials within watersheds. Wetlands often function like natural sponges, storing water during floods and slowly releasing it over time, thereby reducing flood heights and volumes of stromwater runoff. Wetlands also influence water quality by acting as sources, sinks, or transformers of nutrients, organic compounds, metals, and other materials. The biologically mediated process of nitrification/denitrification in the nitrogen cycle by wetland bio-organisms can transform the majority of nitrogen entering wetlands, causing between 70% and 90% loss of nitrogen to the atmosphere. Phosphorus entering wetlands can be removed through uptake by plants and soil microbes, with sediment deposition, and by chemical precipitation. Interaction with wetland soils can also remove metals from surface and ground water, and thus is an effective means of mitigating acid mine drainage. Lastly, wetlands act as filters of sediments and organic matter. In general, wetlands with abundant vegetation will be more capable of reducing runoff velocity and removing pollutants from the water than a wetland with less vegetation.

In addition to hydrologic and water quality effects, wetlands also play an integral role in the ecology of watersheds. The combination of shallow water, high levels of nutrients, and primary productivity is ideal for the development of organisms that form the base of the food web and feed many species of fish, amphibians, shellfish, and insects. Many species of birds and mammals rely on wetlands for food, water, and shelter, especially during migration and breeding.

In the Schuylkill River watershed, wetlands reduce the likelihood of flood damage, help control increases in the rate and volume of runoff from urban areas, and improve water quality by intercepting surface runoff and reducing nutrient and sediment loads. Efforts should therefore be made to protect and restore wetlands throughout the watershed. Areas of hydric soils may offer the best potential for wetlands recreation or restoration.

Code	*Recommendation*	*Appropriate Partners*	*Issues Addressed*	*Sections*
R5.9	**Identify and Enforce Sediment and Erosion Control Problems and Violations**	PA DEP, County Conservation Districts, municipalities, cooperative extension, US EPA, nonprofit watershed groups, soil conservation districts	Non-point source pollution (sediment, erosion)	5.5.8

Description

Sediment loading from construction sites and other land cover disturbances within the Schuylkill River watershed can degrade habitat and impair stream health. Unlike other non-point source pollution problems, sediment erosion from construction sites is relatively easy to identify, and can be controlled with the use and enforcement of proper erosion and sediment control measures. Examples of these measures include straw bales, silt fences, grassed swales, vegetative filter strips, and sedimentation basins. Most construction projects are required to have erosion and sedimentation plans;

however, plans frequently are either not adequate or not properly maintained, resulting in significant sediment loading to streams. Municipalities and other government agencies should take measures to assure that procedures are in place for monitoring compliance with erosion and sedimentation plans.

In addition, citizen volunteers can be trained to help monitor their watershed for existing and potential erosion and sediment problems. For example, the Delaware Nature Society (http://www.delawarenaturesociety.org) has established a *Soil Watch* program in which volunteers learn what problems to look for in the watershed, and how to report problems to the appropriate agencies and organizations. Such a program could be established in municipalities within the Schuylkill River watershed. Other information and guidance about erosion and sedimentation plans can be obtained from the Pennsylvania Department of Environmental Protection (http://www.dep.state.pa.us), County Conservation Districts, soil conservation districts, and the US EPA (http://www.epa.gov).

Code	*Recommendation*	*Appropriate Partners*	*Issues Addressed*	*Sections*
R5.10	**Establish Uniform, Watershed-wide Criteria for Permitted Discharges from Sewage Treatment Plants (STPs)**	PA DEP, US EPA	Point source pollution (pathogens, nutrients)	5.5.9

Description

Criteria for permitted discharges of pollutants such as fecal coliforms vary among different PA DEP regions within the Schuylkill River watershed. Efforts should be made to establish uniform, watershed-wide criteria for permitted discharges from sewage treatment plants throughout the watershed.

Code	*Recommendation*	*Appropriate Partners*	*Issues Addressed*	*Sections*
R5.11	**Monitor Nutrients from All Sewage Treatment Plants**	PA DEP, utilities, municipalities	Point source pollution (nutrients from STPs)	5.5.9

Description

Sewage treatment plants may not monitor all relevant nitrogen and phosphorus concentrations in their effluent. Monitoring and reporting nutrient releases from all sewage treatment plants would provide important information about nutrient loading to Schuylkill River subwatersheds, and would help target plants that may need advanced levels of sewage treatment. This should be emphasized where problems associated with elevated nutrient concentrations, such as excessive algae growth, are observed downstream of discharge locations.

Code	*Recommendation*	*Appropriate Partners*	*Issues Addressed*	*Sections*
R5.12	**Promote Tertiary Treatment of Sewage Effluent**	PA DEP, municipalities	Point source pollution (nutrients from STPs)	5.5.9

Description

Effluent from sewage treatment plants can impair water quality, particularly in areas immediately downstream of discharge locations, and during low-flow conditions. Nutrient loading and other pollution from treatment plants is easily identified, however, and for many plants can be decreased by upgrading to advanced tertiary treatment processes. In the Schuylkill River watershed, less than half of the treatment plants currently provide tertiary treatment.

In Schuylkill River subwatersheds with high nutrient loading from treatment plants, water quality improvements could be made by upgrading treatment facilities to provide tertiary treatment. However, the cost of upgrading plants can be high, and plant upgrades should be evaluated against alternative methods of reducing nutrients, such as non-point focused nutrient management practices and BMPs. Often programs are available through the state and federal government to help financially support municipal efforts to increase the treatment level. Upgrading sewage treatment plants also should be emphasized where problems associated with elevated nutrient concentrations are observed downstream of discharge locations.

Code	*Recommendation*	*Appropriate Partners*	*Issues Addressed*	*Sections*
R5.13	**Identify and Control Discharges of Untreated Sewage from "Wildcat Systems" and Combined Sewer Overflows (CSOs)**	PA DEP, municipalities, health departments, utilities	Point source pollution (nutrients, pathogens)	5.5.9

Description

Untreated sewage effluent contains harmful pathogens, high amounts of nutrients, and potentially many other pollutants. Discharges of untreated sewage to rivers and streams represent a serious threat to stream and human health. Illegal discharges of untreated domestic sewage, or "wildcat" systems, are known to occur in the rural headwaters areas of Schuylkill County, and should be located and brought into compliance with existing regulations as quickly as possible. Programs should be established to assist municipalities and property owners who are not able to pay the cost of constructing or upgrading facilities.

Combined sewer overflows in urban areas such as Reading and Philadelphia are another source of untreated sewage discharge within the Schuylkill River watershed. Continuing efforts should be made to meet or exceed NPDES requirements, and decrease the frequency and duration overflows.

Code	*Recommendation*	*Appropriate Partners*	*Issues Addressed*	*Sections*
R5.14	**Establish Septic Education, Registration, Inspection, and Maintenance Programs**	PA DEP, health departments, municipalities, nonprofit watershed groups, US EPA	Non-point source pollution (nutrients)	5.5.7

Description

Failing or improperly maintained septic systems can cause high nutrient loading and associated water quality impairment. Septic system siting and permitting for all on-lot disposal systems is regulated under the Pennsylvania Code, Title 25, Chapter 73 (http://www.pacode.com/secure/data/025/chapter73/chap73toc.html). Septic system maintenance is the responsibility of property owners.

To minimize water quality impairment due to septic systems, programs should be established: to educate property owners about how septic systems can impact water quality; to provide guidance about the proper maintenance of septic systems; and, to provide the information and tools necessary for property owners to test their systems to ensure continued proper functioning. The on-lot septic system permitting program is handled by health department officials in Philadelphia, Montgomery, and Chester Counties. In other counties, Sewage Enforcement Officers oversee the program. Education and testing programs should be coordinated with current on-site programs administered by county Sewage Enforcement Officers or health departments.

Code	*Recommendation*	*Appropriate Partners*	*Issues Addressed*	*Sections*
R5.15	**Size and Maintain Culverts and Bridges to Ensure Minimal Impact to Streams**	Municipalities, PA Dept. of Transportation, PA DEP	Stormwater runoff Non-point source pollution (sediment, erosion)	5.5.4

Description

Culverts and bridges frequently constrict and change the natural flow of streams resulting in downstream bank instability and erosion. When flows exceed design specifications, generally the 10 or 25 year flood flows, culverts can overflow and cause flooding (Riley 1998). Culverts also can cause flooding when clogged with sediment or debris. During low flows, improperly designed culverts can cause a shallow water barrier that fish and other stream organisms cannot cross.

Culvert structures should be sized and designed to adequately accommodate flood flows as well as low flow channel conditions. In developing areas, culvert design should account for projected growth and associated increases in storm runoff volumes, which can deposit litter, sediment and pollutants into streams. Where problems with flooding or channel erosion persist, culverts should be replaced with bridges that allow the stream to flow without any obstruction. Bridges also must be properly designed to manage flood flows and minimize the accumulation of debris. All culverts and bridges must be inspected and maintained on a regular basis.

Code	*Recommendation*	*Appropriate Partners*	*Issues Addressed*	*Sections*
R5.16	**Conduct Inventories and Studies to Identify and Remove Dams Where Restoration Benefits Outweigh Present Uses and Effects**	PA DEP, PA Fish and Boat Commission, nonprofit watershed groups	Habitat quality Water supply	5.5.5

Description

There are approximately 280 dams in the Schuylkill River watershed. Dams can adversely affect the health of rivers and streams by altering flow regimes, changing water temperature and chemistry, altering sediment transport and physical habitat, and disrupting resident and migratory fish communities. Many dams in the watershed no longer serve their intended purpose and/or are potential safety hazards, and have been designated by PA DEP as "orphans" with no legal owner.

In recent years, dam removal has been employed in Pennsylvania and other states as a method for restoring free-flowing stream ecosystems and migratory fish communities. Determining the benefits of dam removal can be complex, and in some cases the ecological benefits of dam removal may be offset by issues related to the release of sediment stored behind the dam, recreational use of the impoundment, or cultural/historical values associated with the dam. Dam removal should be considered where the ecological and/or safety benefits outweigh present uses and other potential impacts of dam removal. Where dam removal is not possible, fishways and fish ladders should be constructed to allow fish passage and migration.

In addition, inventories and a study of existing dams in the Schuylkill River watershed should be done to determine the current uses and benefits. Information about dam removal in the Schuylkill River watershed is available from PA DEP, the Delaware Riverkeeper Network (http://community.homeearth.com/welcome.asp?cn=DRN) and the PA Fish and Boat Commission.

Code	*Recommendation*	*Appropriate Partners*	*Issues Addressed*	*Sections*
R5.17	**Identify Sources and Mitigate Effects of Acid Mine Drainage (AMD)**	PA DEP, County Conservation Districts, nonprofit watershed groups	Acid mine drainage	General

Description

Acid mine drainage (AMD) is a significant source of water pollution in the mining region of the Schuylkill River headwaters. AMD and associated pollutants, including heavy metals, can have severe impacts on aquatic ecosystem health, frequently destroying entire ecosystems. Most, but not all, of this pollution is in the form of discharges from mines abandoned before the 1964 amendment to the Clean Streams Law that required mine operators to treat mine drainage (PA DEP 1999). Since that time, applicants for mining permits have been required to demonstrate that mining would not cause mine drainage pollution following reclamation of the mine.

In current and historic mining areas, undocumented sources of AMD should be identified and monitored to determine the scope and magnitude of impacts to water quality and aquatic ecosystems. A program for restoring streams impacted by AMD should be implemented, and the permitting of new mines should rigorously evaluate the potential for future liability and AMD problems. Restoration should seek to raise the pH of the effluent and reduce metals concentrations in aquatic ecosystems. Potential restoration methods include chemical treatment, and alternatives such as constructed wetlands, limestone channels, and bioremediation techniques. Generally, passive treatment is preferred over methods requiring active management.

The Pennsylvania DEP (1999) recently reviewed the current mine permitting program, and made several recommendations for managing AMD problems.

(1) Better methods should be developed for predicting post-mining manganese problems.
(2) Continuing education for permit reviewers has been very successful in maintaining a high level of technical ability and should be continued.
(3) Pit water and untreated discharge effluents should be sampled and documented on a regular basis.
(4) Special handling and alkaline addition sites warrant increased inspection frequency and should be documented in detail in inspection reports.
(5) Low rates of alkaline addition cannot be relied on to make a marginal permit issueable.
(6) Classification and use of receiving streams should be given consideration in permit decisions.
(7) Caution must be exercised in reviewing permits with all sandstone overburden or where the only source of neutralization potential is in sandstone.
(8) No environmental reason exists to leave coal outcrop barriers in place.
(9) All of the available permit review tools, not just overburden analysis, should be considered in the review of a permit application.

The recently released Upper Schuylkill River Tributaries Assessment Report (L. Robert Kimball & Associates, Inc. 2000) identifies major non-point/acid mine drainage (NPS/AMD) sources within the upper Schuylkill River watershed area, compiles existing available analytical/physical data associated with those discharges, and evaluates the impacts in regard to water quality. Results include a ranking of 35 individual AMD source locations, and identification of eleven priority sites within an area from the headwaters of the Schuylkill River near Tuscarora to the confluence of the West Branch Schuylkill River and the main stem in Schuylkill Haven. For more information contact PA DEP's Bureau of Abandoned Mine Reclamation (http://www.dep.state.pa.us), local County Conservation Districts, or local watershed conservation groups.

Code	*Recommendation*	*Appropriate Partners*	*Issues Addressed*	*Sections*
R5.18	**Monitor and Regulate Existing and Future Groundwater Withdrawals**	DRBC, PA DEP, PA DCNR	Water supply Habitat quality	General

Description

Groundwater is an integral part of the water cycle, and should not be considered separate from surface water. During dry weather, groundwater is the principal source of streamflow, and when depleted streams and wetlands can be significantly impacted due to reduced flow. Groundwater supplies vary throughout the Schuylkill River watershed due to differences in geologic composition, and the balance between recharge from precipitation and discharge as streamflow and from pumped wells. In order to protect existing uses of groundwater as well as stream health, groundwater pumping within the Schuylkill River watershed should be carefully monitored and regulated to ensure that supplies are not depleted.

The Delaware River Basin Commission (DRBC) currently regulates groundwater withdrawals throughout the Schuylkill River watershed. Groundwater depletion is of particular concern in the Ground Water Protected Area of Southeastern Pennsylvania which encompasses parts of Berks, Bucks, and Chester Counties, and all of Montgomery County (DRBC 1999). Groundwater supplies in this area are managed by DRBC through numerical ground water withdrawal limits. This program should be continued, and similar regulations should be considered in other areas where groundwater depletion is a problem. For more information about this program contact the Delaware River Basin Commission (http://www.state.nj.us/drbc).

Code	*Recommendation*	*Appropriate Partners*	*Issues Addressed*	*Sections*
R5.19	**Support PEMA Removal of Structures from Flood Prone Areas**	PEMA, FEMA, County Emergency Management Offices	Stormwater runoff Non-point source pollution	General

Description

In an effort to break the repetitive flood disaster cycle of damage-rebuild-damage, the Pennsylvania Emergency Management Agency (PEMA) has established a Hazard Mitigation Program which promotes the acquisition and relocation or removal of structures from flood-prone areas. The program also supports efforts to flood-proof existing structures and other measures to provide protection or reduce likely damage from future disasters. In addition to safety and property damage issues, removal of structures from floodplains will provide ecological benefits, including reduced non-point source pollution, and reduced stormwater runoff. Efforts should be made to support PEMA removal of structures from flood prone areas. Competitive Hazard Mitigation Grants are available to help residents and business owners with these types of projects. For further information consult the PEMA Hazard Mitigation Office (http://www.pema.state.pa.us), your County Emergency Management Coordinator, or the Federal Emergency Management Agency (FEMA) (http://www.fema.gov).

Code	*Recommendation*	*Appropriate Partners*	*Issues Addressed*	*Sections*
R5.20	**Fund Studies to Document Watershed Condition and Resources**	PA DEP, PA DCNR, US EPA, USDA, private foundations	Stormwater runoff Non-point source pollution Point source pollution Habitat quality Water supply	General

Description

Watershed management should be based on sound scientific principles and reliable field data. In order to develop effective management policies, studies should be conducted to document watershed condition and resources including detailed water budgets, water quality trends, land cover changes, the location and hydrologic/ecological significance of quarries and quarry pumping, the extent of riparian disturbance, wetland disturbance, and other characteristics. A program of basic research and technology transfer should be supported. Research areas of particular concern include: the effects of urban development and other land-use changes on streams; restoration methods and where within the watershed restoration is most needed; evaluation of best management practices; potential problems associated with climate change; and, evaluation of institutional or educational programs for promoting conservation and stewardship. Other studies of value in assessing and managing water resources in the Schuylkill River watershed include the design and implementation of a water quality monitoring network, and studies investigating water use and water balance to determine the limitations of existing surface and groundwater supplies throughout the watershed.

Code	*Recommendation*	*Appropriate Partners*	*Issues Addressed*	*Sections*
R5.21	**Support Studies to Assess the Impacts of Mineral Extraction on Water Quality and Quantity**	PA DEP, PA DCNR, US EPA, private foundations	Point source pollution Habitat quality Water supply	General

Description

For mining operations in the watershed, there may be potential metals and sediment impacts on adjacent streams; when closed down, there may be potential groundwater/hydrology impacts. In order to better understand both water quality and water quantity issues in the watershed, these impacts should be assessed.

Code	*Recommendation*	*Appropriate Partners*	*Issues Addressed*	*Sections*
R5.22	**Complete Comprehensive Water Budget Studies for the 37 Subwatersheds in the Schuylkill Drainage**	PA DEP, PA DCNR, US EPA, private foundations	Stormwater runoff Non-point pollution Point source pollution Habitat quality Water supply	General

Description

Over 3 million people draw their water supply from the Schuylkill basin. A reliable potable water supply needs to be secured, at a minimum, in the Schuylkill River watershed. Ideally, aquatic habitat value also should be secured. Follow-up studies to the current Source Water Assessment (SWA) should conduct combined surface and ground water studies to generate watershed-based water budgets, while also considering the combined impacts of point and non-point pollution, so that a prioritized strategic plan of action can be developed to preserve the watershed's water resources. Where possible, the cumulative impacts of water withdrawal (regardless of well size), discharge, transfers out of the watershed and aquifer recharge should be factored into the source water analysis and strategic plan.

Code	*Recommendation*	*Appropriate Partners*	*Issues Addressed*	*Sections*
R5.23	**Support Cost-Effectiveness Studies on Treating Point Versus Non-Point Source Pollution Impacts**	PA DEP, PA DCNR, US EPA, private foundations	Stormwater runoff Non-point pollution Point source pollution Habitat quality Water supply	General

Description

The current SWA, or follow-up studies, should prioritize which water pollution issues to address first in terms of cost-effectiveness. Subwatershed-based cost-benefit analysis of treating point versus non-point source pollution impacts should direct strategic action on pollution treatment in the watershed.

Code	*Recommendation*	*Appropriate Partners*	*Issues Addressed*	*Sections*
R5.24	**Support Cumulative Impact Assessments for Point and Non-point Source Pollution**	PA DEP, PA DCNR, US EPA, private foundations	Stormwater runoff Non-point pollution Point source pollution Habitat quality Water supply	General

Description

The current SWA, or follow-up studies, should assess the cumulative impacts of point and non-point pollution, and if possible, also assess the cumulative water extraction, discharge and recharge effects on a subwatershed basis across the entire watershed.

Code	*Recommendation*	*Appropriate Partners*	*Issues Addressed*	*Sections*
R5.25	**Support Outreach Phase for Implementation of the Schuylkill Source Water Assessment (SWA)**	PA DEP, PA DCNR, US EPA, private foundations	Stormwater runoff Non-point pollution Point source pollution Habitat quality Water supply	General

Description

The current SWA should be implemented through a follow-up outreach/marketing/crosswalk phase that ensures the guidelines it provides are adopted by municipalities, point-source facilities, nonprofits and citizens where necessary adopted throughout the watershed. This assessment should be done on a subwatershed basis to facilitate implementation.

5.7 References

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