HAVERFORD COLLEGE

Stormwater Master Plan
Volume One
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Aerial Photograph of the College Campus

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STORMWATER MASTER PLAN

HAVERFORD COLLEGE

VOLUME ONE

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Residence of the College President

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Founders Hall Plaza

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1 EXECUTIVE SUMMARY

Haverford College, which is the oldest planned college landscape in the country, has a distinct sense of place that supports innovative education and community involvement. Managing stormwater runoff from developed areas in an ever-changing regulatory environment, along with the need to expand or upgrade college facilities in an environmentally sustainable manner, is a challenge for any institutional entity. Haverford College has been on the forefront of evolving stormwater management techniques and measures over the last several years and wants to continue its leadership in attaining its sustainability goals and objectives. The College, as a member of the "Tri-College Consortium" of Philadelphia-area Quaker colleges, embraces Quaker ideology regarding social responsibility, simple living, and conservation of resources. This Stormwater Master Plan is a commitment by the College to study and understand existing and future stormwater management challenges so that stormwater generated on campus can be managed in a sustainable and responsible manner. The stormwater management implementation strategies set forth in the Plan, which are based on priorities developed with the College staff, will serve as a guide for future decision making.

The College does not anticipate any appreciable building expansion in the next few years. Therefore, this framework for developing and maintaining state-of-the-art stormwater management focuses on addressing existing stormwater issues on campus while also establishing recommended stormwater management performance requirements for future development. The overall Stormwater Master Plan is comprised of a number of sub-sections, which are summarized below. Refer to the following chapters for full details on each topic.

Note: A glossary of technical terms is provided at the end of Volume 1 for reference.

Physical, Cultural, and Ecological Context

The planning team reviewed the College archive documents and participated in site walks with College/Arboretum staff. The geologic, ecological, horticultural, cultural, and engineering context of the campus were evaluated to inform planning efforts relating to existing and proposed stormwater management.

Existing Stormwater Management Practices and Issues

Sub-watersheds within the campus were delineated based on topography and storm sewer conveyance infrastructure. The impervious cover rate for each sub-watershed was calculated, and each sub-watershed was modeled based on its area, land cover, slope, and soil characteristics. Runoff rate and volume for the existing conditions were tabulated for the 2, 10, 25 and 100-year storm events using the NRCS TR-55 methodology.

Perhaps the most significant stormwater management master planning task was assessment of the campus conveyance system in terms of capacity. Site storm drainage pipe systems were modeled based on archive drawings provided by the College, and analyzed for capacity based on the Rational Method for runoff generation. In general, the campus drainage system was found to have adequate capacity. Several problem areas were identified and recommended for upgrade, the most salient of which was the 30” culvert at the Visitor’s Parking Lot.

Even the best and most advanced stormwater management techniques can be greatly reduced in function without proper Operation and Maintenance (O&M) protocols. Current maintenance practices were determined based on interviews with College staff. Existing campus Best Management Practices (BMP) such as pervious paving, underground infiltration, and bioretention areas should be the subject of a more aggressive Operation and Maintenance program than is currently employed. The Stormwater Master Plan therefore includes a campus-wide Stormwater BMP O&M Manual to be used by building and grounds personnel to ensure system components are functioning at their highest efficiency. The manual includes a schedule for required maintenance and worksheets to guide and document required inspections and maintenance actions.

Sustainable Site Development and Proposed Stormwater Management Solutions and Standards

This chapter evaluates the green construction rating systems currently in widespread use - Leadership in Energy and Environmental Design (LEED) and Sustainable Sites Initiative (SITES) - and establishes the recommended stormwater management performance standards to be applied for future construction at Haverford College that go “above and beyond” the minimum regulatory requirements.

A listing of the most applicable stormwater management Best Management Practices (BMPs) for the Haverford College campus is provided. The description of each BMP type describes the situation in which it is best employed, a general description of the function, photographs, and a case study of where that type of BMP has been used successfully in the past.

Recommended stormwater management improvement projects to address existing stormwater issues on campus are described in this chapter. The recommended projects include:

- Pinetum Bioretention Basin
- Pinetum Native Species Resilient Habitat
- Stokes Hall Drainage Improvements
- Roberts Hall Drainage Improvements
- Haverfarm And Facilities Management Complex Basin Improvements
- Eroded Stream Restoration
- Visitor’s Parking Lot Culvert Replacement
- Upper Pond Sediment Trapping Enhancement
- Duck Pond Buffering and Water Quality Enhancements
- Duck Pond Outfall Enhancements
- Additional South Parking Lot Infiltration Bed
- Campus-wide Storm Sewer System TV Inspection
- Storm Sewer Upgrades

Regulatory Considerations and Funding Opportunities

Guidance relative to existing and anticipated changes to the local, state and federal regulatory environments is provided in the Stormwater Master Plan. The most relevant regulations are the Township stormwater management ordinance, and the statewide National Pollutant Discharge Elimination System (NPDES) program that is administered by the County Conservation District.

Ryan Pinetum

Potential grant funding opportunities to facilitate construction of stormwater management improvements are listed with descriptions in the Stormwater Master Plan.

1 – 1 Acknowledgements

The following organizations and individuals contributed to the preparation of this Stormwater Master Plan:

HAVERFORD COLLEGE:

- Don Campbell, Director of Facilities Management
- William Anderko, Assistant Director of Facilities Management
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2 INTRODUCTION

This report was commissioned to develop a cohesive strategy for addressing the College's current and future stormwater management challenges. The planning approach requires a comprehensive understanding of the physical and cultural aspects of the campus as well as natural resources and ecological processes at play within the greater landscape.

View of Sharples Hall and the Sciences Center

The College provided drawings and reports for existing facilities and facilities currently under construction. Archive documents related to campus utilities and land use were also provided. Site walks with the planning team members and College / Arboretum staff were conducted to review existing site features and ecological context.

New aerial photography and topographic mapping was performed for the campus in December 2018 to serve as the base plan for the study. This mapping provided topographic contours at one-foot intervals, a color aerial image, and depicted current campus conditions relative to buildings, paving, and vegetative cover.

A series of coordination meetings with College staff was conducted to discuss sub-watershed mapping, future campus planning, ecological systems, and Stormwater Best Management Practices (both existing and proposed). These meetings helped to develop priorities and align expectations for the Stormwater Master Plan. Sub-watershed delineation was then undertaken along with documentation of the campus storm drainage collection system based on archive documents and site walks. As stipulated by the College, no topographic survey or entry into storm sewer structures was undertaken as part of the preparation of this Stormwater Master Plan. Estimates of pollutant loadings were developed for existing conditions, and data from the reviews and investigations described above were used to identify the most favorable stormwater Best Management Practices to employ on the campus as well as to provide recommendations on the Operations and Maintenance of the existing stormwater management systems. To assist the College staff in prioritizing various recommended improvement projects, an order of magnitude cost estimate was prepared for each recommended project to inform the decision-making process with budgetary estimates and considerations.

The following chapters will expand upon the topics of campus setting and context, existing stormwater management, proposed stormwater management, current stormwater-related regulations, and available grant/funding opportunities.

The information summarized in these topics comprises the Stormwater Master Plan. This plan will provide guidance to College personnel in addressing existing and future stormwater management challenges in an ecologically and environmentally sensitive matter.

3 CAMPUS SETTING

3-1 Cultural Context

Haverford College was the first College founded by the Society of Friends in 1833. The 225-acre property includes several historic structures. The area where the College was founded was part of a larger predominantly agricultural region that involved livestock, grain production, orchards and garden produce. Grist and sawmills were built on Cobb's Creek in the early 1800's to produce lumber, gun powder, and cotton. Successful mills necessitated improved transportation routes, which then opened the Township for new development. The Philadelphia and Columbia Railroad extended from Broad Street west along Railroad Avenue in Haverford Township, enhancing general commerce. All of these events contributed to the founding of Haverford College.

1887 Atlas of Properties along the Pennsylvania R.R.

The College straddles the county line and is located in both Haverford Township, Delaware County and Lower Merion Township, Montgomery County.

3–1a Quaker Education

There are common threads that run through each school of the Society of Friends. They all seek to foster community spirituality, responsibility, and stewardship. Because a Quaker education endeavors to be socially responsible and promote living in harmony with natural surroundings, Haverford College aspires to stormwater management standards that go beyond the minimum requirements established by prevailing regulations and aspires to correct the ecological impacts of historical development.

3–1b Stewardship

Managing stormwater runoff from buildings, paved surfaces, lawns and fields in a responsible way increases groundwater recharge, which is instrumental to maintaining the base flow of the College's streams and creeks. It also reduces erosion and sedimentation while improving water quality. Protecting natural systems for present day use and appreciation preserves eco-systems and their essential functions for future generations. This is an ethically responsible approach that is consistent with Haverford College's guiding principles.

Stewardship is one of the building blocks in the Quaker education and one that manifests itself in stormwater management goals that go beyond baseline regulations from an environmental perspective.

Fine Arts Center Alley

3-2 Physical Context

3-2a Geology

The geologic setting can have a significant impact on stormwater management due to its influence on soil properties and infiltration characteristics, topography, drainage patterns, groundwater impacts, and construction effort. The infiltration characteristics of the campus are particularly important because infiltration of rainfall contributes to stream base-flows and is the primary technique for managing runoff volume for construction projects per the applicable stormwater management regulations.

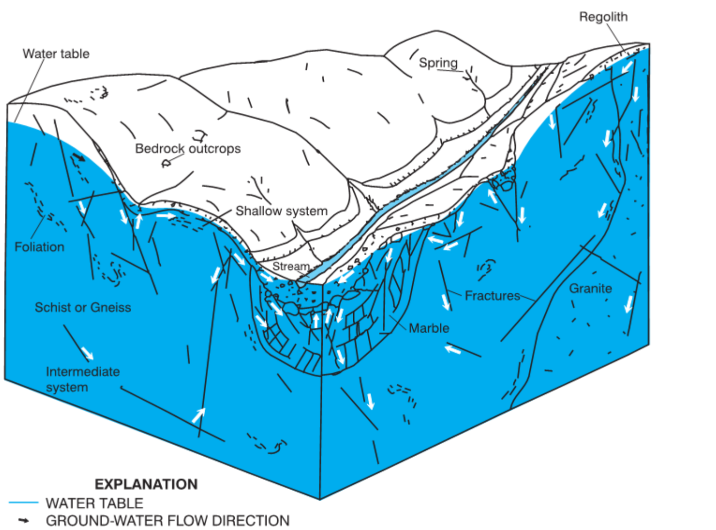


Figure 13. Topographic, geologic, and hydrologic features of the Piedmont Physiographic Province, Piedmont Upland Section.

The Haverford College campus is mapped as underlain by the Wissahickon Formation (Geologic Symbol: Xwc), according to the Commonwealth of Pennsylvania, Topographic and Geologic Survey, *Geologic Map of Pennsylvania*, 1980.

As noted in The Pennsylvania Geological Survey, Engineering Characteristics of the Rocks of Pennsylvania, Fourth (4th) Series, Revised 1982, the metamorphic Wissahickon Formation "is typically composed of mica schist, characterized by its distinct foliation, which is caused by the preferential orientation of quartz, feldspar, muscovite, and chlorite. The bedding within this formation is typically fissile to thin, and steeply dipping in most places. The cleavage has a platy pattern, and is well developed. This rock type is somewhat resistant to weathering, and often highly weathered to a moderate depth. This formation typically offers good surface drainage. Joint and cleavage openings provide a low secondary porosity and low permeability. Excavation within this material is typically moderately easy in weathered horizons and difficult in un-weathered rock."

The campus's location over the geology of the schist of the Wissahickon Formation presents both opportunities and constraints for stormwater management.

Based on our experience, and considering site topography and elevations ranging from approximately 300 to 390 across the campus, surface drainage and the thickness of the weathered saprolite soil profile over bedrock will represent primary variables for stormwater management. Secondary considerations will include the degree of human disturbance to the soil profile through historical site development, depth to seasonal high-water tables, and the saprolite orientation and gradation of residual soils in each location.

Due to variability associated with infiltration potential in schist geology, site specific investigation will be necessary to verify potential and support design efforts for specific stormwater management facilities. Consideration of the physical/geologic setting will help inform expectations and prioritize design decisions.

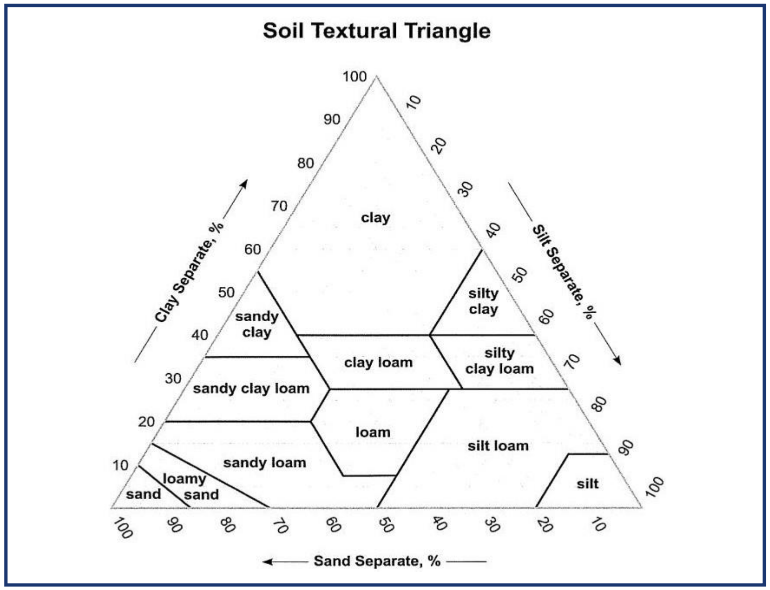
3-2b Soil

Soil is material found at the surface of the earth which has formed over time by the actions of climate and living organisms on the underlying geological parent material. It varies across the landscape according to these soil forming factors along with the additional factor, topography. Soil consists of both organic and mineral fractions. The organic fraction comes from decaying plant and animal debris and the mineral component is derived from inorganic sources subdivided in terms of particle size into stones, sand, silt, and clay.

A review of the National Resource Conservation Service (NRCS) Soil Survey via Web Soil Survey for the campus area indicates that soils are expected to consist of Glenelg, Manor, Glenville, Hatboro, and “made land” type soils. The soils map also identifies Urban land soil complexes indicating notable impervious coverage. The Glenelg soil series is typically comprised of very deep and deep, well drained soil formed in residuum from micaceous schist bedrock. Glenelg type soils are often conducive to installation of structural stormwater infiltration BMPs, with the greatest hydraulic conductivity typically being found in its loamy to sandy soil horizons. The Manor soil series is categorized as very deep, well drained soil. For stormwater management purposes, Manor soils can be regarded as very similar to Glenelg soils; however, Manor soils lack development of a fine-grained subsoil horizon. The Glenville soil series is characterized as very deep, moderately well drained or somewhat poorly drained, typically formed in residuum from metamorphic and crystalline bedrock types. Glenville type soils are limited for structural infiltration facilities use by slowly permeable soil horizons and seasonal saturation or regional groundwater intrusion. The Hatboro soil series consists of very deep, poorly drained soils formed in alluvium from metamorphic and crystalline rock parent materials. Hatboro soils are not suitable for structural infiltration BMPs due to shallow seasonal water table saturation and/or near-surface regional groundwater levels. Hatboro soils are often occupied by wetland plant communities.

One of the most important soil properties is soil texture, which refers to the relative proportions of sand, silt, and clay found in a soil sample. The soil texture determines the extent and size of pore spaces, which in turn determines the rate with which water passes through a soil (i.e. its permeability). Infiltration rates are used to describe how fast water or rainfall can move through soil mantle at or near the surface. When the rate of rainfall exceeds the rate at which the soil can infiltrate, runoff occurs.

Infiltration rates for soils are a very important aspect of stormwater management. Soils are grouped into Hydrologic Soil Groups (HSGs) A, B, C, and D with Group A being the most infiltrative and D being the least. Figure 3.1 shows the various soil associations found on campus. Figure 3.2 shows the relative distribution of campus soils based on hydrologic soil group (HSG).



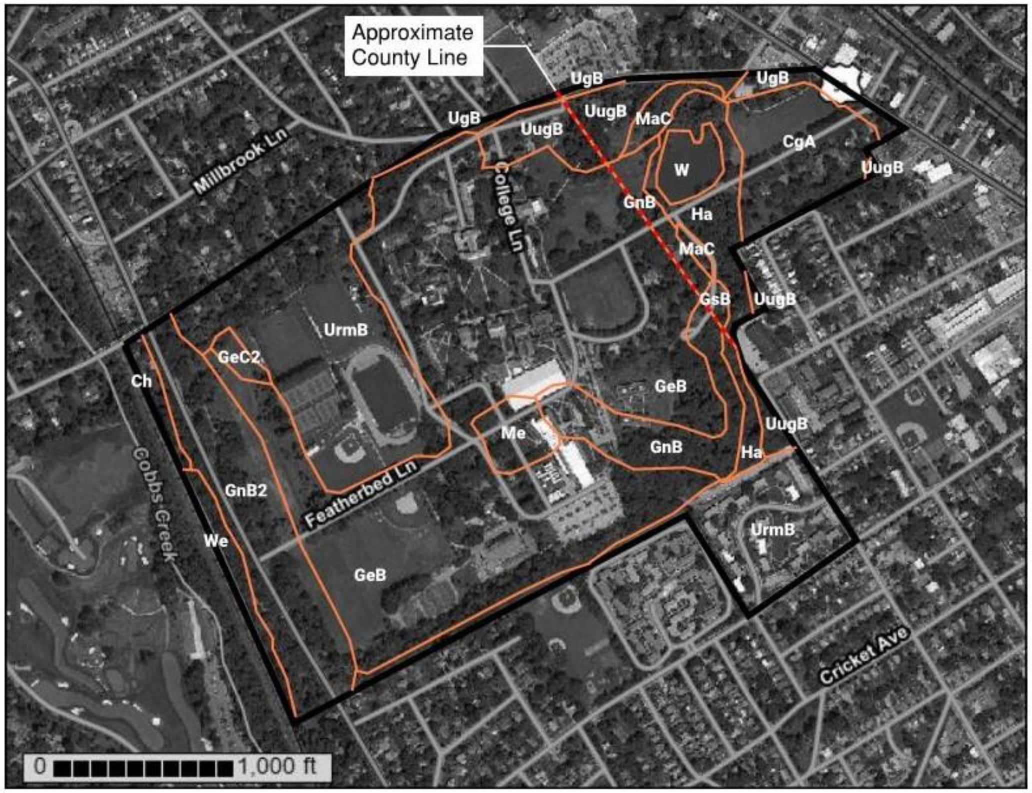


Figure 3.1: Soil Associations

KEY – DELAWARE COUNTY		
SOIL	**SOIL NAME**	**HYDROLOGIC GROUP**
Ch	Chewacla silt loam	B/D
GeB	Glenelg channery loam	B
GeC2	Glenelg channery silt loam	B
GnB	Glenville silt loam	C/D
GnB2	Glenville silt loam	C/D
Ha	Hatboro silt loam	B/D
Me	Made Land	C
UgB	Urban Land	D
UrmB	Urban Land - Glenelg complex	B
UugB	Urban Land - Udorthents	C
We	Wehadkee silt loam	B/D

KEY – MONTGOMERY COUNTY		
SOIL	**SOIL NAME**	**HYDROLOGIC GROUP**
CgA	Chester silt loam	B
GnB	Glenelg silt loam	B
GsB	Glenville silt loam	C/D
Ha	Hatboro silt loam	B/D
MaC	Manor loam	B
UgB	Urban Land	D
UugB	Urban Land - Udorthents	C
W	Water	-

Figure 3.2: Campus Hydrologic Soil Groups

3-2c Topography

Topography is the configuration of a surface including its vertical elevation changes and the position of its natural and man-made features.

The changes in the earth's surface define mountains, valleys, and water courses. Through survey measurements of relative elevation and position, a three dimensional model of the earth's surface can be created. The product of the model is a contour map which is an essential tool in understanding and planning for stormwater management.

Duck Pond – Upper Meadow

Campus contour elevations vary from a low point of 300-feet at the south end of the Haverford College Apartments site to a high point of 392-feet along College Avenue north of the Dining Center. The ridges and swales between these points determine the subwatershed boundaries as shown in Figure 4.1 (in the next chapter of this report).

The vertical rise divided by the horizontal run (i.e. the slope) of the land features influences how runoff is accumulated and the rate at which it is conveyed from the higher to lower elevations.

3-3 Ecological Context

The Haverford College Arboretum landscape boasts a diverse palette of plants reflecting the 1834 design by William Carvill, rather than the native oak forest that would have once dominated this area. While a priority for the College will no doubt be the continued maintenance of the wide variety of Arboretum specimens, including the Pinetum, there are also opportunities to support native ecological function through the stewardship of the stream corridor, Cobbs Creek floodplain and to provide habitat for native wildlife species, in support of bioregional resilience. It is worth looking at a broader ecological context to better understand this potential of the campus landscape to restore and enhance ecosystem health.

3-3a Habitat Biodiversity

Referencing existing studies by the Environmental Systems Research Institute (ESRI) and The Nature Conservancy (TNC), we find that the Cobbs Creek watershed lacks regional-scale "habitat cores" – large, minimally disturbed natural areas – and that it lacks regional "resilient landscapes" – defined by TNC as an area of land with high microclimate diversity that supports higher biodiversity over time. Habitat patches in the Cobbs Creek watershed are smaller and concentrated along streams. Therefore, wildlife in the local watershed are primarily sustained by riparian habitat fragments, and more mobile species such as birds are also supported by interaction with habitat in other watersheds. This context makes existing forest, wetland, and meadow vegetation patches of particular importance to local wildlife in the Cobbs Creek watershed.

Haverford College's location in the headwaters of Cobbs Creek (refer to Figure 3.3) presents important aquatic habitat and water quality opportunities. Habitat and water quality enhancements on campus can thus have greater positive influence per acre on adjacent waterways and riparian areas than can other parcels downstream. Farther downstream in the watershed, there is a greater accumulation of acreage from other properties that influences Cobbs Creek and its tributaries.

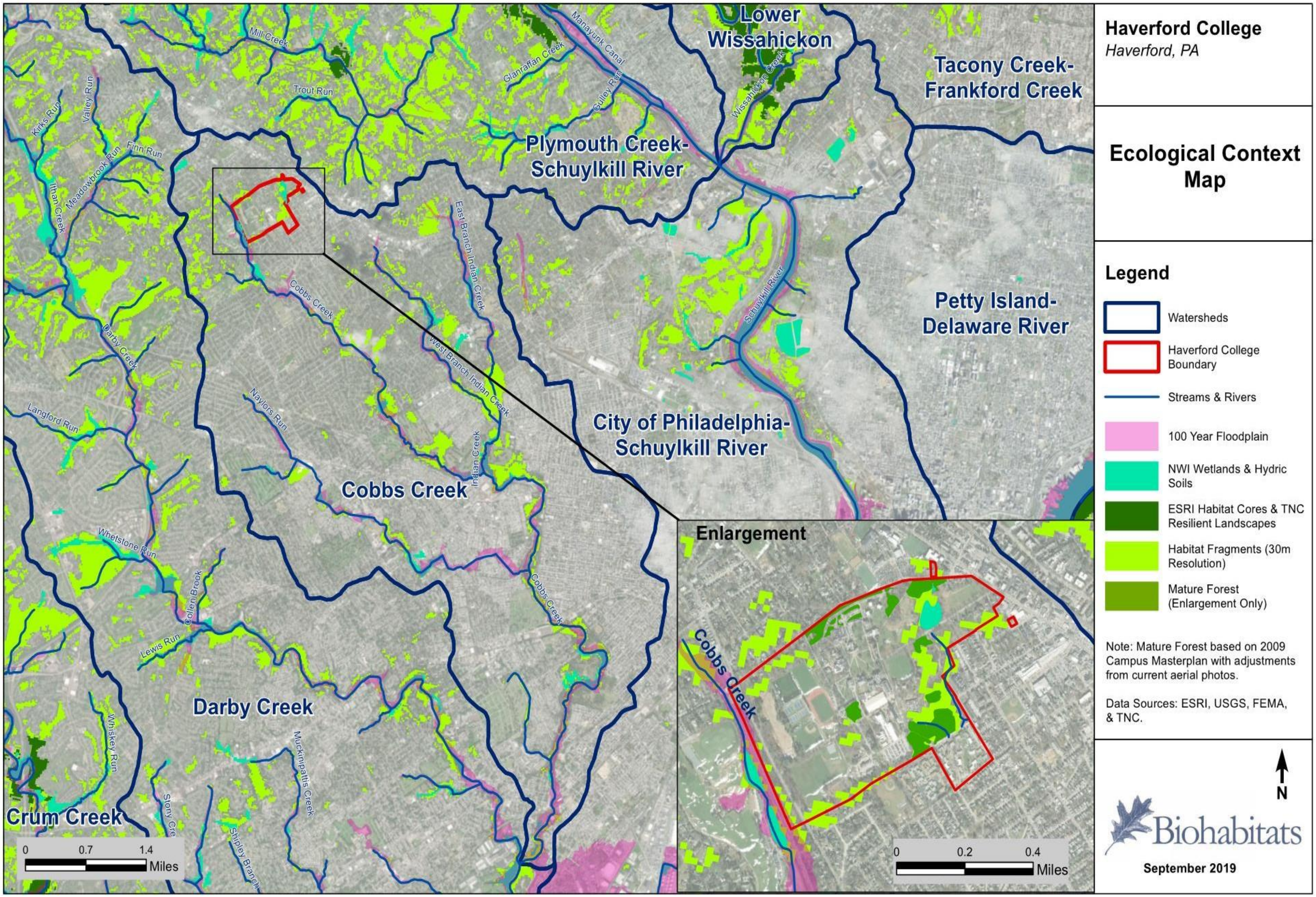


Figure 3.3: Ecological Context Map

3-3b Riparian Corridors

If we look to less developed riparian corridors in nearby watersheds for reference, we see two of particular value that lend additional information about the local native ecology – the Wissahickon Creek and the Schuylkill River. In the Wissahickon Valley the watershed association has protected a green space along the Creek that reflects native conditions at the Green Ribbon Preserve. In this preserve the communities of note are floodplain and floodplain terrace systems. Forest includes the *sycamore (river birch) box-elder floodplain forest* characterized by sycamore, slippery elm, red maple and occasional silver maple species. In the floodplain terrace above, *bottomland oak-hardwood palustrine forest* is found, with swamp white oak, pin oak, white ash, green ash, black walnut, cottonwood, shagbark hickory, shellbark hickory, red maple, honeylocust, and tulip tree. Areas outside of the terrace provide further evidence of a *riparian red oak- mixed hardwood forest* with the following species: red oak, American beech, tulip tree, mockernut hickory, white oak, white ash, and flowering dogwood, as well as spicebush, blackhaw, northern arrowwood, spring beauty, and mayapple in the shrub and groundcover layer. Upland forests in another location along the Wissahickon reflect species of the *dry oak-heath forest* including black oak, white oak, southern red oak, American beech, black birch, tulip poplar, red maple, bitternut hickory, scarlet oak, chestnut oak, black cherry, flowering dogwood, and sassafras. (Montgomery County, PA)

Given this region's connection to the Atlantic flyway it is worth also noting the diversity of bird species that travel along the Delaware River corridor seeking refuge and habitat in the Philadelphia region. According to e-bird.org over 160 unique bird species have been identified on the Haverford campus. Migratory bird species, which spend part of their life cycle in the region, include the ruby-crowned kinglet, snow goose, pine siskin, and the yellow-rumped warbler.

College Lane Culvert and Streambank Protection

3-3c Ecological Context Recommendations

The Haverford College Arboretum (400 species of trees and shrubs) was officially founded in 1974 to continue stewardship of the landscape's historic design and pastoral character. The goal is to support stewardship of the historic and specimen trees and maintain the historic design intent. A robust renewal project was recently kicked off after the completion of the College's first comprehensive tree assessment. Initial steps taken after that study will include the pruning of 408 trees and the removal of 406 specimens that were defective, decaying or failing. The plan is that for every tree removed two are planted to support long-term growth. As removal continues it will be prudent to reflect on both the original designer's intent as well as the native plant palette reflected in the regional ecology. In addition to tree management, the arboretum also maintains the native meadow in the center of the Pinetum and plants understory native trees and shrubs in the mature woods.

An increase of native tree canopy and other native vegetation on campus would increase habitat value on site and for the local watershed. Typical native tree species observed on site along the stream corridor reflect the riparian red oak mixed hardwood and terrace bottomland oak-hardwood palustrine forest plant communities, including white oak, tulip poplar, red maple, silver maple, black cherry, green ash, black walnut, sweetgum, red mulberry, grey birch, black locust, honeylocust, and American beech. These species and the regional reference plant communities could provide a basis for increasing ecological function on campus.

In addition to providing local habitat, an increase of native tree canopy would also provide “stepping stones” for animal movement to scattered, larger forest patches farther downstream within the Cobbs Creek watershed, and between the more forested adjacent watersheds. Expansion and enhancement of existing mature forest would increase the ability to support biodiversity. Increase of tree canopy to facilitate east-west movement of fauna across campus would better connect the Cobbs Creek riparian forest and wetlands to the larger forest patches, wetlands, and stream on the east side of campus. The pond and associated aquatic and riparian habitat on campus offer a significant opportunity to enhance habitat along with water quality.

Many resident and migratory birds, and wildlife in general, will interact with water sources on a regular basis. The quality of that associated habitat, and connectivity to and from it, will affect the biodiversity that it can support. An increase in native species structural diversity below the native tree canopy will increase wildlife habitat value, particularly for foraging and nesting birds. This entails increasing native species presence below the tree canopy in multiple layers. Additionally, these measures would provide some level of water quality increase by increasing rainfall interception and infiltration.

Streams on campus show the impacts of development within their local watersheds. Impervious surfaces and soil compaction have increased runoff volumes and eroded stream banks. Sediment from the erosion has impacted instream habitat structure and created steep banks that limit amphibian and reptile movement from water to floodplain forest. Stabilization of eroded stream banks and increased rainwater infiltration and storage on campus would help reduce further stream habitat impacts. Stream baseflow is low and streams are buried from Haverford College southward, which significantly limits habitat potential for fish. Campus streams do have some cobble and gravel bed

Duck Pond

Figure 3.4: Potential Tree Canopy Expansion

structure that likely provides habitat for aquatic insects. These structures should be enhanced with future stream restoration and bank stabilization.

As a relatively large open water body, the Duck Pond is a locally unique habitat for fish, amphibians, and reptiles. It is also used by Canada geese, whose waste can be a pollutant source that impacts water quality, with negative effects on the aquatic food web. Enhancement of surrounding vegetation and water quality improvement would increase the Duck Pond's value as aquatic habitat.

Some nonnative invasive species were observed across campus including trees such as Amur corktree, Norway maple, and white mulberry, and shrubs and herbaceous species such as English ivy, multiflora rose, garlic mustard, Japanese knotweed, and wineberry. These species vigorously compete and often negatively impact native species of higher habitat value. Management of these invasive species will help increase existing forest quality and future viability.

Through these approaches, ecological context and history can help guide ecological restoration, enhancement, and management at Haverford College.

3-4 <u>Engineering Context</u>

Unmanaged stormwater runoff from development impacts the Haverford College campus in three (3) ways:

- Increased Rate of Discharge
- Degraded Water Quality
- Increased Runoff Volume

When these three (3) factors are not managed, flooding, erosion, and degradation of surface water quality occur.

3-4a Increased Rate of Discharge

The "rate of discharge" is a measure of how fast stormwater runoff leaves a site. Traditionally, civil engineers have focused their design efforts on slowing down the peak rate for storm events using detention facilities. A detention basin collects the excess runoff from changed surface conditions (e.g. conversion of meadow to parking lot) and then slowly releases it to the downstream watershed. While control of peak rates is important, peak rate control alone is inadequate to manage all of the potential impacts of increased stormwater runoff. It was unfortunately the sole management strategy used across Pennsylvania for many years.

The landscape position that a particular site has within a watershed impacts the recommended release rate for various design storms. Per the Act 167 Watershed Plan for the Darby-Cobbs Creek Watershed, the Haverford College campus is located in Management District A which is subject to the following peak rate control guidelines:

Proposed Conditions Peak Rate	Shall Not Exceed	Existing Conditions Peak Rate
2 – year	…	1 – year
5 – year	…	5 – year
10 – year	…	10 – year
25 – year	…	25 – year
100 – year	…	100 - year

These are the least restrictive of the Management District requirements of the Darby-Cobbs Creek Act 167 Plan, which increase in severity as locations move down the watershed towards the Delaware River.

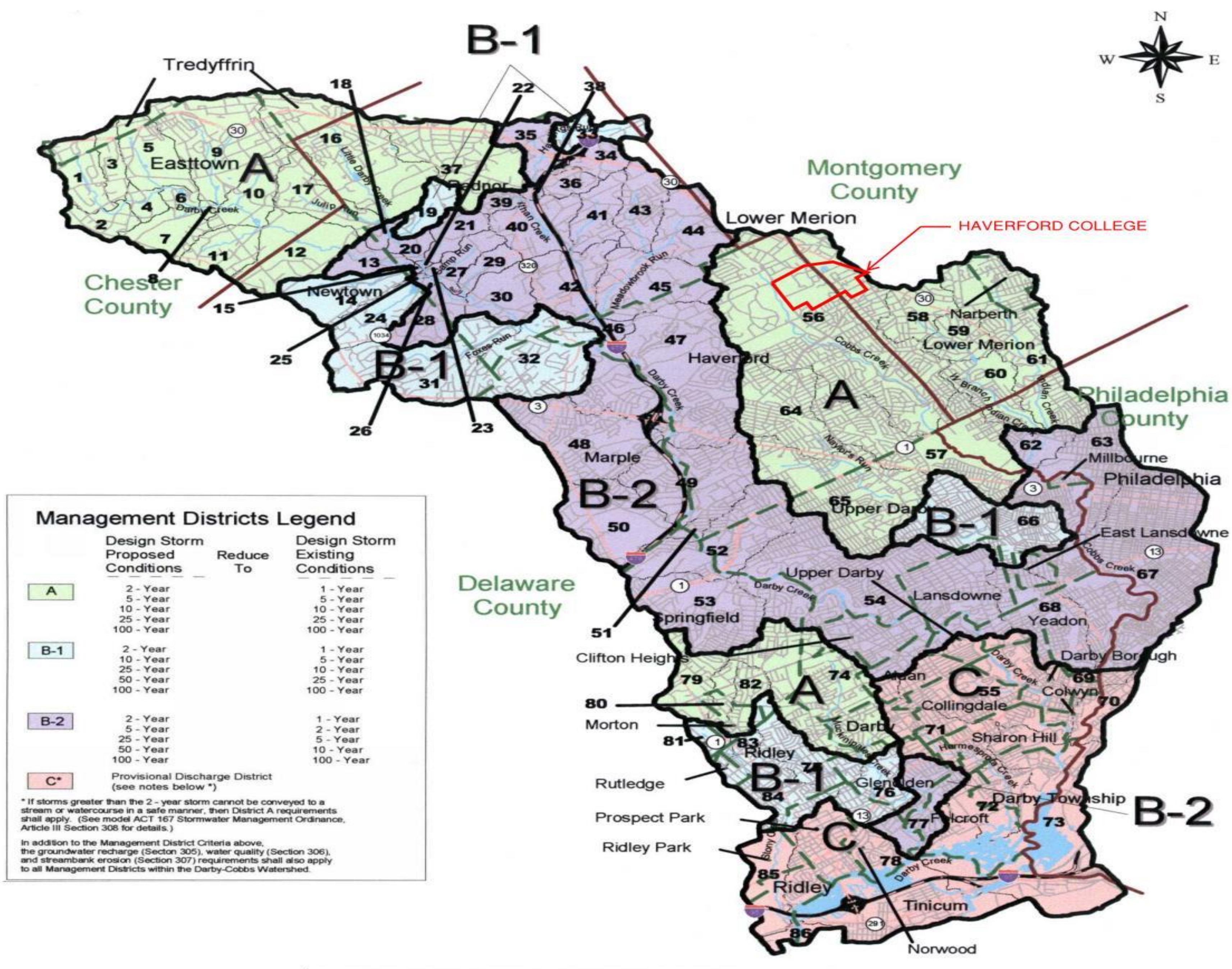


Figure 3.5: Rate Release Districts

3-4b Increased Runoff Volume

As the proportion of impervious cover within a watershed increases, the volume of stormwater runoff is increased. The increase varies with the storm event magnitude. For example, a typical campus 2-year rainfall of 3.27 inches in 24-hours creates 2.6 inches of additional runoff for every square foot of impervious surface added, compared to an HSG B soil area with woodland cover. This contributes to flooding and reduction of groundwater recharge and stream base flow. As runoff volume increases, small swales and meandering streams can be transformed into highly eroded and deeply incised channels by the extended timeframe of erosive flows. The erosion, transport, and deposition natural process associated with streams is accelerated with increased runoff volume, which changes the natural shape and form of channels. Pools and riffles that support aquatic communities are altered as the channel erodes and stream bottom habitat is degraded by sediment deposition.

Concrete Weir in Stream Near Nature Trail

This low-head dam is an example of how human activities can fragment stream reaches, decrease natural resiliency, contribute to stream bank erosion, and impact the ability for fish and macroinvertebrates to reach spawning sites.

Volume control efforts focus on managing runoff from smaller but much more frequent rainfalls that comprise the majority of runoff events. Since the runoff volume for infrequent storms (such as the 100-year events) is so large and occurs so rarely, it is not practical to use these large storm events as the basis for volume control requirements. Typically, bank-full stream flow occurs somewhere between the 1-year and 2-year storm event. For this reason, the 2-year event is used for design of stormwater management practices relative to volume increase.

Replicating natural hydrologic conditions in the watershed through the use of stormwater management practices is a sustainable approach to addressing stormwater runoff issues. When existing vegetation is removed, it removes the single largest component of the natural hydrologic regime, evapotranspiration. This is why management practices like green roof systems, riparian corridor enhancement, infiltration, and bioretention are so important in replacing lost evapotranspiration.

"Capture and Re-use" is another tool that can be used to control volume increases. Cisterns and subsurface tanks can collect runoff from building roof tops, which can be re-used for landscape irrigation and / or flushing toilets in buildings.

3-4c Degraded Water Quality

The increased rate and volume of surface runoff due to site development are the two most obvious results of urbanization. However, the pollutants transported in the runoff also present a significant impact to the health of the watershed. Pollutants such as us phosphorous, nitrogen, hydrocarbons, synthetic organics and sediment are suspended and dissolved in the runoff. They come from chemically maintained lawns and landscape areas as well as “hot spot” impervious areas like parking lots and heavily traveled roads.

Stormwater pollutants are found in two forms – particulates and solutes. Particulates include total suspended solids (TSS), total phosphorous (TP), most organic matter, metals, and pesticides. They remain in suspension and are very difficult to settle out as they are transported in small particles or colloids. It is possible to add chemicals to a runoff containment to accelerate settling of particles but subsequent removal of sludge is required, making that approach impractical for many situations.

Solutes are soluble pollutants such as nitrate, ammonia, organic chemicals, and many pesticides. They typically do not exhibit any increase during storm events and may actually be diluted by runoff. Filtration through soil and vegetation is the most effective method to remove the pollutant load. Stormwater flow across vegetated filler strips and riparian buffers is also a very effective way to improve runoff quality.

An additional concern is the thermal characteristics of the runoff. Groundwater feeding into a stream is at a relatively constant temperature. Stormwater runoff from impervious surfaces tends to be warmer in the summer months and colder in the winter months compared to groundwater baseflows, which creates thermal extremes that negatively impact aquatic organisms. Fish like native trout are especially susceptible to stream temperature variations due to the decreased capacity for dissolved oxygen associated with higher temperatures.

Stormwater quantity and quality are closely related in that many management strategies that address one will also address the other. Managing water quality for the “first flush” of runoff, which carries the heaviest pollutant load, provides a significant benefit for downstream waterways and aquatic habitats.

Example of sediment-laden discharge to stream

4 EXISTING STORMWATER RUNOFF AND MANAGEMENT

4-1 Existing Drainage Areas, Impervious Coverage, and Runoff Quantity & Quality

Annual rainfall in the Haverford College geographic area amounts to around 45-inches. Precipitation occurs most frequently in small storms which represent the majority of both the number of rainfall events and cumulative rainfall volumes. Large, intense rainfall events have a low probability of occurrence.

Typically, for an undisturbed area of woods and fields, 55% of rainfall is returned to the atmosphere through evapotranspiration. Runoff occurs for about 18% of the rainfall and baseflow (infiltration) to the aquifier or streams amounts to 27%. After development occurs, which creates extensive impervious surfaces, evapotranspiration and baseflow are drastically reduced and runoff is increased.

Tritton Hall Meadow

Modeling of the campus hydrology provides a quantitative means of understanding impacts of existing and potential development. Determining the boundaries between campus sub-watersheds is the first step in the quantitative analysis of runoff dynamics. The sub-watersheds are defined by localized topographic features and stormwater piping infrastructure. Understanding where gravity and topography will direct runoff allows for the mapping of discharge points or "points of interest," which are typically located at low points around the campus perimeter.

The sub-watersheds described below were delineated based upon a review of the topography, storm sewer infrastructure, and downstream conditions. Refer to Figure 4.1 for a graphical depiction of the sub-watersheds. The topography for all sub-watersheds ranges from moderately to fairly steeply sloped.

Sub-Watershed WS-1 is an area in the southwest quadrant of the campus that includes the Organic Farm and Garden, Facilities Management Complex, athletic fields, and wooded areas along the Nature Trail. The entirety of WS-1 drains through an existing storm sewer system that connects to the drainage system in Haverford Road.

Sub-Watershed WS-2 is a large area along the western perimeter of campus that includes athletic fields, tennis courts, the Ryan Pinetum, and wooded areas along the Nature Trail. This watershed drains in a westerly direction to Haverford Road via overland flow.

Sub-Watershed WS-3 is a relatively small and less developed area that contains faculty housing and portions of the campus roadway network. WS-3 drains in a northwesterly direction to College Avenue via overland flow.

Sub-Watershed WS-4 is moderately sized area that contains the Haverford College Apartments (HCA), Visitor's Parking Lot, portions of the campus road network, and wooded areas along the Nature Trail. This area drains to the south to Ardmore Avenue, and includes a substantial 144"x60" box culvert that carries the flow of a stream beneath the HCA site. Additionally, a 30" culvert carries the flow from a stream channel originating in the central area of campus under the Visitor's Parking Lot to the aforementioned box culvert.

Sub-Watershed WS-4A is the large, highly developed area in the center of campus that contains academic buildings, athletic facility buildings, dormitories, parking lots, and roads. WS-4A drains through a heavily eroded stream channel to the 30" culvert described under WS-4.

Sub-Watershed WS-4B is a moderately sized area in the southeast portion of campus that includes faculty housing, roads, substantial wooded areas, and a stream that flows from the Duck Pond to the box culvert described under WS-4. This stream is in reasonably good condition due to successful stream bank stabilization projects undertaken by the College.

Sub-Watershed WS-4C is a moderately sized area in the northeast portion of campus that includes the dining center, academic/administrative buildings, dormitories, roadways, wooded areas along the Nature Trail, and the 3 acre Duck Pond. Upstream of the Duck Pond is the smaller "Upper Pond", which serves as a forebay for the Duck Pond and receives an upstream off-site drainage area of about 150 acres of developed area.

Sub-Watershed WS-5 is a small, wooded drainage area located along the southern boundary of campus that drains to Haverford Road.

Since impervious cover is a primary factor that leads to issues caused by stormwater runoff, the impervious cover within each sub-watershed was quantified. Refer to Table 4.1 for a summary of sub-watershed areas and impervious coverage rates. Sub-watersheds WS-2 and WS-4A have the largest contributory drainage areas. WS-4A has both a large size and nearly the highest impervious coverage rate, which is directly related to the heavy erosion of the stream channel and flooding of the 30" culvert at the Visitor's Parking Lot that will be described in detail in Section 4-2. While WS-2 has a lower impervious coverage rate, it still has a significant size and minimal stormwater management; this is directly related to the runoff-related issues occuring at the Pinetum and Haverford Road that will be described in more detail in Section 4-2.

TABLE 4.1
SUB-WATERSHED AREA & IMPERVIOUS COVERAGE

Sub-Watershed ID	Area (Ac.)	Impervious Coverage
WS-1	13.6	18.5%
WS-2	46.1	17.2%
WS-3	8.4	20.8%
WS-4	14.3	38.8%
WS-4A	46.6	38.0%
WS-4B	30.2	15.7%
WS-4C	32.1	16.4%
WS-5	2.3	0.0%

After delineation of the sub-watersheds, the existing land cover conditions, steepness of slopes, and soil types were quantified and used to determine the different stormwater generation characteristics of each sub-watershed.

Precipitation rates for various storm frequencies were then applied to quantify the rate of discharge and volume of runoff for each storm event.

Modeling of runoff characteristics is accomplished using computer programs specifically adapted for predicting storm event outcomes. They have been tested over decades of use and are the methods accepted by regulatory authorities. Two such hydrology models were used in this report. The first is *HydroCAD* which is based on the Natural Resources Conservation Service (NRCS) TR-55 methodology. This method uses land cover, soil, and slope characteristics to assess peak rate of flow and runoff volume for individual “design storms”. The design storms used in this study are as follows:

2 - year storm	**3.27” of rain in 24-hour period**
10 - year storm	**4.82” of rain in 24-hour period**
25 - year storm	**5.85” of rain in 24-hour period**
100 - year storm	**7.64” of rain in 24-hour period**

It should be noted that over 95% of the annual rainfall volume impacting the Haverford College campus occurs in events that are less than the 2-year storm.

Refer to Tables 4.2 and 4.3 for summaries of the peak rates of runoff and runoff volumes, respectively, for each sub-watershed.

The second model employed is *WinSLAMM*, which evaluates runoff volume and pollutant loading for each land use within a source. The software evaluates small storm hydrology based on the concept that the majority of the runoff volume and pollutant loadings in urban areas are a result of small and medium rainfall events. This provides the ability to target the highest loading areas and recommend improvements to reduce runoff volume and pollution loading from these areas.

TABLE 4.2
RUNOFF PEAK RATE OF DISCHARGE (cfs)

Sub-Watershed ID	2-YEAR	10-YEAR	25-YEAR	100-YEAR
WS-1	10.5	23.1	33.2	52.6
WS-2	45.9	94.9	131.9	201.1
WS-3	7.9	17.0	24.2	38.0
WS-4	25.3	46.1	61.5	90.2
WS-4A	82.9	148.5	196.5	284.4
WS-4B	38.6	79.7	110.5	167.5
WS-4C	45.9	92.9	127.8	192.0
WS-5	0.3	1.4	2.5	4.7

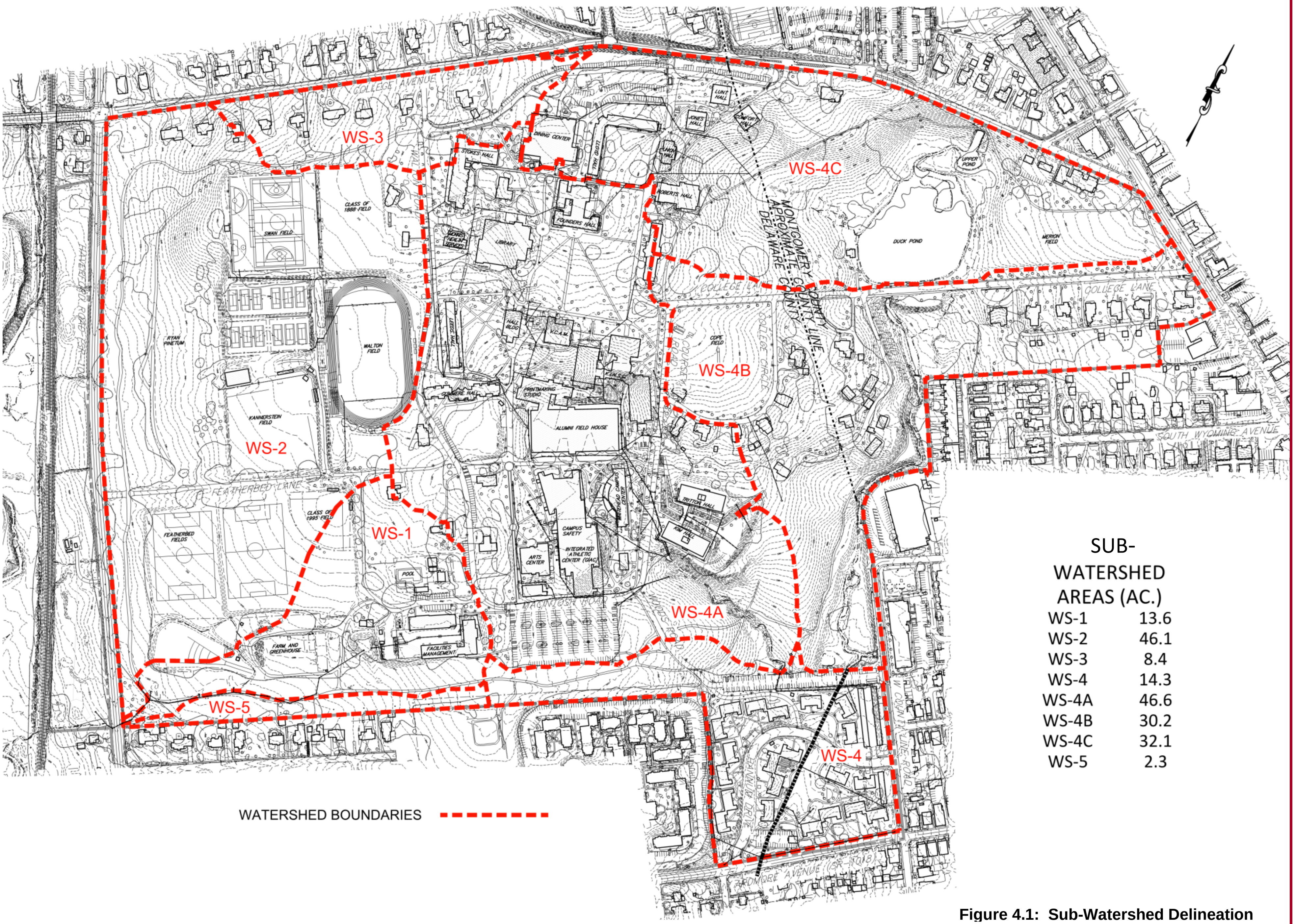
TABLE 4.3
RUNOFF VOLUME (ac-ft)

Sub-Watershed ID	2-YEAR	10-YEAR	25-YEAR	100-YEAR
WS-1	1.021	2.02	2.797	4.288
WS-2	4.216	8.108	11.029	16.514
WS-3	0.672	1.307	1.796	2.733
WS-4	1.71	2.967	3.891	5.61
WS-4A	5.963	10.304	13.454	19.257
WS-4B	2.751	5.32	7.246	10.859
WS-4C	3.182	6.077	8.233	12.258
WS-5	0.06	0.185	0.293	0.512

Refer to Table 4.4 for a tabulation of *WinSLAMM* pollutant generation calculations for each sub-watershed. Detailed *WinSLAMM* output and methodology information are provided in Appendix A.

TABLE 4.4
EXISTING ANNUAL POLLUTANT GENERATION YIELD (LBS)

Sub - Watershed	Total Solids	Phosphorus	Nitrate	Copper	Lead	Zinc
1	11,784	44.6	27.0	0.6	1.2	4.9
2	54,460	219.4	106.1	2.2	4.7	13.7
3	10,431	40.5	21.7	0.4	1.0	3.0
4	14,215	48.2	37.2	0.8	1.7	7.4
4A	46,956	161.7	126.9	2.5	5.5	25.8
4B	6,753	16.5	20.0	0.6	0.9	5.6
4C	38,181	151.4	81.0	1.6	3.7	14.0
5	938	4.1	1.5	0.0	0.1	0.2



SUB-WATERSHED AREAS (AC.)

WS-1	13.6
WS-2	46.1
WS-3	8.4
WS-4	14.3
WS-4A	46.6
WS-4B	30.2
WS-4C	32.1
WS-5	2.3

Figure 4.1: Sub-Watershed Delineation

4-2 <u>Existing Stormwater Runoff Issues</u>

Refer to Figure 4.2 for a graphical depiction of the location of the existing stormwater runoff issues described in sections 4-2a through 4-2d.

4-2a Ryan Pinetum

The Campus Club, established in 1901 by Haverford College alumni and faculty to preserve the beauty of the campus, first envisioned “a comprehensive planting of trees” in 1928. Members spent the next two decades transplanting hundreds of young conifers to an 18-acre site near the southwestern boundary of the college. The trees were arranged as a scientific collection, grouped by family and genus. Over the years, the trees have matured, and many more have been added. In the late 1980s, volunteers Nancy and Dick Ryan led a team to inventory and label the trees. In April 1993, the area’s largest and finest collection of mature conifers was officially dedicated as the Ryan Pinetum.

Ryan Pinetum

Currently the Pinetum exists as a “ring” of showcase conifers around an open area being managed as native meadow. A walking tour of the Pinetum indicates that paths are meant to direct visitors around the entire site to see each group of species. Stormwater flows from the Walton Field, Swan Field, Kannerstein Field, Bramall & Marshall Tennis Courts, and Class of 1888 Field athletic complex and adjacent upslope areas flow through existing stormwater infrastructure into the Pinetum. Three stormwater pipe outfalls and one grass swale convey water directly on the ground surface along the western edge of the tennis courts. Archive utility plans also show the possibility of a septic leech field in this vicinity. Several clusters of hemlock and spruce along this eastern side of the Pinetum are showing decline and mortality is occurring. It is believed that the excessive moisture due to stormwater contributions from the Walton Field area are negatively impacting the health and survival of the Pinetum trees. In addition, concentrated surface flow is also causing surface erosion and rilling downslope of the Pinetum along the existing Nature Trail. In addition, and Haverford Road experiences frequent flooding in part due to runoff from the Haverford College campus.

4-2b Cobbs Creek Tributary

The intersection of Macintosh and Coursey Roads is a low point on campus where stormwater collects and overflows into a tributary of Cobbs Creek. Significant runoff flow rate and velocity has eroded the stream bank significantly over the years and has caused it to become unstable. The stormwater runoff also contains road salt, automobile fluids and fertilizers. The force and velocity of runoff during heavy storms carries significant debris to a downstream culvert at the Visitors Parking Lot, which frequently clogs and leads to flooding. The flooding has not only affected the Visitors parking lot but also the Haverford College Apartments (HCA) complex.

4-2c Upper Pond & Duck Pond

The Upper Pond, which is located near the northern property line and receives a significant off-site drainage area, essentially serves as a forebay / sedimentation basin for the Duck Pond. Runoff from off-site upstream drainage area carries road salt, fertilizers/nutrients, automobile fluids, and sediment from township streets. These sediments and pollutants collect in the Upper Pond but also migrate into the Duck Pond over time. Both ponds have been dredged in the last six years. The Upper Pond was dredged to a depth of approximately 4 feet, but current depth has been reduced to 18", meaning that dredging may again be required. The Duck Pond was dredged in 2017 to a depth of 7 feet. Before the dredging, it was approximately 2 feet in depth and suffered from significant algal blooms that led to several fish kills over the past decade. Algal blooms occur in shallow standing water with high nutrient loads (such as those received from upstream drainage areas) due to higher water temperature and presence of nutrients to support significant plant growth; the algae then causes dissolved oxygen in the water body to drop significantly, which is harmful or fatal to aquatic life.

4-2d Organic Farm & Community Garden (a.k.a. "Haverfarm")

Established in 2010, "The Haverfarm is a year-round farming and educational space designed to integrate sustainable food and agriculture into the academic and extracurricular lives of Haverford students, faculty, staff, and community members…Produce is distributed to students, community members, the dining center and local food banks."

The Haverfarm is composed of multiple growing plots but the main production area is the approximately 25,000 square feet of tilled land in the southwestern corner of the campus. The 2018 Annual Farm Report indicated that "…students learn the basics of organic agriculture by helping with soil preparation, weeding, planting, harvesting, and composting." The intent of the Haverfarm is to grow edible produce that has limited exposure to chemical fertilizers or pesticides. Unfortunately, due to its location downslope of several managed lawn and sports grass turf areas, chemicals applied to these areas potentially enter the production area during heavy rain events.

Stormwater flows from the Featherbed and Class of 1995 Fields and adjacent upslope areas to the northeast through existing grass swales or on the road surface into the Haverfarm production plot. Even though the road along the northern side of the production area acts a berm that holds back and collects water, this wet depression has a limited capacity for larger amounts of water. When it reaches capacity, any additional rain overflows into and through the production area, causing both erosion of soil and unwanted saturation by runoff possibly containing fertilizers and pesticides. These contaminants are problematic for an operation that strives to be organic.

4-3 <u>Inventory of Existing Stormwater Facilities</u>

Haverford College has a number of existing stormwater management Best Management Practices (BMPs) in place that help to reduce the rate and volume and improve the quality of stormwater runoff from campus. These BMPs were identified through a combination of site walks with College staff and review of archive drawings provided by the College. To assist the College in understanding the extent of existing stormwater management systems and what future improvements may be needed, an inventory of the existing BMPs has been prepared. The order of the BMPs described below was developed based on BMP location, beginning in the west and proceeding in an easterly direction (with the more northern BMP being listed first when located at a similar easting with another BMP). Refer to Figure 4.2 for a graphical depiction of BMP locations.

1. Southwest Infiltration Bed

Location: Near the southwest corner of the College's property, approximately 50-75 feet west of Haverford Road.

Description: An underground 20'Wx80'Lx4'D volume of crushed stone, containing one 18" perforated HDPE pipe and one 24" perforated HDPE pipe. Two manholes and two drainage inlets provide access to the pipes. One of the drainage inlets serves as an outlet structure; when the underground storage volume fills with stormwater, the water level rises until it spills out the top of the outlet structure located near the northwest corner of the infiltration bed.

Status: Needs immediate maintenance.

Required Action: Immediate maintenance is required. During a site visit when the BMP's location was discovered (it was previously unknown to current College staff), it was observed that the underground storage volume was holding water at one structure and filled with sediment and debris at the other structure. It appeared that maintenance had not been performed in many years. The sediment and debris and water should be removed by a maintenance contractor, and the infiltration bed should be monitored following a future rain event. If the bed holds water for greater than 72 hours after the rain event, it shall be considered as a failure of the infiltration BMP, and the BMP may need to be replaced. Contact Gilmore & Associates at 610-444-9006 for assistance.

1A. Seepage Pits Beneath Drainage Inlets

Location: At seven of the drainage inlets in the storm sewer conveyance system between the outlet from the Facilities Management Complex Stormwater Basin and Haverford Road.

Description: The drainage inlet structures were built with open bottoms that drain to aggregate filled seepage pits located beneath the structures.

Status: No known issues.

Required Action: The College should investigate whether geotextile fabric is in place at the top of each seepage pit. The geotextile fabric is needed to filter sediment from stormwater runoff before it enters the seepage pit so that sediment does not clog the open pores between the aggregate. Then, begin routine maintenance per the Haverford College Stormwater BMP Operations and Maintenance Manual.

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2. Swan Field

Location: West of Walton Lane, south of College Avenue, east of Ryan Pinetum, north of Bramall & Marshall Tennis Courts.

Description: An 8-inch deep bed of porous stone located underneath the artificial turf athletic field. An outlet control structure regulates the flow that enters the outfall pipe.

Status: No known issues.

Required Action: Begin routine maintenance per the Haverford College Stormwater BMP Operations and Maintenance Manual.

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3. Infiltration Beds at Kannerstein Field Batting Tunnel

Location: The batting tunnel is located at the northwest corner of Kannerstein Field, which is located west of Walton Field and south of Bramall & Marshall Tennis Courts. One infiltration bed is located on the south side and one on the north side of the batting tunnel.

Description: Two (2) 6'Wx90'Lx5'D volumes of AASHTO #1 stone with 8" diameter perforated pipe running along the center of each infiltration bed. There are two cleanouts at the ground surface for each infiltration bed.

Status: No known issues.

Required Action: Begin routine maintenance per the Haverford College Stormwater BMP Operations and Maintenance Manual.

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4. Bioretention Basin near Organic Farm and Garden

Location: On the north side of the driveway that loops around the organic farm and garden.

Description: Depression approximately 1 foot deep and 500 square feet in area, with vegetation.

Status: No known issues.

Required Action: Begin routine maintenance per the Haverford College Stormwater BMP Operations and Maintenance Manual.

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5. Facilities Management Complex Infiltration Basin

Location: At the west end of the Facilities Management Complex, east of the organic farm and garden.

Description: Depression approximately 4 feet deep and 10,000 square feet in area (including side slopes), with incoming and outgoing storm sewer pipes. A concrete outlet control structure regulates the flow that enters the outfall pipe.

Status: No known issues.

Required Action: Begin routine maintenance per the Haverford College Stormwater BMP Operations and Maintenance Manual. Maintenance activities should be coordinated to minimize adverse impact to the bee colonies that have been installed near the basin.

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6. Stokes Hall Infiltration Bed

Location: On the east side of the portion of the building that is oriented north to south, and on the south side of the portion of the building that is oriented east to west.
Description: An underground 5'Wx20'Lx3'D volume of AASHTO #1 stone, containing two 6" diameter perforated PVC pipes. One 24"x24" drainage inlet structure and one cleanout at the ground surface provide access to the underground pipes.

Status: No known issues.

Required Action: Begin routine maintenance per the Haverford College Stormwater BMP Operations and Maintenance Manual.

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7. Stokes Hall Vegetated Roof

Location: On top of the east wing of the building (which is oriented east to west).

Description: An approximately 8,000 square foot vegetated roof.

Status: No known issues.

Required Action: Continue routine maintenance per the Haverford College Stormwater BMP Operations and Maintenance Manual.

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8. Magill Library Rain Garden #1

Location: Located at roughly the middle of the west face of the library building.

Description: Depression approximately 1 foot deep and 300 square feet in area, with vegetation and 24”x24” concrete drainage structure.

Status: No known issues.

Required Action: Begin routine maintenance per the Haverford College Stormwater BMP Operations and Maintenance Manual.

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9. Magill Library Rain Garden #2

Location: Located near the southwest corner of the library building, about 20 feet west of the building.

Description: Depression approximately 1 foot deep and 300 square feet in area, with vegetation and 24”x24” concrete drainage structure.

Status: No known issues.

Required Action: Begin routine maintenance per the Haverford College Stormwater BMP Operations and Maintenance Manual.

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10. Magill Library Infiltration Bed

Location: Located approximately 110 feet to the southwest of the library building and 50 feet to the east of Walton Lane.

Description: A volume of AASHTO #3 stone, 4’-4” deep and approximately 1,000 square feet in area, containing an 8” diameter perforated HDPE pipe and an 18” diameter plastic outlet control structure that regulates the flow that enters the outfall pipe.

Status: No known issues.
Required Action: Begin routine maintenance per the Haverford College Stormwater BMP Operations and Maintenance Manual.

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11. V.C.A.M. Bioretention Basin

Location: Located approximately 100 feet south of V.C.A.M, just north of the Printmaking Studio.

Description: Depression approximately 18 inches deep and 1,500 square feet in area, with vegetation, concrete outlet structure, and outfall pipe.

Status: No known issues.

Required Action: Continue routine maintenance per the Haverford College Stormwater BMP Operations and Maintenance Manual.

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12. South Parking Lot Infiltration Bed

Location: At the northeast corner of the South Parking Lot, which is on the south side of Coursey Road, across the road from GIAC.

Description: An underground 80’Wx125’Lx12’D volume of AASHTO #1 stone, containing 370 L.F. of 24” diameter perforated HDPE pipes. Three manholes provide access to the perforated pipe system. Additionally, there is a concrete outlet control structure that regulates the flow that enters the outfall pipe.

Status: No known issues.

Required Action: Begin routine maintenance per the Haverford College Stormwater BMP Operations and Maintenance Manual.

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13. South Parking Lot Pervious Pavement

Location: The entire South Parking Lot (on the south side of Coursey Road, across the road from GIAC) was paved with pervious asphalt pavement.

Description: Approximately 86,500 square feet of pervious asphalt pavement.

Status: Needs immediate maintenance.

Required Action: Per discussions with College staff, the pervious pavement has never been maintained since it was installed roughly 15 years ago. The pervious pavement should be vacuum swept heavily and thoroughly to attempt to remove accumulated sediment, grit, and debris that may be clogging the pores of the pervious pavement. After the vacuum cleaning, the pervious pavement should be monitored during rain events so that its performance can be compared to that of the adjacent standard impervious asphalt pavement of Coursey Road. If the pervious pavement does not have noticeably reduced runoff compared to the standard pavement, the pervious pavement may have been irreparably clogged due to lack of maintenance and may need to be replaced. Contact Gilmore & Associates at 610-444-9006 for assistance.

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14. Tritton Hall & Kim Hall Infiltration Bed

Location: Between Tritton & Kim residence halls.

Description: An underground volume crushed stone, 5 feet deep, approximately 8,300 square feet in area, containing a variety of storage chambers and storm sewer pipes and structures. A concrete outlet control structure located outside of the footprint of the infiltration bed (to the south of the bed, east of Kim Hall) regulates the flow that enters the outfall pipe. The infiltration bed is buried under a substantial depth (approximately 11 feet) of earthen fill material.

Status: No known issues.

Required Action: Per discussions with College staff, this BMP is regularly maintained by Stormwater Compliance, LLC. No action is required by the College.

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15. Tritton Hall & Kim Hall Bioretention Basin

Location: Immediately east of Tritton Hall.

Description: Depression approximately 1 foot deep and 800 square feet in area, with vegetation, concrete outlet structure, and outfall pipe.

Status: No known issues.

Required Action: Per discussions with College staff, this BMP is regularly maintained by Stormwater Compliance, LLC. No action is required by the College.

16. Tritton Hall & Kim Hall Vegetated Roofs

Location: Roof areas of Tritton & Kim residence halls.

Description: Approximately 13,000 square foot combined area of vegetated roof.

Status: No known issues.

Required Action: Per discussions with College staff, these BMPs are regularly maintained by Stormwater Compliance, LLC. No action is required by the College.

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17. Upper Pond

Location: Approximately 100 feet south of Railroad Avenue, 800 feet east of the north dorms, and 900 feet west of the College entrance from Lancaster Avenue.

Description: Approximately 5,000 square foot wet pond that serves as a settling basin/forebay for the duck pond. Heavy sediment loads from off-site upstream drainage areas settle into the Upper Pond, necessitating relatively frequent dredging of the Upper Pond. Eutrophic / low dissolved oxygen conditions have occurred in the Upper Pond in the past, creating algal blooms that can result in sedimentation of organic matter.

Status: The Upper Pond is functioning, but the sediment depth appears to have reaccumulated significantly since the last dredging. The College should consider dredging the Upper Pond again, or undertaking a more substantial improvement project (refer to Section 5-3). It is recommended that the College coordinate with Lower Merion Township to explore ways that the off-site upstream drainage area could be studied and improved to reduce the sediment load received by the Upper Pond. Sediment is a targeted pollutant in the Township's Municipal Separate Storm Sewer System (MS4) permit, and the campus's location in the headwaters of the Cobbs Creek watershed may be ideal for a joint project between the Township and the College to reduce sediment loads.

Required Action: Continue routine maintenance per the Haverford College Stormwater BMP Operations and Maintenance Manual until the improvement project can be undertaken.

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18. Duck Pond

Location: Approximately 225 feet south of Railroad Avenue, 600 feet east of the north dorms, and 900 feet west of the College entrance from Lancaster Avenue.

Description: Approximately 137,000 square foot wet pond that serves as an aesthetic feature for campus.

Status: Since the Duck Pond was dredged fairly recently, there are no known issues that would require immediate action.

Required Action: Continue routine maintenance per the Haverford College Stormwater BMP Operations and Maintenance Manual, and consider addition of aeration as described in proposed Project #8 in Chapter 5-3 later in this report.

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19. College Lane Rain Garden

Location: Located on the south side of College Lane, across from the road from the Duck Pond.

Description: Depression approximately 9-12 inches deep and 800 square feet in area, with vegetation.

Status: Functioning, but experiencing erosion.

Required Action: There appears to be a flow path along the western side of the rain garden that is notably eroded. The erosion should be repaired and stabilized with vegetation. The berm of the rain garden should be graded such that the overflow at the lowest point of the berm is directed to the receiving channel (which is roughly at the center of the rain garden). Slope stabilization netting should be installed where concentrated flows are expected to occur (such as at the berm outlet spillway). Then, continue routine maintenance per the Haverford College Stormwater BMP Operations and Maintenance Manual.

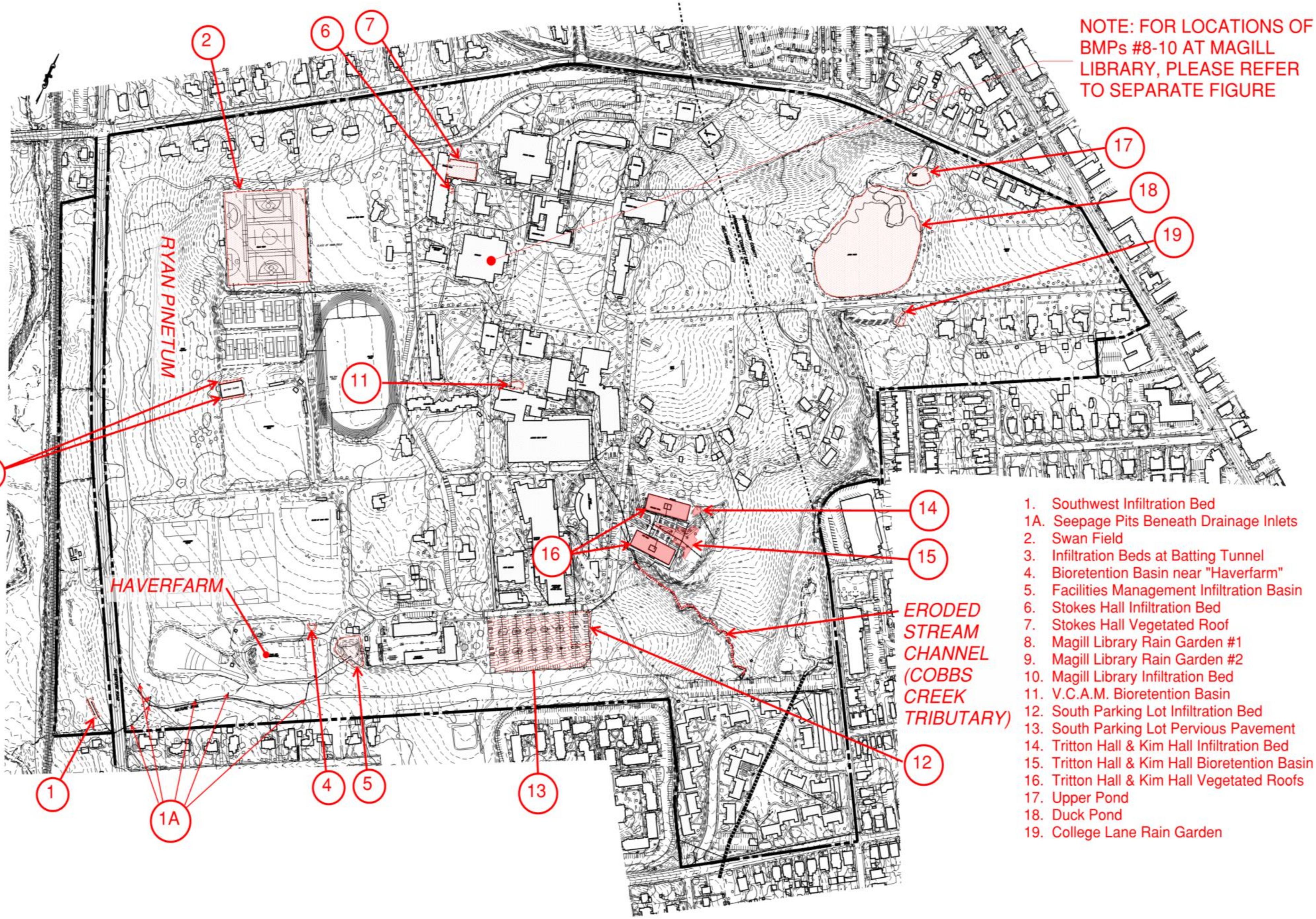


Figure 4.2: Existing Stormwater BMP Location Map

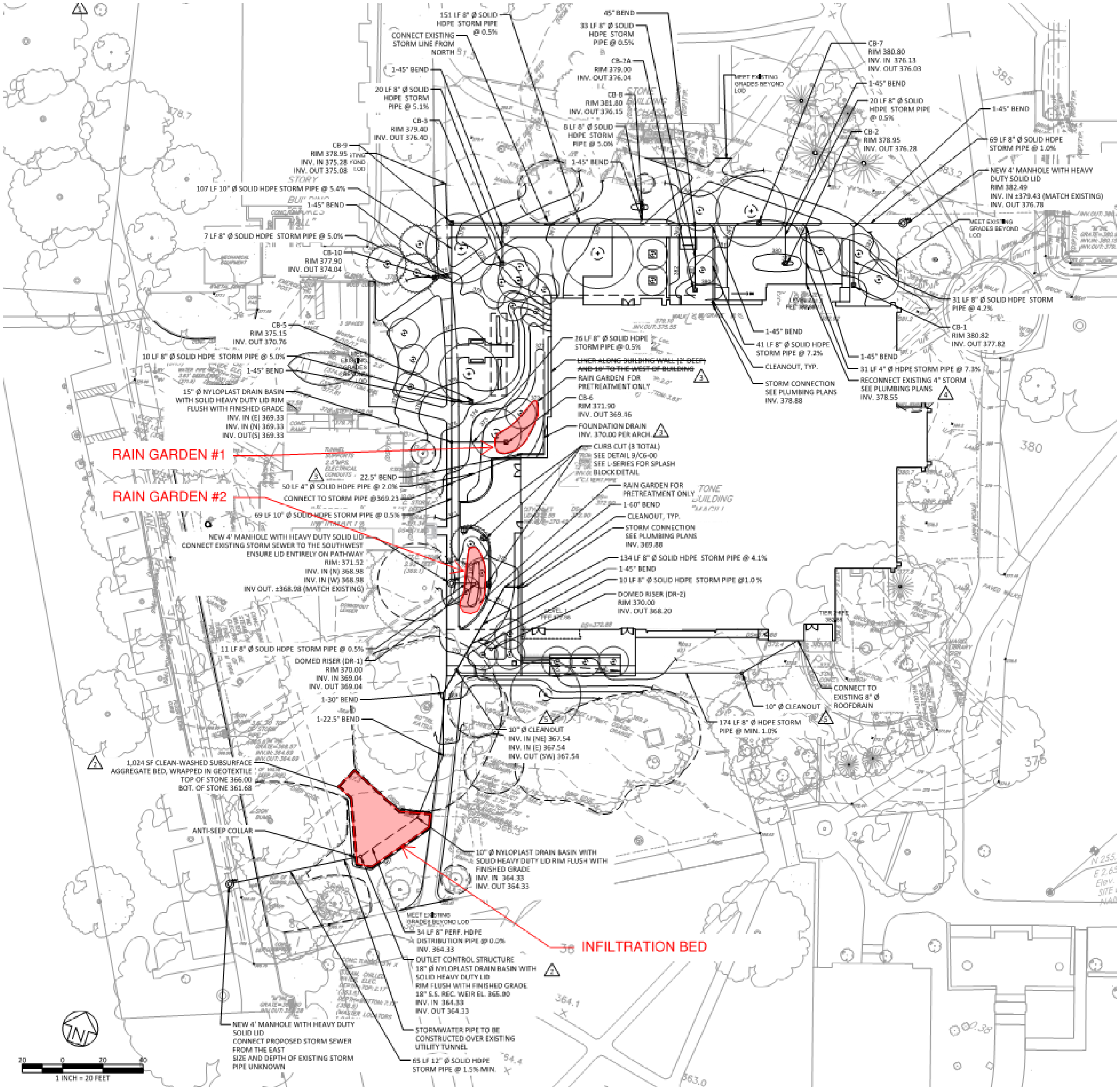


Figure 4.3: Existing Stormwater BMP Location Map at Magill Library

4-4 Existing Hydraulic Capacity Analysis

In an effort to identify any existing stormwater conveyance capacity issues, the College's storm drainage systems were analyzed using the *Hydraflow Storm Sewers Extension* for AutoCAD Civil 3D, which is based on the Rational Method for calculation of stormwater runoff. The model of the existing storm sewer system was developed based on archive plan information provided by the College; per the scope of the stormwater master plan, no field topographic survey was performed to support the analysis. Drainage areas and land covers to surface drainage inlets were determined based on a combination of aerial topographic mapping performed by Cooper Aerial, Inc. in December 2018 and the aforementioned archive plans. Refer to Figure 4.4 for a graphical depiction of the drainage areas delineated for the storm sewer inlets. The capacity analysis included pipe systems with surface drainage inlets. Pipelines that carry roof runoff only and no ground surface drainage were not analyzed for this site storm sewer capacity analysis.

In cases where data could not be located in available archive plans or where multiple sources provided conflicting information, the data used in the analysis was based on professional judgement and past experience with similar drainage systems.

Drainage systems were considered to be adequate if the pipes have capacity to carry flows from the 100-year storm event without the hydraulic grade line rising above the top of grate for any storm sewer structure. Grate inlet capacities were not modeled as the available archive plans did not define grate sizes and openings, and grate capacity is also highly dependent on maintenance (e.g. leaf removal). Per the hydraulic capacity analysis documented in Appendix A, the majority of the campus drainage pipe systems analyzed have capacity for the 100-year storm event. The following portions of the overall drainage system were found to have inadequate capacity (refer to Figure 4.5 for a graphical location of these areas):

1. The Facilities Management Complex Stormwater Management Basin was found to have capacity for the 10-year storm event. For larger storms, the basin will overflow via the emergency spillway and drain overland in a westerly direction towards Haverford Road. It is recommended that the Facilities Complex Stormwater Management Basin be enlarged so that it has capacity to control the 100-year storm event for the contributory drainage area, at minimum. The College should also consider further expanding the basin to manage runoff from the Class of 1995 athletic field, which would intercept runoff that, as previously described, creates issues for the organic farm and garden in the existing condition. Refer to Section 5-3 for additional detail regarding the recommended improvements for the Facilities Complex Stormwater Management Basin.

2. Related to Item #1 above, the storm sewer system that drains to the Facilities Management Complex Stormwater Management Basin was found to have capacity for the 5-year storm event. It is not mandatory to increase the capacity of this storm sewer system, because any overflows will be directed to the Facilities Complex Stormwater Management Basin via overland flow. As an optional/low priority improvement project, the capacity of this system could be upgraded to eliminate minor nuisance flooding for events greater than the 5-year storm event. Refer to Section 5-3 for additional detail regarding the recommended improvements.

3. The storm sewer system that receives the outflow from the Facilities Management Complex Stormwater Management Basin and drains in a westerly direction across Haverford Road has capacity for only the 5-year storm event. This is due to the significant outflow from the basin, which is undersized as described in #1 above.

In lieu of upgrading this system, which runs through wooded areas, it is recommended that the Facilities Management Complex Stormwater Management Basin be expanded to provide significant peak rate reduction for flows entering the basin. If the outfall storm sewer system received a significantly lower peak flow rate from the basin, it would have capacity to carry the 100-year storm event.

4. The 30” culvert at the Visitor’s Parking Lot (which carries the flow from numerous drainage systems discharging to the stream in the vicinity of Kim Hall) is very undersized and lacks capacity for the 2-year storm event. This has caused flooding at the Visitor’s Parking Lot and Haverford College Apartments (HCA) site. It is recommended that this culvert be replaced with a larger culvert as a relatively high priority project. Refer to Section 5-3 for additional detail regarding the recommended improvements.

5. The storm sewer system on the south side of the Field House was found to lack capacity for the 2-year storm event. The capacity issue appears to apply to the entire connected drainage system from the upgrade extents to the Field House. Downstream of the Field House, the pipes are larger and have greater capacity. While the model predicts that this storm sewer system (upstream of the Field House) is undersized for the drainage area that it receives, discussions with College staff revealed that there have not been any associated flooding issues. Therefore, while storm sewer capacity upgrades are recommended, they have been rated as low priority due to the lack of associated historical flooding issues.

6. The storm sewer system on the north side of KINSC was found to lack capacity for the 2-year storm event. The capacity issue appears to apply to the entire connected drainage system from the upgrade extents to KINSC. While the model predicts that this storm sewer system is undersized for the drainage area that it receives, discussions with College staff revealed that there have not been any associated flooding issues once maintenance was done to remove debris from the pipe in the vicinity of Hilles Hall. Therefore, while storm sewer capacity upgrades are recommended, they have been rated as low priority due to the lack of associated recent flooding issues. Refer to Section 5-3 for additional detail regarding the recommended improvements. Downstream of KINSC, that pipe system has capacity for the 100-year storm event.

7. The curb opening for drainage of Coursey Road (located approximately 100 feet north of the intersection with Woods Road) was found to have inadequate capacity for the 2-year storm event, meaning that stormwater would overflow the top of curb adjacent to the curb opening. The depth of this flow would therefore cause the entire road to be covered with water at the low point of the road profile. It is recommended that drainage at the low point of Coursey Road be enhanced by enlarging the curb opening and adding a storm sewer collection system to intercept runoff before it reaches the low point of the roadway. Since the drainage path from the curb opening leads to the eroded stream that flows to the 30” culvert at the Visitor’s Parking Lot, it is recommended that roadway drainage improvements be constructed in conjunction with a stream restoration project for the eroded stream. Refer to Section 5-3 for additional detail regarding the recommended improvements.

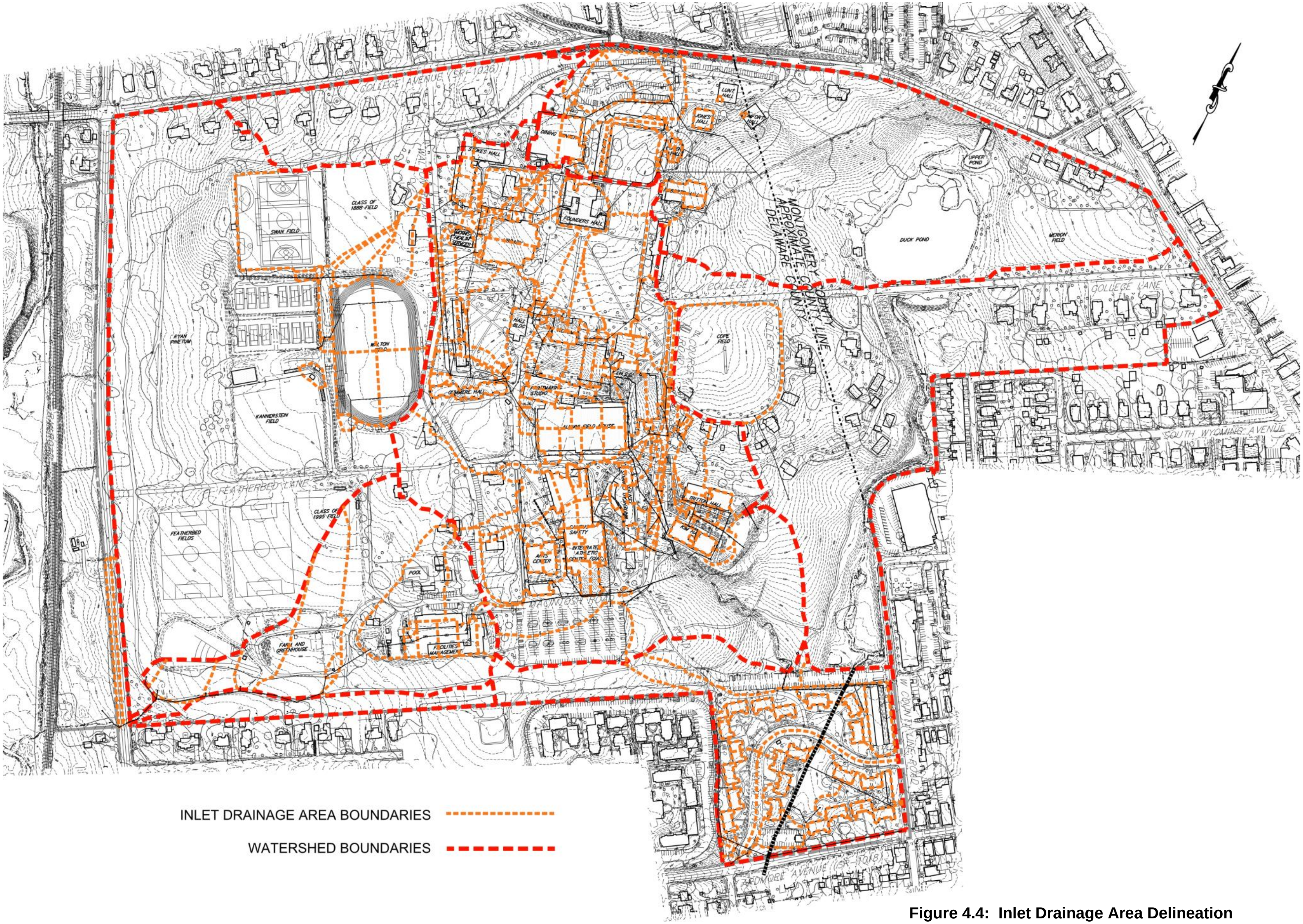


Figure 4.4: Inlet Drainage Area Delineation

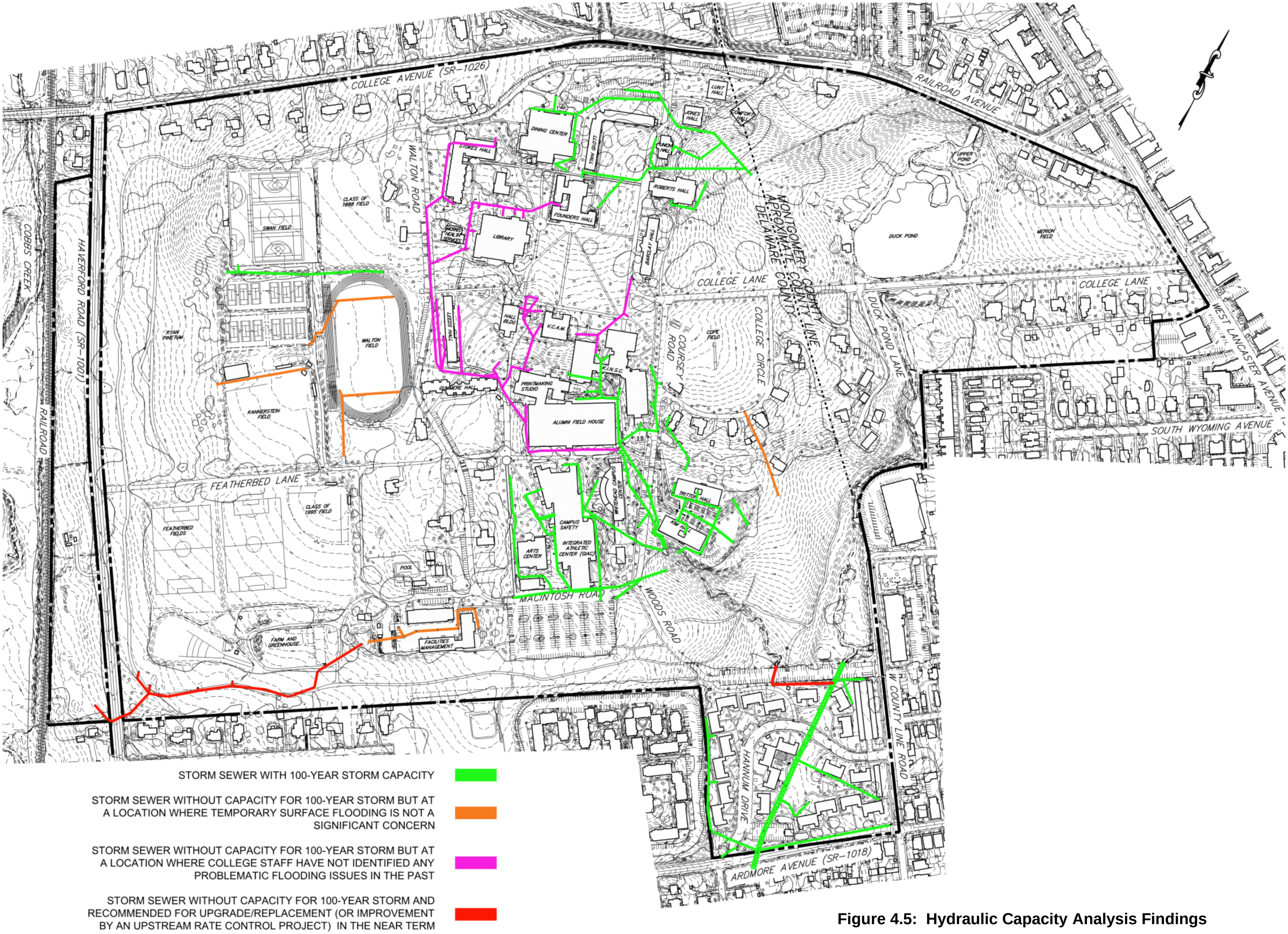


Figure 4.5: Hydraulic Capacity Analysis Findings

4-5 Operations & Maintenance of Stormwater Facilities

Existing maintenance practices for stormwater management BMPs were determined via discussions with College staff, and consist of the following:

1. Stokes Hall Vegetated Roof: The College works with the company "Roofmeadow" to inspect the vegetated roof of Stokes Hall two times per year. If vegetation has died, it is replaced following the inspection to maintain vegetative coverage of the green roof.

2. Upper Pond and Duck Pond: The Upper Pond is dredged on an as-needed basis every 5-10 years. The Duck Pond is dredged on an as-needed basis with a frequency less than once per 20 years. On a monthly basis, a contractor hired by the College inspects the outlet riser and grate at the Upper Pond and clears any trash and debris from that structure.

3. College Lane Rain Garden: The rain garden is weeded approximately once per month to control invasive plant growth.

4. V.C.A.M. Bioretention Basin: The bioretention basin is weeded approximately once every 2-3 months to control invasive plant growth.

5. The bioretention basin, subsurface infiltration bed, and vegetated roofs at Tritton and Kim Halls are maintained by Stormwater Compliance, LLC.

Since regular maintenance is important for the continued functionality of stormwater management BMPs, a Stormwater BMP Operations and Maintenance (O&M) Manual has been prepared to guide the College's future maintenance efforts. Refer to the O&M Manual in Appendix B. Note: since the stormwater management BMPs at Tritton and Kim Halls are maintained by Stormwater Compliance, LLC, those BMPs are not included in the O&M Manual.

SITE: HAVERFORD COLLEGE - V.C.A.M.
BMP NAME: BIORETENTION BASIN
BMP TYPE: BIORETENTION BASIN

REQUIRED INSPECTION/MAINTENANCE FREQUENCY:
4 TIMES PER YEAR (QUARTERLY)
INSPECT AFTER RAIN EVENTS GREATER THAN 3.25" IN A 24-HOUR PERIOD

PREVENTIVE MAINTENANCE

- ☐ Check outlet structure riser to ensure top grate and outlet pipe are not obstructed. Remove trash/debris as needed. Check concrete structure for any signs of cracking, spalling, or other deterioration.
- ☐ Remove weeds from bioretention basin.
- ☐ Perennial plantings may be cut down at the end of the growing season. The plant material that was cut down shall be removed and composted or disposed of of-site.
- ☐ Replenish mulch once per year. Every third year, completely replace mulch.
- ☐ Evaluate health of plantings/vegetation and replant/reseed as need to maintain healthy vegetation.
- ☐ Remove trash and debris from bioretention basin.
- ☐ Confirm that stormwater is not held in bioretention basin longer than 72 hours after the end of most recent rainfall.

NAME OF PERSON PERFORMING INSPECTION: ____________
DATE OF PREVENTIVE MAINTENANCE INSPECTION: ____________

☐ 1st Quarter ☐ 2nd Quarter ☐ 3rd Quarter ☐ 4th Quarter ☐ Rainfall

CORRECTIVE MAINTENANCE (IF INSPECTION FINDS PROBLEMS THAT MUST BE ADDRESSED)

- ☐ Remove sediment when depth exceeds 1". Sediment may be stored on campus at a location with sediment controls, or may be removed from the site by a contractor.
- ☐ Repair any erosion that is discovered during the inspection.
- ☐ Repair outlet structure if concrete is cracked or spalling.
- ☐ If the bioretention basin is not draining in 72 hours, till the bioretention soils with disc harrow or equivalent equipment to loosen them, then replant vegetation. If that is not effective, contact Gilmore & Associates at 610-444-9006 for assistance.

PERSON/CONTRACTOR PERFORMING MAINTENANCE: ____________
DATE OF CORRECTIVE MAINTENANCE: ____________

Notes:

Figure 4.6: Sample BMP Maintenance Log Sheet

5 PROPOSED STORMWATER MANAGEMENT (SWM)

5-1 Sustainable Site Development

As described previously in this report, past development without provision for management of stormwater has caused substantial environmental degradation in the watershed. To avoid worsening and to reverse existing problems such as flooding, erosion, and low water quality, future development must be undertaken in a sustainable manner.

There are two primary sustainability rating systems in widespread use today. The Leadership in Energy and Environmental Design (LEED) rating system is a building-centric system that also addresses associated site elements. The Sustainable Sites Initiative (SITES) rating system is centered on principles of ecosystem interaction, human health and well-being. It was developed through a collaborative interdisciplinary effort of the American Society of Landscape Architects Fund, the Lady Bird Johnson Wildflower Center at the University of Texas at Austin, and the Unites States Botanic Garden. Both of these rating systems apply guidelines and performance benchmarks for sustainable land design and development in the form of credits.

Due to the in-depth approach with respect to site-related impacts (as opposed to buildings), the SITES rating system is the more applicable system of the two for exterior stormwater management in a campus setting.

The SITES rating system involves a wide variety of categories, including Site Context, Pre-Design Assessment and Planning, Education, Innovation, and Site Design relating to Water, Soil + Vegetation, Materials Selection, and Human Health + Well Being.

Projects achieving the certification requirements of the SITES program help to reduce water demand, filter and reduce stormwater runoff, provide wildlife habitat, reduce energy consumption, improve air quality, improve human health, and increase outdoor recreation opportunities.

Due to the wide variety of credit categories associated with the SITES rating system, many of the categories are not relevant to the scope of this Stormwater Master Plan. Furthermore, some Owners find that the cost of obtaining the formal SITES or LEED certification can be significant, and that funding required to obtain the certification could be better employed to construct additional or improved sustainability features. Therefore, rather than recommending compliance and/or certification with either LEED or SITES in its entirety, it is recommended that the College provide stormwater management for future development of campus that meets or exceeds the requirements of the following stormwater management credits from the SITES rating system:

Credit 3.1: Manage precipitation on site

> *Retain the precipitation volume from the 60th percentile precipitation event as defined by the U.S. EPA in the Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects under Section 438 of the Energy Independence and Security Act.*

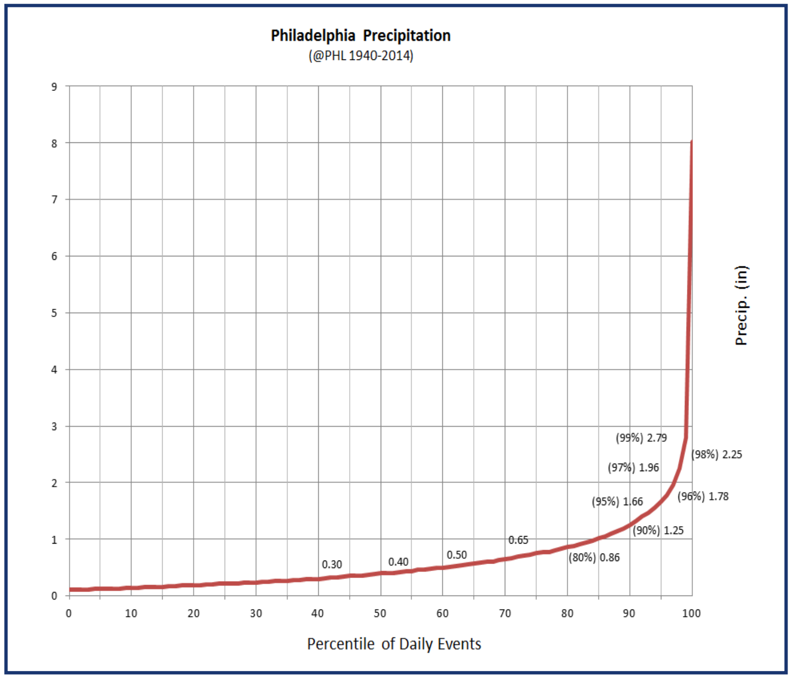
Credit 3.3: Manage precipitation beyond baseline

> *Retain or treat precipitation volume for the 95th percentile precipitation event.*

Credit 3.6: Restore aquatic ecosystems

> *Restore the geographic extent of the aquatic ecosystem within the SITES project boundary for a minimum of 90 percent of the geographic extent.*

In relation to the percentile storm events referenced in the SITES credits, the 95th percentile storm event is the rainfall depth where 95 percent of all rainfalls (in a selected historical rainfall data set) are equal to or less than that depth. In order to determine the rainfall depth of the 95th percentile event, historical rainfall data must be analyzed so that the mutual relationships of all rain events of varying sizes can be understood (snow events and rainfalls less than 0.1 inches are excluded from the analysis). Haverford College is located in fairly close proximity to the Philadelphia airport, so historical rainfall data at the airport for a period of more than 70 years was analyzed. The statistical analysis finds that 95 percent of the historical storms at the



Philadelphia airport in the data set are less than 1.66 inches. Therefore, the 95th percentile storm event for Haverford College is defined as 1.66 inches of rainfall.

If the College does pursue LEED certification for future building projects, it is noted that in the current LEED v4, two or three rainwater management credits are awarded for managing the 95th or 98th percentile storm events, respectively.

In addition to meeting the requirements of SITES or LEED stormwater management credits, future development must also comply with Federal, State, and Local stormwater management laws and regulations. Refer to Chapter 6 for a description of the regulatory considerations associated with earth disturbance and stormwater management.

Since historical development on campus has compromised certain aquatic and ecosystem resources at Haverford College (primarily the stream from Kim Hall to the Visitor's Parking Lot), the College's Stormwater Master Plan represents a unique opportunity to repair this damage. By going "above and beyond" regulatory requirements, Haverford College can demonstrate environmental stewardship by planning, funding and implementing projects to mitigate and repair environmental impacts caused by historical development.

5-2 Recommended Stormwater Best Management Practices (BMPs)

Determination of the Best Management Practice (BMP) most suitable for application begins with a thorough site assessment of the natural systems at work at a specific site. These natural systems include wetlands, floodplains, riparian areas, soil, geology, vegetation, and more. The Pennsylvania Department of Environmental Protection (PADEP) enacted the Stormwater Best Management Practices Manual on December 30, 2006. The manual provides guidance on managing all aspects of stormwater rate, volume, quality and groundwater recharge. The following selection criteria outlines the BMPs most applicable to the Haverford College campus given the previously outlined Physical Context. It should be noted that the PADEP Manual divides BMPs into Structural and Non-Structural practices. Generally, Non-Structural practices take the form of broader planning and design approaches such as minimizing total disturbed and impervious area or protecting riparian areas. Structural BMPs typically lend themselves to stormwater calculations to determine specific sizing and dimensional characteristics of each practice. The following structural BMPs are recommended for use on the Haverford College campus:

Pervious Pavement with Infiltration Bed – Sub-watersheds that have relatively large expanses of paved surfaces with slopes less than 4% that receive minimal heavy vehicle traffic are good candidates for this practice. Pervious pavement consists of a permeable surface course underlain by a uniformly-graded stone bed which provides temporary storage for peak rate control and infiltration. The surface course can consist of pervious asphalt, pervious concrete, or pervious structural pavers laid on a bed of crushed stone aggregated placed on uncompacted soil. The graded bottom of the infiltration bed should be level to maximize the storage volume for a given pavement area. Pervious pavement can provide excellent water quality improvement by trapping and filtering sediment and grit out of stormwater; it is critical to perform regular maintenance of the pervious pavement surface so that it does not become clogged by these materials. The flat infiltration bed area beneath the pavement and crushed stone volume may be terraced to accommodate locations where the combination of pavement area size and ground slope would result in large depths at the upgrade end of the bed.

Pervious Pavement with Infiltration Bed

Case Study: Pervious asphalt pavement was employed at a long term student parking lot at a private college in central Delaware County, PA The entire student parking lot was paved with impervious pavement, which slopes inwards to a central bioretention basin. The impervious pavement has been operational since 2016 and no reports of issues have been received.

Bioretention – A method of treating stormwater in relatively small sub-watersheds by pooling water on the surface and encouraging filtering and settling of suspended soils and sediment at the soil / water interface. Bioretention techniques are used to accomplish water quality improvement and water quality reduction.

Bioretention

Case Study: While bioretention basins are employed frequently throughout the Philadelphia region, two specific bioretention basins are described below due to the similarity between their locations and the Haverford College campus. The bioretention basins in question are located at a private college in central Delaware County, PA, and became operational in 2014 and 2016, respectively. The first is the bioretention basin at the center of the student parking lot described in the "Pervious Pavement" section above. The second bioretention basin receives runoff from a heavily used staff and faculty parking lot driveway. Both basins are functioning well and no reports of issues have been received.

Bioretention

Subsurface Infiltration Bed – Generally consists of a perforated pipe system encased in a stone envelope buried beneath a landscape or paved surface. Subsurface infiltration features can stand alone as significant stormwater runoff volume, rate and quality control practices. They have the added benefit of full functionality year-round given that the infiltration surface is typically below the frost line. This BMP is recommended for sub-watersheds where soil conditions are expected to yield usable infiltration rates, and where competing interests make underground location of a BMP desirable so that land area can be used for multiple purposes. Subsurface infiltration beds can be combined with pervious pavement BMPs to reduce the storm sewer infrastructure required to deliver stormwater to the infiltration bed.

Subsurface Infiltration Bed

Case Study: While subsurface infiltration beds are employed frequently throughout the Philadelphia region, one specific infiltration bed is described below due to the similarity between its locations and the Haverford College campus. This particular infiltration bed was located in a

Subsurface Infiltration Bed

creative location upgrade of the majority of the site. Extensive soil testing located high permeability soils at a significant depth, which allowed the surrounding site area and a large portion of the proposed building roof to drain to the infiltration bed. The excellent soil infiltration rates allow for significant runoff volume reduction and groundwater recharge. This case study illustrates the importance of soil testing to locate the best locations to support infiltration.

Infiltration Basin – A shallow impoundment that stores and infiltrates runoff over a level, uncompacted area with relatively permeable soils. The size and shape can vary from one large basin to multiple, smaller basins throughout the site. This BMP is recommended for sub-watersheds that have adequate land area available to support a surface infiltration basin. An infiltration basin is typically larger than a bioretention basin, but is planted with turf grass rather than wetland-type seed mixes. Infiltration basins can likely blend into existing maintained turf areas on campus more easily than bioretention basins if that is desired.

Case Study: Surface infiltration basins were constructed at the Chester County Public Safety Training Facility site in South Coatesville Borough, Chester County, PA. The training facility campus is similar to a college campus, although it has larger extents of impervious coverage which made the use of infiltration basins more appropriate than bioretention basins. The basins have been functioning since 2012 with no reported issues.

Infiltration Basin

Vegetated Swale / Bioswale – A vegetated open channel that is designed to reduce runoff velocity, provide filtration, and in some cases, infiltrate runoff from adjacent impervious

Vegetated Swale / Bioswale

surfaces. It is typically a broad, shallow, trapezoidal or parabolic channel, densely planted with a variety of trees, shrubs, and/or grasses. They provide an environmentally superior alternative to conventional curb and gutter conveyance systems, and convey partially treated stormwater flows to subsequent BMPs for additional rate, volume, and water quality management.

Case Study: Vegetated swales were constructed at the Dansko Distribution Center in Penn Township, Chester County, PA in 2012. The swales reduced the velocity of stormwater and provided pretreatment before the stormwater reached the downgrade infiltration basins. The use of vegetated swales significantly reduced the quantity of storm sewer required for the project.

Vegetated Roof – By placing vegetation on roof surfaces, the hydrologic characteristics are altered to more closely match surface vegetation than a conventional roof. In order to make them practical for installation on typical roof structures, lightweight materials are used including engineered soil media. Waterproofing materials and reliable drought-tolerant plant material are also employed. The most common type is the “extensive” vegetated roof which has a soil mantle of 2” – 4” thick. “Intensive” vegetated roofs typically have a soil depth of 12” – 18” and are used much less frequently due to the significant structural requirements to support the weight of soil and water.

Case Study: Haverford College currently operates vegetated roofs on Stokes Hall, Tritton Hall, and Kim Hall. College staff have not reported any issues with these BMPs.

Water Quality Filters & Hydrodynamic Devices – Vary in size and function, but all utilize some form of settling and filtration to remove particulate pollutants from stormwater runoff. Water quality filters, catch basin inserts, and pre-cast vault hydrodynamic devices are commercially available and are recommended for sub-watersheds with existing storm sewer conveyance systems but that do not have adequate space for installation of basin or infiltration bed type BMPs. Water quality inserts can capture a great deal of sediment and debris without the need for earth disturbance that is associated with a larger BMP such as a subsurface infiltration bed. In sub-watersheds where other BMPs are proposed, water quality inserts are less relevant since the other BMPs will provide sediment and debris removal.

Water Quality Filters & Hydrodynamic Devices

Case Study: Water quality inserts were utilized at a private college in central Delaware County, PA to manage stormwater quality at drainage inlets located downgrade of the proposed stormwater management BMPs such as infiltration beds and bioretention basins. Due to topographic constraints, it was not feasible to provide water quality management without the use of the inserts.

A hydrodynamic separator was installed at a William Penn School District bus parking and maintenance facility in Colwyn Borough, Delaware County, PA. The “Vortechs” unit manufactured by Contech captures and retains both sediment and oil, improving water quality where the storm drainage system discharges to Cobbs Creek.

Riparian Buffer Restoration – Provides ecological and water quality benefits adjacent to streams, ponds and wetlands. Restoration of this ecological habitat is a responsive action to past activities that may have eliminated or reduced vegetation. Buffers are characterized by high species density, high species diversity, and high bio-productivity as a transition between aquatic and upland environments.

Riparian Buffer Restoration

Runoff Capture and Reuse / Rainwater Harvesting – This BMP is recommended for sub-watersheds that are to have buildings or significant building expansions constructed in the future. Rainwater harvesting systems typically collect roof runoff in a watertight underground cistern due to the reduced level of filtration that is required (compared to collecting runoff from the ground surface) and the ease of stormwater collection. Rainwater that is collected in cisterns in this manner is typically used to flush toilets or irrigate landscaping, which contributes to campus sustainability efforts by reducing public water consumption. The reuse of stormwater for potable water needs is not advised due to the need for significant water treatment.

Runoff Capture and Reuse / Rainwater Harvesting

Case Study: A 15,000-gallon rainwater harvesting tank was installed at a private college in central Delaware County, PA. The tank collects rainwater from rooftop areas, which is then utilized to flush toilets in the adjacent academic building.

Soil Amendment and Restoration – The process of improving disturbed soils and low organic soils by restoring soil porosity and/or adding a soil amendment such as compost for the purpose of re-establishing the soil's long-term capacity for infiltration and pollutant removal. Two methods have been shown to have restorative results on soil damaged by compaction. The first is adding compost which enhances pore spaces and supplies slow release nutrients to plans. The second is tilling, typically down to a depth of 18", which aerates and breaks up compacted soils to improve infiltration and vegetative growth characteristics.

Case Study: At the Hillview Residential Development in Valley Township and Caln Township, Chester County, PA, prolonged construction resulted in a large stockpile of surplus soil. Construction vehicle traffic around the stockpile was heavy for years, resulting in substantial soil compaction. To restore the area after completion of construction, the stockpile was graded out and the soils were amended by deep tilling to break up compaction; then, the disturbed area was seeded with meadow mix for permanent vegetative stabilization. The meadow was successfully established in 2014.

5-3 Proposed Stormwater Management Improvement Projects

The following is a series of descriptions for projects that are recommended for the College to undertake to address existing stormwater runoff issues on campus. Completion of these projects will reduce on-site and downstream flooding and erosion, improve water quality, and help to restore a sustainable system of stormwater management and conveyance on the Haverford College campus. The listing is in priority order, with the projects listed first having the highest priority. Refer to Figure 5.1 for a graphical depiction of the proposed stormwater management improvement projects. An Order of Magnitude Cost Estimate for each project is provided in Appendix C.

Project #1A: Pinetum Bioretention Basin

The Campus Club, established in 1901 by Haverford College alumni and faculty to preserve the beauty of the campus, first envisioned "a comprehensive planting of trees" in 1928. Members spent the next two decades transplanting hundreds of young conifers on an 18-acre site near the southwestern boundary of the college. The trees were arranged as a scientific collection, grouped by family and genus. Over the years, the trees have matured, and many more were added. In the late 1980s, volunteers Nancy and Dick Ryan led a team to inventory and label the trees. In April 1993, the area's largest and finest collection of mature conifers was officially dedicated as the Ryan Pinetum (Haverford College Arboretum- Pinetum Tour Brochure).

Currently the Pinetum exists as a "ring" of showcase conifers around an open area managed as native meadow (Figure 1). A walking tour of the Pinetum indicates that paths are meant to direct visitors around the entire site to see each group of species. Stormwater flows from upland portions of the campus (Walton Field, Swan Field, Kannerstein Field, Bramall & Marshall Tennis Courts, and Class of 1888 Field athletic complex), through existing stormwater infrastructure, and into the eastern edge of the Pinetum. Three stormwater pipe outfalls and one grass swale convey water directly to the Pinetum along the western edge of the tennis courts. Utility plans also show the possibility of a septic leech field in this vicinity. Per a site visit with College staff, the trees in the vicinity of the septic leech field are in good health so the leech field is not currently a source of concern.

Ryan Pinetum

Several clusters of hemlock and spruce along the eastern side of the Pinetum are showing decline and mortality is occurring. It is believed that the excessive moisture due to stormwater contributions from the Walton Field area are negatively impacting the health and survival of the Pinetum trees. In addition, concentrated surface flow along the western edge is causing erosion and rilling downslope of the Pinetum along the existing Nature Trail. There is also relatively frequent flooding along Haverford Road partially due to the surface flow draining to the road from campus.

To resolve the issues occurring at the Pinetum, this project would create a bioretention basin near the western edge of the Ryan Pinetum to intercept overland runoff from the Pinetum, athletic fields, and tennis courts. Currently, these areas drain to Haverford Road without any management and contribute to significant flooding on the roadway during intense rain events. Storm pipe discharge points on the eastern edge of the Pinetum should be extended to the new bioretention basin (following a route that minimizes impact to Pinetum tree specimens) to eliminate the adverse impacts currently being experienced by Pinetum trees due to oversaturation of the surrounding soil. Soil infiltration testing should be performed at the location of the proposed bioretention basin. Assuming that the soils there are conducive to infiltration, the bioretention basin could provide significant reductions to runoff peak rate and volume, as well as improvements to water quality. The College's contribution to flooding issues on Haverford Road would be significantly reduced, and Pinetum trees would benefit by the redirection of storm pipe discharges. To provide a non-erosive conveyance across the Nature Trail, the bioretention basin would include an underground pipe outlet that would connect to the existing storm sewer in Haverford Road. It is noted that this would require a PennDOT Utility Highway Occupancy Permit (HOP).

Project #1B: Pinetum Native Species Resilient Habitat

In September 2019, a number of trees were removed from the vicinity of the storm pipe outfall at the eastern edge of the Pinetum between Swan Field and the tennis courts. These trees were not Pinetum specimens, but were rather unintentional volunteers that had grown there over time. The clearing of this area provides an opportunity to create a native species resilient habitat area with stormwater management (in the form of a bioretention basin). This project could be undertaken in conjunction with Project #1A or as a stand-alone project. Additionally, the 18" storm pipe draining to this location could be removed and replaced with a bioswale for stormwater conveyance and water quality improvements.

Project #2: Stokes Hall Drainage Improvements

Local storm drainage improvements are needed to address water entry issues into the Stokes Hall lower level lecture hall area that occur during intense rain events. Improvements would likely consist of an additional storm drain adjacent to the entry door on the south side of the building, as well as minor grading changes and an additional storm drain at the top of the exterior stairs to direct runoff from the walking path away from the building entry. Correction of this existing issue could avoid significant future expense, as well as aid the College's sustainability efforts by reducing the quantity of flood-damaged building materials that need to be replaced.

Project #3: Roberts Hall Drainage Improvements

Local storm drainage improvements are needed to address water entry issues into the south stairwell and lower level of Roberts Hall that occur during intense rain events. Improvements would likely consist of the removal of a paved walkway that currently directs runoff down a rather steep incline directly to the stairway doors, creation of a landscape berm to redirect runoff, repaving of the site walkways so that their cross-slope slopes away from Roberts Hall, and extension of roof drain piping for the north end of Barclay Hall so that the pipes discharge downgrade of the problematic location at Roberts Hall. Correction of this existing issue could avoid significant future expense, as well as aid the College's sustainability efforts by reducing the quantity of flood-damaged building materials that need to be replaced.

Project #4: Haverfarm And Facilities Management Complex Basin Improvements

Established in 2010, "The Haverfarm is a year-round farming and educational space designed to integrate sustainable food and agriculture into the academic and extracurricular lives of Haverford students, faculty, staff and community members…Produce is distributed to students, community members, the dining center and local food banks." (Haverfarm Mission Statement, 2019)

The Haverfarm is composed of multiple growing plots but the main production area is the approximately 25,000 square feet of tilled land in the southwestern corner of the campus. The 2018 Annual Farm Report indicated that

Haverfarm During Growing Season

"…students learn the basics of organic agriculture by helping with soil preparation, weeding, planting, harvesting, and composting." The intent of the Haverfarm is to grow edible produce that has limited exposure to chemical fertilizers or pesticides. Unfortunately, due to its location downslope of several managed lawn and sports grass turf areas, chemicals applied to these areas potentially enter the production area during heavy rain events.

Stormwater flows from the Featherbed and Class of 1995 Fields and adjacent upslope areas to the northeast through existing grass swales or on the road surface into the Haverfarm production plot. Even though the road along the northern side of the production area acts as a berm that holds back and collects water, this wet depression has limited capacity for larger amounts of water. When it reaches capacity, any additional rain overflows into and through the production area, causing both erosion of soil and unwanted saturation with potentially contaminated rain run-off.

Existing Vegetated Swale Along the Athletic Field

A two-pronged solution to this issue is recommended. For the first portion of the project, a diversion swale could be constructed to intercept runoff from the athletic fields and carry it to the west, thus preventing stormwater from reaching the Haverfarm production plots. Certain existing vegetation along this route could be impacted to construct these improvements. A surface infiltration basin with underground storage should be constructed near the treeline at the downgrade end of the athletic fields, to provide stormwater rate, volume, and quality management for this area of campus which is currently uncontrolled and contributes to flooding of Haverford Road.

The second portion of the project would be to create a storm sewer connection from the existing small bioretention basin north of the Haverfarm to the existing stormwater management basin just across the road to the east. An evaluation of the existing stormwater management basin determined that an expansion of this facility is required to accommodate current stormwater volumes. Any modifications to this existing facility could be designed to accommodate a redirection of flows from the surrounding drainage area, thus also managing some of the runoff that is causing issues for the Haverfarm. A small berm may be needed to ensure that the intended drainage area is collected and does not reach the farm production plots.

Project #5: Eroded Stream Restoration

The stream channel and outfalls adjacent to Woods Road and Kim Hall in the southeast region of campus are severely eroded and contribute sediment to the downstream watershed. Flows from the central campus area reach this eroded channel via 18" and 24" stormwater pipe outfalls as well as localized overland flow. The areas below the pipe outfalls are steep and severely eroded; previous stabilization measures appear to have failed and provide minimal energy dissipation to prevent erosion. The following photograph depicts the stream channel above the walking bridge and the next photograph depicts the stream channel condition below the walking bridge.

Upper Stream Channel (West of the Walking Bridge)

Upper Stream Channel (East of the Walking Bridge)

The total stream and outfall channel length is approximately 800 feet. Average channel depth is approximately four (4) feet and average width is 15 feet. These channel dimensions are significantly larger than those predicted for a stable channel with a watershed of similar size. This channel can be described as “entrenched”, meaning that the vertical erosion has disconnected the stream channel from its historic floodplain. It can also be described as “over-widened”, meaning that the lateral erosion of the stream banks has resulted in a wide channel section relative to the average amount of flow. Because the stream is unable to access the floodplain during storm events, this entrenched and over-widened channel condition focuses most of the flowing water’s energy on the channel bed and banks. This degraded condition results in significant channel erosion as compared to a stream that can access the adjacent floodplain, which allows a reduction of erosive forces on the primary stream channel.

This channel erosion is most likely being caused by increases in watershed imperviousness (paved and compacted areas) and increased rainfall amounts/extreme storm events in southeast Pennsylvania. The downstream culvert (under the Visitor’s Parking Lot) is also impacted by deposited sediment at the culvert entrance from upstream channel erosion. The Visitor’s Parking Lot flooding and recommendations are discussed in more detail in a separate project.

Stream restoration and outfall stabilization depicted in the next two (2) pictures is recommended to address channel and outfall erosion. The stabilization of the stormwater outfalls and restoration of the stream channel would offer several benefits including:

- Reduced sediment erosion and downstream transport
- Protected roots on stream bank
- Improved aesthetics of the stream corridor
- Improved aquatic and riparian habitat
- Restored connection between the stream and floodplain
- Rehydrated floodplain wetlands
- Protected infrastructure
- Added credit towards stormwater permit goals / requirements

Recommended restoration approaches include:

- Rebuild the outfall protections including installation of rock plunge pool energy dissipaters and raising the downstream channel inverts to reduce the amount of vertical drop at the pipe outfalls.

- Remove and replace the failing gabion basket wall which imbricated boulder wall protection.

- Restore upper reach (between outfalls and walking bridge) of stream channel by raising channel invert with step pool sequence in channel for vertical grade control. Grade banks to reduce slope and replant with native riparian vegetation. Install rock or wood toe protection as required for steeper bank areas.

Example of a Completed Outfall and Stream Restoration Project – Photo Credit Biohabitats, Inc.

- Restore lower reach (between walking bridge and culvert entrance) by grading the banks and adding rock or wood bank toe protection. Grade banks to a stable slope and plant with native, riparian vegetation.

Example of a Completed Outfall and Stream Restoration Project – Photo Credit Biohabitats, Inc.

- In conjunction with the stream improvements, drainage improvements at the low point of Coursey Road should also be considered. The curb opening for drainage is undersized and needs to be enlarged. A formalized drainage channel from the curb opening to the stream should be constructed to provide a non-erosive stormwater conveyance between the road and the stream.

Project #6: Visitor's Parking Lot Culvert Replacement

The Visitor's Parking Lot in the southeast region of campus experiences frequent flooding. When the capacity of the existing 30" culvert is exceeded, the flood waters flow over the Visitor's Parking Lot, continue south, and impact the Haverford College Apartments site. The primary causes of flooding appear to be an undersized culvert for the contributing stream and frequent clogging of the culvert entrance caused by debris and sediment. The 30" culvert connects to the 60"x144" box culvert that conveys the stream from the Duck Pond under the Haverford College

Partially Clogged Trash Screen Upstream of Culvert Entrance

Wedge Shaped Debris Rack Installed Upstream of a Culvert Entrance

Apartments site. The box culvert has adequate capacity, so only the 30” culvert from the upstream side of the Visitor’s Parking Lot to the box culvert needs to be replaced. The existing 30” culvert has a vertical rebar trash screen immediately upstream of the culvert entrance that captures some debris before entering the culvert but also contributes to the clogging and reduction of capacity of the culvert.

Replacing the existing culvert with a higher capacity culvert is the recommended solution to the flooding. Additional recommended enhancements include installing an improved trash/debris rack at the culvert entrance, a second trash/debris rock a few feet upstream of the culvert entrance to create a two-stage debris interception scheme, and grading a larger depositional area at the culvert entrance to reduce the concentration of sediment and debris at the entrance. Regarding the trash rack at the culvert entrance, a rack with more surface area would allow more debris to be captured before significant clogging or reduction in hydraulic capacity occurs. Also, trash racks with a wedge configuration typically maintain improved hydraulic capacity by encouraging settling upstream of the inlet at the front edge of the wedge.

Excavation of the low depositional area that can be described as a floodplain bench or wetland upstream of the culvert entrance is another possible alternative to reduce sediment and debris clogging at the entrance. This area would allow for some deposition of sediment and debris over a larger area upstream of the culvert rather than concentrating all materials at the debris rack at the culvert entrance as well as reducing the required maintenance frequency. This feature could be incorporated into a comprehensive restoration of the upstream channel (Project #5 above), which would be advisable from a permitting and approval standpoint as well.

Lastly, the project should include drainage swales on the south side of the Visitor’s Parking Lot to divert any overflows from extremely large or intense storm events away from the HCA buildings and roadway. The overflows would be directed to the vicinity of the box culvert at the north end of the HCA site, where additional drainage inlets should be added so that overflows can be drained into the box culvert.

Project #7: Upper Pond Sediment Trapping Enhancement

The approximately 5,500 square foot Upper Pond serves as a sediment settling basin/forebay that helps to reduce sediment entry to the Duck Pond. The drainage area to the Upper Pond is approximately 150 acres, most of which is off-site. To improve sediment trapping efficiency, the size of the Upper Pond could be increased by expanding it an easterly direction where there would be relatively minimal impact to existing vegetation. It appears that an expansion of around 4,500 square feet would be feasible, which would nearly double the size of the Upper Pond. In addition to improved sediment capture efficiency, the larger volume would reduce the frequency of required dredging for the Upper Pond. Improved maintenance access could be provided as part of the improvement of this pond as well as sediment monitoring recommendations and dredging interval predictions.

Project #8: Duck Pond Buffering and Water Quality Enhancements

Additional Pond buffer enhancement is recommended for the southeastern edge of the Duck Pond. Some buffer enhancements have been completed by the College including installation of split rail fencing and low frequency mowing between the fencing. Additional expansion of the buffer width and enhanced tree and shrub plantings would provide increased water quality treatment of runoff directly to the pond as well as discouraging use by Canada Geese, which are a known source of nutrient and bacterial pollutants.

The grassed swale that drains to the southeastern edge of the Duck Pond (east of College Lane) could be retrofitted as an infiltration or bioretention swale to provide improved stormwater treatment. This retrofit would allow a reduction in flow volume reaching the pond and provide filtering of runoff that would otherwise reach the pond directly during storm events.

Lastly, solar powered aerators could be added to the Duck Pond to improve dissolved oxygen levels, which would be beneficial for aquatic life by preventing algal growth and increasing dissolved oxygen levels.

Project #9: Duck Pond Outfall Enhancements

The outlet control weir for the Duck Pond could be modified to provide increased temporary water storage depth in the pond. By temporarily holding additional water during storm events and releasing it slowly, downstream flooding and erosion could be significantly reduced. Another strategy for reducing downstream flooding and erosion even further is to intentionally lower the pond water level prior to large storms, to increase the storage volume available for runoff received from upstream off-site drainage areas. The College currently has the ability to do this via a manually actuated valve in the pond spillway, but it is difficult to access the valve. As a further improvement, the existing valve could be replaced with an electrically-actuated remotely-controlled valve so that College staff can control the water level of the pond from their offices at the Facilities Management Complex. A level sensor in the pond would relay water depth information to staff in real time so that they can decide when to open and close the valve. Another variation would be to use an electrically-actuated remotely-controlled valve that is automated by a pond management software that is linked to weather forecasts (there is an annual fee associated with this type of system).

It is noted that PADEP dam permitting/approvals would likely be required for the suggested pond modifications.

Project #10: Additional South Parking Lot Infiltration Bed

In an effort to reduce erosion of the stream channel that begins around Kim Hall and reduce downstream flooding (such as flooding that occurs at the 30” culvert at the Visitors Parking Lot), an additional subsurface infiltration bed beneath the South Parking Lot could be constructed. Stormwater flows from the storm sewer system that runs between the Fine Arts Center and the Foundry could be redirected to the new infiltration bed, which would reduce the rate and volume of stormwater discharges. After being detained in the infiltration bed, any runoff that is not infiltrated can be released back to the storm sewer running down Macintosh Road to Coursey Road and to the outfall point at the upper end of the stream channel. This project is still recommended even if the separate stream restoration project is completed, as it will contribute to continued success of the stream restoration, reduce downstream flooding, and help to lessen the College’s overall stormwater runoff so that it is closer to that which existed prior to unmanaged human development activities.

Project #11: Storm Sewer Television (TV) Inspection

It is recommended that, as an approximately 5-year project, the entire campus storm sewer network be inspected with TV camera equipment to identify any broken, collapsed, or structurally unsound pipes so that they may be repaired. The inverts of corrugated metal pipes in particular are very prone to deterioration from corrosion due to the frequent presence of water. Video inspection recordings should be kept on file for future reference and comparison. A base map should be prepared that tracks when each element of the storm sewer network was inspected, as well as any repairs that were made based on the inspection.

If deteriorating pipes are identified before they are structurally unsound, they can typically be repaired by methods such as sliplining or cured-in-place-pipe relining for a significantly lower cost than excavate-replace-backfill construction methods. The order of magnitude cost estimate in Appendix C is for the first year of the project; the costs for subsequent years should be reevaluated after completion of the first year. Metal and clay pipes should be re-inspected within a maximum of five years, while concrete and HDPE pipes that were found to be in good condition should be re-inspected within a maximum of 10-years. In all cases, pipes should be re-inspected if ground subsidence or other occurrence indicates a potential problem with a storm sewer pipe.

The College may wish to develop a Geographical Information System (GIS) database for tracking storm sewer data such as pipe materials and sizes, inspection dates, and dates and methods of repair.

Project #12: Storm Sewer Upgrades

Refer to the hydraulic capacity analysis for the existing storm sewer system in Section 4-4. The storm sewer systems northwest of the Field House and north of K.I.N.S.C. could be enlarged to provide improved capacity. As described in Section 4-4, these improvements are rated as low priority because the College has not had historical flooding issues associated with these systems. Due to the low priority and the undetermined quantity and method of pipe replacement, an order of magnitude cost estimate has not been prepared for this project.

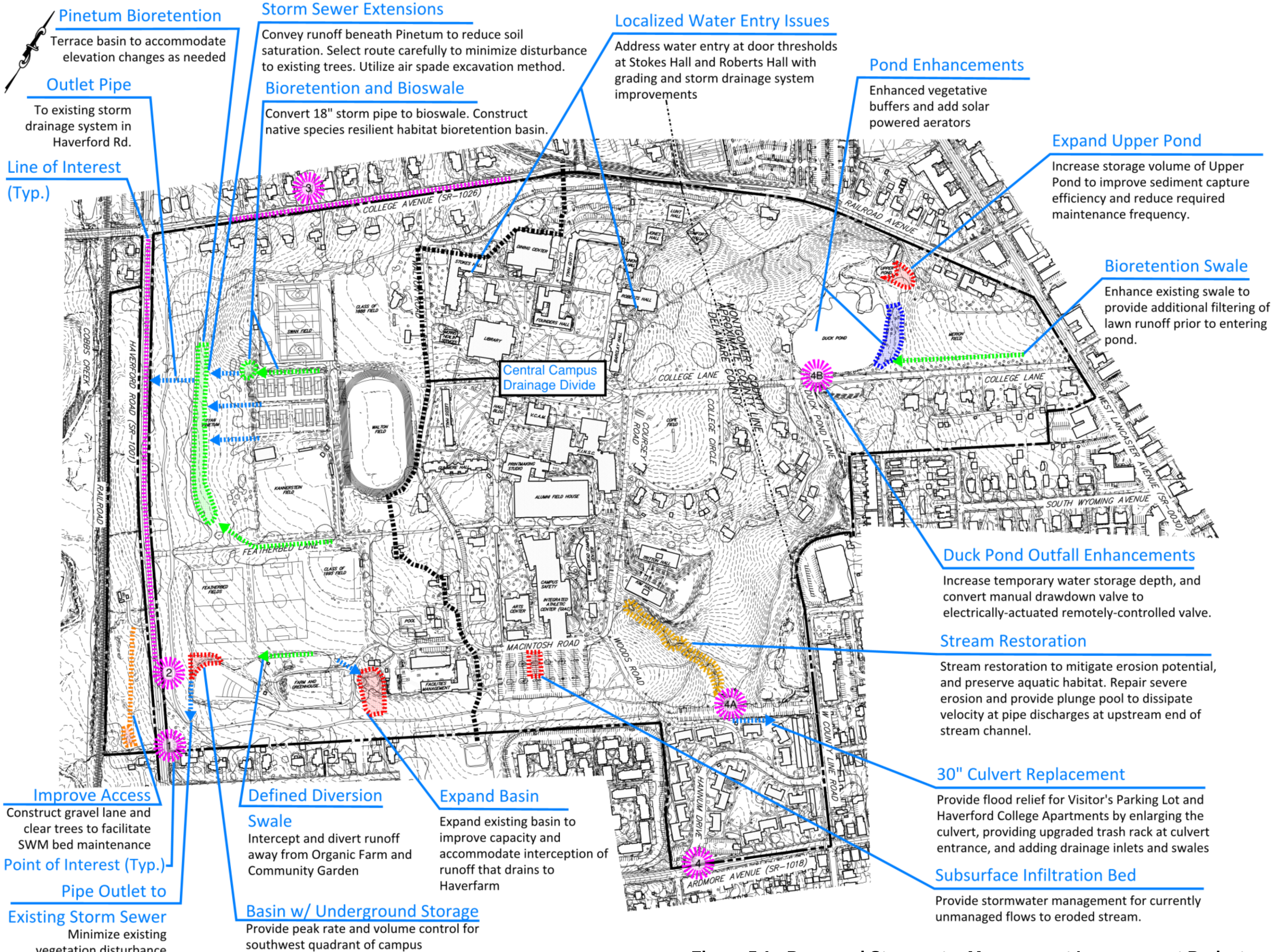


Figure 5.1: Proposed Stormwater Management Improvement Projects

6 REGULATORY CONSIDERATIONS

The legislative basis for statewide stormwater management is the Pennsylvania Stormwater Management Act of 1978, which is also known as "Act 167". The Act 167 program requires that each county in a given watershed regulate land use activities that affect runoff and surface and groundwater quality and quantity. In general, development projects that increase impervious coverage also cause an increase in the peak rate and volume of stormwater runoff, which is detrimental to natural waterways due to erosion and flooding. Also, suspended and dissolved pollutants that are present in stormwater runoff can harm water quality and aquatic habitats. The Delaware County Planning Department has developed an Act 167 Plan for the Darby – Cobbs Creek Watershed that establishes stormwater management standards to improve the condition of the watershed. The Darby – Cobbs Creek watershed is divided into four (4) Management Districts (A, B-1, B-2 and C). The Haverford College campus is located within Management District A. Haverford Township enacted a stormwater ordinance in 2005, titled "Township of Haverford Stormwater Management Code". This ordinance is based on and is consistent with the Act 167 Plan developed for the Darby – Cobbs Creek watershed.

Federal regulations require all land development projects that propose to disturb one (1) acre or more to obtain a National Pollutant Discharge Elimination System (NPDES) permit. NPDES permits authorize discharge from erosion and sediment control facilities during construction and approve Post-Construction Stormwater Management (PCSWM) measures. The NPDES program is based on the Environmental Protection Agency's "Clean Water Act" and includes requirements that municipalities and many institutions throughout Pennsylvania obtain permits for their stormwater discharges.

Municipal Separate Storm Sewer Systems (MS4) are man-made drainage systems such as gutters, pipes, and ditches, which convey only stormwater. Municipalities subject to MS4 requirements must develop, implement, and maintain comprehensive stormwater management programs with the goal of reducing the discharge of pollutants to receiving waters. Haverford Township does not currently have any MS4 regulations that affect land disturbance projects on the College campus. However, additional regulations affecting private institutions such as the College could be enacted in the future. Such regulations could require landowners to undertake projects to reduce sediment and pollutant loads from their properties.

Act 167, the Township stormwater ordinance, and NPDES regulations work in conjunction to reduce or prevent the water resource and stream impairment issues that arise from inadequate management of stormwater.

Volume Control

The Township stormwater management ordinance requires that the volume to be infiltrated shall be equal to one inch of rainfall over all of the proposed impervious surfaces. NPDES directives require the net 2-year volume increase from pre-development land cover to post-development land cover to be infiltrated. For NPDES volume control calculations, the pre-development land cover must be considered as woods, meadows, or impervious cover (based on actual land cover) with 20% of any impervious cover being considered meadow in the calculations. Infiltration of the 2-year storm net volume increase replicates the pre-development conditions by providing groundwater recharge, which feeds stream base flow. In the Philadelphia region, over 95% of the annual rainfall volume occurs in storm events that are less than the 2-year storm event (approximately 3.27 inches of rain in a 24-hour period). With the large majority of storms being smaller than the 2-year storm, designing Best Management Practices (BMPs) for the 2-year storm can have significant positive impact on the watershed.

Peak Rate Control

The Township's location in Management District A of the Darby – Cobbs Creek watershed per the Act 167 Plan requires that post development peak rates shall not exceed the following parameters:

Post-Development Peak Rate	Shall Not Exceed	Pre-Development Peak Rate
2-Year	≤	1-Year
5-Year	≤	5-Year
10-Year	≤	10-Year
25-Year	≤	25-Year
50-Year	≤	50-Year
100-Year	≤	100-Year

The pre-development land cover assumptions for the peak rate analysis vary depending on the classification of the project as new development or redevelopment. If considered new development, the pre-development land cover must be considered woods or meadow. If considered re-development, the ground cover used in determining the existing conditions flow rate for the developed portion of the site shall be based on actual land over conditions (i.e., lawn area may be considered as lawn, rather than meadow).

The Township's stormwater ordinance defines redevelopment as "any development that requires demolition or removal of existing structures or impervious surfaces at a site and replacement with new impervious surfaces. Maintenance activities such as top-layer grinding and re-paving are not considered redevelopment. Interior remodeling and tenant improvements are also not considered redevelopment". Based on this definition, many of the improvements associated with typical continued development of the college campus could potentially be considered redevelopment. The Township determines applicability of this ordinance section on a case-by-case-basis.

Water Quality

The Township's stormwater ordinance, and the NPDES permit program prior to December 8, 2020) do not require quantitative calculations demonstrating removal of pollutant concentrations. Rather, water quality requirements are assumed to be met if the net 2-year volume increase or water quality volume is infiltrated. This approach is based on the prototypical performance of BMPs as set forth in the PA Stormwater BMP Manual (2006). In the infrequent cases where the net 2-year volume increase cannot be infiltrated due to site soil conditions, additional water quality BMPs and calculations may be required. The goal is to demonstrate 85% reduction of Total Suspended Solids and Phosphorus, and 50% reduction of nitrates.

The BMP manual does not however establish pollutant removal goals for metals such as copper, lead and zinc.

Future Regulations

As of the date of this stormwater master plan, NPDES permit requirements are in the midst of changing; however, the county conservation districts have not yet issued guidance and interpretations relating to the changes. Future construction projects proposing to disturb greater than one acre of land area should thoroughly evaluate NPDES permit requirements at the outset of the project.

Another change that is anticipated to occur in the next 1-2 years the issuance of a new PA Stormwater Best

Management Practices Manual, which would supersede the aforementioned 2006 manual. The new manual could alter the required design and performance standards for stormwater BMPs. While PADEP has hinted about issuance of the manual, the actual timeframe for release of the new manual is currently unknown.

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7 GRANT FUNDING OPPORTUNITIES

Funding in the form of grants and loans is available through local, state, and national organizations year-round. Below is a list of potential funding sources that could be pursued for the implementation of recommendations made in the Haverford College Stormwater Master Plan.

Eligibility to apply for grant opportunities can differ. As an Institution of Higher Education and Nonprofit 501 (c) (3), Haverford College might be considered an eligible 'applicant' for most of the grants listed below. However, some grants will require the College to apply through Haverford Township or Lower Merion Township or a qualified environmental not-for-profit to be eligible.

As previously noted, sediment is a targeted pollutant in Lower Merion Township's Municipal Separate Storm Sewer System (MS4) permit, and the campus's location in the headwaters of the Cobbs Creek watershed may be ideal for a joint project between the Township and the College to reduce sediment loads.

DCCD Mini-Grant Program - The *Delaware County Conservation District* provide competitive mini-grants to conserve natural resources, educate, and significantly improve water quality within Delaware County. Supported projects range from streambank stabilization, riparian improvements and stream monitoring, to public workshops and nature trails. Eligible applicants include school based environmental clubs and local environmental organizations.

- Request Amount: Maximum $500
- Match: None
- Note: Utilize student environmental club or group from within the College to apply

Growing Greener - The *Pennsylvania Department of Environmental Protection* offers funding to support Projects that reduce nonpoint source (NPS) pollution, improve water quality and address stream degradation through BMPs. The program focus is within Chesapeake Bay, with split focus on Ohio, Allegheny, Monongahela, Genesee and Delaware River Basins. Eligible projects include the development and implementation of stormwater management projects, new and enhanced riparian buffers and restored waterways.

- Request Amount: Dependent upon available yearly revenues
- Match: Minimum 15%

Section 319 Nonpoint Source Management Grants Program - The *Environmental Protection Agency* provides funding to support projects that address NPS pollution from agriculture, stormwater runoff, stream channel degradation and Abandoned Mine Drainage (AMD). Preference is given to those that effectively address areas of concern in cost-effective ways, with a second priority for statewide or regional projects.

- Request Amount: N/A
- Match: N/A

Tree-Vitalize Watershed Grant Program - The *Pennsylvania Department of Environmental Protection* and *Aqua Pennsylvania* provide grants for riparian restoration and stormwater management. Applicants must be certified Tree Tenders.

- Request Amount: Reasonable Requests
- Match: Minimum 25% Cash/In-Kind

Municipal Assistance Program (MAP) - The *Pennsylvania Department of Community & Economic Development* provides funds for local governments to the planning and implementation of multiple services including floodplain management to reduce flooding events and manage stormwater.

- Request Amount: Dependent upon available funds
- Match: 50%; 25% of which must be non-state funded
- Note: Apply under Haverford or Lower Merion Township

Watershed Restoration & Protection Program (WRPP) - The *Pennsylvania Department of Community & Economic Development* administers funds from the Marcellus Legacy Fund for watershed restoration and protection projects, which involve the construction, expansion, improvement or repair, maintenance, or rehabilitation of a new or existing watershed protection Best Management Practices.

- Request Amount: Not to exceed $300,000
- Match: Minimum 15%

Flood Mitigation Program (FMP) - The *Pennsylvania Department of Community & Economic Development* administers funds through Act 13 from the Marcellus Legacy Fund to aid flood mitigation projects identified as eligible by a flood protection authority or local government. Eligible projects plan for and/or construct flood mitigation techniques that will manage stormwater.

- Request Amount: Maximum $500,000; Minimum total project cost $50,000
- Match: Minimum 15% Cash/Equivalent
- Note: Coordination with municipality likely needed

Community Conservation Partnership Program (C2P2) Riparian Forest Buffer Program - The *Pennsylvania Department of Conservation & Natural Resources* presently offers matching grants for the identification of sites in need of riparian forest buffers, as well as the design, establishment, continued oversight, and short-term maintenance for said buffers.

- Request Amount: Reasonable requests; Minimum award $50,000
- Match: Minimum 50%

Multifunctional Riparian Forest Buffer Program - *The Department of Conservation & Natural Resources and the Pennsylvania Infrastructure Investment Authority* provide funding assistance to support riparian forest buffer projects that identify design, establish, monitor and/or maintain multifunctional buffers that provide harvest opportunities.

- Request Amount: Reasonable Requests
- Match: None

Delaware River Restoration Fund - The *National Fish and Wildlife Foundation* along with the *William Penn Foundation* provide competitive funding to support the restoration of polluted waters to improve habitat, specifically for target species, including the eastern brook trout and river herring. Top 3 Priority Areas include: 1) stewardship of working lands; 2) restoration of wetlands, floodplains and stream corridors; and 3) promotion of green infrastructure for adoption in urban/suburban landscapes.

- Request Amount: $500,000
- Match: Minimum 25% (50% if requesting over 100K)

PA Small Water and Sewer Grant Program - The *Pennsylvania Department of Community & Economic Development/Commonwealth Financing Authority* provides grants for small water, sewer, storm sewer, and flood control infrastructure projects, to assist with the construction, improvement, expansion, or rehabilitation or repair of a water supply system, sanitary sewer system, storm sewer system, or flood control projects.

- Request Amount: $30,000 - $500,000
- Match: Not Required
- Note: Apply under Haverford or Lower Merion Township

Glossary of Terms

Act 167 – The Pennsylvania Stormwater Management Act, 32 P.S. §§ 680,1— 680.17. It provides for the regulation of land and water use for flood control and storm water management purposes, imposing duties and conferring powers on the DEP, municipalities and counties, providing for enforcement, and making appropriations.

Adsorption – The physical adherence or bonding of ions and molecules to the surface of another molecule. The preferred process used in cleanup of environmental spills.

Aerobic – Requiring oxygen (e.g. bacteria that function in the presence of free dissolved oxygen).

Aggradation – The excessive accumulation of sediment that results in raising streambed elevation.

Algal Bloom – 1) Rapid growth of algae on the surface of lakes, streams, or ponds; stimulated by nutrient enrichment. 2) A heavy growth of algae In and on a body of water as a result of high phosphate concentration such as from fertilizers and detergents. It is associated with Eutrophication and results in a deterioration in water quality.

Alluvial Deposit – Material deposited by a stream or other body of running water.

Alluvial Soil – Soil developed from transported and relatively recently deposited material (alluvium).

Anaerobic ---Not requiring free oxygen (e.g. bacteria that function in the absence of dissolved free oxygen).

Antecedent Moisture – The degree of wetness of soil at the be9inning of a runoff, determined by summation of weighted daily rainfall amounts for a period preceding the runoff.

Antidegradation Best Available Combination of Technologies (ABACT) – Environmentally sound and cost effective treatment, land disposal, pollution prevention and stormwater reuse BMPs that individually or collectively manage the difference in the net change in stormwater volume, rata *and* quality for the storm events up to and including the 2-year/24-hour storm when compared to the stormwater rate, volume and quality prior to the earth disturbance activities to maintain and protect the existing quality of the receiving surface waters of this Commonwealth.

Attenuation – 1) Reduction in magnitude, as in lowering of peak runoff discharge rates, in the case of dry ponds. 2) The reduction of contaminant concentrations, as in the action of biodegradation in wetlands or bioretention facilities.

Available Soil Moisture – That portion of moisture in soils that can be readily absorbed by plant roots.

Bank Rehabilitation and Bank Protection – To restore and/or protect the bank of a stream, lake, pond, or reservoir against erosion, scour, or sloughing by using any of the following: slope protection, dumped rock protection, cribbing, walls, channel deflectors, vegetative stabilization techniques.

Bankfull Discharge (Bankfull Flow) – The stream flow that transports the majority of a stream's sediment load over time and thereby forms the channel; the discharge that fills a stable alluvial channel to the elevation of the active floodplain; bankfull discharge is the basis for measuring width/depth ratio and entrenchment ratio.

Base Flow – Normally refers to the stream levels associated primarily with groundwater or subsurface contributions, as opposed to storm flow which corresponds to stream levels associated with recent precipitation and surface runoff.

Best Management Practices (BMP) – Activities, facilities, measures, planning or procedures used to minimize accelerated erosion and sedimentation and manage stormwater to protect, maintain, reclaim, and restore the quality of waters and the existing and designated uses manage the volume, rate and water quality of stormwater runoff.

Biochemical Oxygen Demand (BOD) – The quantity of oxygen needed by microorganisms in a body of water to decompose the organic matter present. An index of water pollution.

Biodiversity – The number of species of plants and animals in a defined area. Biodiversity is measured by a variety of indices that consider the number of species and, in some cases, the distribution of individuals among species.

Biofiltration – The simultaneous process of filtration, infiltration, adsorption, and biological uptake of pollutants in stormwater that takes place when runoff Rows over and through vegetated areas.

Bloom – A phenomenon whereby excessive nutrients within a body of water results in an explosion of plant life, resulting in a depletion of oxygen and fish kill, usually caused by runoff containing fertilizers.

Buffer – A vegetated strip immediately adjacent to a water body. The primary function of buffers is to protect the receiving water from sediment and pollutants derived from upstream areas. Ancillary benefits may include infiltration of rainfall and habitat enhancement. A buffer is a special case of a filter strip. Forested riparian buffers are one example of a best management practice related to the use of buffers.

Bypass – A channel, pipe, or system used to convey base flow around a work area to a stable downstream discharge point.

Capillary Water – Water just above the water table that is drawn up out of an aquifier due capillary action of the soil.

Capture – 1) Diversion of the flow of water in the upper part of a stream or watershed by the headward growth of another stream. 2) Diversion of runoff from one drainage area to another due to earthmoving activities or construction of stormwater systems.

Catchment – 1) An area confined by drainage divides, usually having only one stream flow outlet; watershed. 2) A reservoir or other basin for catching water.

CFS, or cfs – Cubic Feet per Second. (Discharge Capacity)

Channel – A watercourse or swale with a defined bed and bank, either natural or manmade.

Channel Capacity – 1) The maximum rate of flow that may occur in a channel without encroaching on the freeboard. 2) The maximum rate of flow that may occur in a stream channel without causing overbank flooding.

Channelization – The creation of a channel or channels resulting in faster water flow, a reduction in hydraulic residence time, and less contact between water and solid surfaces in the water body.

Channel Scour – The erosive action of water and sediment that removes and carries away bed and bank material.

Channery Soil – Soil that is by volume more than 15% thin, flat fragments of sandstone, shale, state, limestone, or schist as much as 6“ along the longest axis.

Clay – A fine-grained cohesive soil whose individual particles are not visible to the unaided eye (less than 0.002 mm dia.). It is typically plastic when wet — moist sample can be rolled into a 3 mm thick thread — and hardens when heated.

Clayey Soil – Any soil having at least 20% clay content.

Clean Streams Law (CAL) – (35 P.S. §§ 691.1----691.1001) Pennsylvania law passed in 1937 to preserve and improve the purity of the waters of the Commonwealth.

Clean Water Act (CWA) ---The federal Water Pollution Control Act (33 U.S.C.A. §g 1251—1376) to regulate discharges to waters within the United States.

CMP Pipe – Corrugated Metal Pipe (n = 0.024 to 0.025).

Coarse Textured Soil – Sand or loamy sand.

Colloidal Particles – Soil particles that are so small — typically 0.0001 to 1 micron in size — and so dispersed in water that they do not settle out, but not so fine and so dispersed as to be dissolved.

Compost – Organic residue or a mixture of organic residues and soil, that has undergone biological decomposition until It has become relatively stable humus.

Concentrated Flow – Runoff which is not in the form of Sheet Flow.

Conduit – Any channel or pipe intended for the conveyance of water, whether open or closed.

Confluence – The point at which 2 or more concentrated flows come together.

Contour Interval – Difference In elevation between two adjacent contours.

Conveyance – The process of water moving from one location to another; a measure of the ability of a stream, channel or conduit to convey water; a comparative measure of the water-carrying capacity of a channel.

Conveyance Channel – A channel constructed for the purpose of conveying clean water through or around a work area, such as outlet channels from sediment basins or traps, temporary stream relocations, etc.).

Culvert – A pipe or box used to convey runoff or stream flow under a roadway or embankment to a discharge point on the downslope side.

Datum – Any numerical or geometric quantity or set of quantities that may serve as a reference or base for other, comparable quantities (e.g. Mean Sea Level).

Degradation – The lowering of a streambed by scour and erosion.

Delineation – The process of deciding where something begins and ends (e.g. wetland boundaries).

Design Capacity – The amount of water a structure is designed to hold or convey under certain restrictions.

Design Criteria – Guidelines upon which planning and engineering decisions and judgments are based.

Design Flow (Q,) – The anticipated peak flow from a Design Storm that a BMP must be able to convey white providing sufficient freeboard.

Design Standards – Detailed engineering drawings and/or specifications promulgated by public or private organizations that leave little choice to design engineers and technicians.

Design Storm – The rainfall duration and return frequency used to size a BMP (e.g. for E&S purposes, Temporary BMPs not located in Special Protection Watersheds are generally designed to have sufficient capacity for the anticipated runoff from a 1-hour storm that has a return frequency of once every 2 years, i.e. a storm of that intensity occurs on average once every 2 years).

Detention Facility – A storage pond or tank (above or below ground) that temporarily stores stormwater runoff and releases it at a slower rate than it was collected. Typically, there is little or no infiltration.

Direct Runoff – The stream flow produced in response to a rainfall event; it is equal to total stream flow minus baseflow.

Discharge – Volume of water exiting a pipe, channel, or impoundment (or passing a given point) during a given period of time – usually measured in cubic feet per second, CFS or gallons per minute, GPM.

Dissolved Solids – The weight of matter in true solution in a stated volume of water, including both inorganic and organic matter.

Diversion – A facility, including a channel or a conveyance constructed up-slope of the disturbed area to divert clean offsite runoff away from the earth disturbance activity.

Drainage Area – The area above a BMP from which runoff would normally drain to that BMP.

Drainage Divide – The boundary, along a topographic high, between one drainage basin and another.

Drainage, Soil – The frequency and duration of periods when the soil is free from saturation.

Well-drained - Excess water drains away rapidly, and no mottling occurs within 36" of the surface.

Moderately Well-Drained - Water is removed from the soil somewhat slowly, resulting in small but significant periods of wetness. Mottling occurs within 18” to 46” of the surface.

Somewhat Poorly-Drained - Water is removed from the soft slowly enough to keep it wet for significant periods, but not all the time. Mottling occurs between 8" and 18’ of the surface.

Poorly Drained - Water is removed so slowly that the soil Is wet for a large part of the time. Mottling occurs between 0 and 8" of the surface.

Very Poorly Drained - Water is removed so slowly that the water table remains at or near the surface most of the time. There may also be periods of surface ponding. The soil has a black to gray surface layer with mottles up to the surface.

Dry Basin – A basin that has an outlet structure designed so that essentially all stored water will be drained from the impoundment by gravity.

Ecosystem – All organisms and the non-living environmental factors with which they interact.

Eutrophic – Water containing an excess of plant-growth nutrients that typically result in algae blooms and extreme (high and low) dissolved-oxygen concentrations.

Eutrophication - The enrichment of water with nutrients, usually phosphorous and nitrogen, which stimulates the growth of algal blooms and rooted aquatic vegetation and accelerates the aging of that water body.

Evapotranspiration – The combined processes of evaporation from the water or soil surface and transpiration of water by plants.

Extended Detention – A function provided by BMPs which incorporate a water quality storage. BMPs with extended detention, intercept runoff and then release it over an extended period of time.

Filter Strip – A vegetated boundary characterized by uniform mild slopes. Filter strips may be provided down-gradient of developed tracts to trap sediment and sediment-borne pollutants and to reduce imperviousness. Filter strips may be forested or vegetated turf. Filter strips located adjacent to waterbodies are called buffers.

Fine Particles -—Silt and clay particles, also called fines.

First Flush – The first portion of runoff generated by a storm event containing the main portion of the pollutant load resulting from the storm.

Flocculant – A chemical added to turbid water to accelerate the formation of clumps from fine- grained particles suspended in the water for the purpose of settling-out those particles prior to discharging into surface waters.

Floodplain — Lands adjoining a river or stream that have been or may be expected to be inundated by flood waters in a 100-year frequency flood.

Floodway – The area of the floodplain required to carry the discharge from a 100-year storm event. Where no FEMA mapping has been completed, it is assumed to be 50’ back from top of the bank.

Fluvial Geomorphology (FGM) – The study of a stream's Interactions with the local climate, geology, topography, vegetation, and land use; the study of how a river carves its channel within its landscape.

Forebay – 1) The water behind a dam. 2) A reservoir or pond situated at the point where a channel or pipe discharges into a sediment basin or detention pond for the purpose of catching sediment and facilitating maintenance.

Fragipan – A natural subsurface soil horizon with high bulk density compared to the soil column above it, seemingly cemented when dry but moderately to weakly brittle when moist.

Frequency of Storm – The average period of years that will elapse before another storm of equal intensity will recur. For example, a 10-year storm can be expected to occur once during a 10-year period. Note: This is based on probabilities. Storms with large return periods, such as 100 years, have been known to follow closely after one another,

Friable – 1) Of rock, the characteristic of crumbling naturally or being easily broken, pulverized, or reduced to powder such as a poorly cemented sandstone. 2) Of soil, the consistency in which moist soil material crushes easily under gentle to moderate pressure — between thumb and forefinger — and coheres when pressed together.

Geotextile – A fabric manufactured from synthetic fiber that is designed to achieve specific engineering objectives, including seepage control, media separation (e.g., between sand and soil), filtration, or the protection of other construction elements such as geomembranes.

Gleyed Soil – Soil that formed under poor drainage, resulting in the reduction of iron and other elements in the profile and in gray colors and mottles.

Gradient ----Change in elevation, velocity, pressure, or other measurable characteristic per unit length, slope.

Greenway – A strip or belt of vegetated land that typically includes both upland and riparian areas. Greenways are often used for recreation, as a land use buffer, or to provide a corridor and habitat for wildlife.

Habitat – The environment occupied by individuals of a particular species, population, or community.

Headwall – A wall of stone, metal, concrete, or wood at the end of a culvert or drain to protect fill from scour or undermining, increase hydraulic efficiency of conduit, divert flow, retard disjointing of short sectional pipe, or serve as a retaining wall.

Headwater – 1) The source and upper reaches of a stream or reservoir. 2) In culverts, it is the depth of the upstream water surface measured from the invert of the culvert entrance.

High Quality Waters – Surface waters having quality which exceeds levels necessary to support propagation of fish, shellfish, and wildlife and recreation in and on the water by satisfying 25 Pa. Code § 93.4b(a),

Horizon – A layer of soil with different color or composition than the layers above and below It.

Hydraulic Gradient – A line which represents the relative force available due to the potential energy available. This is a combination of energy due to the height of the water and internal pressure. In an open channel, the line corresponds to the water surface.

Hydrograph – A graphical representation of the rate of flow, stage, velocity or other property of water at a specific point over a period of time (usually during a storm or flood event).

Hydrologic Cycle – The circuit of water movement from the atmosphere to the earth and back to the atmosphere by various processes such as precipitation, runoff, infiltration, evaporation, and transpiration.

Hydrologic Soil Group – A classification of soils according to infiltration rates. Group A soils have the highest infiltration rates, and therefore, the lowest runoff potentials, while Group D soils have the lowest infiltration rates and (highest runoff potentials).

Impervious Surface – Hard ground cover that prevents or retards the entry of water into the soil and increases runoff, such as asphalt, concrete, rooftops, etc.

Incised Stream – A stream in which scouring causes the channel to degrade or down-cut to a point where the stream is no longer connected to its floodplain.

Infiltration – The entrance of surface water into the soil, usually at the soil /air interface.

infiltration Rate – The maximum rate at which water can enter a soil under specified conditions.

Infiltration Testing – Specific tests designed to measure the saturated movement of water into the soil in a single direction downward through a two-dimensional soil surface.

Limnetic – 1) Relating to or inhabiting the open water part of a freshwater body with a depth that light penetrates. 2) The area of a wetland without emergent vegetation.

Mitigation – The replacement of functional values lost when an ecosystem is altered. Mitigation can include replacement, restoration, and enhancement of functional values.

Native Species – A species that is part of an area's original flora or fauna.

Natural Drainage – The flow patterns of stormwater runoff over land before development.

Nitrates – One form of nitrogen that plants can take up through their roots and use for growth (NOT).

NRCS – Natural Resources Conservation Service, formerly known as SCS, a federal agency under the U.S. Department of Agriculture which, among other things, provides technical assistance to conservation districts, assists farmers in developing conservation plans, provides soil survey information, and assists local governments in planning and installation of erosion and flood control projects.

100-Year Flood – A flood having a one-percent chance of being equated or exceeded in any given year.

Open Channel Flow – Flow in an open conduit or channel that is driven by gravitational forces.

Parent Material -----The unconsolidated and more or less chemically weathered material from which a soil has been derived.

Particulate Matter -—--Solid material in water; either in the solid or dissolved state.

Peak Attenuation Storage – The volume set aside within a BMP for the purpose of attenuating the inflow runoff peak rate.

Peak Discharge – The maximum design flow rate at which runoff from a drainage area discharges past a specific point.

Percolation – The downward movement under the influence of gravity of water under hydrostatic pressure through the interstices of the rock or soil.

Percolation Rate – The rate, typically expressed in inches/hour or inches/day, at which water moves through the soil profile.

Permeability – The ability of rock, soil or other material to transmit a gas or liquid.

Permeability Rate – The rate at which water will move through a saturated soil. Permeability rates are classified as follows:

Very Slow:	< 0.06	in/hr.
Slow:	0.06 to 0.20	in/hr.
Moderately Slow:	0.20 to 0.63	in/hr.
Moderate:	0.63 to 2.0	in/hr.
Moderately Rapid:	2.0 to 6.3	in/hr.

Rapid:	6.3 to 20.0	in/hr.
Very Rapid:	> 20.0	In/hr.

Phosphates – An important nutrient for plant growth (PO_4).

Physiographic Region – A large-scale unit of land having similar climate, geology, topography, and other physiographic features.

Pollutant – Any contaminant or other alteration of the physical, chemical, biological or radiological integrity of surface water which causes or has the potential to cause pollution as defined in section 1 of The Clean Streams Law (35 P.S. §§ 691.1---691.1001).

Pollutant Removal – Removing pollutants by decomposing them or eliminating them from an area or system, or rendering non-harmful or unavailable in a soil or medium by means of adsorption, chelation, and similar binding mechanisms.

Pore Space – Open space in rock or granular material; also known as interstices.

Porosity – The ratio of pore space to total volume of soil or rock. These pore spaces might or might not be interconnected.

Precipitation – A deposit on the earth of hail, mist, sleet, rain or snow.

Rainfall Intensity - In the Rational Equation, it is the rate of rainfall in inches per hour.

Light Rain:	$\leq$ 0.10	in/hr.
Moderate Rain:	0.11 to 0.30	in/hr.
Heavy Rain:	> 0.30	in/hr.

Receiving Water – A water body into which wastewater or treated effluent is discharged.

Recharge – Replenishment of groundwater reservoirs by infiltration through permeable soils.

Return Period (Storm Event) – The average period of time between the occurrence of storms of equal or greater magnitude. The probability that such a storm will occur in any given year is equal to the reciprocal of the return period (e.g. there is a 50% chance that a 2-year storm event will occur in any given year, but only a 10% chance that a 10-year storm event will occur).

Riparian – Pertaining to a stream or river. Also, plant communities occurring in association with any spring, lake, river, stream, or creek through which waters flow at least periodically.

Riparian Corridor – A narrow strip of land centered on a stream that includes the floodplain as well as related habitats adjacent to the floodplain. Also called a riparian zone.

Riverine Wetlands – Wetlands associated with rivers.

Runoff – That portion of a rainfall or snowmelt that flows over the surface.

Runoff Capture Design Storm – Benchmark rainfall event, used to develop criteria for designing the groundwater recharge function of BMPs. The runoff capture design storm is the largest rainfall event from which no appreciable runoff is expected to occur. Complete specification of the storm includes the rainfall depth in. inches, return frequency and storm duration. The distribution of rainfall in Pennsylvania is a Type II rainfall distribution. See Section 5.3 of the Handbook.

Runoff Capture Storage – The combined storage volume provided by BMPs on a site for the retention and eventual infiltration of rainfall.

Runoff Capture Volume – The minimum volume of rainfall that should be retained and completely infiltrated onsite during every storm. It is also equal to the rainfall quantity associated with the runoff capture design storm. The runoff capture volume is conveniently stated as a rainfall volume, in inches, over the area of the site.

Runoff Peak Attenuation Design Storm – Benchmark rainfall event, used to develop criteria for the design of runoff peak attenuation BMPs. The design criteria generally requires that the predicted post development peak runoff rate for the selected runoff peak attenuation design storm will not exceed the peak associated with redeveloped condition. Complete specification of the storm includes rainfall depth in inches, return frequency and storm duration. The distribution of rainfall in Pennsylvania is a Type II rainfall distribution.

Sand – 1) Soil particles ranging from 0.05 to 2.0 mm in diameter; individual particles are visible to the unaided human eye. 2) A soil textural class inclusive of all soils which at least 70% sand and 15% or less clay.

Saturated Soil – Soil in which the pore space is completely filled with water.

Scour – 1) The erosive action of flowing water in streams that removes and carries away material from the bed and bank. 2) Erosion at the outfall of a pipe or channel.

Seasonal High Water Table – Shallow water tables associated with periods of recent high levels of precipitation and/or low levels of evapo-transpiration.

Sediment – Soils or other erodible materials transported by stormwater as a product of erosion.

Seepage – 1) Groundwater emerging at the surface. 2) Water flowing through an embankment used to impound water.

Shear Strength - A measure of the ability of a material to resist slope failure, such as slumping, flowing, etc. Materials with low shear strength are more susceptible to landslides and embankment failures.

Sheet Flow – Water flow with a relatively thin and uniform depth.

Silt – 1) A non-cohesive soil whose individual particles are not visible to the unaided human eye – 0.05 mm - 0.002 mm. Silt will crumble when rolled into a ball. 2) A soil textural class indicating more than 80% silt.

Soil – 1) The earth materials which have been so modified and acted upon by physical, chemical, and biological agents that it will support rooted plants. 2) Earthen materials – down to bedrock – affected by an earthmoving project.

Soil Horizon – One of the layers of the soil profile (i.e. A – uppermost layer containing organic material; B – layer where material leached from layer A accumulates; C – parent material from which overlying layers were formed) that has developed characteristics distinct from those of the layers above and below.

Soil Texture – A classification of soils based on the size distribution of mineral grains comprising the soil; the relative proportions of silt, sand, clay, and gravel in a soil.

Stream Channel – Any watercourse having defined bed and banks, either natural or artificial, with perennial or intermittent flow.

Succession – The temporal changes of plant and animal populations and species in an area that has been disturbed.

Total Organic Carbon (TOC) – A measure of the total reduced carbon in a water sample.

Total Phosphorus (TP) – A measure of the total phosphorus in a water sample, including organic and inorganic phosphorus in particulate and soluble forms.

Total Suspended Solids (TSS) – A measure of the filterable matter in a water sample.

Transition Zone – The area between habitats or ecosystems (see ecotones). Frequently, transition zone is used to refer to the area between uplands and wetlands. In other cases, wetlands are referred to as transitional areas between uplands and aquatic ecosystems.

Transpiration – The transport of water vapor from the soil to the atmosphere through growing plants.

Turbidity – A measure of the reduced clarity of water caused by suspended particles, such as sift, clay, organic material, etc.

Type II Rainfall Distribution – Standard NRCS 24-hour rainfall distribution which applies to the state of Pennsylvania. The distribution allocates rainfall as a percentage of total rainfall over discrete time intervals.

Upland – An area that is not an aquatic, wetland, or riparian habitat. An area that does not have the hydrologic regime necessary to support hydrophytic vegetation.

Water Quality – A term used to describe the physical, chemical, thermal, and biological characteristics of water, usually in respect to its suitability for a particular use.

Water Quality Design Storm – Benchmark rainfall event, used to develop criteria for the design of water quality BMPs. Water quality design storms are used to size BMPs that are intended to achieve specific quality treatment objectives. Criteria based on water quality storms generally require that the design treatment efficiency be achieved during the water quality design storm and all smaller events. Complete specification of the storm includes rainfall depth in inches, return frequency and storm duration. The distribution of rainfall in Pennsylvania is a type II rainfall distribution.

Water Quality Storage – The volume set aside within a BMP to detain storm runoff. The detained water is released over an extended period of time. The water quality storage is frequently expressed as a multiple of the water quality volume.

Water Quality Velocity – The maximum flow velocity encountered in a water quality BMP during the course of the water quality design storm.

Water Quality Volume – The total volume of runoff which is delivered to the inlet of a water quality BMP during the course of the water quality design storm.

Water Table – The surface of a groundwater body at which the water is at atmospheric pressure; the upper surface of the ground water reservoir.

Watershed – An area confined by drainage divides usually having only one streamflow outlet.

Weir – A device used to control and measure water flow.