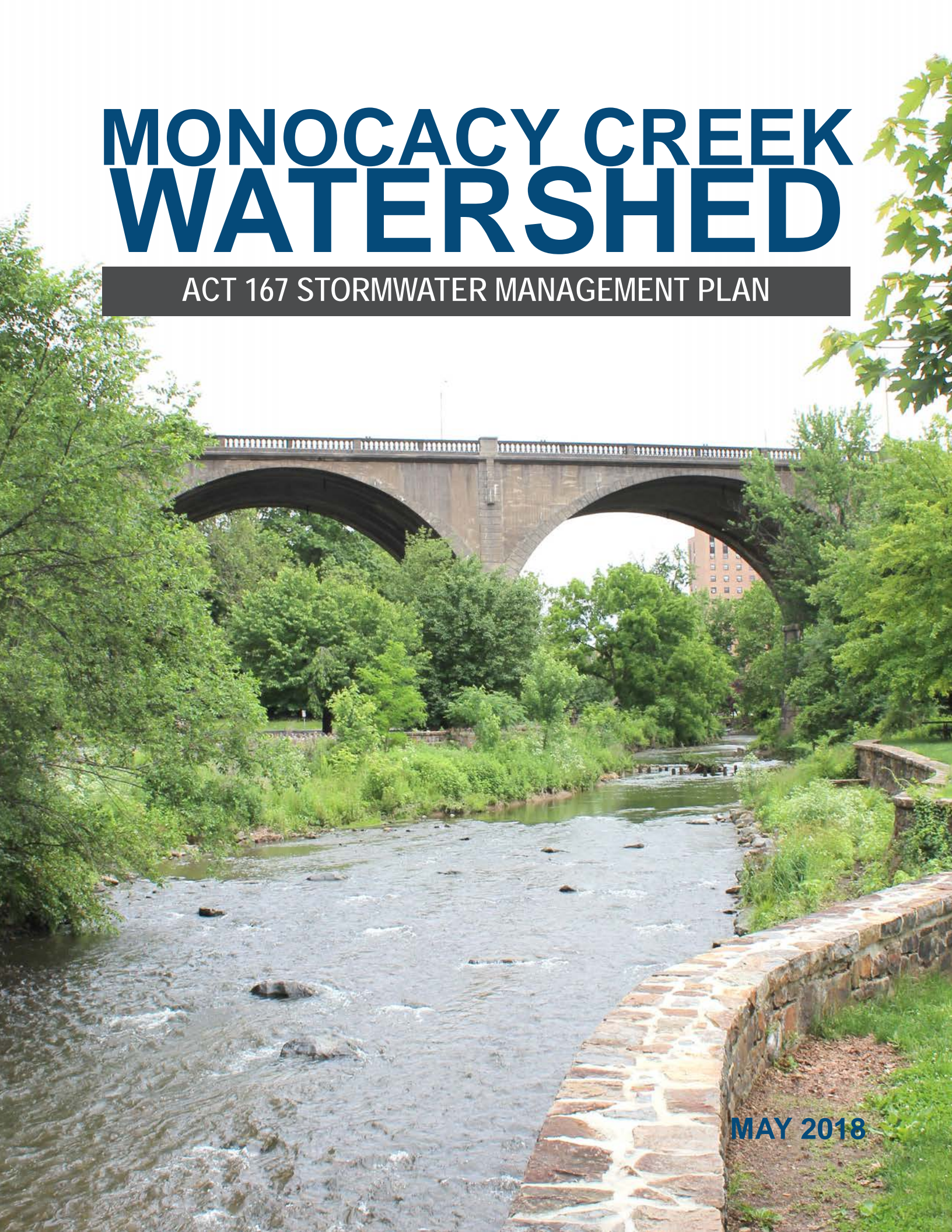


MONOCACY CREEK WATERSHED

ACT 167 STORMWATER MANAGEMENT PLAN



MAY 2018

MONOCACY CREEK WATERSHED ACT 167 STORMWATER MANAGEMENT PLAN

This Plan has been prepared by the Lehigh Valley Planning Commission on behalf of Northampton County and Lehigh County. The Plan contains revisions based upon the review comments received from the Monocacy Creek Watershed Advisory Committee.

The preparation of this report was funded by the City of Bethlehem through a grant from the Pennsylvania Department of Environmental Protection.

May 2018

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Northampton County Adoption, January 4, 2018

**Approved by the Pennsylvania Department of
Environmental Protection, May 21, 2018**



Monocacy Park, photo by Craig Kackenmeister, LVPC



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Thanks to the City of Bethlehem for providing funding for the preparation of this report.



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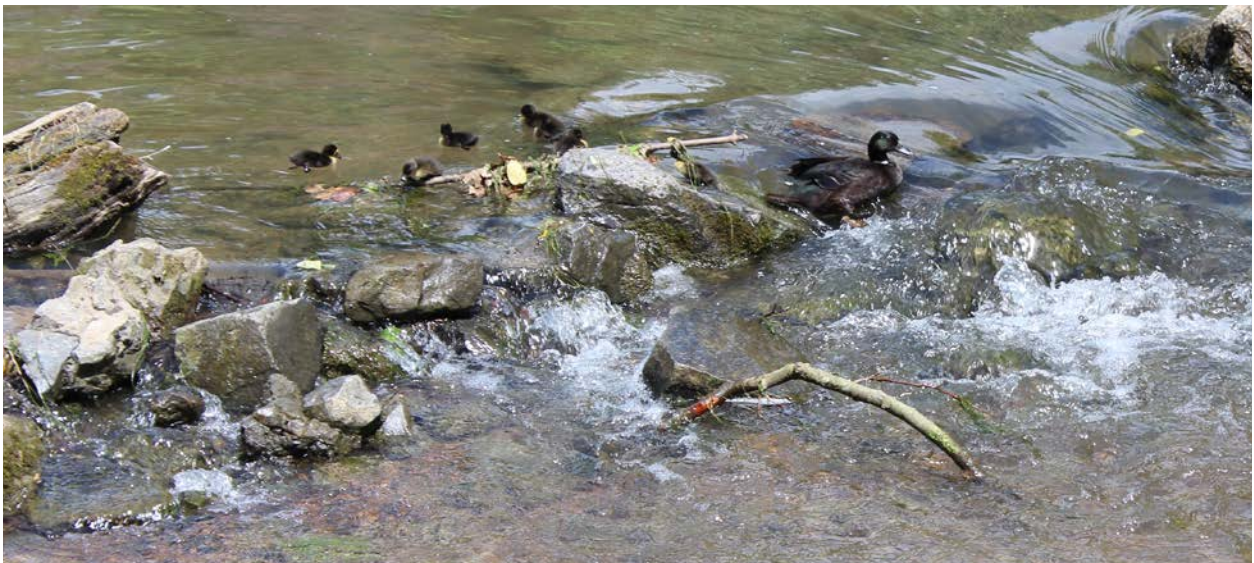
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Monocacy Park, photo by Craig Kackenmeister, LVPC



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Historic Bethlehem, photo by Craig Kackenmeister, LVPC

Monocacy Creek Act 167 Plan

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EXECUTIVE SUMMARY



Great Blue Heron on Monocacy Creek at Monocacy Park, photo by Craig Kackenmeister, LVPC

Monocacy Creek Act 167 Plan

The Pennsylvania Stormwater Management Act, Act 167 of 1978, provides the framework for improved management of the storm runoff impacts associated with the development of land. The purposes of the Act are to encourage the sound planning and management of storm runoff, to coordinate the stormwater management efforts within each watershed, and to encourage the local administration and management of a coordinated stormwater program. For the Monocacy Creek, this means that ten Northampton County municipalities, two Lehigh County municipalities and the City of Bethlehem, which is in both counties, have a stake in how stormwater runoff is managed in the watershed.

Act 167 stormwater management on a watershed level provides a significant step forward in the sound management of the runoff impacts of new development. The storm runoff control strategy established by an Act 167 Plan provides for new development to occur, while ensuring that existing drainage problems are not aggravated nor new problems created.

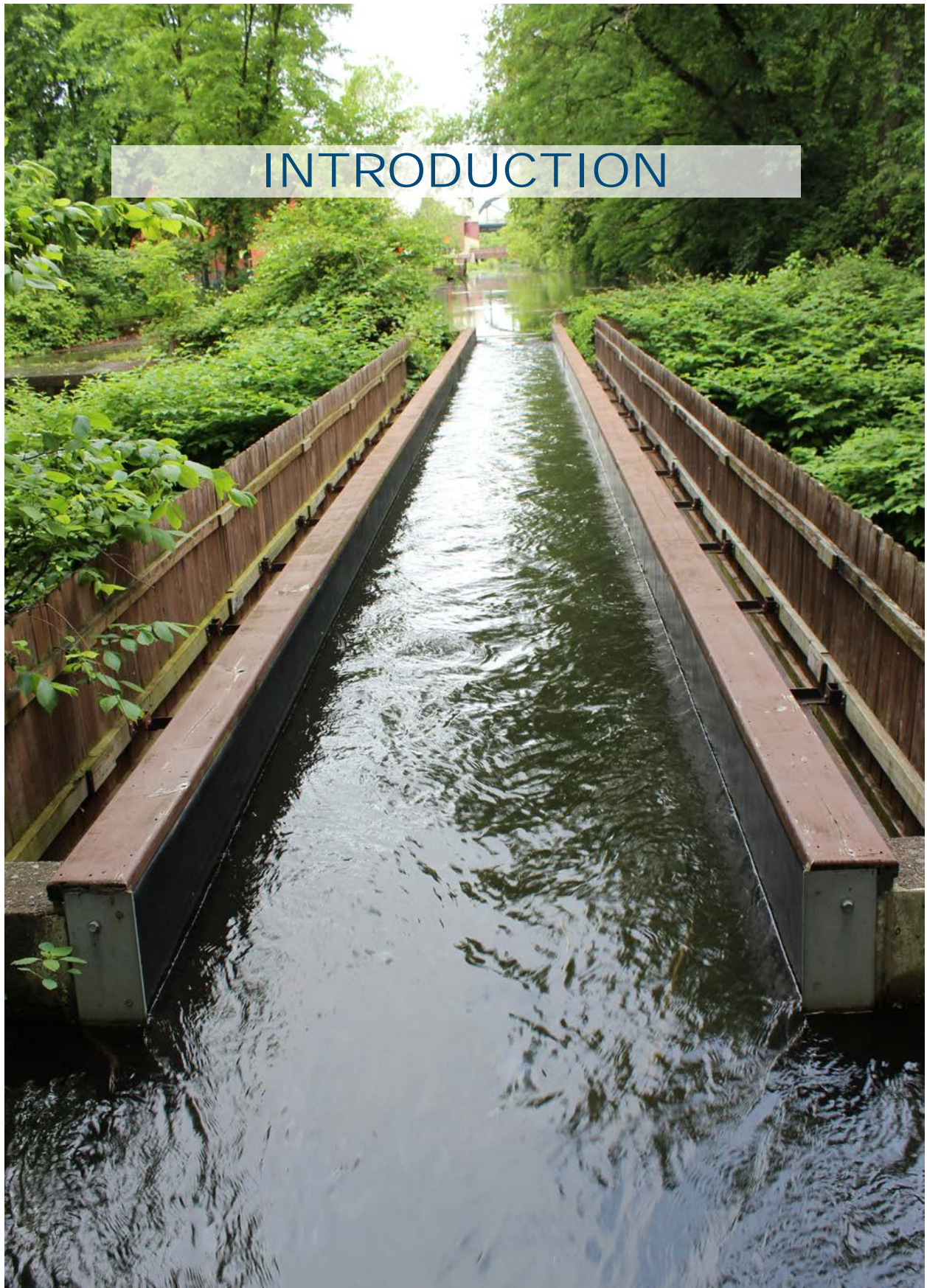
It is important to understand that an Act 167 Plan is not a land use plan. Runoff controls developed in the plan are not based upon controlling the location, type, density or rate of development throughout the watershed. The stormwater runoff performance standards are based on the assumption that development will occur throughout the watershed consistent with municipal zoning. The plan is designed to provide for new development yet control the associated storm runoff impacts.

One especially important aspect of the Act 167 process is the need to periodically update the plan. The original *Monocacy Creek Act 167 Stormwater Management Plan* and Model Municipal Ordinance was adopted by Lehigh and Northampton counties and approved by the Pennsylvania Department of Environmental Protection in 1989. The Model Municipal Ordinance for the Monocacy Creek was updated to include stormwater quality standards in April 2006 as part of the “*Global*” *Act 167 Plan Update*. Global refers to the 11 watersheds included in the study, including the Monocacy Creek, for which the ordinance was updating a water quantity ordinance prepared under Act 167 within the Lehigh Valley. Updating the plan guarantees a dynamic system of watershed runoff control sensitive to changing watershed characteristics and regulatory context. The Monocacy Creek Watershed Act 167 Stormwater Management Plan has been prepared for Lehigh and Northampton counties by the Lehigh Valley Planning Commission.

The implementation of the Monocacy Creek Act 167 Stormwater Management Plan is primarily through the adoption and enforcement of the Model Municipal Ordinance by the 13 watershed municipalities. The Model Municipal Ordinance contains the criteria and standards to regulate new development and redevelopment activities and mitigate the stormwater impacts of those activities regarding the rate, volume and quality of runoff. The Model Municipal Ordinance has evolved from the original 1989 *Monocacy Creek Plan* and the 2006 “*Global*” *Plan Update*. Key changes to the Model Municipal Ordinance in this Plan are as follows:

- Definitions and standards are more closely aligned with those used by the Pennsylvania Department of Environmental Protection for projects requiring a Post-Construction Stormwater Management Permit.
- Standards are added to better ensure that the pre-development water balance is more closely reflected in the post-development condition through the choice of stormwater management Best Management Practices in site design. Water balance refers to the ultimate fate of rainfall impacting the site in terms of whether it becomes runoff, groundwater recharge or returns to the atmosphere as evapotranspiration. These standards primarily ensure that groundwater recharge is not dramatically increased through stormwater management designs that do not provide opportunities for evapotranspiration.
- Standards are added to better ensure the application of green infrastructure practices that take advantage of vegetative means to manage stormwater runoff. The Plan Ordinance has a “green infrastructure first” standard that requires designs to provide an overall design that mimics natural runoff, recharge and evapotranspiration.

A key ingredient of the Model Ordinance is that it retains the responsibility of the Lehigh Valley Planning Commission to review development and redevelopment projects for consistency with the Ordinance. This provision has been in place since the original 1989 *Monocacy Creek Plan*. The Lehigh Valley Planning Commission review provides a consistent interpretation of the standards in the Model Municipal Ordinance and serves to coordinate the review of development and redevelopment plans with the municipalities.



INTRODUCTION

Monocacy Creek Aqueduct, photo by Craig Kackenmeister, LVPC

The Pennsylvania Stormwater Management Act, Act 167 of 1978, provides the framework for improved management of the storm runoff impacts associated with the development of land. The purposes of the Act are to encourage the sound planning and management of storm runoff, to coordinate the stormwater management efforts within each watershed, and to encourage the local administration and management of a coordinated stormwater program. For the Monocacy Creek, this means that ten Northampton County municipalities, two Lehigh County municipalities and the City of Bethlehem, which is in both counties, have a stake in how stormwater runoff is managed in the watershed. Without coordinating their efforts through a watershed analysis, the 13 municipalities would establish a fragmented system of stormwater management with uncertain results.

The difference between at-site runoff control philosophy and the Act 167 watershed-level philosophy is the consideration of downstream impacts. Whereas the objective of typical at-site design would only be to control post-development peak runoff rates to pre-development levels from the site itself, a watershed-level design would be geared towards maintaining existing peak flow rates in the entire drainage system. The latter requires knowledge of how the site relates to the entire watershed in terms of the timing of peak flows, contribution to peak flows at various downstream locations and the impact of the additional runoff volume generated by development of the site.

Act 167 stormwater management on a watershed level provides a significant step forward in the sound management of the runoff impacts of new development. The storm runoff control strategy established by an Act 167 Plan provides for new development to occur, while ensuring that existing drainage problems are not aggravated nor new problems created. It will not, however, eliminate storm drainage problems or flooding. To effectively implement an Act 167 program, it is necessary to understand the following limitations of the process as well as the strengths.

- Storm runoff criteria are based on controlling “design” storm events applied uniformly over the entire watershed. Natural storms, which may vary in duration, intensity and total depth of rainfall throughout the watershed, may, in certain instances, create runoff events that cannot be effectively controlled.
- The runoff control criteria developed as part of an Act 167 Plan will not correct existing drainage problem areas.
- An Act 167 Plan will not prevent the inundation of floodplain areas. These areas are intended by nature to carry storm runoff.

It is also important to understand that an Act 167 Plan is not a land use plan. Runoff controls developed in the plan are not based upon controlling the location, type, density or rate of development throughout the watershed. The stormwater runoff performance standards are based on the assumption that development will occur throughout the watershed consistent with municipal zoning. The plan is designed to provide for new development yet mitigate the associated storm runoff impacts.

An important aspect of an Act 167 Plan is that it establishes a process for decision making. It establishes the existing interrelationships between the various parts of a watershed in terms of peak flows and the “timing” of those peak flows. The peak flows and timing relationships provide for development of a runoff control philosophy geared towards minimizing the storm runoff impacts of new development.

Act 167 is a three-step process of runoff control that works as follows:

1. Documentation of the existing state of storm runoff in the watershed. This is the documentation of the existing physical characteristics of the watershed (e.g., land use, soils, slopes, storm sewers, etc.), documentation of existing storm drainage problems and flow obstructions, and documentation of the peak flow and timing relationships.
2. Preparation of the plan to control storm runoff water quantity and water quality impacts from new development. The plan includes runoff control performance standards for new development and a process for site specific evaluation and design. The performance standards do not dictate the control methods to be used but rather will indicate the necessary end product. The runoff control philosophy



Monocacy Creek in the Borough of Bath, photo by Craig Kackenmeister, LVPC

is designed to prevent new problem areas from developing. Stated otherwise, the runoff control philosophy seeks to ensure that peak runoff rates throughout the watershed will not increase with development and that the water quality impacts of new development will be mitigated.

3. Development of priorities for implementation. With the accomplishment of the first two aspects of the Act 167 process, the third aspect involves developing a prioritized list of actions aimed at improving the current state of storm runoff in the watershed. This means preparing a strategy for dealing with the existing storm drainage problem areas within each municipality.

One especially important aspect of the Act 167 process is the need to periodically update the plan. The original *Monocacy Creek Act 167 Stormwater Management Plan* and Model Municipal Ordinance was adopted by Lehigh and Northampton counties and approved by the Pennsylvania Department of Envi-

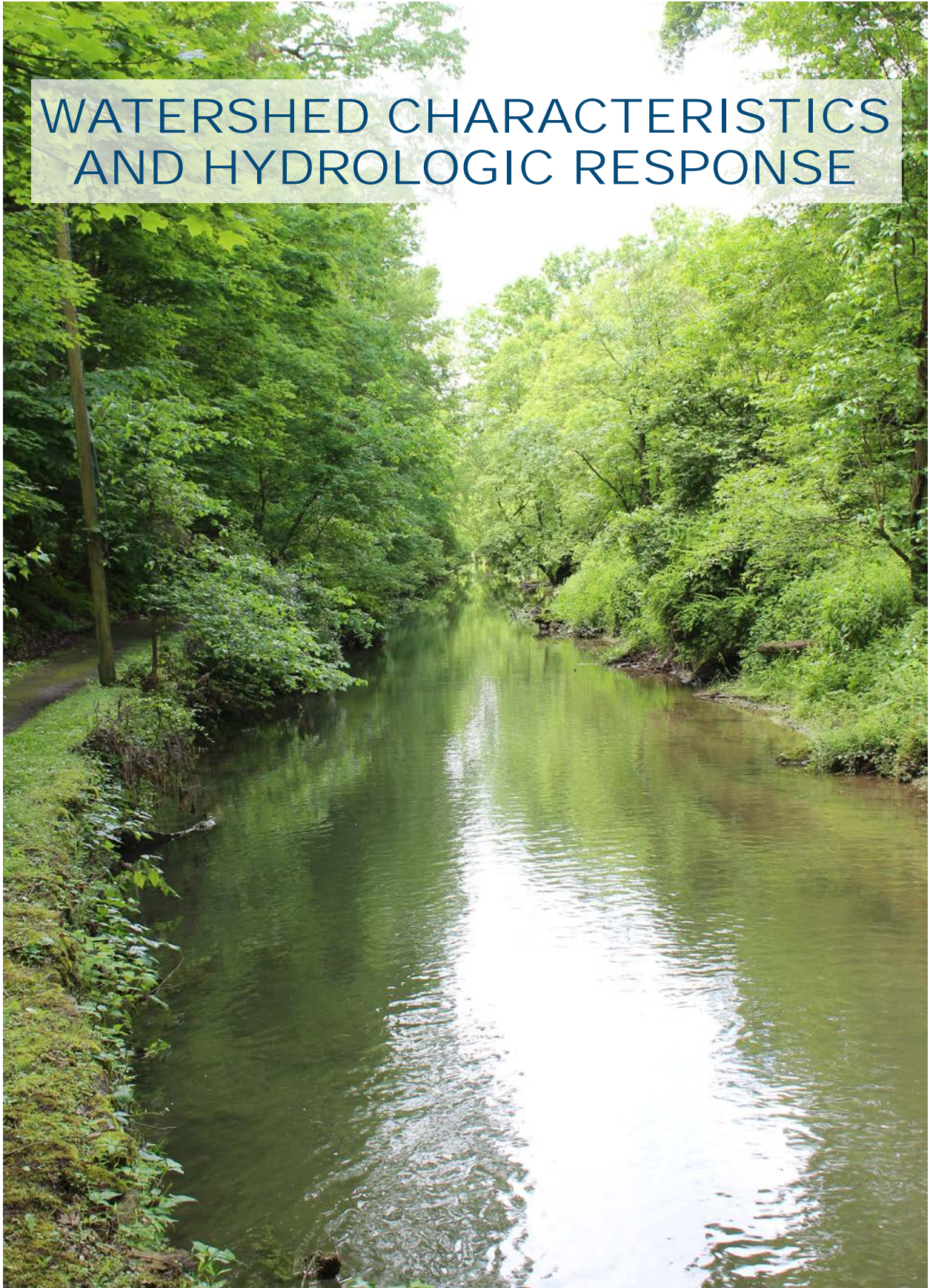
Monocacy Creek Act 167 Plan

ronmental Protection in 1989. The Model Municipal Ordinance for the Monocacy Creek was updated to include stormwater quality standards in April 2006 as part of the “*Global*” *Act 167 Plan Update*. Global refers to the 11 watersheds included in the study, including the Monocacy Creek, for which the ordinance was updating a water quantity ordinance prepared under Act 167 within the Lehigh Valley. This guarantees a dynamic system of watershed runoff control sensitive to changing watershed characteristics and regulatory context. Please refer to the original 1989 *Monocacy Creek Plan* and the “*Global*” *Plan Update* on the Lehigh Valley Planning Commission website at www.lvpc.org. These documents provide more complete descriptions of factors built into those efforts than included here. The Monocacy Creek Watershed Act 167 Stormwater Management Plan has been prepared for Lehigh and Northampton counties by the Lehigh Valley Planning Commission.

To ensure the involvement of the municipalities and agencies that will be impacted by the stormwater management plan, Act 167 requires that a Watershed Advisory Committee be formed. The purposes of the Committee are to assist in the development of the plan and familiarize the municipalities involved with the stormwater management concepts evolving from the plan process. Each municipality in the watershed and the County Conservation District are required to be represented on the Committee. Representation by additional agencies and interest groups are optional at the discretion of the county. Listed below are the names of the persons and their affiliations who participated on the Monocacy Creek Watershed Advisory Committee.

Municipality/Organization	Name
City of Allentown	Richard Rasch
Borough of Bath	Bradford Flynn
City of Bethlehem	Michael Waldron
Bethlehem Township	Gregory Duncan
Bushkill Township	Brian Harris
Borough of Chapman	Christopher Cortright
East Allen Township	James Milot
Hanover Township (L)	Al Kortze
Hanover Township (N)	Vincent Milite
Lower Nazareth Township	Lori Seese
Moore Township	David Tashner
Borough of Nazareth	Al Kortze
Upper Nazareth Township	E.J. Mentry
Federal Highway Administration – PA Division	Jonathan Crum
Lehigh County Conservation District	William McFadden
Lehigh University	Tara Troy
Northampton County Conservation District	Nathan Pritchard
Northampton County Emergency Management	Nick Tylenda
PA Department of Environmental Protection	Ronald Yablonsky
PA Department of Environmental Protection	Robert Jevin
PA Department of Transportation District 5-0	John Bohman
PA Fish & Boat Commission	Bryan Chikotas
Trout Unlimited – Monocacy Chapter	Erik Broesicke
Wildlands Conservancy	Kate Ebel

WATERSHED CHARACTERISTICS AND HYDROLOGIC RESPONSE



Monocacy Creek at Housenick Park in Bethlehem, photo by Craig Kackenmeister, LVPC

A. General Characteristics

The Monocacy Creek is a tributary of the Lehigh River, and its watershed is located predominantly within Northampton County, with a small area located in the City of Allentown, City of Bethlehem and Hanover Township, Lehigh County. The creek has a drainage area of 49.3 square miles. The watershed is comprised of the mainstem Monocacy Creek and the East Branch Monocacy Creek.

The headwaters of the creek are underlain by the Martinsburg shale formation, which consists of three distinct parts. Uppermost in the watershed, the geology is primarily banded clay slate or shale, with small amounts of sandstone. Beds of sandstone dominate the middle Martinsburg area, although some slaty beds are also present. The lowermost shale region contains the banded clay slate similar to the upper region, but with more sand and thinner beds. Below the Martinsburg shale formation in the watershed lies a vast area of predominantly limestone. Jacksonburg, Beekmantown and Allentown limestone make up approximately 90% of the geology of the lower two-thirds of the Monocacy Creek Watershed. The three limestone formations are part of the Great Valley Section of the Valley and Ridge Physiographic Province.

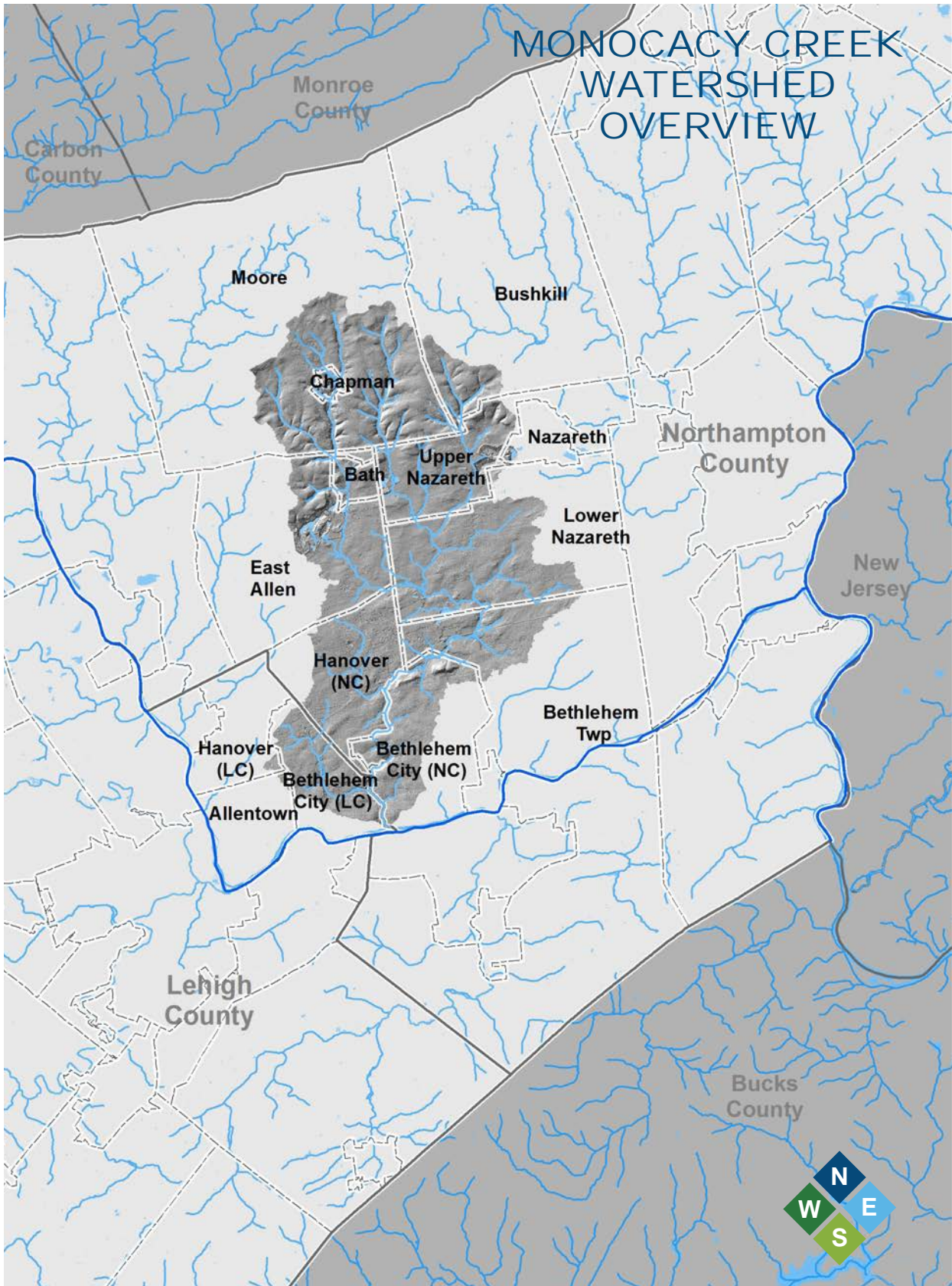


Monocacy Creek at Sand Island Park in Bethlehem,
photo by Craig Kackenmeister, LVPC

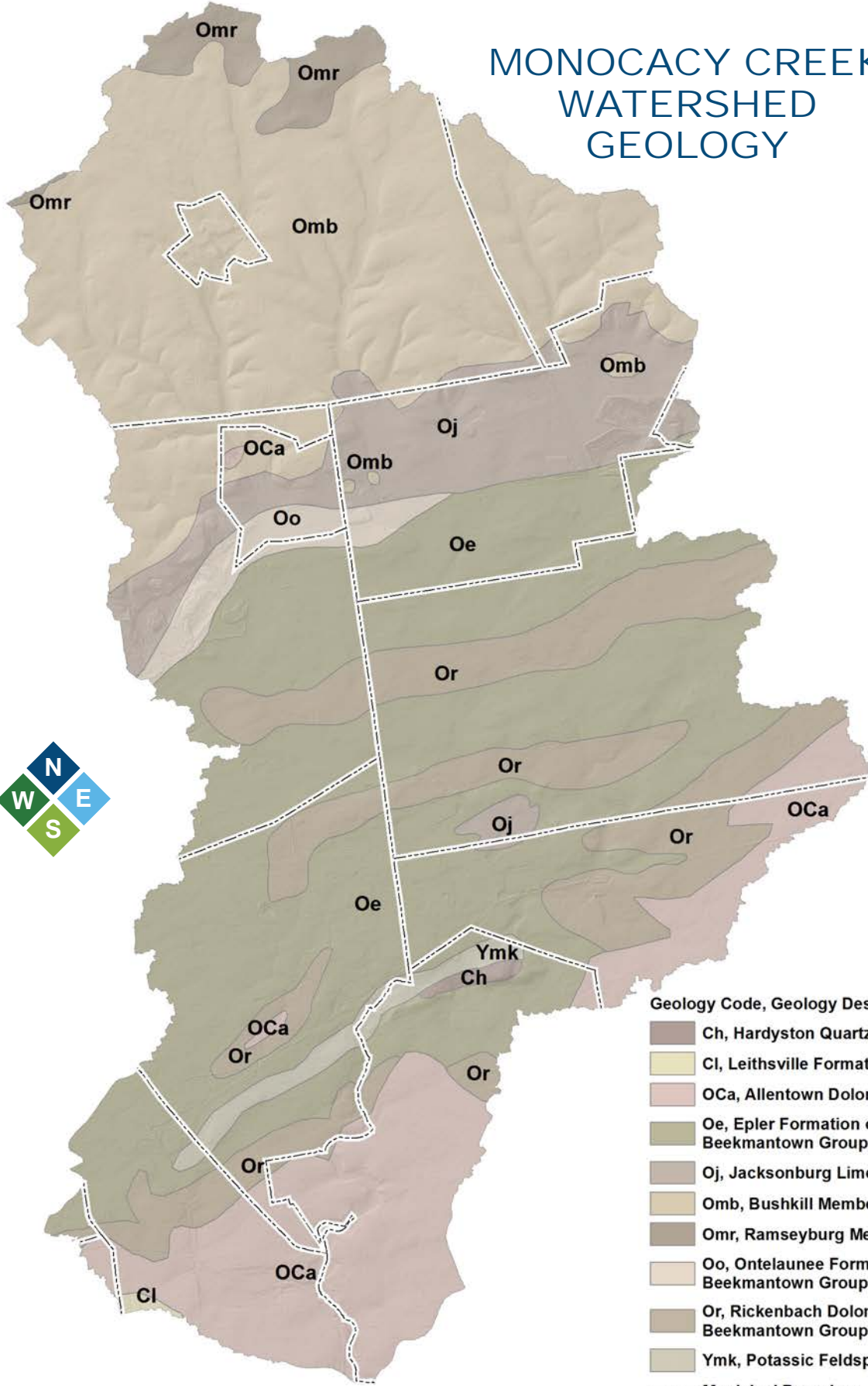
The topography of the slate areas of the watershed is characterized by low, flat-topped hills dissected by the creek, producing steep-sided valleys. There are numerous quarries throughout the slate areas, some of which are partially filled with water, creating small lakes. The topography of the limestone portion of the watershed is very flat, with gently sloping valleys. Sinkholes and closed depressions occur frequently. Limestone quarries occur within this area of the watershed. During drier months, certain stretches of the creek will disappear to groundwater only to reappear from springs further downstream. Groundwater in the limestone region flows mainly in well-defined channels formed by solution of limestone along joints. Springs emerge throughout the lower portion of the limestone region, especially at contact with non-limestone bedrock. An area of concentrated springs occurs as far upstream as Camel's Hump, a granitic outcrop near the northern boundary of the City of Bethlehem between Routes 191 and 512. The metamorphic gneiss restricts the passage of groundwater flowing from the limestone region, causing it to exit in a series of springs in the immediate vicinity of the Monocacy Creek. There are nine documented springs in the vicinity of Camel's Hump and a total of 64 springs located within the 12-mile stretch of creek between Camel's Hump and the Lehigh River. The springs are known to substantially increase the Monocacy Creek's flow, and their cooler temperature relative to surface flows in the warmer months helps to maintain the natural trout habitat.

According to the Lehigh Valley Planning Commission's *Monocacy Creek Watershed Preliminary Hydrologic Budget*, January 1998, average annual precipitation in the Monocacy Creek Watershed for the period of 1949-1996 was 44.5 inches, of which 3.04 inches (about 7%) became runoff. Evapotranspiration for the watershed has been estimated at an annual average of 27.7 inches.

The Pennsylvania Department of Environmental Protection has designated water quality criteria that are designed to protect the water uses within a given watershed. The Monocacy Creek has two water



MONOCACY CREEK WATERSHED GEOLOGY



- Geology Code, Geology Description**
- Ch, Hardyston Quartzite
 - Cl, Leithsville Formation
 - OCa, Allentown Dolomite
 - Oe, Epler Formation of the Beekmantown Group
 - Oj, Jacksonburg Limestone
 - Omb, Bushkill Member
 - Omr, Ramseyburg Member
 - Oo, Ontelaunee Formation of the Beekmantown Group
 - Or, Rickenbach Dolomite of the Beekmantown Group
 - Ymk, Potassic Feldspar Gneiss
 - Municipal Boundary

uses that are protected: cold water fishes and high quality waters. Cold Water Fishes standards help protect aquatic life by the maintenance and/or propagation of fish species and flora and fauna, which are native to cold water habitats. High Quality Waters are surface waters having a quality that exceeds levels necessary to support propagation of fish, shellfish and wildlife and recreation in and on the water by satisfying certain chemical and/or biological conditions.

The criteria state that high quality waters are to be protected and maintained at their existing quality or enhanced, unless it can be shown that any increased discharge of any pollutant is justified as a result of economic or social development that is of significant public value. The best available treatment and land disposal technologies must be used where economically feasible and environmentally sound.

The Monocacy Creek is used primarily for aesthetic and recreational purposes and is known for its excellent fishing. Segments of the Monocacy Creek are designated by the Pennsylvania Fish and Boat Commission as a Class A Wild Trout and Trophy Trout stream. Class A Wild Trout streams support a population of wild (natural population) trout of sufficient size and abundance to support a long-term and rewarding sport fishery. The Class A Wild Trout designation is on two segments of the stream: 1) Route 987 Bridge south of Chapman Borough downstream to Route 248 Bridge in Bath Borough and 2) the northern boundary of the Gertrude B. Fox County Park downstream to the stream's mouth at the Lehigh River. The Trophy Trout designation runs from the northern boundary of the Gertrude B. Fox County Park near Route 22 and Route 191 downstream to Illick's Mill Dam. In the Trophy Trout section, only artificial lures or flies may be used; no live or natural bait is allowed.

Land use within the watershed varies from predominantly urban land uses at the lower portion of the watershed (City of Bethlehem, near the mouth of the Monocacy) to more suburban/rural land uses in the northern, upstream portion of the watershed (Lower Nazareth, Upper Nazareth, East Allen, Moore and Bushkill townships). An exception to this is the Borough of Bath, located near the top of the watershed, which is predominantly urbanized, although it is relatively small. In total, the Monocacy Creek Watershed is approximately 50% urban/suburban land uses and 50% rural/agricultural land uses.

B. Hydrologic Response

Rainfall-runoff processes vary widely from one watershed to another. In predicting the impact of future development on runoff response, it is therefore important to understand the rainfall-runoff processes in the watershed of interest. In the Monocacy Creek Watershed, extensive precipitation and streamflow records permit a thorough analysis of rainfall-runoff processes and how they have changed over time.

Data Sources

Precipitation records for the Monocacy Creek Watershed are available from the National Weather Service station at the Lehigh Valley International Airport. This weather station is located less than a mile from the southwestern border of the Monocacy Creek Watershed, and has recorded hourly precipitation since May 1948. Streamflow records for the Monocacy Creek Watershed are available from the United States Geological Survey stream gage on the Monocacy Creek mainstem in Monocacy Park. This gaging station is located approximately 2.1 miles upstream from the mouth of Monocacy Creek at the Lehigh River.

For the Monocacy Creek stream gage, it is important to note that the available peak streamflow record falls into two classes: systematic and historic. The systematic record includes all of the annual peaks recorded on the Monocacy Creek since the installation of the stream gage. According to the United States Geological Survey, this record is "intended to constitute an unbiased and representative

sample of the population of all possible annual peaks at the site.”¹ For many gaging stations, the United States Geological Survey also provides information on noteworthy floods that occurred before the installation of the stream gage. This information may be acquired from newspapers, letters or other historic sources, and is referred to as the historic record. Provided that the historic record meets certain criteria, supplementing the systematic record with the historic record will provide more information on the frequency of high-magnitude peaks.

The systematic record for the Monocacy Creek begins in October 1948, when the recording gage was first installed, and continues to the present. The historic record for the Monocacy Creek consists of a large flash flood that was observed on July 10, 1945. The high-water mark left by the flood was 9.74 feet, which was determined to correspond to a peak flow of approximately 5,200 cubic feet per second.

1989 Findings

The 1989 plan for the Monocacy Creek Watershed used the systematic streamflow record available at the time to develop an understanding of rainfall-runoff processes. This record included the 38 annual peaks recorded between October 1948 and September 1986, and excluded the historic flood of 1945.

The first key finding presented in the plan was the flood frequency table. By fitting a known probability distribution to the record of annual peaks, it is possible to estimate the likelihood that the peak streamflow in any given year will exceed different flow thresholds. Engineers and planners are generally interested in a wide range of flow thresholds—from the smaller, more frequent events that have a 50% chance of exceedance in any given year to the larger, less frequent events that have a 1% chance of exceedance in any given year. Engineers and planners often use the “return period” associated with different flow thresholds as shorthand for the probability of exceedance. The return period associated with a particular flow threshold is found by dividing the probability of exceedance into the number 1 and should not be interpreted as the expected length of time between events of that size. For example, a peak flow with a 50% chance of exceedance in any given year has a return period of 2 years (or $1 \div 0.5$), while a peak flow with a 1% chance of exceedance in any given year has a return period of 100 years (or $1 \div 0.01$).

The 1989 plan used the most common probability distribution for predicting design floods, the Log Pearson Type III distribution, to generate a flood frequency table. As noted in the 1989 plan, the ability to accurately define the probability of experiencing different peaks is limited by the short periods of record available for most stream gages. This limitation is intuitive for the largest peak flows (a 38-year period of record is clearly insufficient to define the 100-year peak flow), but affects smaller peak flows as well. To illustrate the uncertainty produced by short periods of record, the 1989 plan noted the vast difference in the 100-year peaks estimated for Monocacy Creek in 1977 and 1989. While a report prepared by the Pennsylvania Department of Environmental Protection—*Water Resources Bulletin No. 13* (October 1977), which is based on 24 years of data—estimated the 100-year peak at 2,907 cubic feet per second, the 1989 plan, based on 38 years of data, estimated the 100-year peak at 4,369 cubic feet per second.

FLOOD FREQUENCY ANALYSIS — 1948-1987

Return Period (years)	Peak Flow (cubic feet per second)
2	574
5	1,133
10	1,656
25	2,529
50	3,361
100	4,369

¹ Flynn, K.M., Kirby, W.H., and Hummel, P.R., 2006, User’s Manual for Program PeakFQ Annual Flood-Frequency Analysis Using Bulletin 17B Guidelines: U.S. Geological Survey, Techniques and Methods Book 4, Chapter B4; 42 pgs.

The second key finding presented in the 1989 plan is related to the seasonality of observed peak flow events. The 1989 plan noted that the largest streamflows of record tended to occur during the winter months. In fact, 16 of the 20 largest runoff events recorded from 1948 to 1987 occurred between January 21 and March 14. The plan also noted that many of these large winter streamflows were associated with relatively small rainfall events. For example, the wintertime storm, which produced the most severe flood of record (at 3,490 cubic feet per second), was a relatively modest storm of 1.51 inches, which is smaller than the 2-year rainfall event for a 24-hour period. These observations could be explained by seasonally frozen soils. When soils are fully or partially frozen, infiltration is greatly reduced, and the volume of surface runoff increases.²

TOP 20 PEAK STREAMFLOWS FROM 1989 MONOCACY CREEK PLAN

Rank of Peak	Peak Flow (cubic feet per second)	Date of Peak	Approximate Return Period (years)
1	3,490	January 25, 1979	70
2	2,340	February 28, 1958	18
3	2,320	January 26, 1978	18
4	2,180	February 26, 1979	15
5	2,150	January 26, 1976	15
6	1,500	February 13, 1971	7
7	1,409	September 8, 1987	6
8	1,340	February 26, 1962	6
9	1,310	February 25, 1979	6
10	1,310	May 30, 1984	6
11	1,290	February 8, 1965	6
12	1,170	March 6, 1963	5
13	1,160	January 21, 1979	5
14	1,150	January 22, 1958	5
15	1,010	February 25, 1977	4
16	923	September 27, 1985	3.5
17	915	January 21, 1959	3.5
18	811	August 8, 1982	3
19	776	February 21, 1986	3
20	755	March 14, 1978	3

2017 Plan

The analysis conducted for this Plan builds upon the analysis conducted for the 1989 plan. As in the 1989 plan, a flood frequency analysis was conducted, and the top 20 recorded flood events were analyzed. Unlike the 1989 plan, however, the analysis conducted for this Plan used both the systematic and historic streamflow records. These records include both the 67 annual peaks recorded between October 1948 and September 2015, and the historic flood recorded in July of 1945. The analysis conducted for this Plan also expands upon the earlier plan to address the roles of storm magnitude and soil saturation in producing peak flows.

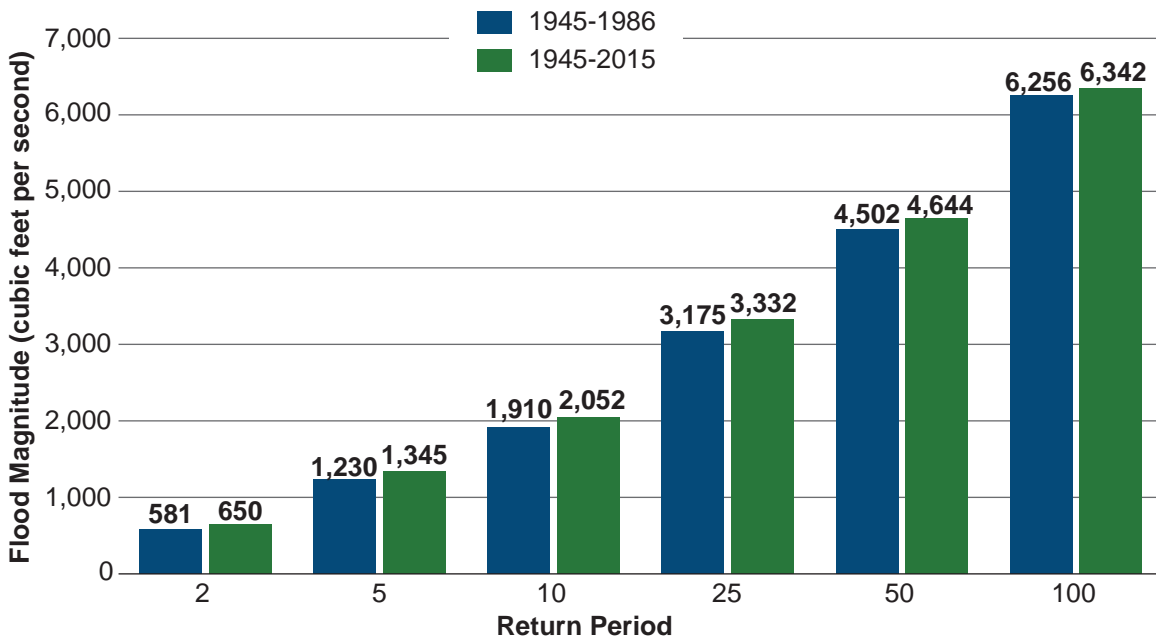
² Mastin, Mark, et. al., Forecasting Runoff in Watersheds with Seasonally Frozen Soils, Poster presentation at the 5th Symposium on the Hydrogeology of Washington State, April 12-14, 2005. Tacoma, Washington.

How Has Watershed Response Changed Since 1989?

The first goal of the updated analysis was to examine how rainfall-runoff processes in the Monocacy Creek Watershed have changed since the 1989 plan. To allow for a comparison of flood frequency tables, the 1989 flood frequency analysis was updated to include the historic flood of 1945. This flood event was estimated to have a magnitude of 5,200 cubic feet per second, exceeding the next largest event of 3,490 cubic feet per second by almost 50%. Adding this flood event to the analysis of peak flows preceding 1987 increased the peak flow estimates for all return periods, but had a particularly dramatic effect on the larger return periods. While the 2-year peak flow estimate increased only 2% (from 569 cubic feet per second to 581 cubic feet per second), the 100-year peak flow estimate increased 38% (from 4,526 cubic feet per second to 6,256 cubic feet per second).

Once the 1989 flood frequency analysis was updated, the flood frequency table calculated for the full period of record (1945-2015) could be compared to the flood frequency table calculated for the period of record preceding 1987. While the full record produced significantly higher values than the pre-1987 record for the 2-year and 5-year peaks, the full record produced only marginally higher values for the 50-year and 100-year peaks. This finding suggests that rainfall-runoff processes have changed in the 30 years since the 1989 plan, and that these changes have impacted the smaller, more frequent runoff events much more than the larger, less frequent runoff events.

Monocacy Creek Flood Frequency Analysis



The seasonality of observed peak flow events also appears to have changed since 1986. For the peak flow record through 1987, only five of the 20 largest runoff events occurred during the non-winter months. For the peak flow record from 1948 through 2015, however, nine of the 20 largest runoff events occurred during the non-winter months. The change in seasonality is even more pronounced when examining the nine peak flows recorded since 1987 that rank among the 20 largest runoff events. Of these nine peak flows, seven occurred during the non-winter months.

TOP 20 PEAK STREAMFLOWS THROUGH 2015

Rank of Peak	Peak Flow (cubic feet per second)	Date of Peak	Approximate Return Period (years)
1	5,470	September 18, 2004	68
2	5,200	July 1945	63
3	3,490	January 25, 1979	34
4	3,050	September 29, 2011	23
5	2,360	October 9, 2005	17
6	2,340	February 28, 1958	14
7	2,320	January 26, 1978	11
8	2,150	January 26, 1976	10
9	1,750	June 15, 2015	9
10	1,500	February 13, 1971	8
11	1,500	March 2, 2007	7
12	1,420	July 10, 2010	6
13	1,410	September 8, 1987	6
14	1,340	February 26, 1962	5
15	1,330	April 3, 2005	5
16	1,310	February 3, 1982	5
17	1,310	May 30, 1984	4
18	1,290	February 8, 1965	4
19	1,270	January 18, 1999	4
20	1,170	March 6, 1963	4

These observations suggest that seasonally frozen soils are playing a diminishing role in the production of annual peak flows. If so, this could reflect either a lower prevalence of seasonally frozen soils, or a higher prevalence of some other watershed condition. For example, the shift towards non-winter peak flows could reflect the increasing importance of impervious cover in generating runoff.

What are the Factors Driving Annual Peak Streamflow?

Several analyses were conducted to better understand the roles of storm intensity and soil saturation in producing peak flows. Increasing storm intensities in the design rainfall charts published by the Pennsylvania Department of Transportation in 1986 and 2007 suggest that a shifting rainfall regime could be playing a role in the observed changes in watershed response.

The depth of rainfall associated with the 2-year through 100-year return

period events increased across all durations of storm from three hours to 24 hours. Shorter durations are more meaningful for smaller watershed areas, and larger durations like 12 hours and 24 hours are more

DESIGN RAINFALL INTENSITY*

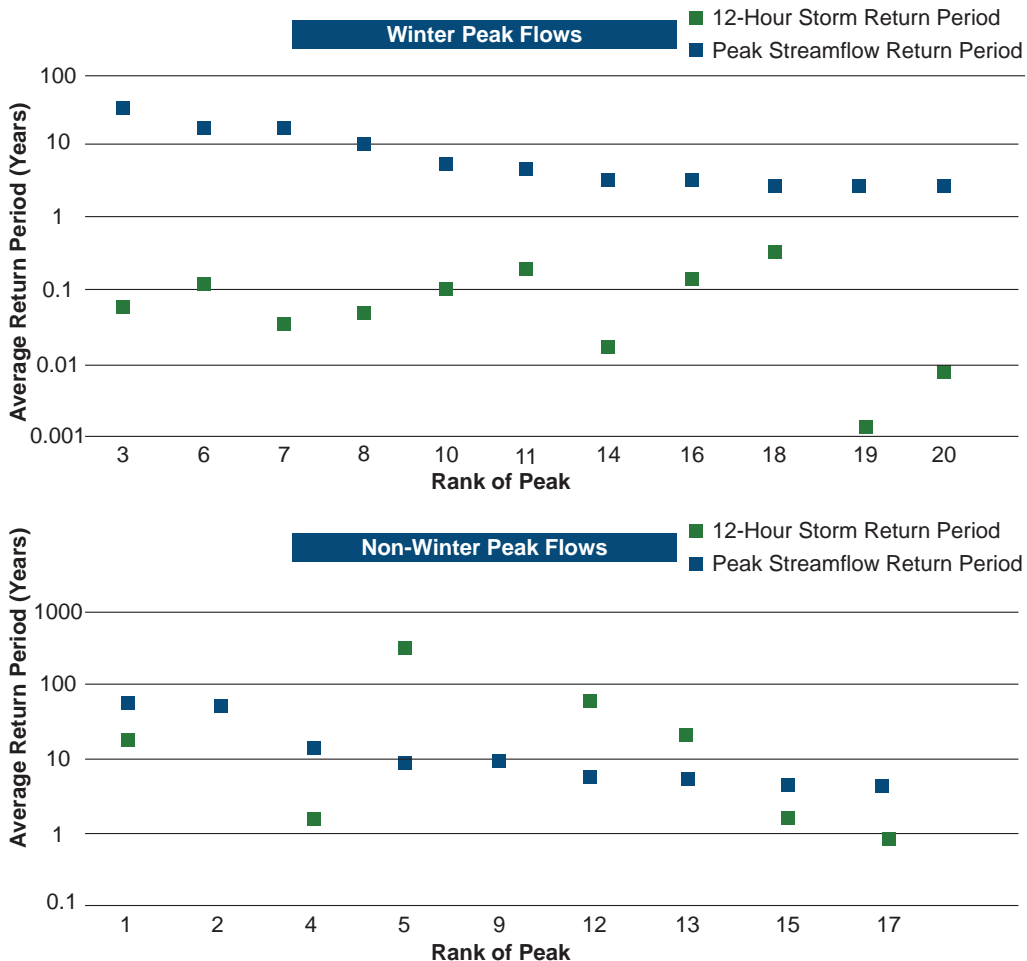
Percent Increase in Design Rainfall Intensity, 1986-2007

Return Period (years)	3 hours	6 hours	12 hours	24 hours
2	0.6%	4.9%	5.2%	5.4%
10	3.3%	2.9%	0.8%	0.2%
25	6.7%	5.6%	3.9%	1.4%
100	7.9%	3.2%	4.3%	2.6%

*Pennsylvania Department of Transportation Design Rainfall Charts, 1986 and 2007

meaningful for larger areas like the whole Monocacy Creek Watershed. For more moderate rainfall events (i.e. the 2-year storm), the Pennsylvania Department of Transportation design rainfall charts suggest that storm intensity increased the most at longer durations. For more severe rainfall events (i.e. the 10-year through 100-year storms), the reverse was observed. The Pennsylvania Department of Transportation design rainfall charts suggest that storm intensity for the 10-year through 100-year storms increased the most at shorter durations. It is important to note, however, that the 1986 and 2007 estimates were derived from very different datasets. While the 2007 estimates reflect data from 278 sites and includes records from 1863-2000, the 1986 estimates are based on data from 153 sites and includes records from 1948-1983.

In discussing the 20 largest floods of record, the 1989 plan noted that the magnitude of peak streamflow events often did not reflect the magnitude of the associated storm event. For example, a severe rainfall event of 7.85 inches in late September 1985 produced a relatively small peak flow of 923 cubic feet per second, while a small rainfall event of 1.51 inches in late January 1979 produced a relatively large peak flow of 3,490 cubic feet per second. To examine the relationship between the magnitude of the annual peak flows and the magnitude of the corresponding storms, the precipitation that produced each of the 20 largest floods of record was analyzed. As suggested in the 1989 plan, the watershed was observed to behave very differently in the winter and non-winter months. For the peak flows that occurred in the winter months, the magnitude of runoff events was more severe across-the-board than the magnitude of the corresponding rainfall events. Once again, this observation could be explained by seasonally frozen soils that amplify the wintertime runoff response. For the peak flows that occurred in the non-winter months, in contrast, the watershed response was more variable. Some runoff events were more severe than the corresponding rainfall event, while others were less severe. The assumption that a rainfall event of a given return period would produce a runoff event of the same return period could, on average, be accurate for non-winter peaks.



One final analysis was conducted to examine the source of the variability in non-winter peak runoff response. For those non-winter peaks that ranked among the 20 largest floods of record, a metric that approximates the baseflow (the mean daily discharge four days prior to the peak flow) was added to the analysis. Baseflow is sustained largely by groundwater flows into the stream channel and is generally correlated with watershed soil saturation. The higher the baseflow, the wetter watershed soils are likely to be, and the less rainfall is likely to soak into the ground. Of the seven non-winter peaks analyzed, three had runoff return periods that were significantly larger than the corresponding rainfall return periods. In each of these cases, the baseflow level was elevated above the annual average. This finding suggests that wet soil conditions and large storm events are both involved in producing high peak flows in the non-winter months.

The prerequisite to the development of a runoff control strategy is the preparation of a hydrologic model that accurately simulates the recorded runoff response of the watershed to given rainfall conditions. The hydrologic model selected for the Monocacy Creek Plan is the U.S. Corps of Engineers' Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS).

The software uses the runoff curve number methodology for runoff generation. Streamflow events of significance have been documented above. Rainfall data associated with each event is available from records kept by the National Weather Service. The National Weather Service recording rain gage at the Lehigh Valley International Airport provides hourly rainfall data and documents the distribution of rain

CALIBRATED HYDROLOGIC ENGINEERING CENTER HYDROLOGIC MODELING SYSTEM MODEL VERSUS MONOCACY CREEK GAGING STATION DATA AT MONOCACY PARK GAGE

Return Period	Peak Flow (cubic feet per second)		
	Gage Data	Model Data	Deviation
2	650	732	12.5%
10	2,052	2,238	9.0%
25	3,332	3,584	7.6%
100	6,342	6,913	9.0%

throughout the storm in addition to the total rainfall depth. Rainfall data for various historical events can be input into the hydrologic model, and the calculated runoff event can be compared to the actual runoff recorded at the stream gage. To the extent that the calculated runoff differs from the recorded runoff, certain model parameters can be adjusted to better simulate the recorded streamflow. The process of model adjustment to match historical data is called calibration. Successful calibration would produce a hydrologic model that adequately simulates recorded streamflow for a broad range of rainfall events.

Calibration of the hydrologic model for historical events is typically problematic due to variations in rainfall throughout the watershed that a single rain gage cannot replicate (see discussion in 1989 *Monocacy Creek Plan*). For this reason, the model for this Plan is calibrated using a design storm methodology. Specifically, the rainfall depth associated with a storm that would be expected to occur once every two years, on average, can be determined by statistical analysis of rainfall data. Likewise, storm depths associated with return periods of 10-, 25- and 100-years can be determined. Calibration of the model can proceed on the assumption that the 2-year rainfall depth should produce approximately the 2-year streamflow. The hydrologic model was run for each of the 2-, 10-, 25- and 100-year storms, and systematic adjustments to the model input were made to best approximate desired flow values. Adjustments made to the model included runoff curve number, overland flow length and slope given the limestone geology, out-of-bank flow velocity and input of flow "losses", representing the process of streamflow being diverted to groundwater through solution channels in the limestone.

Calibration of the runoff model is important for ensuring that the assumptions used in the physical data preparation and those inherent to the model itself do not preclude a reasonable representation of the actual runoff response of the watershed. It would not be reasonable to assume, however, that simply by calibration of the model that the flow rate at any point in the watershed could be defined accurately. Calibration of the model only deals with the runoff at the gaging station location. A calibrated model is simply a verification that the process used to develop the model is valid and that flows generated throughout the watershed can be used with an increased level of confidence.



Monocacy Creek Stream Gage at Monocacy Park, photo by Craig Kackenmeister, LVPC

MONOCACY CREEK WATERSHED LAND DEVELOPMENT AND RUNOFF IMPACTS



Monocacy Creek at Christian Spring Road, photo by Craig Kackenmeister, LVPC

A. General Land Development Impacts on Storm Runoff

Development of land will, in general, cause a higher percentage of a given rainfall to become runoff. The primary reason for this is the increase in the amount of impervious cover on the land surface (e.g., roofs, driveways, parking areas, roads, etc.). Impervious cover does not allow rainfall to infiltrate into the ground, such that most rainfall becomes runoff. The exception to this would be where impervious cover drains onto pervious areas, which would provide for some infiltration. Impervious coverage for the watershed is measured using a Geographic Information System Land Cover dataset prepared for the Delaware River Watershed by the University of Vermont. Land cover provides a snapshot of what actually exists on the land. This land cover dataset was originally prepared using 2013 imagery and Light Detection and Ranging data, also known as LiDAR data, but was updated to reflect 2015 imagery for the Monocacy Creek Watershed. The categories were also updated to reflect the needs of the stormwater model.

Land Cover	Percent Imperviousness
Agriculture	0
Impervious	100
Other Pervious	0
Quarry	0
Water	0
Woods	0

The development of land that is currently in woods, agriculture or other pervious land cover could have a significant impact on the percent of impervious cover. The cumulative runoff impact of this type of development for a large watershed like the Monocacy Creek could be severe without implementation of the proper runoff management controls.

A series of curves, or hydrographs, present the typical runoff response of the watershed area versus time for percent imperviousness ranging from 5% to 25%. The watershed area used for the analysis represents an average size subarea as used in the Monocacy Creek runoff modeling process (i.e. 300 acres). The rainfall event used to produce the hydrographs was a two-hour storm of 1.3 inch depth.

The amount of impervious cover is not the only factor affecting the amount of runoff produced by a given land area. Certain land cover produces more runoff than others for the same rainfall. The Natural Resources Conservation Service has researched the runoff response of various types of land cover and translated the results into a parameter called the runoff curve number. Simply described, the runoff curve number system is a ranking of the relative ability of various land cover types to produce runoff. Higher curve numbers reflect a greater potential for producing runoff.

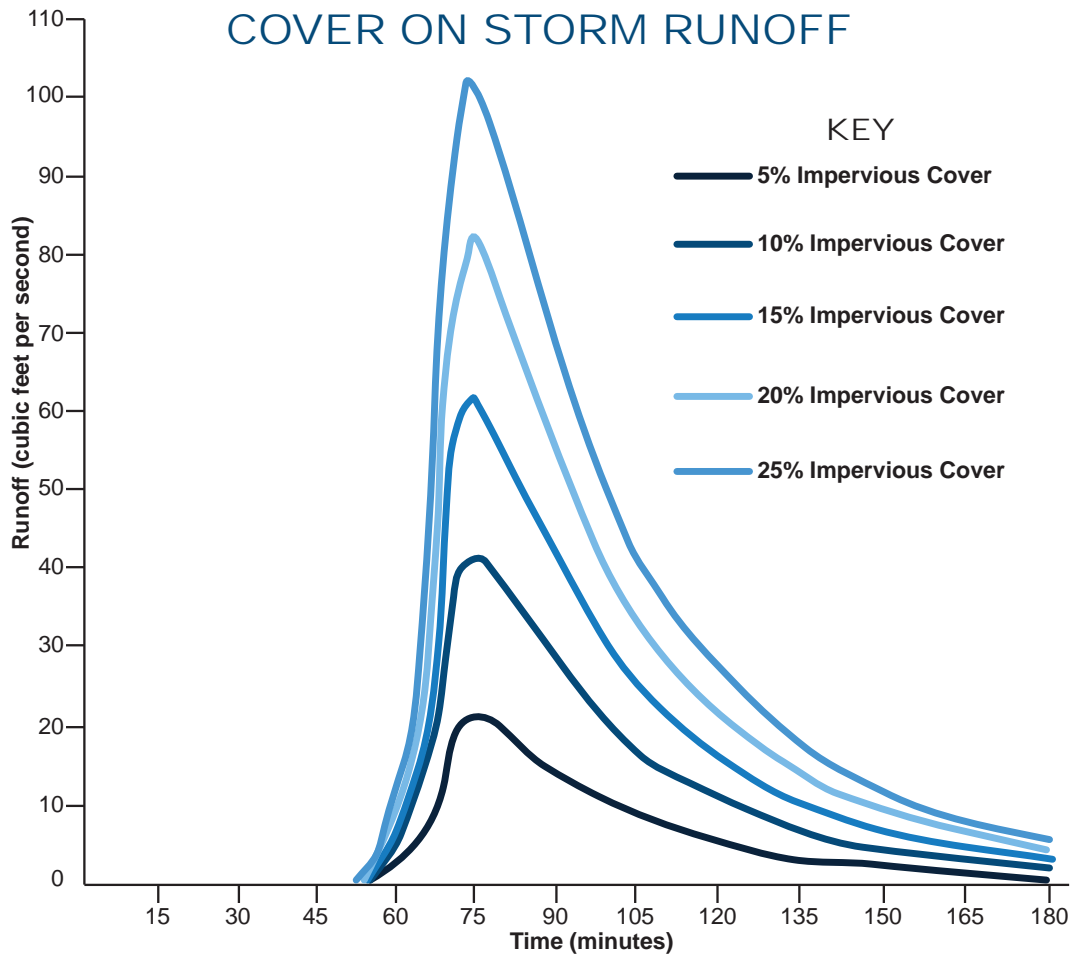
RUNOFF CURVE NUMBER BY LAND COVER CATEGORY*

Land Cover	Runoff Curve Number
Woods	55
Agriculture	72
Lawn	61
Meadow	58
Impervious	98

*Data is for Hydrologic Soil Group B.

One final factor affecting the impact of development on storm runoff is difficult to quantify but is perhaps very important in the Monocacy Creek Watershed. The carbonate bedrock underlying approximately 65% of the watershed has the characteristic of developing solution channels in the bedrock, which can be manifested on the land surface as closed depressions and sinkholes. In the “existing” condition, the closed depressions and sinkholes can prevent a significant amount of runoff from entering the stream channel. Closed depressions simply create ponds of water, and sinkholes divert surface runoff to the groundwater regime. The alteration of these depressions and sinkholes with de-

IMPACT OF IMPERVIOUS COVER ON STORM RUNOFF



development of land can increase the storm runoff received by the stream beyond that anticipated using the curve number and percent impervious methodology.

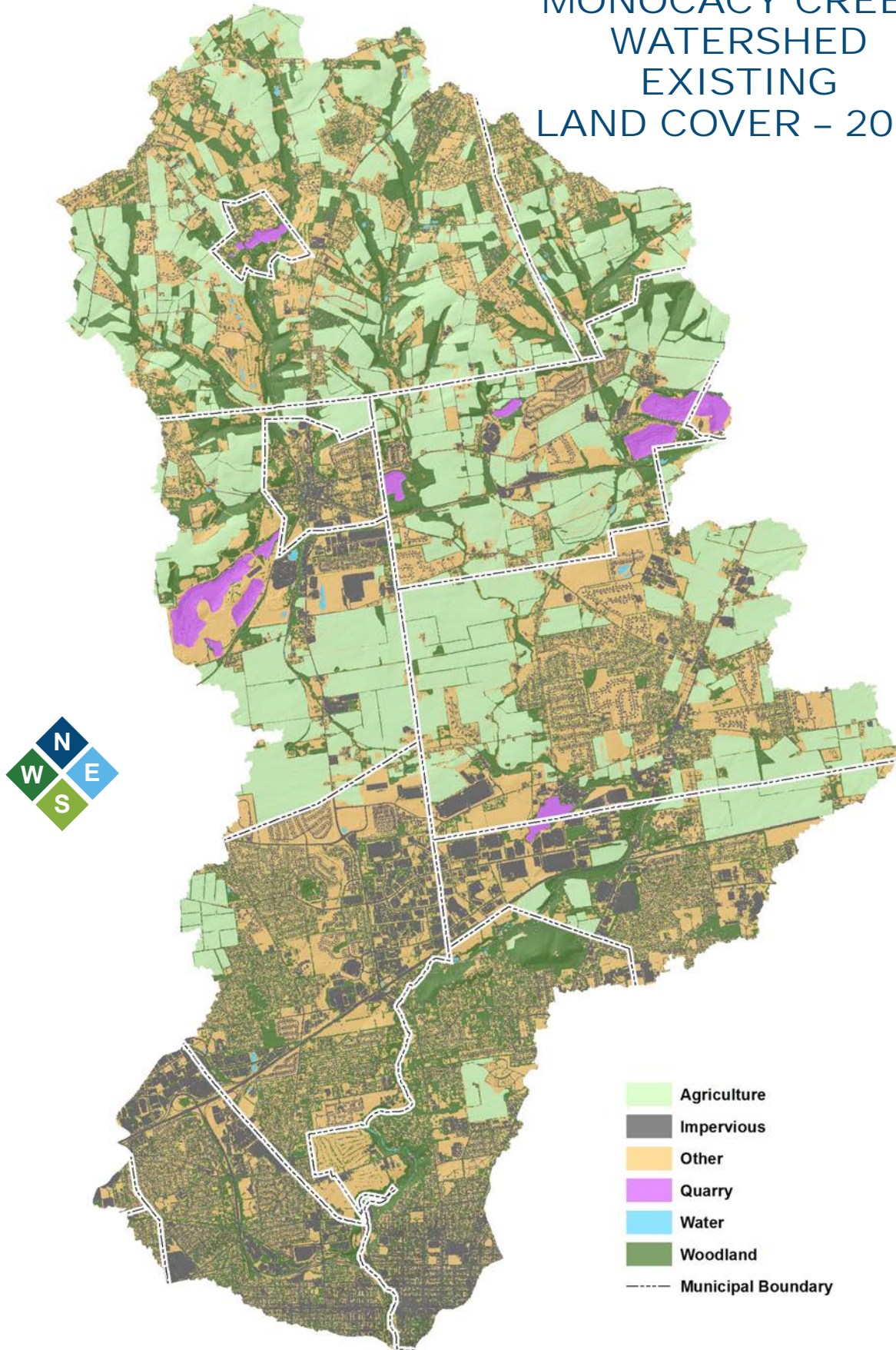
B. Historical Monocacy Creek Watershed Development

Like much of the Lehigh Valley, development within the Monocacy Creek Watershed during the 2000s could be described as a concentration of urban-type development in and around the City of Bethlehem and more suburban development progressing north through the watershed.

Existing land use has been tracked by the Lehigh Valley Planning Commission using a Geographic Information System since 2002. This data indicates that the Monocacy Creek Watershed has experienced the development of previously undeveloped areas. Overall, developed land uses have increased over 5.3% since 2002. This increase in developed uses is roughly split between residential (2.4%) and non-residential (2.9%) uses. Undeveloped areas of the Monocacy Creek Watershed decreased by 9.2%. While a larger portion of this decrease is accounted for by development, there was an increase of just over 5% in the parks, recreation and open space land use category. This indicates that while these municipalities are losing land to development they are simultaneously preserving lands for parks, recreation and open space.

Development in place in 2015 represents the “existing” situation insofar as the preparation of the Plan is concerned. Stormwater runoff calculated based on the existing land cover condition defines the goal of the Plan Update, i.e. no increase in existing peak flows throughout the watershed. The “stress” applied to the system is the increase in impervious cover in the watershed associated with new land

MONOCACY CREEK WATERSHED EXISTING LAND COVER - 2015



development. Quantification of the stress requires an assumption of a future land use/land cover condition throughout the watershed. Future land use/land cover condition assumptions used in the development of the Plan are discussed in the following section.

C. Future Monocacy Creek Watershed Development

Projection of a future land cover condition for the purpose of determining the runoff impacts of new development is an essential part of the Plan preparation process. Only through an understanding of the increase in both volume of runoff and peak rate of runoff associated with development of the watershed can a sound control strategy be devised.

The future land cover scenario evaluated is based on the assumption that development would occur throughout the watershed based upon current zoning. Municipal zoning districts throughout the Monocacy Creek Watershed can be categorized as industrial, commercial, agricultural or residential at various densities. For the purpose of evaluation of the future zoned condition land use, a composite zoning map of the watershed was prepared. Each of the zoning districts was placed into one of the following categories.

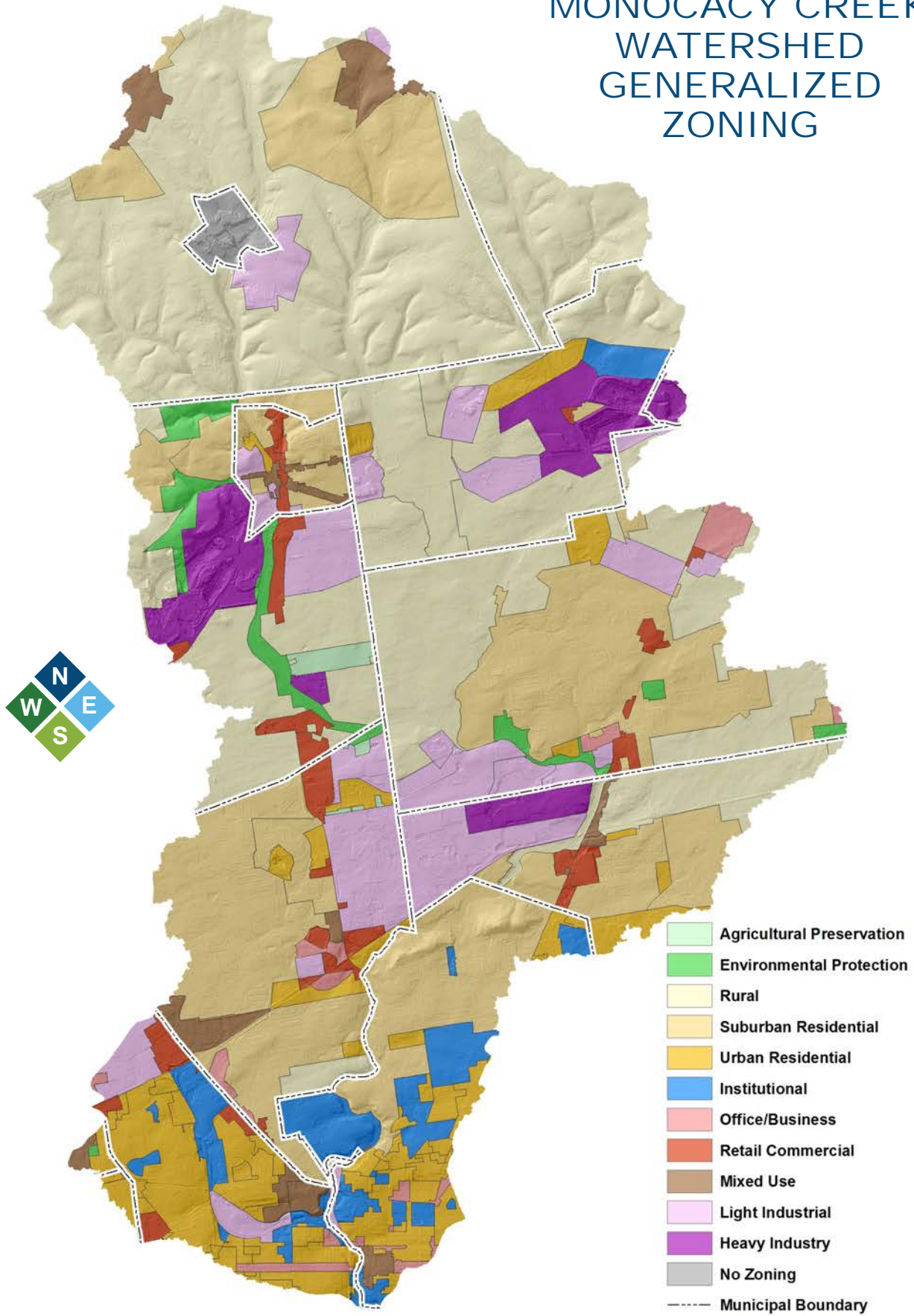
- Agricultural preservation
- Environmental protection
- Industrial
- Institutional
- Mixed use
- Office/business
- Commercial
- Rural residential
- Suburban residential
- Urban residential

The composite zoning map for undeveloped areas of the watershed was color-coded to reflect the categorization. Land cover for existing developed areas under each zoning category were calculated. The future impervious coverage and pervious curve number needed by the hydrologic model were calculated using the zoning category and data from the existing developed area analysis.

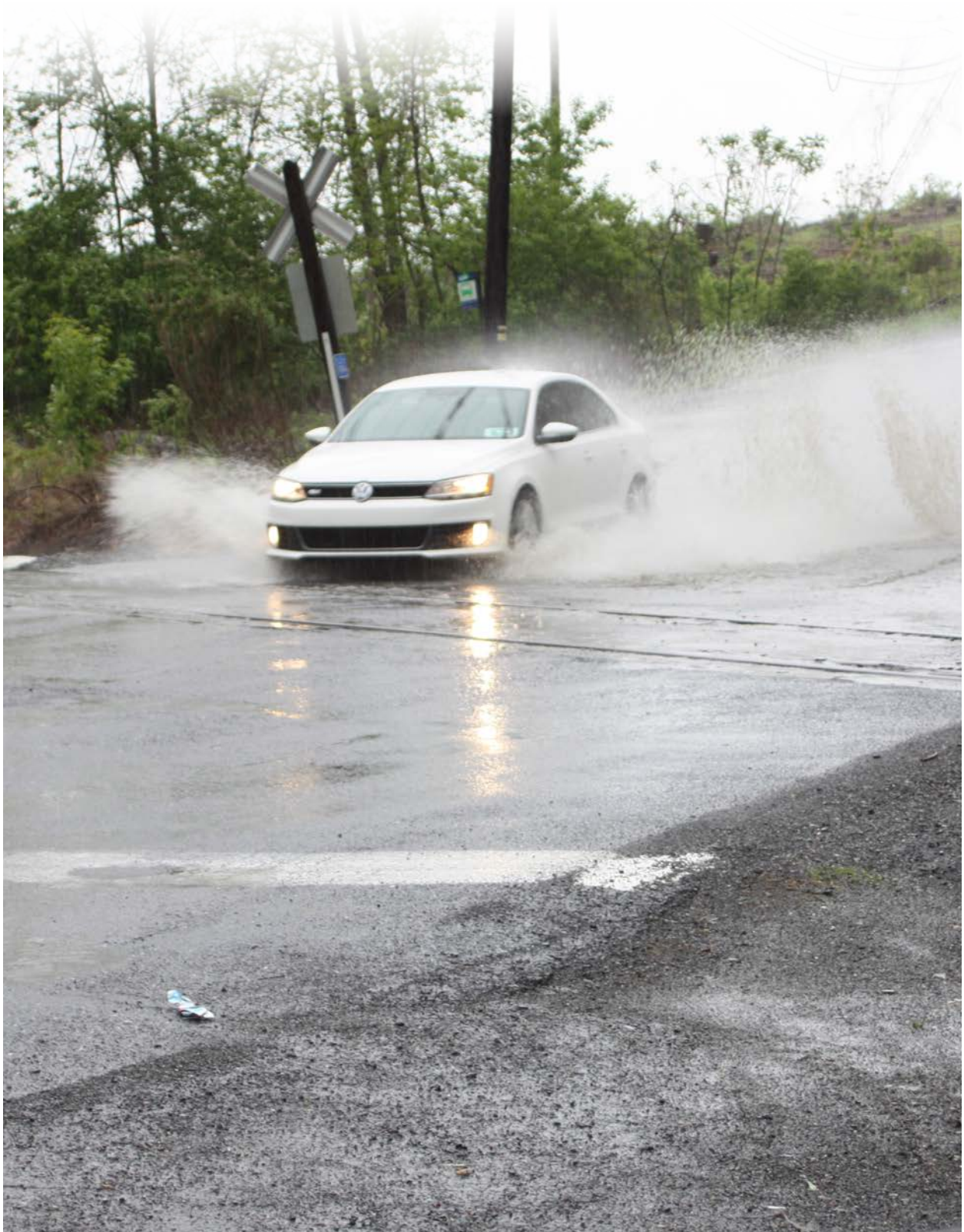


Parking lot off Northampton Street in Borough of Bath, photo by Craig Kackenmeister, LVPC

MONOCACY CREEK WATERSHED GENERALIZED ZONING



FLOODPLAIN INFORMATION



Railroad crossing on Brodhead Road near Route 191, photo by Craig Kackenmeister, LVPC

A. Floodplain Delineation

The Federal Emergency Management Agency has prepared County Flood Insurance Studies and floodplain mapping for both Lehigh and Northampton counties that include all the municipalities in the Monocacy Creek Watershed. However, not all of the municipalities have delineated 100-year floodplains within the watershed. Of the 13 municipalities located within the watershed, all but three have stream segments with delineated 100-year floodplains. The three municipalities that do not have delineated floodplains are the City of Allentown and Hanover Township in Lehigh County and Nazareth Borough in Northampton County. For the remaining ten municipalities, stream segments with delineated 100-year floodplains have been determined by either detailed methods or approximate methods. The floodplains for stream segments determined by detailed methods include documented flow values at selected floodplain cross-sections, flood profiles along the stream length and base flood elevations. Detailed hydraulic analyses were not performed for the 100-year floodplains determined by approximate methods, therefore, no base flood elevations or depths are shown for those areas.

The Lehigh County Flood Study is available at both the Lehigh Valley Planning Commission office, City of Allentown and Hanover Township, Lehigh County. The effective date for the study and floodplain mapping is July 16, 2004. The Northampton County Flood Study is available at the Federal Emergency Management Agency Map Center website. The effective date for the study and floodplain mapping is July 16, 2014. The City of Bethlehem is located in both Lehigh and Northampton counties but is included in its entirety in the Northampton County Flood Insurance Study and floodplain mapping.

The Federal Emergency Management Agency's Community Rating System uses a system of credits whereby communities that exceed the minimum requirements of the National Flood Insurance Program secure reductions in the flood insurance premiums for their residents. Regulating development through a stormwater management plan that has been approved by a state agency, such as an Act 167 Plan, qualifies for additional credits. Erosion and sediment control regulations can also qualify for additional credits. Communities that require new developments to include in their design of stormwater management facilities appropriate Best Management Practices that will improve surface water quality can qualify for additional credits as well.



Monocacy Creek in Historic Bethlehem, photo by Craig Kackenmeister, LVPC

B. Existing and Future Floodplain Development

The land uses within the floodplain consist primarily of agriculture, open space and low-density residential development, along with various park and outdoor recreation properties:

Archibald Johnson Conservation Area	Lower Nazareth Township Park
Bath Borough Tot Lot	Monocacy Complex
Bethlehem Golf Club	Monocacy Creek Park
Burnside Plantation	Monocacy Meadows
Creekside Park	Monocacy Nature Center
D & L Trail	Monocacy Park and Illick's Mill
F-3 Fishing Club	Monocacy Way
Georgetown Road Park	Moravian College Athletic Fields
Gertrude B. Fox County Park	Moravian Colonial Industrial Quarter
Hahn's Meadow Park	Silvercrest Meadows Open Space
Hanover Township Trail	Southmoore Golf Course
Janet Johnston Housenick & William D Housenick Memorial Park	Surry Glen Park
Johnston Park	Volunteer Firefighters Park
Lower Nazareth Rod and Gun Club	Whitetail Golf Club

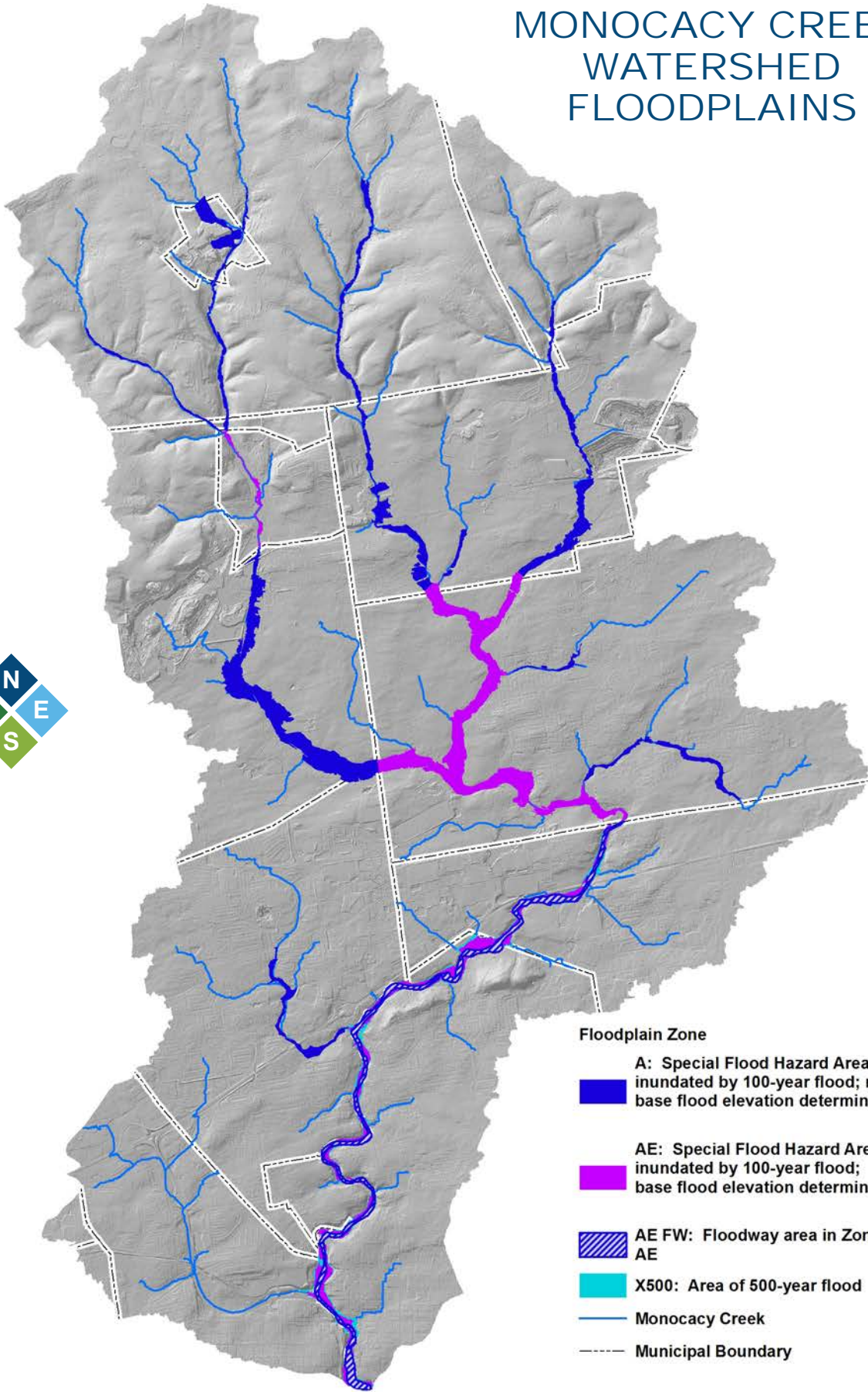
The above notwithstanding, there also currently exists many instances of development within the 100-year floodplain in the Monocacy Creek Watershed. In the upper reaches of the watershed, which is relatively rural, floodplain development takes the form of scattered residences and encroachments associated with road crossings. In the downstream urban areas, the natural floodplain has, in many instances, been completely modified by development activities, resulting in higher flood damage potential and lesser flood carrying capacity.

Development within the watershed currently takes place under rules established by Pennsylvania Act 166 of 1978, the Floodplain Management Act. Act 166 requires municipalities to adopt ordinances to regulate the type and extent of development within floodplain areas. All of the municipalities in the watershed have enacted ordinances consistent with Act 166. With enforcement of those ordinances, any future floodplain development will be limited to that which would not significantly alter the carrying capacity of the floodplain or be subject to a high damage potential.

For the purposes of the Monocacy Creek Stormwater Management Plan, the damage potential of existing and future floodplain development will be minimized using the following philosophy:

- Damage potential of existing floodplain development will remain unchanged for storm events representing the 2-year through 100-year return period events through implementation of the stormwater management criteria included in the Stormwater Management Plan.
- Damage potential for future floodplain development will be minimized by only permitting specific types of development that are damage resistant consistent with the Floodplain Management Act, as implemented through municipal floodplain regulations and the Pennsylvania Department of Environmental Protection's Chapter 105 Dam Safety and Waterway Management Regulations and Chapter 106 Floodplain Management Regulations.
- Damage potential of existing and future floodplain development may be reduced with implementation of remedial measures for areas subject to inundation. The effectiveness and design life of any remedial measures would be enhanced by implementation of the Stormwater Management Plan for the Monocacy Creek Watershed.

MONOCACY CREEK WATERSHED FLOODPLAINS



Floodplain Zone

- A:** Special Flood Hazard Area inundated by 100-year flood; no base flood elevation determined.
- AE:** Special Flood Hazard Area inundated by 100-year flood; base flood elevation determined.
- AE FW:** Floodway area in Zone AE
- X500:** Area of 500-year flood
- Monocacy Creek
- - - Municipal Boundary

EXISTING STORM DRAINAGE PROBLEM AREAS AND SIGNIFICANT OBSTRUCTIONS



Historic Bethlehem, photo by Craig Kackenmeister, LVPC

A. Existing Storm Drainage Problem Areas

An important goal of Act 167 is to prevent any existing storm drainage problem areas from getting worse. The first step toward that goal is to identify the existing problem areas. Each municipality in the Monocacy Creek Watershed was provided with an opportunity to document the existing drainage problems within its borders. The starting point for the drainage problem inventory was the original *Monocacy Creek Watershed Act 167 Stormwater Management Plan*, March 1989, which documented 38 problems throughout the watershed. Each municipality had an opportunity to provide an updated status on whether the problems remained or had been corrected and provide information on additional problem areas. This process resulted in the documentation of 35 existing drainage problems in the watershed. Since the 1989 plan, 11 problems were resolved, eight new problems have been identified and 27 of the 38 original problems remain. The type of problem identified was typically street and/or property flooding. Bushkill Township identified one problem area, however, the problem involved aging gabion baskets, not street or property flooding. Moore Township identified three problem areas, however, only two involved street flooding. The remaining problem involved stream bank erosion. Only the problems involving street or property related flooding were included in the inventory.

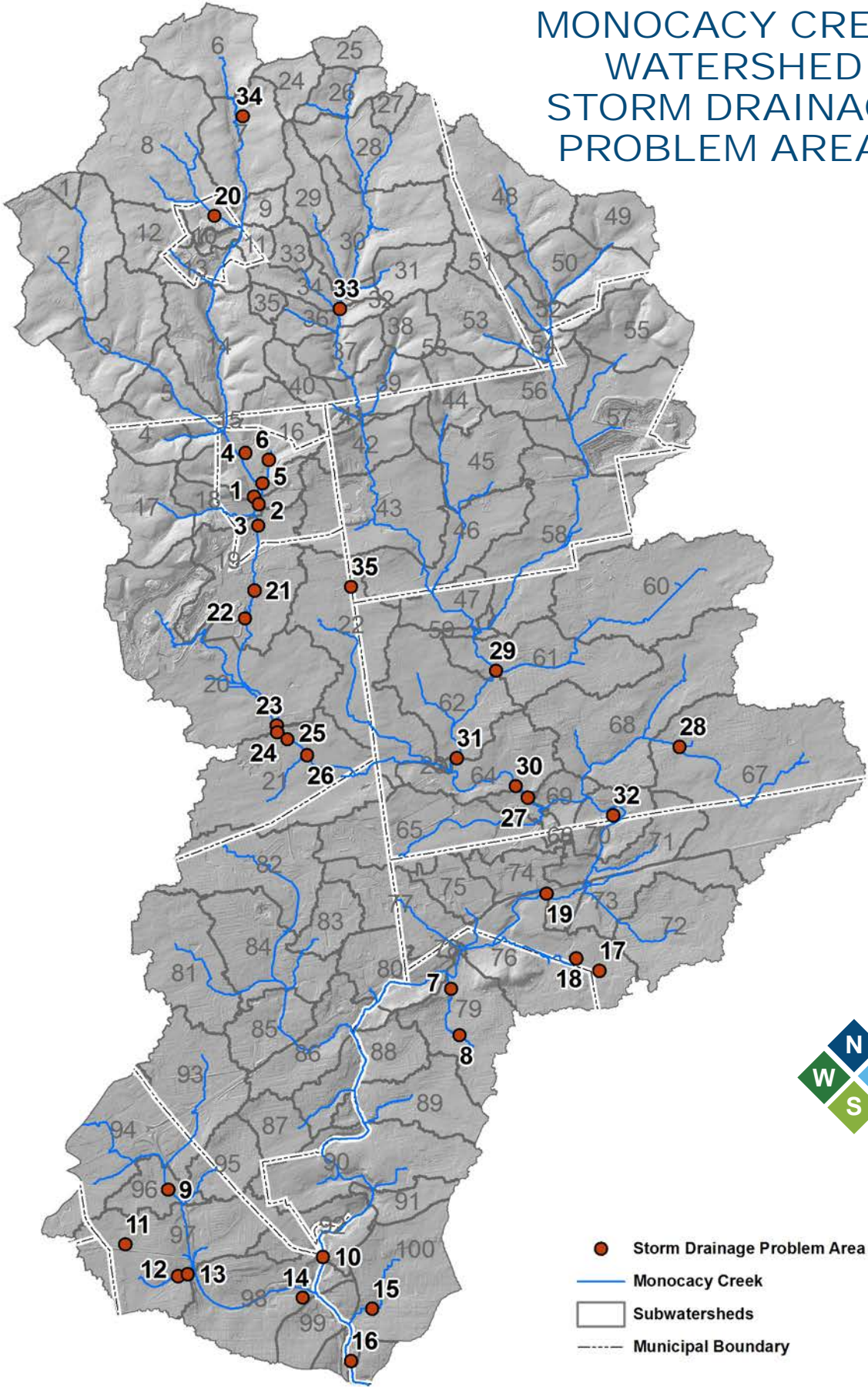
For modeling purposes, the subarea and reach numbers (if applicable) were identified for each of the problem areas. A subarea is the finest unit of breakdown of the watershed for which runoff values have been calculated. A reach is the swale, channel or stream segment that drains a particular subarea. Note that 21 of the drainage problems are on identified reaches, indicating that peak runoff values are readily available from the modeling process for those problem areas.

Generalized proposed solutions to the identified storm drainage problem areas have been provided by municipal representatives. Proposed solutions include specific proposals based upon municipal studies of the problem areas, where available, and solutions that are readily apparent to the municipal representatives for the less complicated problem areas. Some of the solutions provided involve work already completed, but the municipality is uncertain if the problems have been resolved. For certain other problem areas, the solutions are not quite so apparent and may require detailed engineering



151 North Chestnut Street in Bath, photo by Craig Kackenmeister, LVPC

MONOCACY CREEK WATERSHED STORM DRAINAGE PROBLEM AREAS



Storm Drainage Problem Areas

1. Northampton St. Bridge (#117)

Municipality: Borough of Bath
Problem: Street and Property Flooding
Subarea: 16
Reach Number: 15
Proposed Solution: Creek dredging/restoration

2. Main Street

Municipality: Borough of Bath
Problem: Street and Property Flooding
Subarea: 18
Reach Number: 16
Proposed Solution: Creek dredging/restoration

3. Mill Street

Municipality: Borough of Bath
Problem: Street and Property Flooding
Subarea: 19
Reach Number: 18
Proposed Solution: Creek dredging/restoration

4. Creek Road at North Chestnut Street

Municipality: Borough of Bath
Problem: Street and Property Flooding
Subarea: 16
Reach Number: 15
Proposed Solution: Completed creek restoration/water pipe replacement (fall 2016)

5. 151 N. Chestnut Street

Municipality: Borough of Bath
Problem: Street and Property Flooding
Subarea: 16
Reach Number: N/A
Proposed Solution: Attempting underground pipe repairs (spring 2017)

6. 100 Block on Sleepy Hollow Road

Municipality: Borough of Bath
Problem: Street and Property Flooding
Subarea: 16
Reach Number: N/A
Proposed Solution: Replace existing drain tile from 12" to 36" or greater

7. Pine Top Trail/Fox Drive/Bierys Bridge Road

Municipality: City of Bethlehem
Problem: Property Flooding
Subarea: 79
Reach Number: N/A
Proposed Solution: Improve channel capacity

8. Johnston Drive

Municipality: City of Bethlehem
Problem: Street Flooding
Subarea: 79
Reach Number: N/A
Proposed Solution: None proposed

9. Valley Park South Apartments

Municipality: City of Bethlehem
Problem: Property Flooding
Subarea: 96
Reach Number: 94
Proposed Solution: Additional detention upstream

10. Schoenersville Road

Municipality: City of Bethlehem
Problem: Street Flooding
Subarea: 98
Reach Number: 92
Proposed Solution: None proposed

11. Pinehurst Road

Municipality: City of Bethlehem
Problem: Street and Property Flooding
Subarea: 97
Reach Number: N/A
Proposed Solution: Detention facility

12. Homestead Avenue

Municipality: City of Bethlehem
Problem: Street and Rear Yard Flooding
Subarea: 97
Reach Number: N/A
Proposed Solution: None proposed

13. Highland and Eaton Avenues

Municipality: City of Bethlehem
Problem: Street and Property Flooding
Subarea: 97
Reach Number: N/A
Proposed Solution: None proposed

14. 5th Avenue at Route 378

Municipality: City of Bethlehem
Problem: Property Flooding
Subarea: 98
Reach Number: N/A
Proposed Solution: Diversion of runoff to Route 378

15. Goepp Street

Municipality: City of Bethlehem
Problem: Street Flooding
Subarea: 100
Reach Number: N/A
Proposed Solution: Additional inlets and relief pipe system

16. Historical Bethlehem Tannery Building

Municipality: City of Bethlehem
Problem: Property Flooding
Subarea: 100
Reach Number: 99
Proposed Solution: None proposed

Storm Drainage Problem Areas

17. Oakland Road

Municipality: Bethlehem Township

Problem: Street Flooding

Subarea: 76

Reach Number: N/A

Proposed Solution: None proposed

18. Nijaro Road and Fornace Road

Municipality: Bethlehem Township

Problem: Street flooding

Subarea: 76

Reach Number: N/A

Proposed Solution: None proposed

19. Christian Spring Road

Municipality: Bethlehem Township

Problem: Street Flooding

Subarea: 74

Reach Number: 73

Proposed Solution: None proposed

20. Yost Road and 5th Street

Municipality: Borough of Chapman

Problem: Street and Property Flooding

Subarea: 8

Reach Number: N/A

Proposed Solution: None proposed

21. Railroad Bridge

Municipality: East Allen Township

Problem: Property Flooding

Subarea: 19

Reach Number: 18

Proposed Solution: None proposed

22. Private Road

Municipality: East Allen Township

Problem: Street Flooding

Subarea: 19

Reach Number: 18

Proposed Solution: None proposed

23. Railroad Bridge

Municipality: East Allen Township

Problem: Property Flooding

Subarea: 20

Reach Number: 19

Proposed Solution: None proposed

24. Route 512

Municipality: East Allen Township

Problem: Street Flooding

Subarea: 20, 21

Reach Number: 20

Proposed Solution: None proposed

25. Railroad Bridge

Municipality: East Allen Township

Problem: Property Flooding

Subarea: 21

Reach Number: 20

Proposed Solution: None proposed

26. Railroad Bridge

Municipality: East Allen Township

Problem: Property Flooding

Subarea: 21

Reach Number: 20

Proposed Solution: None proposed

27. Hanoverville Road

Municipality: Lower Nazareth Township

Problem: Street Flooding

Subarea: 66

Reach Number: 64

Proposed Solution: None proposed

28. Hecktown Road

Municipality: Lower Nazareth Township

Problem: Street Flooding

Subarea: 67

Reach Number: N/A

Proposed Solution: Culvert installation

29. Georgetown Road at Ash Drive

Municipality: Lower Nazareth Township

Problem: Street Flooding

Subarea: 61

Reach Number: 60

Proposed Solution: None proposed

30. Georgetown Road

Municipality: Lower Nazareth Township

Problem: Street Flooding

Subarea: 64

Reach Number: 63

Proposed Solution: Bridge replacement on Georgetown Road in progress

31. Steuben Road

Municipality: Lower Nazareth Township

Problem: Street Flooding

Subarea: 62, 64

Reach Number: 61

Proposed Solution: Both bridges replaced in 2016

32. PA Route 191

Municipality: Lower Nazareth Township

Problem: Property Flooding

Subarea: 70

Reach Number: 69

Proposed Solution: Bridges along Route 191 replaced several years ago

33. Keeler Road

Municipality: Moore Township

Problem: Localized Flooding

Subarea: 36

Reach Number: 34

Proposed Solution: Install new pipe. Permit received

Storm Drainage Problem Areas

34. Trach Road at South Summit Road

Municipality: Moore Township

Problem: Street Flooding

Subarea: 7

Reach Number: 6

Proposed Solution: Rebuild Trach Road, install storm pipe crossing on South Summit Road

35. Township Line Road at White Fence Lane

Municipality: Upper Nazareth Township

Problem: Street Flooding

Subarea: 22

Reach Number: N/A

Proposed Solution: Minor regrading/clean-up, continued monitoring and maintenance



Monocacy Creek at Sand Island Park, photo by Craig Kackenmeister, LVPC



Monocacy Creek at Housenick Park, photo by Craig Kackenmeister, LVPC

evaluations to determine the most cost-effective solution. Therefore, no solutions to these problem areas have been provided by the municipality.

B. Significant Obstructions

An obstruction in a watercourse can be defined, borrowing from Chapter 105 of the State's Rules and Regulations, as follows:

"A dike, bridge, culvert, wall, wingwall, fill, pier, wharf, embankment, abutment or other structure located in, along or across or projecting into any...channel or conveyance of surface water having defined bed and banks, whether natural or artificial, with perennial or intermittent flow."

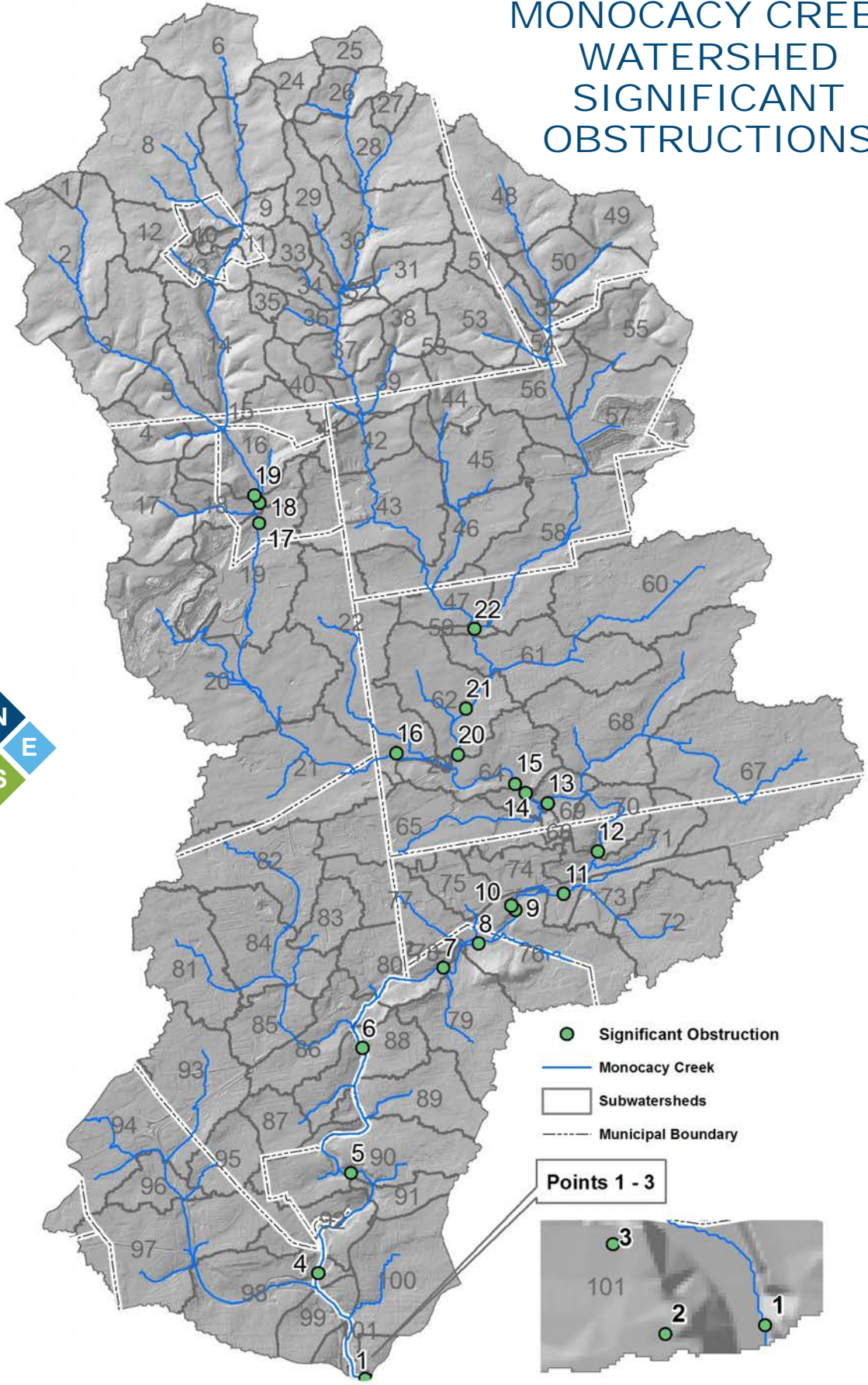
For the purpose of Act 167, it is necessary to narrow the definition to include only those obstructions that are "significant" on a watershed basis. For the Monocacy Creek Stormwater Management Plan, the following distinction will be used:

An obstruction in a stream or channel shall be deemed "significant" if it has been documented to create a flooding or backwater condition of approximately one foot or more for the 10-year to 100-year return period event as identified in the County Flood Insurance Studies.

Using the above definition, 22 significant obstructions have been identified within the Monocacy Creek Watershed. Obstruction capacities are estimated from the Flood Insurance Studies and expressed as the return period event or events that best describe the free flow of runoff. For example, if the obstruction can pass the 10-year return period event without causing a one-foot rise in elevation, the capacity is expressed as greater than the 10-year return period and less than the 50-year return period event. For those stream segments with only a 100-year flow determined, the capacity is either expressed as approximately a 100-year return period or less than a 100-year return period.

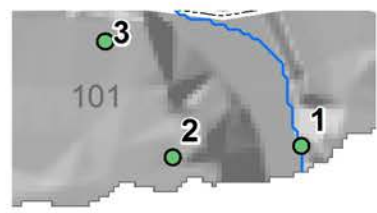
There are six identified significant obstructions that coincide with documented storm drainage problem areas. The importance of the identified significant obstructions and problem areas as part of the development of a runoff control strategy is discussed in the Watershed-Level Runoff Control Philosophy and Performance Standards chapter.

MONOCACY CREEK WATERSHED SIGNIFICANT OBSTRUCTIONS



- Significant Obstruction
- Monocacy Creek
- Subwatersheds
- Municipal Boundary

Points 1 - 3



Significant Obstruction Inventory from Flood Insurance Studies

MAIN BRANCH MONOCACY CREEK			
Number	Obstruction	Municipality	Capacity by Return Period
1	Abandoned Lehigh Canal	City of Bethlehem	>10-year, <50-year
2	Railroad	City of Bethlehem	>10-year, <50-year
3	West Lehigh Street	City of Bethlehem	>10-year, <50-year
4	Railroad	City of Bethlehem	~100-year*
5	Dam	City of Bethlehem	<10-year
6	Dam	City of Bethlehem	<10-year
7	Railroad	City of Bethlehem	>10-year, <50-year
8	Railroad	City of Bethlehem	>10-year, <50-year
9	Railroad Crossing No. 2	Bethlehem Township	<10-year
10	Private Bridge	Bethlehem Township	<10-year
11	Railroad Crossing No. 1	Bethlehem Township	>10-year, <50-year
12	Brodhead Road	Bethlehem Township	>10-year, <50-year
13	Railroad	Lower Nazareth Township	<100-year*
14	Railroad: Coincides with Problem Area No. 27	Lower Nazareth Township	<100-year*
15	Georgetown Road: Coincides with Problem Area No. 30	Lower Nazareth Township	<100-year*
16	Access Road/Culvert	Lower Nazareth Township	<100-year*
17	Mill Street: Coincides with Problem Area No. 3	Borough of Bath	<100-year*
18	East Main St. (Rt. 248): Coincides with Problem Area No. 2	Borough of Bath	<100-year*
19	Northampton St. (Rt. 248): Coincides with Problem Area No. 1	Borough of Bath	<100-year*
EAST BRANCH MONOCACY CREEK			
Number	Obstruction	Municipality	Capacity by Return Period
20	Steuben Road: Coincides with Problem Area 31	Lower Nazareth Township	~100-year*
21	Access Road	Lower Nazareth Township	~100-year*
22	Access Road/Culvert	Lower Nazareth Township	<100-year*

* Stream segments with only a 100-year flow determined
Key: < less than; > greater than; ~ approximately



Historic Bethlehem, photo by Craig Kackenmeister, LVPC

STORM RUNOFF CONTROL TECHNIQUES



Rock-lined swale near intersection of Brodhead Road and Christian Spring Road,
photo by Craig Kackenmeister, LVPC

The Monocacy Creek Watershed Land Development and Runoff Impacts chapter identified the impacts of land development on stormwater runoff and documented the need to control those impacts with sound stormwater management techniques. The Watershed-Level Runoff Control Philosophy and Performance Standards chapter presents the performance standards for runoff control for new development applicable to the various watershed areas necessary to achieve sound runoff management from a watershed perspective. Therefore, the Land Development and Runoff Impacts chapter defines the problem and the Runoff Control Philosophy and Performance Standards chapter identifies the necessary end product. This chapter will identify the runoff control techniques available as the “means” to the desired end product to mitigate the runoff impacts of new development.

The runoff control techniques presented include “structural” and “non-structural” stormwater management controls. Structural means that they are physical facilities for runoff abatement. Non-structural controls refer to land use management techniques geared toward minimizing storm runoff impacts through control of the type and extent of new development throughout the watershed. The Monocacy Creek Stormwater Management Plan is based on the assumption that new development of various types will occur throughout the watershed (except as regulated by floodplain regulations) and that both structural and non-structural controls will be required to minimize the runoff implications of the new development. Both structural and non-structural techniques can be termed Best Management Practices for stormwater management.

The runoff control technique data has been summarized from the *Pennsylvania Stormwater Best Management Practices Manual*. For more complete descriptions of the runoff control techniques and updated information as available, please refer to the latest edition of the *Pennsylvania Stormwater Best Management Practices Manual*.

A. Non-Structural Practices

Protect sensitive and special value features: To minimize stormwater impacts, land development should avoid impacting and encroaching upon areas with important natural stormwater functional values (floodplains, wetlands, riparian areas, drainage ways, etc.) and with stormwater impact sensitivities (steep slopes, threatened or endangered species habitat, adjoining properties, etc.). Development should occur in areas where these sensitive/special value resources do not exist so that their valuable functions are not lost.

Protect/consERVE/enhance riparian areas: Riparian areas are vegetated ecosystems along a waterbody that serve to buffer the waterbody from the effects of runoff by providing water quality filtering, recharge, rate attenuation and volume reduction, and shading of the waterbody by vegetation. Riparian areas also provide habitat and may include streambanks, wetlands, floodplains and transitional areas. This practice focuses on protection, maintenance and enhancement of existing riparian forest buffers.

Protect/utilize natural flow pathways in overall stormwater planning and design: Most natural sites have identifiable features such as swales, depressions, watercourses, ephemeral streams, etc., which serve to effectively manage any stormwater generated on the site. By identifying, protecting and utilizing these features, a development can minimize its stormwater impacts. These features can be used to reduce or eliminate the need for structural drainage systems.

Cluster uses at each site; build on the smallest area possible: Clustering requires natural features on a site to be set aside as permanently protected open space, while development is concentrated on the remainder of the site. Clustering development significantly reduces the amount of impervious cover that would be required for a conventional development while allowing the environmental features on the site to perform their natural functions.

Concentrate uses area-wide through smart growth practices: Growth is directed to areas or groups of parcels in the municipality that are most desirable and away from areas or groups of parcels that are not. These smart growth techniques include transfer of development rights, effective agricultural zoning, urban growth boundaries, purchase of development rights, and conservation easements, among others.

Minimize total disturbed area – grading: Reduction of site disturbance by grading can be accomplished in several ways. The requirements of grading for roadway alignment and roadway slope frequently increase site disturbance throughout a land development site and on individual lots. Far less grading and a far less disruptive site design can be accomplished if the site design better conforms to the existing topography and land surface. For individual lots, conventional lot layout geometry can also impose added earthwork and grading that could be avoided.

Minimize soil compaction in disturbed areas: Healthy soils that have not been compacted perform numerous stormwater functions, including minimizing runoff and erosion, and maximizing water-holding capacity, among others. Once compacted, these functions are diminished and can never be completely restored. This practice is intended to prevent compaction or minimize the degree and extent of compaction in areas that are to be pervious following development.

Revegetate and reforest disturbed areas using native species: This practice emphasizes the selection and use of vegetation that does not require significant chemical maintenance by fertilizers, herbicides and pesticides. Native species have the greatest tolerance and resistance to pests and require far less fertilization and chemical application than non-native species.

Reduce street imperviousness: Streets can comprise the largest single component of imperviousness in residential design. Imperviousness greatly influences stormwater runoff volume and quality by facilitating the rapid transport of stormwater and collecting pollutants from atmospheric deposition, vehicle leaks, etc. Increased imperviousness alters an area's hydrology, habitat structure and water quality. Pavement can be minimized by using alternative roadway layouts, restricting on-street parking, minimizing cul-de-sac radii and using permeable pavers.

Reduce parking imperviousness: In commercial and industrial areas, parking lots may comprise the largest percentage of impervious area. Parking lot size is dictated by lot layout, stall geometry and parking ratios. Modifying all or any of these three aspects can serve to minimize the total impervious areas associated with parking lots.

Rooftop disconnection: Building codes have historically encouraged the rapid conveyance of rooftop runoff away from building structures, specifying minimum slopes that serve to accelerate overland flow onto and across lawns, directed more rapidly toward streets and gutters. Disconnecting roof leaders from conventional stormwater conveyance systems allows rooftop runoff to be collected and managed on-site. Rooftop runoff can be directed to designed vegetated areas for on-site storage, treatment and volume control. Runoff may also be directed to non-vegetated practices, such as dry wells, rain barrels and cisterns for stormwater retention and volume reduction.

Disconnection from storm sewers: Roads and driveways account for a large percentage of post-development imperviousness. Conventional stormwater management has involved the rapid removal and conveyance of stormwater from these surfaces. Roads and driveways contribute toxic chemicals, oil and metals to stormwater runoff. A variety of alternatives exist for redirecting road and driveway runoff away from stormwater collection systems. In addition to vegetated swales, infiltration trenches or bioretention areas may be utilized. Curbing may be eliminated entirely or selectively eliminated.

Street sweeping: Larger debris material and smaller particulate pollutants are removed by street sweeping equipment, preventing this material from clogging the stormwater management system and washing into receiving waterways/waterbodies.

B. Structural Practices

Pervious pavement with infiltration bed: Pervious pavement consists of a permeable surface course underlain by a uniformly-graded stone bed that provides temporary storage for peak rate control and promotes infiltration. Pervious pavement is well suited for parking lots, walking paths, sidewalks, playgrounds, plazas, tennis courts and other similar uses.

Infiltration basin: An infiltration basin is a shallow impoundment that temporarily stores and infiltrates runoff over a level, uncompacted (preferably undisturbed) area with relatively permeable soils. The basin should avoid disturbance of existing vegetation, which promotes evapotranspiration.

Subsurface infiltration bed: A subsurface infiltration bed provides temporary storage and infiltration of stormwater runoff by placing storage media of varying types beneath the proposed surface grade.

Infiltration trench: An infiltration trench consists of a continuously perforated pipe in a stone-filled trench designed so that storm events are conveyed through the pipe with some runoff volume reduction.

Rain garden/bioretention: A rain garden is an excavated shallow surface depression planted with specially selected native vegetation to treat and capture runoff. Rain garden vegetation serves to filter and transpire runoff, and the root systems can enhance infiltration. Properly designed rain garden/bioretention techniques mimic natural forest ecosystems through species diversity, density and distribution of vegetation and the use of native species, resulting in a system that is resistant to insects, disease, pollution and climatic stresses.

Dry well/seepage pit: A dry well is a subsurface storage facility that temporarily stores and infiltrates stormwater runoff from the roofs of structures and discharge the stored runoff via infiltration into the surrounding soils. By capturing runoff at the source, drywells can reduce the increased volume of stormwater generated by the roofs of structures.

Constructed filter: Filters are structures or excavated areas containing a layer of sand, compost, organic material, peat or other filter media that reduces pollutant levels in stormwater runoff by filtering sediments, metals, hydrocarbons and other pollutants.

Vegetated swale: Vegetated swales are broad, shallow channels designed to slow runoff, promote infiltration, and filter pollutants and sediments in the process of conveying runoff. Vegetated swales provide an environmentally superior alternative to conventional curb and gutter conveyance systems. Swales are heavily vegetated with a dense and diverse selection of native, close-growing, water resistant plants with high pollutant removal potential.

Vegetated filter strip: Filter strips are gently sloping, densely vegetated areas that filter, slow and infiltrate sheet flowing stormwater. Filter strips are best utilized to treat runoff from roads and highways, roof downspouts, small parking lots and pervious surfaces.

Infiltration berm and retentive grading: Infiltration berms are linear landscape features located parallel to existing site contours in a moderately sloping area. They can be described as built-up earthen embankments with sloping sides, which function to retain runoff, promote infiltration and slow down or divert stormwater flows. They create shallow depressions that collect and temporarily store stormwater runoff, allowing it to infiltrate into the ground and recharge groundwater.

Vegetated roof: Extensive vegetated roof covers are usually six inches or less in depth and completely cover a conventional flat or pitched roof, providing the roof with hydrologic characteristics that more closely match surface vegetation. They are typically intended to achieve a specific environmental benefit, such as rainfall runoff mitigation.

Runoff capture and reuse: Capture and reuse encompasses a wide variety of water storage techniques (including rain barrels and cisterns) designed to capture precipitation from rooftops or other impervious areas, hold it for a period of time, and reuse the water. Spray irrigation is a form of capture/reuse.

Constructed wetland: Constructed wetlands are shallow marsh systems planted with emergent vegetation that are designed to treat stormwater runoff. While they are one of the best practices for pollutant removal, they can also mitigate peak rates and even reduce runoff volume to a certain degree.

They use a relatively large amount of space and require an adequate source of inflow to maintain the permanent water surface.

Wet pond/retention basin: Wet ponds are stormwater basins that include a permanent pool for water quality treatment and additional capacity above the permanent pool for temporary storage. They do not achieve significant groundwater recharge or volume reduction but can be effective for pollutant removal and peak rate mitigation.

Dry extended detention basin: A dry extended basin is an earthen structure constructed either by impoundment of a natural depression or excavation of existing soil that provides temporary storage of runoff to prevent downstream flooding impacts. The primary purpose of the basin is to reduce stormwater runoff peaks.

Water quality filters and hydrodynamic structures: A broad spectrum of practices have been designed to remove non-point source pollutants from runoff as part of the runoff conveyance system. These structural practices vary in size and function, but all utilize some form of settling and filtration to remove particulate pollutants from stormwater runoff.

Riparian buffer restoration: A riparian buffer is a permanent area of trees and shrubs located adjacent to streams, lakes, ponds and wetlands that provide a number of benefits, including stormwater management functions. Riparian forests are the most beneficial type of buffer for the ecological and water quality benefits they provide. Restoration of this ecologically sensitive habitat is a responsive action to past activities that may have eliminated any vegetation.

Landscape restoration: Landscape restoration is the general term used for sustainable landscaping practices that are implemented outside of riparian buffer areas. The landscape plays a vital role in mitigating the volume and rate of stormwater runoff. The practices include restoration of forest and/or meadow and the conversion of turf to meadow. Landscape restoration involves the careful selection and use of vegetation that does not require significant chemical maintenance by fertilizers, herbicides and pesticides.

Soil amendment and restoration: Animals, farm equipment, trucks, construction equipment, cars and people cause soil compaction. Soil amendment and restoration is the process of restoring disturbed soils by restoring soil porosity and/or adding a soil amendment, such as compost, for the purpose of reestablishing the soil's long term capacity for infiltration and pollution removal.

Floodplain restoration: Floodplain restoration tries to mimic the interaction of groundwater, stream baseflow and root systems. It is an effective tool to meet water quality and quantity requirements, prevent riparian problems from getting worse, and fix current problems caused by historical practices. A restored floodplain and stream may greatly enhance infiltration and storage of surface flow in the floodplain, which reduces flood flow stages, volumes and peak discharges.

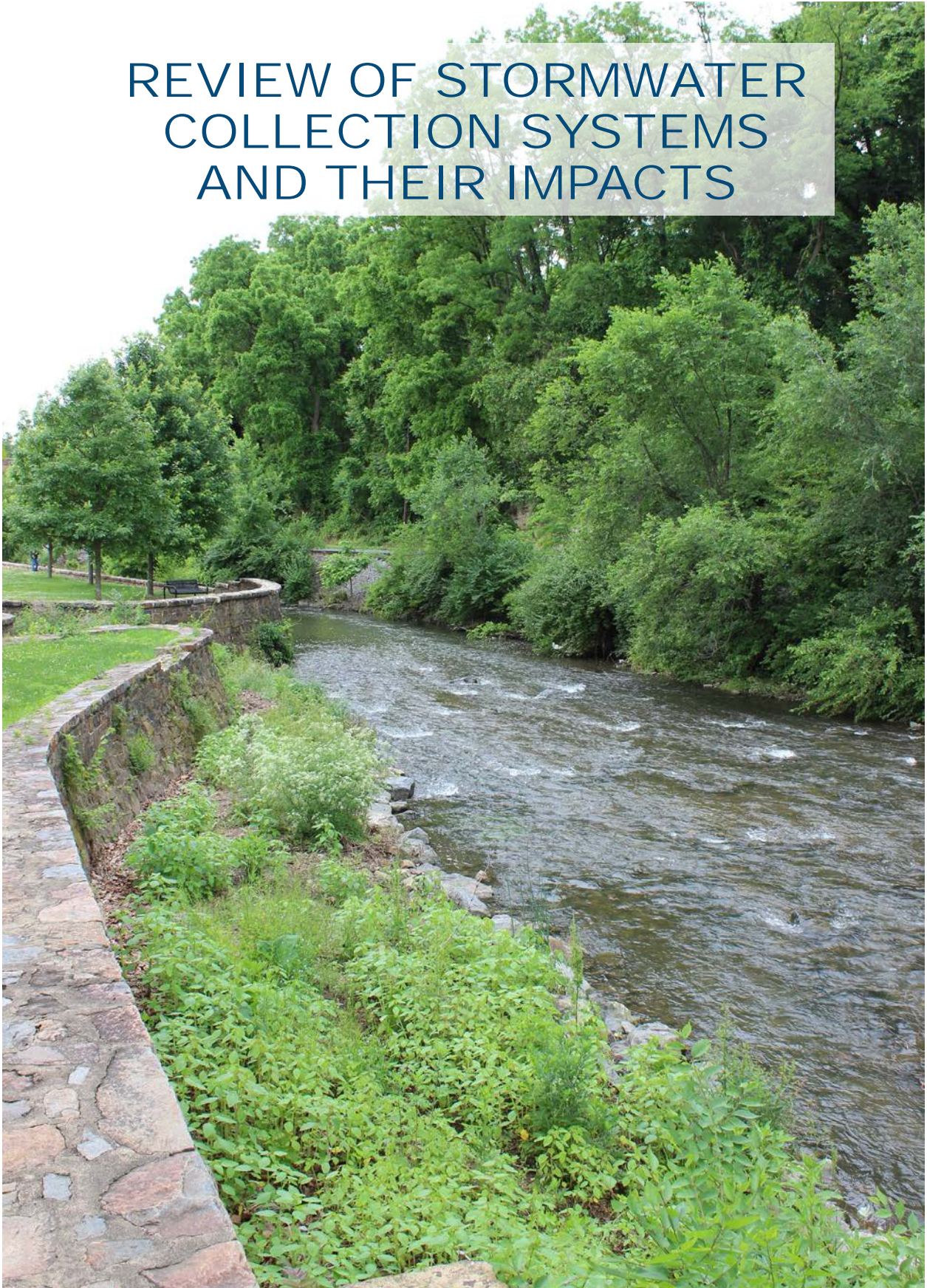
Level spreader: Level spreaders are measures that reduce the erosive energy of concentrated flows by distributing runoff as sheet flow to stabilized vegetative surfaces. They may also promote infiltration and improved water quality.

Special detention areas - parking lot, rooftop: These are places such as parking lots and rooftops that are primarily intended for other uses but that can be designed to temporarily detain stormwater for peak rate mitigation.



Wet pond/retention basin, photo by Craig Kackenmeister, LVPC

REVIEW OF STORMWATER COLLECTION SYSTEMS AND THEIR IMPACTS



Historic Bethlehem, photo by Craig Kackenmeister, LVPC

A. Existing Stormwater Collection Systems and Their Impacts

The existing stormwater collection and conveyance system was incorporated into the computer model of the watershed as follows:

- Subareas (which represent the smallest watershed breakdown for modeling purposes) were drawn to be consistent with the areas drained by storm sewers, i.e. the area drained by any one storm sewer system would be wholly within one subarea.
- Where applicable, major stormwater collection/conveyance facilities have been incorporated into the runoff model as “reaches.” A reach in the model is a channel segment that forms the link between subareas.

There are only two man-made storm runoff conveyance facilities used as reaches in the Monocacy Creek hydrologic model. The two reaches are consecutive sections of the open channel along Route 378 between Eaton Avenue and the confluence of the channel with the Monocacy Creek mainstem near Mauch Chunk Road. Located to the north and east of Route 378, the open channel drains nearly four square miles within the City of Bethlehem, Hanover Township, Northampton County and Hanover Township and the City of Allentown in Lehigh County. The upstream part of the open channel near Eaton Avenue is a concrete channel and has been designated reach number 96 of the hydrologic model. The downstream part of the open channel has been designated as reach number 97. It is composed of a sediment and rock-bottomed channel immediately downstream of reach 96 and a concrete channel/culvert system beginning at the Eighth Avenue cloverleaf at Route 378. Since only one cross-section may be used to describe a given reach, the rock and sediment-bottomed section was used because it is much longer (i.e. more representative) than the concrete section. Approximate hydraulic capacities of the two open channels were calculated using the Manning formula.

For storm sewer systems that were not part of the model structure, the effectiveness of the systems can only be addressed in the context of whether they coincide with documented storm drainage problem areas.

B. Future Stormwater Collection Systems

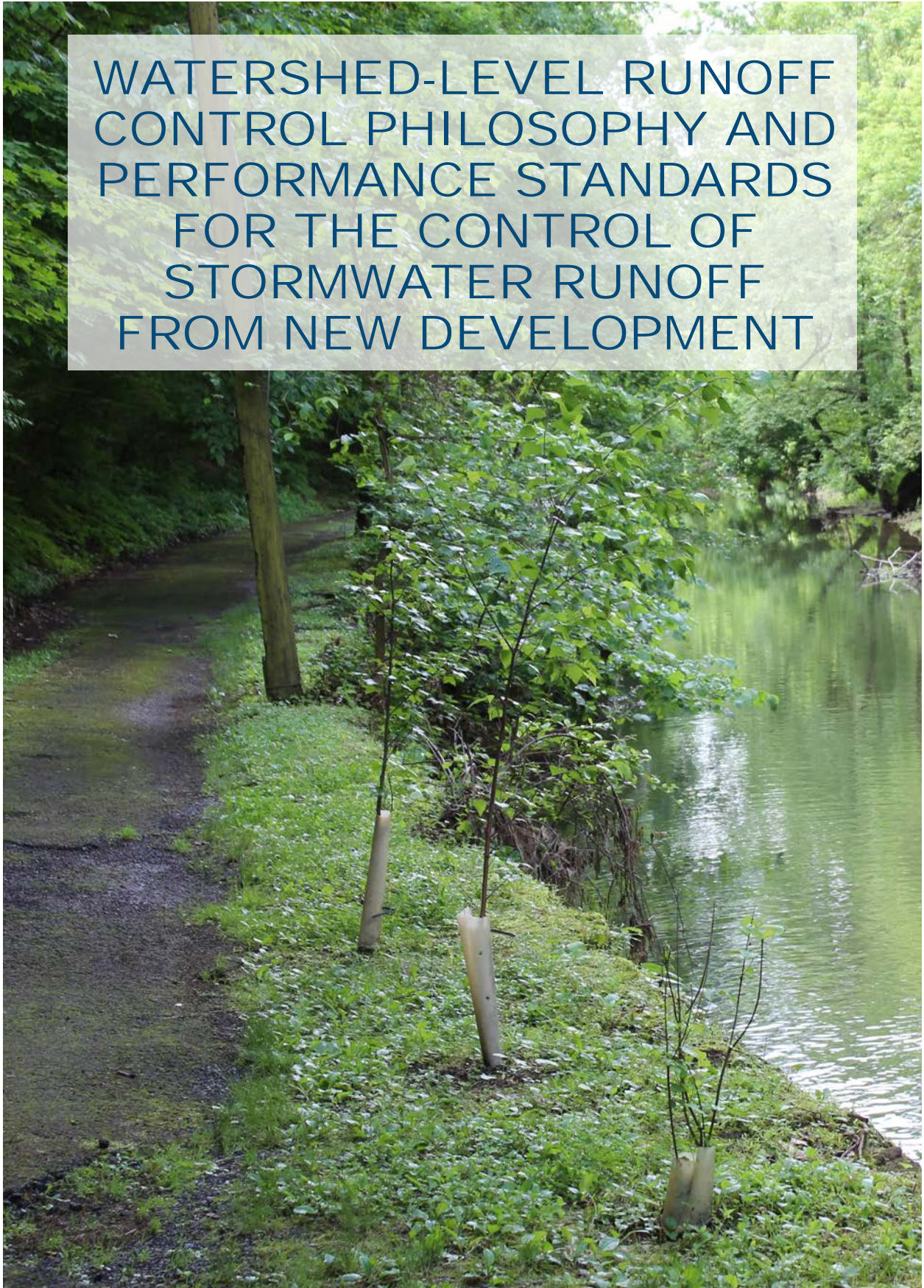
Typically, storm drainage improvements are constructed either as part of land developments (by the developer) or as remedial measures as part of the municipal capital or maintenance programs. In this manner, projects are constructed as money becomes available in the capital or maintenance budget. The effect of the approach in most cases is a piecemeal process of storm drainage improvements rather than one based on a comprehensive program keyed to future needs.

The Monocacy Creek Stormwater Management Plan can impact this situation in two ways. First, implementation of the performance standards specified in the Watershed-Level Runoff Control Philosophy and Performance Standards chapter would prevent the formation of new storm drainage problems or the aggravation of existing problems by maintaining peak flow values throughout the watershed to existing levels. This would allow for the development of a comprehensive remedial strategy based on the assurance that solutions would not eventually be obsolete with additional development. Second, the storm drainage problem area inventory in the Existing Storm Drainage Problem Areas and Significant Obstructions chapter provides an excellent basis for development of a storm drainage capital improvements inventory. Actual improvements required would be determined from engineering analysis of the problems.

C. Existing and Proposed Flood Control Projects

There is only one existing flood control project impacting the Monocacy Creek Watershed. The Corps of Engineers constructed flood walls, a levee and a dike to protect the old industrial area of the City of Bethlehem (within the Monocacy Creek Watershed) from the backwater impacts of the Lehigh River flows. There are no other existing or proposed flood control projects within the Monocacy Creek Watershed.

WATERSHED-LEVEL RUNOFF
CONTROL PHILOSOPHY AND
PERFORMANCE STANDARDS
FOR THE CONTROL OF
STORMWATER RUNOFF
FROM NEW DEVELOPMENT



Monocacy Creek at Housenick Park, photo by Craig Kackenmeister, LVPC

Earlier chapters identified the impacts of new development on stormwater runoff and the techniques available to control those impacts either on-site or with regional facilities. This chapter will identify the water quality and water quantity performance standards or goals that need to be met for various areas of the watershed to minimize the adverse stormwater impacts of new development. The method used to determine the water quantity performance standards was the development of a detailed hydrologic computer model of the watershed that could be “stressed” under various design conditions to evaluate control options. The specific computer model used was the Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS) because it provides acceptable hydraulic and hydrologic accuracy, has minimal input data requirements and produces total runoff data and not merely peaks.

Construction of the computer model of the Monocacy Creek Watershed first involved breaking the watershed down into small pieces of approximately 300 acres average size. These pieces, or subareas are the building blocks of the model. For each of the 101 subareas, the computer model generates a runoff hydrograph (flow versus time) for a particular rainfall event. Stream channel data provides the linkage between subareas and establishes the timing of one part of the watershed relative to another. The model provides the tool for analysis of the watershed and determination of an appropriate control strategy. The manner in which the model has been used to develop the control strategy and the actual control strategy itself are discussed in the following sections.

A. Watershed-Level Runoff Control Philosophy

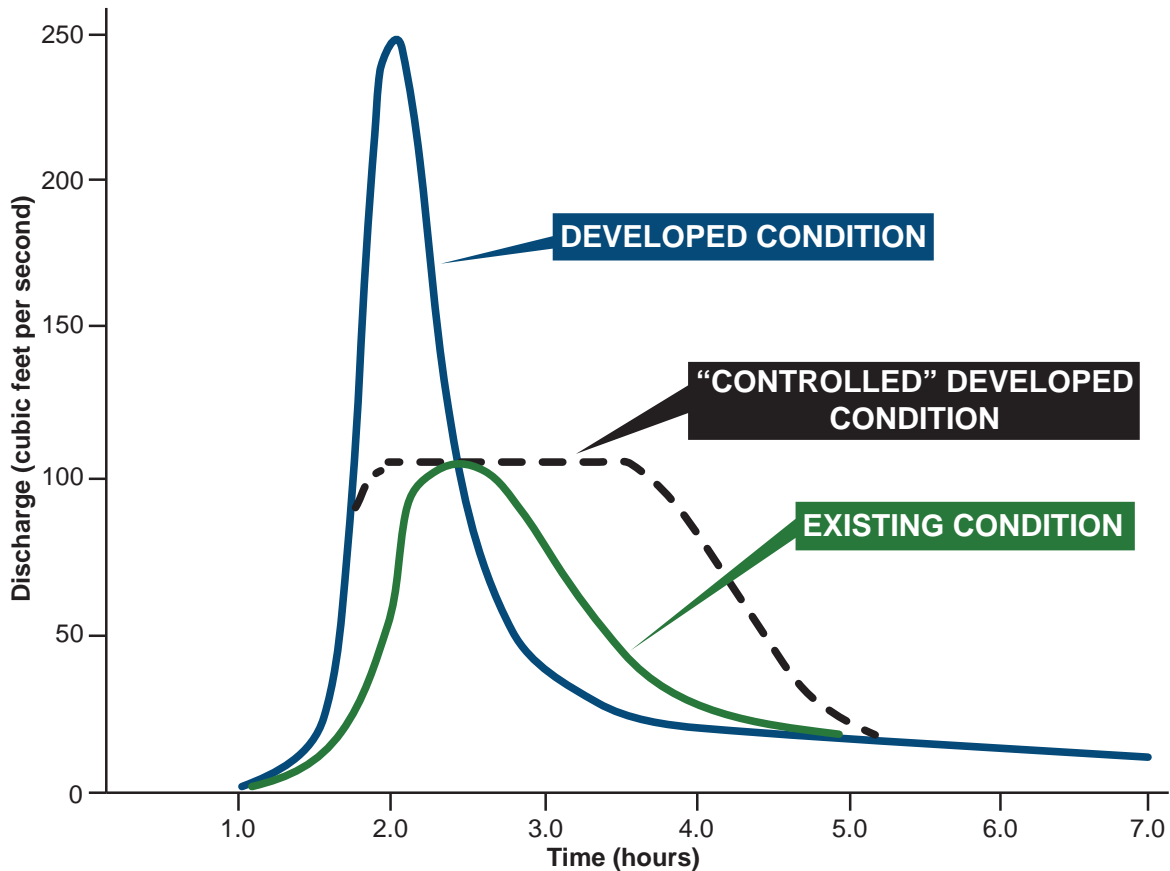
Prior to the original *Monocacy Creek Act 167 Stormwater Management Plan* in 1989, stormwater management decisions for new development in the Monocacy Creek Watershed were made using “at-site” philosophy. This was the case for two reasons. First, municipalities in the watershed did not require consideration of the downstream impacts of storm runoff from new developments in their subdivision ordinances. Second, the municipal engineers did not have a watershed database to rely on to quantify those impacts. The bottom line, therefore, is that at-site considerations dictated the recommended controls.

The difference between at-site runoff control philosophy and the Act 167 watershed-level philosophy is the consideration of downstream impacts. Whereas the objective of typical at-site design would only be to control post-development peak runoff rates to pre-development levels from the site itself, a watershed-level design would be geared towards maintaining existing peak flow rates in the entire drainage system. The latter requires knowledge of how the site relates to the entire watershed in terms of the timing of peak flows, contribution to peak flows at various downstream locations and the impact of the additional runoff volume generated by development of the site. The proposed watershed-level runoff control philosophy is based on the assumption that runoff volumes will increase with development and, except for the 2-year return period volume, rather than attempting to reduce post-development volume for all design events, seeks to “manage” the increase in volumes such that peak rates of runoff throughout the watershed are not increased.

The basic goal, therefore, of both the at-site and watershed-level philosophies is the same, i.e. no increase in the peak rate of runoff. The end products, however, can be very different as illustrated in the following simplified example.

A typical at-site runoff control strategy for dealing with the increase in the peak rate of runoff with development is illustrated below. The “Existing Condition” curve represents the pre-development runoff hydrograph. The “Developed Condition” hydrograph portrays three important changes in the site runoff response with development—a higher peak rate, a faster occurring peak (shorter time for the peak rate to occur) and an increase in total runoff volume. The “Controlled Developed Condition” hydrograph is based on limiting the post-development runoff peak rate to the pre-development level through use of detention facilities. The impact of “squashing” the post-development runoff to the pre-development peak is that the peak rate occurs over a much longer period of time. The instantaneous pre-development peak has become an extended peak (approximately two hours long in this example) under the Controlled Developed Condition.

TYPICAL "AT-SITE" RUNOFF CONTROL PHILOSOPHY



At-site, the maintenance of the pre-development peak rate of runoff is an effective management approach. The potential detrimental impact of this approach is that if runoff volume leaving the site is increasing with development, the cumulative impact of that volume increase is to fill downstream channels and not leave capacity for existing peak flows from a site. This translates into the need to reduce peak rates of flow leaving development sites to less than pre-development levels. This approach is termed the release rate approach. A complete description of the release rate concept can be found in the original *Monocacy Creek Watershed Act 167 Stormwater Management Plan*, March 1989 available from the Lehigh Valley Planning Commission website at www.lvpc.org.

1) Release Rate Concept

The description above indicated that in certain circumstances it is not enough to control post-development runoff peaks to pre-development levels if the overall goal is no increase in peak runoff at any point in the watershed. The reasons for this are how the various parts of the watershed interact, in time, with one another and the increased volume of runoff with development. The critical runoff control criteria for a given site or watershed area is not necessarily its own pre-development peak rate of runoff but rather the pre-development contribution of the site or watershed area to the peak flow at a given point of interest.

Conventional at-site detention philosophy would control post-development peak runoff flows to 100% of pre-development levels. The release rate concept would dictate a more stringent level of control based on downstream conditions. Therefore, in exchange for increased runoff volume with development, the peak rate of runoff will need to be reduced relative to pre-development conditions for certain parts of the watershed. The release rate for those watershed areas, or subareas, is defined in equation form as follows:

Release Rate = Subarea Contribution to Point of Interest Peak/Subarea Peak Flow

2) Point of Interest Selection

The determination of appropriate release rates for various subareas of the watershed is based on the analysis of downstream conditions at selected points of interest. Therefore, selection of the points of interest is a critical element in the development of the watershed-level runoff control strategy. For the Monocacy Creek Watershed Act 167 Plan, the following items have been considered in the selection of the points of interest:

- (a) Existing storm drainage problem areas (35) - identified through the Watershed Advisory Committee municipal representatives
- (b) Significant obstructions (22) - identified from detailed Flood Insurance Studies as obstructions that raise flood heights
- (c) All subarea boundaries (101) - identified by breakdown of the watershed for modeling purposes
- (d) Municipal boundaries

The overall goals of Act 167 are to prevent the aggravation of existing drainage problem areas and to prevent the formation of new problem areas through the coordination of storm runoff decisions throughout the watershed. At minimum, therefore, existing storm drainage problem areas must be used as points of interest for hydrograph analysis. Of the 35 identified problem areas, 21 are located on main reaches of the runoff model, and 14 are located within individual drainage areas. Only the 21 main reach problem areas can be analyzed using the model directly. The remaining 14 problem areas would require a more localized analysis of the impact of potential new development sites that drain through these “off-line” problem areas.

Prevention of any new storm drainage problem areas is by far the more difficult Act 167 goal. Ensuring that no new problems are created requires that either (1) peak runoff values are not increased at any point in the watershed, or (2) peak flow values are only increased to the point that the existing drainage system can safely convey the increased flows. Option 2 would require knowledge of the capacity of the drainage system at every point in the watershed. Certainly this is not the case for the 49.3 square mile Monocacy Creek Watershed. For modeling purposes, the average capacities of the major drainage elements have been determined using simplified methods. Actual capacities may differ significantly depending upon the accuracy of the assumptions used in the simplified approach. In addition, even calibration of the runoff model does not guarantee accurate runoff values at every point in the watershed. The conclusion is that, even though it may be possible to increase peak flow values at various points in the watershed without creating new drainage problems, the ability to accurately define those areas and identify the allowable increase in peak flow does not exist within the Act 167 planning effort. Therefore, a conservative engineering approach and practicality dictate using the philosophy of maintaining existing peak flow rates.

With the control philosophy decided, it is still necessary to determine at what points in the watershed the philosophy will be applied. Strict adherence to the philosophy would mean using the most detailed level of watershed breakdown available as the control points, i.e. the 101 subarea boundaries. Using the 101 subarea boundaries as control points would also effectively control all of the other possible control options (i.e. significant obstructions and municipal boundaries, as well as the existing main reach problem areas).

Municipal boundaries as possible control points have their justification in the goals of Act 167 itself, namely to coordinate the runoff control efforts of all the municipalities in the watershed. Municipal coordination could mean, at minimum, that the stormwater management decisions made for a development in one municipality do not have an adverse impact on any other downstream municipality. Therefore, using municipal boundaries as points of interest could ensure the minimum acceptable coordination consistent with Act 167.

Each of the individual control point categories (existing drainage problem areas, significant obstructions and municipal boundaries) are valid control points for formulation of a runoff management plan. Since, as stated above, using the 101 subarea boundaries effectively incorporates all the other control categories, the 101 subarea boundaries are used as the critical drainage points for runoff analysis. Therefore, the runoff from a particular subarea has been analyzed at every other downstream subarea and the appropriate control philosophy devised based on not increasing the peak flow at any of the 101 subarea boundaries.

B. Peak Runoff Rate Performance Standards

1) Description of Performance Standard Districts

A major goal of the Act 167 Plan effort is to determine the appropriate runoff control strategy for successfully dealing with the runoff impacts of new development. The control plan is based on dividing the Monocacy Creek Watershed into two basic districts with a finer breakdown in one of the districts. Note that the runoff control strategy for the 2-year return period event is to control the post-development runoff peak flow and volume to no greater than the pre-development runoff peak flow and volume. The volume control is consistent with requirements for sites needing post-construction stormwater management permits and is carried forward here to regulate all activities associated with this Model Ordinance. With the 2-year volume controlled, the peak rate control necessary for the 2-year event is to simply meet the pre-development peak. Meeting the pre-development peak rate is the same as a 100% Release Rate. Both of the districts are described below:

(a) Release Rate Districts - There are six single release rate districts that differ in the extent to which the post-development runoff must be controlled. The release rate districts are 50%, 60%, 70%, 80%, 90% and 100%. Within a given district, the post-development peak rate of storm runoff must be controlled to the stated percentage of the pre-development peak rate of runoff for each of the 10-, 25- and 100-year return period storms to protect downstream watershed areas.

There is one dual release rate district. Within this district, the 10-year return period event needs to meet a 30% release rate, and the 25-year and higher return period events need to meet a 100% release rate.

(b) Conditional No Detention Districts - These watershed areas peak very early with respect to the total watershed peak flow and contribute very minimal flow to the watershed peak flow. For that reason, these watershed areas may discharge post-development peak runoff without detention for the 10- through 100-year return periods without adversely affecting the total watershed peak flow. These areas are designated as "conditional" no detention areas because in certain instances the "local" runoff conveyance facilities, which transport runoff from the site to the main channel, may not have adequate capacity to safely transport the peak flows associated with no detention for a proposed development. In those instances, a 100% release rate control would have to be provided or, alternately, the capacity deficiency(ies) would have to be corrected.

A map of the Monocacy Creek Watershed performance standard districts and release rate summary table are located in Appendix A of the Model Ordinance at the end of the Plan.

C. Existing Water Balance Preservation and Green Infrastructure Standards

1) Determining the Water Quality Volume

In the current model ordinance applicable to the Monocacy Creek Watershed prepared as part of the *"Global" Water Quality Update*, April 2006, two different methods were used to calculate the water quality volume: the incremental 2-year runoff volume, based on the 24-hour, 2-year return period storm, and a rational method-based formula using the post-development coefficient and a rainfall depth of 1.25 inches. The greater of these two volumes was used but capped at a maximum volume equal to 1.25 inches of runoff over the entire site. The 1.25 inches represents the rainfall depth associated with 90% of the annual rainfall in the Lehigh Valley. Stated otherwise, if all rainfall up to and including a 1.25 inch storm plus the first 1.25 inches of larger storms is counted, it represents

90% of all annual rainfall. Through the post-construction stormwater management permitting program, the Pennsylvania Department of Environmental Protection uses a standard that requires the entire incremental 2-year runoff volume to be controlled such that the volume leaving the site does not increase with development for the 2-year storm. From a rainfall capture perspective, a 2-year, 24-hour storm of 3.0 inches represents about 99% of annual rainfall. It is intended as a volume that needs to be treated to remove contaminants and mitigate erosion of downstream channels. Bankfull conditions for natural channels are typically based on about a 2-year return period. Therefore, this return period is key to preventing increased erosion for receiving channels. If 2-year runoff volumes do not increase and release rates ensure peak flow rates don't increase with development, downstream channels would presumably be protected from erosion. Since a goal with updating the water quality standards is to achieve greater consistency with Department of Environmental Protection standards, this Plan includes the 2-year incremental runoff volume as the water quality volume.

2) Determining the Existing Water Balance

As stated above, control of the water quality volume will require a development plan to restrict the runoff volume leaving the site for storms up to and including the 2-year return period event. Post-development runoff must either be recharged or returned to the atmosphere through evapotranspiration. If ordinances don't place limits on recharge, virtually the entire annual rainfall could result in direct recharge to groundwater. This is specifically problematic in carbonate bedrock areas, but can be problematic in any geologic setting in terms of upsetting the natural water balance.

A key to preventing situations where groundwater recharge would be greatly increased due to development, possibly with detrimental side effects, is to attempt to quantify the eventual fate of rainfall in the pre-development condition, be it runoff, recharge or evapotranspiration. Natural or existing water balance can be inferred from various sources, including the *Technical Best Management Practice Manual & Infiltration Feasibility Report: Infiltration of Stormwater in Areas Underlain by Carbonate Bedrock within the Little Lehigh Creek Watershed*, Lehigh Valley Planning Commission, 2002, as well as data prepared by the Lehigh Valley Planning Commission for the Monocacy and Jordan creeks based on stream gage analyses. Consistently through these sources, groundwater recharge is about 30% of annual rainfall, while runoff ranges from approximately 10% to 20% depending on the extent of development in a watershed. Based on this data, we can make the following generalization about the fate of runoff in the "natural" condition:

Runoff – 10% of annual rainfall

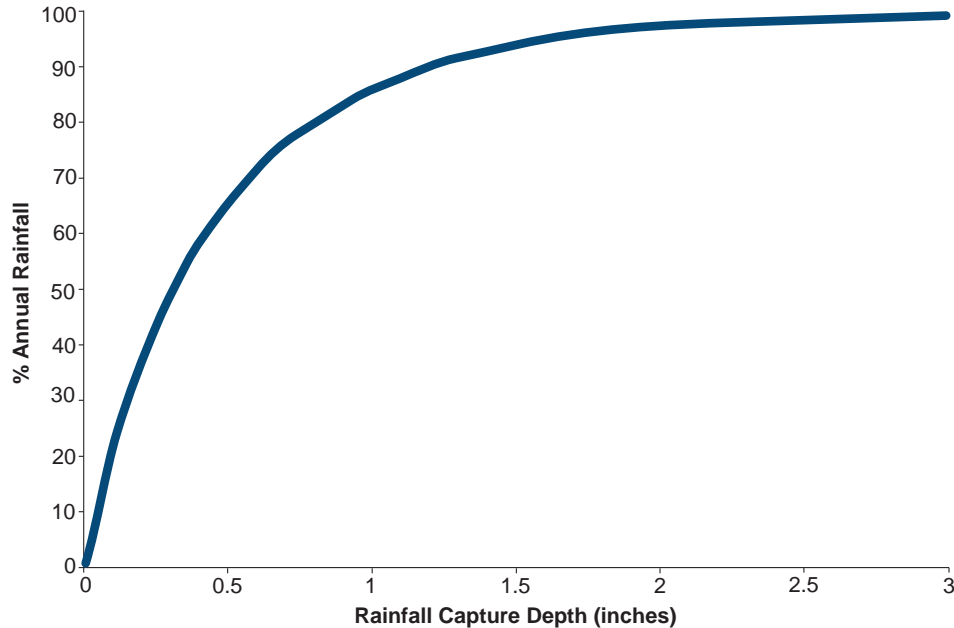
Recharge – 30% of annual rainfall

Evapotranspiration – 60% of annual rainfall

As stated above, over 99% of all annual rainfall is included if you capture the 3.0 inches of rainfall associated with a 2-year, 24-hour storm. The non-linear relationship between rainfall capture depth and percent annual rainfall is shown below. This graph is based on capturing all the rainfall in storms up to and including the listed depth plus the listed depth of larger storms. From the graph, a 0.1-inch capture depth translates into 22% of annual rainfall. A 0.5-inch capture depth includes 65% of annual rainfall. A 3-inch capture depth (2-year storm) is slightly greater than 99% of annual rainfall. The key idea from the chart is that very small rainfall capture volumes will have a very large influence on annual water balance.

The most critical aspect for determining post-development water balance is the fate of runoff produced by impervious surfaces as passed through various Best Management Practices (Practices). Impervious surfaces produce a well understood "transform" of rainfall to runoff such that most rainfall will become runoff. The change from pervious cover to impervious cover with development can dramatically alter peak runoff rate and runoff volume. Practices can be employed to manage rate and volume impacts, but the annual water balance implications of those choices may not be understood or considered. There is very little available data on water balance by Best Management Practices. However, some very simple rules can be used to classify Practices by the predominant fate of runoff. Practices that are based on vegetative uptake and soil renovation of runoff and/or

PERCENT ANNUAL RAINFALL VERSUS RAINFALL CAPTURE DEPTH



surface infiltration are termed Vegetated/Surface Practices. Practices that initially direct runoff to an underground infiltration surface are Direct Recharge/Subsurface Practices. Practices that mainly pass runoff volume through such that the volume leaves the facility as runoff are Runoff Practices. Best Management Practices can then be classified as Vegetated/Surface, Direct Recharge/Subsurface or Runoff Practices on the basis of the predominant fate of runoff.

For an assessment of the fate of runoff directed to Best Management Practices, operating rules are needed for each type of Practice. Two of the rules are quite simple. For Runoff Practices, all water directed to them is assumed to be eventually released as runoff. For Direct Recharge/Subsurface Practices, all water directed to them is assumed to be released as recharge. Vegetated/Surface Practices are different. Water directed to these Practices will have some fraction of the water become evapotranspiration. Some fraction of the water directed to them may become recharge. Any runoff greater than the design capacity will leave the facility as runoff. Again, the operating rule is that these Practices most closely distribute water directed to them in a way that mimics the natural landscape. With this in mind, impervious areas of a site directed to Vegetated/Surface Practices should most closely reproduce a natural water balance. Runoff volume released from a site is restricted by the incremental 2-year return period water quality volume standard such that only about 10% of proposed impervious could be directed solely to Runoff Practices. Since almost all runoff directed to Direct Recharge/Subsurface Practices becomes recharge, only about one-third of proposed impervious (owing to some evapotranspiration off pavement) could be discharged to Direct Recharge/Subsurface Practices to preserve annual water balance.

Referring back to the proposed water quality volume, the change in 2-year runoff volume with development may not leave the site as runoff and must therefore be directed to some combination of Vegetated/Surface and/or Direct Recharge/Subsurface Practices. Since the water quality volume will mostly reflect the creation of impervious surfaces, this means that most proposed impervious cover will need to be directed to Vegetated/Surface and/or Direct Recharge/Subsurface Practices. Again, Vegetated/Surface Practices most closely mimic natural conditions, and Direct Recharge/Subsurface Practices create higher than natural recharge. Therefore, restriction of the use of Direct Recharge/Subsurface Practices is appropriate to maintain annual water balance near natural conditions.

The standard in this Plan is that direct recharge of runoff from impervious areas by employing Direct Recharge/Subsurface Practices shall be limited to 30% of the site's annual rainfall. This translates into a maximum of one-third of the site as impervious being directed to Direct Recharge/Subsurface Practices when designed to capture the full 2-year event. Any sites with less than 33% impervious cover proposed would be exempt from this water balance standard. Direct Recharge/Subsurface Practices designed to capture less than the full 2-year event can direct more site impervious to these Practices. Appendix C of the Model Ordinance shows the design curves for implementing this standard from a rainfall capture perspective for capture volumes of 0.0 to 3.0 inches. Since the Best Management Practices design storage is a function of percent annual rainfall and the runoff fraction, a curve is created to solve for the maximum storage volume allowable for a given percent impervious and percent direct recharge. However, this assumes that runoff will first flow into a Direct Recharge/Subsurface Practice and then flow into a Vegetated/Surface Practice downstream when the storage volume is exceeded. This is not always the case. Sites may be designed to drain to a Vegetated/Surface Practice first and overflow downstream into a Direct Recharge/Subsurface facility. Based on the design storage volume of the Vegetated/Surface Practice, the amount of direct recharge that occurs from the overflow into the downstream Direct Recharge/Subsurface Practice can be calculated.

Given this data, the water quality standards are as follows:

- a) The entire water quality volume shall be captured and treated by either Direct Recharge/Subsurface or Vegetated/Surface Practices.
- b) As much proposed impervious area as practical shall be directed to water quality Practices.
- c) Existing impervious area that is not proposed to be treated by Direct Recharge/Subsurface Practices should be excluded from all water balance calculations.
- d) A maximum of 30% of the total annual rainfall for a site may be directly recharged to groundwater using Direct Recharge/Subsurface Practices for runoff from impervious areas.
 - i.) For development sites with greater than 33% proposed impervious cover:
 - (1) If all impervious cover is directed to Vegetated/Surface Practices to capture the entire 2-year, 24-hour event, the direct recharge standard is met.
 - (2) Up to 33% of the site as impervious cover may be directed to Direct Recharge/Subsurface Practices designed to capture the entire 2-year, 24-hour event provided the overall Vegetated/Surface Practice "first" standard is met. All remaining impervious cover shall be directed to Vegetated/Surface Practices designed to capture the remainder of the water quality volume.
 - (3) For Vegetated/Surface and/or Direct Recharge/Subsurface Practices designed for runoff from impervious areas designed to capture less than the entire 2-year, 24-hour event, Appendix C shall be used to assure that the maximum direct recharge standard is met.
 - ii.) The maximum 30% direct recharge standard applies on an overall site basis, rather than in each drainage direction.

3) Green Infrastructure Standard

Green infrastructure can be defined in a number of ways. Some examples are listed below.

- Green infrastructure can be thought of as the sum of all our natural resources. It includes all the interconnected natural systems in a landscape, such as intact forests, woodlands, wetlands, parks and rivers, as well as those agricultural soils that provide clean water, air quality, wildlife habitat and food. (North Carolina Forest Service, *Evaluating and Conserving Green Infrastructure Across the Landscape*, 2013)
- Green infrastructure is a strategically planned and managed network of wilderness, parks, greenways, conservation easements and working lands with conservation value that supports native species, maintains natural ecological processes, sustains air and water

resources, and contributes to the health and quality of life for America's communities and people. (Benedict and McMahon, *Green Infrastructure*, 2006)

- Green infrastructure is a cost-effective, resilient approach to managing wet weather impacts that provides many community benefits. While single-purpose gray stormwater infrastructure—conventional piped drainage and water treatment systems—is designed to move urban stormwater away from the built environment, green infrastructure reduces and treats stormwater at its source while delivering environmental, social and economic benefits. (U.S. Environmental Protection Agency)
- Green infrastructure is an adaptable term used to describe an array of products, technologies and practices that use natural systems—or engineered systems that mimic natural processes—to enhance overall environmental quality and provide utility services. As a general principal, green infrastructure techniques use soils and vegetation to infiltrate, evapotranspire and/or recycle stormwater runoff. (PA Department of Conservation and Natural Resources)
- Green infrastructure is a network of decentralized stormwater management practices, such as green roofs, trees, rain gardens and permeable pavement, that can capture and infiltrate rain where it falls, thus reducing stormwater runoff and improving the health of surrounding waterways. (Center for Neighborhood Technology and American Rivers, *The Value of Green Infrastructure*, 2010)

Based on the above, on a larger scale, the concept of green infrastructure can be thought of as all the natural assets of a region: the interconnected network of woodlands, parks, wetlands, rivers, agricultural soils and other open spaces. The natural environment provides a variety of essential functions, including flood protection, stormwater management, clean air and water, wildlife habitat, food, and recreational opportunities, among others, and are vital to the health and well-being of a community.

Frequently, the development of land results in the major alteration of the natural landscape: extensive site clearing where existing vegetation is removed and soils are disturbed and compacted. These activities have a significant impact on natural system services, including stormwater management. The protection of natural resources should be a top priority for communities to maintain the services nature provides at no cost. American Forests estimated that trees in the nation's metropolitan areas contribute \$400 billion in stormwater retention by eliminating the need for expensive stormwater retention facilities (Benedict and McMahon, 2006). A large mature oak tree can transpire 40,000 gallons of water per year; that is water that is not entering storm drains and thereby causing runoff, excessive streamflows and downstream erosion (U.S. Environmental Protection Agency, *Reducing Urban Heat Islands: Compendium of Strategies*, 2008). In a study of 27 U.S. water suppliers, researchers found that protecting forested watersheds used for drinking water sources can reduce capital, operational and maintenance costs for drinking water treatment. Researchers found that watersheds with a greater percentage of protected forest correlate to fewer water treatment expenditures: for each 10% increase in watershed forest cover, there is about a 20% decrease in treatment costs (Ernst, Caryn, Richard Gullick and Kirk Nixon. *Conserving Forests to Protect Water*, 2004).

At the site development scale, green infrastructure can be characterized as an environmentally sensitive approach, involving a combination of techniques, which preserves natural systems and hydrologic functions on a site. In fact, the natural resources on a site should be protected and used in site design planning as part of the stormwater management solution. Overall, green infrastructure techniques minimize the impacts of development (low impact development) on the natural environment, including clustering and concentrating development, minimizing disturbed areas and reducing impervious cover. The use of Non-structural Practices that involve vegetation, soils and natural processes encourages stormwater treatment, infiltration and transpiration on the site, as opposed to conveyance of stormwater off-site. The *Pennsylvania Stormwater Best Management Practices Manual* (2006) describes both structural and non-structural techniques to manage stormwater on a site. Some Best Management Practices classified as structural in the state manual can be considered green infrastructure because they are natural systems-based, involving vegetation and soil mechanisms, and can be used in combination with Non-structural Practices.

For purposes of this Plan, the intent is to see how the Model Ordinance could encourage or mandate green infrastructure approaches for managing stormwater on a development or redevelopment site. The current stormwater management ordinances in effect in the Monocacy Creek Watershed are based on the “Global” Act 167 Stormwater Management Plan Water Quality Update April 2006. Global refers to the eleven watersheds included in the study, including the Monocacy Creek, for which the ordinance was updating a water quantity ordinance prepared under Act 167 within the Lehigh Valley. The existing ordinance provides performance standards for water quality and quantity control, but no specific standard to ensure green infrastructure approaches are applied on a site other than a general requirement to infiltrate a portion of site runoff, if feasible.

The U.S. Environmental Protection Agency prepared a summary of stormwater management green infrastructure ordinance approaches in various communities across the country in *Green Infrastructure Case Studies: Municipal Policies for Managing Stormwater with Green Infrastructure*, August 2010. Many of the ordinance approaches involve mandating a certain volume of runoff to be infiltrated or treated by water quality Best Management Practices. In Pennsylvania, this standard is already implemented through the Post-Construction Stormwater Management Permit process for qualifying sites through the water quality volume standard described previously. The same standard is included in the Monocacy Creek Plan Model Ordinance for all regulated sites. The City of Portland has a more proactive approach to green infrastructure by requiring a specific hierarchy for consideration of site runoff control practices. Runoff infiltration with vegetated infiltration facilities is required to the maximum extent practicable followed by options that overflow these facilities to subsurface infiltration facilities. In effect, this ordinance mandates green infrastructure approaches as a first option, depending on site characteristics that may limit its practicability.

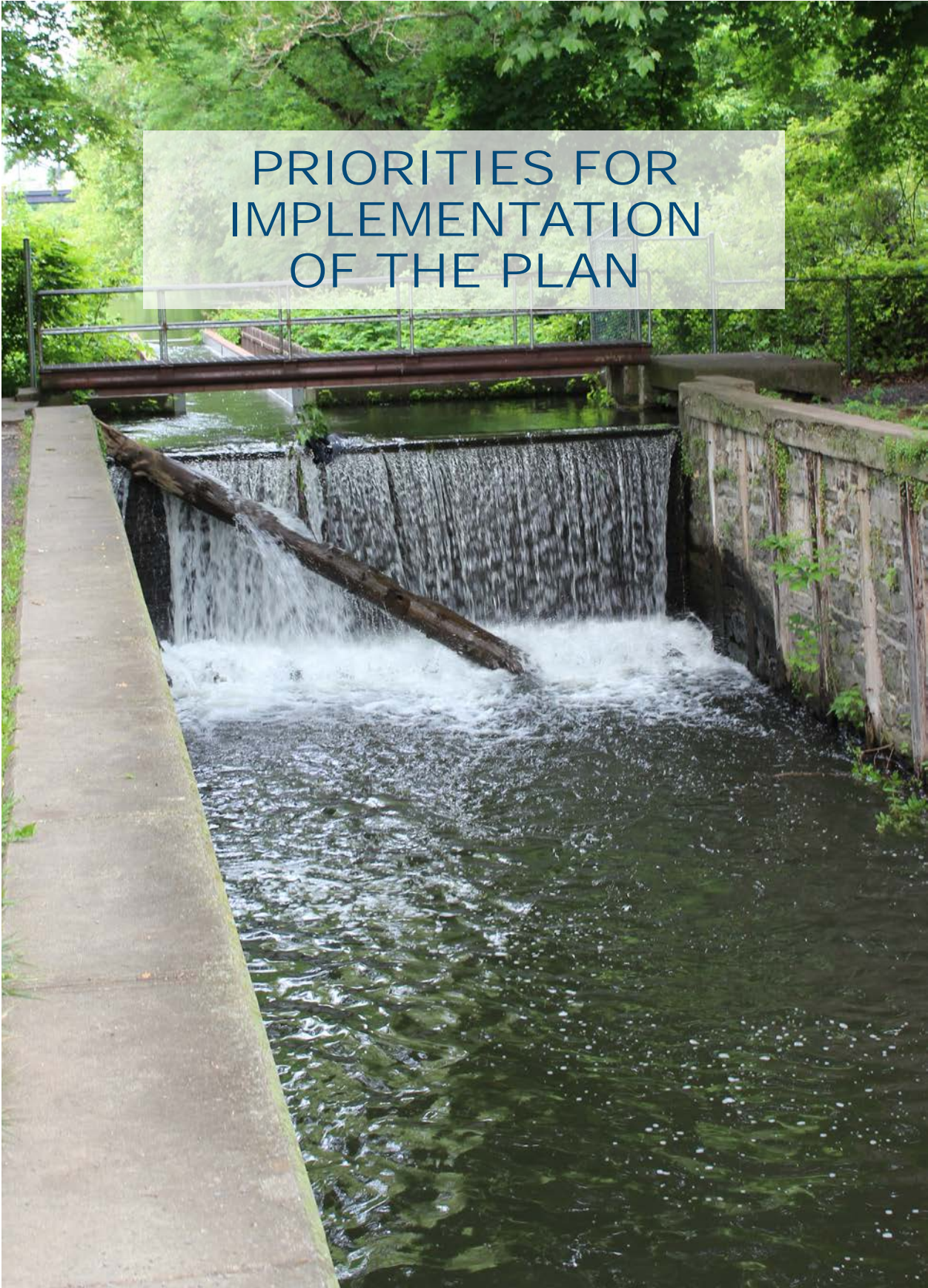
The standard included in the Monocacy Creek Plan mirrors the City of Portland Ordinance as a “green infrastructure first” approach. Building off of the water balance standard discussion that preceded this section, maintaining the natural water balance of evapotranspiration, recharge and runoff with development of a site requires that standards are needed to choose appropriate Best Management Practices in site design. Water quality and green infrastructure approaches to site design often means a decentralized approach to stormwater management, as described in the last bullet above, where there may be many smaller Best Management Practices applied to a site rather than concentrating all runoff into one large structure. The many Best Management Practices can have highly varied design concepts and can be designed to “capture” different amounts of rainfall/runoff. The water balance design curves take that into consideration and provide the designer with the means to meet the performance standards. A key part of the design curves is that, if all proposed impervious cover was treated equally in choosing and designing Best Management Practices, each square foot of impervious cover would require 0.38 inches of runoff to be treated first with Vegetated/Surface Practices. This standard is included in the Model Ordinance to best implement the green infrastructure approach and ensure that more natural approaches are accomplished in all site stormwater management designs.

The specific standard included in the Model Ordinance is as follows:

Vegetated/Surface Practices shall be employed “first” for the site to capture the equivalent of a minimum of 0.38 inches of runoff for each square foot of impervious area, unless proven not feasible by the applicant. For proposed impervious cover directed to multiple Practices, the Vegetated/Surface Practice capture volume chart in Appendix C shall be used to determine overall site compliance. Direct Recharge/Subsurface Practices may be used “first” for portions of the impervious cover provided the overall Vegetated/Surface Practice “first” standard is met.

D. Performance Standard Implementation Provisions

The performance standards specified above represent one-half of the storm runoff control strategy for the Monocacy Creek Watershed. The other half of the strategy is composed of the provisions necessary to implement the performance standards, including the types of new development to which the standards apply, runoff calculation methodology, determining downstream channel capacity, among others. These provisions are described within the Municipal Ordinance chapter.



PRIORITIES FOR
IMPLEMENTATION
OF THE PLAN

Monocacy Creek at Sand Island Park, photo by Craig Kackenmeister, LVPC

The Monocacy Creek Stormwater Management Plan preparation process is complete with the Northampton County and Lehigh County adoption of the draft Plan and submission of the final Plan to the Pennsylvania Department of Environmental Protection for approval. Procedures for the review and adoption of the Plan are included in the Plan Review, Adoption and Updating Procedures chapter. Subsequent activities to carry out the provisions of the Plan are considered to be part of the implementation of the Plan. The initial step of Plan implementation is Pennsylvania Department of Environmental Protection approval. Plan approval sets in motion the mandatory schedule of adoption of municipal ordinance provisions to implement the stormwater management criteria. Monocacy Creek municipalities have six months from state approval to adopt the necessary ordinance provisions. Failure to do so could result in the withholding of state funds to the municipality(ies) per Act 167.

Additional implementation activities are the formal publishing of the final Plan after approval, development of a local program to coordinate with the state regarding permit reviews for stream encroachments, diversions, etc., and development of a systematic approach for correction of existing storm drainage problem areas. The priorities for Plan implementation are presented in detail below in (essentially) chronological order.

A. Pennsylvania Department of Environmental Protection Approval of the Plan

Upon adoption of the Plan by Northampton and Lehigh counties, the Plan is submitted to the state for approval. The state review process involves determination that all of the requirements for an Act 167 Plan have been satisfactorily completed.

The Pennsylvania Department of Environmental Protection action to either approve or disapprove the Plan must take place within 90 days of receipt of the Plan by the Department. Otherwise, the Plan would be approved by default.

B. Publishing the Plan

The Lehigh Valley Planning Commission will publish additional copies of the Plan after state approval. At minimum, one copy of the Plan will be provided to each municipality. The Plan will also be available from the Lehigh Valley Planning Commission website at www.lvpc.org.

C. Development of a Local Program to Coordinate with the Pennsylvania Department of Environmental Protection Regarding Chapter 105 and Chapter 106 Permit Application Reviews

Stream encroachments, stream enclosures, waterway diversions, water obstructions and other activities regulated by Chapter 105 and Chapter 106 of the State Rules and Regulations may have a bearing on the effectiveness of the runoff control strategy developed for the Monocacy Creek Watershed. Activities of this type may modify the conveyance characteristics of the watershed and, hence, impact on the relative timing of watershed peak flows and/or the ability of the conveyance facilities to safely transport peak flows. Therefore, to ensure that the state permitting process is consistent with the adopted and approved Plan, a local review of Chapter 105 and Chapter 106 permit applications is provided for in the Ordinance included in the Plan.

D. Municipal Adoption of Ordinance Provisions to Implement the Plan

The key ingredient for implementation of the Stormwater Management Plan is the adoption of the necessary ordinance provisions by the Monocacy Creek municipalities. Provided as part of the Plan is the Monocacy Creek Watershed Act 167 Stormwater Management Model Ordinance, which is a single purpose stormwater ordinance that could be adopted by each municipality essentially as is to implement the Plan. The single purpose ordinance was chosen for ease of incorporation into the existing structure of municipal ordinances. All that would be required of any municipality would be to adopt the ordinance itself and adopt the necessary tying provisions into the existing subdivision and land development ordinance and zoning ordinance. The tying provisions would simply refer any applicable

regulated activities within the Monocacy Creek Watershed to the single purpose ordinance from the other ordinances.

It is not required, however, that a municipality adopt the single purpose ordinance. At the municipality's discretion, it may opt to incorporate all of the necessary provisions into the existing ordinances rather than adopt a separate ordinance. In this event, the municipalities must ensure that the amended ordinances satisfactorily implement the approved Plan.

E. Development of a Systematic Approach for Correction of Existing Storm Drainage Problem Areas

Correction of the existing storm drainage problem areas in the watershed is not specifically part of the Act 167 planning process. However, the development of the Plan has provided a framework for their correction for the following reasons: (1) existing storm drainage problems have been documented through interaction with the Watershed Advisory Committee, and (2) implementation of the runoff control criteria specified in the Plan will prevent the existing drainage problems from becoming worse (and prevent the creation of new drainage problem areas).

With the above in mind, each municipality within the Monocacy Creek Watershed should take the following steps to implement solutions to the existing storm drainage problem areas:

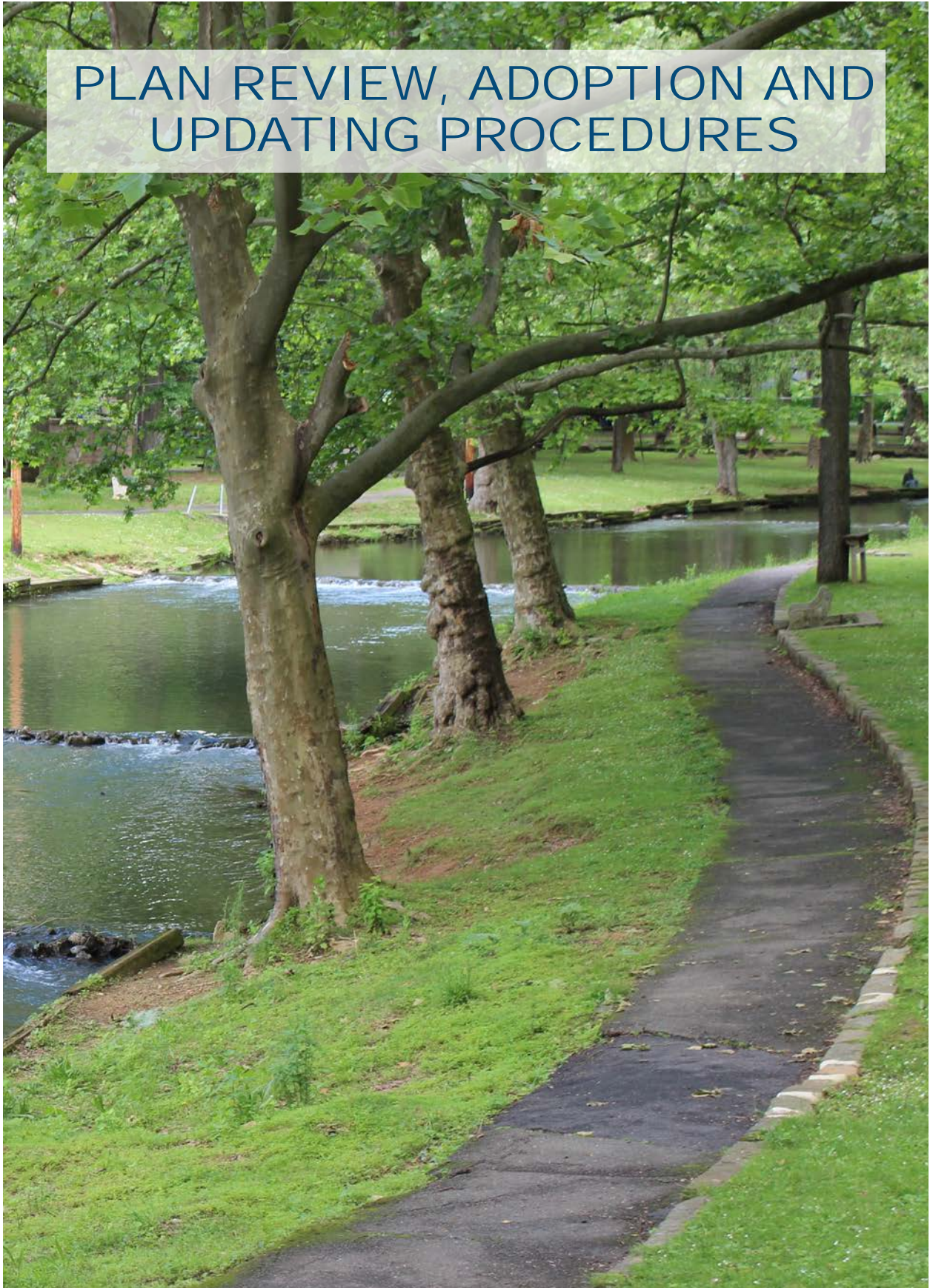
- 1) Prioritize the list of storm drainage problems within the municipality based on frequency of occurrence, potential for injury to persons or property, damage history, public perception of the problems and other appropriate criteria.
- 2) For the top priority drainage problems in the municipality, conduct detailed engineering evaluations to determine the exact nature of the problems (if not known), determine alternative solutions, provide cost estimates for the alternative solutions, and recommend a course of municipal action.
- 3) On the priority and cost basis, incorporate implementation of recommended solutions to the drainage problems in the annual municipal capital budget or the municipal maintenance budget as funds are available.

The above-stated procedure for dealing with existing storm drainage problem areas is not a mandatory action placed on municipalities with the adoption of the Plan. Rather, it represents one systematic method to approach the problems uniformly throughout the watershed and attempt to improve the current runoff situation in the watershed. The key elements involved in the success of the remedial strategy will be the dedication of the municipalities to construct the corrective measures and the consistent and proper application of the runoff control criteria specified in the Plan. The latter element is essential to ensure that remedial measures do not become obsolete (under-designed) by increases in peak flows with development.



Rain garden at Upper Saucon Township Water Authority
Photo by Craig Kackenmeister, LVPC

PLAN REVIEW, ADOPTION AND UPDATING PROCEDURES



Monocacy Park, photo by Craig Kackenmeister, LVPC

A. Plan Review and Adoption

The opportunity for local review of the draft Stormwater Management Plan is a prerequisite to County adoption of the Plan. Local review of the Plan is composed of three parts, namely Watershed Advisory Committee review, municipal review and County Council/County Board of Commissioners' review. Local review of the draft Plan is initiated with the completion of the Plan by the Lehigh Valley Planning Commission and distribution to the Watershed Advisory Committee. Presented below is a chronological listing and brief narrative of the required local review steps through County adoption.

- 1) Watershed Advisory Committee Review - This Committee has been formed to assist in the development of the Monocacy Creek Watershed Plan. Municipal members of the committee have provided input data to the process in the form of storm drainage problem area documentation, proposed solutions to drainage problems, etc. The Committee met on seven occasions to review the progress of the Plan. Municipal representatives on the Committee have the responsibility to report on the progress of the Plan to their respective municipalities. Review of the draft Plan by the Advisory Committee will be expedited by the fact that the members are already familiar with the objectives of the Plan, the runoff control strategy employed and the basic contents of the Plan. The output of the Watershed Advisory Committee review would be a letter outlining the Committee comments, which would be included with the draft Plan for municipal and County consideration.
- 2) Municipal Review - Act 167 specifies that prior to adoption of the draft Plan by the County, the planning commission and governing body of each municipality in the watershed must review the Plan for consistency with other plans and programs affecting the watershed. Of primary concern during the municipal review would be the draft Monocacy Creek Watershed Act 167 Storm Water Management Model Ordinance, which would implement the Plan through municipal adoption. The output of the municipal review would be a letter directed to the County Council and County Board of Commissioners outlining the municipal suggestions, if any, for revising the draft Plan (or Ordinance) prior to County adoption.
- 3) County Review and Adoption - Upon completion of the review by the Watershed Advisory Committee and each municipality, the draft Plan will be submitted to both the Northampton County Council and Lehigh County Board of Commissioners for their consideration.

The County review of the draft Plan will include a detailed review by the Council and Board of Commissioners and an opportunity for public input through the holding of a public hearing. A public hearing on the draft Plan must be held with a minimum two-week notice period with copies of the draft Plan available for inspection by the general public. Any modifications to the draft Plan would be made by the Counties based upon input from the public hearing, comments received from the municipalities in the watershed or their own review. Adoption of the draft Plan by Northampton County and Lehigh County would be by resolution and require an affirmative vote of the majority of members of the Council and Board of Commissioners, respectively.

The adopted Plan would be submitted by the Lehigh Valley Planning Commission to the Pennsylvania Department of Environmental Protection for their consideration for approval. Accompanying the adopted Plan to the state would be the review comments of the municipalities.

B. Procedure for Updating the Plan

Act 167 specifies that the County must review and, if necessary, revise the adopted and approved plan every five years, at minimum. Any proposed revisions to the Plan would require municipal and public review prior to County adoption consistent with the procedures outlined above. An important aspect of the Plan is a procedure to monitor the implementation of the Plan and initiate review and revisions in a timely manner. The process to be used for the Monocacy Creek Stormwater Management Plan will be as outlined below.



Historic Bethlehem, photo by Craig Kackenmeister, LVPC



Monocacy Park, photo by Craig Kackenmeister, LVPC

- 1) Monitoring of the Plan Implementation - The Lehigh Valley Planning Commission will be responsible for monitoring the implementation of the Plan by maintaining a record of all development activities within the watershed. Development activities are defined as those activities regulated by the Stormwater Management Plan as described in the Municipal Ordinance chapter and included in the Model Municipal Ordinance. Specifically, the Lehigh Valley Planning Commission will monitor the following data records:
 - (a) All subdivision and land developments subject to review per the Plan that have been approved within the watershed.
 - (b) All building permits subject to review per the Plan that have been approved within the watershed.
- 2) Review of Adequacy of Plan - The Lehigh Valley Planning Commission will periodically review the Stormwater Management Plan and determine if the Plan is adequate for minimizing the runoff impacts of new development. At minimum, the information to be reviewed by the Lehigh Valley Planning Commission will be as follows:
 - (a) Development activity data as monitored by the Lehigh Valley Planning Commission.
 - (b) Information regarding additional storm drainage problem areas if provided by the municipalities.
 - (c) Zoning amendments within the watershed.
 - (d) Adequacy of the administrative aspects of regulated activity review.

The Lehigh Valley Planning Commission will review the above data and make recommendations to the Counties as to the need for revisions to the Monocacy Creek Watershed Stormwater Management Plan.



MUNICIPAL ORDINANCE
TO IMPLEMENT
THE MONOCACY CREEK
WATERSHED STORMWATER
MANAGEMENT PLAN

Monocacy Park in Bethlehem, photo by Craig Kackenmeister, LVPC

The implementation of the runoff control strategy for new development will be through municipal adoption of the appropriate ordinance provisions. As part of the preparation of the Monocacy Creek Watershed Stormwater Management Plan, a municipal Ordinance has been prepared that would implement the Plan provisions presented in the Watershed-Level Runoff Control Philosophy and Performance Standards chapter. The Ordinance is a single purpose ordinance that could be adopted essentially as is by the municipalities. Tying provisions would also be required in the municipal subdivision and land development ordinance and the municipal building code to ensure that activities regulated by the Ordinance were appropriately referenced. The Monocacy Creek Watershed Act 167 Stormwater Management Ordinance will not completely replace the existing storm drainage ordinance provisions currently in effect in the Monocacy Creek municipalities. The reasons for this are as follows:

- Not all of the municipalities in the Monocacy Creek Watershed are completely within the watershed. For those portions of the municipality outside of the Monocacy Creek Watershed, the existing ordinance provisions would still apply.
- Only permanent stormwater control facilities are regulated by the Act 167 Ordinance. Stormwater management and erosion and sedimentation control during construction would continue to be regulated under existing laws and ordinances.
- The Act 167 Ordinance contains only those stormwater runoff control criteria and standards that are necessary or desirable from a total watershed perspective. Additional stormwater management design criteria (i.e. inlet spacing, inlet type, collection system details, etc.) that should be based on sound engineering practice should be regulated under the current ordinance provisions or as part of the general responsibilities of the municipal engineer.
- The Act 167 Ordinance contains criteria and standards for runoff control from new development that are the minimum criteria from a watershed perspective. Individual municipalities may adopt more stringent ordinance provisions so long as consistency with the Plan is maintained.

The Act 167 Ordinance is composed of the basic ordinance body and a set of appendices. The body of the document is organized into nine articles as follows:

1. General Provisions
2. Definitions
3. Stormwater Management Requirements
4. Drainage Plan Requirements
5. Inspections
6. Fees and Expenses
7. Stormwater BMP Operations and Maintenance Plan Requirements
8. Prohibitions
9. Right of Entry, Notification and Enforcement

The Appendices include a map of the Monocacy Creek Watershed stormwater management districts and release rate summary table, as well as technical data to be used in the calculation methodology. As adopted by each municipality, the stormwater management districts map and release rate summary table would simply be for that municipality, rather than the whole watershed.

Although the actual stormwater control provisions may vary significantly from an existing municipal ordinance, the structure of the Ordinance itself is very similar to many existing ordinances. The actual ordinance adopted by a municipality to implement the Monocacy Creek Act 167 Plan may differ in form from the Ordinance provided herein so long as it includes, at minimum, all of the provisions of the suggested Ordinance. A municipality may tailor the Ordinance provisions to best fit into their current ordinance structure. Two notes on the Ordinance for municipalities to consider are as follows:

- A “hardship waiver” procedure has been included as Section 407 within Article 4 - Drainage Plan Requirements. A municipality may wish to restructure the waiver procedure into a separate Article perhaps as a formal municipal hearing provision. The minimum requirement of the hardship waiver procedure as adopted by a municipality is that it include all four of the “findings” included with the Plan version of the provision.
- The maintenance provisions included in Article 7 are structured to eliminate any uncertainty as to the party responsible for continuing maintenance. The elimination of “gray areas” of maintenance responsibilities is the minimum criteria imposed by the Ordinance. A municipality may be able to restructure the maintenance provisions to accomplish this minimum goal and place less of a burden on the municipality itself for continuing maintenance.

Presented as the remainder of this chapter is the Monocacy Creek Watershed Act 167 Stormwater Management Plan Model Ordinance.





Intersection of Route 248 and Route 987 in Bath, photo by Craig Kackenmeister, LVPC

MONOCACY CREEK WATERSHED ACT 167 STORMWATER MANAGEMENT ORDINANCE



Monocacy Park, photo by Craig Kackenmeister, LVPC

MONOCACY CREEK WATERSHED ACT 167 STORMWATER MANAGEMENT ORDINANCE

ARTICLE 1 GENERAL PROVISIONS

SECTION 101.SHORT TITLE

The Ordinance shall be known and may be cited as the “Monocacy Creek Watershed Act 167 Stormwater Management Ordinance.”

SECTION 102.STATEMENT OF FINDINGS

The governing body of the municipality finds that:

- A. Inadequate management of accelerated runoff of stormwater resulting from development throughout a watershed increases flood flows and velocities, contributes to erosion and sedimentation, changes the natural hydrologic patterns, destroys aquatic habitat, elevates aquatic pollutant concentrations and loadings, overtaxes the carrying capacity of streams and storm sewers, greatly increases the cost of public facilities to carry and control stormwater, undermines floodplain management and flood control efforts in downstream communities, reduces groundwater recharge, and threatens public health and safety.
- B. A comprehensive program of stormwater management, including reasonable regulation of development and activities causing accelerated erosion and loss of natural infiltration, is fundamental to public health, safety, and welfare and the protection of the people of the municipality and all of the people of the Commonwealth, their resources and the environment.
- C. Stormwater can be an important resource by providing groundwater recharge for water supplies and baseflow of streams, which also protects and maintains surface water quality.
- D. Public education on the control of pollution from stormwater is an essential component in successfully addressing stormwater.
- E. Federal and State regulations require certain municipalities to implement a program for stormwater controls. These municipalities are required to obtain a permit for stormwater discharges from their separate storm sewer systems under the National Pollutant Discharge Elimination System (NPDES).
- F. Non-stormwater discharges to municipal separate storm sewer systems can contribute to pollution of the waters of the Commonwealth.

SECTION 103.PURPOSE

The purpose of this Ordinance is to promote the public health, safety and welfare within the Monocacy Creek Watershed by minimizing the damages and maximizing the benefits described in Section 102 of this Ordinance by provisions designed to:

- A. Manage stormwater runoff impacts at their source by regulating activities which cause stormwater problems.
- B. Utilize and preserve the desirable existing natural drainage systems.

- C. Encourage infiltration of stormwater, where appropriate, to maintain groundwater recharge, to prevent degradation of surface and groundwater quality, and to otherwise protect water resources.
- D. Maintain the existing flows and quality of waterways and wetlands in the municipality and the Commonwealth.
- E. Preserve and restore the flood carrying capacity of streams.
- F. Provide for proper maintenance of all permanent stormwater management BMPs that are implemented in the municipality.
- G. Provide review procedures and performance standards for stormwater planning, design, and management.
- H. Manage stormwater impacts close to the runoff source which requires a minimum of structures and relies on natural processes.
- I. Meet legal water quality requirements under State law, including regulations at 25 Pa. Code Chapter 93.4a to protect and maintain “existing uses” and maintain the level of water quality to support those uses in all streams, and to protect and maintain water quality in “special protection” streams.
- J. Prevent scour and erosion of streambanks and streambeds.
- K. Provide standards to meet the NPDES permit requirements.

SECTION 104. STATUTORY AUTHORITY

The municipality is empowered to regulate these activities by the authority of the Act of October 4, 1978, P.L. 864 (Act 167). 32 P.S. Section 680.1, et seq., as amended, the “Stormwater Management Act”, Act 247, the Pennsylvania Municipalities Planning Code of July 31, 1968, P.L. 805; 53 P.S. §10101, as reenacted and amended, and the [appropriate municipal code].

SECTION 105. APPLICABILITY

This Ordinance shall only apply to those areas of the municipality which are located within the Monocacy Creek Watershed as delineated on an official map available for inspection at the municipal office. A map of the Monocacy Creek Watershed at a reduced scale is included in Appendix A for general reference.

All activities that may affect stormwater runoff, including land development and earth disturbance activity, are subject to regulation by this Ordinance. Regulated activities include:

- A. Land development.
- B. Subdivision.
- C. Construction of new or additional impervious surfaces (driveways, parking lots, etc.).
- D. Construction of new buildings or additions to existing buildings.
- E. Diversion or piping of any natural or man-made stream or channel.

- F. Installation of stormwater systems or appurtenances thereto.
- G. Regulated Earth Disturbance Activities.
- H. Other than that included in 105.A through G, any Earth Disturbance Activities or any activities that include the alteration or development of land in a manner that may affect stormwater runoff onto adjacent property.

SECTION 106. EXEMPTIONS

- A. Impervious Cover – Any proposed Regulated Activity, except those defined in Section 105.E through 105.H, which would create 10,000 square feet or less of additional impervious cover is exempt from the Drainage Plan preparation provisions of this Ordinance. If a site has previously received an exemption and is proposing additional development such that the total impervious cover on the site exceeds 10,000 square feet, and the currently proposed impervious cover is at least 1,000 square feet, a Drainage Plan shall be required for the new proposal.
 - 1. The date of the municipal Ordinance adoption of the original Monocacy Creek Act 167 Stormwater Management Ordinance, March 1989 shall be the starting point from which to consider tracts as “parent tracts” in which future subdivisions and respective impervious area computations shall be cumulatively considered.
 - 2. For development taking place in stages, the entire development plan must be used in determining conformance with these criteria.
 - 3. For a parent tract with a prior exemption, the current Drainage Plan shall control the runoff from only the impervious cover currently proposed, unless the proposed impervious cover is on a building lot from the previous exemption; in such case, all impervious cover proposed on that building lot since the ordinance adoption shall meet the ordinance provisions.
 - 4. Additional impervious cover shall include, but not be limited to, additional indoor living spaces, decks, patios, garages, driveways, storage sheds and similar structures, and roof, parking or driveway areas, and any new streets and sidewalks constructed as part of or for the proposed Regulated Activity.
 - 5. Any additional areas proposed initially to be gravel, crushed stone, porous pavement, etc., shall be assumed to be impervious for the purposes of comparison to the exemption criteria. Any existing gravel, crushed stone or hard-packed soil areas on a site shall be considered as pervious cover for the purpose of exemption evaluation.

If a Drainage Plan is required, the pre- and post-development calculations should be based on actual cover conditions regardless of any assumptions made for purposes of exemption evaluation.

- B. Prior Drainage Plan Approval – Any Regulated Activity for which a Drainage Plan was previously prepared as part of a subdivision or land development proposal that received preliminary plan approval from the municipality prior to the effective date of this Ordinance is exempt from the Drainage Plan preparation provisions of this Ordinance, except as cited in Section 106.D, provided that the approved Drainage Plan included design of stormwater facilities to control runoff from the site currently proposed for Regulated Activities consistent with ordinance provisions in effect at the time of approval, and the approval has not lapsed under the Municipalities Planning Code. If significant revisions are made to the Drainage Plan

after both the preliminary plan approval and the effective date of this Ordinance, preparation of a new Drainage Plan, subject to the provisions of this Ordinance, shall be required. Significant revisions would include a change in control methods or techniques, relocation or redesign of control measures, or changes necessary because soil or other conditions are not as stated on the original Drainage Plan.

- C. Activities associated with 105.H shall be exempt from the Drainage Plan preparation requirements of the Ordinance unless the municipality determines that the activity could create a new or relocated concentrated drainage discharge. Agricultural activity as may be covered by Section 105.H is exempt from the Drainage Plan provisions of this Ordinance.
- D. These exemptions shall not relieve the applicant from implementing such measures as are necessary to protect health, safety and property, and to meet State Water Quality Requirements. These measures include adequate and safe conveyance of stormwater on the site and as it leaves the site. These exemptions do not relieve the applicant from the responsibility to secure permits or approvals for activities regulated by any other applicable code, rule, act, or ordinance.
- E. No exemptions shall be provided for Regulated Activities as defined in Sections 105.E through 105.G.
- F. Agricultural activity is exempt from the rate control and Drainage Plan preparation requirements of this Ordinance provided the activities are performed according to the requirements of 25 Pa. Code 102.
- G. Timber harvesting activities are exempt from the rate control and Drainage Plan preparation requirements of this Ordinance provided the activities are performed according to the requirements of 25 Pa. Code 102.
- H. The municipality may deny or revoke any exemption pursuant to this Section at any time for any project that the municipality believes may pose a threat to public health, safety, property or the environment.

SECTION 107. REPEALER

Any ordinance of the municipality inconsistent with any of the provisions of this Ordinance is hereby repealed to the extent of the inconsistency only.

SECTION 108. SEVERABILITY

Should any section or provision of this Ordinance be declared invalid by a court of competent jurisdiction, such decision shall not affect the validity of any of the remaining provisions of this Ordinance.

SECTION 109. COMPATIBILITY WITH OTHER ORDINANCE REQUIREMENTS

Approvals issued pursuant to this Ordinance do not relieve the applicant of the responsibility to secure required permits or approvals for activities regulated by any other applicable code, rule, act or ordinance.

SECTION 110. DUTY OF PERSONS ENGAGED IN THE DEVELOPMENT OF LAND

Notwithstanding any provisions of this Ordinance, including exemption and waiver provisions, any landowner and any person engaged in the alteration or development of land which may affect stormwater runoff characteristics shall implement such measures as are reasonably necessary to prevent injury to health, safety, or other property. Such measures shall include such actions as are required to manage the rate, volume, direction and quality of resulting stormwater runoff in a manner which otherwise adequately protects health and property from possible injury.

ARTICLE 2 DEFINITIONS

For the purposes of this Ordinance, certain terms and words used herein shall be interpreted as follows:

- A. Words used in the present tense include the future tense; the singular number includes the plural, and the plural number includes the singular; words of masculine gender include feminine gender; and words of feminine gender include masculine gender.
- B. The word “includes” or “including” shall not limit the term to the specific example but is intended to extend its meaning to all other instances of like kind and character.
- C. The words “shall” and “must” are mandatory; the words “may” and “should” are permissive.

Accelerated Erosion – The removal of the surface of the land through the combined action of human activities and natural processes, at a rate greater than would occur because of the natural processes alone.

Agricultural Activity – Activities associated with agriculture such as agricultural cultivation, agricultural operation, and animal heavy use areas. This includes the work of producing crops including tillage, land clearing, plowing, disking, harrowing, planting, harvesting crops or pasturing and raising of livestock and installation of conservation measures. Construction of new buildings or impervious area is not considered an agricultural activity.

Best Management Practice (BMP) – Activities, facilities, measures or procedures used to manage stormwater quantity and quality impacts from the Regulated Activities listed in Section 105, to meet State Water Quality Requirements, to promote groundwater recharge and to otherwise meet the purposes of this Ordinance.

Best Management Practice Operations and Maintenance Plan – Documentation, included as part of a Drainage Plan, detailing the proposed BMPs, how they will be operated and maintained and who will be responsible.

Bioretention – Densely vegetated, depressed features that store stormwater and filter it through vegetation, mulch, planting soil, etc. Ultimately stormwater is evapotranspirated, infiltrated or discharged. Optimal bioretention areas mimic natural forest ecosystems in terms of species diversity, density, distribution, use of native plants, etc.

Buffer – (1) Streamside Buffer – A zone of variable width located along a stream that is vegetated and is designed to filter pollutants from runoff.

(2) Special Geologic Feature Buffer – A required isolation distance from a special geologic feature to a proposed BMP needed to reduce the risk of sinkhole formation due to stormwater management activities.

Capture/Reuse – Stormwater management techniques such as cisterns and rain barrels which direct runoff into storage devices, surface or sub-surface, for later reuse, such as for irrigation of gardens and other planted areas.

Carbonate Bedrock – Rock consisting chiefly of carbonate minerals, such as limestone and dolomite; specifically a sedimentary rock composed of more than 50% by weight of carbonate minerals that underlies soil or other unconsolidated, superficial material.

Cistern – An underground reservoir or tank for storing rainwater.

Closed Depression – A distinctive bowl-shaped depression in the land surface. It is characterized by internal drainage, varying magnitude and an unbroken ground surface.

Concentrated Drainage Discharge – Stormwater runoff leaving a property via a point source.

Conservation District – The Lehigh or Northampton County Conservation District, as applicable.

Constructed Wetlands – Constructed wetlands are similar to wet ponds (see below) and consist of a basin which provides for necessary stormwater storage as well as a permanent pool or water level, planted with wetland vegetation. To be successful, constructed wetlands must have adequate natural hydrology (both runoff inputs as well as soils and water table which allow for maintenance of a permanent pool of water). In these cases, the permanent pool must be designed carefully, usually with shallow edge benches, so that water levels are appropriate to support carefully selected wetland vegetation.

Culvert – A pipe, conduit or similar structure including appurtenant works which carries surface water.

Dam – An artificial barrier, together with its appurtenant works, constructed for the purpose of impounding or storing water or another fluid or semifluid or a refuse bank, fill or structure for highway, railroad or other purposes which does or may impound water or another fluid or semifluid.

DEP – The Pennsylvania Department of Environmental Protection.

Design Storm – The depth and time distribution of precipitation from a storm event measured in probability of occurrence (e.g., 100-yr. storm) and duration (e.g., 24-hour) and used in computing stormwater management control systems.

Detention Basin – A basin designed to retard stormwater runoff by temporarily storing the runoff and releasing it at a predetermined rate.

Developer – A person, partnership, association, corporation or other entity, or any responsible person therein or agent thereof, that undertakes any Regulated Activity of this Ordinance.

Development Site (Site) – The specific tract of land for which a Regulated Activity is proposed.

Diffused Drainage – See Sheet Flow.

Direct Recharge/Subsurface BMP – A BMP designed to direct runoff to groundwater recharge without providing for vegetative uptake. Examples include infiltration trenches, seepage beds, drywells and stormwater drainage wells such that nearly all runoff becomes recharge to groundwater.

Drainage Easement – A right granted by a land owner to a grantee, allowing the use of private land for stormwater management purposes.

Drainage Plan – The documentation of the proposed stormwater quantity and quality management controls to be used for a given development site, including a BMP Operations and Maintenance Plan, the contents of which are established in Section 403.

Earth Disturbance Activity – A construction or other human activity which disturbs the surface of the land, including, but not limited to, clearing and grubbing, grading, excavations, embankments, land development, agricultural activity, timber harvesting activities, road maintenance activities, mineral extraction, building construction and the moving, depositing, stockpiling or storing of soil, rock or earth materials.

Erosion – The removal of soil particles by the action of water, wind, ice or other geological agents.

Existing Uses – Those uses actually attained in the water body on or after November 28, 1975, whether or not they are included in the water quality standards. (25 Pa. Code Chapter 93.1)

Fill – Man-made deposits of natural soils or rock products and waste materials.

Filter Strips – See Vegetated Buffers.

Freeboard – The incremental depth in a stormwater management structure, provided as a safety factor of design, above that required to convey the design runoff event.

Groundwater Recharge – Replenishment of existing natural underground water supplies.

Hardship Waiver Request – A written request for a waiver alleging that the provisions of this Ordinance inflict unnecessary hardship upon the applicant. A Hardship Waiver does not apply to and is not available from the water quality provisions of this Ordinance and should not be granted.

Hot Spot Land Uses – A land use or activity that generates higher concentrations of hydrocarbons, trace metals or other toxic substances than typically found in stormwater runoff. These land uses are listed in Appendix H.

Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS) – The computer-based hydrologic modeling technique developed by the U.S. Army Corps of Engineers and adapted to the Monocacy Creek Watershed for the Act 167 Plan Update. The model was “calibrated” to reflect actual flow values by adjusting key model input parameters.

Hydrologic Soil Group (HSG) – Soils are classified into four HSG’s (A, B, C and D) to indicate the minimum infiltration rates, which are obtained for bare soil after prolonged wetting. The Natural Resources Conservation Service (NRCS) of the U.S. Department of Agriculture defines the four groups and provides a list of most of the soils in the United States and their group classification. Soils become less permeable as the HSG varies from A to D. The soils in the area of the development site may be identified from a web soil survey report that can be accessed at www.websoilsurvey.sc.egov.usda.gov/App/HomePage.htm.

Impervious Surface (Impervious Cover) – A surface which prevents the percolation of water into the ground.

Infiltration Practice – A practice designed to allow runoff an opportunity to infiltrate into the ground (e.g., French drain, seepage pit, seepage trench or bioretention area).

Karst – A type of topography or landscape characterized by surface depressions, sinkholes, rock pinnacles and an uneven bedrock structure, underground drainage and caves. Karst is formed on carbonate rocks, such as limestone or dolomite.

Land Development – Any of the following activities:

- (1) The improvement of one lot or two or more contiguous lots, tracts or parcels of land for any purpose involving (i) a group of two or more residential or nonresidential buildings, whether proposed initially or cumulatively, or a single nonresidential building on a lot or lots regardless of the number of occupants of tenure; or (ii) the division or allocation of land or space between

or among two or more existing or prospective occupants by means of, or for the purpose of streets, common areas, leaseholds, condominiums, building groups or other features.

(2) A subdivision of land.

(3) Development in accordance with Section 503 (1.1) of the Pennsylvania Municipalities Planning Code.

Loading Rate – The ratio of the land area draining to the system, as modified by the weighting factors in Section 308.B. compared to the base area of the infiltration system.

Low Impact Development – A development approach that promotes practices that will minimize post-development runoff rates and volumes thereby minimizing needs for artificial conveyance and storage facilities. Site design practices include preserving natural drainage features, minimizing impervious surface area, reducing the hydraulic connectivity of impervious surfaces and protecting natural depression storage.

“Local” Runoff Conveyance Facilities – Any natural channel or man-made conveyance system which has the purpose of transporting runoff from the site to the Mainstem.

Mainstem (Main Channel) – Any stream segment or other conveyance used as a reach in the Monocacy Creek hydrologic model.

Manning Equation (Manning formula) – A method for calculation of velocity of flow (e.g., feet per second) and flow rate (e.g., cubic feet per second) in open channels based upon channel shape, roughness, depth of flow and slope. “Open channels” may include closed conduits so long as the flow is not under pressure.

Maryland Stormwater Design Manual – A stormwater design manual written by the Maryland Department of the Environment and the Center for Watershed Protection. The Manual can be obtained through the following web site: www.mde.state.md.us.

Minimum Disturbance/Minimum Maintenance Practices (MD/MM) – Site design practices in which careful limits are placed on site clearance prior to development allowing for maximum retention of existing vegetation (woodlands and other), minimum disturbance and compaction of existing soil mantle and minimum site application of chemicals post-development. Typically, MD/MM includes disturbance setback criteria from buildings as well as related site improvements such as walkways, driveways, roadways, and any other improvements. These criteria may vary by community context as well as by type of development being proposed. Additionally, MD/MM shall include provisions (e.g., deed restrictions, conservation easements) to protect these areas from future disturbance and from application of fertilizers, pesticides and herbicides.

Municipality – [municipal name], Lehigh or Northampton County (as applicable), Pennsylvania.

No Harm Runoff Quantity Option – The option of using a less restrictive runoff quantity control if it can be shown that adequate and safe runoff conveyance exists and that the less restrictive control would not adversely affect health, safety and property.

NPDES – National Pollutant Discharge Elimination System.

NRCS – Natural Resources Conservation Service - U.S. Department of Agriculture. (Formerly the Soil Conservation Service.)

Oil/Water Separator – A structural mechanism designed to remove free oil and grease (and possibly solids) from stormwater runoff.

Outfall – “Point source” as described in 40 CFR § 122.2 at the point where the municipality’s storm sewer system discharges to waters of the Commonwealth.

Owner – One with an interest in and often dominion over a property.

Peak Discharge – The maximum rate of flow of stormwater runoff at a given location and time resulting from a specified storm event.

Person – An individual, partnership, public or private association or corporation, firm, trust, estate, municipality, governmental unit, public utility or any other legal entity whatsoever which is recognized by law as the subject of rights and duties.

Point Source – Any discernible, confined and discrete conveyance, including, but not limited to, any pipe, ditch, channel, tunnel or conduit from which stormwater is or may be discharged, as defined in State regulations at 25 Pa. Code § 92.1.

Preliminary Site Investigation – The determination of the depth to bedrock, the depth to the seasonal high water table and the soil permeability for a possible infiltration location on a site through the use of published data and on-site surveys. In carbonate bedrock areas, the location of special geologic features must also be determined along with the associated buffer distance to the possible infiltration area. See Appendix G.

Pre-treatment – Measures implemented for Hot Spot Land Uses designed to reduce the concentration of hydrocarbons, trace metals and other toxic substances to levels typically found in stormwater runoff.

Public Water Supplier – A person who owns or operates a Public Water System.

Public Water System – A system which provides water to the public for human consumption which has at least 15 service connections or regularly serves an average of at least 25 individuals daily at least 60 days out of the year. (See 25 Pa. Code Chapter 109)

Qualified Geotechnical Professional – A licensed professional geologist or a licensed professional engineer who has a background or expertise in geology or hydrogeology.

Rational Method – A method of runoff calculation using a standardized runoff coefficient (rational ‘c’), acreage of tract and rainfall intensity determined by return period and by the time necessary for the entire tract to contribute runoff. The rational method formula for peak rate calculation is stated as follows: $Q = ciA$, where “Q” is the calculated peak flow rate in cubic feet per second, “c” is the dimensionless runoff coefficient (see Appendix C), “i” is the rainfall intensity in inches per hour, and “A” is the area of the tract in acres. The Rational method formula for runoff volume calculation is as follows: $V = cPA/12$ where “c” and “A” are as noted above, “P” is the total depth of precipitation for the design event in inches, and “V” is the total runoff volume in acre-feet.

Reach – Any of the natural or man-made runoff conveyance channels used for watershed runoff modeling purposes to connect the subareas and transport flows downstream.

Regulated Activities – All activities that may affect stormwater runoff, including land development and earth disturbance activity, which are subject to regulation by this Ordinance.

Regulated Earth Disturbance Activities – Activity involving earth disturbance, other than agricultural activity, subject to regulation under 25 Pa. Code 92, 25 Pa. Code 102, or the Clean Streams Law.

Release Rate – The percentage of the pre-development peak rate of runoff for a development site to which the post-development peak rate of runoff must be controlled to avoid peak flow increases throughout the watershed.

Return Period – An expression of the intensity of an event based on its statistical chance of being equaled or exceeded in any given year. An event with a 1% chance in any given year is stated to have a 100-year return period. An event with a 50% chance is stated to have a 2-year return period. Over a very long period of record, events might be expected to recur on average in accordance with their return period.

Road Maintenance – Earth disturbance activities within the existing road cross-section such as grading and repairing existing unpaved road surfaces, cutting road banks, cleaning or clearing drainage ditches and other similar activities.

Runoff – That part of precipitation which flows over the land.

Runoff BMP – A BMP designed for essentially the full volume of runoff entering the BMP to be discharged off-site.

Sediment Traps/Catch Basin Sumps – Chambers which provide storage below the outlet in a storm inlet to collect sediment, debris and associated pollutants, typically requiring periodic clean out.

Seepage Pit/Seepage Trench – An area of excavated earth filled with loose stone or similar material and into which surface water is directed for infiltration into the ground.

Separate Storm Sewer System – A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels or storm drains) primarily used for collecting and conveying stormwater runoff.

Sheet Flow – Stormwater runoff flowing in a thin layer over the ground surface.

Soil-Cover-Complex Method – A method of runoff computation developed by NRCS which is based upon relating soil type and land use/cover to a runoff parameter called a Curve Number.

Special Geologic Features – Carbonate bedrock features, including but not limited to closed depressions, existing sinkholes, fracture traces, lineaments, joints, faults, caves, pinnacles and geologic contacts between carbonate and non-carbonate bedrock which may exist and must be identified on a site when stormwater management BMPs are being considered.

Spill Prevention and Response Program – A program that identifies procedures for preventing and, as needed, cleaning up potential spills and makes such procedures known and the necessary equipment available to appropriate personnel.

State Water Quality Requirements – As defined under State regulations—protection of designated and existing uses (See 25 Pa. Code Chapters 93 and 96)—including:

- A. Each stream segment in Pennsylvania has a “designated use,” such as “cold water fishes” or “potable water supply,” which is listed in Chapter 93. These uses must be protected and maintained, under State regulations.
- B. “Existing uses” are those attained as of November 1975, regardless whether they have been designated in Chapter 93. Regulated Earth Disturbance Activities must be designed to protect and maintain existing uses and maintain the level of water quality necessary to protect those uses in all streams, and to protect and maintain water quality in special protection streams.
- C. Water quality involves the chemical, biological and physical characteristics of surface water bodies. After Regulated Earth Disturbance Activities are complete, these characteristics can be

impacted by addition of pollutants such as sediment, and changes in habitat through increased flow volumes and/or rates as a result of changes in land surface area from those activities. Therefore, permanent discharges to surface waters must be managed to protect the stream bank, streambed and structural integrity of the waterway, to prevent these impacts.

Storage Indication Method – A method of routing or moving an inflow hydrograph through a reservoir or detention structure. The method solves the mass conservation equation to determine an outflow hydrograph as it leaves the storage facility.

Storm Drainage Problem Areas – Areas which lack adequate stormwater collection and/or conveyance facilities and which present a hazard to persons or property. These areas are either documented in Appendix B of this Ordinance or identified by the municipality or municipal engineer.

Storm Sewer – A system of pipes or other conduits which carries intercepted surface runoff, street water and other wash waters, or drainage, but excludes domestic sewage and industrial wastes.

Stormwater – The surface runoff generated by precipitation reaching the ground surface.

Stormwater Drainage Wells – Wells for injection of stormwater to the subsurface that are regulated by the U.S. Environmental Protection Agency to protect underground sources of drinking water.

Stormwater Filters – Any number of structural mechanisms such as multi-chamber catch basins, sand/peat filters, sand filters, and so forth which are installed to intercept stormwater flow and remove pollutants prior to discharge. Typically, these systems require periodic maintenance and clean out.

Stormwater Management Plan – The plan for managing stormwater runoff adopted by Lehigh and/or Northampton County for the Monocacy Creek Watershed as required by the Act of October 4, 1978, P.L. 864, (Act 167), as amended, and known as the “Stormwater Management Act”.

Stream – A Watercourse.

Subarea – The smallest unit of watershed breakdown for hydrologic modeling purposes for which the runoff control criteria have been established in the Stormwater Management Plan.

Subdivision – The division or redivision of a lot, tract or parcel of land by any means into two or more lots, tracts, parcels or other divisions of land including changes in existing lot lines for the purpose, whether immediate or future, of lease, partition by the court for distribution to heirs or devisees, transfer of ownership or building or lot development: provided, however, that the subdivision by lease of land for agricultural purposes into parcels of more than ten acres, not involving and new street or easement of access or any residential dwelling, shall be exempted.

Surface Waters – Perennial and intermittent streams, rivers, lakes, reservoirs, ponds, wetlands, springs, natural seeps and estuaries, excluding water at facilities approved for wastewater treatment such as wastewater treatment impoundments, cooling water ponds and constructed wetlands used as part of a wastewater treatment process.

Swale – A low-lying stretch of land which gathers or carries surface water runoff. See also Vegetated Swale.

Technical Best Management Practice Manual & Infiltration Feasibility Report, November 2002 – The report written by Cahill Associates that addresses the feasibility of infiltration in carbonate bedrock areas in the Little Lehigh Creek Watershed. The report is available at the Lehigh Valley Planning Commission offices.

Timber Harvesting Activities – Earth disturbance activities, including the construction of skid trails, logging roads, landing areas and other similar logging or silvicultural practices.

Trash/Debris Collectors – Racks, screens or other similar devices installed in a storm drainage system to capture coarse pollutants (trash, leaves, etc.).

Vegetated Buffers – Gently sloping areas that convey stormwater as sheet flow over a broad, densely vegetated earthen area, possibly coupled with the use of level spreading devices. As water quality BMPs, vegetated buffers serve to filter pollutants from runoff and promote infiltration. Vegetated buffers should be situated on minimally disturbed soils, have low-flow velocities and extended residence times. Vegetated buffers may be, but are not restricted to, use in riparian (streamside) conditions.

Vegetated Roofs – Vegetated systems installed on roofs that generally consist of a waterproof layer, a root-barrier, drainage layer (optional), growth media, and suitable vegetation. Vegetated roofs store and eventually evapotranspire the collected rooftop rainfall; overflows may be provided for larger storms.

Vegetated Swales – Vegetated earthen channels designed to convey and possibly treat stormwater. As water quality BMPs, these are broad, shallow, densely vegetated, earthen channels designed to treat stormwater through infiltration, evapotranspiration, and sedimentation. Swales should be gently sloping with low flow velocities to prevent erosion. Check dams may be added to enhance performance.

Vegetated/Surface BMP – A BMP designed to provide vegetative uptake and soil renovation or surface infiltration of runoff. Capture/reuse BMPs are included if the captured runoff is applied to vegetated areas. Examples include bioretention and surface infiltration basins.

Watercourse – Any channel of conveyance of surface water having defined bed and banks, whether natural or artificial, with perennial or intermittent flow.

Water Quality Inserts – Any number of commercially available devices that are inserted into storm inlets to capture sediment, oil, grease, metals, trash, debris, etc.

Water Quality Volume (WQv) – The increase in runoff volume on a development site associated with a 2-year, 24-hour storm event.

Waters of the Commonwealth – Any and all rivers, streams, creeks, rivulets, impoundments, ditches, watercourses, storm sewers, lakes, dammed water, wetlands, ponds, springs and all other bodies or channels of conveyance of surface water, or parts thereof, whether natural or artificial, within or on the boundaries of this Commonwealth.

Watershed – The entire region or area drained by a river or other body of water, whether natural or artificial.

Wet Detention Ponds – Basins that provide for necessary stormwater storage as well as a permanent pool of water. To be successful, wet ponds must have adequate natural hydrology (both runoff inputs as well as soils and water table which allow for maintenance of a permanent pool of water) and must be able to support a healthy aquatic community so as to avoid creation of mosquito and other health and nuisance problems.

**ARTICLE 3
STORMWATER MANAGEMENT REQUIREMENTS**

SECTION 301. GENERAL REQUIREMENTS

- A. All Regulated Activities in the municipality shall be subject to the stormwater management requirements of this Ordinance.
- B. Storm drainage systems shall be designed to preserve natural watercourses except as modified by stormwater detention facilities, recharge facilities, water quality facilities, pipe systems or open channels consistent with this Ordinance.
- C. The existing locations of concentrated drainage discharge onto adjacent property shall not be altered without written approval of the affected property owner(s).
- D. Areas of existing diffused drainage discharge onto adjacent property shall be managed such that, at minimum, the peak diffused flow does not increase in the general direction of discharge, except as otherwise provided in this Ordinance. If diffused flow is proposed to be concentrated and discharged onto adjacent property, the developer must obtain the written approval of the affected property owner(s). Areas of existing diffused drainage discharge shall be subject to any applicable release rate criteria in the general direction of existing discharge whether they are proposed to be concentrated or maintained as diffused drainage areas.
- E. Where a site is traversed by watercourses other than those for which a 100-year floodplain is defined by the municipality, there shall be provided drainage easements conforming substantially with the line of such watercourses. The width of any easement shall be adequate to provide for unimpeded flow of storm runoff based on calculations made in conformance with Section 308 for the 100-year return period runoff and to provide a freeboard allowance of one-half (0.5) foot above the design water surface level. The terms of the easement shall prohibit excavation, the placing of fill or structures, and any alterations which may adversely affect the flow of stormwater within any portion of the easement. Also, periodic maintenance of the easement to ensure proper runoff conveyance shall be required. Watercourses for which the 100-year floodplain is formally defined are subject to the applicable municipal floodplain regulations.
- F. Post construction BMPs shall be designed, installed, operated and maintained to meet the requirements of the Clean Streams Law and implementing regulations, including the established practices in 25 Pa. Code Chapter 102 and the specifications of this Ordinance as to prevent accelerated erosion in watercourse channels and at all points of discharge.
- G. No Earth Disturbance Activities associated with any Regulated Activities shall commence until approval by the municipality of a plan which demonstrates compliance with the requirements of this Ordinance.
- H. Techniques described in Appendix F (Low Impact Development Practices) of this Ordinance are encouraged because they reduce the costs of complying with the requirements of this Ordinance and the State Water Quality Requirements.
- I. Infiltration for stormwater management is encouraged where soils and geology permit, consistent with the provisions of this Ordinance and, where appropriate, the Recommendation Chart for Infiltration Stormwater Management BMPs in Carbonate Bedrock in Appendix D.

SECTION 302. PERMIT REQUIREMENTS BY OTHER GOVERNMENT ENTITIES

- A. Other regulations contain independent permit requirements that apply to certain Regulated and Earth Disturbance Activities eligible for authorization by the Municipality in accordance with the permitting requirements in this Ordinance. Permit requirements pursuant to those other regulations must be met prior to commencement, and during the conduct, of such Regulated and Earth Disturbance Activities, as applicable:
 - 1. All Regulated and Earth Disturbance Activities subject to permit requirements by DEP under regulations at 25 Pa. Code Chapter 102.
 - 2. Work within natural drainageways subject to permit by DEP under 25 Pa. Code Chapter 102 and Chapter 105.
 - 3. Any stormwater management facility that would be located in or adjacent to surface waters, including wetlands, subject to permit by DEP under 25 Pa. Code Chapter 105.
 - 4. Culverts, bridges, storm sewers or any other facilities which must pass or convey flows from the tributary area and any facility which may constitute a dam subject to permit by DEP under 25 Pa. Code Chapter 105.
 - 5. Projects that involve use of PennDOT right-of-way, or that involve new discharges onto or toward PennDOT right-of-way, are subject to the requirements, including the permitting requirements, of Title 67, Chapter 441 of the Pennsylvania Code.

SECTION 303. EROSION AND SEDIMENT CONTROL DURING REGULATED EARTH DISTURBANCE ACTIVITIES

- A. No Regulated Earth Disturbance Activities within the municipality shall commence until approval by the municipality of an Erosion and Sediment Control Plan for construction activities. Written approval by DEP or a delegated County Conservation District shall satisfy this requirement.
- B. A written Erosion and Sediment Control Plan is required by DEP regulations for any Earth Disturbance Activity under Pa. Code § 102.4(b).
- C. A DEP NPDES Stormwater Discharges Associated with Construction Activities Permit is required for Regulated Earth Disturbance Activities of one acre or greater under Pa. Code Chapter 92.
- D. Evidence of any necessary permit(s) for Regulated Earth Disturbance Activities from the appropriate DEP regional office or County Conservation District must be provided to the municipality before the commencement of an Earth Disturbance Activity.
- E. A copy of the Erosion and Sediment Control Plan and any permit, as required by DEP regulations, shall be available at the project site at all times.

SECTION 304. POST CONSTRUCTION WATER QUALITY CRITERIA

- A. No Regulated Earth Disturbance Activities within the municipality shall commence until approval by the municipality of a Drainage Plan which demonstrates compliance with this Ordinance.

- B. The Water Quality Volume (WQv) shall be captured and treated with Vegetated/Surface and/or Direct Recharge/Subsurface BMPs. The WQv shall be calculated as the difference in runoff volume from pre-development to post-development for the 24-hour, 2-year return period storm. This may be calculated using either the Soil-Cover-Complex Method or Rational Method using the 2-year rainfall depth as noted in Section 308.I. The effect of closed depressions on the site shall be considered in this calculation. The WQv shall be captured and treated in a manner consistent with the standards outlined in Section 305 of the Ordinance.
- C. The WQv shall be calculated for each post-development drainage direction on a site for sizing BMPs. Site areas having no impervious cover and no proposed disturbance during development may be excluded from the WQv calculations and do not require treatment.
- D. The applicant shall document the bedrock type(s) present on the site from published sources. Any apparent boundaries between carbonate and non-carbonate bedrock shall be verified through more detailed site evaluations by a qualified geotechnical professional.
- E. For each proposed Regulated Activity in the watershed where an applicant intends to use infiltration BMPs, the applicant shall conduct a Preliminary Site Investigation, including gathering data from published sources, a field inspection of the site, a minimum of one test pit and a minimum of two percolation tests, as outlined in Appendix G. This investigation will determine depth to bedrock, depth to the seasonal high water table, soil permeability and location of special geologic features, if applicable. This investigation may be done by a certified Sewage Enforcement Officer (SEO) except that the location(s) of special geologic features shall be verified by a qualified geotechnical professional.
- F. Sites where applicants intend to use infiltration BMPs must meet the following criteria:
- Depth to bedrock below the invert of the BMP greater than or equal to 2 feet.
 - Depth to seasonal high water table below the invert of the BMP greater than or equal to 2 feet; except for infiltration of residential roof runoff where the seasonal high water table must be below the invert of the BMP.
 - Soil permeability (as measured using the standards listed in Appendix C of the Pennsylvania Stormwater Best Practices Manual) greater than or equal to 0.1 inches/hour and less than or equal to 10 inches per hour.
 - Setback distances or buffers as follows:
 - 100 feet from water supply wells, or 50 feet in residential development.
 - 10 feet downgradient or 100 feet upgradient from building foundations.
 - 50 feet from septic system drainfields.
 - 50 feet from a geologic contact with carbonate bedrock unless a Preliminary Site Investigation is done in the carbonate bedrock to show the absence of special geologic features within 50 feet of the proposed infiltration area.
- G. In entirely carbonate areas, where the applicant intends to use infiltration BMPs, the Preliminary Site Investigation described in Appendix G shall be conducted. For infiltration areas that appear feasible based on the Preliminary Site Investigation, the applicant shall conduct the Additional Site Investigation and Testing as outlined in Appendix G. The soil depth, percolation rate and proposed loading rate, each weighted as described in Section 308, along with the buffer from special geologic features shall be compared to the Recommendation Chart for Infiltration Stormwater Management BMPs in Carbonate Bedrock in Appendix D to determine if the site is recommended for infiltration. In addition to the recommendation from Appendix D, the conditions listed in Section 304.F are required for infiltration in carbonate areas.
- H. Site areas proposed for infiltration shall be protected from disturbance and compaction except as necessary for construction of infiltration BMPs.

- I. If infiltration of the entire WQv is not proposed, the remainder of the WQv shall be treated by acceptable BMPs for each discharge location. Acceptable BMPs are listed in Appendix H.
- J. Stormwater runoff from Hot Spot land uses shall be pre-treated. Suggested methods of pre-treatment are listed in Appendix H.
- K. The use of infiltration BMPs is prohibited on Hot Spot land use areas unless the applicant can demonstrate that existing and proposed site conditions, including any proposed runoff pre-treatment, create conditions suitable for runoff infiltration under this Ordinance.
- L. Stormwater infiltration BMPs shall not be placed in or on a special geologic feature(s). Additionally, stormwater runoff shall not be discharged into existing on-site sinkholes.
- M. Stormwater drainage wells may only be used for runoff from roof areas.
- N. Applicants shall request, in writing, Public Water Suppliers to provide the Zone I Wellhead Protection radius, as calculated by the method outlined in the Pennsylvania Department of Environmental Protection Wellhead Protection regulations, for any public water supply well within 400 feet of the site. In addition to the setback distances specified in Section 304.F, infiltration is prohibited in the Zone I radius as defined and substantiated by the Public Water Supplier in writing. If the applicant does not receive a response from the Public Water Supplier, the Zone I radius is assumed to be 100 feet.
- O. The municipality may, after consultation with DEP, approve alternative methods for meeting the State Water Quality Requirements other than those in this Ordinance, provided that they meet the minimum requirements of, and do not conflict with, State law including but not limited to the Clean Streams Law.

SECTION 305. GREEN INFRASTRUCTURE AND EXISTING WATER BALANCE PRESERVATION STANDARDS

- A. The entire WQv as calculated in Section 304.B of this Ordinance shall be captured and treated by either Direct Recharge/Subsurface and/or Vegetated/Surface BMPs.
- B. As much proposed impervious area as practical shall be directed to water quality BMPs.
- C. Existing impervious area that is not proposed to be treated by Direct Recharge/Subsurface BMPs should be excluded from all water balance calculations.
- D. Vegetated/Surface BMPs shall be employed "first" for the site to capture the equivalent of a minimum of 0.38 inches of runoff for each square foot of impervious area, unless proven not feasible by the applicant. For proposed impervious cover directed to multiple BMPs, the Vegetated/Surface BMP capture volume chart in Appendix C shall be used to determine overall site compliance. Direct Recharge/Subsurface BMPs may be used "first" for portions of the impervious cover provided the overall Vegetated/Surface BMP "first" standard is met.
- E. A maximum of 30% of the total annual rainfall for a site may be directly recharged to groundwater using Direct Recharge/Subsurface BMPs, for runoff from impervious areas.
 - 1. For development sites with greater than 33% proposed impervious cover:
 - a. If all impervious cover is directed to Vegetated/Surface BMPs to capture the entire 2-year, 24-hour event, the Direct Recharge standard is met.

- b. Up to 33% of the site as impervious cover may be directed to Direct Recharge/Subsurface BMPs designed to capture the entire 2-year, 24-hour event provided the overall Vegetated/Surface BMP “first” standard is met. All remaining impervious cover shall be directed to Vegetated/Surface BMPs designed to capture the remainder of the WQv.
 - c. For Vegetated/Surface and/or Direct Recharge/Subsurface BMPs designed for runoff from impervious areas designed to capture less than the entire 2-year, 24-hour event, Appendix C shall be used to assure that the maximum Direct Recharge standard is met.
2. The maximum 30% Direct Recharge standard applies on an overall site basis, rather than in each drainage direction.

SECTION 306. STORMWATER MANAGEMENT DISTRICTS

- A. Mapping of Stormwater Management Districts - To implement the provisions of the Monocacy Creek Watershed Stormwater Management Plan, the municipality is hereby divided into Stormwater Management Districts consistent with the Monocacy Creek Release Rate Map presented in the Plan. The boundaries of the Stormwater Management Districts are shown on an official map which is available for inspection at the municipal office. A copy of the official map at a reduced scale is included in Appendix A for general reference.
- B. Release Rate Districts - There are six single release rate districts that differ in the extent to which the post-development runoff must be controlled. The release rate districts are 50%, 60%, 70%, 80%, 90% and 100%. Within a given district, the post-development peak rate of storm runoff must be controlled to the stated percentage of the pre-development peak rate of runoff for each of the 10-, 25-, 50- and 100-year return period storms to protect downstream watershed areas.

There is one dual release rate district. Within this district, the 10-year return period event needs to meet a 30% release rate, and the 25-year and higher return period events need to meet a 100% release rate.

- C. Conditional No Detention Districts - These watershed areas peak very early with respect to the total watershed peak flow and contribute very minimal flow to the watershed peak flow. For that reason, these watershed areas may discharge post-development peak runoff without detention for the 10- through 100-year return periods without adversely affecting the total watershed peak flow. These areas are designated as "conditional" no detention areas because in certain instances the “local” runoff conveyance facilities, which transport runoff from the site to the main channel, may not have adequate capacity to safely transport the peak flows associated with no detention for a proposed development. In those instances, a 100% release rate control would have to be provided or, alternately, the capacity deficiency(ies) would have to be corrected.

SECTION 307. STORMWATER MANAGEMENT DISTRICT IMPLEMENTATION PROVISIONS

- A. Applicants shall provide a comparative pre- and post construction stormwater management hydrograph analysis for each direction of discharge and for the site overall to demonstrate compliance with the provisions of this Ordinance.
- B. Any stormwater management controls required by this Ordinance and subject to release rate criteria shall meet the applicable release rate criteria for each of the 2-, 10-, 25-, 50- and 100-year return period runoff events consistent with the calculation methodology specified in

Section 308.

- C. The exact location of the Stormwater Management District boundaries as they apply to a given development site shall be determined by mapping the boundaries using the two-foot topographic contours provided as part of the Drainage Plan. The District boundaries as originally drawn coincide with topographic divides or, in certain instances, are drawn from the intersection of the watercourse and a physical feature such as the confluence with another watercourse or a potential flow obstruction (e.g., road, culvert, bridge, etc.). The physical feature is the downstream limit of the subarea, and the subarea boundary is drawn from that point up slope to each topographic divide along the path perpendicular to the contour lines.
- D. Any downstream capacity analysis conducted in accordance with this Ordinance shall use the following criteria for determining adequacy for accepting increased peak flow rates:
 - 1. Natural or man-made channels or swales must be able to convey the increased runoff associated with a 2-year return period event within their banks at velocities consistent with protection of the channels from erosion.
 - 2. Natural or man-made channels, swales, culverts, bridges, storm sewers or any other facilities which must convey flows from the tributary area must be able to convey the increased 25-year return period runoff.
- E. For a proposed development site located within one release rate category subarea, the total runoff from the site shall meet the applicable release rate criteria. For development sites with multiple directions of runoff discharge, individual drainage directions may be designed for up to a 100% release rate so long as the total runoff from the site is controlled to the applicable release rate.
- F. For a proposed development site located within two or more release rate category subareas, the peak discharge rate from any subarea shall be the pre-development peak discharge for that subarea multiplied by the applicable release rate. The calculated peak discharges shall apply regardless of whether the grading plan changes the drainage area by subarea. An exception to the above may be granted if discharges from multiple subareas re-combine in proximity to the site. In this case, peak discharge in any direction may be a 100% release rate provided that the overall site discharge meets the weighted average release rate.
- G. For sites straddling major watershed divides (e.g., Monocacy Creek and Bushkill Creek), runoff volumes shall be managed to prevent diversion of runoff between watersheds, as practicable.
- H. Within a release rate category area, for a proposed development site which has areas which drain to a closed depression(s), the design release from the site will be the lesser of (a) the applicable release rate flow assuming no closed depression(s) or (b) the existing peak flow actually leaving the site. In cases where (b) would result in an unreasonably small design release, the design discharge of less than or equal to the release rate will be determined by the available downstream conveyance capacity to the main channel calculated using Section 307.D and the minimum orifice criteria.
- I. Off-site areas which drain through a proposed development site are not subject to release rate criteria when determining allowable peak runoff rates. However, on-site drainage facilities shall be designed to safely convey off-site flows through the development site using the capacity criteria in Section 307.D and the detention criteria in Section 308. In addition to the criteria in Section 307.D, on-site conveyance systems designed to carry runoff to a detention basin must be able to transport the basin's 100-year tributary flow either in-system, in-gutter or overland.

Monocacy Creek Act 167 Plan

- J. For development sites proposed to take place in phases, all detention ponds shall be designed to meet the applicable release rate(s) applied to all site areas tributary to the proposed pond discharge direction. All site tributary areas will be assumed as developed, regardless of whether all site tributary areas are proposed for development at that time. An exception shall be sites with multiple detention ponds in series where only the downstream pond must be designed to the stated release rate.
- K. Where the site area to be impacted by a proposed development activity differs significantly from the total site area, only the proposed impact area shall be subject to the release rate criteria. The impact area includes any proposed cover or grading changes.
- L. Development proposals which, through groundwater recharge or other means, do not increase either the rate or volume of runoff discharged from the site compared to pre-development are not subject to the release rate provisions of this Ordinance.
- M. “No Harm” Water Quantity Option - For any proposed development site, the developer has the option of using a less restrictive runoff control if the developer can prove that special circumstances exist for the proposed development site and that “no harm” would be caused by discharging at a higher runoff rate than that specified by this Ordinance. Special circumstances are defined as any hydrologic or hydraulic aspects of the development itself not accommodated by the runoff control standards of this Ordinance. Proof of “no harm” would have to be shown from the development site through the remainder of the downstream drainage network to the confluence of the Monocacy Creek with the Lehigh River. Proof of “no harm” must be shown using the capacity criteria specified in Section 307.D. if downstream capacity analysis is a part of the “no harm” justification.

Attempts to prove “no harm” based upon downstream peak flow versus capacity analysis shall be governed by the following provisions:

1. Any available capacity in the downstream conveyance system as documented by a developer may be used by the developer only in proportion to his development site acreage relative to the total upstream undeveloped acreage from the identified capacity (i.e. if his site is 10% of the upstream undeveloped acreage, he may use up to 10% of the documented downstream available capacity).
2. Developer-proposed runoff controls which would generate increased peak flow rates at storm drainage problem areas would, by definition, be precluded from successful attempts to prove “no harm”.
3. Any downstream capacity improvements proposed by the developer as part of a “no harm” justification would be designed using the capacity criteria specified in Section 307.D. Peak flow contributions to the proposed improvements shall be calculated as the larger of: (1) assuming the local watershed is in the existing condition, or (2) assuming that the local watershed is developed per current zoning and using the specified runoff controls.

Any “no harm” justifications shall be submitted by the developer as part of the Drainage Plan submission per Article 4. Developers submitting “no harm” justifications must still meet all of the water quality requirements in Section 304. The municipality will process all eligible “no harm” requests in accordance with Section 304.O.

- N. Capacity Improvements - In certain instances, local drainage conditions may dictate more stringent levels of runoff control than those based upon protection of the entire watershed. In these instances, if the developer could prove that it would be feasible to provide capacity improvements to relieve the capacity deficiency in the local drainage network, then the capacity improvements could be provided by the developer in lieu of runoff controls on the

development site. Peak flow calculations shall be done assuming that the local watershed is in the existing condition and then assuming that the local watershed is developed per current zoning and using the specified runoff controls. Any capacity improvements would be designed using the larger of the above peak flows and the capacity criteria specified in Section 307.D. All new development in the entire subarea(s) within which the proposed development site is located shall be assumed to implement the developer's proposed discharge control, if any.

- O. Release Rates need to be met year round. Designs involving BMPs that function differently in winter versus non-winter conditions (e.g., capture/reuse with spray irrigation shut off for the winter) must still meet release rates during the winter.

SECTION 308. CALCULATION METHODOLOGY

- A. Stormwater runoff from all development sites shall be calculated using either the Rational Method or the Soil-Cover-Complex methodology.
- B. Infiltration BMP loading rate percentages in the Recommendation Chart for Infiltration Stormwater Management BMPs in Carbonate Bedrock in Appendix D shall be calculated as follows:

$$\frac{\text{Area Tributary to infiltration BMP}}{\text{Base Area of infiltration BMP}} * 100\%$$

The area tributary to the infiltration BMP shall be weighted as follows:

All disturbed areas to be made impervious:	weight at 100%
All disturbed areas to be made pervious:	weight at 50%
All undisturbed pervious areas:	weight at 0%
All existing impervious areas:	weight at 100%

- C. The design of any detention basin intended to meet the requirements of this Ordinance shall be verified by routing the design storm hydrograph through the proposed basin using the storage indication method or other methodology demonstrated to be more appropriate. For basins designed using the Rational Method technique, the design hydrograph for routing shall be either the Universal Rational Hydrograph or another Rational hydrograph that closely approximates the volume of the Universal Rational Hydrograph.
- D. BMPs designed to store or infiltrate runoff and discharge to surface runoff or pipe flow shall be routed using the storage indication method.
- E. BMPs designed to store or infiltrate runoff and discharge to surface runoff or pipe flow shall provide storage volume for the full WQv below the lowest outlet invert.
- F. Wet Detention Ponds designed to have a permanent pool for the WQv shall assume that the permanent pool volume below the primary outlet is full at the beginning of design event routing for the purposes of evaluating peak outflows.
- G. All above-ground stormwater detention facilities shall provide a minimum 0.5 feet of freeboard above the maximum pool elevation associated with the 2- through 100-year runoff events, or an additional ten percent of the 100-year storage volume as freeboard volume, whichever is greater. All below-ground stormwater detention and infiltration facilities shall have an additional ten percent of the 100-year storage volume available within the storage medium, as well as a minimum of 0.5 feet of freeboard. The freeboard shall be measured from the maximum pool elevation to the invert of the emergency spillway for above-ground facilities, and from the maximum pool elevation to the lowest overflow elevation for below-ground

facilities. The 2- through 100-year storm events shall be controlled by the primary outlet structure. An emergency spillway for each above-ground basin shall be designed to pass the 100-year return frequency storm peak basin inflow rate with a minimum 0.5 foot freeboard measured to the top of basin. The freeboard criteria shall be met considering any off-site areas tributary to the basin as developed, as applicable. Exceptions to the freeboard requirements are as follows:

1. Bioretention BMPs with a ponded depth less than or equal to 0.5 feet are exempt from the freeboard requirements.
2. Small detention basins, with a ponded depth less than or equal to 1.5 feet or having a depth to the top of the berm less than or equal to 2.5 feet, may provide twenty percent additional storage volume measured from the maximum ponded depth to the invert of the emergency spillway in lieu of the above requirements. The depth of the emergency spillway must be sufficient to pass either two times the 100-year peak or the 100-year peak with 0.2' of freeboard to the top of berm, whichever is greater.
3. Small infiltration basins, with a ponded depth less than or equal to 1.5 feet or having a depth to the top of the berm less than or equal to 2.5 feet, may provide twenty percent additional storage volume measured from the maximum ponded depth to the top of the berm in lieu of the above requirements. In this case, an emergency spillway is only necessary if runoff in excess of the basin volume would cause harm to downstream owners. If a spillway is necessary, it must be sufficiently sized to pass the 100-year peak inflow.

If this detention facility is considered to be a dam as per DEP Chapter 105, the design of the facility must be consistent with the Chapter 105 regulations, and may be required to pass a storm greater than the 100-year event.

- H. The minimum circular orifice diameter for controlling discharge rates from detention facilities shall be three (3) inches. Designs where a lesser size orifice would be required to fully meet release rates shall be acceptable with a 3-inch orifice provided that as much of the site runoff as practical is directed to the detention facilities. The minimum 3-inch diameter does not apply to the control of the WQv.
- I. Runoff calculations using the Soil-Cover-Complex method shall use the Natural Resources Conservation Service Type II 24-hour rainfall distribution. The 24-hour rainfall depths for the various return periods to be used consistent with this Ordinance may be taken from NOAA Atlas 14, Precipitation Frequency Atlas of the United States, current volume, or the Pennsylvania Department of Transportation Drainage Manual, 2015 Edition for Region 4. The following values are taken from the Drainage Manual:

<u>Return Period</u>	<u>24-Hour Rainfall Depth</u>
1-year	2.64 inches
2-year	3.16 inches
5-year	3.91 inches
10-year	4.57 inches
25-year	5.60 inches
50-year	6.53 inches
100-year	7.63 inches

A graphical and tabular presentation of the Type II-24 hour distribution is included in Appendix C.

- J. Runoff calculations using the Rational Method shall use rainfall intensities consistent with appropriate times of concentration and return periods and NOAA Atlas 14, Precipitation

Frequency Atlas of the United States Precipitation and Intensity Charts, current volume, as presented in Appendix C.

- K. Runoff Curve Numbers (CN's) to be used in the Soil-Cover-Complex method shall be based upon the table presented in Appendix C.
- L. Runoff coefficients for use in the Rational Method shall be based upon the table presented in Appendix C.
- M. All time of concentration calculations shall use a segmental approach which may include one or all of the flow types below:
 - 1. Sheet Flow (overland flow) calculations shall use either the NRCS average velocity chart (Figure 3-1, Technical Release-55, 1975) or the modified kinematic wave travel time equation (equation 3-3, NRCS TR-55, June 1986). If using the modified kinematic wave travel time equation, the sheet flow length shall be limited to 50 feet for designs using the Rational Method and limited to 150 feet for designs using the Soil-Cover-Complex method.
 - 2. Shallow Concentrated Flow travel times shall be determined from the watercourse slope, type of surface and the velocity from Figure 3-1 of TR-55, June 1986.
 - 3. Open Channel Flow travel times shall be determined from velocities calculated by the Manning Equation. Bankfull flows shall be used for determining velocities. Manning 'n' values shall be based on the table presented in Appendix C.
 - 4. Pipe Flow travel times shall be determined from velocities calculated using the Manning Equation assuming full flow and the Manning 'n' values from Appendix C.
- N. If using the Rational Method, all pre-development calculations for a given discharge direction shall be based on a common time of concentration considering both on-site and any off-site drainage areas. If using the Rational Method, all post-development calculations for a given discharge direction shall be based on a common time of concentration considering both on-site and any off-site drainage areas.
- O. When conditions exist such that a proposed detention facility may experience a tailwater effect, the basin shall be analyzed without any tailwater effect for all storm events for comparison against the required Release Rates. An additional routing of the 100-year storm with the full tailwater effect shall be performed to check that the basin has sufficient storage to contain the 100-year tributary flow and meet freeboard requirements.
- P. The Manning Equation shall be used to calculate the capacity of watercourses. Manning 'n' values used in the calculations shall be consistent with the table presented in Appendix C or other appropriate standard engineering 'n' value resources. Pipe capacities shall be determined by methods acceptable to the municipality.
- Q. The Pennsylvania DEP, Chapter 105, Rules and Regulations, apply to the construction, modification, operation or maintenance of both existing and proposed dams, water obstructions and encroachments throughout the watershed. Criteria for design and construction of stormwater management facilities according to this Ordinance may differ from the criteria that are used in the permitting of dams under the Dam Safety Program.

ARTICLE 4 DRAINAGE PLAN REQUIREMENTS

SECTION 401. GENERAL REQUIREMENTS

For any of the Regulated Activities of this Ordinance, prior to the final approval of subdivision and/or land development plans, or the issuance of any permit, or the commencement of any Regulated Earth Disturbance Activity, the owner, subdivider, developer or his agent shall submit a Drainage Plan and receive municipal approval of the Plan.

SECTION 402. EXEMPTIONS

Exemptions from the Drainage Plan Requirements are as specified in Section 106.

SECTION 403. DRAINAGE PLAN CONTENTS

The following items shall be included in the Drainage Plan:

- A. General
 - 1. General description of project.
 - 2. General description of proposed permanent stormwater controls.
 - 3. The name and address of the project site, the name and address of the owner of the property and the name of the individual or firm preparing the Drainage Plan.

- B. Map(s) of the Project Area Showing:
 - 1. The location of the project relative to highways, municipalities or other identifiable landmarks.
 - 2. Existing contours at intervals of two (2) feet. In areas of steep slopes (greater than 15%), five-foot contour intervals may be used. Off-site drainage areas impacting the project including topographic detail.
 - 3. Streams, lakes, ponds or other bodies of water within the project area.
 - 4. Other features including flood hazard boundaries, existing drainage swales, wetlands, closed depressions, sinkholes and areas of natural vegetation to be preserved.
 - 5. Locations of proposed underground utilities, sewers and water lines. The locations of all existing and proposed utilities, sanitary sewers and water lines within 50 feet of property lines of the project site.
 - 6. An overlay showing soil types and boundaries based on the county soil survey, as applicable, latest edition. Any hydric soils present on the site should be identified as such.
 - 7. An overlay showing geologic types, boundaries and any special geologic features present on the site.
 - 8. Proposed changes to land surface and vegetative cover.
 - 9. Proposed structures, roads, paved areas and buildings.

10. Final contours at intervals of two (2) feet. In areas of steep slopes (greater than 15%), five-foot contour intervals may be used.
11. Stormwater Management District boundaries applicable to the site.
12. Clear identification of the location and nature of permanent stormwater BMPs.
13. An adequate access easement around all stormwater BMPs that would provide municipal ingress to and egress from a public right-of-way.
14. A schematic showing all tributaries contributing flow to the site and all existing man-made features beyond the property boundary that would be affected by the project.
15. The location of all public water supply wells within 400 feet of the project and all private water supply wells within 100 feet of the project.

C. Stormwater Management Controls and BMPs

1. All stormwater management controls and BMPs shall be shown on a map and described, including:
 - a. Groundwater recharge methods such as seepage pits, beds or trenches. When these structures are used, the locations of septic tank infiltration areas and wells shall be shown.
 - b. Other control devices or methods such as roof-top storage, semi-pervious paving materials, grass swales, parking lot ponding, vegetated strips, detention or retention ponds, storm sewers, etc.
2. All calculations, assumptions and criteria used in the design of the BMPs shall be shown.
3. All site testing data used to determine the feasibility of infiltration on a site.
4. All details and specifications for the construction of the stormwater management controls and BMPs.

- D. The BMP Operations and Maintenance Plan, as required in Article 7, describing how each permanent stormwater BMP will be operated and maintained and the identity of the person(s) responsible for operations and maintenance. A statement must be included, signed by the landowner, acknowledging that the stormwater BMPs are fixtures that cannot be altered or removed without approval by the municipality.

SECTION 404. PLAN SUBMISSION

- A. For Regulated Activities specified in Sections 105.A. and 105.B:
1. The Drainage Plan shall be submitted by the developer to the municipal secretary (or other appropriate person) as part of the Preliminary Plan submission for the subdivision or land development.
 2. Four (4) copies of the Drainage Plan shall be submitted.
 3. Distribution of the Drainage Plan will be as follows:

- a. One (1) copy to the municipal governing body.
 - b. One (1) copy to the municipal engineer.
 - c. Two (2) copies to the Lehigh Valley Planning Commission (LVPC), except for Drainage Plans involving less than 10,000 square feet of additional impervious cover.
4. Drainage Plans involving more than 10,000 square feet of additional impervious cover shall be submitted by the developer (possibly through the municipality) to the LVPC as part of the Preliminary Plan submission. The LVPC will conduct an advisory review of the Drainage Plan for consistency with the Monocacy Creek Watershed Stormwater Management Plan. The LVPC will not review details of the Erosion and Sedimentation Plan or the BMP Operations and Maintenance Plan.
- a. Two (2) copies of the Drainage Plan shall be submitted.
 - b. The LVPC will provide written comments to the developer and the municipality, within a time frame consistent with established procedures under the Municipalities Planning Code, as to whether the Drainage Plan has been found to be consistent with the Stormwater Management Plan.
- B. For Regulated Activities specified in Sections 105.C. and 105.D, the Drainage Plan shall be submitted by the developer to the municipal building permit officer as part of the building permit application.
- C. For Regulated Activities specified in Sections 105.E, 105.F. and 105.G:
1. The Drainage Plan shall be submitted by the developer to the Lehigh Valley Planning Commission for coordination with the DEP permit application process, as needed, under Chapter 105 (Dam Safety and Waterway Management), Chapter 106 (Flood Plain Management) of DEP's Rules and Regulations and the NPDES regulations.
 2. One (1) copy of the Drainage Plan shall be submitted.
- D. Earthmoving for all Regulated Activities under Section 105 shall be conducted in accordance with the current Federal and State regulations relative to the NPDES and DEP Chapter 102 regulations.

SECTION 405.DRAINAGE PLAN REVIEW

- A. The municipality shall review the Drainage Plan, including the BMP Operations and Maintenance Plan, for consistency with this Ordinance. The municipality shall also review the Drainage Plan against any additional storm drainage provisions contained in the municipal subdivision and land development or zoning ordinance, as applicable.
- B. The municipality shall notify the applicant in writing whether the Drainage Plan, including the BMP Operations and Maintenance Plan, is approved, consistent with time frames as established by the current Pennsylvania Municipalities Planning Code.
- C. The municipality shall not approve any subdivision or land development (Regulated Activities 105.A. and 105.B.) or building permit application (Regulated Activities 105.C. and 105.D.) if the Drainage Plan has been found to be inconsistent with this Ordinance.
- D. The municipality may require an "As-Built Survey" of all stormwater BMPs and an explanation of any discrepancies with the Drainage Plan.

SECTION 406. MODIFICATION OF PLANS

A modification to a Drainage Plan for a proposed development site which involves a change in control methods or techniques, or which involves the relocation or redesign of control measures, or which is necessary because soil or other conditions are not as stated on the Drainage Plan (as determined by the municipality) shall require a resubmission of the modified Drainage Plan consistent with Section 404 subject to review per Section 405 of this Ordinance.

SECTION 407. HARDSHIP WAIVER PROCEDURE

The municipality may hear requests for waivers where it is alleged that the provisions of this Ordinance inflict unnecessary hardship upon the applicant. The waiver request shall be in writing and accompanied by the requisite fee based upon a fee schedule adopted by the municipality. A copy of the waiver request shall be provided to each of the following: municipality, municipal engineer, municipal solicitor and Lehigh Valley Planning Commission. The request shall fully document the nature of the alleged hardship.

The municipality may accept a waiver request provided that the Municipality determines that in each case the request satisfies all of the following findings:

1. That there are unique physical circumstances or conditions, including irregularity of lot size or shape, or exceptional topographical or other physical conditions peculiar to the particular property, and that the unnecessary hardship is due to such conditions, and not the circumstances or conditions generally created by the provisions of this Ordinance in the Stormwater Management District in which the property is located;
2. That because of such physical circumstances or conditions, there is no possibility that the property can be developed in strict conformity with the provisions of this Ordinance, and that the authorization of a waiver is therefore necessary to enable the reasonable use of the property;
3. That such unnecessary hardship has not been created by the applicant;
4. That the waiver, if authorized, will represent the minimum waiver that will afford relief and will represent the least modification possible of the regulation in issue; and
5. That financial hardship is not the criteria for granting of a hardship waiver.

In processing any waiver request, the municipality may attach such conditions and safeguards as it may deem necessary to implement the purposes of this Ordinance. If a Hardship Waiver is granted, the applicant must still manage the quantity, velocity, direction and quality of resulting storm runoff as is necessary to prevent injury to health, safety or other property.

- A. For Regulated Activities described in Section 105.A. and B., the [municipal governing body] shall hear requests for and decide on hardship waiver requests on behalf of the municipality.
- B. For Regulated Activities in Section 105.C, D., E., F. and G., the Zoning Hearing Board shall hear requests for and decide on hardship waiver requests on behalf of the municipality.
- C. The municipality will process all eligible waiver requests in accordance with the provisions of Section 304.O.

**ARTICLE 5
INSPECTIONS**

SECTION 501. SCHEDULE OF INSPECTIONS

- A. DEP or its designees (e.g., County Conservation District) normally ensure compliance with any permits issued, including those for stormwater management. In addition to DEP compliance programs, the municipality or its designee may inspect all phases of the construction, operations, maintenance and any other implementation of stormwater BMPs.
- B. During any stage of the Regulated Earth Disturbance Activities, if the municipality or its designee determines that any BMPs are not being implemented in accordance with permit conditions or this Ordinance, the municipality may suspend or revoke any existing permits issued by the municipality or other approvals issued by the municipality until the deficiencies are corrected.

**ARTICLE 6
FEES AND EXPENSES**

SECTION 601. GENERAL

The municipality may charge a reasonable fee for review of the Drainage Plan, including the BMP Operations and Maintenance Plan, to defray review costs incurred by the municipality. The applicant shall pay all such fees.

SECTION 602. EXPENSES COVERED BY FEES

The fees required by this Ordinance shall at a minimum cover:

- A. The review of the Drainage Plan, including the BMP Operations and Maintenance Plan, by the municipality.
- B. The site inspection.
- C. The inspection of required controls and improvements during construction.
- D. The final inspection upon completion of the controls and improvements required in the plan.
- E. Any additional work required to monitor and enforce any permit provisions, regulated by this Ordinance, correct violations, and assure the completion of stipulated remedial actions.
- F. Administrative and clerical costs.

ARTICLE 7
STORMWATER BMP OPERATIONS AND MAINTENANCE PLAN REQUIREMENTS

SECTION 701. GENERAL REQUIREMENTS

- A. No Regulated Earth Disturbance Activities within the municipality shall commence until approval by the municipality of the BMP Operations and Maintenance Plan which describes how the permanent (e.g., post construction) stormwater BMPs will be properly operated and maintained.

SECTION 702. RESPONSIBILITIES FOR OPERATIONS AND MAINTENANCE OF BMPS

- A. The BMP Operations and Maintenance Plan for the project site shall establish responsibilities for the continuing operation and maintenance of all permanent stormwater BMPs, as follows:
 - 1. If a Plan includes structures or lots which are to be separately owned and in which streets, sewers and other public improvements are to be dedicated to the municipality, stormwater BMPs may also be dedicated to and maintained by the municipality.
 - 2. If a Plan includes operations and maintenance by a single owner or if sewers and other public improvements are to be privately owned and maintained, then the operation and maintenance of stormwater BMPs shall be the responsibility of the owner or private management entity.
- B. The municipality shall make the final determination on the continuing operations and maintenance responsibilities. The municipality reserves the right to accept or reject the operations and maintenance responsibility for any or all of the stormwater BMPs.

SECTION 703. ADHERENCE TO APPROVED BMP OPERATIONS AND MAINTENANCE PLAN

It shall be unlawful to alter or remove any permanent stormwater BMP required by an approved BMP Operations and Maintenance Plan or to allow the property to remain in a condition which does not conform to an approved BMP Operations and Maintenance Plan unless an exception is granted in writing by the municipality.

SECTION 704. OPERATIONS AND MAINTENANCE AGREEMENT FOR PRIVATELY-OWNED STORMWATER BMPS

- A. The property owner shall sign an operations and maintenance agreement with the municipality covering all stormwater BMPs that are to be privately-owned. The agreement shall be substantially the same as the agreement in Appendix E of this Ordinance.
- B. Other items may be included in the agreement where determined by the municipality to be reasonable or necessary to guarantee the satisfactory operation and maintenance of all permanent stormwater BMPs. The agreement shall be subject to the review and approval of the municipality.

SECTION 705. STORMWATER MANAGEMENT EASEMENTS

Stormwater management easements shall be provided by the property owner if necessary for access for inspections and maintenance or for preservation of stormwater conveyance, infiltration, detention areas and other BMPs by persons other than the property owner. The purpose of the easement shall be specified in any agreement under Section 704.

SECTION 706. RECORDING OF APPROVED BMP OPERATIONS AND MAINTENANCE PLAN AND RELATED AGREEMENTS

- A. The owner of any land upon which permanent BMPs will be placed, constructed or implemented, as described in the BMP Operations and Maintenance Plan, shall record the following documents in the county Office of the Recorder of Deeds for Lehigh or Northampton County, as applicable, within 90 days of approval of the BMP Operations and Maintenance Plan by the municipality:
 - 1. The Operations and Maintenance Plan or a summary thereof.
 - 2. Operations and Maintenance Agreements under Section 704.
 - 3. Easements under Section 705.
- B. The municipality may suspend or revoke any approvals granted for the project site upon discovery of the failure of the owner to comply with this Section.

SECTION 707. MUNICIPAL STORMWATER BMP OPERATIONS AND MAINTENANCE FUND

- A. Persons installing stormwater BMPs shall be required to pay a specified amount to the Municipal Stormwater BMP Operations and Maintenance Fund to help defray costs of operations and maintenance activities. The amount may be determined as follows:
 - 1. If the BMP is to be privately-owned and maintained, the amount shall cover the cost of periodic inspections by the municipality in perpetuity, as determined by the municipality.
 - 2. If the BMP is to be owned and maintained by the municipality, the amount shall cover the estimated costs for operation and maintenance in perpetuity, as determined by the municipality.
 - 3. The amount shall then be converted to present worth of the annual series values.
- B. If a BMP is proposed that also serves as a recreation facility (e.g., ball field, lake), the municipality may adjust the amount due accordingly.

**ARTICLE 8
PROHIBITIONS**

SECTION 801. PROHIBITED DISCHARGES AND CONNECTIONS

- A. Any drain or conveyance, whether on the surface or subsurface, that allows any non-stormwater including sewage, process wastewater, and wash water to enter a regulated small municipal separate storm sewer system (MS4) or to enter the surface waters of this Commonwealth is prohibited.
- B. No person shall allow, or cause to allow, discharges into a regulated small MS4, or discharges into waters of this Commonwealth, which are not composed entirely of stormwater, except (1) as provided in paragraph C below and (2) discharges authorized under a state or federal permit.
- C. The following discharges are authorized unless they are determined to be significant contributors to pollution a regulated small MS4 or to the waters of this Commonwealth:
 - 1. Discharges or flows from firefighting activities.

2. Discharges from potable water sources including water line flushing and fire hydrant flushing, if such discharges do not contain detectable concentrations of Total Residual Chlorine (TRC).
 3. Non-contaminated irrigation water, water from lawn maintenance, landscape drainage and flows from riparian habitats and wetlands.
 4. Diverted stream flows and springs.
 5. Non-contaminated pumped ground water and water from foundation and footing drains and crawl space pumps.
 6. Non-contaminated HVAC condensation and water from geothermal systems.
 7. Residential (i.e., not commercial) vehicle wash water where cleaning agents are not utilized.
 8. Non-contaminated hydrostatic test water discharges, if such discharges do not contain detectable concentrations of TRC.
- D. In the event that the municipality or DEP determines that any of the discharges identified in Subsection C significantly contribute pollutants to a regulated small MS4 or to the waters of this Commonwealth, the municipality or DEP will notify the responsible person(s) to cease the discharge.

SECTION 802. ROOF DRAINS AND SUMP PUMPS

Roof drains and sump pumps shall discharge to infiltration or vegetative BMPs wherever feasible.

SECTION 803. ALTERATION OF STORMWATER MANAGEMENT BMPs

No person shall modify, remove, fill, landscape, or alter any stormwater management BMPs, facilities, areas, or structures that were installed as a requirement of this Ordinance without the written approval of the Municipality.

ARTICLE 9 RIGHT OF ENTRY, NOTIFICATION AND ENFORCEMENT

SECTION 901. RIGHT OF ENTRY

- A. Upon presentation of proper credentials and with the consent of the land owner, duly authorized representatives of the municipality may enter at reasonable times upon any property within the municipality to inspect the implementation, condition or operation and maintenance of the stormwater BMPs or to investigate or ascertain the condition of the subject property in regard to any aspect regulated by this Ordinance.

- B. In the event that the land owner refuses admission to the property, duly authorized representatives of the municipality may seek an administrative search warrant issued by a district justice to gain access to the property.

SECTION 902. NOTIFICATION

- A. Whenever the municipality finds that a person has violated a prohibition or failed to meet a requirement of this Ordinance, the municipality may order compliance by written notice to the responsible person. Such notice may require without limitation:
 - 1. The name of the owner of record and any other person against whom the municipality intends to take action.
 - 2. The location of the property in violation.
 - 3. The performance of monitoring, analyses and reporting.
 - 4. The elimination of prohibited connections or discharges.
 - 5. Cessation of any violating discharges, practices or operations.
 - 6. The abatement or remediation of stormwater pollution or contamination hazards and the restoration of any affected property.
 - 7. Payment of a fine to cover administrative and remediation costs.
 - 8. The implementation of stormwater BMPs.
 - 9. Operation and maintenance of stormwater BMPs.
- B. Such notification shall set forth the nature of the violation(s) and establish a time limit for correction of the violation(s). Said notice may further advise that should the violator fail to take the required action within the established deadline, the work will be done by the municipality or designee and the expense thereof, together with all related lien and enforcement fees, charges and expenses, shall be charged to the violator.
- C. Failure to comply within the time specified shall also subject such person to the penalty provisions of this Ordinance. All such penalties shall be deemed cumulative and shall not prevent the municipality from pursuing any and all other remedies available in law or equity.

SECTION 903. PUBLIC NUISANCE

- A. The violation of any provision of this Ordinance is hereby deemed a Public Nuisance.
- B. Each day that an offense continues shall constitute a separate violation.

SECTION 904. SUSPENSION AND REVOCATION OF PERMITS AND APPROVALS

- A. Any building, land development or other permit or approval issued by the municipality may be suspended or revoked by the municipality for:
 - 1. Non-compliance with or failure to implement any provision of the permit.
 - 2. A violation of any provision of this Ordinance.
 - 3. The creation of any condition or the commission of any act during construction or development which constitutes or creates a hazard or nuisance, pollution or which endangers the life or property of others.

- B. A suspended permit or approval shall be reinstated by the municipality when:
 - 1. The municipality or designee has inspected and approved the corrections to the stormwater BMPs or the elimination of the hazard or nuisance.
 - 2. The municipality is satisfied that the violation of the ordinance, law or rule and regulation has been corrected.
 - 3. Payment of all municipal fees, costs and expenses related to or arising from the violation has been made.
- C. A permit or approval which has been revoked by the municipality cannot be reinstated. The applicant may apply for a new permit under the procedures outlined in this Ordinance.

SECTION 905.PENALTIES

- A. Any person, partnership or corporation who or which has violated the provisions of this Ordinance shall, upon being found liable therefore in a civil enforcement proceeding commenced by the municipality, pay a judgment of not more than Five Hundred (\$500.00) Dollars plus all court costs, including reasonable attorney's fees incurred by the municipality as a result thereof. No judgment shall commence or be imposed, levied or payable until the date of the determination of a violation by the district justice. If the defendant neither pays nor timely appeals the judgment, the municipality may enforce the judgment pursuant to a separate violation, unless the district justice, determining that there has been a violation, further determines that there was a good faith basis for the person, partnership, or corporation violating this Ordinance to have believed that there was no such violation, in which event there shall be deemed to have been only one such violation until the fifth (5th) day following the date of the determination of a violation by the district justice and thereafter each day that a violation continues shall constitute a separate violation.
- B. The court of common pleas, upon petition, may grant an order of stay upon cause shown, tolling the per diem judgment pending a final adjudication of the violation and judgment.
- C. Nothing contained in this Section shall be construed or interpreted to grant to any person or entity other than the municipality the right to commence any action for enforcement pursuant to this Section.
- D. District justices shall have initial jurisdiction in proceedings brought under this Section.
- E. In addition, the municipality, through its solicitor, may institute injunctive, mandamus or any other appropriate action or proceeding at law or in equity for the enforcement of this Ordinance. Any court of competent jurisdiction shall have the right to issue restraining orders, temporary or permanent injunctions, mandamus or other appropriate forms of remedy or relief.

SECTION 906.APPEALS

Any person aggrieved by any action of the municipality or its designee relevant to the provisions of this Ordinance may appeal using the appeal procedures established in the Pennsylvania Municipalities Planning Code.

APPENDIX A

- A1:** Municipal Map of Stormwater Release Rates*
- A2:** Release Rate Summary Table

APPENDIX B

- B1:** Map of Storm Drainage Problem Areas*
- B2:** Description of Storm Drainage Problem Areas

APPENDIX C

- C1:** NRCS Type II 24-Hour Rainfall Distribution (Graphic and Tabular)
- C2:** Precipitation Intensity and Depth Charts
- C3:** Runoff Curve Numbers and Percent Imperviousness Values
- C4:** Runoff Coefficients for the Rational Method
- C5:** Manning 'n' Values
- C6:** Percent Direct Recharge per Fraction Impervious versus Storage Curve
- C7:** Percent Direct Recharge per Fraction Impervious versus Storage Curve Usage Instructions
- C8:** Percent Annual Rainfall versus Vegetated/Surface BMP Design Runoff Chart

APPENDIX D

- D1:** Recommendation Chart for Infiltration Stormwater Management BMPs in Carbonate Bedrock

APPENDIX E

- E1-3:** Stormwater Best Management Practices Operations and Maintenance Agreement

APPENDIX F

- F1-2:** Low Impact Development Practices

APPENDIX G

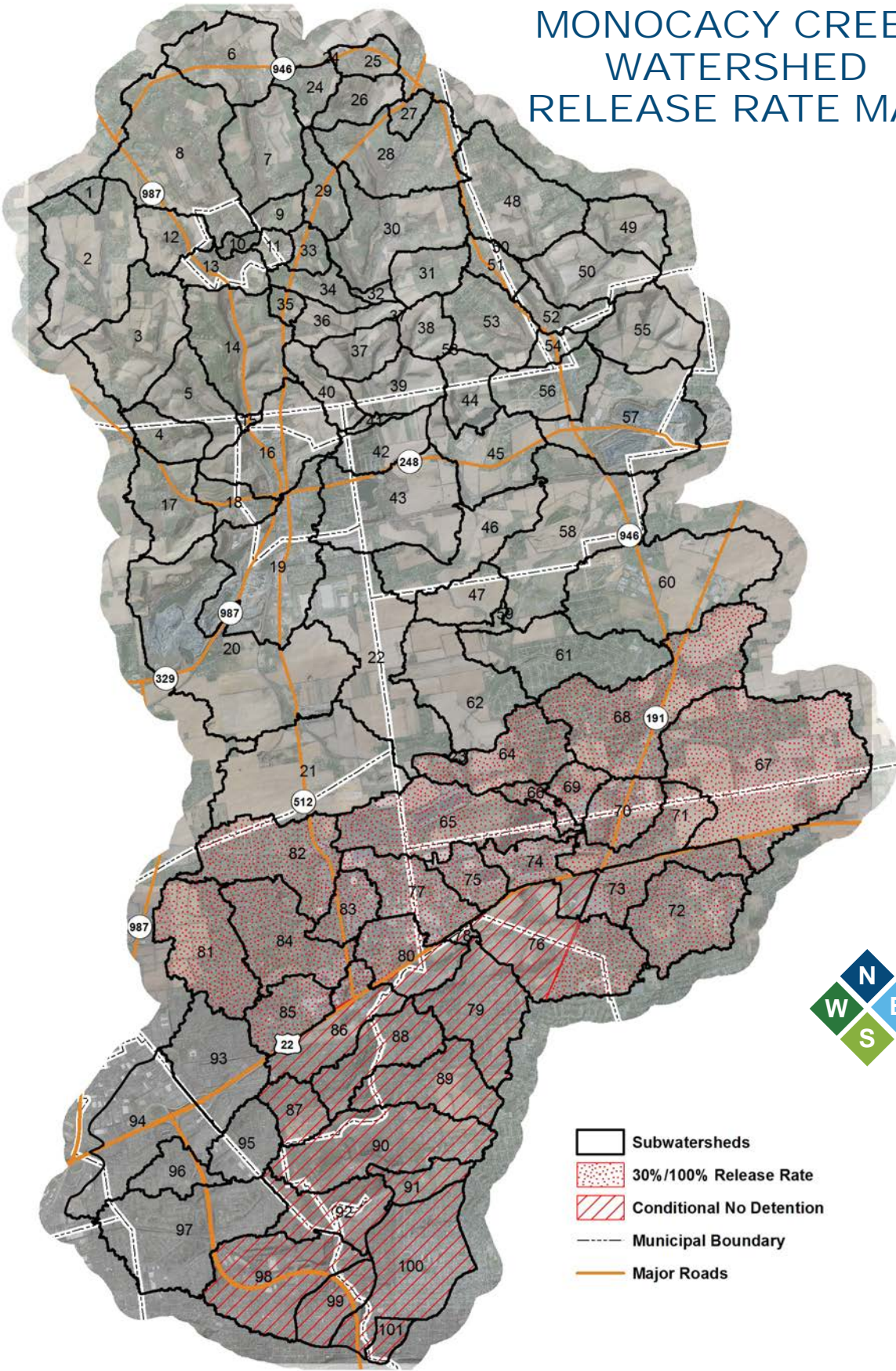
- G1-3:** Preliminary Site Investigation and Testing Requirements

APPENDIX H

- H1-3:** List of Acceptable BMPs

* Individual Municipal maps available from the Lehigh Valley Planning Commission upon request

MONOCACY CREEK WATERSHED RELEASE RATE MAP



- Subwatersheds
- 30%/100% Release Rate
- Conditional No Detention
- Municipal Boundary
- Major Roads



RELEASE RATE SUMMARY TABLE

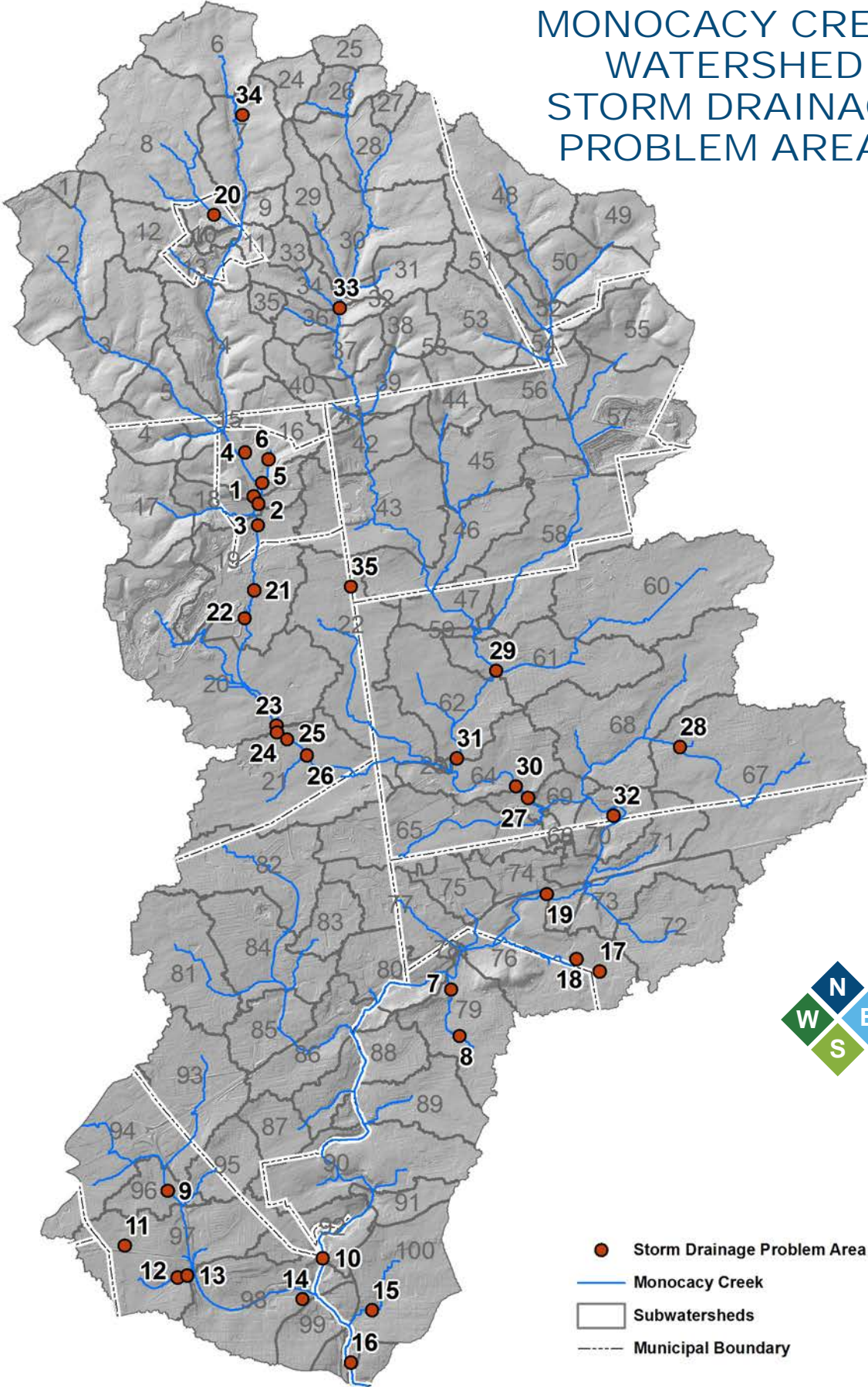
10-year through 100-year return periods

Subarea	Release Rate %	Subarea	Release Rate %	Subarea	Release Rate %
1	90	34	80	67	30/100*
2	90	35	80	68	30/100*
3	90	36	80	69	30/100*
4	80	37	70	70	30/100*
5	70	38	80	71	30/100*
6	100	39	70	72	30/100*
7	80	40	70	73	See Map
8	90	41	70	74	See Map
9	80	42	70	75	30/100*
10	80	43	50	76	See Map
11	80	44	80	77	30/100*
12	90	45	50	78	CND**
13	70	46	50	79	CND**
14	70	47	50	80	See Map
15	70	48	100	81	30/100*
16	70	49	90	82	30/100*
17	80	50	70	83	30/100*
18	50	51	80	84	30/100*
19	50	52	70	85	30/100*
20	50	53	80	86	See Map
21	50	54	60	87	CND**
22	50	55	80	88	CND**
23	100	56	60	89	CND**
24	100	57	50	90	CND**
25	100	58	50	91	CND**
26	90	59	50	92	CND**
27	90	60	50	93	50
28	90	61	50	94	100
29	80	62	50	95	90
30	80	63	100	96	90
31	80	64	30/100*	97	80
32	80	65	30/100*	98	CND**
33	80	66	30/100*	99	CND**
				100	CND**
				101	CND**

*The 30% release rate applies to the 10-year return period event, and the 100% release rate applies to the 25-year and higher events.

** Conditional No Detention

MONOCACY CREEK WATERSHED STORM DRAINAGE PROBLEM AREAS



Storm Drainage Problem Areas

1. Northampton St. Bridge (#117)

Municipality: Borough of Bath
Problem: Street and Property Flooding
Subarea: 16
Reach Number: 15
Proposed Solution: Creek dredging/restoration

2. Main Street

Municipality: Borough of Bath
Problem: Street and Property Flooding
Subarea: 18
Reach Number: 16
Proposed Solution: Creek dredging/restoration

3. Mill Street

Municipality: Borough of Bath
Problem: Street and Property Flooding
Subarea: 19
Reach Number: 18
Proposed Solution: Creek dredging/restoration

4. Creek Road at North Chestnut Street

Municipality: Borough of Bath
Problem: Street and Property Flooding
Subarea: 16
Reach Number: 15
Proposed Solution: Completed creek restoration/water pipe replacement (fall 2016)

5. 151 N. Chestnut Street

Municipality: Borough of Bath
Problem: Street and Property Flooding
Subarea: 16
Reach Number: N/A
Proposed Solution: Attempting underground pipe repairs (spring 2017)

6. 100 Block on Sleepy Hollow Road

Municipality: Borough of Bath
Problem: Street and Property Flooding
Subarea: 16
Reach Number: N/A
Proposed Solution: Replace existing drain tile from 12" to 36" or greater

7. Pine Top Trail/Fox Drive/Bierys Bridge Road

Municipality: City of Bethlehem
Problem: Property Flooding
Subarea: 79
Reach Number: N/A
Proposed Solution: Improve channel capacity

8. Johnston Drive

Municipality: City of Bethlehem
Problem: Street Flooding
Subarea: 79
Reach Number: N/A
Proposed Solution: None proposed

9. Valley Park South Apartments

Municipality: City of Bethlehem
Problem: Property Flooding

Subarea: 96

Reach Number: 94
Proposed Solution: Additional detention upstream

10. Schoenersville Road

Municipality: City of Bethlehem
Problem: Street Flooding
Subarea: 98
Reach Number: 92
Proposed Solution: None proposed

11. Pinehurst Road

Municipality: City of Bethlehem
Problem: Street and Property Flooding
Subarea: 97
Reach Number: N/A
Proposed Solution: Detention facility

12. Homestead Avenue

Municipality: City of Bethlehem
Problem: Street and Rear Yard Flooding
Subarea: 97
Reach Number: N/A
Proposed Solution: None proposed

13. Highland and Eaton Avenues

Municipality: City of Bethlehem
Problem: Street and Property Flooding
Subarea: 97
Reach Number: N/A
Proposed Solution: None proposed

14. 5th Avenue at Route 378

Municipality: City of Bethlehem
Problem: Property Flooding
Subarea: 98
Reach Number: N/A
Proposed Solution: Diversion of runoff to Route 378

15. Goepp Street

Municipality: City of Bethlehem
Problem: Street Flooding
Subarea: 100
Reach Number: N/A
Proposed Solution: Additional inlets and relief pipe system

16. Historical Bethlehem Tannery Building

Municipality: City of Bethlehem
Problem: Property Flooding
Subarea: 100
Reach Number: 99
Proposed Solution: None proposed

17. Oakland Road

Municipality: Bethlehem Township
Problem: Street Flooding
Subarea: 76
Reach Number: N/A
Proposed Solution: None proposed

18. Nijaro Road and Fornance Road

Municipality: Bethlehem Township

Problem: Street flooding

Subarea: 76

Reach Number: N/A

Proposed Solution: None proposed

19. Christian Spring Road

Municipality: Bethlehem Township

Problem: Street Flooding

Subarea: 74

Reach Number: 73

Proposed Solution: None proposed

20. Yost Road and 5th Street

Municipality: Borough of Chapman

Problem: Street and Property Flooding

Subarea: 8

Reach Number: N/A

Proposed Solution: None proposed

21. Railroad Bridge

Municipality: East Allen Township

Problem: Property Flooding

Subarea: 19

Reach Number: 18

Proposed Solution: None proposed

22. Private Road

Municipality: East Allen Township

Problem: Street Flooding

Subarea: 19

Reach Number: 18

Proposed Solution: None proposed

23. Railroad Bridge

Municipality: East Allen Township

Problem: Property Flooding

Subarea: 20

Reach Number: 19

Proposed Solution: None proposed

24. Route 512

Municipality: East Allen Township

Problem: Street Flooding

Subarea: 20, 21

Reach Number: 20

Proposed Solution: None proposed

25. Railroad Bridge

Municipality: East Allen Township

Problem: Property Flooding

Subarea: 21

Reach Number: 20

Proposed Solution: None proposed

26. Railroad Bridge

Municipality: East Allen Township

Problem: Property Flooding

Subarea: 21

Reach Number: 20

Proposed Solution: None proposed

27. Hanoverville Road

Municipality: Lower Nazareth Township

Problem: Street Flooding

Subarea: 66

Reach Number: 64

Proposed Solution: None proposed

28. Hecktown Road

Municipality: Lower Nazareth Township

Problem: Street Flooding

Subarea: 67

Reach Number: N/A

Proposed Solution: Culvert installation

29. Georgetown Road at Ash Drive

Municipality: Lower Nazareth Township

Problem: Street Flooding

Subarea: 61

Reach Number: 60

Proposed Solution: None proposed

30. Georgetown Road

Municipality: Lower Nazareth Township

Problem: Street Flooding

Subarea: 64

Reach Number: 63

Proposed Solution: Bridge replacement on Georgetown Road in progress

31. Steuben Road

Municipality: Lower Nazareth Township

Problem: Street Flooding

Subarea: 62, 64

Reach Number: 61

Proposed Solution: Both bridges replaced in 2016

32. PA Route 191

Municipality: Lower Nazareth Township

Problem: Property Flooding

Subarea: 70

Reach Number: 69

Proposed Solution: Bridges along Route 191 replaced several years ago

33. Keeler Road

Municipality: Moore Township

Problem: Localized Flooding

Subarea: 36

Reach Number: 34

Proposed Solution: Install new pipe. Permit received

34. Trach Road at South Summit Road

Municipality: Moore Township

Problem: Street Flooding

Subarea: 7

Reach Number: 6

Proposed Solution: Rebuild Trach Road, install storm pipe crossing on South Summit Road

35. Township Line Road at White Fence Lane

Municipality: Upper Nazareth Township

Problem: Street Flooding

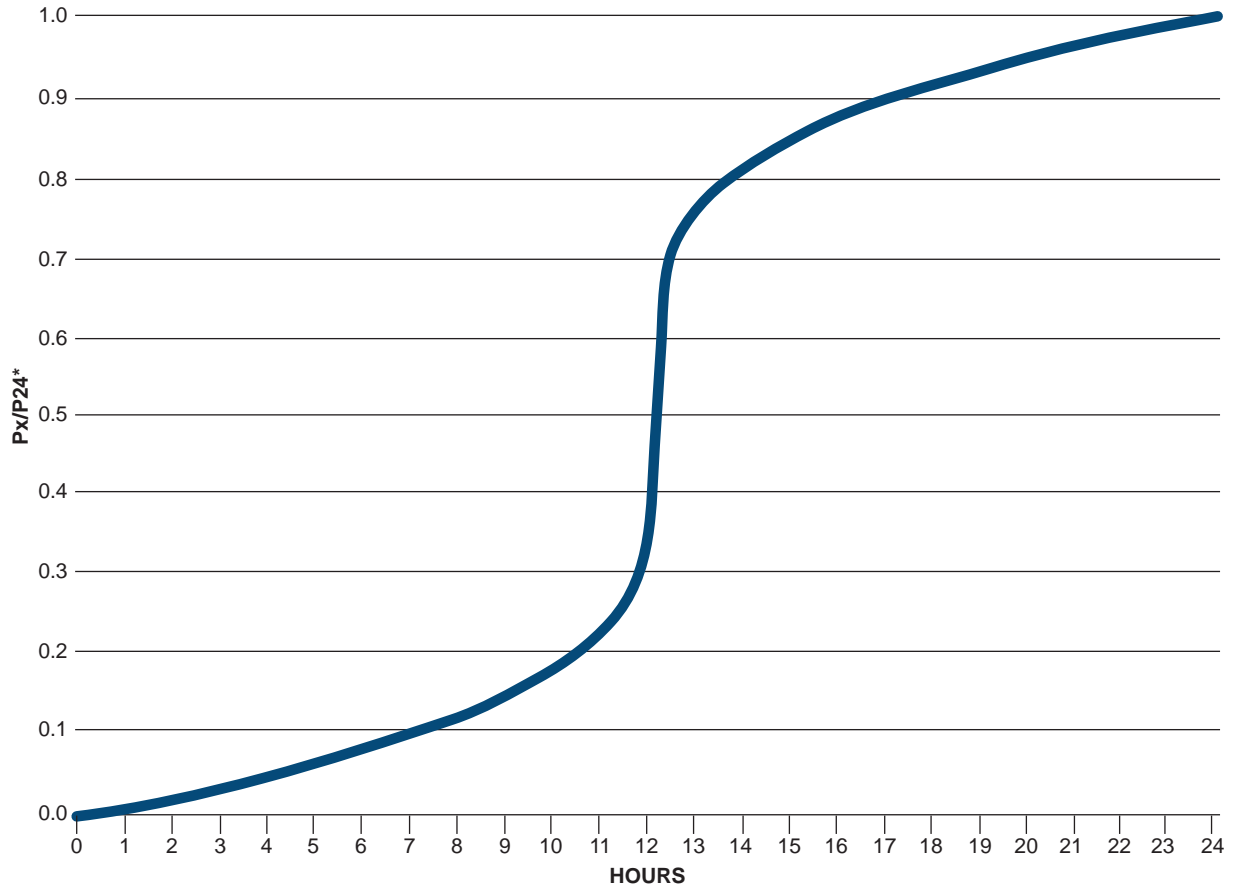
Subarea: 22

Reach Number: N/A

Proposed Solution: Minor regrading/clean-up, continued monitoring and maintenance

APPENDIX C

NRCS TYPE II RAINFALL DISTRIBUTION



* Px/P24 equals cumulative percentage rainfall as a fraction of the total 24 hour rainfall

Hour/Min	Px/P24	Hour/Min	Px/P24	Hour/Min	Px/P24	Hour/Min	Px/P24
1 00	.0107	8 20	.1270	12 20	.6925	16 20	.8866
2 00	.0222	8 40	.1356	12 40	.7361	16 40	.8940
3 00	.0345	9 00	.1449	13 00	.7639	17 00	.9009
4 00	.0479	9 20	.1549	13 20	.7850	17 20	.9075
5 00	.0626	9 40	.1659	13 40	.8023	17 40	.9138
6 00	.0790	10 00	.1781	14 00	.8170	18 00	.9199
6 20	.0849	10 20	.1918	14 20	.8299	19 00	.9365
6 40	.0910	10 40	.2077	14 40	.8415	20 00	.9515
7 00	.0975	11 00	.2266	15 00	.8520	21 00	.9651
7 20	.1043	11 20	.2506	15 20	.8616	22 00	.9776
7 40	.1114	11 40	.2843	15 40	.8705	23 00	.9892
8 00	.1190	12 00	.3773	16 00	.8788	24 00	1.0000

PRECIPITATION INTENSITY AND DEPTH CHARTS*

Partial duration series-based point precipitation intensity frequency estimates (in inches/hour)
Average recurrence interval (years)

Duration	1	2	5	10	25	50	100
5-min	3.85	4.57	5.38	5.99	6.76	7.32	7.88
10-min	3.07	3.66	4.31	4.79	5.36	5.80	6.23
15-min	2.55	3.06	3.62	4.02	4.52	4.89	5.24
30-min	1.75	2.11	2.56	2.91	3.34	3.66	4.00
60-min	1.09	1.32	1.64	1.89	2.22	2.48	2.75
2-hr	0.650	0.785	0.984	1.14	1.36	1.54	1.74
3-hr	0.476	0.575	0.716	0.829	0.988	1.12	1.26
6-hr	0.303	0.364	0.451	0.523	0.627	0.715	0.812
12-hr	0.186	0.224	0.278	0.325	0.393	0.453	0.519
24-hr	0.109	0.131	0.164	0.191	0.232	0.266	0.304

Partial duration series-based point precipitation depth frequency estimates (in inches)
Average recurrence interval (years)

Duration	1	2	5	10	25	50	100
5-min	0.321	0.381	0.448	0.499	0.563	0.610	0.657
10-min	0.511	0.610	0.718	0.798	0.894	0.966	1.04
15-min	0.638	0.764	0.905	1.00	1.13	1.22	1.31
30-min	0.873	1.05	1.28	1.45	1.67	1.83	2.00
60-min	1.09	1.32	1.64	1.89	2.22	2.48	2.75
2-hr	1.30	1.57	1.97	2.28	2.72	3.09	3.48
3-hr	1.43	1.73	2.15	2.49	2.97	3.36	3.79
6-hr	1.82	2.18	2.70	3.13	3.75	4.28	4.86
12-hr	2.24	2.70	3.35	3.91	4.74	5.46	6.26
24-hr	2.62	3.14	3.93	4.59	5.56	6.39	7.30

*Source: NOAA Atlas 14, Volume 2, Version 3

RUNOFF CURVE NUMBERS AND PERCENT IMPERVIOUSNESS VALUES*

Cover Description		Curve numbers for hydrologic soil group**			
Land Use/Cover Type	Average Percent Impervious Area	A	B	C	D
Open space (lawns, parks, golf courses, cemeteries, etc.): Good condition (grass cover greater than 75%)		39	61	74	80
Impervious areas: Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads: Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Urban districts:					
Commercial and business	85%	89	92	94	95
Industrial	72%	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (townhouses)	65%	77	85	90	92
1/4 acre	38%	61	75	83	87
1/3 acre	30%	57	72	81	86
1/2 acre	25%	54	70	80	85
1 acre	20%	51	68	79	84
2 acre	12%	46	65	77	82
Woods		30	55	70	77
Agriculture		Refer to Table 2-2b in source document (TR55) by crop type and treatment			
Meadow: Continuous grass, protected from grazing and generally mowed for hay		30	58	71	78

*Source: Natural Resources Conservation Service Technical Release No. 55, Second Edition, June 1986

**Hydrologic Soil Group based on the USDA Soil Survey

RUNOFF COEFFICIENTS FOR THE RATIONAL METHOD*
HYDROLOGIC SOIL GROUP AND SLOPE RANGE**

Land Use	A			B			C			D		
	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Cultivated ^A	0.18 ^a	0.23	0.28	0.24	0.29	0.33	0.30	0.34	0.38	0.33	0.37	0.41
	0.23 ^b	0.29	0.34	0.30	0.36	0.40	0.36	0.41	0.45	0.39	0.44	0.48
Pasture ^B	0.09	0.13	0.17	0.19	0.24	0.29	0.27	0.31	0.36	0.31	0.35	0.39
	0.12	0.17	0.23	0.24	0.30	0.36	0.33	0.38	0.43	0.37	0.42	0.46
Meadow, Lawn ^C	0.05	0.08	0.12	0.15	0.20	0.24	0.23	0.28	0.32	0.28	0.32	0.36
	0.07	0.12	0.17	0.19	0.25	0.30	0.28	0.34	0.39	0.33	0.39	0.43
Forest, Woods	0.03	0.05	0.08	0.11	0.16	0.20	0.20	0.25	0.29	0.25	0.30	0.34
	0.04	0.08	0.12	0.15	0.21	0.26	0.25	0.31	0.36	0.31	0.37	0.41
Gravel	0.24	0.29	0.33	0.32	0.36	0.40	0.35	0.39	0.43	0.37	0.41	0.44
	0.30	0.36	0.40	0.38	0.43	0.47	0.42	0.46	0.50	0.44	0.48	0.51
Parking, other Impervious	0.85	0.86	0.87	0.85	0.86	0.87	0.85	0.86	0.87	0.85	0.86	0.87
	0.95	0.96	0.97	0.95	0.96	0.97	0.95	0.96	0.97	0.95	0.96	0.97
Residential, Commercial, Industrial and Other "Developed"	Runoff coefficients should be calculated based upon weighted average of impervious area coefficients and pervious area coefficients from above based upon soil type, slope and the particular development proposal.											

*Coefficients for all land uses except parking and other impervious cover are based on the Rossmiller Equation for translating NRCS curve numbers into Rational Method 'c' values. The source for the parking and other impervious cover coefficients is RAWLS, W.J., S.L. WONG and R.H. McCUEN, 1981. Comparison of urban flood frequency procedures. Preliminary draft report prepared for the Soil Conservation Service, Beltsville, M.D.

**Hydrologic Soil Group based on the USDA Soil Survey.

^a Runoff coefficients for storm recurrence intervals less than 25 years.

^b Runoff coefficients for storm recurrence intervals of 25 years or more.

^A Represents average of cultivated land with and without conservation treatment from TR-55, January 1975. These values are consistent with several categories of cultivated lands from TR-55, June 1986.

^B Represents grasslands in fair condition with 50% to 75% grass cover.

^C Represents grasslands in good condition with greater than 75% grass cover.

MANNING 'n' VALUES BY TYPICAL REACH DESCRIPTION

Reach Description	Manning 'n'
Natural stream, clean, straight, no rifts or pools	0.030
Natural stream, clean, winding, some pools and shoals	0.040
Natural stream, winding, pools, shoals stony with some weeds	0.050
Natural stream, sluggish with deep pools and weeds	0.070
Natural stream, or swale, very weedy or with timber under brush	0.100
Concrete pipe, culvert or channel	0.012
Corrugated metal pipe	0.012-0.027*

*Depending upon type and diameter

ROUGHNESS COEFFICIENTS (MANNING 'n') FOR SHEET FLOW

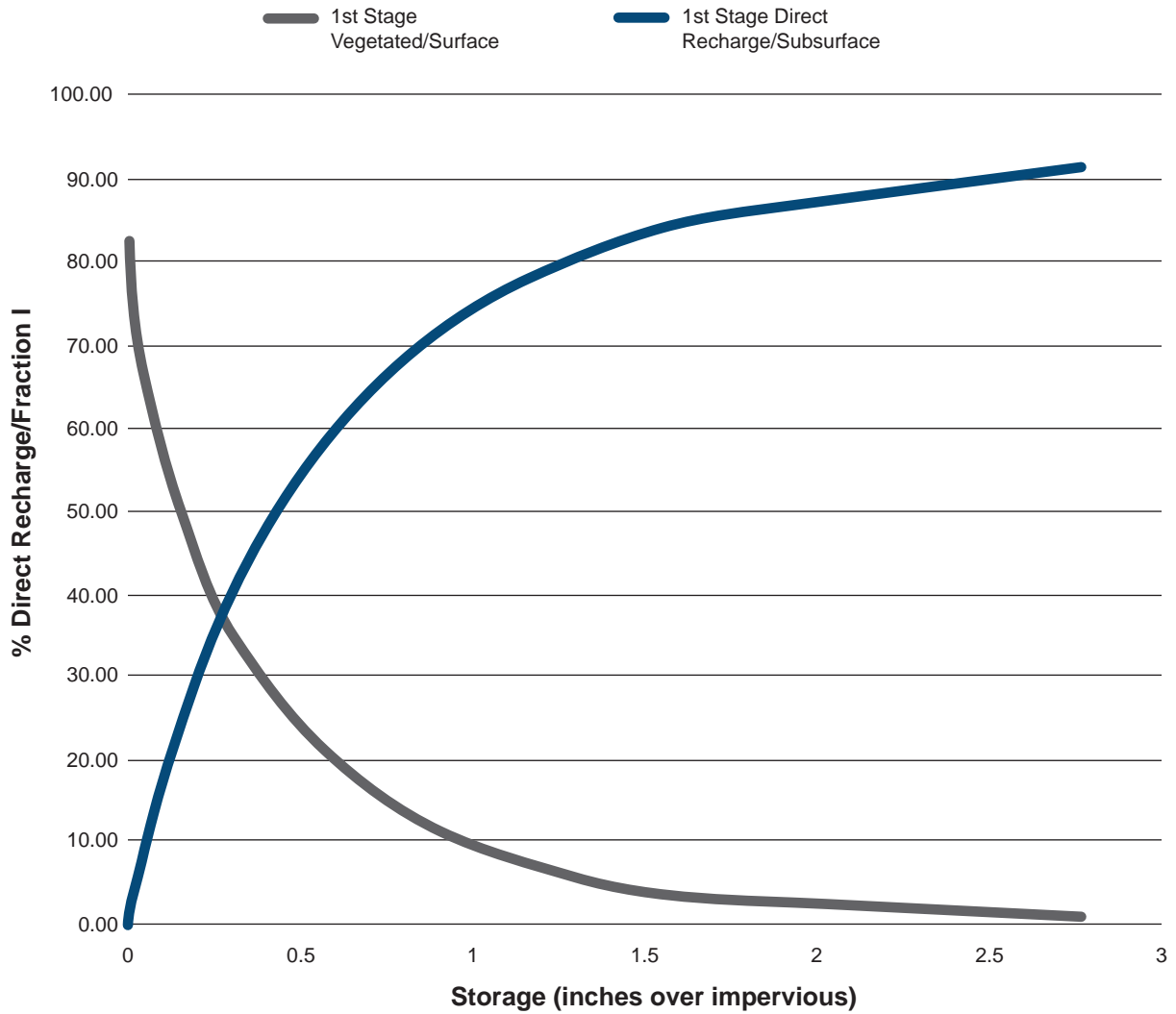
Surface Description	Manning 'n'¹
Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.050
Cultivated soils:	
Residue cover <= 20%	0.060
Residue cover > 20%	0.170
Grass:	
Short grass prairie	0.150
Dense grasses ²	0.240
Bermuda grass	0.410
Range (natural)	0.130
Woods: ³	
Light underbrush	0.400
Dense underbrush	0.800

¹ The 'n' values are a composite of information compiled by Engman (1986).

² Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass and native grass mixtures.

³ When selecting 'n', consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

PERCENT DIRECT RECHARGE PER FRACTION IMPERVIOUS VS. STORAGE



Note: See C7 for instruction on how to use the chart

PERCENT DIRECT RECHARGE PER FRACTION IMPERVIOUS VERSUS STORAGE CURVE USAGE INSTRUCTIONS

The “1st Stage Direct Recharge” curve is based on impervious areas being diverted first to a Direct Recharge/Subsurface BMP designed to capture less than the 2-year event, with the remaining 2-year runoff overflowing into a Vegetated/Surface BMP. The “1st stage Vegetated/Surface” curve is based on reversing the above. The curves may be used for the whole site, or for pieces of a site to achieve successful designs as follows:

- A. If used for whole site designs, the “fraction I” used is the proposed impervious as a fraction of the entire site. As an example, for a 60% impervious site with all impervious directed to a first stage Direct Recharge/Subsurface BMP, use 30% Direct Recharge with 0.60 fraction I to yield 50% Direct Recharge/fraction I and translate into 0.42 inches of storage over impervious areas. The total first stage Direct Recharge maximum BMP storage is 0.42 inches of depth times the surface area of the impervious cover. Similarly, if a first stage Vegetated/Surface BMP followed by a second stage Direct Recharge/Subsurface BMP was used, the minimum Vegetated/Surface storage is 0.15 inches over the impervious cover.

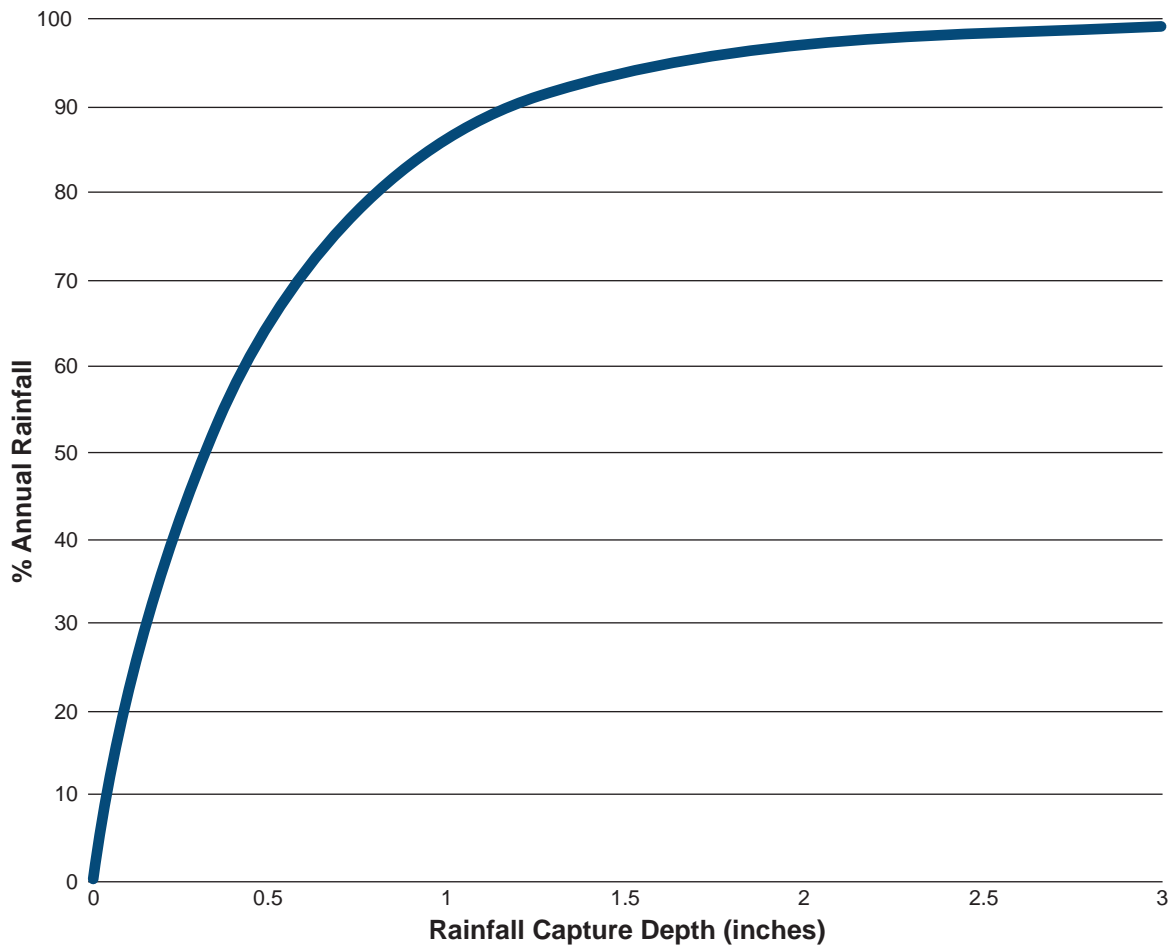
- B. If used for pieces of the site smaller than the whole site, the fraction I used is the impervious cover of the part of the site in question as a fraction of the area of the same piece. Each piece may be designed for 30% Direct Recharge if desired, but individual pieces may exceed 30% Direct Recharge provided all BMPs on site are providing less than 30% Direct Recharge in aggregate. In this case, the BMP storage for each piece is used in the chart with the fraction I using the whole site area to determine the contribution of each piece to the 30% Direct Recharge allowable. As an example, still using the 60% impervious site, a piece of the site uses a Direct Recharge/Subsurface BMP first. The piece is half of the total area of the site and is 80% impervious. The BMP is designed for 0.6 inches of runoff from the impervious surfaces. Using 0.6 inches of storage and a fraction I of 0.80, the piece is designed for (%Direct Recharge/fraction I = 60) 48% Direct Recharge. The impervious cover in this piece has fraction I of 0.4 of the overall site acreage and, therefore, using 0.6 inches of storage and a fraction I of 0.4 yields a Direct Recharge/fraction I of 60% using the graph which solves to a Direct Recharge of 24%. This means that this piece uses 24% of the allowable 30% Direct Recharge. The remaining piece(s) will need to be designed for 6% or less Direct Recharge. The remaining piece in this example has a fraction I of the overall site of 0.2. Using 6% Direct Recharge and a fraction I of 0.2 yields a Direct Recharge/fraction I of 30%. Entering the graph at that value, the maximum storage for the piece in a first stage Direct Recharge/Subsurface BMP is 0.2 inches over the impervious portion of its tributary area.

- C. If more than two stages of Vegetated/Surface and Direct Recharge/Subsurface BMPs are used to control the WQv, the design considerations are as follows:
 - 1. If the design has a first stage Vegetated/Surface BMP draining to additional stage Vegetated/Surface BMPs and subsequent Direct Recharge/Subsurface BMP, add the storage volumes of the Vegetated/Surface BMPs and use this volume as the first stage Vegetated/Surface storage volume.
 - 2. Similarly, if two or more Direct Recharge/Subsurface BMPs are used first followed by a Vegetated/Surface BMP, add the storage volumes of the Direct Recharge/Subsurface BMPs and use this volume as the first stage Direct Recharge BMP storage volume.
 - 3. In designs with more than two Vegetated/Surface or Direct Recharge/Subsurface BMPs used in series to control the WQv and rules C.1 and C.2 don't apply, the chart shall be applied conservatively to assure the Direct Recharge standard is not violated. For example, with proposed use of a first stage Direct Recharge/Subsurface BMP, second stage Vegetated/Surface BMP, and third stage Direct Recharge/Subsurface BMP, all storage provided shall be assumed to be Direct Recharge for use in the chart.

Essentially, any Vegetated/Surface BMP applied beyond the first stage will be ignored for purposes of determining compliance with the Direct Recharge standard.

PERCENT ANNUAL RAINFALL VERSUS VEGETATED/SURFACE BMP DESIGN RUNOFF CHART

To use this chart, for a given fraction of site impervious directed to a Vegetated/Surface BMP, calculate the runoff capture depth over the impervious in inches, use the curve to find % annual rainfall. The weighted average of % annual rainfall considering all impervious cover to all BMPs must be a minimum of 56%.



APPENDIX D

Recommendation Chart for Infiltration Stormwater Management BMPs in Carbonate Bedrock*														
CARBONATE BEDROCK														
SITE RISK FACTORS	Geology Type	Less than 2 Feet			2 to 4 Feet			Over 4 Feet to 8 Feet			Over 8 Feet			
	Effective Soil Thickness	Low/Med/High Buffer	Low Buffer	Medium Buffer	High Buffer	Low Buffer	Medium Buffer	High Buffer	Low Buffer	Medium Buffer	High Buffer	Low Buffer	Medium Buffer	High Buffer
DESIGN FACTORS	Special Geologic Features**	(Unacceptable)	Preliminary	Preliminary	Preliminary	Preliminary	Preliminary	Preliminary	Preliminary	Preliminary	Preliminary	Preliminary	Preliminary	Preliminary
	Infiltration Loading Rates (% Increase) ***	(Unacceptable)	0-100% 300% 500%	0-100% 300% 500%	0-100% 300% 500%	0-100% 300% 500%	0-100% 300% 500%	0-100% 300% 500%	0-100% 300% 500%	0-100% 300% 500%	0-100% 300% 500%	0-100% 300% 500%	0-100% 300% 500%	0-100% 300% 500%
PROGRAM SUMMARY GUIDANCE ****			RECOMMENDED	RECOMMENDED	RECOMMENDED	RECOMMENDED	RECOMMENDED	RECOMMENDED	RECOMMENDED	RECOMMENDED	RECOMMENDED	RECOMMENDED	RECOMMENDED	NOT RECOMMENDED



* Source: Developed by Cahill Associates based on information in "Technical Best Management Practice Manual & Infiltration Feasibility Report", November 2002 and input from the LVPC, 2003.

** Special Geologic Feature Buffer widths are as follows:

- Low Buffer is less than 50 feet
- Medium Buffer is 50 feet to 100 feet
- High Buffer is greater than 100 feet

*** Rates greater than 500% not recommended.

**** Assumes adequately permeable soils and lack of natural constraints as required for all infiltration systems.

- 1 Infiltration systems may be allowed at the determination of the Engineer and/or Geologist, provided that a Detailed Site Investigation is undertaken which confirms nature of rock, location of Special Geologic Features, and adequacy of the buffer between the SGF and the proposed stormwater system(s).
- 2 In these Special Geologic Features: Low Buffer situations, infiltration systems may be allowed at the determination of the Engineer and/or Geologist, provided that a Detailed Site Investigation is undertaken and a 25 foot buffer from SGFs is maintained.

APPENDIX E

**STORMWATER BEST MANAGEMENT PRACTICES
OPERATIONS AND MAINTENANCE AGREEMENT**

THIS AGREEMENT, made and entered into this _____ day of _____, 20____, by and between _____, (hereinafter the "Landowner"), and _____ County, Pennsylvania, (hereinafter "municipality");

WITNESSETH

WHEREAS, the Landowner is the owner of certain real property as recorded by deed in the land records of _____ County, Pennsylvania, Deed Book _____ at Page _____, (hereinafter "Property").

WHEREAS, the Landowner is proceeding to build and develop the Property; and

WHEREAS, the stormwater management BMP Operations and Maintenance Plan approved by the municipality (hereinafter referred to as the "Plan") for the property identified herein, which is attached hereto as Appendix A and made part hereof, as approved by the municipality, provides for management of stormwater within the confines of the Property through the use of Best Management Practices (BMP's); and

WHEREAS, the municipality, and the Landowner, his successors and assigns, agree that the health, safety, and welfare of the residents of the municipality and the protection and maintenance of water quality require that on-site stormwater Best Management Practices be constructed and maintained on the Property; and

WHEREAS, for the purposes of this agreement, the following definitions shall apply:

- BMP – "Best Management Practice;" activities, facilities, designs, measures or procedures used to manage stormwater impacts from land development, to protect and maintain water quality and groundwater recharge and to otherwise meet the purposes of the Municipal Stormwater Management Ordinance, including but not limited to infiltration trenches, seepage pits, filter strips, bioretention, wet ponds, permeable paving, rain gardens, grassed swales, forested buffers, sand filters and detention basins.
- Infiltration Trench – A BMP surface structure designed, constructed, and maintained for the purpose of providing infiltration or recharge of stormwater into the soil and/or groundwater aquifer,
- Seepage Pit – An underground BMP structure designed, constructed, and maintained for the purpose of providing infiltration or recharge of stormwater into the soil and/or groundwater aquifer,
- Rain Garden – A BMP overlain with appropriate mulch and suitable vegetation designed, constructed, and maintained for the purpose of providing infiltration or recharge of stormwater into the soil and/or underground aquifer; and

WHEREAS, the municipality requires, through the implementation of the Plan, that stormwater management BMPs as required by said Plan and the Municipal Stormwater Management Ordinance be constructed and adequately operated and maintained by the Landowner, his successors and assigns; and

NOW, THEREFORE, in consideration of the foregoing promises, the mutual covenants contained herein, and the following terms and conditions, the parties hereto agree as follows:

Monocacy Creek Act 167 Plan

1. The BMPs shall be constructed by the Landowner in accordance with the plans and specifications identified in the Plan.
2. The Landowner shall operate and maintain the BMP(s) as shown on the Plan in good working order acceptable to the municipality and in accordance with the specific maintenance requirements noted on the Plan.
3. The Landowner hereby grants permission to the municipality, its authorized agents and employees, to enter upon the property, at reasonable times and upon presentation of proper identification, to inspect the BMP(s) whenever it deems necessary. Whenever possible, the municipality shall notify the Landowner prior to entering the property.
4. In the event the Landowner fails to operate and maintain the BMP(s) as shown on the Plan in good working order acceptable to the municipality, the municipality or its representatives may enter upon the Property and take whatever action is deemed necessary to maintain said BMP(s). This provision shall not be construed to allow the municipality to erect any permanent structure on the land of the Landowner. It is expressly understood and agreed that the municipality is under no obligation to maintain or repair said facilities, and in no event shall this Agreement be construed to impose any such obligation on the municipality.
5. In the event the municipality, pursuant to this Agreement, performs work of any nature, or expends any funds in performance of said work for labor, use of equipment, supplies, materials, and the like, the Landowner shall reimburse the municipality for all expenses (direct and indirect) incurred within 10 days of receipt of invoice from the municipality *and if not timely paid, a municipal lien shall be placed upon the premises for 110% of the invoice amount, plus statutorily allowed fees, expenses and costs.*
6. The intent and purpose of this Agreement is to ensure the proper maintenance of the on-site BMP(s) by the Landowner; provided, however, that this Agreement shall not be deemed to create or effect any additional liability of any party for damage alleged to result from or be caused by stormwater runoff.
7. The Landowner, its executors, administrators, assigns, and other successors in interests, *hereby release and hold harmless* the municipality's employees and designated representatives from all damages, accidents, casualties, occurrences or claims which might arise or be asserted against said employees and representatives from the construction, presence, existence, or maintenance of the BMP(s) by the Landowner or municipality. In the event that a claim is asserted against the municipality, its designated representatives or employees, the municipality shall promptly notify the Landowner and the Landowner shall defend, at his own expense, any suit based on the claim. If any judgment or claims against the municipality's employees or designated representatives shall be allowed, the Landowner shall pay all costs and expenses regarding said judgment or claim.
8. The municipality shall inspect the BMP(s) *as necessary* to ensure their continued functioning.

This Agreement shall be recorded at the Office of the Recorder of Deeds of _____ County, Pennsylvania, and shall constitute a covenant running with the Property and/or equitable servitude, and shall be binding on the Landowner, his administrators, executors, assigns, heirs and any other successors in interests, in perpetuity.

ATTEST:

WITNESS the following signatures and seals:

(SEAL)

For the municipality:

(SEAL)

For the Landowner:

ATTEST:

_____ (City, Borough, Township)

County of _____, Pennsylvania

I, _____, a Notary Public in and for the County and State aforesaid, whose commission expires on the _____ day of _____, 20__, do hereby certify that _____ whose name(s) is/are signed to the foregoing Agreement bearing date of the _____ day of _____, 20__, has acknowledged the same before me in my said County and State.

GIVEN UNDER MY HAND THIS _____ day of _____, 20__.

NOTARY PUBLIC

(SEAL)

APPENDIX F

LOW IMPACT DEVELOPMENT PRACTICES

ALTERNATIVE APPROACH FOR MANAGING STORMWATER RUNOFF

Natural hydrologic conditions may be altered radically by poorly planned development practices, such as introducing unneeded impervious surfaces, destroying existing drainage swales, constructing unnecessary storm sewers, and changing local topography. A traditional drainage approach of development has been to remove runoff from a site as quickly as possible and capture it in a detention basin. This approach may lead ultimately to the degradation of water quality as well as expenditure of additional resources for detaining and managing concentrated runoff at some downstream location.

The recommended alternative approach is to promote practices that will minimize post-development runoff rates and volumes, which will minimize needs for artificial conveyance and storage facilities. To simulate pre-development hydrologic conditions, forced infiltration is often necessary to offset the loss of infiltration by creation of impervious surfaces. The ability of the ground to infiltrate depends upon the soil types and its conditions.

Preserving natural hydrologic conditions requires careful alternative site design considerations. Site design practices include preserving natural drainage features, minimizing impervious surface area, reducing the hydraulic connectivity of impervious surfaces, and protecting natural depression storage. A well-designed site will contain a mix of all those features. The following describes various techniques to achieve the alternative approach:

- **Preserving Natural Drainage Features.** Protecting natural drainage features, particularly vegetated drainage swales and channels, is desirable because of their ability to infiltrate and attenuate flows and to filter pollutants. However, this objective is often not accomplished in land development. In fact, commonly held drainage philosophy encourages just the opposite pattern—streets and adjacent storm sewers typically are located in the natural headwater valleys and swales, thereby replacing natural drainage functions with a completely impervious system. As a result, runoff and pollutants generated from impervious surfaces flow directly into storm sewers with no opportunity for attenuation, infiltration, or filtration. Developments designed to fit site topography also minimize the amount of grading on site.
- **Protecting Natural Depression Storage Areas.** Depression storage areas have no surface outlet, or drain very slowly following a storm event. They can be commonly seen as ponded areas in farm fields during the wet season or after large runoff events. Traditional development practices eliminate these depressions by filling or draining, thereby obliterating their ability to reduce surface runoff volumes and trap pollutants. The volume and release rate characteristics of depressions should be protected in the design of the development site. The depressions can be protected by simply avoiding the depression or by incorporating its storage as additional capacity in required detention facilities.
- **Avoiding Introduction of Impervious Areas.** Careful site planning should consider reducing impervious coverage to the maximum extent possible. Building footprints, sidewalks, driveways and other features producing impervious surfaces should be evaluated to minimize impacts on runoff.
- **Reducing the Hydraulic Connectivity of Impervious Surfaces.** Impervious surfaces are significantly less of a problem if they are not directly connected to an impervious conveyance system (such as storm sewer). Two basic ways to reduce hydraulic connectivity are routing of roof runoff over lawns and reducing the use of storm sewers. Site grading should promote

increasing travel time of stormwater runoff, and should help reduce concentration of runoff to a single point in the development.

- **Routing Roof Runoff over Lawns.** Roof runoff can be easily routed over lawns in most site designs. The practice discourages direct connections of downspouts to storm sewers or parking lots. The practice also discourages sloping driveways and parking lots to the street. By routing roof drains and crowning the driveway to run off to the lawn, the lawn is essentially used as a filter strip.
- **Reducing the Use of Storm Sewers.** By reducing use of storm sewers for draining streets, parking lots, and back yards, the potential for accelerating runoff from the development can be greatly reduced. The practice requires greater use of swales and may not be practical for some development sites, especially if there are concerns for areas that do not drain in a “reasonable” time. The practice requires educating local citizens and public works officials, who expect runoff to disappear shortly after a rainfall event.
- **Reducing Street Widths.** Street widths can be reduced by either eliminating on-street parking or by reducing roadway widths. Municipal planners and traffic designers should encourage narrower neighborhood streets which ultimately could lower maintenance.
- **Limiting Sidewalks to One Side of the Street.** A sidewalk on one side of the street may suffice in low-traffic neighborhoods. The lost sidewalk could be replaced with bicycle/recreational trails that follow back-of-lot lines. Where appropriate, backyard trails should be constructed using pervious materials.
- **Using Permeable Paving Materials.** These materials include permeable interlocking concrete paving blocks or porous bituminous concrete. Such materials should be considered as alternatives to conventional pavement surfaces, especially for low use surfaces such as driveways, overflow parking lots, and emergency access roads.
- **Reducing Building Setbacks.** Reducing building setbacks reduces driveway and entry walks and is most readily accomplished along low-traffic streets where traffic noise is not a problem.
- **Constructing Cluster Developments.** Cluster developments can also reduce the amount of impervious area for a given number of lots. The biggest savings is in street length, which also will reduce costs of the development. Cluster development clusters the construction activity onto less-sensitive areas without substantially affecting the gross density of development.

APPENDIX G

PRELIMINARY SITE INVESTIGATION AND TESTING REQUIREMENTS

Required Data and Site Information: The following data shall be gathered utilizing standard testing procedures as part of a Preliminary Site Investigation:

- Bedrock composition – Any apparent boundaries between carbonate and non-carbonate bedrock must be verified by a qualified geotechnical professional.
- Bedrock structural geology – This includes the possible presence of faults and mapping of conspicuous fracture traces or lineaments.
- Overburden and soil mantle composition and thickness.
- Permeability of the soil.
- Depth to the seasonal high water table.
- Presence of special geologic features – This includes sinkholes, closed depressions, fracture traces, lineaments, joints, faults, caves, pinnacles and geologic contacts between carbonate and non-carbonate bedrock.

Preliminary Site Investigation Required for Sites Intending to Use Infiltration

Review of Available Data, Maps and Reports: Some of the required information, as listed above, can be found in existing published data. Suggested resources include the following:

- Geologic maps and references for the development area.
- The Little Lehigh Creek Basin Carbonate Prototype Area Closed Depression Map – available at the LVPC.
- USGS topographic maps.
- Lehigh and Northampton County soil survey maps.
- Aerial photographs from the LVPC or other sources.
- Relevant Pennsylvania Geologic Survey Open File Reports that provide maps of sinkholes and Karst features for Lehigh County (OF 87-01) and Northampton County (OF 87-02).
- Kochanov and Reese (2003). Density of Mapped Karst Feature in South-Central and Southeastern Pennsylvania (Map 68).
- DCNR Online Sinkhole Inventory - (<http://www.dcnr.state.pa.us/topogeo/hazards/sinkhole/default.asp>).

Field Inspections: In addition to gathering data from published sources, a field inspection of the proposed site is required. A field inspection can provide additional information relating to site features such as carbonate bedrock features, indicators of seasonal high stream-level or water table levels, streams, springs, etc.

Soil Test Pit and Percolation Test Requirements: A minimum of one test pit and a minimum of 2 percolation tests are required for every site. A test pit is a 2-3 foot wide, 8 foot deep trench excavated with a backhoe for observing subsurface conditions. The test pits will be used to describe soil depth and quality, including soil horizons, and testing of permeability or percolation rates and can be conducted by a certified Sewage Enforcement Officer.

Percolation tests are to be conducted as follows (adapted from § 73.15. “Percolation Tests” of the Pennsylvania Code):

1. The percolation tests shall be made in separate holes uniformly spaced over the possible infiltration area.
2. An “Initial Presoak” should not be performed.
3. Percolation holes located within the possible infiltration area shall be used in the calculation of the average percolation rate.
4. Holes having a uniform diameter of 6 to 10-inches shall be bored or dug as follows:

- a. To the depth of the bottom of the possible infiltration BMP.
 - b. Alternate depths if the test pits/auger holes indicate that the soils are more suitable at a different depth (i.e. if a clay horizon is identified and more suitable soils are located beneath the horizon, an infiltration test should be performed in the suitable horizon).
5. The bottom and sides of the hole shall be scarified with a knife blade or sharp-pointed instrument to completely remove any smeared soil surfaces and to provide a natural soil interface into which water may percolate. Loose material shall be removed from the hole. Two inches of coarse sand or fine gravel shall be placed in the bottom of the hole to protect the soil from scouring and clogging of the pores.
 6. Immediately before the percolation test, as a final presoak, water shall be placed in the hole to a minimum depth of 6-inches over the gravel and readjusted every 30 minutes for 1 hour.
 7. The drop in the water level during the last 30 minutes of the final presoaking period shall be applied to the following standard to determine the time interval between readings for each percolation hole:
 - a. If water remains in the hole, the interval for readings during the percolation test shall be 30 minutes.
 - b. If no water remains in the hole, the interval for readings during the percolation test may be reduced to 10 minutes.
 8. After the final presoaking period, water in the hole shall again be adjusted to approximately 6-inches over the gravel and readjusted when necessary after each reading.
 - a. Measurement to the water level in the individual percolation holes shall be made from a fixed reference point and shall continue at the interval determined from step No. 7 (above) for each individual percolation hole until a minimum of eight readings are completed or until a stabilized rate of drop is obtained, whichever occurs first. A stabilized rate of drop means a difference of ¼-inch or less of drop between the highest and lowest readings of four consecutive readings.
 - b. The drop that occurs in the final period in percolation test holes, expressed as inches per hour, shall be used to calculate the average percolation rate.
 - c. When the rate of drop in a percolation test is too slow to obtain a measurable rate, the rate of 0.25 inches per hour shall be assigned to that hole for use in calculating the average percolation rate. The infiltration area may be placed over holes with no measurable rate when the average percolation rate for the possible infiltration area is within the acceptable range.

When a percolation test hole yields a percolation rate of greater than 12-inches per hour, the proposed infiltration area may not be designed or installed within 25-feet of this hole unless the municipality determines that a testing anomaly caused the fast percolation rate and a retest of the area yields acceptable percolation rates. This percolation rate limit is established to protect groundwater quality and to minimize the risk of subsidence.

Additional Site Investigation and Testing Required if Infiltration is Proposed

Soil Test Pit Requirements: The required number of test pits varies with Effective Soil Thickness. As risk factors increase, the number of test pits increases. A minimum of 2 test pits, uniformly spaced within the proposed infiltration area (e.g., the 2 pits should be centered on each half of the proposed infiltration area), are required for any site proposing infiltration unless the applicant can demonstrate that one test pit is adequately representative of the area proposed for infiltration. For larger infiltration areas, multiple test pits shall be developed at the densities as listed below:

Effective Soil Thickness (ft.)	Test Pit Density (per acre of proposed infiltration area)*	Percolation Tests (per acre of proposed infiltration area)**	Auger Grid Spacing (Feet On-Center)***
8	4	8	50
4 to 8	6	12	35
2 to 4	8	16	25

*No. of Test Pits required = Infiltration sq. ft./43,560 sq. ft. x test pit density from chart rounded up to the nearest whole number

** No. of Percolation Tests required = Infiltration sq. ft./43,560 sq. ft. x percolation tests from chart rounded up to the nearest whole number

***Auger testing is only required on Carbonate sites.

Soil Auger Testing Requirements for Carbonate Areas: Because soil depth is not uniform in many carbonate areas, test pits will not be sufficient to accurately determine the depth to bedrock. Augering provides this essential data as inexpensively as possible. Track-rig rotary soil auger test drilling allows relatively inexpensive, qualitative determination of the presence of overburden voids and will generally penetrate to the top-of-bedrock. Augers typically extend to depths of 20 feet. Special augers extend to as much as 50 feet. Augers do not extend into the bedrock. Auger testing should be performed in a grid pattern across the proposed infiltration area, spaced as indicated in the above table.

Percolation Testing Requirements: For each proposed infiltration area, a minimum of six percolation tests shall be conducted with a vertical component permeability test unless the applicant can demonstrate that fewer tests accurately represent the percolation rate of the proposed infiltration area. Additional testing shall be required if the initial test results show significant variability in the vertical component percolation rate. For larger infiltration areas, percolation tests shall be conducted at the densities listed in the table above.

APPENDIX H

LIST OF ACCEPTABLE BMPs

Best Management Practice	Design Reference Number ^B
Bioretention ^A	4,5,11,16
Capture/Reuse	4,14
Constructed Wetlands	4, 5, 8, 10, 16
Dry Extended Detention Ponds	4, 5, 8, 12, 18
Minimum Disturbance/Minimum Maintenance Practices	1, 9
Significant Reduction of Existing Impervious Cover	N/A
Stormwater Filters ^A (Sand, Peat, Compost, etc.)	4, 5, 10, 16
Vegetated Buffers/Filter Strips	2, 3, 5, 11, 16, 17
Vegetated Roofs	4, 13
Vegetated Swales ^A	2, 3, 5, 11, 16, 17
Water Quality Inlets ^C	4, 7, 15, 16, 19
Wet Detention Ponds	4, 5, 6, 8

^A This BMP could be designed with or without an infiltration component. If infiltration is proposed, the site and BMP will be subject to the testing and other infiltration requirements in this Ordinance.

^B See table below.

^C Water Quality Inlets include such BMPs as Oil/Water Separators, Sediment Traps/Catch Basin Sumps and Trash/Debris Collectors in Catch Basins.

LIST OF ACCEPTABLE BMPs

Number	Design Reference Title
1	“Conservation Design For Stormwater Management – A Design Approach to Reduce Stormwater Impacts from Land Development and Achieve Multiple Objectives Related to Land Use,” Delaware Department of Natural Resources and Environmental Control, The Environmental Management Center of the Brandywine Conservancy, September 1997.
2	“A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone,” Schueler, T.R., Kumble, P. and Heraty, M., Metropolitan Washington Council of Governments, 1992.
3	“Design of Roadside Channels with Flexible Linings,” Federal Highway Administration, Chen, Y.H. and Cotton, G. K., Hydraulic Engineering Circular 15, FHWA-IP-87-7, McLean Virginia, 1988.
4	“Stormwater Best Management Practices Manual,” Pennsylvania Department of Environmental Protection, January 2005 or current version.
5	“Evaluation and Management of Highway Runoff Water Quality,” Federal Highway Administration, FHWA-PD-96-032, Washington, D.C., 1996.
6	“Evaporation Maps of the United States,” U.S. Weather Bureau (now NOAA/National Weather Service) Technical Paper 37, Published by Department of Commerce, Washington D.C., 1959.
7	“Georgia Stormwater Manual,” AMEC Earth and Environmental, Center for Watershed Protection, Debo and Associates, Jordan Jones and Goulding, Atlanta Regional Commission, Atlanta, Georgia, 2001.
8	“Hydraulic Design of Highway Culverts,” Federal Highway Administration, FHWA HDS 5, Washington, D.C., 1985 (revised May 2005).
9	“Low Impact Development Design Strategies <i>An Integrated Design Approach</i> ,” Prince Georges County, Maryland Department of Environmental Resources, June 1999.
10	“Maryland Stormwater Design Manual,” Maryland Department of the Environment, Baltimore, Maryland, 2000.
11	“Pennsylvania Handbook of Best Management Practices for Developing Areas,” Pennsylvania Department of Environmental Protection, 1998.
12	“Recommended Procedures for Act 167 Drainage Plan Design,” LVPC, Revised 1997.
13	“Roof Gardens History, Design and Construction,” Osmundson, Theodore. New York: W.W. Norton & Company, 1999.
14	“The Texas Manual on Rainwater Harvesting,” Texas Water Development Board, Austin, Texas, Third Edition, 2005.
15	“VDOT Manual of Practice for Stormwater Management,” Virginia Transportation Research Council, Charlottesville, Virginia, 2004.
16	“Virginia Stormwater Management Handbook,” Virginia Department of Conservation and Recreation, Richmond, Virginia, 1999.
17	“Water Resources Engineering,” Mays, L. W., John Wiley & Sons, Inc., 2005.
18	“Urban Hydrology for Small Watersheds,” Technical Report 55, U.S. Department of Agriculture, Natural Resources Conservation Service, 1986.
19	U.S. EPA, Region 1 New England web site (as of August 2005) http://www.epa.gov/NE/assistance/ceitts/stormwater/techs/html

LIST OF ACCEPTABLE BMPs PRE-TREATMENT METHODS FOR “HOT SPOT” LAND USES

Hot Spot Land Use	Pre-treatment Method(s)
Vehicle Maintenance and Repair Facilities including Auto Parts Stores	<ul style="list-style-type: none"> - Water Quality Inlets - Use of Drip Pans and/or Dry Sweep Material Under Vehicles/Equipment - Use of Absorbent Devices to Reduce Liquid Releases - Spill Prevention and Response Program
Vehicle Fueling Stations	<ul style="list-style-type: none"> - Water Quality Inlets - Spill Prevention and Response Program
Storage Areas for Public Works	<ul style="list-style-type: none"> - Water Quality Inlets - Use of Drip Pans and/or Dry Sweep Material Under Vehicles/Equipment - Use of Absorbent Devices to Reduce Liquid Releases - Spill Prevention and Response Program - Diversion of Stormwater away from Potential Contamination Areas
Outdoor Storage of Liquids	<ul style="list-style-type: none"> - Spill Prevention and Response Program
Commercial Nursery Operations	<ul style="list-style-type: none"> - Vegetated Swales/Filter Strips - Constructed Wetlands - Stormwater Collection and Reuse
Salvage Yards and Recycling Facilities*	<ul style="list-style-type: none"> - BMPs that are a part of a Stormwater Pollution Prevention Plan under an NPDES Permit
Fleet Storage Yards and Vehicle Cleaning Facilities*	<ul style="list-style-type: none"> - BMPs that are a part of a Stormwater Pollution Prevention Plan under an NPDES Permit
Facilities that Store or Generate Regulated Substances*	<ul style="list-style-type: none"> - BMPs that are a part of a Stormwater Pollution Prevention Plan under an NPDES Permit
Marinas*	<ul style="list-style-type: none"> - BMPs that are a part of a Stormwater Pollution Prevention Plan under an NPDES Permit
Certain Industrial Uses (listed under NPDES)*	<ul style="list-style-type: none"> - BMPs that are a part of a Stormwater Pollution Prevention Plan under an NPDES Permit

*Regulated under the NPDES Stormwater Program

Design references for the pre-treatment methods, as necessary, are listed below. If the applicant can demonstrate to the satisfaction of the municipality that the proposed land use is not a Hot Spot, then the pre-treatment requirement would not apply.

Pre-treatment Method	Design Reference ^A
Constructed Wetlands	5, 6, 10, 12, 18
Diversion of Stormwater Away from Potential Contamination Areas	5, 13
Stormwater Collection and Reuse (especially for irrigation)	5, 16
Stormwater Filters (Sand, Peat, Compost, etc.)	5, 6, 12, 18
Vegetated Swales	2, 4, 6, 13, 18, 19
Water Quality Inlets	5, 9, 17, 18, 21

^A These numbers refer to the Design Reference Title Chart beginning on H2.



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