PERKIOMEN CREEK HEADWATERS

- ACT 167 –

STORMWATER MANAGEMENT PLAN

Draft Plan June 2009

Lehigh Valley Planning Commission

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This is the text prepared by the Lehigh Valley Planning Commission (LVPC) on behalf of Lehigh County. It contains revisions, as necessary, based on comments received from the Perkiomen Creek Headwaters Watershed Plan Advisory Committee.

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Draft Plan June 2009

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June 2009

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CHAPTER 1. INTRODUCTION

The Pennsylvania Stormwater Management Act of 1978, Act 167, provides the framework for the improved management of the storm runoff impacts associated with the development of land by encouraging the sound planning management of storm runoff, coordinating the stormwater management efforts within each watershed, and encouraging the local administration and management of a coordinated stormwater program. Until now, stormwater management decisions have been made at the municipal level through enforcement of local ordinances based upon whatever runoff control philosophy the municipality opted to use. For the Perkiomen Creek Headwaters, four Lehigh County municipalities have a stake in how stormwater runoff is managed in the watershed. Without an effort to coordinate their efforts through watershed analyses, the four municipalities would establish a fragmented system of stormwater management based on municipal boundaries with uncertain results. At best, the fragmented system results in an inefficient process of runoff control management, whereby conservative engineering design would dictate "over-control" of runoff. At worst, the fragmented approach could result in the creation of additional storm drainage problems and associated costs and hazards, which could occur even though all of the municipalities are diligently administering and enforcing their ordinances. The existing ordinances do not require any analysis of impacts beyond municipal boundaries, and a watershed-wide data base has not been available to quantify downstream impacts.

The difference between an 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 be to control the post-development peak rate of runoff to the pre-development peak rate for a given storm event, a watershed-level design would be focused on maintaining the peak rate of the entire watershed. The watershed-level design assumes that runoff volume will increase with development for the highest intensity events, and requires an analysis of how each site relates to the watershed in terms of the timing of the peak flow, the contribution of peak flows at various downstream locations, and the impact of the additional runoff volume generated by development. The plan is intended to "manage" the increase in runoff volume such that the peak rates throughout the watershed are not increased.

On a watershed-level, Act 167 stormwater management will provide a significant step forward in the sound management of the storm 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 and that new drainage problems are not created. However, the storm runoff control strategy will not eliminate existing problem areas, nor will it prevent flooding. To effectively implement an Act 167 program, it is necessary to understand the following strengths and limitations:

- An Act 167 plan is not an engineering design document, but it provides an engineering framework for individual site evaluation and design.

- 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 create runoff events which cannot be effectively controlled.

- The runoff control criteria developed as part of an Act 167 plan will not correct existing drainage problems.

- An Act 167 plan will not prevent the inundation of floodplain areas. These areas are intended to carry storm runoff by nature.

It is also important to understand that an Act 167 plan is not a land use plan. Although some control techniques discussed in Chapter 6 deal with controlling runoff through creative land use practices, runoff controls developed in this plan are not based upon controlling the location, type, density, or rate of development in the watershed. The performance standards are based on the assumption that development will occur.

The most important aspect of an Act 167 plan is that it establishes a process for decision-making. It defines the existing relationships between the various parts of a watershed in terms of the "timing" of peak flows from multiple sources, which provides for the development of the watershed-wide runoff control philosophy for controlling runoff impacts.

Act 167 is essentially a three-step process of runoff control which proceeds as follows:

1. Documentation of the existing state of stormwater runoff in the watershed. This includes the documentation of existing physical characteristics of the watershed (e.g. land use, soils, slopes, storm sewers, etc.), existing storm drainage problems, and the peak flow and timing relationships. The existing condition establishes the baseline against which all runoff control measures will be judged.

2. Preparation of the plan to control stormwater runoff from new development. The plan includes runoff control performance standards for new development *and* a process for site specific analysis and design. The performance standards do not dictate the control methods required, but rather indicate the necessary end product. The runoff control philosophy is intended to ensure that peak runoff rates through the watershed will not increase with development. Successful implementation of the control philosophy would mean the continuation of the "status quo" runoff situation: existing problem areas will not be fixed, but they will not be exacerbated, and new problem areas will not be created.

3. Development of priorities for implementation. This involves developing a prioritized list of actions aimed at improving the current state of stormwater runoff in the watershed, essentially preparing a strategy for dealing with the existing drainage problem areas within each municipality.

One especially important aspect of the Act 167 process is the need to periodically update the plan. Act 167 specifies that a plan must be updated every five years. This guarantees a dynamic system of stormwater control sensitive to changing watershed characteristics.

The *Perkiomen Creek Headwaters – Act 167 – Stormwater Management Plan* has been prepared for Lehigh County by the Lehigh Valley Planning Commission (LVPC). The County has designated the LVPC to prepare the watershed plans for all watersheds on its behalf.

The LVPC has used two engineering consultants for the preparation of the Perkiomen Creek Headwaters Plan. Dr. David F. Kibler, P.E., is recently retired as a civil engineering professor from Virginia Tech. Dr. Kibler was formerly a professor of civil engineering at Pennsylvania State University. He has served as a consultant to the LVPC since the inception of Act 167 planning in the mid-1980s. Dr. Kibler was primarily involved in the hydrologic model development and calibration associated with the Perkiomen Creek Headwaters Plan. He provided further assistance regarding technical aspects of the model ordinance. Allen R. O'Dell, P.E., has served as a consultant to the LVPC since the early 1990s reviewing the engineering aspects of subdivision and land development plans versus the criteria contained in various Act 167 ordinances. For the Perkiomen Creek Headwaters Plan, Mr. O'Dell assisted with model ordinance development.

To ensure the involvement of the municipalities and agencies which will be impacted by the Stormwater Management Plan, Act 167 requires that a Watershed Plan Advisory Committee be formed to assist in the development of the Plan, and to familiarize the municipalities involved with the stormwater management concepts evolving from the plan process. Each municipality in the watershed, plus the County Conservation District, is required to be represented on the Committee. Representation by additional agencies and interest groups is allowed at the discretion of the County. Listed in Table 1 on page 1-4 are the names and agencies of the persons who participated on the Perkiomen Creek Headwaters Watershed Plan Advisory Committee.

The general framework for the Perkiomen Creek Headwaters Act 167 Plan has been developed from three sources, namely Act 167 itself, the Department of Environmental Protection's (DEP) Stormwater Management Guidelines, which represent the Department's interpretation of the Act, and the previous watershed stormwater management plans prepared by the LVPC.

As part of the development of the Perkiomen Creek Headwaters Plan, the LVPC has used a Geographic Information System (GIS) and ArcGIS software. The existing land use data for municipalities in Lehigh County was downloaded from Lehigh County's GIS. Land use data for areas outside of Lehigh County was obtained from Berks and Montgomery counties. Land use, soils, and zoning coverages were used in the watershed modeling process.

TABLE 1
PERKIOMEN CREEK HEADWATERS WATERSHED PLAN ADVISORY COMMITTEE

Municipality/Organization	**Name**
Lehigh County	
Lehigh County	Jan Creedon
Lower Macungie Township	Douglas Brown
Lower Milford Township	Donna Wright
Upper Milford Township	Daniel DeLong
Upper Saucon Township	Sharyn Heater
Lehigh County Conservation District	Rebecca Kennedy
	John Bohman
	Jeff Zehr
Lehigh Valley Builders Association	John Howard
	Jack Calahan
Wildlands Conservancy	Kristie Fach
Berks County	
Berks County Planning Commission	Ashley Mazurek
Hereford Township	No representative designated
Longswamp Township	Katherine Harms
Bucks County	
Bucks County Planning Commission	Dennis Livrone
	Alice Walters
Milford Township	No representative designated
Montgomery County	
Montgomery County Planning Commission	Drew Shaw
	Alexis Melusky
Upper Hanover Township	No representative designated
Other	
PA Department of Environmental Protection	Jennifer Kehler
PA Department of Transportation	Jeff Smallman
PA Turnpike Commission	Donald Steele
PA Fish & Boat Commission	Lee Creyer
Perkiomen Watershed Conservancy	Crystal Gilchrist
US Department of Agriculture - Natural Resources Conservation Service	Peter Zakanycz

CHAPTER 2. STUDY AREA CHARACTERISTICS AND HYDROLOGIC RESPONSE

A. General Characteristics

The Perkiomen Creek Headwaters study area is located in the southwestern part of Lehigh County, with some upstream areas extending into small areas of Berks, Montgomery, and Bucks counties. The various subwatersheds that comprise the headwaters generally flow south out of Lehigh County into the surrounding counties noted above. The subwatersheds that begin in Lehigh County will all combine below the Green Lane Reservoir at the confluence of the Perkiomen and Unami creeks, as shown in Figure 1. Note that only the gray areas of Figure 1 were included in the study area of this Act 167 Plan. The remaining areas are shown simply to illustrate how these subwatersheds combine downstream.

The Perkiomen Creek Headwaters consist of four main drainage areas tributary to multiple drainage channels in Lehigh County. The Perkiomen Creek has a tributary area of 5.5 square miles and flows to the southwest into Berks County. The Hosensack Creek (which includes flow tributary to Indian Creek) has a tributary area of 17.7 square miles and flows to the southwest into Montgomery County. The Hosensack Creek flows into the Perkiomen Creek north of East Greenville, upstream of the Green Lane Reservoir. The Macoby Creek has a tributary area of 2.4 square miles and also flows to the southwest into Montgomery County. It flows into the southeast end of the Green Lane Reservoir, where it joins with the Perkiomen Creek. The Unami Creek (which includes flow tributary to Licking, Molasses, and Schmoutz creeks) has a tributary area of 3.7 square miles and flows to the southeast into Bucks County at multiple locations. Schmoutz, Molasses, and Licking creeks will all flow into the Unami Creek in Bucks County, which meets the Perkiomen below the Green Lane Reservoir. The subwatersheds are shown in Figure 2 with the municipal boundaries highlighted. Table 2 lists each subwatershed and its respective drainage area in square miles.

TABLE 2
PERKIOMEN CREEK HEADWATERS SQUARE MILEAGE

Subwatershed	Area (Square Miles)
Perkiomen Creek Mainstem	5.50
Hosensack Creek	17.65
Macoby Creek	2.44
Unami Creek	3.73
Total Study Area	29.32

The area of the Perkiomen Creek Headwaters is underlain by two geologic formations. These formations are gneiss in the Reading Prong in the Perkiomen mainstem and the upstream areas of the Hosensack subwatershed, and Triassic shale and conglomerates in the lower part of the Hosensack and the entire Macoby, and Unami Creek subwatersheds. Figure 3 is a map of the geology of the Perkiomen Creek Headwaters.

FIGURE 1
Perkiomen Creek Headwaters Study Area Location Map

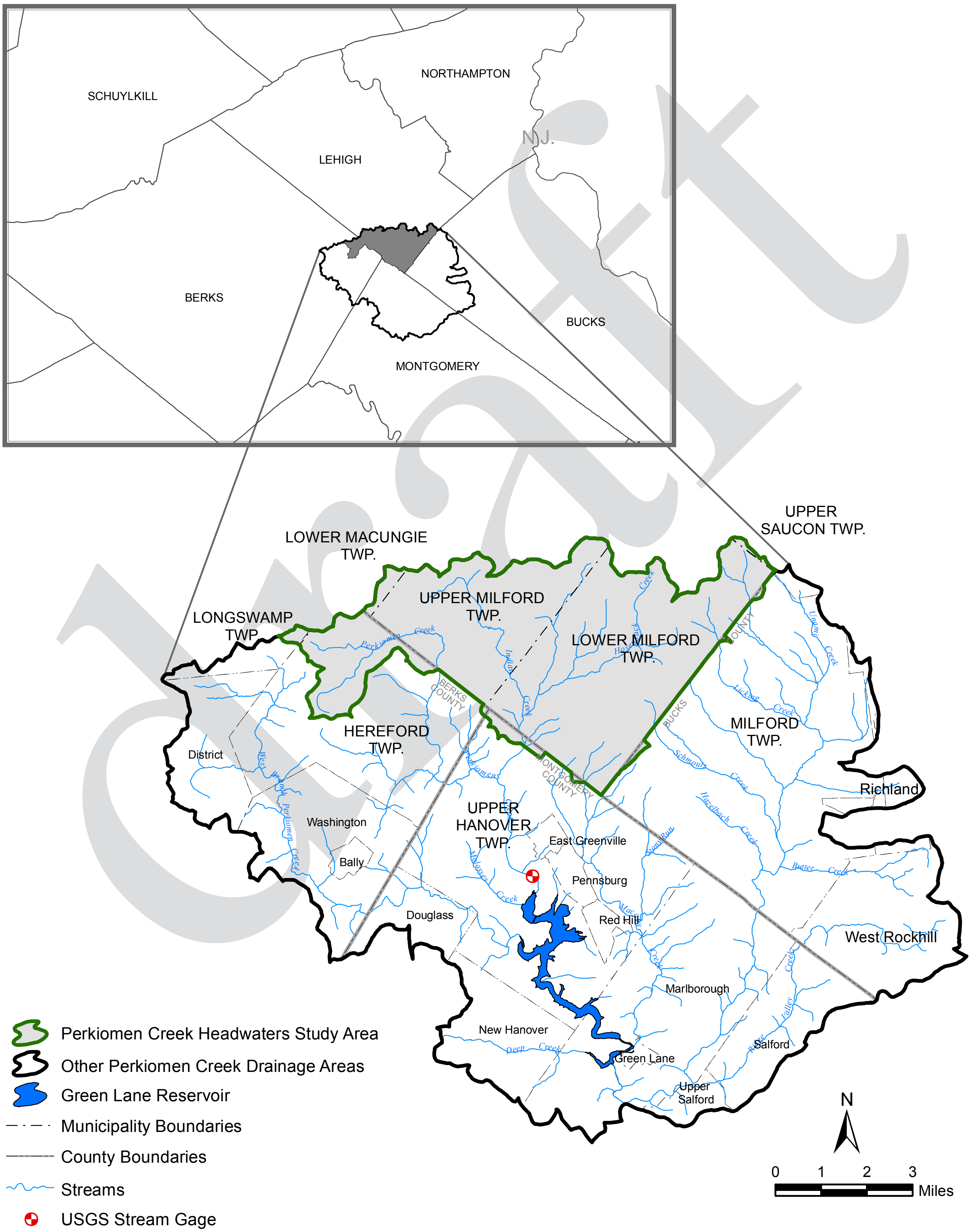
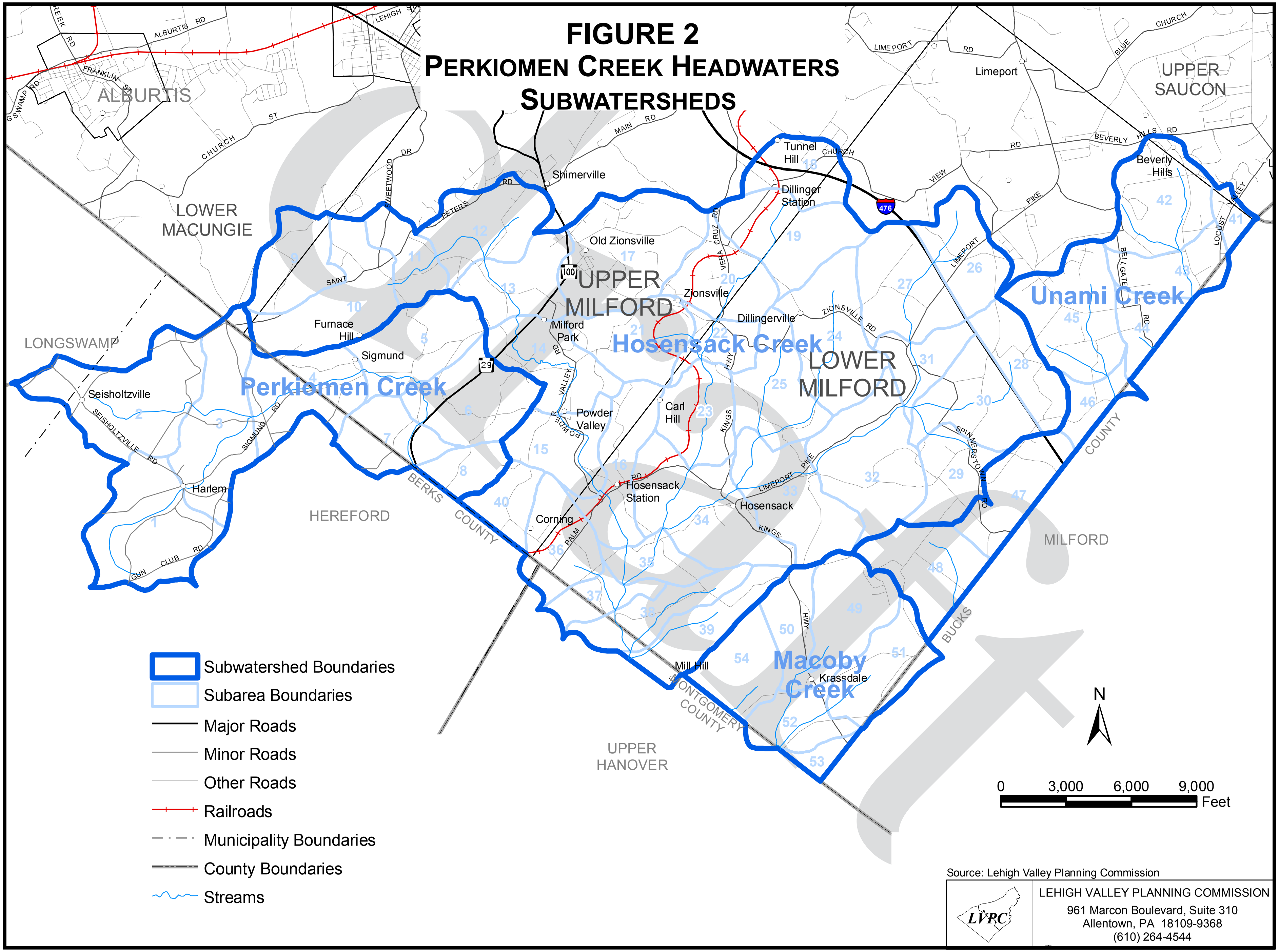


FIGURE 2
PERKIOMEN CREEK HEADWATERS SUBWATERSHEDS



The predominant soils found in the Perkiomen Creek Headwaters are classified as Hydrologic Soils Group B. Hydrologic Soil Groups (HSGs) are classifications which indicate the relative runoff potential of soils based on infiltration rates for various soil types. Runoff potential increases with decreasing infiltration rates as you progress from HSG A to HSG D soils. HSG A soils are sandy soils with high infiltration rates and low runoff potential. There are no HSG A soils in the Perkiomen Creek Headwaters. Group B soils have moderate infiltration rates and consist mostly of moderately deep, well-drained soils. Group C soils have low infiltration rates. This group consists mostly of soils which impede the downward movement of water. Group D soils have very low infiltration rates and therefore high runoff potential. This group consists mostly of soils with a clay layer and a permanent high water table. Hydrologic Soil Groups are one element used in determining runoff curve numbers and Rational ‘c’ values. Within the Perkiomen Creek Headwaters, Gladstone Gravelly Silt Loam is the most common soil type. These soils are classified as HSG B, and are commonly found on upland divides and in rolling foothills. Other common soil types in the study area include Arendtsville Gravelly Silt Loam (HSG B), Penn Channery Silt Loam (HSG C), and Towhee Silt Loam (HSG D). Figure 4 is a map of the study area soils by HSG.

Land use within the study area is predominantly residential in the upstream areas of the subwatersheds and agricultural in the lower parts of the study area. There are no urban areas in the study area, but there is a PPL generator station in the Hosensack Creek watershed.

The Pennsylvania Department of Environmental Protection (DEP) has designated the Perkiomen mainstem as High Quality Waters - Cold Water Fishes (HQ-CWF) above SR 1010 (Seisholtzville Road), and Trout Stocking Fishes (TSF) between SR 1010 and the Green Lane Reservoir. The CWF water quality criterion is designed for protection of aquatic life (fish species and flora and fauna) which are native to a cold water environment. Specific criteria include levels of ammonia, nitrogen, bacteria, pH, total dissolved solids, dissolved oxygen, and temperature, among others. The TSF criterion is designed to protect native trout populations from February 15 through July 31. The Hosensack Creek has been classified as CWF by DEP. The Macoby Creek has been classified as TSF. The Unami Creek has been designated as High Quality Waters-Trout Stocking Fishes (HQ-TSF). Those watersheds that have been designated as High Quality Waters (HQ) must meet standards to preserve the chemistry and biology of the receiving stream. These designations are current as of the preparation of this Act 167 Plan, but changes to these designations have been recently proposed.

B. Hydrologic Response

There are no United States Geologic Survey (USGS) formal stream gages or miscellaneous measurement sites within the study area. However, there are two active stream gages further downstream on the Perkiomen Creek: at East Greenville and Graterford. The East Greenville gage is approximately 3 miles downstream of the Lehigh County boundary at the bottom of the Hosensack Creek subwatershed, as noted on Figure 1. This gage records flows from the Perkiomen and Hosensack study areas, as well as

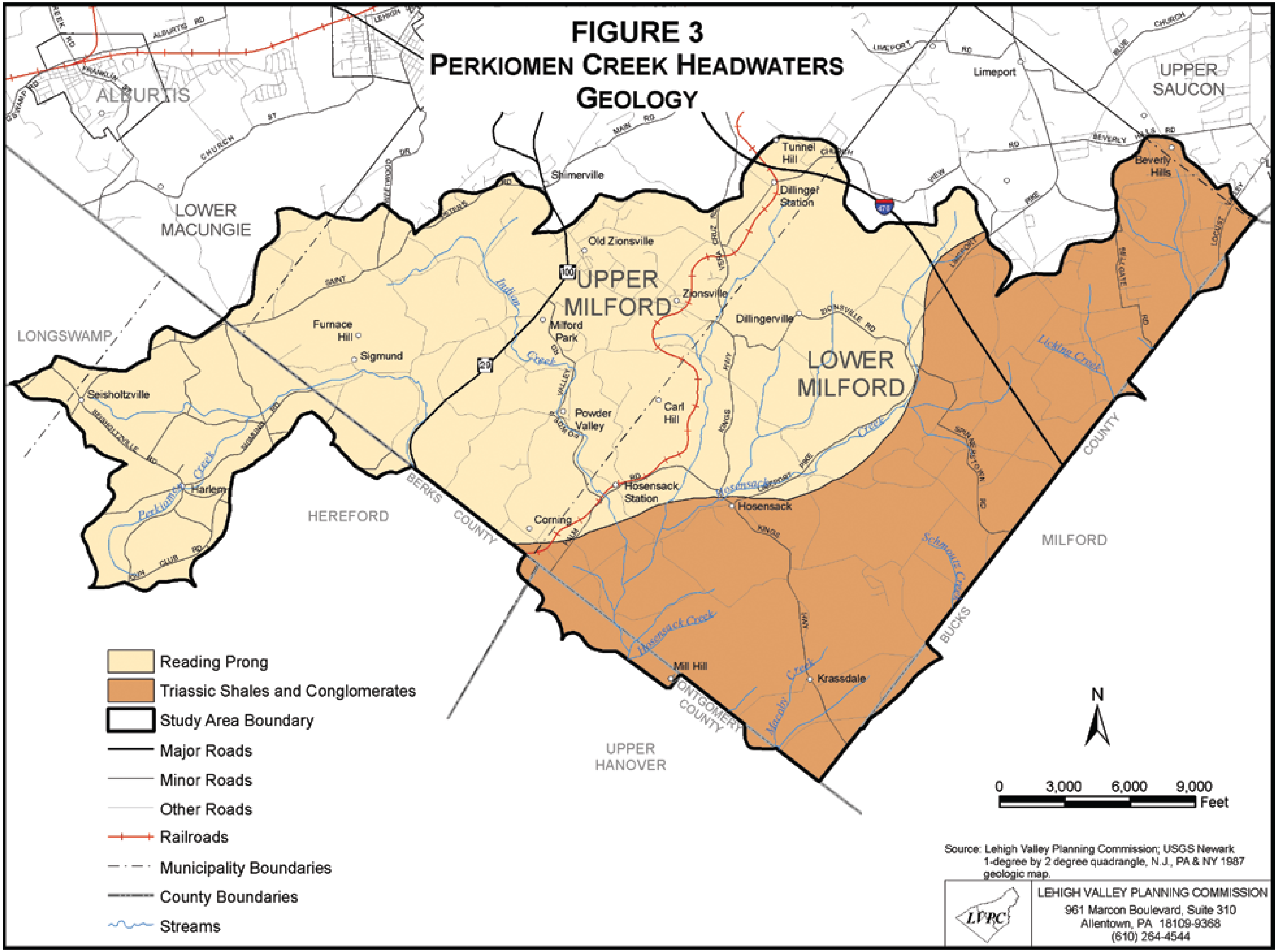
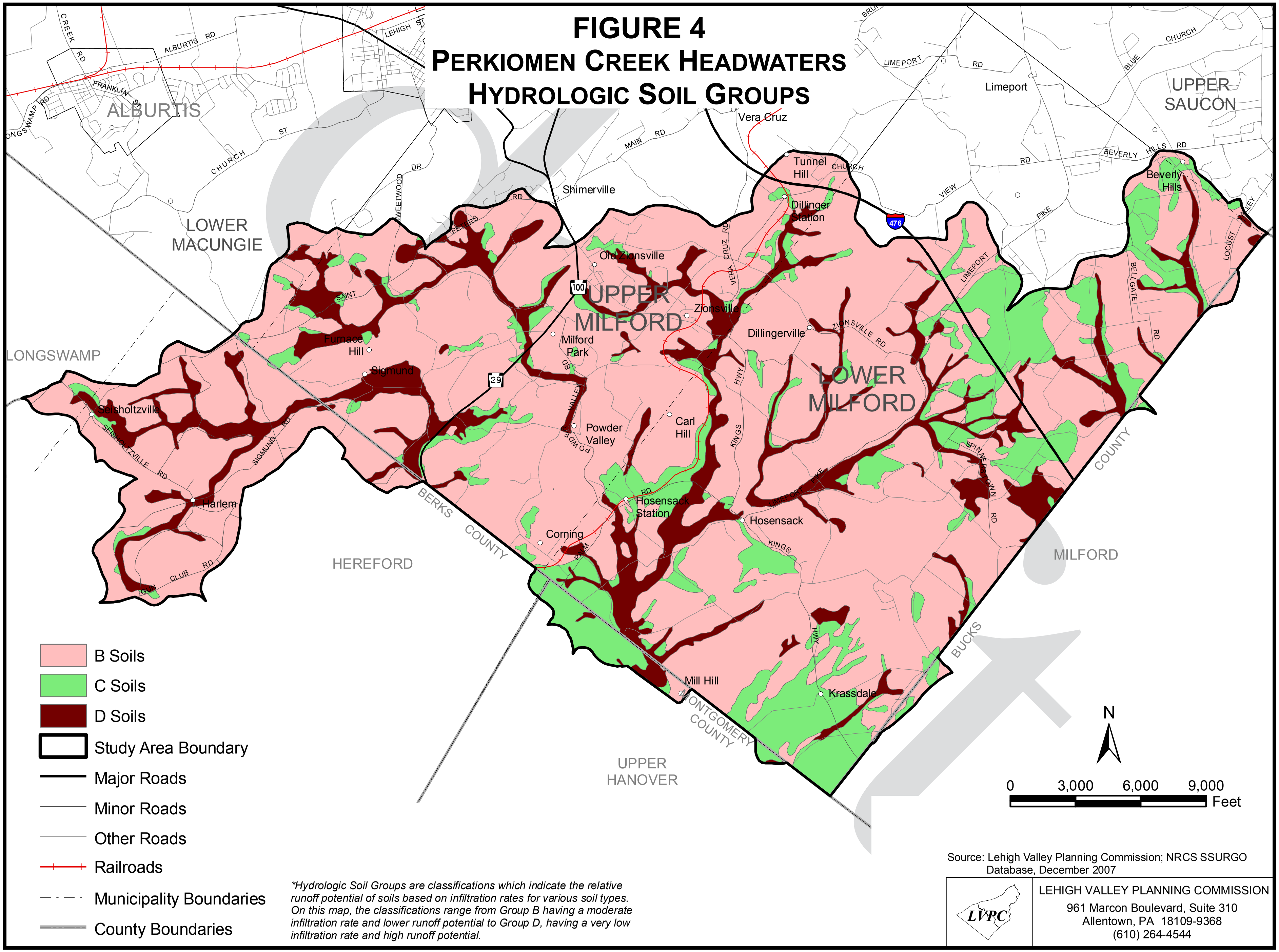


FIGURE 3
PERKIOMEN CREEK HEADWATERS
GEOLOGY
ALBURTIS
LOWER MACUNGIE
LONGSWAMP
UPPER MILFORD
LOWER MILFORD
UPPER SAUCON
HEREFORD
UPPER HANOVER
MILFORD
BERKS COUNTY
BUCKS COUNTY
MONTGOMERY COUNTY
Limeport
Shimerville
Tunnel Hill
Dillinger Station
Old Zionsville
Zionsville
Dillingerville
Milford Park
Furnace Hill
Sigmund
Seisholtzville
Harlem
Powder Valley
Carl Hill
Hosensack Station
Hosensack
Corning
Beverly Hills
Mill Hill
Krassdale
Indian Creek
Perkiomen Creek
Hosensack Creek
Licking Creek
Schmoutz Creek
Macoby Creek
Reading Prong
Triassic Shales and Conglomerates
Study Area Boundary
Major Roads
Minor Roads
Other Roads
Railroads
Municipality Boundaries
County Boundaries
Streams
N
0 3,000 6,000 9,000 Feet
Source: Lehigh Valley Planning Commission; USGS Newark 1-degree by 2 degree quadrangle, N.J., PA & NY 1987 geologic map.
LEHIGH VALLEY PLANNING COMMISSION
961 Marcon Boulevard, Suite 310
Allentown, PA 18109-9368
(610) 264-4544

FIGURE 4
PERKIOMEN CREEK HEADWATERS HYDROLOGIC SOIL GROUPS



15.1 square miles below the study areas and has a period of record from 1982 to the present. The Graterford gage is approximately 15 miles downstream of the bottom of the Hosensack Creek subwatershed. All of the runoff from the Perkiomen Creek Headwaters is recorded by this gage, as well as 249.7 square miles downstream of the study area. This gage has records from 1915 to the present.

Since the gages monitor areas greatly in excess of the study area, the peak flows from the subwatersheds needed to be estimated. There are several ways for this to be accomplished. One such method is the PSU IV procedure for estimating flood peaks in ungaged watersheds developed by Penn State in 1981. This method provides a relatively simple means of estimating peak flows from general watershed characteristics and the watershed's location within Pennsylvania. Estimation of peak flows for a watershed using data from previously calibrated watersheds is also possible. Flow data from all previously modeled watersheds from Act 167 plans in the Lehigh Valley was used to develop peak flow estimates. This correlation technique is based on the relative drainage areas of two watersheds and known peak flows from previous studies. Also, since USGS gage data is available at East Greenville and Graterford, it is possible to perform a flood frequency analysis to determine the flood peaks for each gage by return period and relate to Perkiomen Creek Headwaters subwatersheds. The Log Pearson 3 (LP3) analysis flood peaks were used to calibrate a correlation between the gage area and each of the areas of the modeled subwatersheds in the Perkiomen Creek Headwaters. Dr. David Kibler performed this analysis using both the East Greenville and Graterford stream gages. Specifically, the calculated peak flows by return period for the East Greenville and Graterford gages were used to calibrate the exponents needed for a correlation procedure. The calibrated exponents were applied to a correlation procedure between the East Greenville gage peak flows and the Perkiomen Creek Headwaters subwatersheds. Last, Flood Insurance Study (FIS) data is available for the Hosensack Creek in Lehigh County. This data included flood peak flows at the county boundary. Table 3 presents the data associated with the Hosensack Creek, representing a 17.37[1] square mile area. A reference for each of the techniques applied is presented as part of the table. Note that not all techniques provide peak flow estimates for all return periods.

[1] The 17.37 square mile area of the Hosensack Creek refers to the area that was used for calibration of the watershed model. There is one 0.28 square mile subarea of the Hosensack watershed that drains over the county boundary before entering the creek, and this was not included in the area used for the initial calibration.

TABLE 3
PEAK FLOW ESTIMATES BY VARIOUS TECHNIQUES AT THE BOTTOM OF THE HOSENSACK CREEK STUDY AREA

Method/Source	Peak Flow Estimates in Cubic Feet Per Second (cfs) for Return Period of:			
	2 Years	10 Years	25 Years	100 Years
PSU IV[a]	1,100	2,561	3,588	5,546
Correlation with[b]:				
Little Lehigh Creek	396	661	1,463	3,150
Jordan Creek	906	2,309	3,226	5,452
Jacoby Creek	542	2,210	3,993	8,817
Log Pearson 3[c]	1,381	3,377	4,850	7,940
Flood Insurance Study[d]	-------	3,000	-------	8,700

[a]*Field Manual of Procedure PSU IV for Estimating Design Flood Peaks on Ungaged Pennsylvania Watersheds*, Pennsylvania State University, April 1981.

[b]Correlation based on the ratio of drainage areas between the listed watershed and the Hosensack Creek study area, raised to the 0.75 power, multiplied by the calibrated peak flow values of the listed watershed developed in previous Act 167 Plans.

[c]*Recommendation for Flood Frequency Analysis in Perkiomen Creek Watershed*. Memorandum from Dr. David Kibler to LVPC revised August 21, 2008. East Greenville data used for flow comparison.

[d]Federal Emergency Management Agency Flood Insurance Study for Lehigh County, Volume 1 of 2. Flow values are given at the county boundary.

As Table 3 shows, there is a good variance in the peak flows for a given return period, depending on the estimation method. For example, the 100-year peak flow estimates vary from a low of 3,150 cfs from the correlation with the Little Lehigh Creek Watershed to a high of 8,817 from the correlation with the Jacoby Creek Watershed. Of this data, the Flood Insurance Data is probably the most accurate representation of the actual conditions, since it is based on a detailed flood study by the Federal Emergency Management Agency (FEMA). Also, since the LP3 correlation is based on the East Greenville USGS gage data downstream of the study area, it should also be considered to be fairly representative of the actual flood peaks. Since the Hosensack Creek study area is entirely in areas without carbonate bedrock, it is unlikely that flow correlations with previously calibrated, partially carbonate bedrock watersheds would be suitable for use in calibrating the Perkiomen model. Finally, compared with the LP3 and FIS data, it seems apparent that PSU IV is underestimating the size of the large flood events. Therefore, the LVPC has opted to calibrate the model to the best fit of both the FIS (where applicable) and LP3 flow values.

The Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) was selected to create the hydrologic model for the watershed in the Perkiomen Creek Headwaters. HEC-HMS was selected for several reasons, including its ease of use, flexibility in modeling techniques, and cost (free). HEC-HMS is able to replicate the performance of the Penn State Runoff Model (PSRM) methodology fairly well, which the LVPC had used for the development of all previous Act 167 Plans.

Calibration of the hydrologic model involves the adjustments of certain parameters of the model to best reproduce actual conditions. In this case, the presumption is that the FIS data provides the best estimates of the actual condition, and that the LP3 data from the East Greenville gage also provides solid estimates for flood peaks. Several sensitivity analyses were performed to determine how significantly the model parameters needed to be adjusted to meet the determined targets in the Hosensack Creek. The overland flow length and slope, Muskingum X (value that accounts for attenuation of the flood wave by the channel; ranges from 0 to 1 as attenuation decreases), and Muskingum K (travel time) values were all first tested separately, and overland flow length and slope and travel time were later adjusted simultaneously to test the model's sensitivity to the adjustment of these parameters. To accomplish the calibration, several adjustments were made to model parameters keyed to flow in the floodplain and the effect of the large number of flow obstructions (culverts, bridges, etc.) in the watershed. Both of these conditions increase the time it takes for the flood wave to propagate downstream. The floodplains in the Perkiomen Headwaters are generally wooded, which generally decreases the velocity of the flood. Also, the large number of obstructions along the channel impedes the flow during large, out-of-bank events. Additionally, data from a detailed flood study at the bottom of the Hosensack Creek subwatershed highlighted a certain obstruction that provided significant attenuation for large flood events, which was included in the model as a reservoir structure. The detailed flood study showed that the bridge over the Hosensack Creek on Shultz Bridge Road would not be overtopped during the 100-year event. This was not echoed by our original estimates of the peak flow capable of being passed under the bridge without overtopping the road based on field measurements. Therefore, the bridge was modeled as the outlet of a reservoir, with enough storage volume behind it so as to bring the 100-year flood elevation up to the road level, but not overtop the roadway. Additionally, the travel time in the channels was increased by a factor of 2.7 for the 10-, 25-, and 100-year storms to simulate the effects of the numerous bridges, culverts, off-line ponds, and other obstructions in the floodplain during out-of-bank events. A catalog of all these potential in-channel and floodplain flow obstructions was developed based on field work and aerial photography. There are 84 potential obstructions in the Perkiomen Creek Headwaters, 51 of which were able to be measured in the field. Of these 51 field-checked bridges and culverts, almost half of them (24 of 51) were not able to pass the 10-year peak flow. This adjustment was not applied to the 2-year event for two reasons: the LP3 target was met for the 2-year storm without any adjustments, and the 2-year event is predominantly an in-bank event, and does not warrant modification based on the effects of the obstructions. Since the study area can be considered homogeneous (i.e. similar geography and topography), and that every (or nearly every) channel has several significant obstructions, the travel time adjustments were applied to each tributary in the study area.

Calibration for design storm events in the Hosensack Creek resulted in peak flow values by return period as presented in Table 4. The table shows a comparison of the calibrated peak flows versus both the LP3 flows from the East Greenville gage and the FIS data calculated at the county boundary. Table 4 shows that the calibration is close to the 2- and 25-year LP3 targets, as well as the 100-year FIS target. The 10-year storm falls between the two targets. The calibration process accomplished the goal of generating peak flows which approximate the FIS and LP3 values while maintaining hydrograph volume since no curve number adjustments were necessary.

TABLE 4
CALIBRATED HEC-HMS HOSENSACK CREEK VALUES VERSUS LP3 AND FIS FLOW TARGETS*

Return Period	Peak Flow			HEC-HMS % Difference**
	HEC-HMS	FIS	LP3	
1	678	----	672	0.9
2	1,387	----	1,381	0.4
5	2,413	----	2,427	-0.6
10	3,288	3,000	3,377	-2.6
25	4,963	----	4,850	2.3
50	6,804	6,400	6,258	6.3
100	8,801	8,700	7,940	1.2

*Data is associated with the entire drainage area to the bottom of the Hosensack Creek study area.

**HEC-HMS percent difference calculated as the HEC-HMS peak flow minus the closer of the two flow targets (FIS or LP3) divided by the same flow target.

The calibrated HEC-HMS data from the Hosensack Creek study area from Table 4 is also presented graphically in Figure 5. The plot of peak flow versus return period is called a “frequency curve” for the study area. The frequency curve is also shown for the Log Pearson 3 analysis.

The remainder of the study area is divided into eleven separate drainage areas for the purpose of modeling. These drainage areas are: the Perkiomen Creek, an unnamed tributary to the Hosensack Creek, the Unami Creek, two unnamed tributaries to the Unami Creek, Licking Creek, Molasses Creek, Schmoutz Creek, the Macoby Creek Branch, an unnamed tributary to the Macoby Creek Branch, and the Macoby Creek. With the exception of the Hosensack Creek, the drainage areas were considered too small to warrant individual calibration of peak flows. Calibration targets derived from correlation to gaged watersheds would be considered less reliable as watershed size decreases. Since these drainage areas have the same basic characteristics of soil, slope, geology, and land use, it was decided that the largest drainage area, in this case the Hosensack Creek, would be calibrated, and the calibration adjustments would be applied to the remaining drainage areas. Therefore, the same travel time adjustments that were applied to the Hosensack Creek were applied to each of these drainage areas. However, there are no detailed flood studies in these drainage areas, and no individual obstructions were included in the model. Table 5 contains the peak flow values at the bottom of each study area.

FIGURE 5
HOSENSACK CREEK FLOOD FREQUENCY AT LEHIGH COUNTY BOUNDARY FROM CALIBRATED HEC-HMS AND LOG-PEARSON 3 CORRELATION

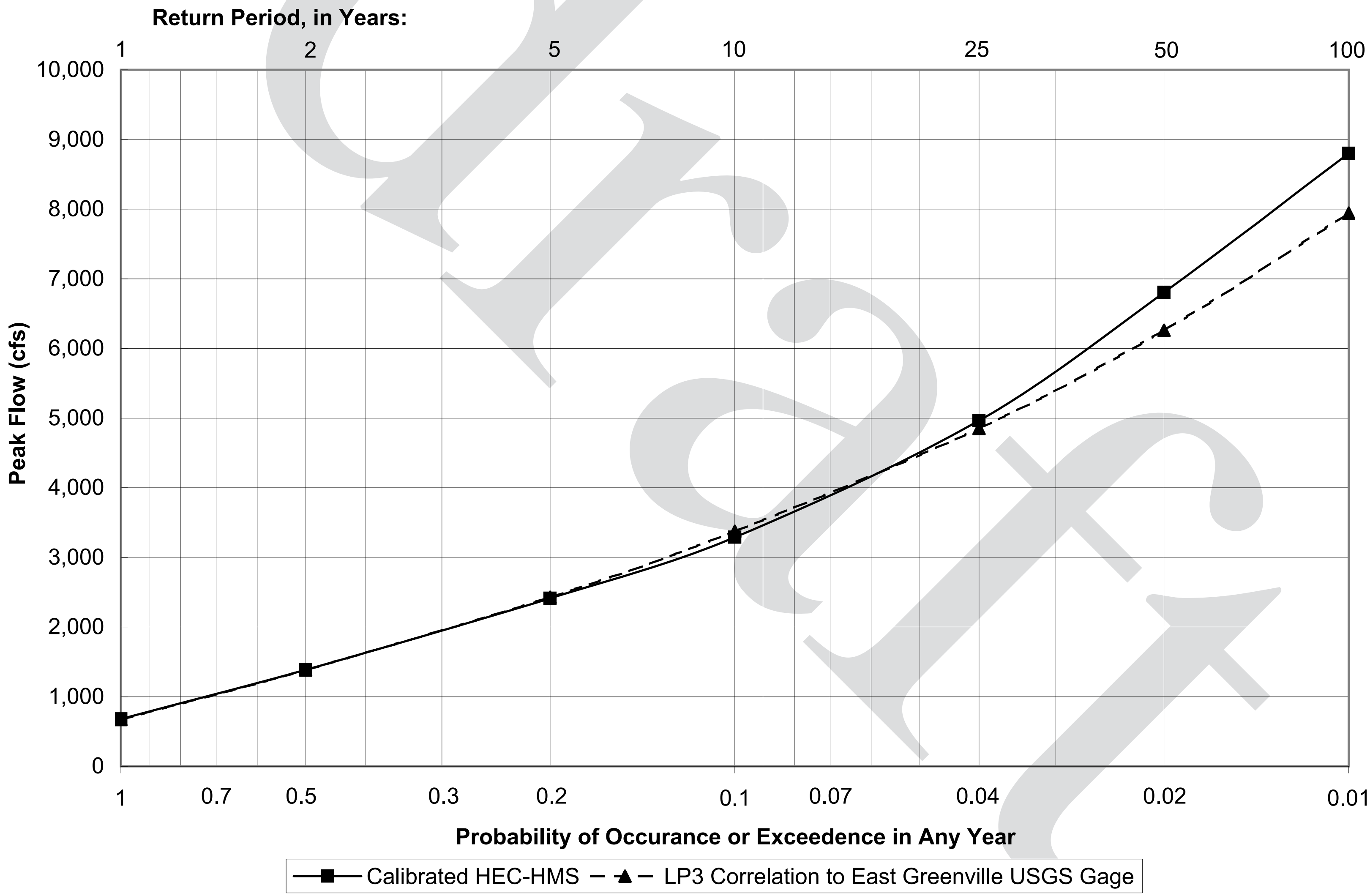


TABLE 5
CALIBRATED HEC-HMS PEAK FLOW VALUES FOR REMAINING DRAINAGE AREAS IN PERKIOMEN CREEK HEADWATERS
Peak Flow (cfs)

	Drainage Areas and Subareas (refer to Plate I inside back cover):					
Return Period	**Perkiomen Subareas 1-8**	**Unnamed Tributary to Hosensack Subarea 40**	**Unami Subarea 41**	**Unnamed Tributary to Unami Subareas 42-43**	**Unnamed Tributary to Unami Subarea 44**	**Licking Subareas 45-46**
1	148	6	14	87	16	61
2	312	15	27	172	34	125
5	562	31	46	291	61	217
10	967	74	91	556	124	424
25	1,535	139	152	897	210	698
50	2,185	228	229	1,296	314	1,029
100	2,894	336	316	1,738	435	1,407

Return Period	**Molasses Subarea 47**	**Schmoutz Subarea 48**	**Macoby Branch Subareas 49-52**	**Unnamed Tributary to Macoby Branch Subarea 53**	**Macoby Subarea 54**
1	18	25	84	18	14
2	38	57	174	34	34
5	69	105	304	51	68
10	143	219	490	94	150
25	247	377	806	142	268
50	380	575	1,197	200	419
100	538	804	1,642	265	597

CHAPTER 3. PERKIOMEN CREEK HEADWATERS LAND DEVELOPMENT AND RUNOFF IMPACTS

A. General Land Development Impacts on Storm Runoff

The necessity for the preparation of a stormwater management plan is created by the fact that land development 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. roof areas, driveway, parking lots, roads, etc.). Impervious cover does not allow rainfall to infiltrate into the ground, instead, it predominantly becomes surface runoff. The exception to this would be when impervious areas drain to pervious areas which would allow for some infiltration. The percentage of impervious cover for a given development varies by the type of development, as shown in Table 6 below.

TABLE 6
"TYPICAL" PERCENT IMPERVIOUSNESS BY LAND USE

Land Use	Percent Imperviousness
1. Woods	0
2. Open Space	0
3. Agriculture	0
4. Low Density Residential	20
5. Medium Density Residential	38
6. High Density Residential	65
7. Industrial	72
8. Commercial	85
9. Institutional	40
10. Large Impervious Areas	100
11. Water Bodies	100
12. Transportation Uses	30
13. Mining	0

The above typical percent imperviousness figures have been developed from standard Natural Resources Conservation Service[2] (NRCS) methodology. The breakdown between the three residential densities is as follows: low density – less than or equal to 2 units per acre; medium density – between 2 and 5 units per acre; high density – greater than or equal to 5 units per acre.

From Table 6, it is clear that the development of land which currently is in woods, open space, or agriculture could have a dramatic impact on the percentage of impervious cover. It is also clear that the cumulative impact of this type of development for a rural area could be severe without implementation of the proper runoff management controls.

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[2] On November 30, 1995, the Soil Conservation Service changed its name to the Natural Resources Conservation Service. When researching methodology or publications generated prior to this date, the author may still be listed as the Soil Conservation Service.

An example of the impacts that increases in impervious cover have on a given watershed area are illustrated in Figure 6. The series of curves, or hydrographs, present the runoff response of the watershed area versus time for percent imperviousness ranging from 5% to 25%, as generated by HEC-HMS (the hydrologic computer model selected for analysis by the LVPC in the Perkiomen Creek Headwaters Act 167 Plan). The watershed area used for this analysis represents a subarea size of 300 acres. The rainfall event used to produce the hydrographs was the NRCS 2-year design storm (24-hour duration, type II distribution, and a 3.0 inch rainfall depth).

From Figure 6, the peak runoff from the watershed area for 5% impervious cover is approximately 18 cfs (cubic feet per second). Further, each 5% increment in impervious cover produces an additional 8 to 11 cfs to the peak runoff such that 25% imperviousness produces 56 cfs runoff peak. If the 5% impervious cover hydrograph represented the “existing” condition of a watershed area, then each 5% increment of impervious cover would increase the surface runoff by about 50% of the pre-development peak flow. In the Perkiomen Creek Headwaters, 33% (18 out of 54) of the watershed subareas have existing impervious cover of 5% or less, and 82% (44 out of 56) have existing impervious cover of 10% or less. It is clear that the runoff impacts of development of the headwaters could be significant.

The amount of impervious cover is not the only factor affecting the amount of runoff produced by a given land area. Irrespective of impervious cover, certain land uses produce more runoff than others for the same rainfall. The NRCS has researched the runoff response for various types of land uses, or 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 use/cover types to produce runoff. Presented in Table 7 are the runoff curve numbers derived from NRCS which have been used in the Perkiomen Creek Headwaters planning process. Higher curve numbers reflect a greater potential for producing runoff.

FIGURE 6
IMPACT OF IMPERVIOUS COVER ON STORM RUNOFF

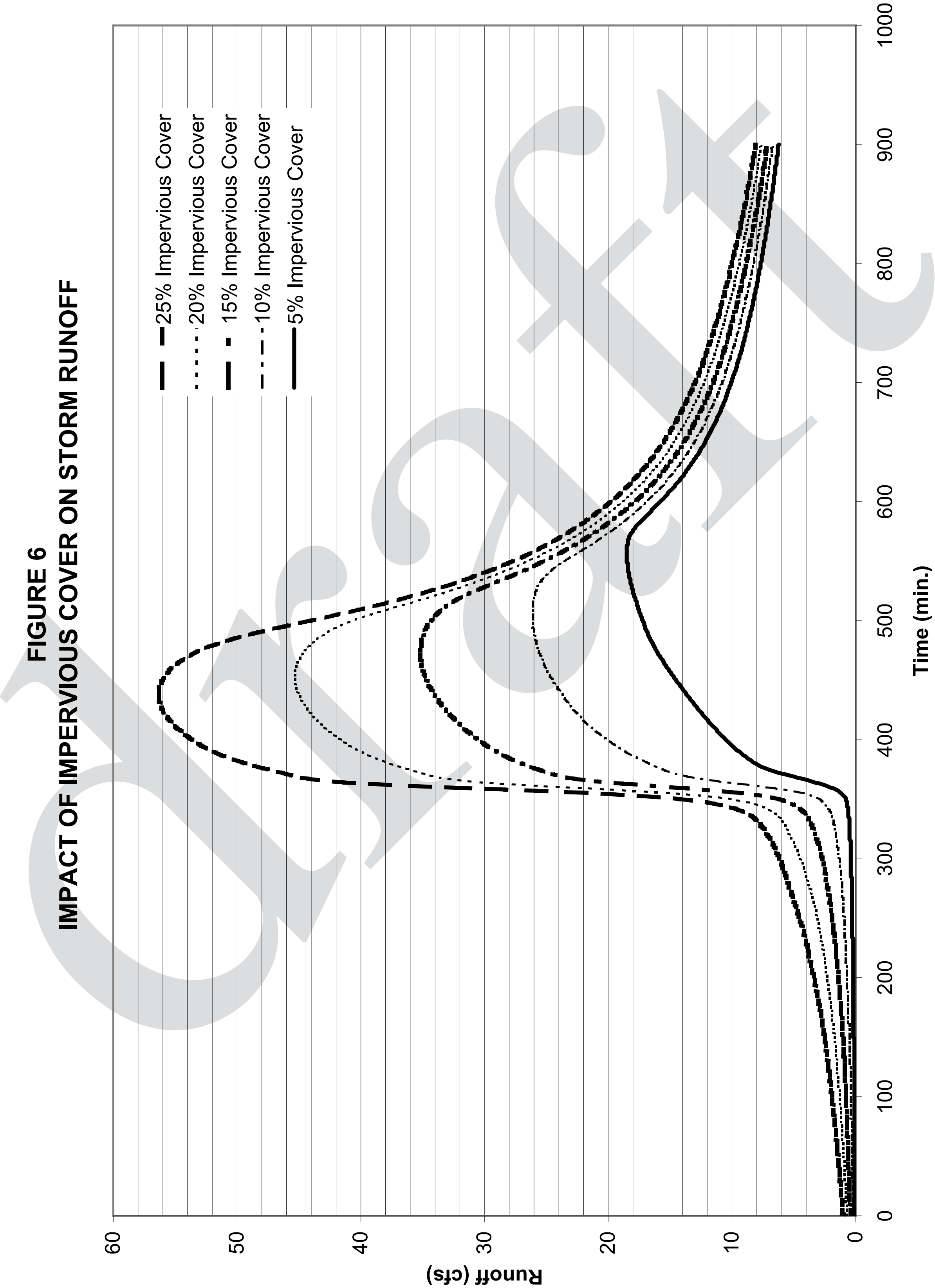

TABLE 7 RUNOFF CURVE NUMBERS BY LAND USE CATEGORY			
	Runoff Curve Number by Hydrologic Soil Group*		
Land Use	**B**	**C**	**D**
1. Woods	55	70	77
2. Open Space	61	74	80
3. Agriculture	76	83	86
4. Low Density Residential	68	79	84
5. Medium Density Residential	75	83	87
6. High Density Residential	85	90	92
7. Industrial	88	91	93
8. Commercial	92	94	95
9. Institutional	76	84	87
10. Large Impervious Areas	98	98	98
11. Water Bodies	100	100	100
12. Transportation Uses	72	81	85
13. Mining	0	0	0

*Curve numbers reflect impervious cover percentages from Table 6.

Note from Table 7 that, for Hydrologic Soil Group B, woods and open space have the lowest two curve numbers at 55 and 61, respectively, and both have zero percent impervious cover associated with them (from Table 6). However, agriculture, even though it has zero percent impervious cover, has a higher runoff curve number than both the low and medium density residential land uses, which have 20% and 38% impervious cover, respectively.

It is not necessarily true from the above that agriculture will produce more runoff than low or medium density residential development. In fact, agriculture can produce significantly less runoff than either one. Factors which affect this relationship include the slope of the land, the average length of overland flow, the depth, intensity, and duration of the rainfall event, and the method of computation, among others.

One final factor that can affect the quantity of stormwater runoff in the Lehigh Valley is carbonate geology. However, this was not a factor in this Act 167 Plan, as there is no carbonate bedrock present in the Perkiomen Creek Headwaters.

The above described impacts of development on storm runoff – impervious cover modification and curve number modification – relate to the rate and volume of runoff generated from a land area. However, an additional potential impact of development is the manner in which the generated runoff is conveyed downstream. Part of a land development may involve the construction of a closed pipe system, channel, or both. Closed pipe systems typically convey water faster than natural systems, and therefore runoff is transported more rapidly downstream. In addition, closed systems do not provide the opportunity for infiltration that exists within natural channels. Existing channels may also be encroached upon by a development. This could take the form of fill to one or both sides of a channel, placement of structures within the channel, or any other modifications of the natural cross-section of the channel. The exact impact on the conveyance characteristics (i.e. depth, width, capacity, velocity) of the channel would depend on the type and extent of the encroachment. A key aspect of the watershed plan is the ability of the conveyance facilities to maintain (or attain) adequacy for transporting anticipated runoff. Any modifications to the conveyance network associated with development should be accomplished in such a way as to provide for continuing transport of the upstream flows in a safe and efficient manner.

B. Historical Perkiomen Creek Headwaters Development

During the past quarter-century, land development within the Perkiomen Creek Headwaters Study Area has predominately consisted of low density residential development. This residential development has been scattered throughout the study area, with Upper Milford Township experiencing the greatest development pressure. Table 8 provides a summary of historical land development within the Perkiomen Creek Headwaters Study Area by municipality and type of development. Data for the table was estimated by the LVPC based upon LVPC land use records, a study area field survey and aerial photograph analysis.

TABLE 8
PERKIOMEN CREEK HEADWATERS STUDY AREA
HISTORICAL LAND DEVELOPMENT*
(Acres)

County / Municipality	Acres Developed over Studied Period **				Average Number of Acres Developed per Year
	Residential	Commercial	Industrial	Total	
Lehigh County					
Lower Macungie Twp.	0.0	0.0	0.0	0.0	0.0
Lower Milford Twp.	698.9	0.0	0.0	698.9	31.8
Upper Milford Twp.	759.1	8.1	0.0	767.2	34.9
Upper Saucon Twp.	33.7	0.0	0.0	33.7	1.5
Berks County ***					
Hereford Twp.	n/a	n/a	n/a	305.3	11.3
Longswamp Twp.	n/a	n/a	n/a	0.0	0.0
Bucks County ***					
Milford Twp.	n/a	n/a	n/a	17.7	0.7
Montgomery County ***					
Upper Hanover Twp.	n/a	n/a	n/a	15.6	0.6

* Source: LVPC land use records, Perkiomen Creek Headwaters Study Area field survey and aerial photograph analysis.

** Land development estimates for Lehigh County were estimated for the period from 1980 through 2002. Land development estimates for Berks, Bucks and Montgomery counties were estimated for the period from 1980 through 2007.

*** A breakdown of land development by land use was not available for this county.

For the portions of the watershed within Lehigh County, LVPC land use records were used to estimate land development for the period from 1980 through 2002. Since none of the Lehigh County municipalities are completely within the study area, land development figures for the study area portion of each municipality were estimated from the corresponding data for the entire municipality. Although land use data for Lehigh County is available for more recent years, the 2002 data was used because it provides the most meaningful comparison to the 1980 data. The land use data for both 1980 and 2002 was estimated using the LVPC's original land use database. For the years following 2002, land use data was estimated using a new LVPC database developed in 2005. Because the two databases classify and estimate land use differently, data from the two databases is not completely comparable. Therefore, an accurate comparison cannot be made between the 1980 land use data and the land use data for any year after 2002.

Because the LVPC land use records only include data for municipalities within the Lehigh Valley, the LVPC employed a different method of measuring development to determine watershed land development outside of Lehigh County. For the portions of the watershed in Berks, Bucks and Montgomery counties, the LVPC used 1981 aerial photographs to estimate the land area that had been developed by the end of 1980. This data was then compared to current land use data gathered by the LVPC during a field survey of the study area performed in early 2008. Comparing the development data from these two sources allowed the LVPC to estimate land development within the portions of the watershed outside of Lehigh County for the period from 1980 through 2007.

As shown in Table 8, approximately 1,500 acres were developed within the Lehigh County portion of the study area over the 22 year period from 1980 through 2002. Approximately 340 acres of the study area were developed outside of Lehigh County during the 27 year period from 1980 through 2007. For residential development, the acreages can be somewhat misleading in that the density of development may vary significantly between municipalities. The number of units constructed in a given municipality could be disproportionate to the acreage when compared with another municipality.

Development in place as of March 2008 represents the "existing" situation for the preparation of the Perkiomen Creek Headwaters Stormwater Management Plan. The existing land use condition was generated using Lehigh County land use records and field surveys. A map of the existing land use is provided as Figure 7. Stormwater runoff calculated based on the existing land use condition defines the goal of the watershed plan (i.e. no increase in existing peak flows throughout the study area). The "stress" applied to the system is the increase in impervious cover in the study area associated with new land development. Quantification of the stress requires an assumption of future land use condition. Future land use condition assumptions used in the development of the watershed plan are discussed in the following section.

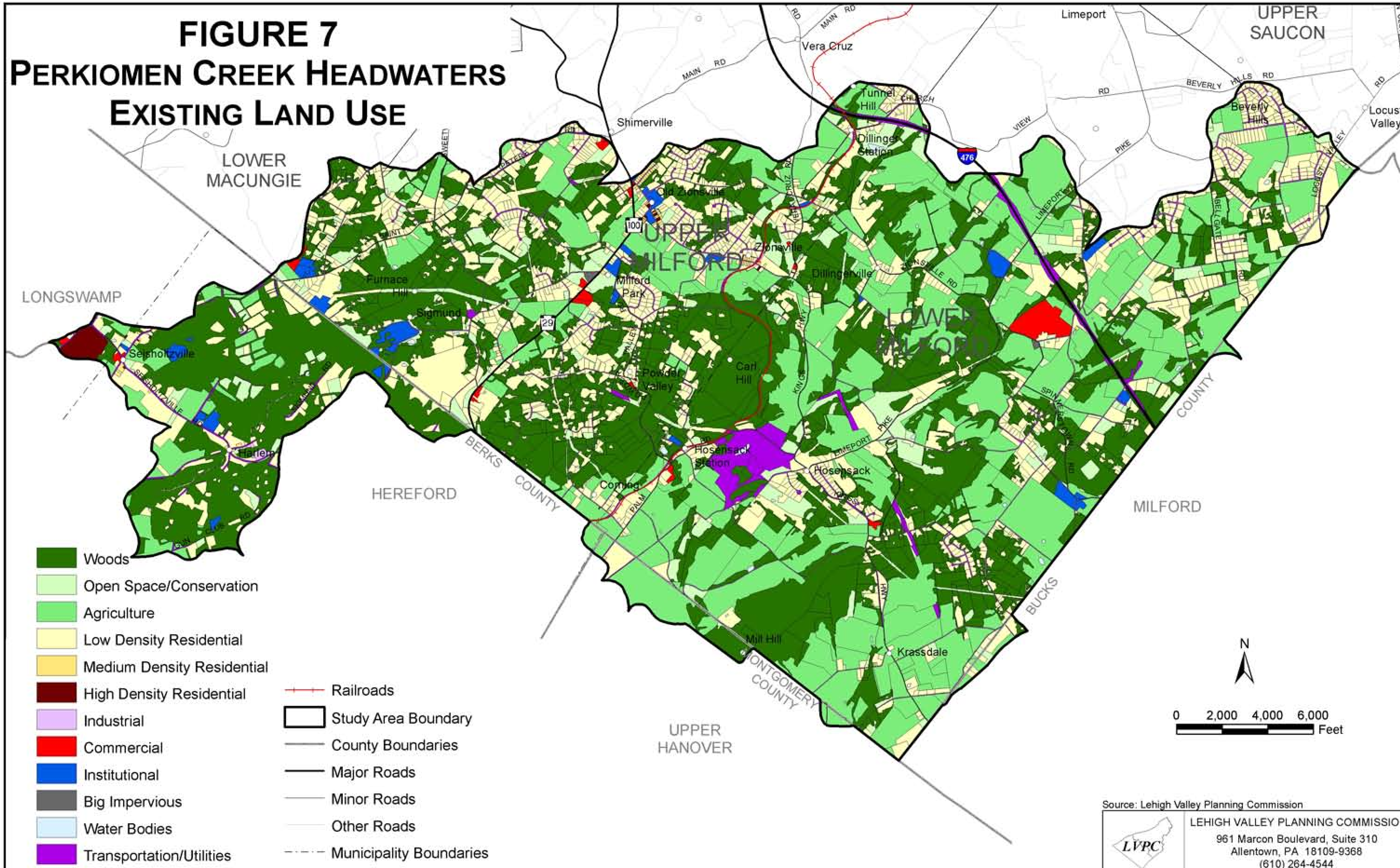
FIGURE 7
PERKIOMEN CREEK HEADWATERS
EXISTING LAND USE
LOWER MACUNGIE
LONGSWAMP
UPPER SAUCON
Limeport
Vera Cruz
Shimerville
Locust Valley
Beverly Hills
Tunnel Hill
Dillinger Station
Old Zionsville
UPPER MILFORD
Zionsville
Dillingerville
Milford Park
Furnace Hill
Sigmund
Seisholtzville
LOWER MILFORD
Powder Valley
Carl Hill
Hosensack Station
Hosensack
Corning
Hereford
HEREFORD
BERKS COUNTY
MILFORD
BUCKS COUNTY
Mill Hill
Krassdale
MONTGOMERY COUNTY
UPPER HANOVER
Woods
Open Space/Conservation
Agriculture
Low Density Residential
Medium Density Residential
High Density Residential
Industrial
Commercial
Institutional
Big Impervious
Water Bodies
Transportation/Utilities
Railroads
Study Area Boundary
County Boundaries
Major Roads
Minor Roads
Other Roads
Municipality Boundaries
N
0 2,000 4,000 6,000
Feet
Source: Lehigh Valley Planning Commission
LVPC
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C. Future Perkiomen Creek Headwaters Development

Projection of a future land use 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 a watershed can a sound control strategy be devised. Typically, a future land use condition is identified for a given “design year.” The design year would be selected based upon the intended design life of the control strategy. Prudent stormwater management would appear to dictate a design life consistent with full development of the watershed. Otherwise, the stormwater management controls put in place today might quickly become outdated should development exceed expectations. Conversely, designing a runoff control strategy based upon the “ultimate” land use condition when that level of development may not occur for 10, 20 or even 40 years or more might appear somewhat impractical.

In an effort to help establish the merits of each approach, two future land use conditions, or scenarios, were investigated. The first is a design life-type scenario of estimating the anticipated development for a ten-year period (2008 to 2018). The second is a form of “ultimate” future land use based upon current zoning. Each of the scenarios is described below.

Land development projected over the period 2008 to 2018 based upon a continuation of historical development trends, and constrained by existing zoning and the availability of undeveloped land, is presented in Table 9. Using the historical trend assumption, approximately 805 acres of additional land development would occur within the Perkiomen Creek watershed by the year 2018.

Table 9 may provide a very reasonable estimate of the study area’s growth over the next decade. For stormwater runoff purposes, however, it is missing a critical element. That is, the table does not help identify where the projected growth may occur within a given municipality (except for Upper Saucon Township). As will be discussed in greater detail in subsequent chapters, the runoff control criteria will be developed for small individual watershed subareas of approximately 300 acres average size. Obviously, when considering watershed areas this small, the “where” question becomes important. An exaggerated example would be that the 349 acres of residential development projected for Upper Milford Township could occur in a scattered fashion throughout residentially-zoned areas (i.e. scattered watershed subareas) or could be concentrated in one or two of the 300-acre areas. The runoff control strategy devised to deal with these two situations could be very different.

TABLE 9 PERKIOMEN CREEK HEADWATERS STUDY AREA PROJECTED LAND DEVELOPMENT 2008-2018* (Acres)				
County / Municipality	**Residential**	**Commercial**	**Industrial**	**Total**
Lehigh County				
Lower Macungie Twp.	0	0	0	0
Lower Milford Twp.	318	0	0	318
Upper Milford Twp.	345	4	0	349
Upper Saucon Twp. **	13	0	0	13
Berks County ***				
Hereford Twp.	n/a	n/a	n/a	113
Longswamp Twp.	n/a	n/a	n/a	0
Bucks County ***				
Milford Twp.	n/a	n/a	n/a	7
Montgomery County ***				
Upper Hanover Twp.	n/a	n/a	n/a	6
TOTAL	n/a	n/a	n/a	806

* Source: Projected based upon historical land development estimates from Table 8.

** Based upon the historical development estimates in Table 8, 15 acres would be developed within the Upper Saucon Township portion of the watershed during the period 2008-2018. However, only 13 acres of this portion of the Township are currently undeveloped.

*** A breakdown of land development by land use was not available for this county.

The second future land use scenario is a full built-out scenario in which the entire watershed is developed according to current zoning regulations. Municipal zoning districts throughout the Perkiomen Creek Headwaters Study Area can be categorized as industrial, commercial, agricultural or residential at various densities. For the purpose of evaluating the future zoned condition land use, a composite zoning map of the study area was prepared. Each of the zoning districts was placed into one of the above categories. The density criteria for residential development is as follows: low density equals two or less units per acre; medium density equals between two and five units per acre; high density equals five or more units per acre. Since the allowable density of residential development can vary widely within a given zoning district, an "average" allowable density was determined from the district description and the district was placed into a low, medium or high density classification.

The future condition land use map represents an "average ultimate" development scenario. It is an ultimate condition because all of the study area that is not protected by either agricultural zoning or an agricultural preservation easement is assumed to be developed. With the exception of one site, areas covered by agricultural zoning or an agricultural preservation easement are assumed to remain in agricultural use and not to be developed. The mentioned exception was made for a Lower Milford Township site that currently contains a nursery and is covered by an agricultural preservation easement. While the nursery use can be considered agricultural, the commercial aspect of the use has required the site to be developed more intensely than agricultural lands are traditionally developed. To ensure that the stormwater management plan accurately accounts for the existing development on this site, this site is classified as commercial in both the existing and future land use maps. The future zoned condition land use map also represents an average condition because, within a zoning district and consistent with the district description, development could occur at a higher or lower density than that assumed. The future land use map is provided as Figure 8.

The decision regarding which of the two future land use conditions to use in structuring the runoff control philosophy can be made fairly readily when considering the structure of Act 167. The Act is based on the assumption that land development will continue to occur and that the stormwater runoff impacts associated with that development are to be controlled. Using the 10-year design period development data would require assumptions as to the distribution of the development within the municipalities. The assumed distributions could be based upon concentrated development or based upon uniform scattered development. In either case, the accuracy of the development location assumptions for small watershed areas could suffer dramatically with unanticipated development in a very short period of time. Conversely, the future zoned condition land use would remain valid until either the zoning changed or major exception uses were allowed. Therefore, the future zoned condition land use will be used as the design land use for formulation of the runoff control plan. Thus, Figure 8 displays the future land use condition as used in the development of the runoff control strategy.

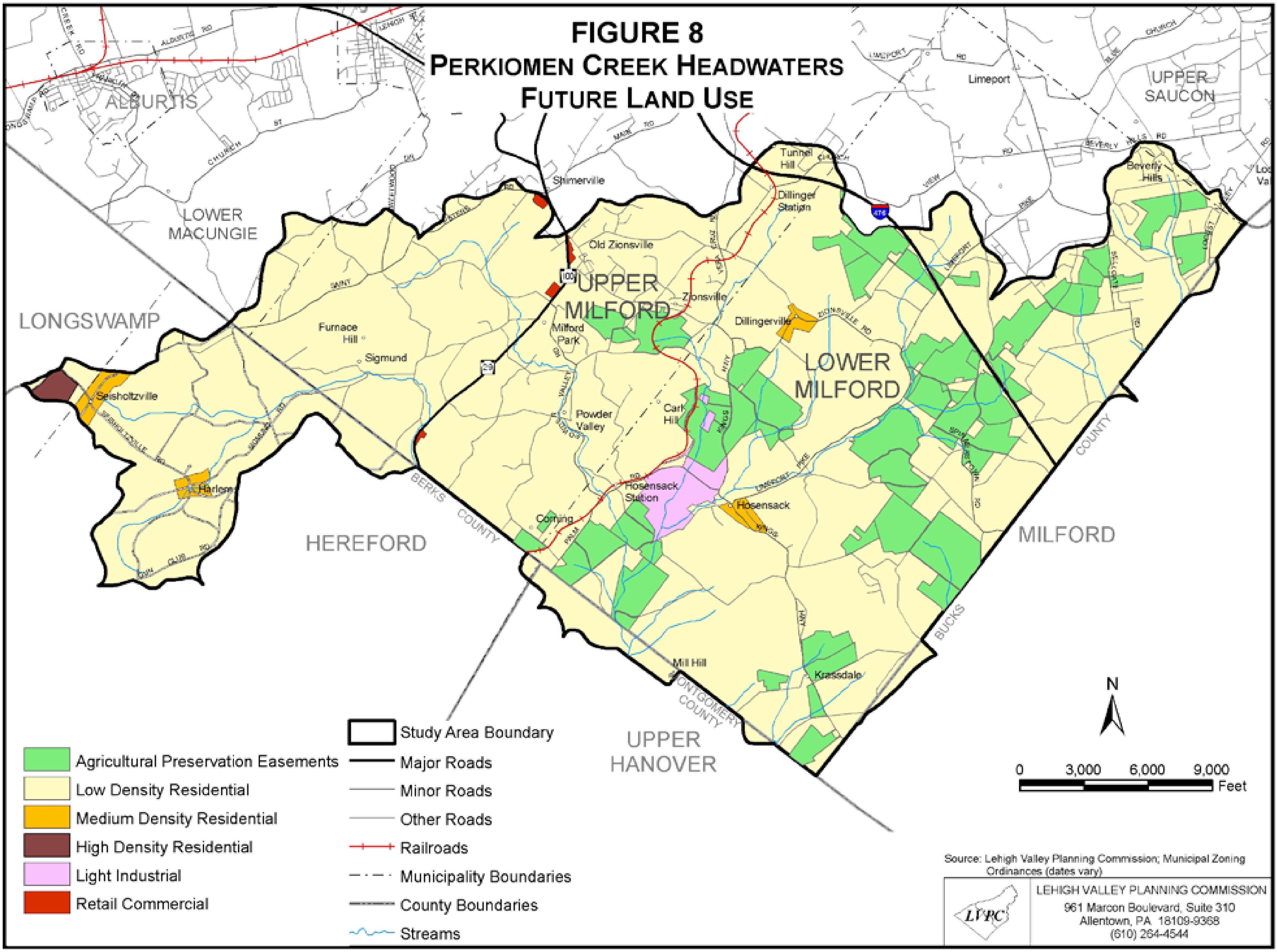
FIGURE 8
PERKIOMEN CREEK HEADWATERS
FUTURE LAND USE
ALBURTIS
LOWER MACUNGIE
LONGSWAMP
HEREFORD
UPPER MILFORD
LOWER MILFORD
MILFORD
UPPER SAUCON
UPPER HANOVER
BERKS COUNTY
MONTGOMERY COUNTY
BUCKS COUNTY
Limeport
Shimerville
Old Zionsville
Zionsville
Tunnel Hill
Dillinger Station
Dillingerville
Beverly Hills
Furnace Hill
Sigmund
Milford Park
Powder Valley
Cark Hill
Hosensack Station
Hosensack
Corning
Seisholtzville
Harlem
Mill Hill
Krassdale
Agricultural Preservation Easements
Low Density Residential
Medium Density Residential
High Density Residential
Light Industrial
Retail Commercial
Study Area Boundary
Major Roads
Minor Roads
Other Roads
Railroads
Municipality Boundaries
County Boundaries
Streams
N
0 3,000 6,000 9,000 Feet
Source: Lehigh Valley Planning Commission; Municipal Zoning Ordinances (dates vary)
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CHAPTER 4. PERKIOMEN CREEK HEADWATERS FLOODPLAIN INFORMATION

A. Floodplain Delineation

The Federal Emergency Management Agency (FEMA) has prepared Flood Insurance Studies and floodplain mapping by county that include all municipalities in the Perkiomen Creek Headwaters. However, not all of the municipalities have a delineated 100-year floodplain within the headwaters. Of the eight municipalities located within the headwaters, only four have delineated floodplains. They include Upper Milford and Lower Milford townships in Lehigh County, Hereford Township in Berks County and Upper Hanover Township in Montgomery County. The county flood studies that include these four municipalities document the 100-year floodplains within the Perkiomen Creek Headwaters. The Lehigh County Flood Insurance Study that includes Upper Milford and Lower Milford townships is available for inspection at the Lehigh Valley Planning Commission office as well as the respective municipal offices and is not reproduced here. The publication date for the Lehigh County Flood Insurance Study is July 16, 2004. The Berks County Flood Insurance Study (publication date of May 21, 2001) that includes Hereford Township and the Montgomery County Flood Insurance Study (publication date of October 19, 2001) that includes Upper Hanover Township are available at their respective county planning agency offices and municipal offices as well.

FEMA'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 which 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 (BMPs) that will improve surface water quality can qualify for additional credits as well.

B. Detailed Versus Non-Detailed Floodplain Delineation by Stream Segment

The 100-year floodplains for the stream segments in Hereford Township and Upper Hanover Township have been determined only by approximate methods. Detailed hydraulic analyses were not performed for these areas and, therefore, base flood elevations have not been determined. For Upper Milford Township and Lower Milford Township in the Perkiomen Creek Headwaters, the 100-year floodplains for some stream segments were determined by non-detailed methods, while others were determined by detailed methods. Detailed investigations include documented flow values at selected floodplain cross-sections, flood profiles along the stream length and base flood elevations. Presented in Figure 9 is a map of the Perkiomen Creek Headwaters with the delineation of detailed versus non-detailed flood mapping by stream segment.

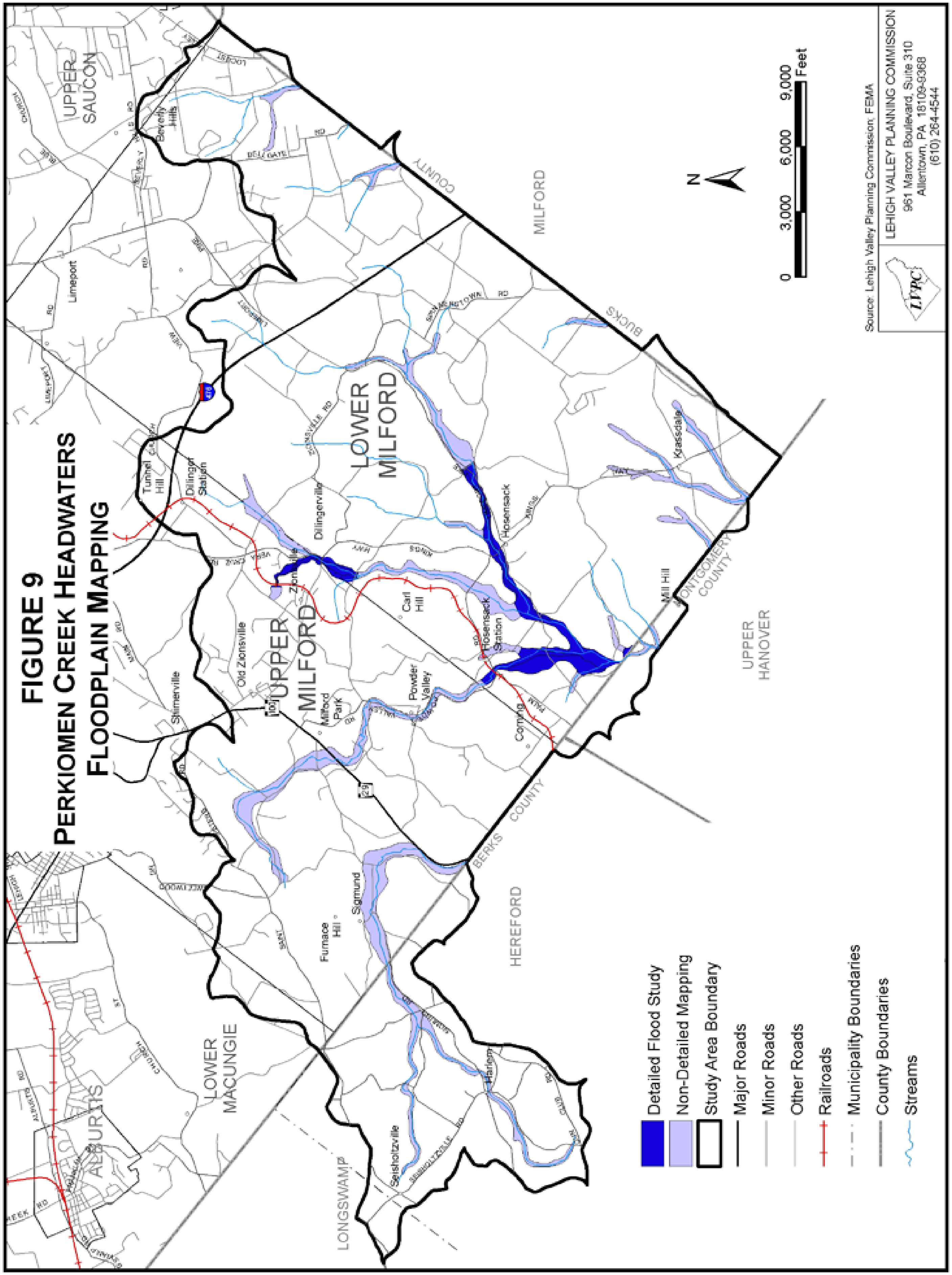
FIGURE 9
PERKIOMEN CREEK HEADWATERS
FLOODPLAIN MAPPING
Detailed Flood Study
Non-Detailed Mapping
Study Area Boundary
Major Roads
Minor Roads
Other Roads
Railroads
Municipality Boundaries
County Boundaries
Streams
UPPER SAUCON
LOWER MILFORD
UPPER MILFORD
MILFORD
UPPER HANOVER
HEREFORD
LOWER MACUNGIE
LONGSWAMP
ALBURTIS
BERKS COUNTY
BUCKS COUNTY
MONTGOMERY COUNTY
Limeport
Beverly Hills
Tunnel Hill
Dillinger Station
Dillingerville
Zionsville
Old Zionsville
Shimerville
Milford Park
Powder Valley
Carl Hill
Hosensack
Hosensack Station
Corning
Mill Hill
Krassdale
Furnace Hill
Sigmund
Harlem
Seisholtzville
N
0 3,000 6,000 9,000 Feet
Source: Lehigh Valley Planning Commission; FEMA
LVPC
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C. Existing and Future Floodplain Development

The Perkiomen Creek Headwaters Study Area is relatively rural. Currently within the study area floodplains, land use consists largely of open space, agriculture and low density residential development. There are also portions of several park/recreation areas located in the floodplains.

Development within the floodplains of the study area is taking place with the 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 study area have enacted ordinances consistent with Act 166. With enforcement of these 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 Perkiomen Creek Headwaters 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 two-year through 100-year return period events through implementation of the stormwater management criteria included in the Stormwater Management Plan for the Perkiomen Creek Headwaters.

- Damage potential for future floodplain development will be minimized by permitting only specific types of development that are damage resistant consistent with the Floodplain Management Act as implemented through the following: municipal floodplain regulations; Department of Environmental Protection 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.

CHAPTER 5. PERKIOMEN CREEK HEADWATERS EXISTING STORM DRAINAGE PROBLEM AREAS AND SIGNIFICANT OBSTRUCTIONS

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 Perkiomen Creek Headwaters was provided an opportunity to document the existing drainage problems within its borders. This yielded the documentation of a total of 23 existing drainage problems in the study area. The type of problem identified was typically street and/or property flooding. Figure 10 is a map of the Perkiomen Creek Headwaters indicating the storm drainage problem areas identified as part of the Stormwater Management Plan. The problem areas on Figure 10 are number coded and keyed to the problem area descriptions presented in Table 10. The "Subarea" and "Reach" columns in Table 10 refer to the location of the problem areas relative to the study area breakdown for modeling purposes. A subarea is the smallest unit of a watershed for which runoff values have been calculated. A reach is the swale, channel, or stream segment which drains a particular subarea. Note that 16 of the drainage problems are on identified reaches indicating that peak runoff values are readily available from the modeling process for these problem areas. These runoff values could be used as input for design of remedial facilities.

The final column in Table 10 was provided to list generalized solutions suggested by municipal representatives. Proposed solutions listed generally include ideas which are readily apparent to the municipal representatives for the less complicated problem areas. For certain other problem areas, the solutions are not quite so apparent and may require detailed engineering evaluations to determine the most cost-effective solution.

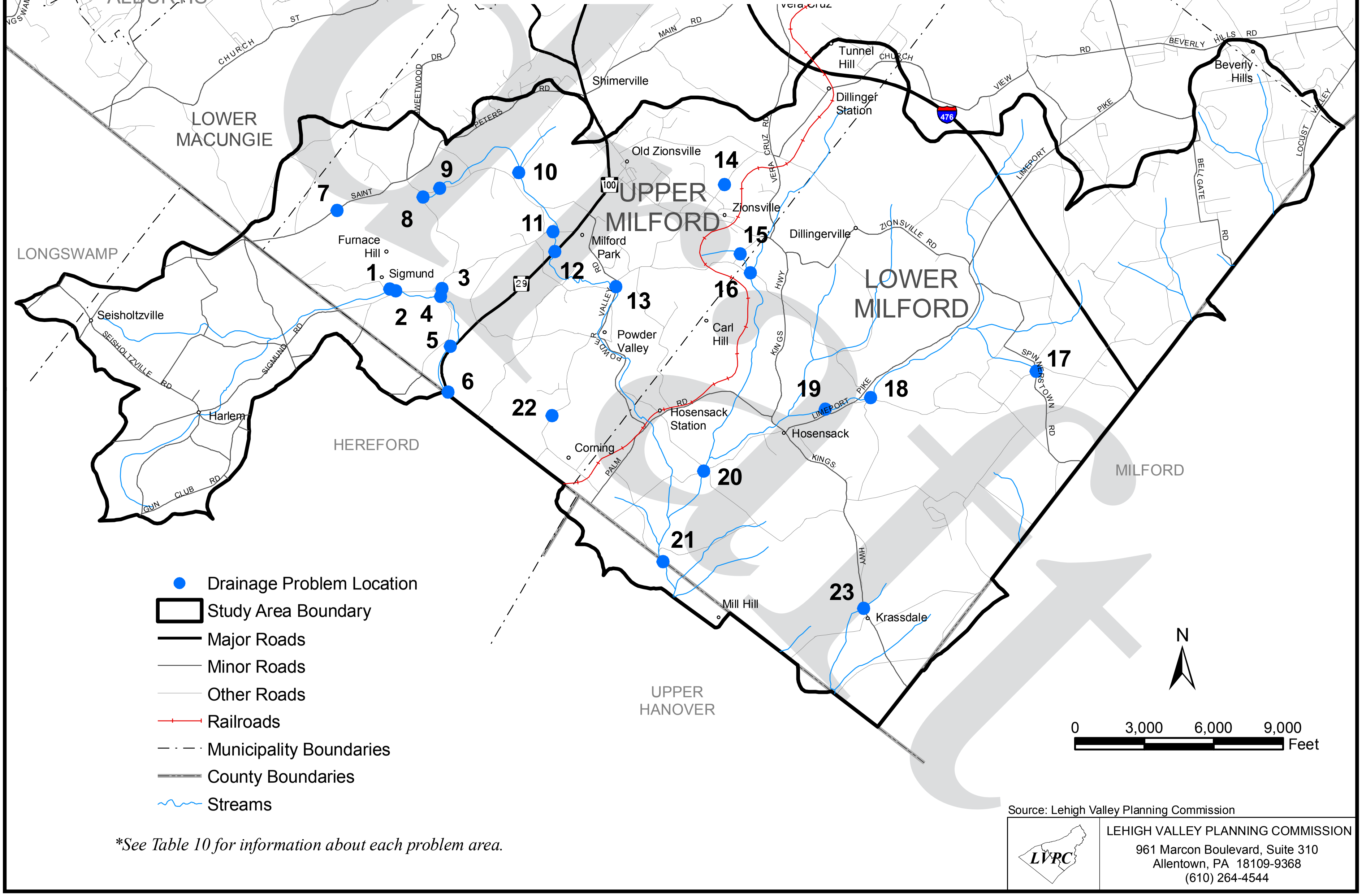
B. Significant Obstructions

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

> "Any 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."

Using the above definition, 82 obstructions have been observed within the Perkiomen Creek Headwaters. Of these obstructions, 51 were located within the public right-of-way and were able to be measured in the field. For each of these, an estimated flow capacity has been calculated. For the purposes of Act 167, it is necessary to refine the list of obstructions to include only those obstructions which are "significant" on a watershed basis. For the Perkiomen Creek Headwaters Stormwater Management Plan, the following distinction has been used:

FIGURE 10
PERKIOMEN CREEK HEADWATERS
STORM DRAINAGE PROBLEM AREA MAP



*See Table 10 for information about each problem area.

TABLE 10
PERKIOMEN CREEK HEADWATERS
STORM DRAINAGE PROBLEM AREAS

No.	Location	Municipality	Problem Description	Subarea No.	Reach No.	Proposed Solution
1	Salem Bible Church Road near Sigmund Road	Upper Milford Twp.	Roadway flooding	5	4	Upgrade drainage facility
2	Sigmund Road near Salem Bible Church Road	Upper Milford Twp.	Roadway flooding	5	4	Upgrade drainage facility
3	Sigmund Road near Yeakels Mill Road	Upper Milford Twp.	Roadway flooding	5	-	Upgrade drainage facility
4	Yeakels Mill Road near Sigmund Road	Upper Milford Twp.	Roadway flooding	5	4	Upgrade drainage facility
5	Yeakels Mill Road near Chestnut Street	Upper Milford Twp.	Roadway flooding	7	6	Upgrade drainage facility
6	7801 Chestnut Street	Upper Milford Twp.	Roadway flooding	8	-	Maintenance and possible upslope stormwater BMP
7	7273 Saint Peters Road	Upper Milford Twp.	Roadway flooding	10	9	Upgrade drainage facility
8	Furnace Hill Road near Indian Creek Road	Upper Milford Twp.	Roadway flooding	10	9	Upgrade drainage facility
9	Indian Creek Road near Furnance Hill Road	Upper Milford Twp.	Roadway flooding	11	10	Upgrade drainage facility
10	Shantz Road near Indian Creek Road	Upper Milford Twp.	Roadway flooding	13	12	Additional culvert pipes and upgrade drainage facilities
11	Tollgate Road east of Swamp Road	Upper Milford Twp.	Roadway flooding	14	13	Upgrade drainage facility
12	6574 Chestnut Street	Upper Milford Twp.	Repetitive flood damage to property	14	-	None proposed
13	Powder Valley Road near Batman Road	Upper Milford Twp.	Roadway flooding	14	13	Upgrade drainage facility
14	4790 Kohler Road	Upper Milford Twp.	Roadway flooding	20	17	Upgrade drainage facility
15	Rock Road near Scout Road	Upper Milford Twp.	Roadway flooding	22	21	Install additional culvert pipes

TABLE 10
PERKIOMEN CREEK HEADWATERS
STORM DRAINAGE PROBLEM AREAS

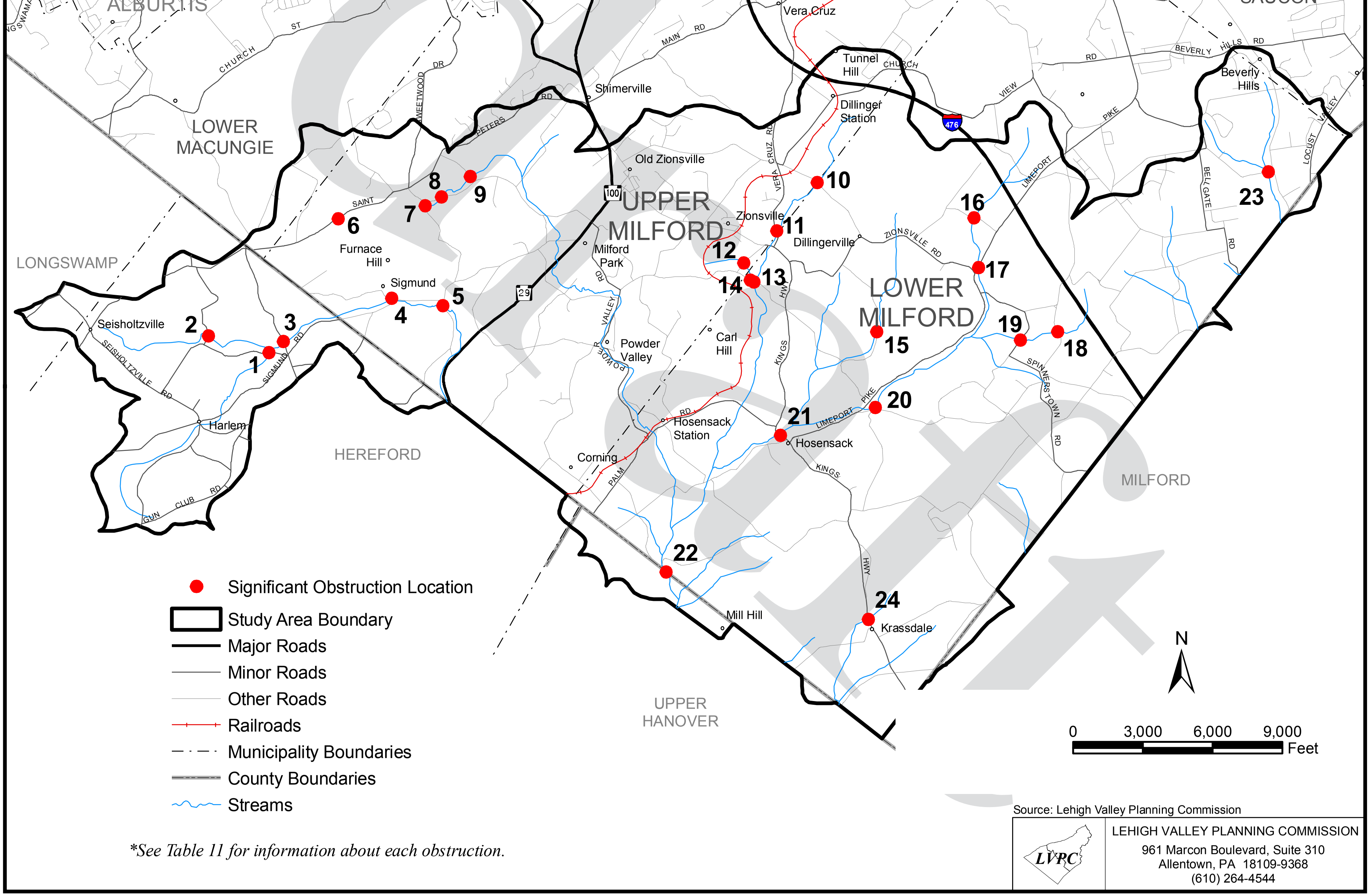
No.	Location	Municipality	Problem Description	Subarea No.	Reach No.	Proposed Solution
16	Scout Road west of King's Highway S	Lower Milford Twp.	Roadway flooding	22	20, 21	None proposed
17	Spinnerstown Road near School House Lane	Lower Milford Twp.	Flooding during minor storm events	29	-	PennDOT coordination and improved drainage facilties
18	School House Lane near Spring Road	Lower Milford Twp.	Roadway flooding	33	32	None proposed
19	Limeport Pike beween Spring Road and Milky Way	Lower Milford Twp.	Roadway flooding	33	-	PennDOT coordination and improved drainage facilties
20	Schultz Bridge Road near Buhman Road	Lower Milford Twp.	Roadway flooding	35	34	None proposed
21	West Mill Hill Road near Yeakel Road	Lower Milford Twp.	Roadway flooding	38	-	None proposed
22	Corning Road below Crown Lane	Upper Milford Twp.	Severe erosion	40	-	Additional facilities and possible upslope BMPs
23	King's Highway S above Kraussdale Road	Lower Milford Twp.	Roadway flooding	50	49	PennDOT coordination and improved drainage facilties

> An obstruction in a stream or channel shall be deemed "significant" if it has an estimated flow capacity which is less than the 10-year return period peak flow from the calibrated hydrologic model prepared as part of the Act 167 Plan.

Using the refined definition, 24 significant obstructions have been identified within the Perkiomen Creek Headwaters and are shown in Figure 11. A list of the significant obstructions is presented in Table 11 which indicates the obstruction number, description, municipality, and *approximate* flow capacity. Obstruction capacities have been estimated based on their upstream geometry as measured, bed slope and roughness factors (where applicable) consistent with the calibrated HEC-HMS models for the watershed in the Perkiomen Creek Headwaters. The estimates reflect reasonable flow capacities of the obstructions for "open channel" flow conditions (i.e. where the obstructions are not submerged). These estimated capacities are for illustration only and shall not be used as absolute capacities for stormwater management decisions. The capacity of any obstruction when used to meet the requirements of this Plan shall be based upon a detailed hydraulic investigation including possible headwater and tailwater conditions, obstruction configuration (abutments, wingwalls, piers, etc.), field measured slopes, and other conditions that may affect the capacity for design flows.

There are 10 areas where identified significant obstructions coincide with documented storm drainage problem areas as noted in Table 11. The importance of the identified significant obstructions and problem areas as part of the development of a runoff control strategy is discussed in Chapter 8.

FIGURE 11
Perkiomen Creek Headwaters
Significant Obstructions



*See Table 11 for information about each obstruction.

TABLE 11
PERKIOMEN CREEK HEADWATERS SIGNIFICANT OBSTRUCTIONS

Number	Obstruction	Municipality	Approximate Flow Capacity (cfs)
1	Township Line Road	Hereford Township	162
2	Hollyberry Road	Hereford Township	171
3	Weaver Road	Hereford Township	380
4	Salem Bible Church Road[1]	Upper Milford Twp.	169
5	Yeakels Mill Road[2]	Upper Milford Twp.	457
6	Saint Peters Road[3]	Upper Milford Twp.	52
7	Furnace Hill Road[4]	Upper Milford Twp.	147
8	Indian Creek Road[5]	Upper Milford Twp.	288
9	Hiestand Road	Upper Milford Twp.	263
10	Church View Road	Upper Milford Twp.	152
11	Vera Cruz Road S	Upper Milford Twp.	240
12	Rock Road[6]	Upper Milford Twp.	40
13	Scout Road[7]	Lower Milford Twp.	410
14	Scout Road[8]	Lower Milford Twp.	431
15	School House Lane	Lower Milford Twp.	93
16	Elementary Road	Lower Milford Twp.	149
17	Limeport Pike	Lower Milford Twp.	206
18	Chestnut Hill Church Road	Lower Milford Twp.	35
19	Spinnerstown Road	Lower Milford Twp.	63
20	School House Lane[9]	Lower Milford Twp.	592
21	King’s Highway S	Lower Milford Twp.	1,341
22	Hosensack Road	Lower Milford Twp.	2,300
23	Wind Hill Road	Lower Milford Twp.	74
24	King’s Highway S[10]	Lower Milford Twp.	104

[1] Significant Obstruction No. 4 coincides with Problem Area No. 1
[2] Significant Obstruction No. 5 coincides with Problem Area No. 4
[3] Significant Obstruction No. 6 coincides with Problem Area No. 7
[4] Significant Obstruction No. 7 coincides with Problem Area No. 8
[5] Significant Obstruction No. 8 coincides with Problem Area No. 9
[6] Significant Obstruction No. 12 coincides with Problem Area No. 15
[7] Significant Obstruction No. 13 coincides with Problem Area No. 16
[8] Significant Obstruction No. 14 coincides with Problem Area No. 16
[9] Significant Obstruction No. 20 coincides with Problem Area No. 18
[10] Significant Obstruction No. 24 coincides with Problem Area No. 23

CHAPTER 6. STORMWATER RUNOFF CONTROL TECHNIQUES

Chapter 3 identified the impacts of land development on stormwater runoff and documented the need to control those impacts with sound stormwater management techniques. Chapter 8 presents the performance standards for runoff control for new development applicable to the various watershed areas necessary to achieve the sound runoff management from a watershed perspective. Therefore, Chapter 3 defines the problem and Chapter 8 identifies the necessary end product. This chapter will identify the runoff control techniques available as the "means" to create the desired end product to mitigate the runoff impacts of new development.

The runoff control techniques presented in Sections A, B and C are "structural" stormwater management controls, meaning that they are physical facilities for runoff abatement. "Non-structural" controls, described in Section D, refer to land use management techniques geared towards minimizing storm runoff impacts through control of the type and extent of new development. The Perkiomen Creek Headwaters Stormwater Management Plan is based on the assumption that new development of various types will occur throughout the study area (except as regulated by floodplain regulations) and that structural controls will be required to minimize the runoff implications of the new development.

Structural controls for managing storm runoff can be categorized as volume controls, rate controls, or water quality controls. Volume controls are designed to allow a certain amount of the total rainfall to infiltrate into the ground. Greater opportunity for infiltration can be provided by minimizing the amount of impervious cover associated with development, by draining impervious areas over lawns and other pervious cover or into specific infiltration devices, and by using grassed swales or channels to convey runoff in lieu of storm sewer systems. Rate controls are designed to regulate the peak discharge of runoff by providing temporary storage of runoff which otherwise would leave the site at an unacceptable peak value. Rate controls, much more so than volume controls, are adaptable to regional considerations for controlling much larger watershed areas than one development site. Water quality controls are designed primarily to reduce the impact of high sediment, pollutant, and/or nutrient loads on receiving water bodies. In some cases, water quality controls can provide some peak rate attenuation, but it is unlikely that they would be able to act as the sole control for a site; other rate and/or volume controls would still be required.

Presented in Sections A, B, and C is a discussion of the various volume and rate controls available for implementation on a development site (or region). The discussion includes a physical description of the control, the applicability of the particular control, and its advantages, disadvantages, and maintenance requirements. The runoff control(s) most applicable to a development site may vary widely depending upon site characteristics such as topography, soils, geology, water table, etc., the type of development proposed and the applicable performance standard which the controls must meet. The developer should consider all these factors in designing the control philosophy.

The runoff control technique information presented herein has been derived primarily from three sources: namely, (1) *New Jersey Stormwater Quantity/Quality Management Manual*, February 1981, prepared for the New Jersey Department of Environmental Protection by the

Delaware Valley Regional Planning Commission; (2) *Allegheny County Act 167 Pilot Stormwater Management Plans – Girty's Run, Pine Creek, Deer Creek, and Squaw Run*, January 1982, prepared for the Allegheny County Department of Planning by Green International, Inc. and Walter B. Satterthwaite, Inc.; and (3) *Pennsylvania Stormwater Best Practices Manual*, December 2006, by the Pennsylvania Department of Environmental Protection.

A. Volume Controls

The increase in runoff volume with development, and the management of that increased volume, is a key element in sound runoff management at the watershed level. Any volume controls implemented on-site for a development would help achieve the goals of the watershed plan. As stated above, the basis for volume control is the provision of a greater opportunity for infiltration of rainfall/runoff into the ground. This opportunity may be provided in a passive sense by simply draining impervious areas over pervious areas and relying on the natural infiltrative capabilities of the pervious areas. Conversely, the opportunity for infiltration could be provided in an active sense by directing runoff into infiltration structures designed to remove a given volume of runoff. A different type of runoff control is based upon the substitution of porous or semi-pervious materials in place of conventional impervious surfaces. Other controls may be based on storing runoff for later use (irrigation, janitorial work, etc.). Also, there are controls that focus on restoring the natural infiltration capacity of soils that have been previously impacted by development. Any or all of these approaches may be applicable to a particular development site.

Volume controls may be used in conjunction with rate controls since volume controls alone would generally not provide complete runoff abatement. The volume controls would, however, provide the benefit of decreasing the size and cost of the rate control facility and would be used to minimize the total cost of on-site runoff control.

1. Pervious Pavement

a.) Description

Pervious pavement consists of a permeable surface course underlain by a uniformly-graded stone bed which provides temporary storage for peak rate control and promotes infiltration. The surface course may consist of porous asphalt, porous concrete, or various porous structural pavers laid on uncompacted soil.

b.) Applicability

Pervious pavement systems can be used in areas such as parking lots, walkways, playgrounds, alleyways, plazas, tennis courts, and other similar uses.

c.) Advantages and Disadvantages

ADVANTAGES

- Does not require additional land space.
- Can reduce size, or possibly eliminate, other drainage facilities via volume control.
- Groundwater recharge.
- Improved preservation of roadside vegetation.
- Flexible measure to provide stormwater detention in both new and existing development.
- Safety improvements such as superior skid resistance during wet conditions, accelerated snow melting and a reduced risk of the formation of "black ice", and enhanced visibility of pavement markings.
- Provides pavement drainage without the need for a crown slope, thus reducing costs and puddling.
- Less noisy than conventional pavements.
- Less costly over time than conventional pavements for most applications, due to lower maintenance costs.

DISADVANTAGES

- Open-graded mixtures may be more prone to water-stripping than conventional dense aggregate mixtures.
- Increased pressure head on pavement from subsurface drainage on steep slopes.
- Clogging may be a problem.
- Water that freezes within the pervious pavement takes longer to thaw and offsets infiltration.
- Motor oil drippings and gasoline may pollute groundwater.
- Costs more to install than traditional pavement.
- Locations limited by site slope, soil permeability, and underlying bedrock.

d.) Maintenance Requirements

Maintenance involves removing debris too coarse to be washed through the pavement system; vacuuming to remove particles that could clog the void space; and patching the surface as needed. Since porous pavements require no more repairs than conventional pavements, maintenance problems can be generally confined to better “housekeeping” and “preventive maintenance” practices and more efficient and effective street cleaning procedures.

2. Infiltration Basin

a.) Description

An infiltration basin is a shallow impoundment that stores and infiltrates runoff over a level, uncompacted, (preferably undisturbed) area with relatively permeable soils.

b.) Applicability

This control may be used where the subsoil is sufficiently permeable to allow a reasonable rate of infiltration and where the water table and bedrock are sufficiently lower than the design depth of the facility. It is not applicable where high concentrations of suspended materials are contained in the runoff without some type of filtering mechanism.

c.) Advantages and Disadvantages

ADVANTAGES

- Can reduce size, or possibly eliminate, other drainage facilities via volume control.
- Groundwater recharge.
- Runoff water quality is improved by the existing natural processes in the soil mantle.
- May help reduce local flood peaks.

DISADVANTAGES

- Locations limited by soil permeability and underlying bedrock.
- Vulnerable to clogging from sediment deposition.

d.) Maintenance Requirements

Catch basins and inlets (upgradient of infiltration basin) should be inspected and cleaned at least two times per year and after runoff events. The vegetation along the surface of the infiltration basin should be maintained in good condition, and any bare spots re-vegetated as soon as possible. Inspect the basin after runoff events and make sure that runoff drains down within 72 hours. Also inspect for accumulation of sediment, damage to outlet control structures, erosion control measures, signs of water contamination/spills, and slope stability in the berms. The original cross-section should be restored when necessary. Accumulated sediment should be removed as necessary.

3. Subsurface Infiltration Bed, Infiltration Trench, and Dry Well/Seepage Pit

a.) Description

Subsurface infiltration beds provide temporary storage and infiltration of stormwater runoff by placing storage media of varying types beneath the proposed surface grade.

An infiltration trench is a perforated pipe in a stone filled trench with a level bottom. An infiltration trench may be used as part of a larger storm sewer system, such as a relatively flat section of storm sewer, or it may serve as a portion of a stormwater system for a small area, such as a portion of a roof or a single catch basin.

A dry well, or seepage pit, is a variation on an infiltration system that is designed to temporarily store and infiltrate rooftop runoff.

b.) Applicability

As with infiltration basins, these controls may be used where the subsoil is sufficiently permeable to allow a reasonable rate of infiltration and where the water table and bedrock are sufficiently lower than the design depth of the facility. It is not applicable where high concentrations of suspended materials are contained in the runoff without some type of filtering mechanism.

c.) Advantages and Disadvantages

ADVANTAGES

- May help reduce local flood peaks.
- Groundwater recharge.

- Creates usable open space on-site.

- Usually unaffected by cold weather.

- Large subsurface infiltration beds could be capable of reducing peak and volume of runoff without additional rate controls.

- Infiltration trenches can combine the conveyance system with a stormwater management control by increasing travel time and infiltrating runoff.

DISADVANTAGES

- Locations limited by soil permeability and underlying bedrock.

- Vulnerable to clogging from sediment deposition.

- Maintenance is difficult if the facility becomes clogged.

d.) Maintenance Requirements

All catch basins and inlets should be inspected and cleaned at least 2 times per year. The overlying vegetation should be maintained in good condition, and any bare spots re-vegetated as soon as possible. Vehicular access on infiltration areas should be prohibited, and care should be taken to avoid excessive compaction by mowers. If access is needed, use of permeable, turf reinforcement should be considered.

4. Rain Garden or Bioretention

a.) Description

A rain garden (also called bioretention) is an excavated shallow surface depression planted with specially selected native vegetation to capture and treat runoff. Properly designed bioretention techniques mimic natural 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.

b.) Applicability

Rain gardens are extremely flexible and can be used in almost any location on any site. If soils are not sufficiently permeable to allow adequate drainage, an underdrain can be used to control overflow.

c.) Advantages and Disadvantages

ADVANTAGES

- Can be more cost effective than traditional landscaping.
- Can balance nicely with other structural management systems, including porous asphalt parking lots, infiltration trenches, as well as non-structural stormwater controls.
- Plant root systems can increase infiltration of runoff.
- Groundwater recharge.
- Reduces stormwater temperature impacts.
- Filters pollutants through soil particles (which trap pollutants) and plant material (which takes up pollutants).
- Enhances site aesthetics.

DISADVANTAGES

- Generally small in surface area and depth, and are not practical to control more frequent (greater than the 2-year) storm events.
- May require manual watering in dry periods.

d.) Maintenance Requirements

While vegetation is being established, pruning and weeding may be required. Detritus may also need to be removed every year. Perennial plantings may be cut down at the end of the growing season. Mulch should be re-spread when erosion is evident and replenished as needed. Once every 2 to 3 years the entire area may require mulch replacement. They should be inspected at least 2 times a year for sediment buildup, erosion, vegetative conditions, etc. Trees and shrubs should be inspected twice per year to evaluate health. During periods of drought, bioretention areas may require watering.

5. Vegetated Roofs

a.) Description

A vegetated roof cover is a veneer of vegetation that is grown on and completely covers an otherwise conventional flat or pitched roof, endowing the roof with hydrologic characteristics that more closely match surface vegetation than the roof. The overall thickness of the veneer may range from 2 to 6 inches and may contain multiple layers, consisting of waterproofing, synthetic insulation, non-soil engineered growth media, fabrics, and synthetic components. Vegetated roof covers can be optimized to achieve water quantity and water quality benefits. Through the appropriate selection of materials, even thin vegetated covers can provide significant rainfall retention and detention functions. Since the purpose of most vegetated roofs is runoff mitigation, they are usually not irrigated. Plants should be selected which will create a vigorous, drought-tolerant ground cover.

b.) Applicability

Vegetated roofs can be installed on any flat roof, or a pitched roof with a slope of less than 30 degrees. The dead load bearing capacity of the roof must also be analyzed to assure that the structure can support the weight of a saturated vegetated roof.

c.) Advantages and Disadvantages

ADVANTAGES

- Does not require additional land space.
- Can mimic pre-development hydrological conditions, particularly for small storms.
- Enhances site aesthetics.
- Improves the efficiency of downstream infiltration facilities.

DISADVANTAGES

- Requires consideration of the building's structural capacity to support the facility.
- Provides no opportunity for groundwater recharge.
- Pitched roofs are less desirable and require additional measures against sliding.
- Could increase the risk of roof leaks if not properly installed.

d.) Maintenance Requirements

During the plant establishment period, periodic irrigation may be required, and three to four visits to conduct basic weeding, fertilization, and in-fill planting are recommended. Thereafter, only two annual visits for inspection and light weeding should be needed.

6. Landscape Restoration

a.) Description

Landscape restoration is the general term used for actively sustainable landscaping practices that are implemented outside of riparian (or other specially protected) buffer areas. Landscape restoration includes the restoration of forest (i.e. re-forestation) and/or meadow and the conversion of turf to meadow.

b.) Applicability

Landscape restoration can be used in any open area. Landscape restoration works to restore land to its original cover (or possibly more pervious cover if meadow is converted to forest), and to restore the infiltration capacity of the area. This control is most applicable for retrofitting projects.

c.) Advantages and Disadvantages

ADVANTAGES

- Meadow areas require little maintenance compared to conventional turf lawns.
- Meadow and forest areas require less long-term financial investment than conventional lawns, due to reduced or non-existent mowing and fertilizer costs.
- Groundwater recharge.

DISADVANTAGES

- Native grasses and flowers establish more slowly than weeds and turf grass, so establishing a meadow condition can be difficult and maintenance-intensive.
- Higher installation costs than conventional turf lawns.
- Can take several years before adequate cover is established.

d.) Maintenance Requirements

Forest restoration areas planted with a cover crop can be expected to require annual mowing and herbicide applicant to control invasives in the first 2-5 years, or until the tree canopy begins to form. Meadow areas should be carefully monitored for weed growth in the first few years. Afterwards, seasonal mowing or burning may be required.

7. Soil Amendment and Restoration

a.) Description

Soil amendment and restoration is the process of improving disturbed soils and low organic soils by restoring soil porosity and/or adding a soil amendment, such as compost, for the purpose of reestablishing the soil's long-term capacity for infiltration and pollutant removal.

b.) Applicability

This control can be used on any part of a construction site that will become compacted during the land development process due to material storage or heavy construction vehicle traffic.

c.) Advantages and Disadvantages

ADVANTAGES

- Decreases runoff volume over extensively graded or otherwise heavily trafficked areas of the site through restoration of the soil's porosity.

- Soil amendments increase the nutrient level of the soil, which benefits vegetative growth.

- Groundwater recharge.

DISADVANTAGES

- Long-term maintenance of amended soils is largely unknown. Compost-amended soils may need to be re-composted on a regular basis.

- Tilling is expensive.

- Wet soils are not suitable for tilling, as they are incapable of being broken up by the tines on the tilling equipment.

- Soil restoration is not suitable for sites with very steep slopes (30%+).

d.) Maintenance Requirements

The soil restoration process may need to be repeated over time, due to compaction by use and/or settling.

8. Runoff Capture and Re-use

a.) Description

Capture and re-use encompasses a wide variety of water storage techniques designed to “capture” precipitation or runoff, hold it for a period of time, and re-use the water. The facility may also be designed as a detention facility with a slow release over time.

b.) Applicability

Since cisterns, rain barrels, and storage media are not dependent on physiological conditions and their sizes can vary as necessary, they are applicable practically everywhere. Cisterns can be installed beneath paved areas or other structural facilities, within a building, or above the ground.

c.) Advantages and Disadvantages

ADVANTAGES

- Minimal space required for implementation, and minimal interference with traffic or people.

- Can be used in existing as well as newly developed areas.

- Potential for multiple uses of stored runoff.

- Keeps runoff on-site, which will affect local flood peaks in a manner similar to infiltration.

DISADVANTAGES

- Less effective in cold weather, since systems must be flushed to prevent damage resulting from freezing.

- To have an impact on runoff, cisterns must have available volume at the beginning of a storm event; full cisterns provide no attenuation.

d.) Maintenance Requirements

Periodic removal of sediment and debris will be necessary to assure maximum operating efficiency. If cistern pumps are employed, routine maintenance and inspections will be necessary to minimize failure. Do not allow water to freeze in the storage devices.

9. Vegetated Swales, Vegetated Filter Strips, and Seepage Areas

a.) Description

These controls utilize grassed areas for managing stormwater runoff by using their natural capacity for reducing runoff velocities, enhancing infiltration, and filtering runoff contaminants.

A vegetated swale (or grassed waterway) is a broad, shallow, trapezoidal or parabolic channel, densely planted with a variety of trees, shrubs, and/or grasses. It is designed to attenuate and in some cases infiltrate runoff volume from adjacent impervious surfaces, allowing some pollutants to settle out in the process. Whenever possible, grasses native to the site should be selected for use to ensure acclimation.

Vegetated filter strips are grass buffer areas that sheet flows or surface runoff are directed across to reduce the flow velocity and cause the heavier particles to settle out of the water. This simultaneously enhances the infiltration of the runoff by passing it over the pervious grass filter. These strips of close growing grasses can be established at the perimeter of disturbed or impervious areas.

Seepage areas are small, grass-covered depressions that surface runoff is directed into to infiltrate the water and filter out particulate contaminants. Seepage areas are constructed by excavating shallow depressions in the land surface or by constructing a system of dikes or berms to temporarily pond water over permeable soils.

b.) Applicability

Mostly applicable in new developments of low to moderate density where the percentage of impervious cover is relatively small. These practices also require that subdivision and site designs respect natural drainage patterns so that they can be modified to accommodate post-development runoff volumes. Successful application is dependent upon such factors as steepness of slopes, anticipated runoff volumes, soil conditions, selection of proper grass cover, and proper long-term maintenance.

c.) Advantages and Disadvantages

ADVANTAGES

- Vegetative swales are less expensive to install than curb and gutter systems.

- Roadside ditches keep flow away from the street thereby reducing the potential for vehicle hydroplaning.

- Increased runoff travel time and groundwater recharge.

- Effective pre-treatment methods for other facilities, especially infiltration facilities which are vulnerable to sediments.

DISADVANTAGES

- Must be located on sufficiently permeable soils.

- Vegetative channels may require more maintenance than curb and gutter systems.

- Streets with swales may require more right-of-way and be less compatible with sidewalk systems.

- Roadside ditches become less feasible as the number of driveway entrances requiring culverts increases.

- Local subdivision ordinances may require curbs and gutters, so municipalities may have to amend their regulations to allow this practice.

- Swales and filter strips can be prone to erosion, especially on steep slopes.

- Only effective when treating small areas.

d.) Maintenance Requirements

Vegetated swales require periodic inspections, especially after large storms, to evaluate whether erosion controls are needed, to remove accumulated debris, and to check the condition of the vegetation. Filter strips also require periodic inspection, but it is particularly important to maintain soil porosity. This can be accomplished by periodically removing thatch and/or mechanically aerating the area when necessary. Seepage areas require similar maintenance to vegetated swales and filter strips. Mowing should be performed with low ground-pressure equipment and a high blade setting (4 to 6 inches), and only when the area is dry.

B. Rate Controls

The performance standard criteria presented in Chapter 8 are geared towards controlling the peak rate of runoff after development to a given percentage of the pre-development peak runoff rate. The bases for establishing the performance standards are the pre-development peak rate, the timing of the pre-development peak with respect to the other watershed areas, and the anticipated increase in volume associated with development. The volume controls described in Section A will remove a portion of the increased volume of runoff and may also help to reduce the peak rate of runoff. However, it is primarily the rate controls which provide the major peak attenuation by storing a large volume of runoff and releasing it at a predetermined slower rate. The various options available for rate control differ only in the location of the runoff storage provided as described below.

1. Detention Basins

a.) Description

Detention basins are impoundments which are designed to store “excess rate” stormwater runoff during a rainfall event and release the stored runoff more slowly. “Excess rate” can be defined as the difference between the uncontrolled post-development hydrograph and the design post-development hydrograph as dictated by the performance standard criteria. Detention basins may be designed as either dry or wet impoundments. Dry impoundments are designed to completely drain after storm events. These include dry detention and extended dry detention facilities. Wet impoundments, or wet ponds, are designed to maintain a permanent pool.

The storage volume required for a detention basin is a function of the change in runoff volume and the pre- and post-development peaks, the performance standard applicable to the site, the extent to which volume controls are used, the outlet structure configuration, and the design storm(s) used.

b.) Applicability

Detention ponds are applicable to any site where rate control is required and sufficient land area exists. Detention basins can be designed for individual site control, or to control runoff from multiple development sites or watershed areas. A DEP dam permit may be required for a stormwater detention facility.

c.) Advantages and Disadvantages

ADVANTAGES

- Offers design flexibility for adapting to a variety of uses.
- Pond construction is relatively simple.
- May allow significant reduction in the size of downstream storm drainage structures.
- May enhance groundwater recharge to some extent.
- Reduces downstream litter and debris.
- Wet ponds (and, to a lesser extent, extended dry detention ponds) improve runoff quality through settling, filtration, uptake, chemical and biological decomposition, volatilization, and adsorption.
- Wet ponds can provide aesthetic and wildlife benefits.

DISADVANTAGES

- Due to the potential to discharge warm water, wet ponds and extended dry detention basins should be used with caution near temperature sensitive water bodies.
- Consumes land area that cannot be developed.
- Possible safety concerns.
- Site hydrology must be considered to determine if a wet pond can receive and retain enough flow from rain, runoff, and groundwater to ensure long-term viability. Modifications to the pond in Hydrologic Soil Group (HSG) A and B soils may be required.
- In carbonate bedrock areas, soil depth and type must be considered in the design to minimize the possibility of sinkhole occurrence.
- Detention basins with impervious lining do not provide groundwater recharge.

d.) Maintenance Requirements

To maintain the design efficiencies of a detention basin, maintenance of the structures and the impoundment areas are essential. Detention basins should be inspected at least four times per year and after major storms. Wet ponds should also be inspected after rapid ice breakup. Inspections should assess the vegetation, erosion, flow channelization, bank stability, inlet/outlet conditions, embankment, and sediment/debris accumulation. Pipe inlets and outlets should be inspected for accumulated sediment and debris. Sediment should be removed from the forebay (if applicable) before it occupies 50 percent of the forebay, typically every five to 10 years. The pond drain (if applicable) should also be inspected and tested four times per year. Measures to offset the production of fast-breeding insects should be taken as necessary.

2. Parking Lot and Roof Detention

a.) Description

Areas such as parking lots, rooftops, or other areas that are primarily intended for other uses can be designed to temporarily detain stormwater for peak rate mitigation. Generally, detention is achieved through the use of a flow control structure that allows runoff to temporarily pond. In most cases ponding depths are kept less than one foot. In rooftop detention, the control structures should be designed so that no water is ponded for small storms.

b.) Applicability

Portions of large, gently sloped parking lots that can be temporarily used for stormwater storage without significantly interfering with normal vehicle and pedestrian traffic are candidates for parking lot storage. New structures with flat rooftops are most applicable for rooftop storage, although retrofits are possible if specific design requirements are met. Areas such as recessed plazas and athletic fields can be used in a similar fashion.

c.) Advantages and Disadvantages

ADVANTAGES

- No additional land requirements.
- Can contribute to maintaining adequate capacity of downstream drainage facilities.
- Adaptable to both new and old facilities.
- Parking lot storage is generally easy to incorporate into parking lot design and construction.

- Water stored on rooftops has high potential for re-use.

- Rooftop storage does not cause any aesthetic or safety concerns and causes minimal interference with traffic and people.

- Low cost and low maintenance.

DISADVANTAGES

- Provides little volume control and negligible water quality benefits.

- Ponding areas are prone to icing in cold weather.

- Parking lot storage may be a public inconvenience.

- Rooftop storage benefits to the owner may outweigh the costs, since leaks can cause damage to buildings and their contents.

- Modifications to the building code may be required before rooftop storage can be used.

d.) Maintenance Requirements

Maintenance activities should include semiannual inspection and cleaning of flow control structures, clearing debris/sediment from detention areas (as necessary), and inspecting the waterproofing in rooftop storage areas.

3. Constructed Wetlands

a.) Description

Constructed wetlands are shallow marsh systems planted with emergent vegetation that are designed to treat stormwater runoff. While they are one of the best methods for pollutant removal, constructed wetlands can also mitigate peak rates and even reduce runoff volume to a certain degree. They also can provide considerable aesthetic and wildlife benefits.

b.) Applicability

Constructed wetlands are applicable in any marshy area, usually underlain by HSG C or D soils with a high water table, on sites that have sufficient hydrologic conditions to maintain a permanent pool in the pond.

c.) Advantages and Disadvantages

ADVANTAGES

- Improve runoff quality through settling, filtration, uptake, chemical and biological decomposition, volatilization, and adsorption.

- Effective at removing many common stormwater pollutants including suspended solids, heavy metals, total phosphorus, total nitrogen, toxic organics, and petroleum products.

- Capable of providing some peak rate control above the permanent pool elevation.

DISADVANTAGES

- Application limited by site hydrology.

- Consumes large amounts of land area that cannot be developed.

d.) Maintenance Requirements

During the first growing season, vegetation should be inspected every two to three weeks. Constructed wetlands should be inspected several times per year and after major storms and rapid ice melt to assess vegetation cover, erosion, flow channelization, bank stability, inlet/outlet conditions, and sediment/debris accumulation. Sediment should be removed from the forebay (if applicable) before it occupies 50 percent of the forebay, typically every three to seven years.

C. Water Quality Treatment Controls

New development in a watershed can introduce large amounts of new sediments, excessive levels of nutrients (such as nitrogen and phosphorus), and other pollutants into the receiving waters. To prevent these contaminants from impacting the watershed, certain measures should be taken to mitigate the potential impact of development on the water quality in the watershed. These controls are designed primarily to reduce the pollutant load from the site by natural, physical, and/or biological processes. These controls do not provide significant peak rate or volume control.

1. Constructed Filter

a.) Description

Filters are structures or excavated areas containing a layer of sand, compost, organic material, peat, or other filter media that reduce pollutant levels in stormwater runoff by filtering sediments, metals, hydrocarbons, and other pollutants. The runoff passes through the filter media and is collected in an under-drain and returned to the conveyance system, receiving waters, or infiltrated into the soil mantle.

b.) Applicability

Filters are applicable in urbanized areas having high pollutant loads and are especially applicable where there is limited area for construction of other water quality BMPs. Filters may be used as a pretreatment method for run-off before it reaches other facilities, especially infiltration systems. Filters may be used in Hot Spot areas for water quality treatment, and spill containment capabilities may be incorporated into a filter.

c.) Advantages and Disadvantages

ADVANTAGES

- Effective pre-treatment to reduce sediment and pollutant loads on other facilities.
- Flexibility of design to meet varying degrees of water quality standards.
- Sand filters can be used to "throttle" unacceptably high infiltration rates.
- If effluent is allowed to infiltrate into the soil mantle, the filter can reduce some runoff volume and increase groundwater recharge.

DISADVANTAGES

- Maintenance can be expensive if the filter media becomes clogged.
- Poor performance in cold weather.

d.) Maintenance Requirements

The filter should be inspected at least four times per year for evidence of standing water and any film or discoloration of surface filter material. Trash and debris should be removed as necessary. Also, scraping the silt with rakes, tilling or aerating the filter area, and/or replacing the filter medium may be required.

2. Water Quality Inlets & Hydrodynamic Devices

a.) Description

Water quality inlets are stormwater inlets that have been fitted with a proprietary product (or the proprietary product replaces the catch basin itself) designed to remove water quality contaminants. They are designed to receive large sediment, suspended solids, oil and grease, and other pollutant loads.

Hydrodynamic devices are on-line structures that separate sediment and pollutants from the flow stream via physical methods. These methods include baffle plate design, vortex design, tube settler design, inclined plate settler design or a combination of these. Ideally, the flow through device should remove litter, oil, sediment, heavy metals, dissolved solids and nutrients.

b.) Applicability

These controls can be used at any existing or proposed inlet where contributing runoff may contain significant levels of sediment and debris: parking lots, gas stations, golf courses, streets, driveways, industrial or commercial facilities, etc.

c.) Advantages and Disadvantages

ADVANTAGES

- Effective pre-treatment to reduce sediment and pollutant loads on other facilities.

- No additional land requirements.

DISADVANTAGES

- Potentially adversely impacted by cold weather.

- Requires rigorous maintenance to be effective.

d.) Maintenance Requirements

Maintenance is crucial for pollutant removal effectiveness. The more frequent a water quality insert is cleaned, the more effective it will be. Follow the manufacturer's guidelines for maintenance, also taking into account expected pollutant load and site conditions. Inlets should be inspected weekly during construction. Post construction, they should be emptied when over half full of sediment (and trash) and cleaned at least twice a year. They should also be inspected after large runoff events.

3. Riparian Buffer Restoration

a.) Description

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

b.) Applicability

Riparian buffer restoration is applicable for sites traversed by, or adjacent to, a stream with a degraded or previously developed riparian buffer.

c.) Advantages and Disadvantages

ADVANTAGES

- Restores the natural pollutant and nutrient removal capacity of the stream bank.
- Enhances site aesthetics.
- Improves biodiversity.

DISADVANTAGES

- Consumes large amounts of land that cannot be developed.
- Considerable financial cost.
- Establishment of the vegetation can take upwards of five years.

d.) Maintenance Requirements

Riparian buffers require diligent maintenance efforts, with inspections at least four times per year, particularly in the first three to five years while vegetation is being established. Buffers need to be regularly watered, mulched, and weeded. Weeds and other invasive species may be controlled with herbicides (only in the first two to three years), mowing (or other mechanical methods), or weed mats. Plants should be inspected for any damage from deer grazing. If tree shelters are employed to protect vegetation, they should be inspected regularly and repaired as needed.

4. Floodplain Restoration

a.) Description

Floodplain restoration aims to mimic the pre-settlement (pre-1600's) conditions of the interaction of groundwater, stream base flow, and root systems in a stream bed. The interaction among the stream's base flow, groundwater, permeable floodplain soils, and riparian root zones provides multiple benefits, including the filtering of sediments and nutrients through retention of frequent high flows onto the floodplain, removal of nitrates from groundwater, reduction of peak flow rates, groundwater recharge/infiltration, and increase of storage and reduction of flood elevation during higher flows.

b.) Applicability

Floodplain restoration can be performed on any location where stream networks have little interaction among the groundwater, stream base flow, and the root systems. This can be done on-site as part of the on-site stormwater management plan, or on projects that do not have a stream on or adjacent to the site, floodplain restoration may be implemented downstream in the watershed.

c.) Advantages and Disadvantages

ADVANTAGES

- Restores pre-settlement stream hydrology.
- Enhances the sediment and nutrient load attenuation capabilities of the stream bank.
- Impacts flood control on the watershed level.

DISADVANTAGES

- Consumes large amounts of land that cannot be developed.
- Considerable financial cost.
- May not be suitable near existing wetlands and mature forests.

d.) Maintenance Requirements

Floodplain areas should be inspected regularly to monitor the vegetative cover. Weeds and other invasive species should be controlled with herbicides (only within the first two to three years), mowing (or other mechanical methods), or weed mats.

D. Nonstructural Stormwater Management Techniques

Nonstructural stormwater management techniques refer to land use management techniques geared toward minimizing storm runoff impacts through control of the type, location, layout, and density of new development. These techniques can be incorporated in the development design process through alternative zoning ordinance and subdivision and land development ordinance (SALDO) provisions, or through creative site planning. These alternative provisions in a zoning ordinance and SALDO can minimize impervious surfaces for a given zoning district. These zoning ordinance and SALDO provisions would aim to move development away from areas that are desirable to preserve, and towards areas that are suitable for development (such as near existing urban and suburban areas, etc.). This can be done either on a per parcel basis, or on a municipality-wide basis. Areas that are desirable for preservation can include any areas that the municipality sees fit to protect, but usually include mature woodlands, wetlands, existing natural drainage systems, riparian areas, and other areas that are important for natural runoff control. Other non-structural controls involve minimizing the impacts of a land development on areas that will be pervious post-development or passing flow from impervious areas over pervious areas to allow it to be partially filtered and possibly infiltrated.

Presented here is a discussion of the various nonstructural practices and controls available for implementation on a development site (or region). The discussion includes a physical description of the control, its advantages and disadvantages, and maintenance requirements (if any). The practices that do not have disadvantages noted can be assumed to be hindered by existing zoning ordinances and SALDOs that limit the extent that the control can be implemented in certain areas. This does not include those controls that only seek to preserve existing features, in which the only disadvantage is a possible loss of profitability from the reduced development area.

1. Protect Sensitive/Special Value Resources

    a.) Description

    To minimize stormwater impacts, land development should avoid affecting and encroaching upon areas with important natural stormwater functional values (floodplains, wetlands, riparian areas, drainageways, others), and with stormwater impact sensitivities (steep slopes, adjoining properties, others) wherever practicable. This avoidance should occur site-by-site and on an area wide basis. Development should not occur in areas where sensitive and/or special value resources exist so that their valuable natural functions are not lost, thereby doubling or tripling stormwater impacts. Sensitive resources also include those resources of special value (such as designated habitat of threatened and endangered species that are known to exist and have been identified through the Pennsylvania Natural Diversity Inventory or PNDI).

b.) Advantages

- Reduces the pollutant load by preventing existing hydrologic features from being converted to impervious, which would increase the impact of the impervious several times over.

- Reduces the pollutant load by minimizing maintained landscape areas (lawns, etc.).

- Preserves site aesthetics and wildlife habitat.

- Preserves the site's ability to reduce runoff through evapotranspiration.

c.) Maintenance Requirements

Typically, the designated open space may be conveyed to the municipality, although most municipalities prefer not to receive these open space portions, including all of the maintenance and other legal responsibilities associated with open space ownership. If the open space will not be received by the municipality, a homeowner's association is the ideal party to own the open space.

2. Protect/Conserve/Enhance Riparian Areas

a.) Description

This control serves to protect the existing natural vegetative buffers protecting streams. The Executive Council of the Chesapeake Bay Program defines a riparian forest buffer as "an area of trees, usually accompanied by shrubs and other vegetation, that is adjacent to a body of water and which is managed to maintain the integrity of stream channels and shorelines, to reduce the impact of upland sources of pollution by trapping, filtering and converting sediments, nutrients, and other chemicals, and to supply food, cover, and thermal protection to fish and other wildlife." Also, it is important to note that riparian buffer areas are not the same as floodplains. While most riparian buffers are within the floodplain, there can be areas where riparian buffers extend beyond the floodplain (such as banks with steep slopes, etc.).

b.) Advantages

- Vegetation provides water quality filtering for sediments, nutrients, and other pollutants.

- Increases the bank stability of the stream.

- Improves groundwater recharge.
- Preserves the existing peak rate and volume control of the wooded area.
- Controls the temperature of the stream shaded by the existing tree canopy.
- Preserves site aesthetics and wildlife habitat.

c.) Maintenance Requirements

Since the purpose of this control is to preserve existing wooded areas, post-development maintenance requirements are not significant.

3. Protect/Utilize Natural Flow Pathways

a.) Description

Most sites have identifiable drainage features such as swales, depressions, watercourses, ephemeral streams, etc. which serve to effectively manage any stormwater that is generated on the site. By identifying, protecting, and utilizing these features a development can minimize its stormwater impacts. Instead of ignoring or replacing natural drainage features with engineered systems that rapidly convey runoff downstream, designers can use these features to reduce or eliminate the need for structural drainage systems.

b.) Advantages

- Natural drainage features can be used as a guide for site design and layout.
- Using natural swales and depressions can decrease the cost associated with engineered controls.
- Preserves the site's ability to reduce runoff through evapotranspiration.
- Can improve water quality through filtration, infiltration, sedimentation, and thermal mitigation.
- Preserves site aesthetics and wildlife habitat.

c.) Maintenance Requirements

Natural drainage features should be protected from upstream increases in peak and volume so as to reduce the risk of channel erosion. Periodic inspections and maintenance actions (if necessary) are important. Inspections should assess erosion, bank stability, sediment/debris accumulation, and vegetative conditions including the presence of invasive species. Problems should be corrected in a timely manner. Protected drainage features should be placed in an easement or other legal measure to protect against future damage and/or neglect.

4. Clustering Development

a.) Description

Clustering is the practice of decreasing lot size while keeping density constant. Development should be concentrated in areas that will allow for the preservation of natural features in other areas of the site. Clustering is beneficial to stormwater management, since it decreases the disturbed area associated with development, and also increases the amount of open space that is preserved. Clustering proposals will require cooperation with the municipality, since clustering techniques are likely to go against the minimum lot size provisions in most municipal ordinances.

b.) Advantages

- Reduces the area impacted by development.
- Preserves the site's ability to reduce runoff through evapotranspiration.
- Preserves site aesthetics and wildlife habitat.
- Reduces total impervious cover by limiting street lengths and reducing the size of other impervious areas (driveways, sidewalks, etc.).

c.) Maintenance Requirements

Ownership of the open space should be established in the same fashion as in the Protect Sensitive/Special Value Resources control.

5. Concentrate Uses Area Wide Through Smart Growth Practices

a.) Description

This control involves using practices that direct growth to areas or groups of parcels in the municipality that are most desirable and away from areas or groups of parcels that are undesirable. This can be thought of as "Super Clustering;" rather than clustering on individual parcels, which will preserve open space in a piecemeal manner across the municipality, using practices such as transfer of development rights, urban growth boundaries, effective agricultural zoning, purchase of development rights, etc. allows for preservation of large amounts of connected, desirable open space across the municipality. "Desirability" is defined in terms of environmental, historical and archaeological, scenic and aesthetic, "sense of place," and quality of life sensitivities and values.

b.) Advantages

- Preserves the natural infiltrative and hydrologic properties of the soil and vegetation on a potentially watershed-impacting level.

- Reduces total impervious cover in the watershed by limiting development to certain areas.

c.) Maintenance Requirements

Ownership of the open space should be established in the same fashion as in the Protect Sensitive/Special Value Resources control.

6. Minimize Total Disturbed Area – Grading

a.) Description

This control involves reducing site grading, removal of existing vegetation (clearing and grubbing), and total soil disturbance. This eliminates the need for reestablishment of a new maintained landscape for the site and lot-by-lot. This can be accomplished by modifying the proposed road system and other relevant infrastructure as well as the building location and elevations to better fit the existing topography. The requirements of grading for roadway alignment (curvature) and roadway slope (grade) frequently increase site disturbance throughout a land development site and on individual lots. In some cases, if the minimum standards for road slope and alignment make it difficult or impossible to implement this control, developers may wish to work with the municipality to possibly deviate from the ordinance standards, without sacrificing public safety standards (regarding sight distance, winter icing, etc.).

b.) Advantages

- Reduces the area impacted by development.

- Preserves the site's ability to reduce runoff through evapotranspiration.

- Reduces the cost of development by minimizing the amount of earthwork required.

- Preserves site aesthetics and wildlife habitat.

c.) Maintenance Requirements

Since this control only involves better site planning techniques, there is no maintenance associated with it. However, if large amounts of open space are to be created as part of the development, ownership of the open space should be established in the same fashion as in the Protect Sensitive/Special Value Resources control.

7. Minimize Soil Compaction in Disturbed Areas

a.) Description

Minimizing soil compaction is the practice of protecting and minimizing damage to soil quality caused by land development. Healthy, native soil will provide significant benefits, including effectively cycling nutrients, minimizing runoff and erosion, maximizing water-holding capacity, reducing storm runoff surges, absorbing and filtering excess nutrients, sediments, and pollutants to protect surface and groundwater, providing a healthy root environment and creating habitat for microbes, plants, and animals, and reducing the resources needed to care for turf and landscape plantings. Compacted soils can never be returned to a perfectly native state (although techniques described in Section A.7: Soil Amendment and Restoration will restore some of the original infiltrative capacity), so it is desirable to protect areas that will be pervious post-development from vehicular traffic, material stockpiling, and other methods of compaction during the land development process.

b.) Advantages

- Preserves the natural infiltrative capacity of the soils on-site.

- Preserves the natural ability of the soils on-site to filter nutrients and pollutants.

- Reduces the need for pesticides and fertilizers to maintain lawns post-development.

c.) Maintenance Requirements

Sites that have minimized soil compaction properly during the development process should require considerably less maintenance than sites that have not. Landscape vegetation will likely be healthier, have a higher survival rate, require less irrigation and fertilizer, and even look better. Some maintenance activities such as frequent lawn mowing can cause considerable soil compaction after construction and should be avoided whenever possible. Planting low-maintenance native vegetation is the best way to avoid damage due to maintenance.

8. Re-vegetate and Re-forest Disturbed Areas with Native Species

a.) Description

This control involves selecting vegetation (i.e., native species) that does not require significant chemical maintenance by fertilizers, herbicides, and pesticides on sites that require landscaping and re-vegetation. This is based on the assumption that native species have the greatest tolerance and resistance to pests and require less fertilization and chemical application than non-native species.

b.) Advantages

- Reduces costs associated with pesticides and fertilizers for vegetated areas.

- Reduction in use of pesticides and fertilizers improves water quality.

c.) Maintenance Requirements

Re-vegetated areas need to be monitored in the first three to five years while vegetation is being established. Woodland areas planted with a proper cover crop can be expected to require annual mowing to control invasives. Application of a carefully selected herbicide around the protective tree shelters/tubes may be necessary, reinforced by selective cutting/manual removal, if necessary. Meadow areas may require a seasonal mowing.

9. Reduce Street and Parking Imperviousness

a.) Description

This control involves reducing impervious street areas, usually by minimizing street widths and lengths, and by minimizing imperviousness associated with parking areas. Street impervious reduction can also be achieved by other methods, such as using pervious pavement (see Section A.1) for parking lanes, or including a landscaped island in the middle of cul-de-sacs. Parking impervious reduction can be accomplished by reducing parking ratios and including pervious overflow parking areas or by having a more efficient parking lot layout (with one-way aisles and angled stalls).

b.) Advantages

- Decreases post-development runoff volume and increases amount of pervious area available for infiltration.

- Improves water quality by decreasing the pollutant load associated with impervious areas.

- Decreases the concentration and energy of stormwater.

c.) Maintenance Requirements

There are no maintenance requirements associated with reducing street and parking imperviousness.

10. Disconnection of Impervious Areas from Storm Sewers

a.) Description

Disconnection of impervious area involves minimizing stormwater volume by directing runoff from roof leaders and impervious roads and driveways to vegetated areas to infiltrate. Impervious areas are directed over a grassed area to an infiltration basin or other volume or water quality control facility. Curb cuts can be used to convey runoff from road and driveway areas if curbs cannot be eliminated from the design.

b.) Advantages

- Increases runoff travel time.

- Promotes infiltration of the roof areas.

- Improves water quality by allowing runoff to be filtered on-site, rather than allowing pollutants to concentrate in a storm sewer.

c.) Maintenance Requirements

There are no maintenance requirements for disconnected impervious areas directly, but downstream controls treating the roof runoff must be maintained for this control to be effective.

11. Streetsweeping

a.) Description

Streetsweeping involves the use of one of several modes of sweeping equipment (such as mechanical, regenerative air, or vacuum filter sweepers) on a programmed basis to remove larger debris material and smaller particulate pollutants, preventing this material from clogging the stormwater management system and washing into receiving waterways.

b.) Advantages and Disadvantages

ADVANTAGES

- Can significantly reduce pollutant loads from highly trafficked roads and parking lots.

DISADVANTAGES

- Winter road conditions can interrupt the sweeping schedule.
- Provides no control for pollutants generated during a rainfall event.
- Modern streetsweeping equipment comes at a cost.

c.) Maintenance Requirements

Other than potential vehicle maintenance to the equipment, there are no maintenance requirements for this control.

CHAPTER 7. REVIEW OF STORMWATER COLLECTION SYSTEMS AND THEIR IMPACTS

A. Existing Stormwater Collection Systems and Their Impacts

As part of an Act 167 plan, existing stormwater collection and conveyance systems throughout the study area are to be documented through correspondence with the municipalities and field surveys. Information on existing storm sewer systems can be important for the hydrologic model, as some systems may be extensive enough to act as the main drainage course for a subarea. These systems would then need to be measured (or have their geometry and dimensions estimated) and input into the model. However, there are no existing stormwater collection and conveyance systems in the Perkiomen Creek Headwaters, so it was not necessary to model them in any way.

B. Future Stormwater Collection Systems

Typically, storm drainage improvements would be constructed either as part of land developments (by the developer) or as remedial measures as part of the municipal capital or maintenance programs on an as-needed basis. As-needed refers to both the severity of the drainage problems and the public support for an improvement. In this manner, projects are constructed as money becomes available in the capital maintenance budget. The effect of this 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 Perkiomen Creek Headwaters Stormwater Management Plan can impact this situation in three ways. First, implementation of the performance standards specified in Chapter 8 would prevent the formation of new storm drainage problems, or the aggravation of existing problems, by maintaining peak flow values throughout the study area at 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 Chapter 5 provides an excellent basis for development of a storm drainage capital improvements inventory. Actual improvements required would be determined from engineering analyses of the problems. Third, any engineering studies conducted for correcting problem areas could benefit from the flow values generated from the computer modeling of the study area as part of this Plan.

Even without the development of a comprehensive remedial strategy, the Stormwater Management Plan will improve the current situation by specifying a consistent design philosophy for all future storm drainage facilities. This design philosophy will relate to both facilities associated with new development and remedial projects.

C. Existing and Proposed Flood Control Projects

There are no existing or proposed flood control projects located within the Perkiomen Creek Headwaters based on State Water Plan data.

CHAPTER 8. WATERSHED-LEVEL RUNOFF CONTROL PHILOSOPHY AND PERFORMANCE STANDARDS FOR THE CONTROL OF STORMWATER RUNOFF FROM NEW DEVELOPMENT

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 performance standards or goals which need to be met for the watersheds to minimize the adverse stormwater impacts of new development. The method used to determine the performance standards was two-fold. A statistical analysis of annual rainfall and the existing water balance was used to determine criteria for water quality and maximum direct groundwater recharge. Additionally, a detailed hydrologic model was developed to "stress" the watershed under various design conditions to evaluate peak rate control options. The specific computer model used was the Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) because it provides acceptable hydraulic and hydrologic accuracy, can utilize multiple computational methodologies, produces total runoff hydrographs rather than individual peaks, and can be programmed on a personal computer.

A. Existing Water Balance Preservation Philosophy

1. Determining the Water Quality Volume

In previous Act 167 Plans prepared by the LVPC, we have used two different methods to calculate the water quality volume (WQv): 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 runoff coefficient and a rainfall depth of 1.25 inches. The greater of these two volumes was used, however, it was 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 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 inch of larger storms is counted, it represents 90% of all annual rainfall. As documented in the *Little Lehigh Creek Water Quality Update, May 2004* and the *"Global" Water Quality Update, April 2006*, this water quality volume was intended as the maximum volume that required capture and treatment to remove water quality contaminants. DEP 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 for the 2-year storm with development. From a rainfall capture perspective, a 2-year, 24-hour storm of 3.0 inches represents about 99% of annual rainfall. This is a rather strict water quality volume control. One reason for its strictness is that it is not simply intended as a volume that needs to be treated to remove contaminants. It is apparently based on a concern that increased runoff volume with development, even if managed through a release rate approach, still may cause increases in flooding downstream. It is also in part based on concern for erosion of downstream channels. Bankfull conditions for natural channels are typically based on about a 2-year return period. This return period, therefore, is key to defining 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. The current LVPC model Act 167 ordinance uses a 30% 2-year release rate as a channel protection standard. From an annual water balance perspective, the difference between a water quality volume based on a 3.0 inch rainfall versus a 1.25 inch rainfall is only about 9% (99% - 90%). However, from a BMP volume perspective, a 3.0 inch rainfall standard would produce about twice the needed volume as a 1.25 inch rainfall standard. At first, this would seem to create higher runoff control costs for a developer. This would be true if the only requirements for runoff control were for water quality purposes. The basic Act 167 ordinance, however, requires runoff control for the 2-year through 100-year return period runoff events. This means that the more strict (i.e. 3.0 inch event) requirement for water quality purposes may not have any bearing on the control cost to a developer that needs to manage runoff up through the 100-year return period (i.e. 7.5 inch event). In fact, a design example created by the LVPC found no appreciable difference in the amount of stormwater management storage volume required for the 100-year control whether 1.25 inches or 3.0 inches was used for determining the water quality volume. Since one of our goals with updating the water quality standards is to achieve greater consistency with DEP standards and since it appears this will not add any significant cost to the developer, this Plan includes the 2-year incremental runoff volume as the WQv.

There are multiple methods to calculate the 2-year incremental volume, all of which produce slightly different results. There are two ways to use the soil-cover-complex method (discussed in more detail below in Section C.2.b) to calculate the WQv. The first is the correct application of the method: to calculate runoff from pervious and impervious areas separately. The other method is to use a single weighted runoff curve number (CN) based on land cover. These two implementations of the same method produce significantly different results: nearly 50% different for lower values of CN (65-70). The only places the two volumes converge are at CN values of 61 and 98: 0% and 100% impervious, respectively. DEP will only accept the "split" approach under the NPDES post-construction permit process, so there is not a compelling reason to allow the less conservative weighted CN approach for calculating the WQv. Another method would be to use the Rational Method with a 3 inch rainfall depth applied to pre- and post-development conditions. At larger values of CN, this volume ends up being much less than the split CN volume. However, at lower values of CN (<80), the Rational Method volume is more than 80% of the TR-55 volumes, and that difference goes to zero as impervious cover goes to zero. In this Plan and Ordinance, both a curve number methodology and the Rational Method are available to designers, so both methods of water quality volume calculation are allowed. If using the CN method, calculating pervious and impervious areas separately is required to implement the method correctly to calculate the WQv and BMP tributary area volumes.

2. Determining the Existing Water Balance

As stated above, control of the water quality volume will require a development plan to severely restrict the runoff leaving the site for storms up to and including the 2-year return period event. On an annual water balance basis, the 3 inch rainfall depth for the 2-year event represents a rainfall capture of more than 99% of annual rainfall based on LVPC analysis of rainfall records from Allentown, Pennsylvania. The end result of the standard is to very significantly reduce runoff on an annual basis. Post-development runoff then 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.

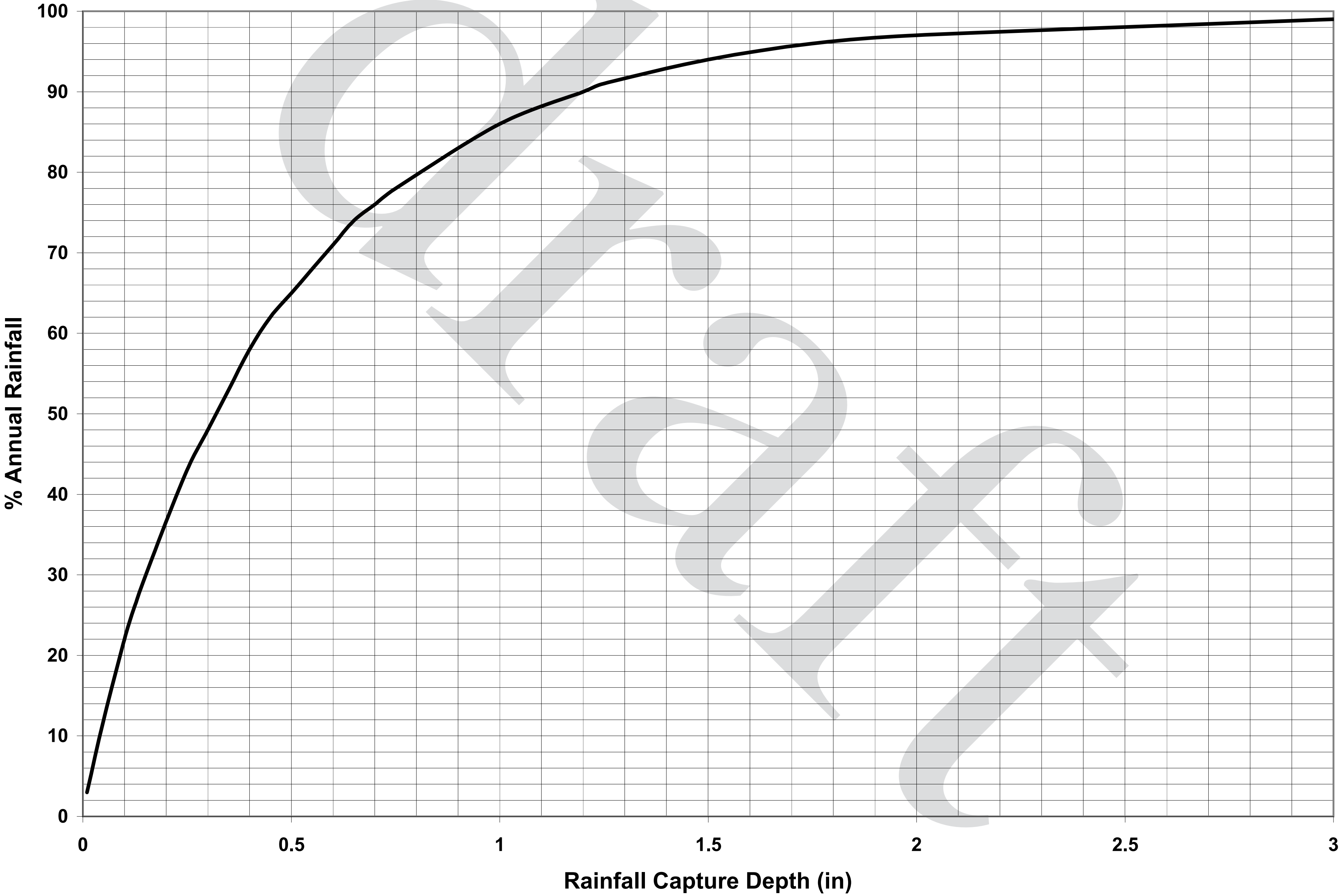
A key to preventing situations where groundwater recharge would be greatly increased due to development, possibly with detrimental side effects, is to attempt to quantify the eventual fate of rainfall in the pre-development condition, be it runoff, recharge, or evapotranspiration. Pre-development or 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*, LVPC 2002, as well as data prepared by the LVPC 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 10-20%. 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
ET – 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. Figure 12 shows the non-linear relationship between rainfall capture depth and percent annual rainfall. 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 BMPs. Impervious surfaces produce a well understood "transform" of rainfall to runoff such that most rainfall will become runoff. The change from pervious cover to

FIGURE 12
PERCENT ANNUAL RAINFALL VERSUS RAINFALL CAPTURE DEPTH



impervious cover with development can dramatically alter peak runoff rate and runoff volume. BMPs can be employed to manage rate and volume impacts, but the annual water balance implications of those choices may not be considered. There is very little available data on BMP water balance. We can begin, however, with some very simple rules to classify BMPs by the predominant fate of runoff. BMPs that primarily provide an opportunity for evapotranspiration (ET) through a vegetative layer are ET BMPs. BMPs that initially direct runoff to an underground infiltration surface are direct recharge (D-RE) BMPs. BMPs that mainly pass runoff volume through such that the volume leaves the BMP as runoff are runoff (RO) BMPs. BMPs can then be classified as evapotranspiration (ET), direct recharge (D-RE), or runoff (RO) BMPs on the basis of the predominant fate of runoff.

Again, we have a relatively clear understanding of the rainfall/runoff response of impervious areas. Pervious areas are also important for annual water balance purposes, but our level of understanding is not as clear. In the pre-development condition, pervious areas probably have an annual water balance representative of the stream gage data presented above, where 60% of annual rainfall becomes ET, 30% becomes recharge, and 10% becomes runoff. However, in the post-development condition soil compaction by heavy equipment probably changes the annual water balance even for proposed pervious areas (i.e. lawns). For purposes of this Plan, the following assessment has been made of pervious areas pre- and post-development. If the natural landscape produces ET, RE and RO in portions of 60%, 30% and 10% of the annual water balance, this translates from Figure 12 into a capture volume of 1.25 inches of annual rainfall since at this point 90% is captured and 10% is runoff. In the post-development case, with the assumption that compacted soil areas would be covered with at least a few inches of topsoil and seeded with grass, the grass and topsoil combination should at least be able to capture the first 0.5 inches of precipitation, thereby producing a 70% rainfall capture with 30% left as runoff. In this simple illustration, runoff would triple from pre- to post-development conditions for these pervious areas on an annual water balance basis. This will be the operating rule for this Plan for water balance purposes. Note that we're not making any judgment how this reflects design storm events of 2- through 100-year return period. These are more severe events than the storms of 3.0 inches or less that are important for annual water balance.

The first step in BMP deployment for a site can be based on what areas don't need BMP controls to meet annual water balance objectives. To preserve the existing water balance, part of the site could be allowed to bypass the BMPs to attempt to maintain existing runoff levels. Additionally, moving toward the goal of having 10% of annual rainfall leave the site as runoff, a significant portion of the site as lawn area can bypass the BMPs. Simply stated, if the whole site was lawn post-development and if lawn was considered equal to pre-development meadow, no BMPs would be needed and 100% of the site could be "bypass" flow to meet pre-development runoff volume. Owing to soil compaction on the site with development and our operating rule regarding water balance characteristics, it is conservatively estimated that only one-third of the site could be discharged as lawn bypassing BMPs. It would still be possible to control the WQv without needing to retain the entire site runoff volume, so this bypass standard should not conflict with the water quality volume requirements of the ordinance.

For an assessment of the fate of runoff directed to BMPs, we need operating rules for how each type of BMP translates runoff received into ET, RE and/or RO. Two of the rules are quite simple. For RO BMPs, all water directed to them will be assumed to be eventually released as runoff. For D-RE BMPs, all water directed to them will be assumed to be released as recharge. ET BMPs are different. Water directed to ET BMPs clearly will have some fraction of the water become evapotranspiration. Some fraction of the water directed to them is also intended to be recharged. Again, our operating rule is the simplest we can make. ET BMPs are assumed to distribute water directed to them in a way that mimics the natural landscape. That is, the natural landscape produces 60% ET, 30% RE and 10% RO. The 10% RO is, in effect, uncaptured by the natural landscape and runs off. The captured rainfall is split two-thirds to ET and one-third to RE. Therefore, all runoff that is intended to be captured by an ET BMP will be assumed to be distributed as 2/3 ET and 1/3 RE. With this in mind, impervious areas of a site directed to ET BMPs should 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 RO BMPs. Since almost all runoff directed to D-RE BMPs becomes recharge, only about one-third of proposed impervious (owing to some ET off pavement) could be discharged to D-RE BMPs 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 ET and/or D-RE BMPs. 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 ET and/or D-RE BMPs. For a 2-year return period storm, the runoff produced from impervious surfaces is about 90% of rainfall based on curve number or rational method approaches. If we use this for water balance purposes also and we ignore runoff because it's less than 10% of annual rainfall, the range of ET and RE we get from impervious areas directed to ET and/or D-RE BMPs is about 70% ET/30% RE if using exclusively ET BMPs, to 10% ET/90% RE if using exclusively D-RE BMPs. Again, ET BMPs mimic natural conditions and D-RE BMPs create higher than natural recharge. It seems clear some restriction of the use of D-RE BMPs is appropriate to maintain annual water balance near natural conditions. The challenge is to use an appropriate standard that takes advantage of the most sound technical justification possible and properly manages the uncertainties involved in the process toward a reasonable design goal.

The best data we seem to have is: natural recharge is about 30% of annual rainfall, the understanding that BMPs that employ an underground infiltration surface will recharge almost all runoff directed to them, and the rainfall to runoff response for impervious areas is much better understood than for pervious areas. We further know that any pervious areas directed to D-RE BMPs will increase annual water balance recharge above that of the impervious areas being recharged. With the water quality volume standard as the 2-year change in runoff volume, we also believe that capturing that volume with ET BMPs exclusively will about match natural RE, and any use of D-RE BMPs will increase RE above the natural conditions. The standard proposed in this Plan is that direct recharge of runoff from impervious areas by employing D-RE BMPs 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 D-RE BMPs 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. D-RE BMPs designed to capture less than the full 2-year event can direct more site impervious to these BMPs. Figure 13 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 BMP design storage is a function of percent annual rainfall and the RO fraction, we can create a curve to solve for the maximum storage volume allowable for a given percent impervious and percent D-RE. However, this assumes that runoff will first flow into a D-RE BMP, and then flow into an ET BMP downstream when the storage volume is exceeded. Of course, this is not always the case. Sites may be designed to drain to an ET BMP first and overflow downstream into a D-RE facility. Based on the design storage volume of the ET BMP, we can calculate the amount of D-RE that occurs from the overflow into the downstream D-RE BMP. These curves, along with instructions for their application, is included in Appendix C of the ordinance.

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

a.) The entire water quality volume shall be captured and treated by either D-RE or ET BMPs.

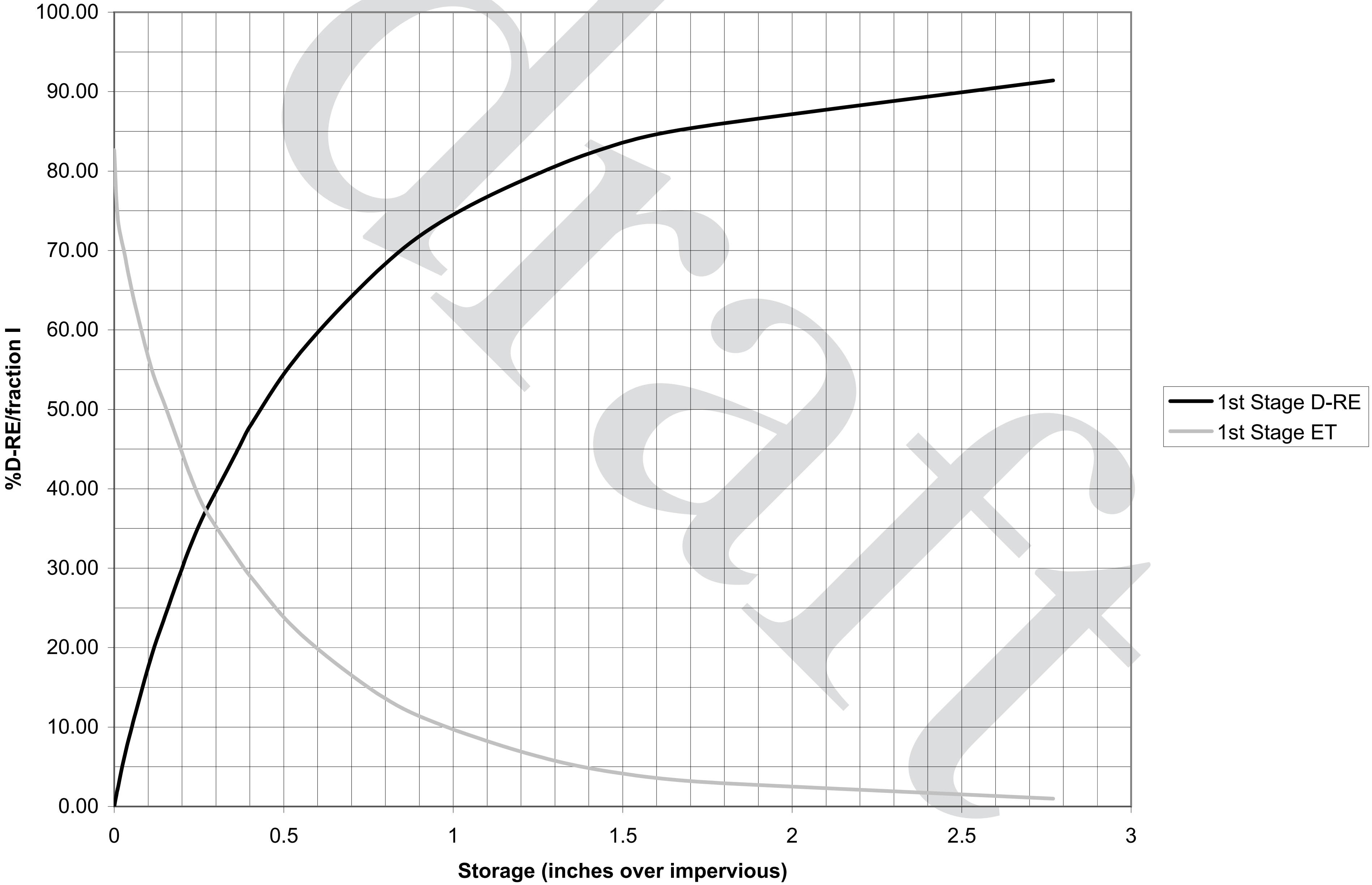
b.) Lawn area up to a maximum of 33% of the entire site area may be allowed to bypass water quality BMPs. As much proposed impervious area as practical shall be directed to water quality BMPs.

c.) Existing impervious area that is not proposed to be treated by D-RE BMPs 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 (D-RE) BMPs for runoff from impervious areas.

    i.) For development sites with greater than 33% proposed impervious cover:

FIGURE 13
PERCENT DIRECT RECHARGE (D-RE) PER FRACTION IMPERVIOUS VERSUS STORAGE



(1) If all impervious cover is directed to ET BMPs to capture the full 2-year event, the D-RE standard is met.

(2) Up to 33% of the site as impervious cover may be directed to D-RE BMPs designed to capture the full 2-year event. All remaining impervious cover shall be directed to ET BMPs designed to capture the remainder of the WQv.

(3) For ET and/or D-RE BMPs designed for runoff from impervious areas designed to capture less than the full 2-year event, Appendix C shall be used to assure that the maximum D-RE standard is met.

ii.) For development sites with less than 33% proposed impervious cover, all proposed impervious and the entire WQv may be directed to D-RE BMPs.

iii.) The maximum 30% D-RE standard applies on an overall site basis, rather than in each individual drainage direction.

B. Watershed-Level Runoff Control Philosophy

1. Watersheds Modeled Using HEC-HMS

Within the Perkiomen Creek Headwaters, there are 12 drainage areas which were modeled using HEC-HMS. The 12 drainage areas are: the Perkiomen Creek, Hosensack Creek, Unami Creek, Licking Creek, Molasses Creek, Schmoutz Creek, Macoby Creek, Macoby Creek Branch and 4 unnamed tributaries to the Hosensack (1), Unami (2), and Macoby Creek Branch (1). The following text refers to the process and the data used in modeling the 12 drainage areas.

Historically, stormwater management decisions for new development have predominantly been made using an “at-site” philosophy. This has been the case for two reasons. First, not all of the four municipalities in the study area in Lehigh County currently require consideration of the downstream impacts of storm runoff from new development in their subdivision ordinances for the Perkiomen Creek Headwaters areas. Second, the municipal engineers do not have a study area database to rely on to quantify any downstream impacts. Therefore, the bottom line is that at-site considerations would typically dictate 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 the post-development peak runoff rates to pre-development level 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 volume generated by development of the site. The proposed watershed-level runoff control philosophy is based on the assumption that runoff volumes will increase somewhat with development. This will be partially mitigated by the proposed water quality standards, which would eliminate the potential increase in runoff volume associated with the 2-year event with development. However, larger events would still create additional runoff volume post-development. The watershed-level philosophy, rather than necessarily attempting to reduce post-development volume across *all* return periods, seeks to "manage" the increase in volume such that peak rates of runoff throughout a watershed are not increased for any storm event. Note that although Act 167 would permit standards to be created to reduce overall peak flows with development, the standards of this plan are created to maintain existing peak flows.

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

Presented in Figure 14 is a typical at-site runoff control strategy for dealing with the increase in peak rate of runoff with development. The "Existing Conditions" 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 shorter time until the peak occurs, and an increase in total runoff volume. The "Controlled Developed Condition" hydrograph is based on limiting the post-development runoff peak to the pre-development level through the 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.

At-site, the maintenance of the pre-development peak rate of runoff is an effective management approach. However, the potential detrimental impact of the approach is illustrated in Figures 15 and 16. Figure 15 represents the existing hydrograph at the point of confluence of Watershed A and Watershed B. The timing relationship of the watersheds is such that Watershed A peaks more quickly (at time t_{PA}), while Watershed B peaks more slowly (at time t_{PB}). Watershed A is an area of significant development pressure and all new development proposals are met with the at-site runoff control philosophy as depicted in Figure 14. The eventual end product of Watershed A development under the "Controlled" Runoff Condition is an extended peak rate of runoff as shown in Figure 16. The extended Watershed A peak occurs long enough so that it coincides with the peak of Watershed B. Since the total hydrograph at the confluence is the sum of A and B, the total hydrograph peak must increase under these conditions to the "Controlled" Total Hydrograph. The conclusion from the above example is that simply controlling peak rates of

FIGURE 14
TYPICAL “AT-SITE” RUNOFF CONTROL PHILOSOPHY

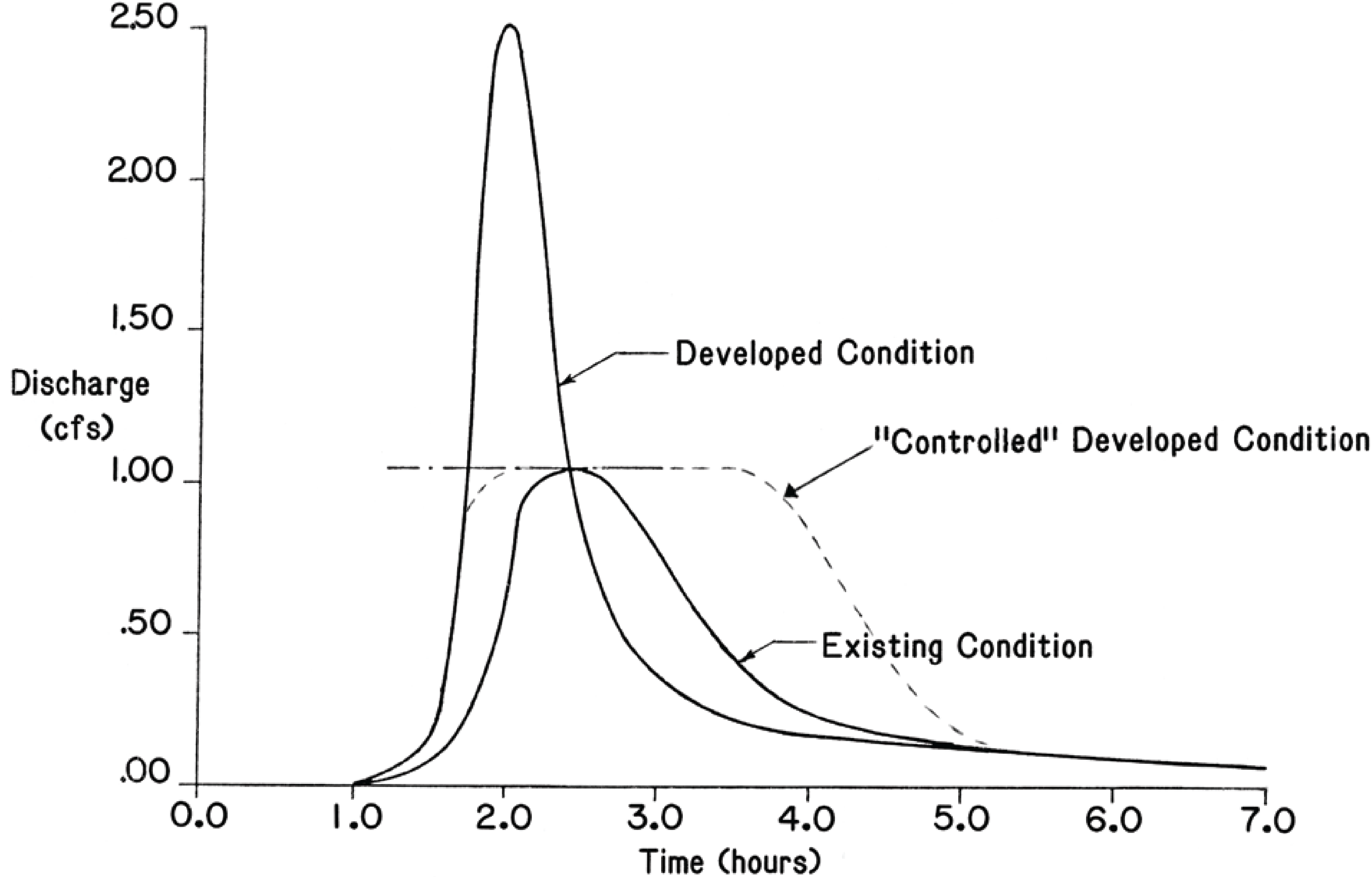


FIGURE 15
EXISTING RUNOFF CONDITION
Pre–Development

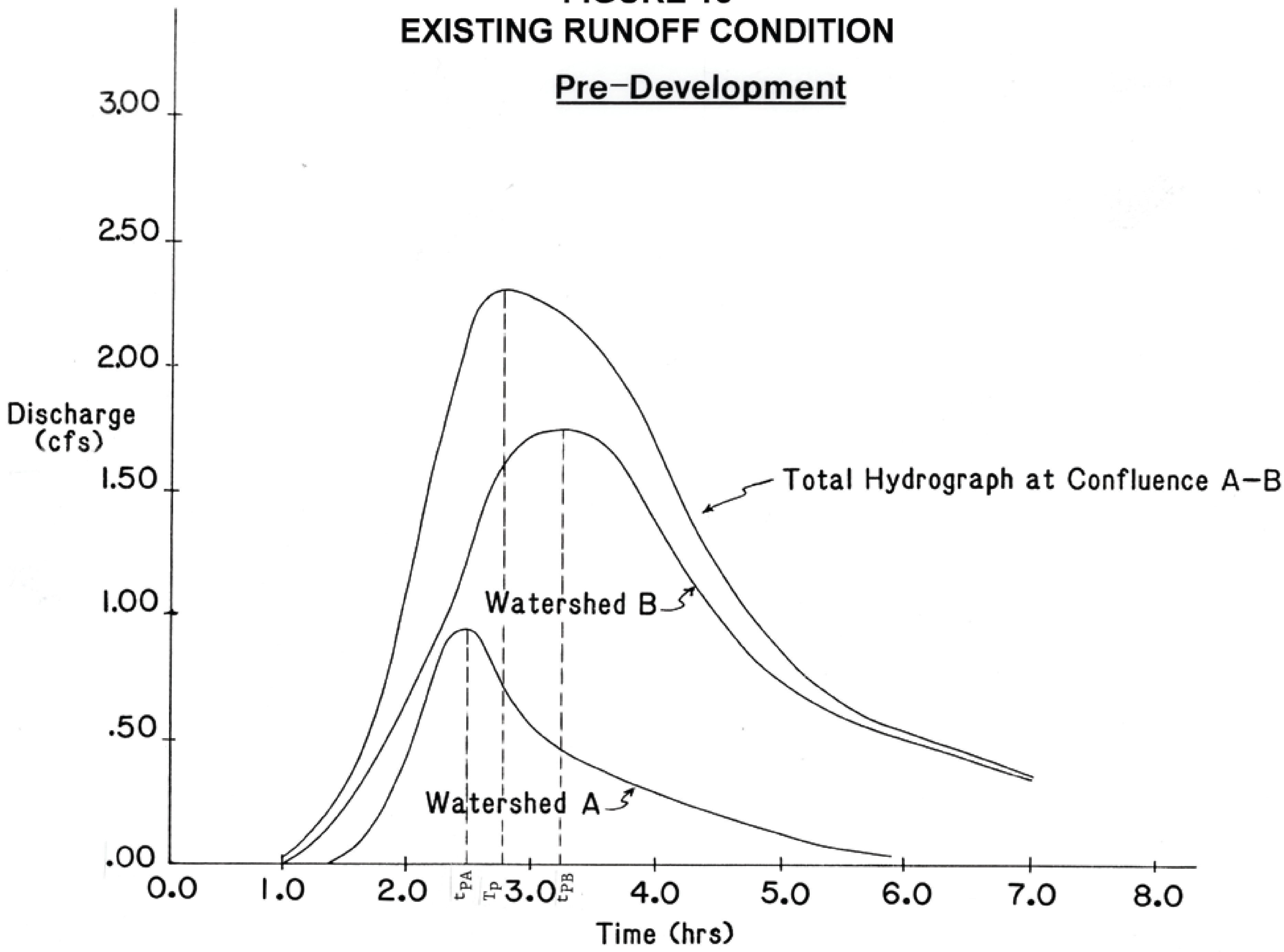
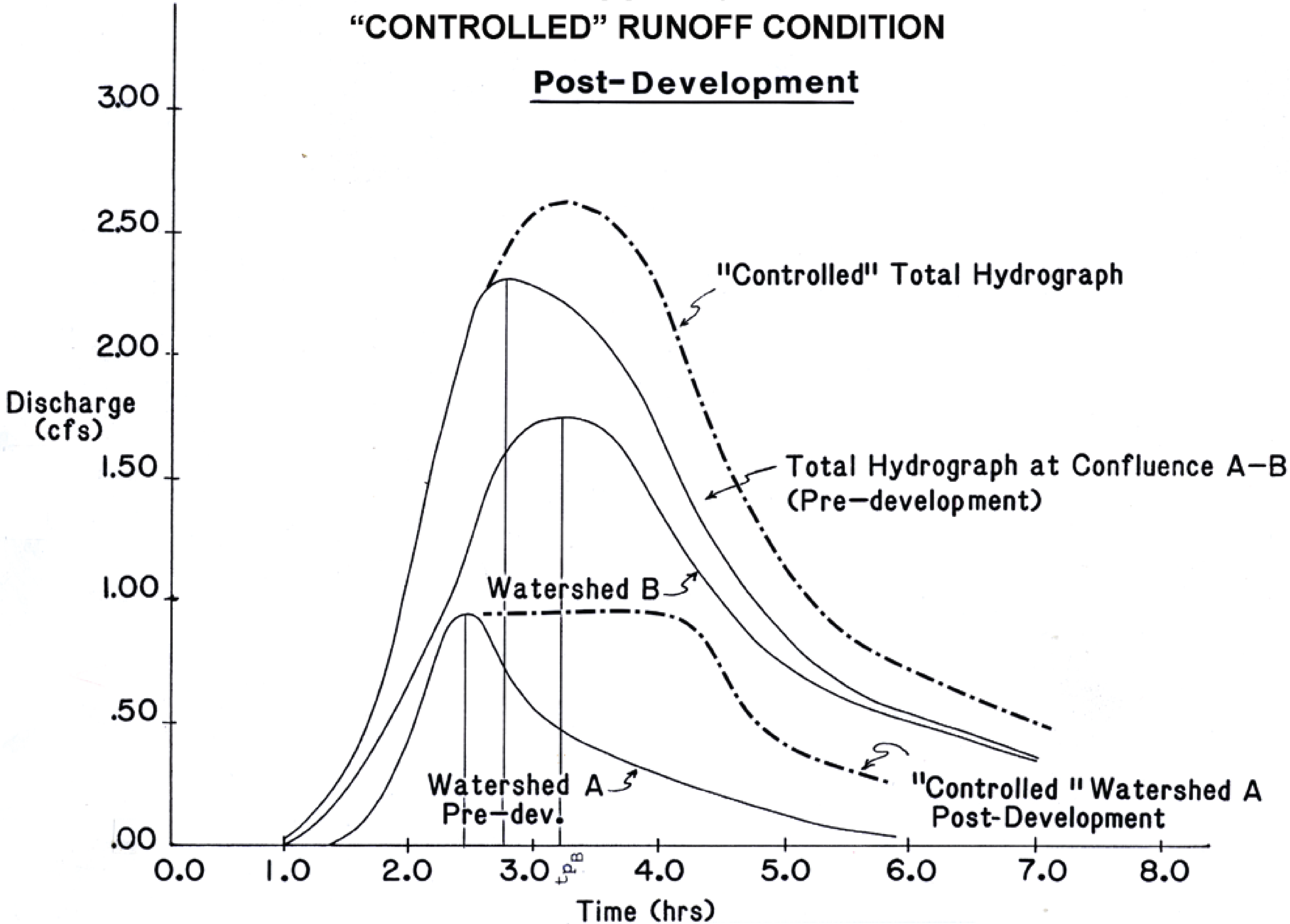


FIGURE 16
"CONTROLLED" RUNOFF CONDITION

Post-Development



runoff at-site does not guarantee an effective watershed-level control because of the increase in total runoff volume.

a.) Release Rate Concept

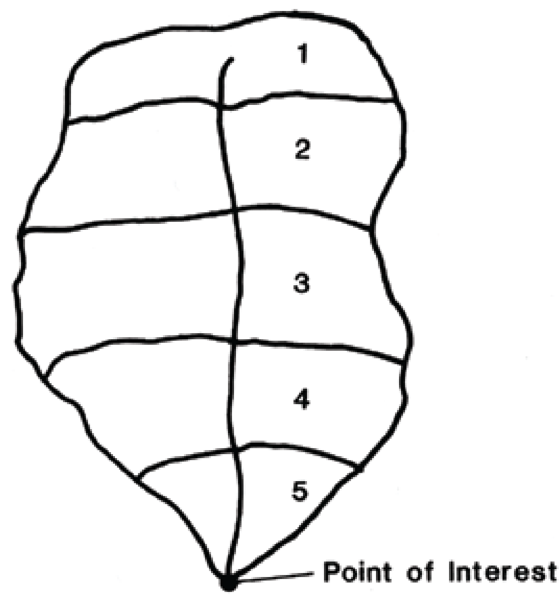
The previous example indicated that in certain circumstances it is not quite enough to control post-development runoff peaks to pre-development levels if the overall goal is no increase in peak runoff at any point in the watershed. The reasons for this are how the various parts of the watershed interact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

Figure 17 indicates how the individual runoff contributions from a number of sites or watersheds create the total hydrograph to a particular point. Areas 1 through 5 each have a particular runoff response to a given rainfall event (i.e. each will generate a characteristic hydrograph). Note that the configuration of the watershed is such that all areas will contribute runoff to the point of interest at the downstream end of area 5. However, the five areas do not contribute at the same time. Flows from area 1 have the farthest to travel to get to the point of interest. Area 5 flows contribute immediately to the point of interest flows. Therefore, the contribution of each area to the hydrograph at the point of interest is the individual area hydrograph lagged in time by an amount equal to the travel time from the area to the point of interest. The total hydrograph at the point of interest and the individual contributions from areas 1 through 5 are shown in Figure 17.

The release rate concept is perhaps best described by looking at how area 4 contributes to the hydrograph at the point of interest. Figure 18 shows the total hydrograph from Figure 17 and the area 4 contribution only. Noteworthy facts regarding the two hydrographs are that area 4 itself peaks before the peak of the total hydrograph (40 minutes versus 50 minutes), the peak flow from area 4 is 100 cfs, and the contribution of area 4 to the peak flow at the point of interest is 75 cfs. Also shown on Figure 18 are the possible outcomes of development occurring in area 4. Specifically, the possible area 4 hydrograph assuming development occurs with no stormwater controls and the resultant hydrograph if all new development uses the at-site philosophy of controlling to pre-development peak levels are shown. Note that in both cases the flow contribution of area 4 to the peak at the point of interest increases (85 cfs for the no control option and 100 cfs for the at-site philosophy option). Therefore, the total peak flow at the point of interest from areas 1 through 5 must increase for both options and neither is an acceptable control strategy. The only acceptable control strategy would be to ensure that the contribution of area 4 to the peak flow at the point of interest does

FIGURE 17
"POINT OF INTEREST" HYDROGRAPH ANALYSIS EXAMPLE

Watershed Configuration



Hydrograph Components at Point of Interest

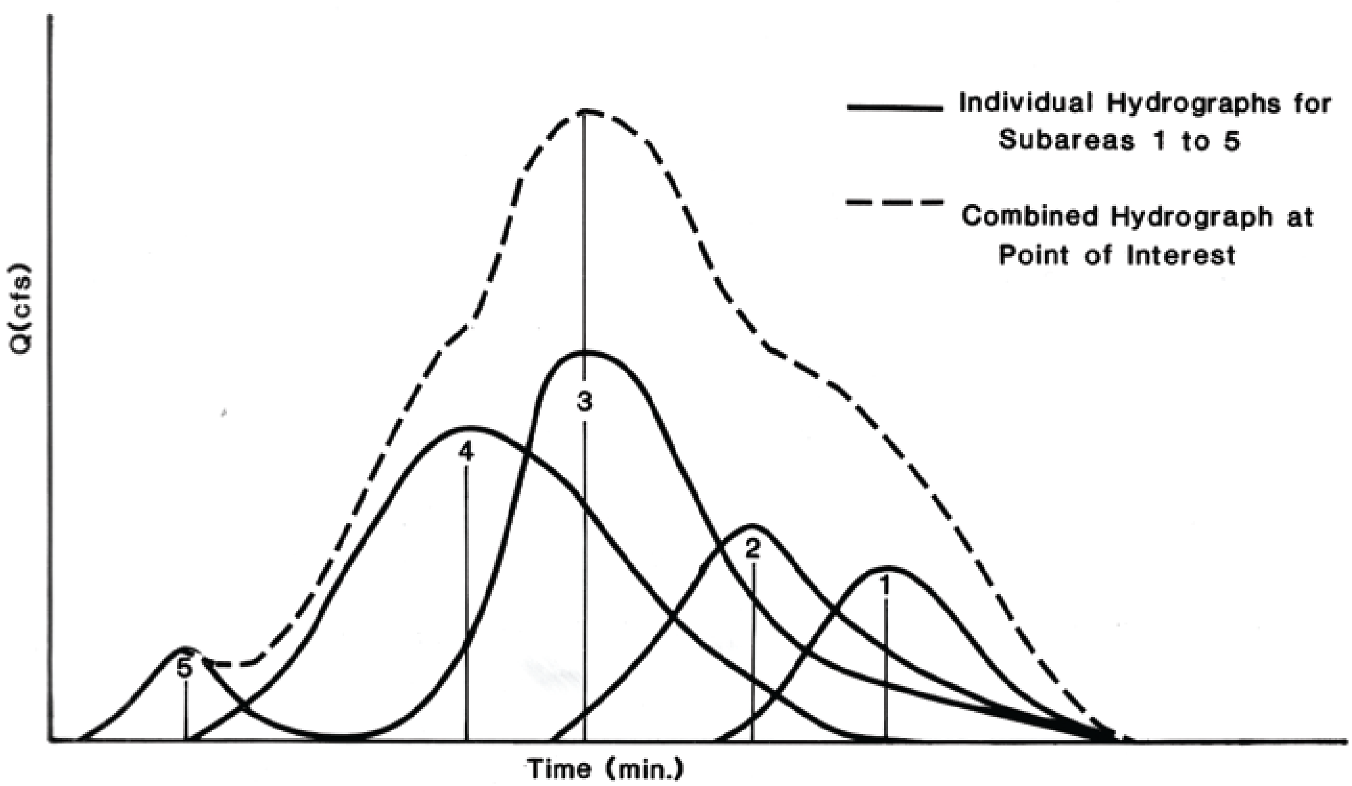
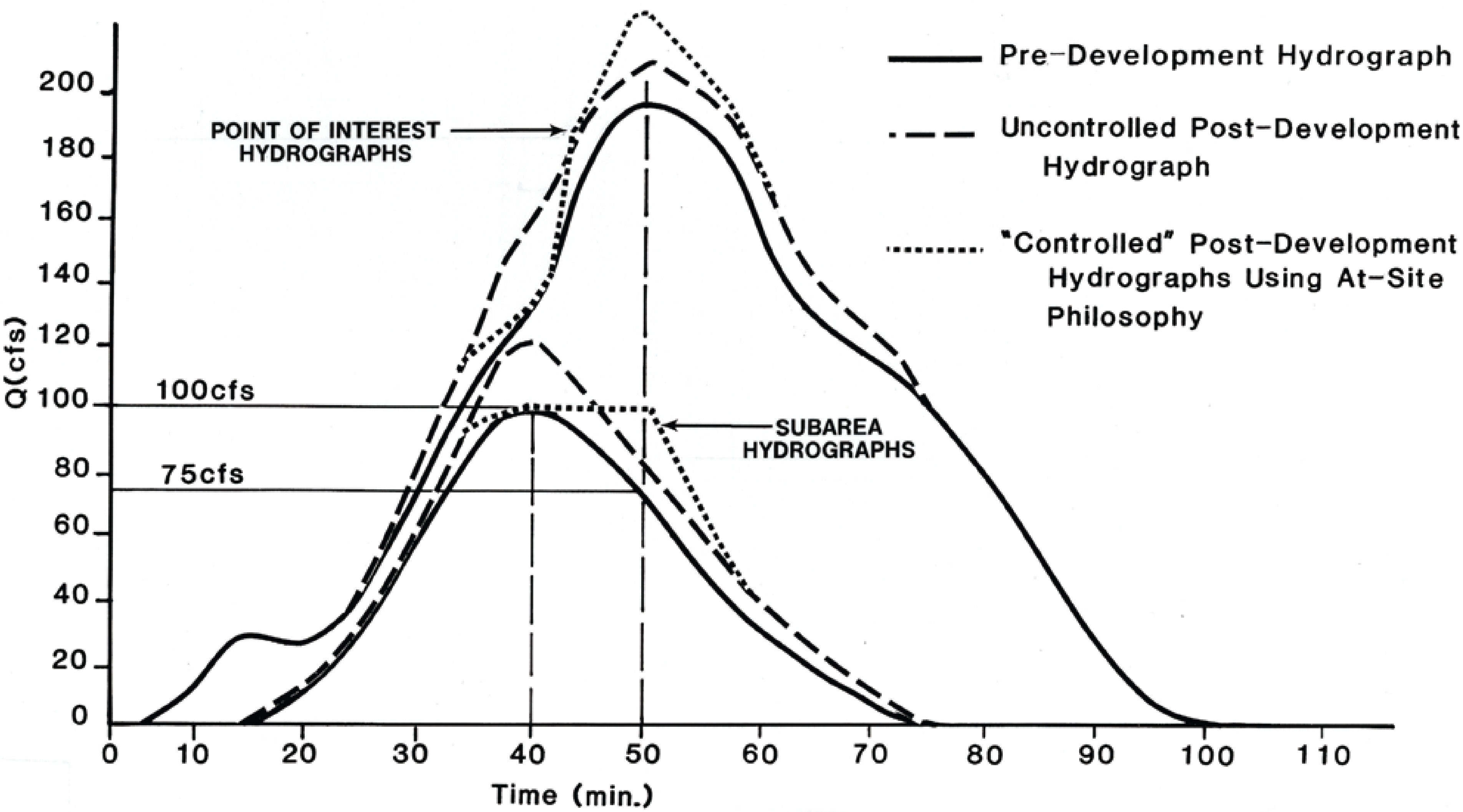


FIGURE 18
HYDROGRAPH ANALYSIS FOR EXAMPLE SUBAREA 4



not exceed 75 cfs. Note that the 75 cfs represents 75% of the 100 cfs peak flow from area 4. This is the basis for the release rate concept.

Conventional at-site detention philosophy would control post-development peak runoff flows to 100% of pre-development level. The release rate concept would dictate a more stringent level of control. For area 4, the release rate would be 75%, meaning that each individual development within area 4 would have to control post-development peak runoff rates to 75% of the pre-development levels as illustrated in Figure 19. Only through this increased level of control for area 4 would the point of interest peak flows not be exceeded. The conclusion is that in exchange for increased runoff volume with development, the peak rate of runoff will actually 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:

$$\text{Release Rate} = \frac{\text{Subarea Contribution to Point of Interest Peak}}{\text{Subarea Peak Flow}}$$

Note that the release rate concept has been developed using area 4 from Figure 17 as an example. The characteristics of area 4 are that it peaks prior to the point of interest peak *and* it contributes flow to the point of interest peak flow. None of the other areas in the example (1, 2, 3, or 5) exhibit both of these characteristics. As such, the proper method of runoff control applicable to these areas may differ from the basic release rate control strategy as discussed in the following section.

b.) Runoff Control Strategy Categorization

The five drainage areas of the previous example, beginning with Figure 17, each contribute to the runoff at the point of interest in a different manner as outlined below:

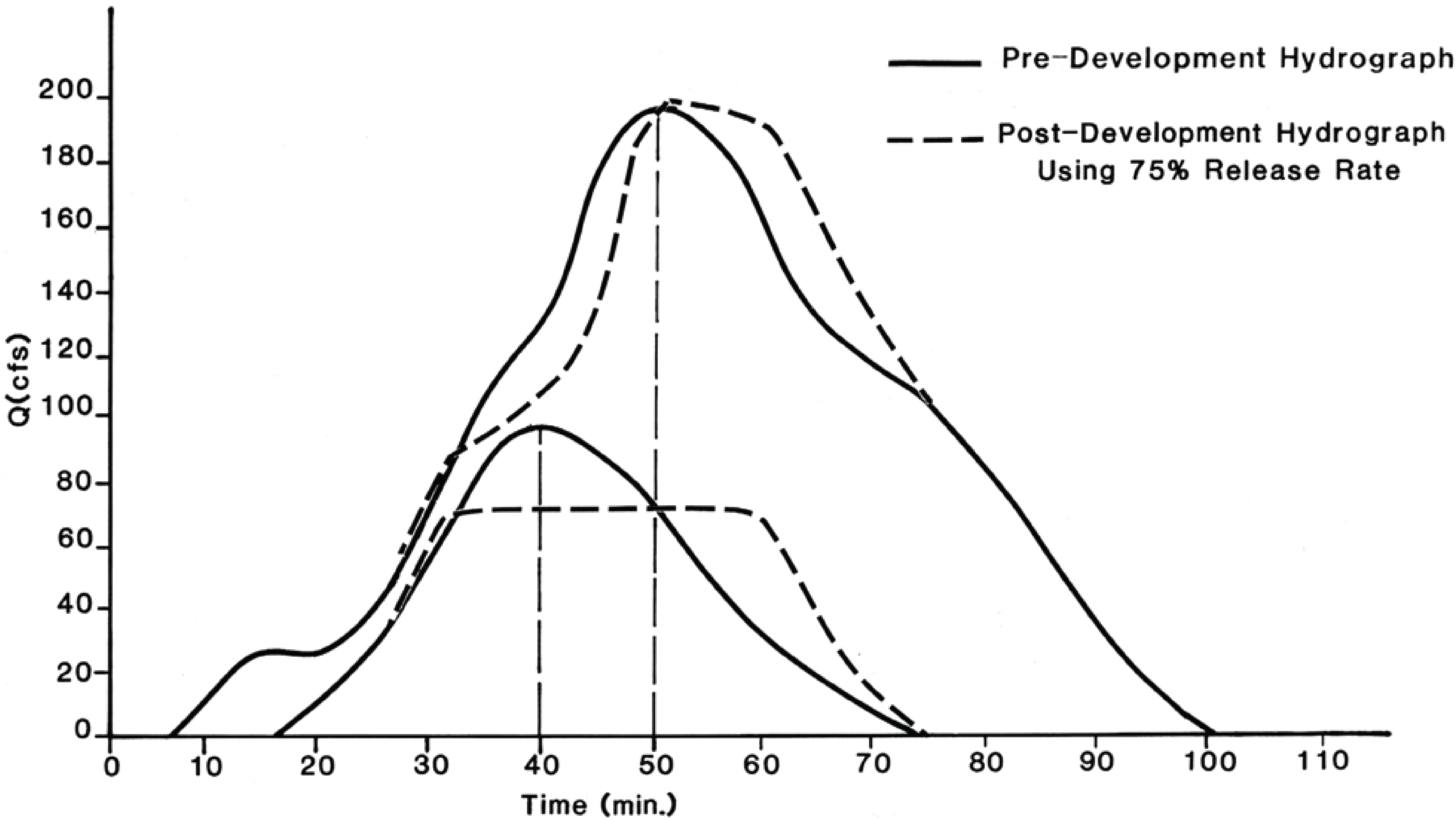
Area 1: Due to its very long travel time, area 1 peaks later than the point of interest peak and does not contribute any runoff to the point of interest peak.

Area 2: Due to its long travel time, area 2 peaks later than the point of interest peak but does contribute to the point of interest peak.

Area 3: Area 3 peaks at exactly the same time as the point of interest peak due to its location in the middle of the watershed. Therefore, 100% of the area 3 peak contributes to the point of interest peak.

Area 4: Area 4 peaks prior to the point of interest peak and contributes runoff to the point of interest peak.

FIGURE 19
RELEASE RATE RUNOFF CONTROL FOR EXAMPLE SUBAREA 4



Area 5: Due to its proximity to the point of interest, area 5 peaks very early (before the point of interest peak) and does not contribute runoff to the point of interest peak.

Each of the above situations presents a different stormwater runoff analysis problem. In fact, each of the five areas define the five different runoff categories which need to be examined in the preparation of a watershed-level runoff control plan. The five categories, or cases, are described in the sections below.

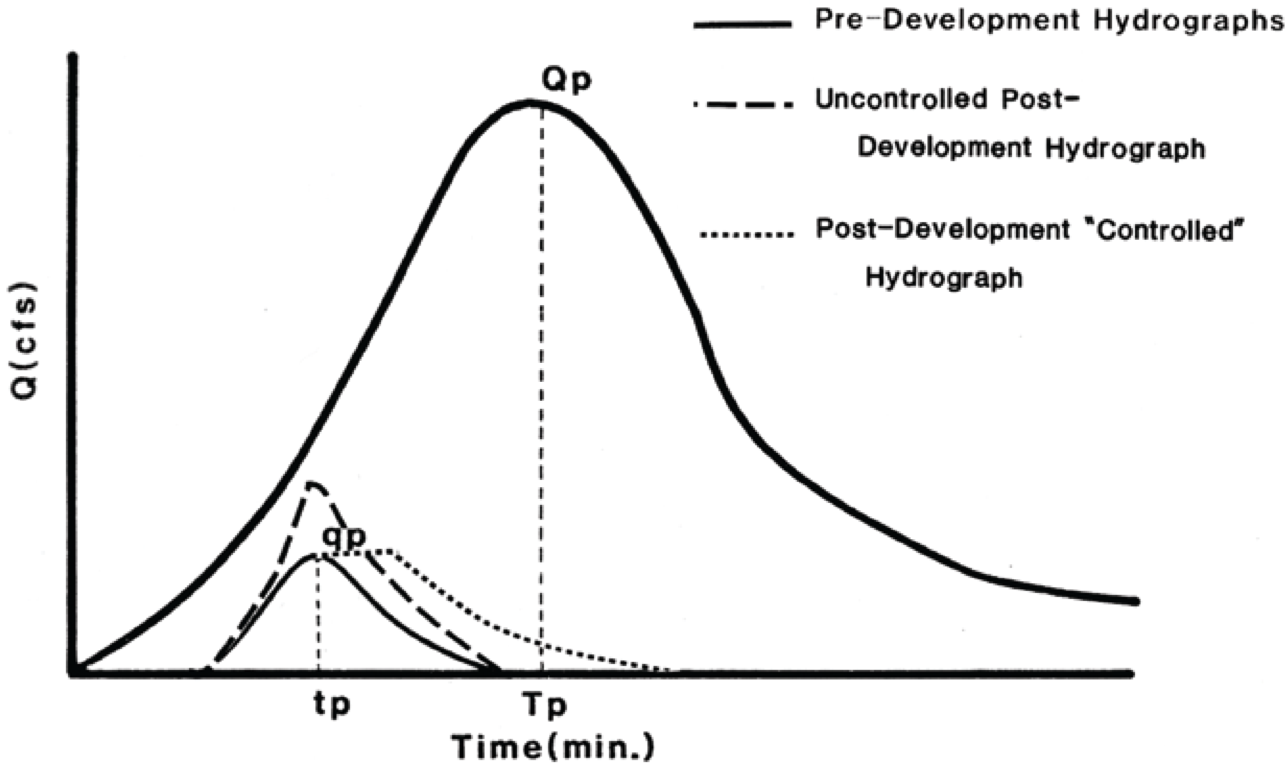
(i) Case I (Equivalent to area 5) – Figure 20 portrays the Case I example of a drainage area which peaks prior to the point of interest peak and does not contribute to the peak flow of interest. From Figure 20, q_p and t_p are the peak flow and time to peak, respectively, of the individual drainage area, and Q_p and T_p are the peak flow and time to peak of the hydrograph at the point of interest. In addition, the value of the individual drainage area hydrograph at any point in time is specified as q @ t, where t is the time in question (e.g. q @ 0, q @ t_p, Q @ $T_p = 0$). Therefore, notationally, Case I is described as follows:

$$t_p < T_p \text{ and } q @ T_p = 0$$

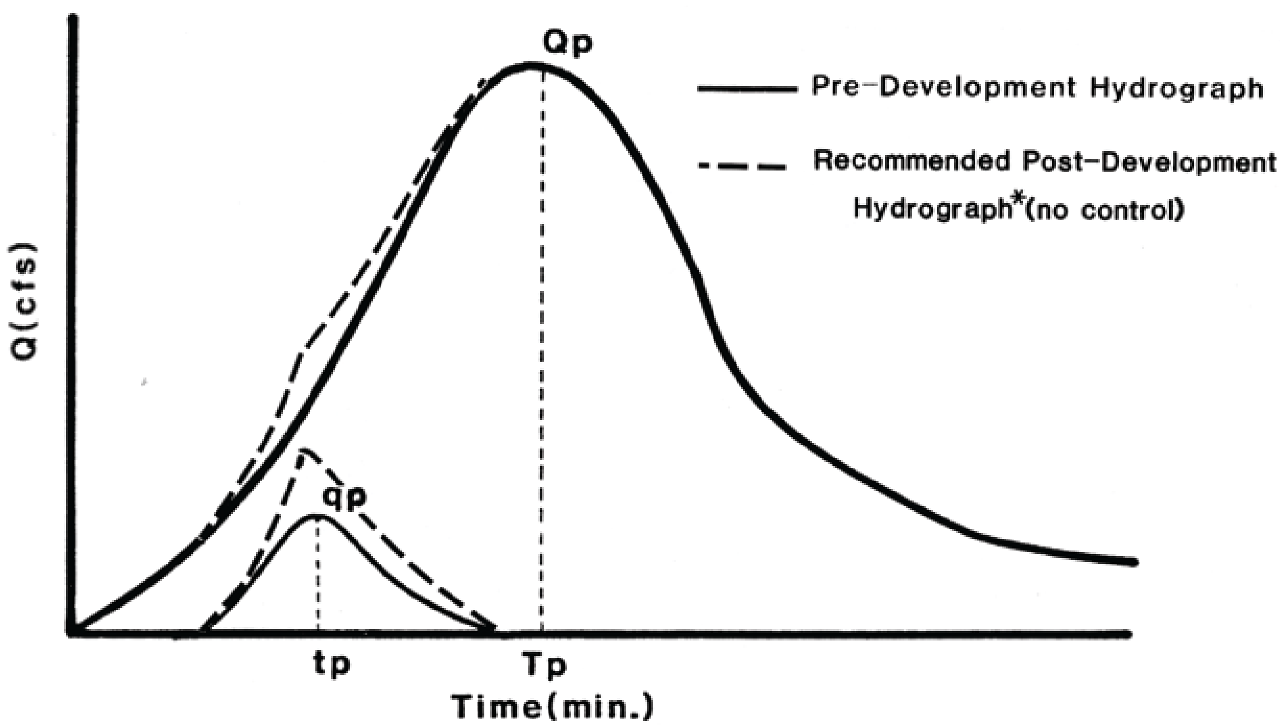
Application of the basic release rate concept to Case I would dictate a release rate of 0% corresponding to the contribution of the drainage area to the point of interest peak. Taken literally, a 0% release rate would mean that no runoff would be allowed to leave the site post-development. Obviously, this would not be a workable control, and in fact, not a necessary one. The reason is that a release rate does not have to be associated with a detention facility geared to pass a certain percentage of the pre-development peak flows. The release rate applicable to Case I is that, whatever the storm runoff control philosophy used, the contribution of the individual drainage area to the point of interest peak should be zero. The most appropriate control in this instance is no control as shown in Figure 20. Any form of detention may extend the peak flow such that the drainage area begins to contribute to the point of interest peak. Simply allowing the drainage hydrograph to peak higher and recede in an uncontrolled fashion results in a more effective approach at the point of interest. Note that the impact of the no control approach for the subarea on the point of interest hydrograph is limited to the rising portion of the hydrograph and not the peak. Therefore, the Case I runoff control philosophy would be no control at all, provided that the unrestricted runoff can be safely transported to the stream channel from each development site.

FIGURE 20
CASE I ANALYSIS CATEGORY AND RUNOFF CONTROL STRATEGY

CASE I: $t_p < T_p$ <u>and</u> subarea does not contribute to subwatershed peak



Recommended Watershed-Level Runoff Control Strategy



*Contingent upon ability of localized drainage network to safely convey higher peak runoff.

(ii) Case II (Equivalent to Area 4) – Figure 21 portrays the Case II example of an area which peaks prior to the peak at the point of interest and does contribute to the peak. Notationally, this is:

$$t_p < T_p \text{ and } q \text{ @ } T_p > 0$$

The calculated release rate for this situation could fall anywhere within the range of 1% to 99%, depending upon the difference between t_p and T_p for various drainage areas which contribute to the point of interest. A 99% release rate area represents essentially the conventional (Case III) detention philosophy of controlling to the pre-development peak rate. The 1% release rate area is essentially a Case I area where, rather than attempting to detain the runoff from new development to 1% of pre-development, a no control approach would be adopted. However, within the range of 1% to 99% the appropriate control strategy is not always clear as will be discussed in Section B.1.d.

(iii) Case III (Equivalent to Area 3) – The Case III situation is presented in Figure 22. Case III represents the simplest control strategy where the release rate is 100% since the time to peak of the drainage area equals the time to peak of the point of interest. For Case III areas, detention should be provided to ensure that post-development peak runoff does not exceed pre-development levels.

(iv) Case IV (Equivalent to Area 2) – Figure 23 displays the Case IV situation where the individual drainage area peaks later than the point of interest peak, and the individual drainage area contributes to the point of interest peak. Notationally, this is:

$$t_p > T_p \text{ and } q \text{ @ } T_p > 0$$

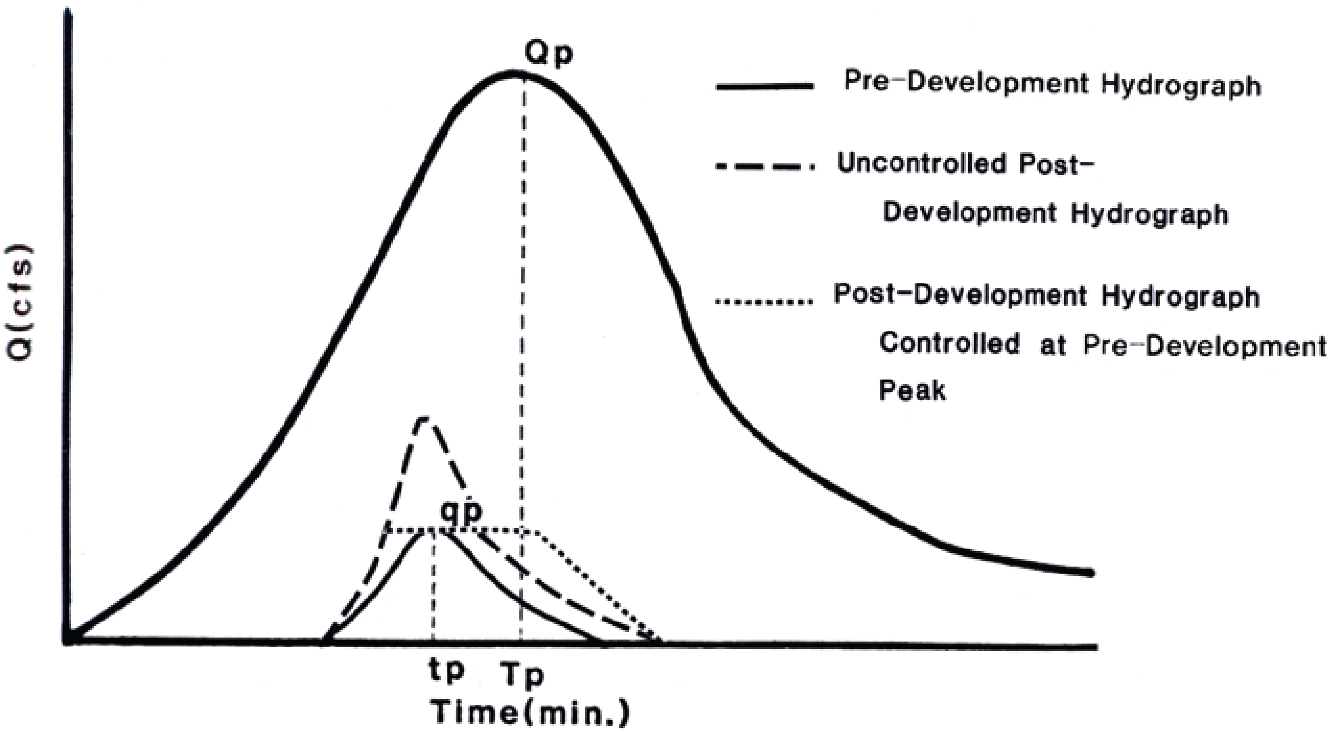
Case IV does not fit the conventional release rate concept because of the relationship between the times to peak. However, as depicted on Figure 23, uncontrolled post-development runoff could increase the point of interest peak because of the tendency of new development to raise the peak of the drainage area *and* decrease the time to peak. The appropriate control strategy would be to simply provide detention for the drainage area designed to slow the rise of the hydrograph to the pre-development level and control peak flows to the pre-development condition.

(v) Case V (Equivalent to Area 1) – The Case V situation is shown in Figure 24 where the individual drainage area time to peak occurs much later than the point of interest peak and the drainage area does not contribute to the point of interest peak. In other words:

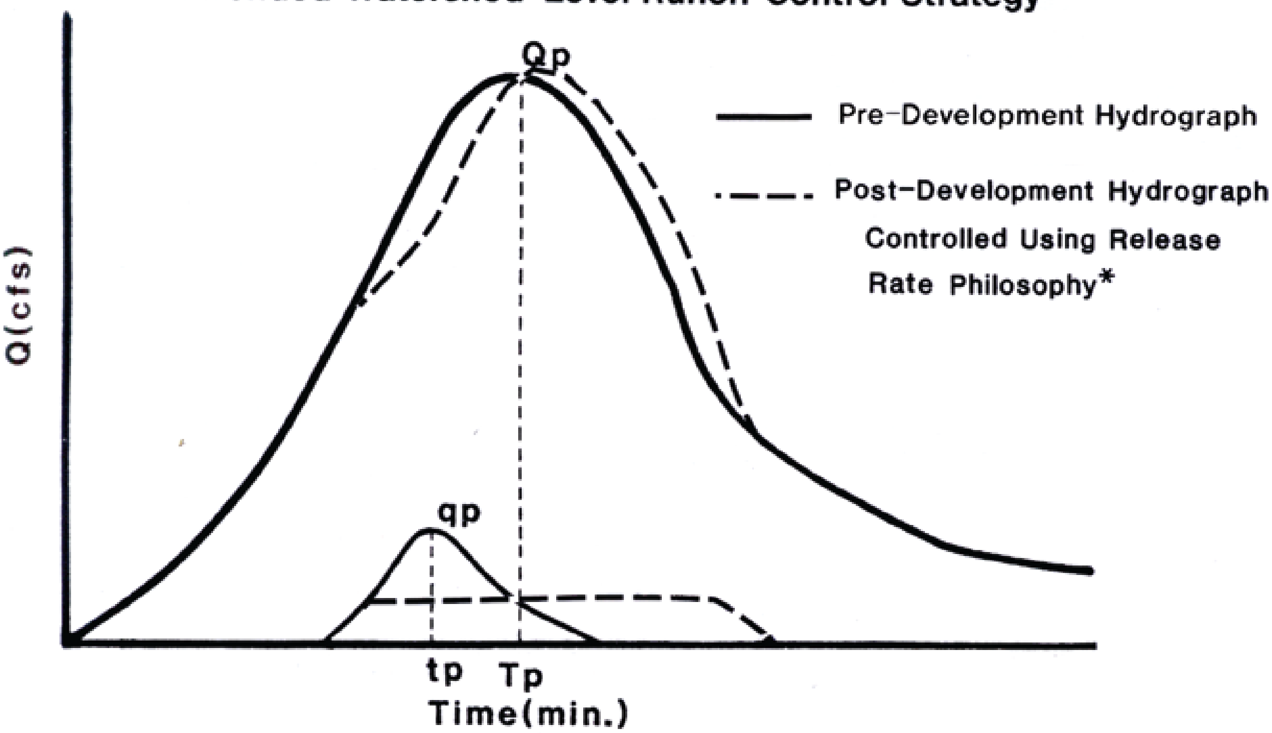
$$t_p > T_p \text{ and } q \text{ @ } T_p = 0$$

FIGURE 21
CASE II ANALYSIS CATEGORY AND RUNOFF CONTROL STRATEGY

CASE II: $t_p < T_p$ <u>and</u> subarea does contribute to subwatershed peak



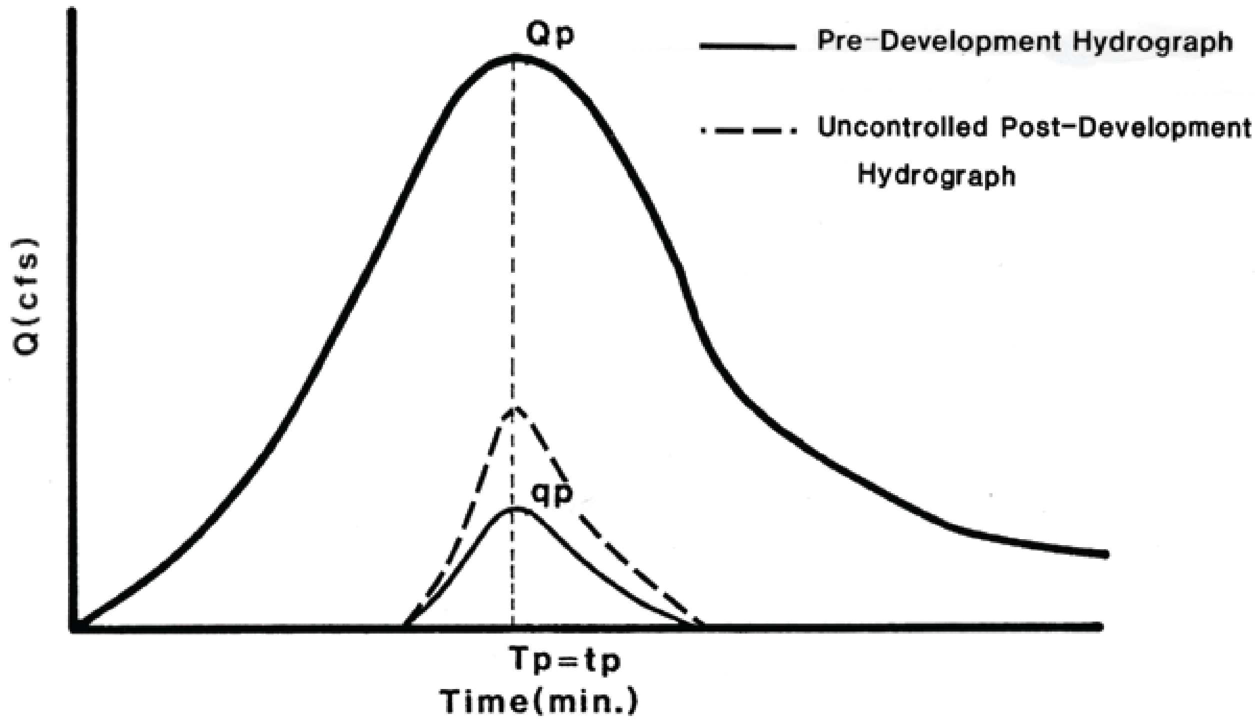
Recommended Watershed-Level Runoff Control Strategy



*For watershed areas which fall into Case II and have very low Release Rates the Case I option would be employed. See text for additional details.

FIGURE 22
CASE III ANALYSIS CATEGORY AND RUNOFF CONTROL STRATEGY

CASE III: $t_p = T_p$



Recommended Watershed-Level Runoff Control Strategy

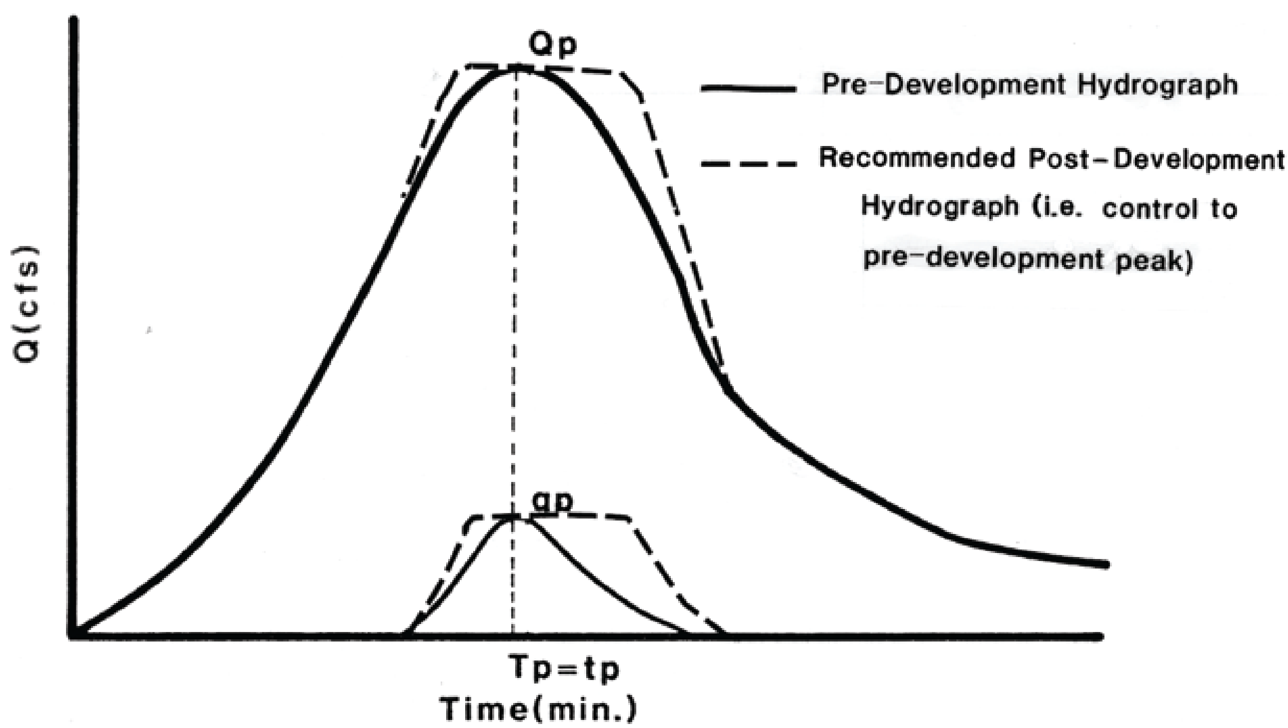
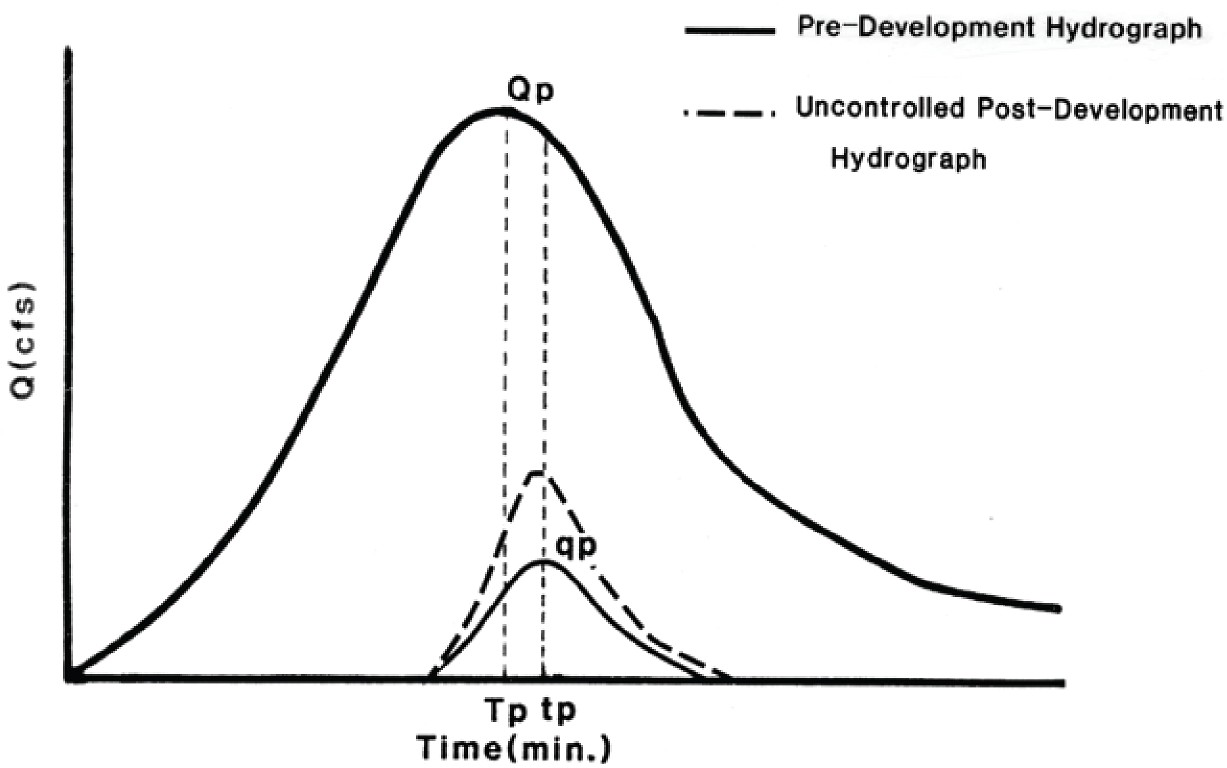


FIGURE 23
CASE IV ANALYSIS CATEGORY AND RUNOFF CONTROL STRATEGY

CASE IV: $t_p > T_p$ and subarea does contribute to subwatershed peak



Recommended Watershed-Level Runoff Control Strategy

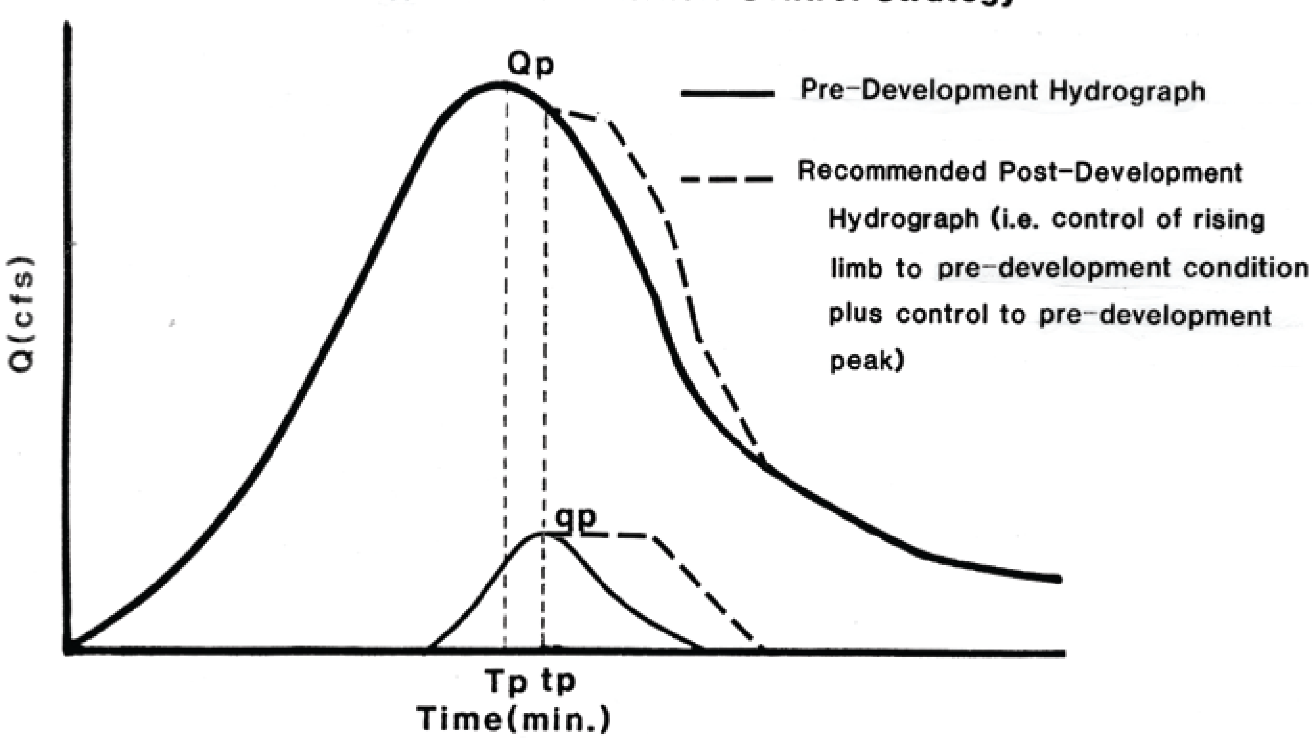
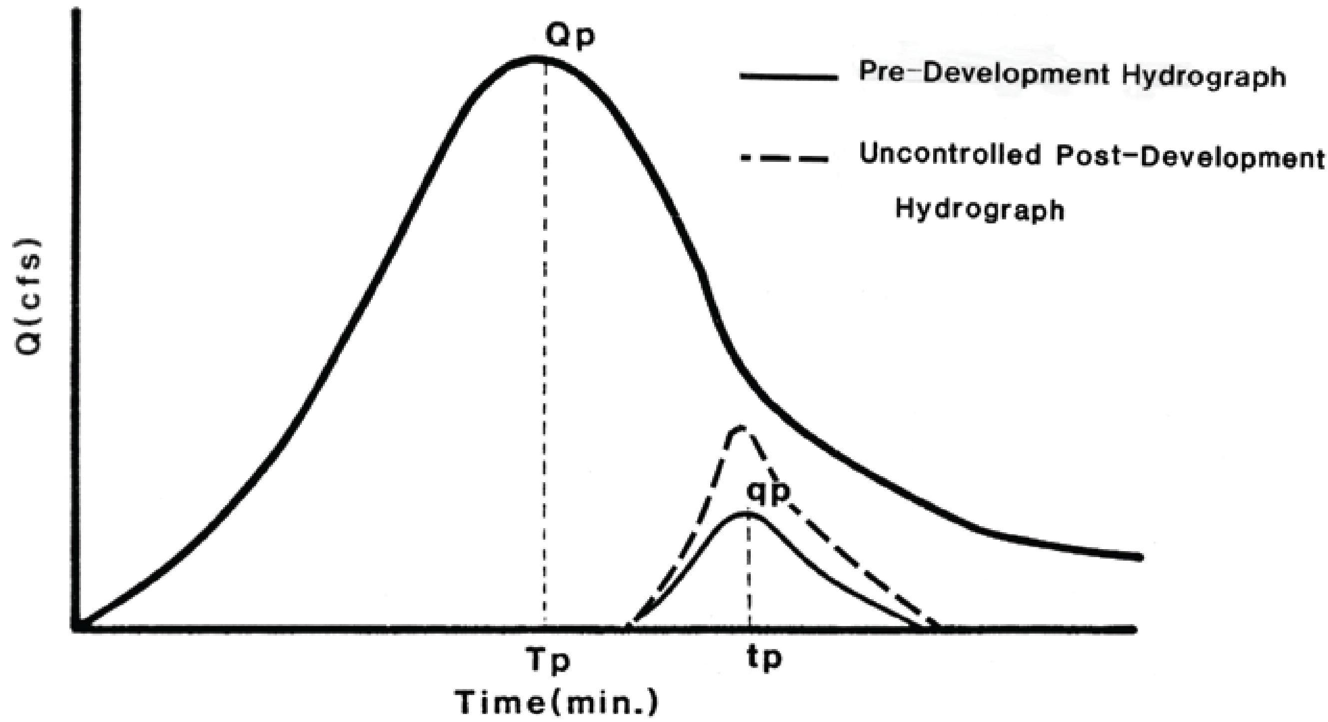
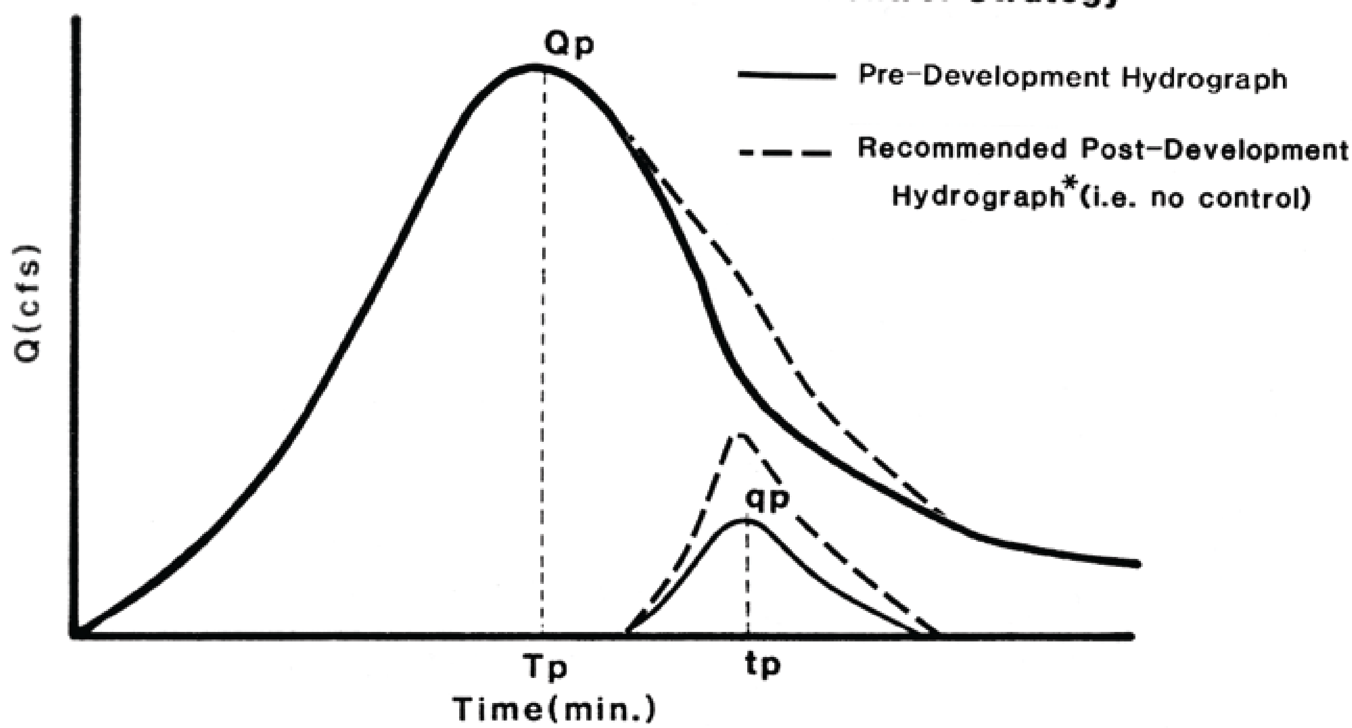


FIGURE 24
CASE V ANALYSIS CATEGORY AND RUNOFF CONTROL STRATEGY

CASE V: $t_p > T_p$ <u>and</u> subarea does not contribute to subwatershed peak



Recommended Watershed-Level Runoff Control Strategy



*Contingent upon ability of localized drainage network to safely convey higher peak runoff.

The runoff control strategy adopted for Case V areas is very nearly inconsequential at the point of interest. Neither uncontrolled post-development runoff nor extended-detention-achieved peaks would have the effect of increasing the point of interest peak flow. However, the analysis performed at Area 5 would need to be also performed at Areas 1 through 4 as will be described below. For this reason a 100% release rate is required for Area 1.

c.) Point of Interest Selection

The five runoff control strategies, Cases I through V, developed above were determined based on a single point of interest at the downstream end of area 5. This was done simply for ease of illustration. In actuality, a point of interest could occur at any location in the watershed, such as the downstream end of area 1, 2, 3, or 4. Given that the relationships between the point of interest hydrograph and a single drainage area hydrograph (as defined by Cases I through V) are determined by travel time between the drainage and the point of interest, selection of the point of interest has a bearing on the runoff control category applicable to each drainage area. Further, the selection of multiple points of interest could mean that each drainage area would fit into multiple control categories. Therefore, selection of the points of interest is a critical element in the development of the watershed-level runoff control strategy. The following items have been considered in the selection of the points of interest:

(i) Existing storm drainage problem areas (23) – identified through the Watershed Plan Advisory Committee municipal representatives.

(ii) Significant obstructions (24) – identified from comparisons of estimated capacity and 10-year return period peak flow.

(iii) All subarea boundaries (54) – identified by breakdown of the subwatersheds for modeling purposes.

(iv) Municipal boundaries.

The overall goals of Act 167 are to prevent the aggravation of existing drainage problems and to prevent the formation of new problems through the coordination of stormwater runoff decisions throughout the watershed. Therefore, at minimum, existing storm drainage problem areas must be used as points of interest for hydrograph analysis. Of the 23 identified problem areas, 20 are located on main reaches of the runoff model and 3 are located within individual drainage areas. The main reach problem areas can be analyzed using the model directly. The remaining 3 problem areas would require a more localized analysis of the impact of potential new development sites which drain through these “off-line” problem areas.

Prevention of any new storm drainage problems 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, which is not available in this case. 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 models 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 in 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. Justification for use of significant obstructions as control points would be that ponding currently occurs at these locations, indicating a lack of adequate conveyance capacity under existing conditions. Increased peak flows at these points would aggravate the current ponding conditions and possibly create a hazard to property or safety.

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 using the 54 subarea boundaries effectively incorporates all the other control strategies, the 54 subarea boundaries have been 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 downstream subarea boundaries.

Devising a runoff control strategy based upon 54 critical points means that each subarea in the watershed will fit into multiple control strategy categories (Cases I through V). The control strategy selected for a particular subarea is based on the most critical category applicable to the subarea. One impact of this is that there are no subareas for which the Case V situation is most critical, since evaluation of upland-most subareas at their own downstream points yields a 100% release rate. Further, only in very isolated instances would a Case IV situation be most critical. Therefore, the control strategy developed is based essentially on runoff control categories I through III.

d.) Return Periods to be Controlled

The performance criteria developed as part of this Plan will be used to control the 2-, 10-, 25-, and 100-year return period events. These four events represent a full range of design frequency events. The 2-year storm event is included because, on a percentage basis, the increase in runoff volume between pre- and post-development conditions is greater for the 2-year event than for any of the other return periods analyzed. This is true because the depth of rainfall is least for the 2-year event, and the pervious areas (lawns, etc.) do not significantly contribute to peak flows or runoff volume. As total rainfall depth increases with return period, pervious areas become saturated and nearly all rainfall becomes runoff – resembling the response of impervious areas. Therefore, the change in imperviousness with development is more difficult to control from a runoff perspective for the more frequent (e.g. 2-year) storms. However, the proposed water quality standards will maintain the existing runoff volume in the watershed, meaning that post-development peak rates from new development only need be controlled to the existing peak flows on-site. The 100-year event was included because many existing municipal ordinances already require analysis of the 100-year storm. Finally the 10- and 25-year storms were included to ensure control of intermediate frequency storm events between the 2- and 100-year extremes.

The preceding sections described the theory behind release rate determination. Section C outlines the actual procedure used to implement the theory. Steps to determine the most appropriate control strategy for each subarea in each subwatershed are as follows:

(i) Run the HEC-HMS model for the “existing” land use condition in each subwatershed for the 2-, 10-, 25- and 100-year storms.

(ii) Beginning with the uppermost subarea, develop each subarea to future land use and assign the highest release rate that does not create a peak flow of greater than 100% of pre-development, if possible. Test the release rate chosen by running HEC-HMS for the 10-year storm, only with the WQv removed from the discharged volume of each subarea to account for the water quality standards. Continue downstream until each subarea has a release rate.

Consistent with the analysis conducted per parts (i) and (ii) above, all subareas in the Perkiomen Creek Headwaters were able to be grouped into a 100% release rate category. In the modeling analysis, three subareas were determined to be "best" controlled (best being defined as having downstream flow increases closest to zero) by a 50% release rate. However, the in-stream improvement of these 50% release rates compared to 100% release rates was very small. Further, inspection of these subareas yields two that have special circumstances that the model doesn't handle well. One subarea is a small junction in the model where the release rate is more a function of the disproportionate size rather than hydrologic contribution. A second subarea actually has a runoff rate decrease with the future land use which shouldn't require a release rate below 100%. The third subarea only reduced the flow by 0.6% using the 50% release rate compared to a 100% release rate. There was a fourth subarea that showed small increases at points downstream (less than 3%), but a more restrictive release rate only exacerbated this condition by extending the hydrograph and adding more volume to the affected downstream peaks. Therefore, it was determined that the most effective release rate strategy, in terms of both cost and performance, was to apply a 100% release rate to every subarea in the watershed.

As discussed earlier, the percentage increase in runoff from development for the 2-year return period storm is the most difficult to control. In previous Act 167 Plans developed by LVPC, a 30% release rate was applied to all areas not designated as no detention areas. This was done for reasons of rate control, as well as water quality and streambed erosion protection. However, with the proposed water quality standards in the Perkiomen Creek Headwaters, the 2-year runoff volume will not increase post-development. Since the release rate concept is based on the assumption that volume will increase post-development, the 2-year event will only need to control runoff to pre-development levels throughout the watershed. Additionally, since the increase in the 2-year volume is being retained post-development, this will also have an impact on the post-development runoff volume of the higher return periods as well. As noted above in Section B.f.ii, when the release rates were tested with the 10-year storm, the WQv (which is equal to the increase in the 2-year runoff volume) was removed from the outflow hydrograph using retention basins in the watershed model. This amount of runoff volume removed from the drainage areas was sufficient for every subarea to be classified as a 100% release rate district.

The final strategy for the Perkiomen Creek Headwaters was chosen to be a single category – 100% Release Rate. The strategy was selected for the reasons discussed above: the control of the increase in the 2-year post-development runoff volume reduces the volume of the 2-year event so that release rates do not apply and removes sufficient volume from the higher return period events such that they are all able to be classified as a 100% release rate district.

C. Performance Standards

1. Description of Performance Standard Districts

The main goal of the Act 167 Plan effort was to determine what levels of runoff control are needed throughout the watershed. With the increased focus on water quality and specification of a water quality volume, as well as the location of the study area (i.e. the study area terminus is based on municipal boundaries, as opposed to the terminus being based on the confluence of the watershed with the Lehigh or Delaware rivers), no detention areas were deemed to be inappropriate for the Perkiomen Creek Headwaters. All of the factors described in Section B of this chapter have been incorporated into a control strategy for successfully dealing with the runoff impacts of new development. The runoff control district for the Perkiomen Creek Headwaters is described below:

a.) 100% Release Rate Districts – The anticipated post-development runoff from these areas can be controlled across the range of return periods from 2- through 100-years by meeting a 100% Release Rate (i.e. post-development discharge is $\leq$ 100% of pre-development) in each drainage district, and by retaining the increase in the 2-year runoff volume on-site.

A map of the Perkiomen Creek Headwaters Study Area drainage districts is included as Plate 1, located inside the back cover of the Plan.

2. Performance Standard Implementation Provisions

The performance standards specified above represent one-half of the stormwater runoff control strategy for the Perkiomen Creek Headwaters. 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, criteria for determining downstream channel capacity and provisions to implement regional detention alternatives. Each of these implementation provisions is addressed separately below.

One additional implementation provision is that the criteria and standards for controlling runoff from new development contained herein are *minimum* criteria necessary for management of runoff from a watershed perspective. Municipalities may implement more stringent criteria so long as the increased stringency does not conflict with the Plan. A more detailed explanation of this aspect of the Plan is presented in the introduction to the municipal ordinance in Chapter 9.

a.) "New Development" Subject to the Performance Standards

"New development" to be regulated by the runoff control plan includes subdivisions, land developments, construction of new or additional impervious surfaces (driveways, parking lots, etc.), construction of new buildings or additions to existing buildings, any earth disturbance or other activities that involve alteration or development of land in a manner that may affect stormwater runoff onto an adjacent property, diversion or piping of any natural or man-made stream channel, and the installation of any storm sewer system. The latter two items have been included because they may have the impact of significantly modifying the conveyance characteristics which have been built into the design of the Plan, and therefore impact the effectiveness of the Plan. An exemption will be provided in the Plan for new developments which are expected to have an insignificant impact on the watershed-level runoff characteristics. The exemption is that any development which creates 10,000 square feet or less of additional impervious cover would not be required to meet the quantity standards of the Plan. The 10,000 square foot criterion is based on the amount of impervious cover which would generate 2 cfs or less additional peak runoff for a five-minute duration storm for a 100-year return period rainfall event. This waiver only applies to land developments, subdivisions and creation of impervious cover or buildings. Also, as stated above, this waiver only applies to the rate control criteria, and not the water quality criteria discussed in Section A of this chapter.

b.) Storm Runoff Calculation Methodology

The performance standards will apply to the range of design storm conditions from a 2-year return period to a 100-year return period. This means that the applicable release rates must be met for the 2-, 10-, 25-, and 100-year return period storm events. In many instances this will mean that detention facilities are designed with multiple stage outlet structures to accommodate the range of return periods.

An important implementation provision is the specification of the runoff calculation methods to be used for development sites within the Perkiomen Creek Headwaters Study Area. Engineering evaluations of the applicability of various calculation methods were conducted as part of the Plan preparation and supported by previous research. The conclusion from the research is that all development sites in the basin may use either the Rational Method or the soil-cover-complex method for determining pre- and post-development runoff peak rates. The soil-cover-complex method was developed by the Natural Resources Conservation Service (NRCS, formerly SCS), and its distinguishing characteristic is the use of a parameter call the Runoff Curve Number. NRCS has analyzed the runoff relationship between the various land cover and soil type combinations and has formulated a scale of the relative ability of the various combinations to produce runoff from a given rainfall. Although the soil-cover-complex method was developed by NRCS, there are many calculation methods available which use the curve number methodology which are not associated with NRCS.

Regardless of the runoff calculation method used, the design of any detention facility to meet the performance standards specified in the Plan must be verified by routing the calculated runoff through the basin. Routing refers to the calculation process of taking the post-development runoff and determining if the detention facility's storage-elevation-outflow characteristics are appropriate for meeting the performance standards.

Closed depressions are one factor which could affect the magnitude of the peak flows a development will produce. In the "existing" condition, closed depressions can prevent a significant amount of runoff from entering the stream channel. The removal of these depressions with development can increase the storm runoff received by the conveyance facilities beyond the available capacity. For this reason, any development proposal which will remove a significant closed depression must demonstrate adequate capacity in the "local" conveyance facilities from the site to the main channel. Proper analysis of channel capacity is outlined in the following section.

c.) Channel Capacity/Capacity Improvement Criteria

Implementation of the performance standard criteria requires the identification of procedures to deal with situations that would arise should local conveyance facilities be unsuitable to carry the increase in runoff associated with a proposed development. Possible channel capacity improvements would be identified as part of a downstream capacity analysis and in certain instances could be implemented in lieu of rate controls. The criteria used to evaluate the adequacy of downstream channel capacity is stated below, all three of which must be met to document adequate downstream capacity.

i.) Natural or man-made channels must be able to convey the runoff associated with a 2-year return period rainfall event within their banks at velocities consistent with protection of the channels from erosion. Acceptable velocities will be based upon criteria contained in the DEP *Erosion and Sediment Pollution Control Program Manual* (April, 1990).

ii.) Natural or man-made channels or swales must be able to convey the 25-year return period runoff without creating any safety or property hazard.

iii.) Culverts, bridges, storm sewers, or any other facilities which must pass or convey flows from the tributary area must be designed in accordance with DEP Chapter 105 regulations (if applicable), and at minimum must pass the increased 25-year return period runoff.

d.) Regional Detention Alternatives

One final aspect of the control philosophy is the provision for regional detention alternatives. The major advantage of a regional facility is the ability to control the runoff from large watershed areas with a single facility rather than one facility for each development site in the tributary area. A single facility may be more aesthetically acceptable than many smaller basins and would offer the benefit of much more efficient maintenance.

However, there are many disadvantages of regional detention facilities. First, regional detention facilities would require large land areas to control large tributary areas. Either the availability of appropriately located land areas, or the cost of the land, or both, could preclude the alternative. Second, the financial arrangements for regional facilities may be very cumbersome, involving municipal or multimunicipal financing up-front to be reimbursed by developers as the tributary area is developed, as one example. For a large tributary area, the payback time frame would be very uncertain. Third, the design of a regional facility outlet release would be keyed to protection of the watershed downstream of the regional control. Development upstream of the basin without implementation of on-site runoff controls could create problems between the development site(s) and the basin. This situation would be contradictory to the goals of Act 167.

The above-stated disadvantages of regional detention facilities aside, it may be feasible to implement regional detention alternatives within the Perkiomen Creek Headwaters. The most likely alternatives would involve relatively small tributary areas representing several development sites. For the purposes of this Plan, any regional detention alternatives would require the initiative of a developer or group of developers to propose a regional facility. The funding, design criteria, maintenance provisions, and other applicable considerations would be the product of developer-municipal discussions. There are no specific recommendations for locations of regional detention facilities incorporated in this Plan.

CHAPTER 9. MUNICIPAL ORDINANCE TO IMPLEMENT THE PERKIOMEN CREEK HEADWATERS STORMWATER MANAGEMENT PLAN

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 Perkiomen Creek Headwaters Stormwater Management Plan, a model Ordinance has been prepared which would implement the Plan provisions presented in Chapter 8. The Ordinance is a single purpose ordinance which 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 *Perkiomen Creek Headwaters Act 167 Stormwater Management Ordinance* will not completely replace the existing storm drainage ordinance provisions currently in effect in the Perkiomen Creek Headwaters municipalities. The reasons for this are as follows:

- Not all of the municipalities in the Perkiomen Creek Headwaters are completely within the watershed. For those portions of a municipality outside the Perkiomen Creek Headwaters, 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 by existing municipal ordinances and DEP criteria. The DEP criteria are provided in the *Erosion and Sedimentation Pollution Control Program Manual* (April, 1990). DEP standards regarding sediment basin design differ from those required by this Ordinance. An acceptable design would meet both criteria.

- The Act 167 Ordinance contains only those stormwater runoff control criteria and standards which are necessary or desirable from a total watershed perspective. Additional stormwater management design criteria (e.g. inlet spacing, inlet type, collection system details, etc.) which should be based on sound engineering practice should be regulated under the current ordinance provisions.

- The Act 167 Ordinance contains criteria and standards for runoff control from new development which are the *minimum* criteria from a watershed perspective. Individual municipalities may adopt more stringent criteria from a watershed perspective. Individual municipalities may adopt more stringent ordinance provisions so long as consistency with the Plan is maintained. Note that more stringent criteria will not always be consistent with the Plan. The minimum municipal ordinance requirements for each article are listed in Table 12 on page 9-3.

- The Act 167 Ordinance provides a waiver for certain regulated activities which create less than 10,000 square feet of new impervious cover. Development plans qualifying for this waiver would still be regulated by the current municipal ordinance and Section 13 of the Pennsylvania Stormwater Management Act.

The Act 167 Ordinance is composed of the basic ordinance body and a set of appendices. The body of the document is organized into eight articles including General Provisions, Definitions, Stormwater Management Requirements, Drainage Plan Requirements, Inspections, Fees and Expenses, Maintenance Responsibilities, and Enforcement.

The Ordinance Appendices, to be made part of the municipal ordinances, should provide maps of the Perkiomen Creek Headwaters, stormwater management districts, and storm drainage problem areas, as well as technical data to be used in the calculation methodology. The Ordinance is intended to be separable from the Plan document itself. The maps in the Ordinance Appendices would be duplicative of those already included in the Plan and are not included in the Plan version of the Ordinance.

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 ordinances. The actual ordinance adopted by a municipality to implement the Perkiomen Creek Headwaters 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. It is noted that 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 includes all five of the “findings” included with the Plan version of the provision.

The Ordinance contains references to the National Pollutant Discharge Elimination System (NPDES) stormwater permit program. Each construction site (where applicable) must meet the NPDES requirements and obtain a proper NPDES permit from the Lehigh County Conservation District or DEP, as applicable.

TABLE 12

MINIMUM MUNICIPAL ORDINANCE REQUIREMENTS

The Act 167 Ordinance contains criteria and standards for runoff control from new development which are the *minimum* criteria required. The model Ordinance contains the criteria that the LVPC will use to provide advisory engineering design reviews to the municipality. However, municipalities can adopt criteria which are more stringent, as long as consistency with the Plan is maintained. The chart below lists each article in the Ordinance with the minimum municipal ordinance requirement for the article.

ARTICLE	TITLE	MINIMUM REQUIREMENT
1	General Provisions	Include verbatim.
2	Definitions	Include verbatim.
3	Stormwater Management Requirements	Include verbatim.
4	Drainage Plan Requirements	*Sections 401, 402, 403, 405, and 406* – Include verbatim. *Section 404* – Municipality and LVPC must receive plan submissions. *Section 407* – Municipality must have process for reviewing waiver requests. The five findings must be included verbatim.
5	Inspections	Municipality must have the right to inspect storm drainage facilities.
6	Fees and Expenses	Municipality may collect fees to cover review costs.
7	Maintenance Responsibilities	Ordinance provision must indicate responsibility for long-term maintenance of storm drainage facilities.
8	Enforcement	Must be included verbatim in a stand-alone ordinance. If stormwater provisions are to be incorporated into an existing SALDO which has enforcement provisions, these sections may not be necessary.
	Appendices	Include verbatim.

Presented as the remainder of this chapter is the *Perkiomen Creek Headwaters Act 167 Stormwater Management Ordinance*.

CHAPTER 10. PRIORITIES FOR IMPLEMENTATION OF THE PLAN

The Perkiomen Creek Headwaters Stormwater Management Plan preparation process is complete with the Lehigh County adoption of the draft Plan and submission of the final Plan to DEP for approval. Procedures for the review and adoption of the Plan are included in Chapter 11. Subsequent activities to carry out the provisions of the Plan are considered by DEP to be part of the implementation of the Plan. The initial step of Plan implementation is DEP approval. Plan approval sets in motion the mandatory schedule of adoption of municipal ordinance provisions to implement the stormwater management criteria. Perkiomen Creek Headwaters municipalities would have six months from DEP approval within which to adopt the necessary municipal ordinance provisions. Failure to do so could result in the withholding of all state funds to the municipality(ies) per Act 167.

Additional implementation activities are the formal publishing of the final Plan after DEP approval, development of a local program to coordinate with DEP regarding permit reviews for stream encroachments, diversions, etc., and the 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. DEP Approval of the Plan

Upon adoption of the Plan by Lehigh County, the Plan is submitted to DEP for approval. The DEP review process involves determination that all of the activities specified in the approved work program have been satisfactorily completed in the Plan. Further, the Department will only approve the Plan if it determines the following:

1. That the Plan is consistent with municipal floodplain management plans, State programs which regulate dams, encroachments and other water obstructions, and State and Federal flood control programs; and

2. That the Plan is compatible with other watershed stormwater plans for the basin in which the watershed is located, and is consistent with the policies of Act 167.

DEP action to either approve or disapprove the Plan must take place within ninety (90) days of receipt of the Plan by the Department. Otherwise, the Plan would be approved by default.

B. Publishing the Plan

Consistent with the Perkiomen Creek Headwaters Work Program, the LVPC will publish additional copies of the study area Plan after DEP approval. One copy of the Plan will be provided to each municipality. Additional separate copies of the *Perkiomen Creek Headwaters Act 167 Stormwater Management Ordinance* will be published for use by the municipalities.

C. Development of a Local Program to Coordinate with DEP 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 DEP's Rules and Regulations may have a bearing on the effectiveness of the runoff control strategy development for the Perkiomen Creek Headwaters. Activities of this type may modify the conveyance characteristics of the study area and have an impact on the relative timing of peak flows and/or the ability of the conveyance facilities to safely transport peak flows. Therefore, to ensure that the DEP permitting process is consistent with the adopted and approved Plan, a local review of Chapter 105 and Chapter 106 permit applications should be coordinated with the DEP review process.

The local review for Lehigh County would be performed by the LVPC and would be accomplished through monitoring of the applications as published in the *Pennsylvania Bulletin*. The LVPC would be responsible for providing comments consistent with the adopted Act 167 Plan within the stated DEP review period. Further, the LVPC would keep records of applications reviewed and the DEP action.

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 Perkiomen Creek Headwaters municipalities. Provided as part of the Plan is the *Perkiomen Creek Headwaters Act 167 Stormwater Management 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 Perkiomen Creek Headwaters to the single purpose ordinance from the other ordinances.

However, it is not required 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 municipality must ensure that the amended ordinance satisfactorily implements 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 study area as documented in Chapter 5 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 Plan Advisory Committee; (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); and (3) the hydrologic model developed to formulate the runoff control criteria could be used as an analytical tool for designing engineering solutions to existing drainage problems.

With the above in mind, each municipality within the Perkiomen Creek Headwaters 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 as shown in Table 10 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. The number of drainage problems to be evaluated by a municipality as a first cut from the priority list should be based on a schedule compatible with completing engineering studies on all problem areas within approximately five years. The Perkiomen Creek Headwaters hydrologic model would be available at the LVPC office to provide flow data as input to the engineering studies.

3. On the priority and cost bases, incorporate implementation of recommended solutions to the drainage problems in the annual municipal capital budget or the municipal maintenance budget as funds are available. Solutions for existing stormwater drainage problems may qualify for low interest loans from the Pennsylvania Infrastructure Investment Authority (PENNVEST). The number of drainage problems corrected in a given year should be based on a maximum ten-year schedule of resolving all existing documented drainage problems in the municipality for which cost-effective solutions exist.

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 study area and attempt to improve the current runoff situation in the basin. The key elements involved in the success of the remedial strategy will be the dedication of the municipalities to construct 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.

CHAPTER 11. PLAN REVIEW, ADOPTION, AND UPDATING PROCEDURES

A. Plan Review and Adoption

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

1. Watershed Plan Advisory Committee Review – This body has been formed to assist in the development of the Perkiomen Creek Headwaters 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 four 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 Plan Advisory Committee review would be a revised 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 study area must review the Plan for consistency with other plans and programs affecting the study area. Of primary concern during the municipal review would be the draft *Perkiomen Creek Headwaters Act 167 Stormwater Management Ordinance*, which would implement the Plan through municipal adoption. The output of the municipal review would be a letter directed to Lehigh County outlining the municipal suggestions, if any, for revising the draft Plan (or Ordinance) prior to adoption by the County.

3. County Review and Adoption – Upon completion of the review by the Watershed Plan Advisory Committee and each municipality, the draft Plan will be submitted to the Lehigh County Commissioners for their consideration.

The County review of the draft Plan will include a detailed review by the County 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 County based upon input from the public hearing, comments received from the municipalities in the study area, or their own review. Adoption of the draft Plan by Lehigh County would be by resolution and require an affirmative vote of the majority of members of the County Commissioners.

The adopted Plan would be submitted by the County to DEP for their consideration for approval. Accompanying the adopted Plan to DEP 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 study area 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 Perkiomen Creek Headwaters Plan will be as outlined below:

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 study area. Development activities are defined as those activities regulated by the Stormwater Management Plan as described in Chapter 9 and included in the recommended municipal ordinance. Specifically, the LVPC will monitor the following data records:

   (a) All subdivision and land developments subject to review per the Plan which have been approved within the study area.

   (b) All building permits subject to review per the Plan which have been approved within the study area.

   (c) All DEP permits issued under Chapter 105 (Dams and Waterway Management) and Chapter 106 (Floodplain Management), including location and design capacity (if applicable).

2. Review of the Adequacy of Plan – The Watershed Plan Advisory Committee will be convened periodically to 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 Committee will be as follows:

   (a) Development activity as monitored by the LVPC.

   (b) Information regarding additional storm drainage problem areas as provided by the municipal representatives to the Watershed Plan Advisory Committee.

(c) Zoning amendments within the study area.

(d) Information associated with any regional detention alternatives implemented within the study area.

(e) Adequacy of the administrative aspects of regulated activity review.

The Committee will review the above data and make recommendations to the County as to the need for revision to the Perkiomen Creek Headwaters Stormwater Management Plan. Lehigh County will review the recommendations of the Watershed Plan Advisory Committee and determine if the revisions are to be made. A revised Plan would be subject to the same rules of adoption as the original Plan preparation.

PLATE 1
PERKIOMEN CREEK HEADWATERS RELEASE RATE MAP