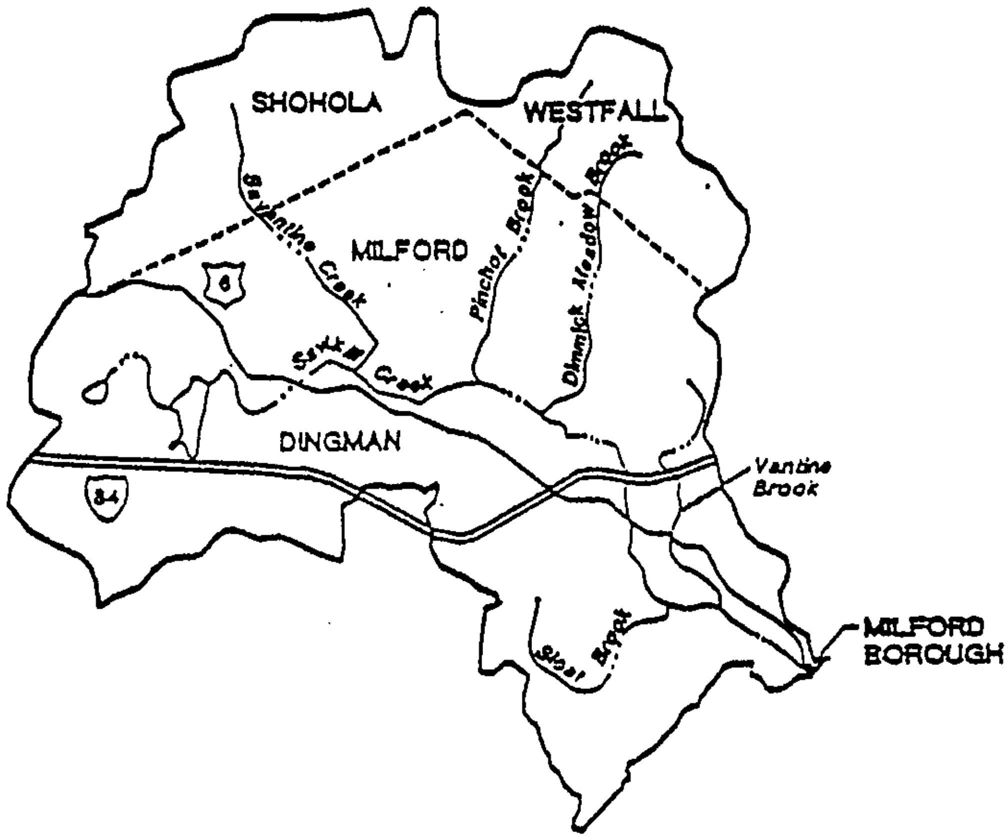
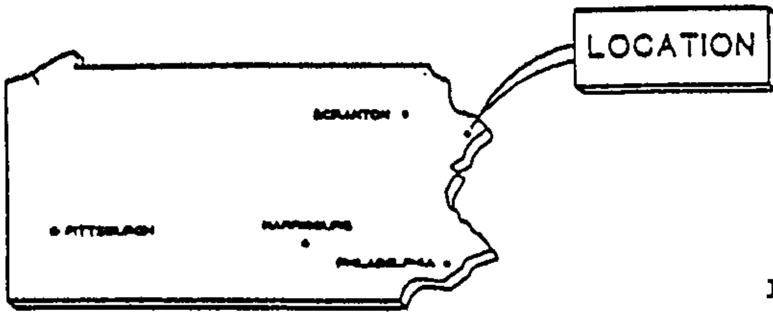
SAWKILL CREEK WATERSHED
— ACT 167 —
STORMWATER MANAGEMENT PLAN





PIKE COUNTY

JULY 1992

OVERVIEW

This plan has been developed for the Sawkill Creek Watershed in Pike County, Pennsylvania under the requirements of the Pennsylvania Stormwater Management Act, Act 167, of 1978. The designated watershed, No. 262:52, encompasses approximately 25 square miles and portions of five municipalities: Dingman Township, Milford Borough, Milford Township, Shohola Township and Westfall Township. With inconsistent existing controls for stormwater management within this watershed, this plan has been developed to focus on a watershed wide consistent set of standards and criteria to control stormwater runoff. The controls established reflect the flooding and quality concerns within the creek itself, as related to potential future development impacts within the study area. Through the Watershed Plan Advisory Committee these concerns have helped form the basis for final determination of control standards.

This plan is developed with the intent to present all information which may be required in order to implement the plan. Background and detailed information as well as applied examples are included as related to both technical/engineering applications as well as institutional and legal framework discussions. The comprehensiveness of the plan covers legal, engineering and municipal government topics which combined form the basis for implementation and enforcement of a final ordinance which will be developed and adopted by each affected municipality. A sample stormwater management ordinance for reference use has been developed as part of the plan and is a separate document. Each municipality has six months to adopt the plan from the date of adoption on the resolution which preceeds the Table of Contents.

WATERSHED PLAN ADVISORY COMMITTEE

Al Greening	Dingman Township
Merritt Quinn	Milford Borough
James Snyder	Milford Township
James Wheatley	Shohola Township
Ken Thiele	Westfall Township
Richard Gross	Pike County Conservation District
Joe Staley	Pike County Planning Commission
Peter T. Wulfhorst	Pike County Planning Commission

TABLE OF CONTENTS

TABLE OF CONTENTS
(continued)

TABLE OF CONTENTS
(continued)

LIST OF TABLES

LIST OF FIGURES

TABLE OF CONTENTS
(continued)

APPENDICES

TABLE OF CONTENTS
(continued)

SECTION 1

INTRODUCTION

1.0 INTRODUCTION

1.1 Basics of Hydrology

Water is located in all regions of the earth. However, its distribution, quality, quantity, and mode of occurrence are highly variable from one location to another. Hydrology is the science of dealing with the properties, distribution, and circulation of water on the surface of the land, in the soil, through fractures in underlying rocks, and in the atmosphere.

The hydrologic cycle, illustrated on Figure 1-1, describes the endless movement of water between the earth and atmosphere through the physical processes of evaporation, transpiration, and precipitation. Water evaporates from oceans, inland lakes, man-made impoundments, flowing streams, and the soil. Transpiration is the process by which vegetation returns water to the atmosphere. Water is transported horizontally through the atmosphere in clouds in the form of vapor, liquid, and ice crystals. Water falls back to earth as precipitation directly into surface waters or onto the land where approximately thirty percent runs off into surface waters. The remaining precipitation that does not evaporate infiltrates into the earth and replenishes groundwater supplies. A portion of the groundwater percolates slowly down through the ground to reappear as baseflow in streams or as seepage into lakes.

1.2 Stormwater

The water that runs off the land into surface waters during and immediately following a rainfall event is referred to as stormwater. In a watershed undergoing urban expansion, the volume of stormwater resulting from a particular rainfall event increases because of the reduction in pervious land area (land not covered by pavement, concrete, or buildings). Although many factors interact to affect this segment of the hydrologic cycle, the most significant that influences the volume of stormwater are:

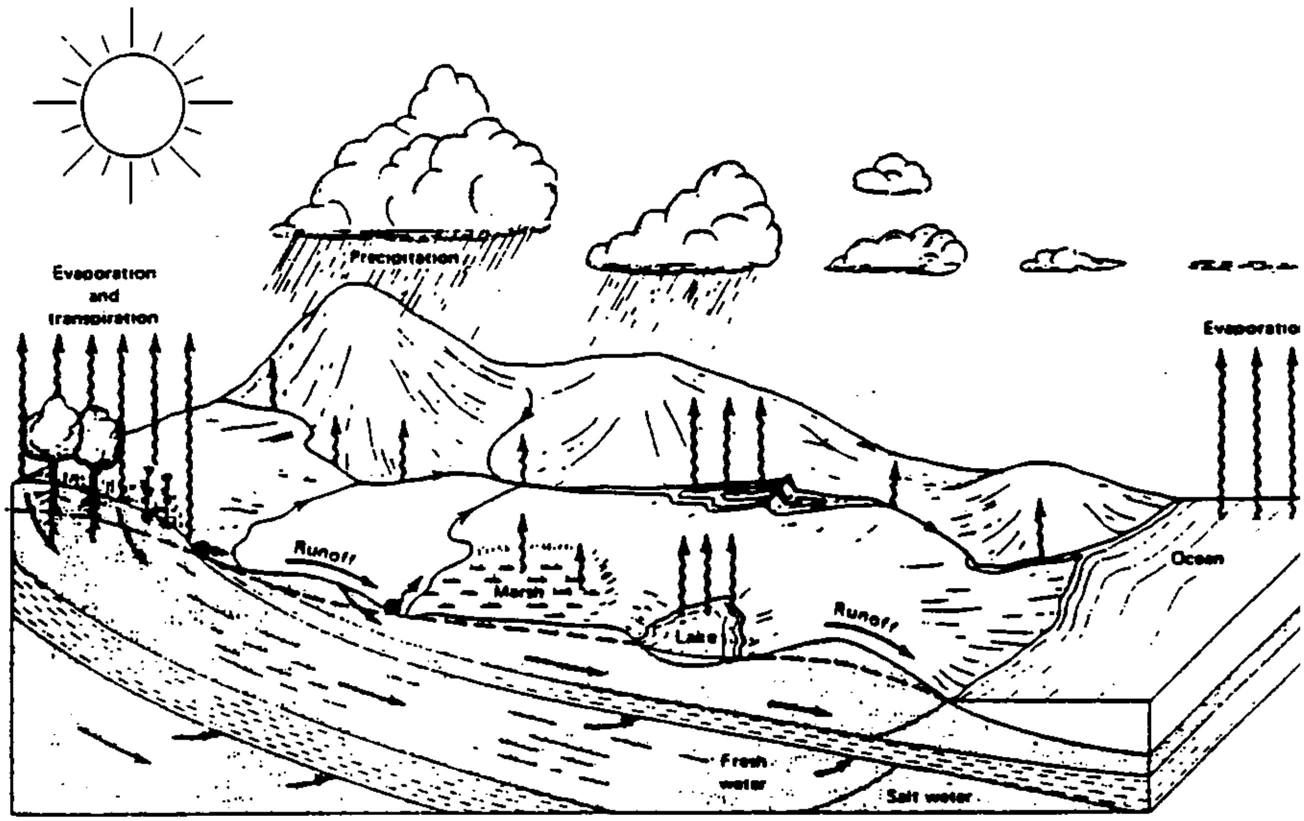
* Precipitation - The volume of water that falls on a specific land area over a given period of time;

* Surface or depression storage - The volume of precipitation that is stored in depressions, either natural or attributed to human activities, on the surface of a specific land area; and

* Infiltration - The volume of precipitation that infiltrates into the ground over a specific land area.

1.2.1 Precipitation

Precipitation is the most variable input to the generation of stormwater runoff. The quantity of precipitation varies geographically, temporally, and seasonally. Records have shown differences of twenty percent or more in the catch of rain gages less than twenty feet apart.



● Spring

Direction of water movement

THE HYDROLOGIC CYCLE

For example, Figure 1-2 displays two rainfall hyetographs which illustrate the significant time variation of rainfall occurring during two thirty-minute rainfall events of equal volume. Even though rainfall volumes are equivalent, stormwater runoff flow rates generated for identical time intervals over a specific land area can be distinctly different for each event.

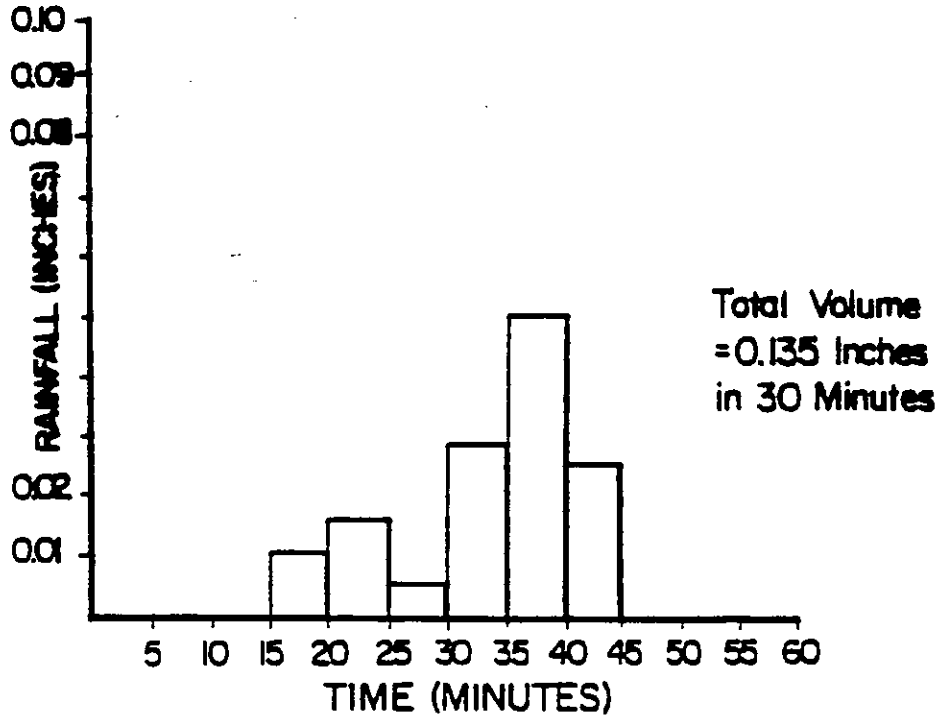
Another varying condition is the volume of precipitation falling at different locations within a watershed during a particular precipitation event. This is illustrated in Figure 1-3. Even with these variations, the statistical analysis of precipitation data has resulted in the ability to establish the probability of storm events of specific volumes and durations occuring. These probabilities are often expressed (for example) as 1-, 2-,..., 10-,..., 25-, and 100-year storm events. That is, the probability of a 25-year storm event occurring in any year is four percent. Figure 1-4 shows an example of rainfall-intensity-duration curves. From an analysis of these curves, the following generalizations can be observed:

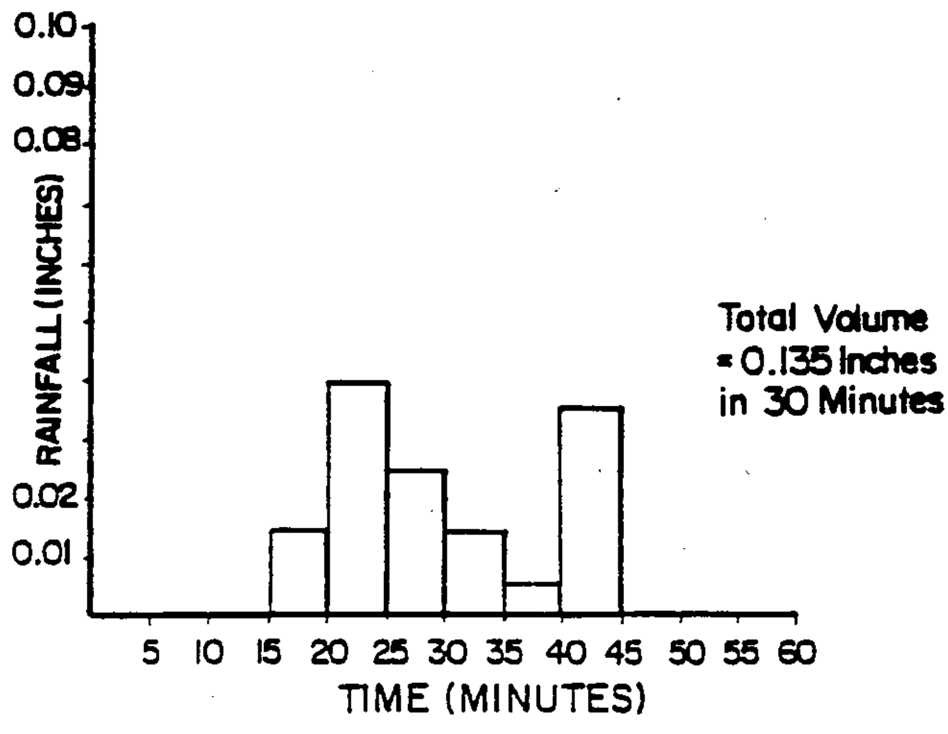
* The more intense the rainfall, the less likely the event is to occur; and

* Higher intensity rainfalls occur over shorter periods of time than lower intensity events.

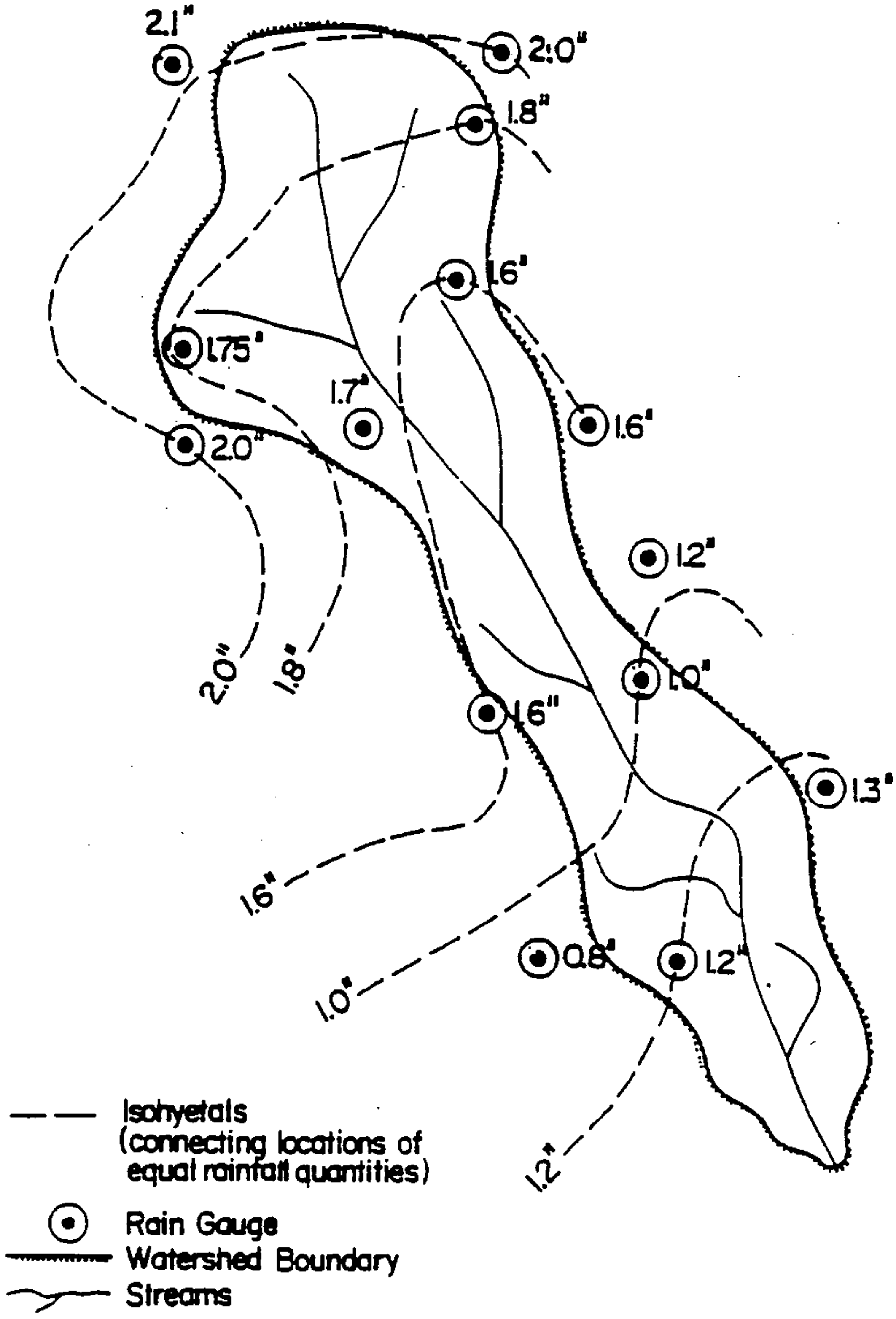
1.2.2 Surface Depression Storage

The initial volume of rainfall during any event becomes trapped in numerous small, natural or man-made depressions. The only escape of this stored water is through evaporation or infiltration. Development activities often alter the terrain to make acreage available for building/paving and to provide for mobility of equipment during construction activities. These practices usually reduce the amount of surface storage, thereby increasing both the volume and rate of stormwater runoff. Specially designed stormwater management facilities (e.g., detention basins, terraced slopes, and level spreaders) incorporated in site designs may artificially provide the surface storage lost during development.

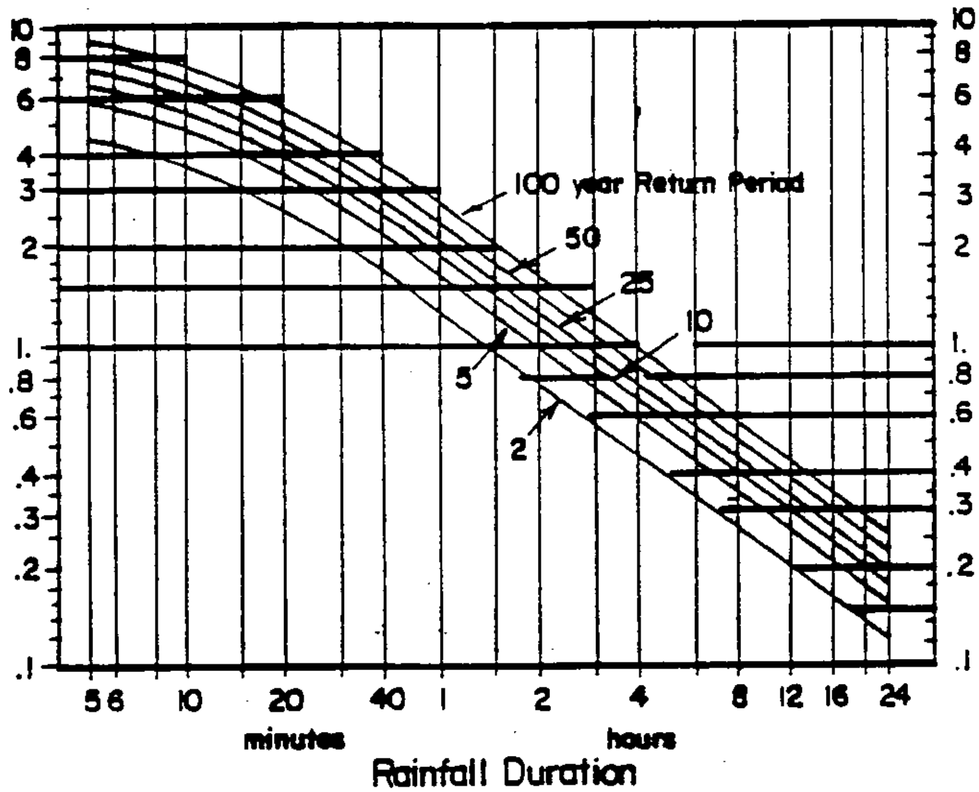




TIME VARIATION OF RAINFALL



STORM PATTERN OVER A WATERSHED



Source: Pennsylvania Department of Transportation

RAINFALL INTENSITY - DURATION - FREQUENCY CURVE

1.2.3 Infiltration

The infiltration rate, the rate at which water enters the soil at the surface, is controlled by surface conditions. The two factors characterizing surface conditions are soil typg ordinances could include stormwater provisions in one ordinance and then reference these stormwater management requirements in the other ordinances. However, if a community utilizes a separate, single-purpose stormwater ordinance, the ordinance should be clearly referenced in the appropriate sections of the municiaplity's zoning, S/LD, and building ordinances. Also, the preamble of a separate stormwater ordinance should indicate that it is being adopted pursuant to the MPC, Stormwater Management Act and applicable sections of the municipal code. When a development activity is within the scope of the MPC, then the municipality should be sure to follow the various plan review processes and other administrative procedures prescribed in same, including the procedures for enacting and amending zoning and development regulations.

1.3 Estimating the Rate and Volume of Stormwater Runoff

At any point of interest along a waterway, the rate of stormwater runoff can be calculated by evaluating the hydrologic characteristics of the watershed (or land area) draining to that point. The hydrologic characteristics include precipitation, surface storage, and infiltration as described in the previous sections.

The excess precipitation remaining after surface storage is filled, and the infiltration rate of the land area is exceeded, becomes overland flow. Overland flow moves in a thin film on the land surface prior to concentrating in a defined "channel" (e.g., paved roadside gutter, grass-covered channel, storm sewer, intermittent stream, etc.). The stormwater runoff that flows from all channels which are tributary to a particular point of interest (e.g., a bridge or a chronic flooding location along a stream) can be combined to form what is referred to as a "hydrograph" at that point.

1.4 Hydrographs

A hydrograph graphically illustrates the rate of runoff in relation to time at a point of interest. This "point of interest" could be a bridge, a culvert, or a constricted channel section. There are a variety of ways to prepare a hydrograph. The most accurate is by comparing recorded rainfall to recorded flows at a stream flow recording station or "gage". This is an ideal approach but is rarely possible due to the lack of stream gages at points of interest. Lacking this data, the common practice to develop hydrographs involves generation of information concerning the rate of runoff by estimating values for individual elements of the hydrologic cycle. An example of the preparation of a stream flow hydrograph is given in Appendix A.

SECTION 2

RATIONALE AND LEGAL FRAMEWORK FOR STORMWATER MANAGEMENT

2.0 RATIONALE AND LEGAL FRAMEWORK FOR STORMWATER MANAGEMENT

2.1 The Need for Stormwater Management

The alteration of native cover and contours to residential, commercial and industrial uses results, in almost all cases, to decreased infiltration of rainfall. This can result in an increase in both the volume and flow rate of stormwater. As development has increased, so has the problem of dealing with the increasing quantity of stormwater. Failure to properly manage increased or accelerated runoff has resulted in increased flooding and stream channel erosion and siltation, and reduced groundwater recharge. The cumulative effect of development in some areas of the state has resulted in more frequent and extensive flooding along both small and large streams, with property damages running into the millions of dollars and even causing loss of life. Stormwater management involves the planning for and implementation of structural and non-structural control methods to mitigate such adverse impacts that can result from the land alteration processes.

2.2 The Need for a Comprehensive Approach

The Pennsylvania General Assembly, recognizing the adverse effects of inadequate management of excessive rates and volumes of stormwater resulting from development, approved the Stormwater Management Act, P.L. 864, No. 167, on October 4, 1978. The statement of legislative findings at the beginning of Act 167 sums up the critical interrelationship between land development, accelerated runoff, and floodplain management. Specifically, this statement of legislative findings points out that:

1. Inadequate management of accelerated runoff of stormwater resulting from development throughout a watershed increases flood flows and velocity, contributes to erosion and sedimentation, overtaxes the carrying capacity of streams and storm sewers, greatly increases the cost of public facilities to carry and control stormwater, undermines floodplain management and floodplain control efforts in downstream communities, reduces groundwater recharge, and threatens public health and safety.

2. A comprehensive program of stormwater management, including reasonable regulation of development and activities causing accelerated runoff, is fundamental to the public health, safety and welfare and the protection of the people of the Commonwealth, their resources and their environment.

Stormwater management has historically been oriented primarily toward addressing the increase in peak runoff rates discharging from individual development sites to protect property immediately downstream. Minimal attention has been given to the effects on locations further downstream (frequently because they were located in another municipality) or to designing stormwater controls within the context of the entire watershed.

Act 167 changes this approach by instituting a comprehensive program of stormwater planning and management. The Act requires Pennsylvania counties to prepare and adopt watershed stormwater management plans for each watershed located in the county, as designated by the Pennsylvania Department of Environmental Resources (PADER). These plans are to be prepared in consultation with the municipalities located in the watershed, working through a watershed advisory committee. The plans are to provide for uniform standards and criteria throughout a watershed for the management of stormwater from developing sites. The types and degree of controls that are prescribed need to be based on the expected development patterns and hydrologic characteristics of each individual watershed.

2.3 Legal Framework

The laws governing surface drainage rights and liabilities have developed over the years as part of Pennsylvania's system of common law. It is a very complex system, not widely understood by non-lawyers, and one which does not always lead to an easy determination of who has what rights and when. Some people have suggested that legal complexities relating to stormwater management may be one reason why more Pennsylvania municipalities have not already developed stormwater regulations. There simply appear to be too many "gray" areas for many local officials' tastes.

Therefore, this section provides a discussion of Act 167, its provisions and potential interpretation, and the other principal State statutes which relate to stormwater management and land development regulations. The other four statutes of primary concern are:

* Floodplain management Act (Act 166-1978);
* Dam Safety and Encroachments Act (Act 325-1978);
* Clean Streams Law (1937 as Amended); and,
* Municipalities Planning Code (Act 247 as Amended).

These laws, in conjunction with Act 167 and the municipal codes, collectively provide the legal mandates and powers to plan and implement a comprehensive stormwater management program at the local level.

2.3.1 Stormwater Management Act (Act 167 - 1978)

There are two key sections of this Act. Section 5 which sets up the watershed stormwater planning programs, and Section 13 which establishes the basic standards to manage stormwater runoff so that reasonable measures are taken to protect other people and property.

o Watershed Stormwater Plans (Section 5 of Act 167)

One of the Act's innovative features is the creation of a public stormwater planning, management and control system at the watershed level. Stormwater plans are to be prepared by the counties for each watershed delineated by PADER. Counties must organize a watershed advisory committee composed of representatives from the municipalities in the watershed and the Pike County Conservation District (PCCD) to advise the county during the planning process. The plans are to be adopted by the county governing bodies and approved by PADER, after public review and comment.

After the adoption and approval of a watershed stormwater management plan, any development that takes place (including subdivisions, flood control projects, highways, public utilities, and stormwater detention facilities) must by constructed in a manner consistent with the plan. This provision gives the stormwater plan a definite legal status.

Also, within six months of the approval of the watershed stormwater management plan, each municipality in the watershed must implement the plan by incorporating the technical standards and criteria into their ordinance framework. These regulations must be consistent with the plan, as well as with the standards of the Stormwater Management Act.

o <u>Standard for Stormwater Management (Section 13 of Act 167)</u>

The basic premise of the Act is that those whose activities generate additional stormwater, increase its velocity, or change the direction of its flow are responsible for controlling and managing that stormwater in such a way that reasonable measures are taken to protect other persons or property, both now and in the future. The Act expresses the Commonwealth's policy to no longer condone the disregard of possible adverse impacts of increased runoff from site development activities and to no longer accept actions that simply shift the burden of stormwater management to downstream property owners and/or public bodies.

The legal requirements for developers and others engaged in the alternation of land are as follows per Section 13 of Act 167.

> "Any landowner and any person engaged in the alteration or development of land which may affect stormwater runoff characteristics shall implement such measures consistent with the provisions of the applicable watershed stormwater plan as are reasonably necessary to prevent injury to health, safety, and/or other property. Such measures shall include such actions as are required:
>
> 1. To assure that the maximum rate of stormwater runoff is no greater after development than prior to development activities; or,
>
> 2. To manage the quantity, velocity, and direction of resulting stormwater runoff in a manner which otherwise adequately protects health and property from possible injury."

Act 167 defines "person" as individuals, private corporations, municipalities, counties, school districts, public utilities, sewer and water authorities, and State agencies. Thus, when public agencies build public facilities such as storm sewers, roads, buildings or utility lines they must comply with Section 13 standards. With this coverage, Section 13 is a truly comprehensive standard for stormwater control.

2.3.2 Floodplain management Act (Act 166 - 1978)

The Floodplain Management Act is the companion law to the Stormwater Management Act. Its basic purposes are to bring about a more intelligent use of floodplain areas and to encourage comprehensive and coordinated programs of floodplain management. The Act requires municipalities with floodplain areas to participate in the National Flood Insurance Program and to enact regulations pertaining to development in floodplain areas. The regulations enacted by municipalities must control new construction and development, at least in accordance with the minimum requirements established by the Federal Emergency Management Agency (FEMA). In addition, the Act requires a closer regulation of certain specific kinds of development in floodplain areas because of the special danger they may pose during times of flooding.

Preserving natural floodplains is a key part of effective stormwater management. Natural flood areas should be maintained as part of the watershed's natural stormwater control system. Accordingly, future stormwater management programs will help to preserve floodplain areas and ensure that properties which are not now subject to flooding do not become so in the future.

2.3.3 Dam Safety and Encroachments Act (Act 325 - 1978)

This Act replaces several older dam safety and waterway obstruction laws. It regulates the construction, alteration, operation, maintenance or abatment of dams, obstructions, encroachments, fill in floodplains, culverts, bridges, retaining walls, and outfalls in a stream or 100-year floodplain. Owners of both new and existing structures must obtain permits from PADER, and permittees are required to inspect, maintain, and repair their waterway structures annually. The Act's provisions apply to private individuals as well as to public agencies.

When issuing permits, the regulations require PADER to consider the project's consistency with State and local floodplain and stormwater management programs. This includes the provisions of Act 167. Once the watershed stormwater plan is approved, PADER will review waterway obstruction permits in light of the plan's standards and criteria. In addition, local municipalities should not issue building permits until the necessary obstruction permits are obtained.

2.3.4 Clean Streams Law (Erosion and Sedimentation Regulations Chapter 102)

The Clean Streams Law of 1937, as amended, empowers PADER to control water pollutants, and since its original enactment, the law's scope and duties have expanded substantially. In 1972, PADER determined that sediment is the single greatest pollutant, by volume, in Pennsylvania waters, and it promulgated regulations for the control of erosion and sedimentation caused by earthmoving activities.

Because stormwater runoff carries and deposits sediment, control of erosion and sedimentation and stormwater management are interrelated. Also, sediment reduces the carrying capacity of watercourses and structures and the holding capacity of natural and artificial stormwater facilities.

State regulations require all earthmoving activities to have erosion and sedimentation control plans, but only sites greater than 25 acres (except agriculture) must obtain permits prior to commencement. In Pike County, the Conservation District administers the erosion and sedimentation regulations up to Level II enforcement as defined by PADER (does not include legal enforcement.

The Clean Streams Law and erosion and sedimentation regulations predate the Stormwater Management Act and, therefore, do not specifically mention the Act. However, it can be assumed that erosion and sedimentation controls should be consistent with the Stormwater Management Act and an approved watershed stormwater plan. Since the erosion and sedimentation controls could affect stormwater runoff management for a site, they would have to comply with Act 167 standards.

2.3.5 Municipalities Planning Code (Act 247, as Amended)

The relevance of the Municipalities Planning Code (MPC) to the stormwater management program is that it is the enabling legislation for municipalities to adopt and enforce zoning, subdivision and land development (S/LD), and official map ordinances. These ordinances will be the principal tools used by the municipalities to implement the watershed stormwater management plan. The various municipal codes authorize communities to adopt building and or/housing codes pursuant to their health, safety, and general welfare powers.

Where stormwater is being regulated for a land use or development activity that property falls within the scope of one of the Planning Code authorities, then the stormwater regulations should be included in the appropriate ordinance. Comprehensive development of associated regulations include utilization of zoning, S/LD, and building code ordinances with respect to stormwater management controls.

Municipalities with existing zoning, S/LD, or building ordinances could include stormwater provisions in one ordinance and then reference these stormwater management requirements in the other ordinances. However, if a community utilizes a separate, single-purpose stormwater ordinance, the ordinance should be clearly referenced in the appropriate sections of the municipality's zoning, S/LD, and building ordinances. Also, the preamble of a separate stormwater ordinance should indicate that it is being adopted pursuant to the MPC, Stormwater Management Act and applicable sections of the municipal code. When a development activity is within the scope of the MPC, then the municipality should be sure to follow the various plan review processes and other administrative procedures prescribed in same, including the procedures for enacting and amending zoning and development regulations.

SECTION 3

EXISTING AND PROJECTED FUTURE WATERSHED CHARACTERISTICS

3.0 EXISTING AND PROJECTED FUTURE WATERSHED CHARACTERISTICS

3.1 General Description of the Sawkill Creek Watershed

The Sawkill Creek Watershed is located in the eastern part of Pike County and is contained within five municipalities: Dingman Township, Milford Borough, Milford Township, Shohola Township, and Westfall Township. Sawkill Creek drains a watershed area of approximately 25 square miles and includes the following primary tributaries: Savantine Creek, Pinchot Brook, Dimmick Meadow Brook, Vantine Brook, and Sloat Brook. Figure 3-1 presents a map of the watershed showing the above municipalities and primary tributaries.

The Sawkill Creek watershed drains the Pocono Plateau above Milford from which it empties into the Delaware River. The upper and middle areas of the watershed consist of lakes, wetlands, and knobby hills. The hilltop levels vary between elevations of 1200 to 1400 feet above sea level. Valley sides are generally moderately sloped. Maximum relief in the watershed is 1,140 feet where the elevation drops from a northwestern high of approximately 1,520 above sea level in the Savantine Creek sub-basin to 380 feet above sea level at the mouth of Sawkill Creek.

The hilltops, remnants of stream erosional process, are separated by fairly steep-sided valleys. In the most southeastern portion of the watershed, the topography is dominated by an escarpment (known as the Cliff) that travels northeast-southwest with steep southeast slopes. Development in the upper and middle sections consist of a major subdivision (Sagamore Estates), a quarry operation, and scattered single family homes. In addition, there are tracts of State forest lands. Table 3 in Section 4.4 presents the detailed breakdown of land use within each subarea of the Sawkill Creek Watershed for existing and future conditions, respectively.

The lower area of the watershed consists of medium hills with narrow V-shaped valleys. Low-density residential development occurs throughout this section with residential homes on smaller lot sizes (quarter-acre) in Milford Borough.

The Sawkill Creek basin lies entirely within the Glaciated Low Plateau section of the Appalachian Plateau physiographic province. The underlying geology of the Sawkill Creek basin is characterized by rock units of the Mahantango, Trimmers Rock, and Catskill Formations. Dark gray siltstones, silty shales, and shales comprise the Mahantango and Trimmers Rock Formations. The Catskill Formation is comprised of gray snadstones, gray and olive silty claystones, and red shales. These underlying geologic formations are covered by glacial till and outwash gravel deposits.

There are four soil associations that commonly occur in the watershed: the Chenango, Volusia, Wurtsboro, and DeKalb. Chenango soils are deep, well-drained and gravelly; developed from glacial outwash. These soils are normally found in lower terraces of larger stream and river valleys. Volusia soils are poorly drained and occur in small valleys and upland depressions. These soils have seasonally high water tables and either are saturated most of the year or have well developed fragipans that impede root growth and penetration.

Soils of the Wurtsboro Association are stony and found in upland areas. The Wurtsboro soils have seasonally high water tables caused by a compact fragipan. DeKalb soils are stony, shaly, well-drained, and found in upland areas.

Using forms prepared by the Pike County Planning Commission, a survey was taken to obtain information from each municipality with regard to stormwater related problems, significant waterway obstructions, existing and proposed flood control projects, stormwater control facilities, and stormwater collection facilities. Summaries of this information are illustrated on Plate Nos. 1 and 2.

3.2 Floodplains

The approximate 100-year floodplains of Sawkill creek and several of its tributaries have been delineated in the flood insurance studies prepared by FEMA under the National Flood Insurance Program for the five municipalities in Pike County. Detailed mapping of those floodplains is available at the Pike County Planning Commission. The only 100-year floodplain is located along the main stem of Sawkill Creek from its confluence with the Delaware River to just above its confluence with Sloat Brook. In addition, Sloat Brook and Vantine Brook contain 100 year floodplain areas near their confluences with Sawkill Creek. Sensitivity to future flooding will be limited because of local municipal floodplain regulations which restrict future devlopment in the 100 year floodplain areas.

3.3 Water Obstructions

Water obstructions are man-made or natural encroachments on a stream which affect its free-flow during times of normal and/or flood flows. Examples of water obstructions include dams, bridges, culverts, retaining walls, and storm sewer outfalls. For the purposes of this plan, obstructions where any dam, bridge, or culvert 18 inches or greater in diameter. These structures were considered to be "points of interest" for the hydrologic modeling efforts. The obstructions were identified through the municipal questionnaire process and by the County Planning Commission. A total of 27 obstructions were identified and are shown on Plate 2. Of the 27 obstructions, 8 were determined to be significant, rendering individual attention in terms of model input and structure performance. The basis for determining "significance" was a combination of the following:

1. Questionnaire identification; and

2. Structure/obstruction resulted in backup or design storage of at least one-half the 100 year event volume from the upstream drainage area. Identification of this criteria was accomplished by any or all of the following:

Flood Insurance Study profiles;

USGS Quadrangle review to identify shallow slope and/or wetlands areas immediately upstream of the structure/obstruction;

Existing reservoirs where a Phase I Corps of Engineers study existed;

Field identification of the obstruction.

The significant obstructions identified by this process are also identified on Plate 2. The table on the page 18 page summarizes the information and capacities of each of these.

The significant obstructions summarized may or may not be a cause of a specific stormwater related problem. The passing of minimal storm flows (i.e., obstruction numbers 1 and 20) may not necessarily mean they would need to be enlarged or modified. The effects of ponding behind the structure and altered outflows would need to be considered in weighing the benefits of structure modifications against the cost of construction modifications.

The municipalities in which each of the 27 obstructions is located may want to consider further evaluations of obstruction significance as part of their priorities for implementation of this plan. Further evaluations or planning considerations may include:

1. Structural integrity;

2. Capacity evaluations for existing and future land use runoff contributions to the structure;

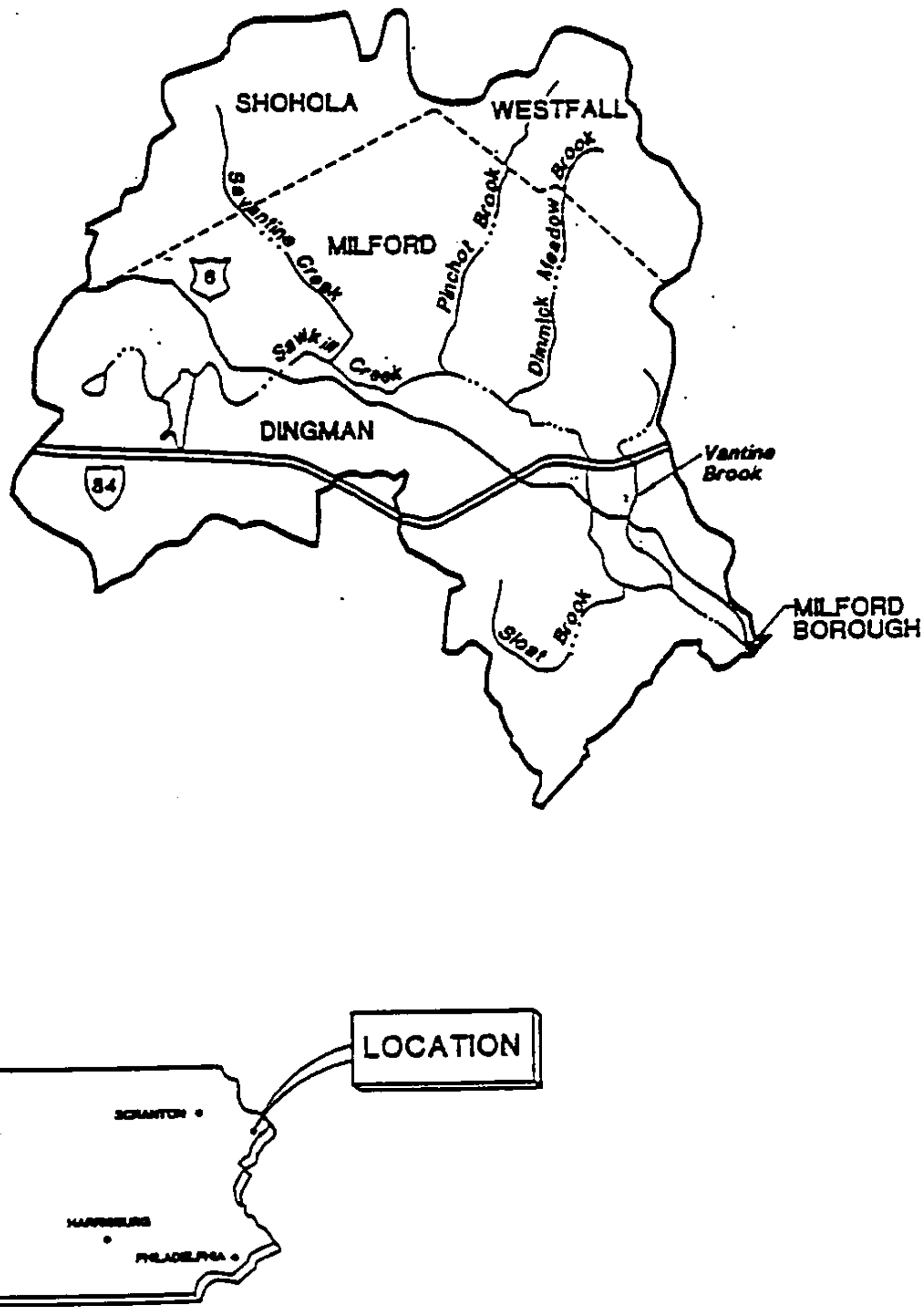
3. Current or proposed zoning within the contributing drainage area of the structure;

4. Structural modifications to the structure/obstructions (such as enlargement of culverts, embankments, etc.);

and

5. Cost benefit analysis.

Several obstructions that can only pass storms under the 10-yr storm should be considered for improvements. This includes the 24" CMP pipe on Township Road 428 in Dingman Township and the dam at Lily Pond in Milford Township. Dingman Township should consider replacing the 24" CMP pipe with a larger pipe. Also, the Lily Pond dam is currently under private ownership and is in need of repairs as a structure.



SAWKILL CREEK WATERSHED MAP

WALTER B. SATTERTHWAITE ASSOC., INC.
720 NORTH FIVE POINTS ROAD · WEST CHESTER, PA. 19380 · (215)692-5770

FIGURE 3-1

3.4 Stormwater Collection Facilities

As part of the municipal survey, officials were asked to identify all stormwater collection facilities. Given the rural nature of the watershed, extensive storm sewer systems were not common. The only stormwater collection facilities in the watershed are storm sewers located in Milford Borough, and storm sewers installed in Milford Borough and Milford Townshipto address an existing stormwater problem. Throughout most of the watershed, storm sewers serve a small area and play an insignificant role in stormwater control.

3.5 Stormwater Management Facilities

Currently, there are two stormwater management facilities located in the Sawkill Creek Watershed. One is located at a commercial development at the intersection of Interstate 84 and Route 6. Here a sedimentation basin was converted into a stormwater detention basin. The basin is privately owned and maintained by the developer. The other facility is located at the new Shohola Elementary School in Shohola Township. The facility is a 5 foot by 200 foot berm that infiltrates stormwater. This prevents excess stormwater flows. Another basin is proposed for a commercial development located in Milford Township at the intersection of Route 6 and Interstate 84. Due to the "Exceptional Value" status of the Sawkill Creek Watershed, this facility has not been constructed to date.

3.6 Stormwater Related Problems

With respect to stormwater flooding, there were only two examples in 8the watershed. One flooding problem is located on Township Road 428 in Milford Township. During heavy rains, the Pinchot Brook floods onto the road. This appears to be caused by a culvert inadequately sized for the associated stream crossing. It is recommended that a larger size culvert pipe be installed to alleviate future flooding problems. The other flood area is associated with a drainage problem at the entrance of Country Club Woods development. The roads serving Country Club Woods were constructed on severe slopes. This has led to erosion problems along them, and flooding problems where the primary subdivision road intersects SR 2011. Since the time of the survey, the entrance has been repaved and the eroded swales redefined and stabilized with rock rip-rap.

SIGNIFICANT OBSTRUCTIONS-SAWKILL CREEK

SIGNIFICANT OBSTRUCTION LOCATION (Plate 2)	SUBAREA LOCATION	DESCRIPTION	CAPACITY INFORMATION	FLOW AT STRUCTURE FOR LAND USE	SUMMARY OF CAPACITY
#1 DINGMAN TWP. TR 428	SA 62	24"CMP Pipe TOP OF ROAD= 814.3 MSL	Q=26 cfs BEFORE OVERTOPPING	Q = 4 cfs 2 Q = 5 cfs 5q	WILL PASS 2-YR STORM
#2 DINGMAN TWP. TRIBUTARY TO SLOAT BROOK	SA 65	CONCRETE ARCH 4'6" HEIGHT 8' WIDTH	Q=26 cfs BEFORE OVERTOPPING	Q=194 cfs 25	WILL PASS 25-YR STORM
#13 MILFORD TWP. INTERSTATE 84 VANTINE BROOK	SA 72	BOX CULVERT 6'X 6'	Q=444 cfs AT ELEVATION 10'ABOVE INVERT OF PIPE INVERT AT ELEVATION 845 FT MSL TOP OF ROAD AT ELEVATION 875 FT MSL	Q=198 cfs 100	WILL PASS 100-YR STORM
#20 MILFORD TWP. CRAFT BROOK	SA 35	LILY POND	SPILLWAY CREST ELEVATION 1155 Q THRU SPILLWAY AT 1156.5=56 cfs	Q=24 cfs 5	WILL PASS 5-YR STORM
#22 MILFORD-DINGMAN TOWNSHIPS, U.S. ROUTE 6 SAWKILL CREEK MAIN STEM	SA 26	CONCRETE BRIDGE 6'HEIGHT 24' WIDTH	Q=1800 cfs BEFORE OVERTOPPING	Q=1497cfs 100	WILL PASS 100-YR STORM
#25 DINGMAN TWP. I-84, GUM BROOK	SA 19	CIRCULAR PIPE 5'DIAMETER	Q=500 cfs BEFORE ROAD OVERTOPPED	Q=219 cfs 100	WILL PASS 100-YR STORM
#26 MILFORD-DINGMAN TOWNSHIPS, ADJACENT TO I-84	SA 22	SAWKILL POND	CREST ELEVATION 1210 Q=250 cfs AT ELEVATION 1212.5	Q=199 cfs 10	WILL PASS 10-YR
#27 SHOHOLA TWP. SAVANTINE CREEK	SA 02	STANLEY R. WHITE DAM	CREST ELEVATION 1215 Q=670 cfs AT ELEVATION 1217	Q=638 cfs 100	WILL PASS 100-YR STORM

3.7 Land Use

Development patterns in the Sawkill Creek Watershed have been influenced by the influx of second home residents and commuters from the New York/New Jersey metropolitan area. In the 1970's many large subdivisions were created in Pike County before there were zoning and subdivision regulations. Consequently many subdivisions contain small lot sizes. More recent subdivisions approved in Pike County contain larger lot sizes. In 1989, the Department of Environmental Resources after public meetings and hearings redesignated the Sawkill Creek watershed as "Exceptional Value Waters". This classification describes streams with excellent existing water quality and environmental features which are deserving of Special Protection. The water quality in "Exceptional Value Waters" shall not be degraded even for social and economic justification. Since 1989, the Department has been working to develop guidelines for controlling point and non-point discharges in "Exceptional Value Waters". Future development in the Sawkill Watershed will be build-out of the existing subdivisions and larger lot subdivisions due to requirements associated with the upgraded water quality of the watershed.

Small scale commercial development will take place in the commercially zoned areas with large commercial development being restricted by the ability to treat sewage utilizing land treatment techniques. The future land development of the watershed was based on the evaluation of municipal zoning regulations and current land ownership of the parcels and reflected a 10-year planning period for development. The only areas that were assumed not to be developable were the existing public lands, floodplains, and severe slopes. Since protection of these environmentally sensitive areas has become an important concern to most municipalities, this was considered to be a valid approach.

SECTION 4

WATERSHED TECHNICAL ANALYSIS

4.0 WATERSHED TECHNICAL ANALYSIS

4.1 Modeling Approach and Goals

The purpose and benefit of this study and implementation plan is to provide all of the municipalities in the watershed (per the requirements of Pennsylvania Act 167) with an accurate and consistent plan for comprehensive stormwater management. Currently, each of the watershed municipalities applies stormwater control regulations. Given the nature of storm runoff and its impacts, as described in Sections 4.4 and 4.5 of this chapter, a critical objective of sound stormwater management planning is to provide for consistency of implementation requirements throughout the watershed. Therefore, the primary objective of the Act 167 technical study of the Sawkill Creek Watershed is to develop a technical and institutional support document to facilitate implementation of consistent regulations throughout the Sawkill Creek Watershed. This includes the selection of design event(s) and performance standard criteria with the understanding that enforcement responsibility and authority will rest with the associated municipalities and the County Planning Department.

The method that has been used to provide these facts for the development of the Sawkill Creek Stormwater Management Plan is runoff (i.e., stormwater) simulation modeling. Computer simulation models are very effective tools for analyzing the effects and impacts of stormwater runoff in urbanizing areas. Computer technology now provides the ability to evaluate the critical elements of the rainfall-runoff process for an urbanizing area, such as the timing of runoff flows throughout the watershed and the specific characteristics of detention and/or delay of runoff in various sections of a watershed. It is only by evaluating these types of situations as part of an overall stormwater management analysis that an effective runoff control system can be developed.

4.2 Overview of the Penn State Runoff Model

The runoff simulation model that was used for the Sawkill Creek Watershed is the Penn State Runoff Model (PSRM). It can be applied on a watershed-wide basis and therefore satisfies the needs of comprehensive stormwater planning as mandated by the Pennsylvania Stormwater Management Act (Act 167). The PSRM simulates rainfall-runoff events on the basis of the following information:

- o Rainfall inputs -
  - rainfall amounts for particular design storm events,
  - rainfall distribution, or pattern, during the course of a particular design storm event;
- o Watershed representation -
  - physical characteristics of the watershed, such as land use and slope data,
  - conveyance system characteristics, such as drainage pipe and stream channel capacities,

- detention area storage characteristics.

Based on these inputs, the model approximates the outcome of the storm in the form of runoff hydrographs for each subarea in the watershed as well as for the cumulative sum of stormwater as it passes through the watershed.

The most important information that is provided by the PSRM, which can be used to make sound stormwater management decisions, includes:

- o The identification of the source of stormwater flows that combine in the downstream portion of a watershed and cause existing damages;
- o The identification of the changes in existing stormwater flows that will result from proposed future development; and
- o The potential benefits that could be achieved through the use of various stormwater management alternatives.

4.3 Model of Existing Conditions

4.3.1 Selection of Subarea Breakpoints

The initial step in the construction of the watershed model was the selection of "breakpoints". Breakpoints are locations along drainage paths and watercourses which are considered to be of interest for a variety of reasons. Within the Sawkill Creek Watershed, breakpoints were selected based on:

- o The location of existing stormwater related problems, as identified by local officials in the municipal questionnaire process;
- o Municipal boundaries;
- o Road and railway crossings;
- o The location of major obstructions such as culverts, bridges, and dams; and,
- o Confluence points of tributaries with the Sawkill Creek, including confluences downstream of large open areas where development can be anticipated.

The breakpoints were used to divide the watershed into numerous subareas or "sub-basins" based on United States Geological Survey (USGS) topographic mapping (Reference 1). When combined, these subareas define the contributing drainage area to each of the selected points of interest. Where necessary, the identified subarea boundaries were verified by field investigation, and appropriate adjustments were made to reflect this information. Additionally, the subareas were chosen to be homogeneous in size wherever possible. They were also limited in area so as to maintain a reasonable level of detail, while keeping them large enough to hold the total number of subareas to a manageable level for modeling purposes. The boundaries of the subareas are shown on Plate No. 3.

4.3.2 Watershed Model Data Requirements

During rainfall events, an entire watershed responds as the "sum" of the responses of its subareas. As noted earlier, PSRM was used to calculate the response of the delineated subareas in the watershed to the rainfall events of interest. Using this model, individual runoff hydrographs were computed for each subarea and moved (i.e., routed) downstream. The time required for the runoff to reach any downstream point reflects the travel time required between subarea outlets and points downstream in the actual pipes or stream channels of the watershed. The flow rate for a point of interest at any time, is simply the sum of flow rates from contributing subareas that have arrived at the point at that moment. Using the watershed model, the tedious summation of these contributions of upstream subareas is performed at each of the specified points of interest. The model forms a time record of the flow rates passing the point, which forms the total (or cumulative) hydrograph for the contributing portion of the watershed. The PSRM performs this summation continuously for each design storm analysis throughout the watershed, calculating runoff hydrographs for all subareas and summing their contributions at all points of interest. At the outlet of the watershed, the model is effectively summing the individual contributions of runoff from all of the associated subareas.

Subarea Runoff Characteristics

The initial step for the hydrologic model (PSRM) to perform is the calculation of the runoff (i.e., stormwater) hydrographs for all subareas that result from the applied storm or "rainfall event". To calculate the runoff hydrograph, the following subarea hydrologic characteristics are required as input to the model:

- The total acreage;
- A composite runoff curve number, computed using U.S. Soil Conservation Service (SCS) TR-55 methods (Reference 2) for the areas of impervious and pervious cover (i.e., lawns, roads, rooftops, woods, meadows, pastures, croplands, etc.) and the associated hydrologic soil groups;
- The average land slope; and,
- A characteristic width of overland flow.

The first three of these items were obtained from detailed mapping of subarea boundaries, soils, slopes, and land use developed by the Pike County Planning Commission (PCPC). To most efficiently assemble the input data for each subarea, the information on the maps was transformed by dividing the watershed into discrete homogeneous parcels of the same hydrologic soil group, slope, or land use and digitizing this information into a computerized Geographic Information System (GIS). The digitized boundaries of the subareas were superimposed over this watershed data, and the required inputs to the models for each subarea were computed within the GIS using an aggregation procedure which quantifies composite subarea characteristics. Using this procedure, the total acreage of each subarea was determined.

In this study, the land uses found in the watershed were subdivided into ten categories. Runoff curve numbers corresponding to each hydrologic soil group were assigned to each land use type using values contained in Table 2-2A of the SCS TR-55 document (Reference 2), and which are based on the land use classifications and the associated percentage of impervious cover. Table 1 shows each land use category, its percentage of impervious cover, and the associated runoff curve number value for the four hydrologic soil groups. The runoff curve numbers presented for "open space" were developed by averaging the TR55 values for open space good condition, open space poor condition and agriculture since these land uses were not differentiated within the study area. Additionally a tabulation similar to Table 1 is used by the GIS to assign runoff curve numbers to each cell in the digital map file. The computer accomplishes this by overlaying the land use and soil attributes for that cell, and assigning the appropriate curve number from the table. The GIS then obtains a composite runoff curve number by computing a weighted average of the curve numbers from all cells contained within a subarea. The computer calculates average land slopes for each subarea by taking weighted average of the slopes within each subarea.

The overland flow width represents a characteristic width of flow across the subarea to the collecting channels, and is directly related to the overland flow travel time. These values were developed by taking hand measurements on the USGS quad maps (Reference 1).

Runoff hydrographs for each subarea were calculated within the PSRM by applying the total rainfall depth for each storm event of interest with an SCS Type II distribution. Each subarea responds to rainfall by allowing an appropriate portion of the rainfall to infiltrate into pervious areas, and the remainder, after initial abstraction and filling of surface depressions, to run off down slope toward the subarea outlet. As more rain falls, the runoff depth increases and it moves more rapidly toward the outlet. The model computes and records a hydrograph of the runoff arriving at the subarea outlet throughout the period of the storm event.

Watershed Travel Times

The total flow at the points of interest, as previously stated, is the sum of flow contributions arriving from upstream subareas. The PSRM simplistically looks at the watershed as a collection of individual subareas connected by drainage elements, generally the main waterway and its tributaries. In order to properly translate, or route, the subarea runoff hydrographs downstream to points of interest, the times required to travel through the drainage element's channels and overbanks to the associated points must be known. Travel times were calculated within the watershed for each drainage element that connects the associated subareas. The lengths and slopes of the main waterway and tributary drainage elements were developed using hand measurements of stream segments and flow paths depicted on USGS topographic mapping (Reference 2). Due to the unavailability of detailed hydraulic information, the average velocities through these stream segements, channels and overbanks were obtained by applying Manning's equation for normal depth to representative channel configurations measured in the field. Channel travel times were then calculated by dividing the computed velocities into the appropriate reach lengths. PSRM does not allow for direct input of separate channel and overbank travel times. Therefore, this is accounted for by adding a parameter referred to as the "CTS" ratio which is a ratio of the overbank travel time to the channel travel time. The appropriate CTS ratio for each of these drainage elements was also calculated in this step.

It should be noted that the input travel times reflect average values for a range of flows that include the storm events of interest. This was accomplished by applying the normal depth equation for several different depths of flow in the cross-section (i.e., at the channel banks, two feet above the channel banks, etc.), and computing the average velocity and channel capacity for use in the travel time computations.

Other Input

An important attribute of PSRM is its capability to model the effects of dams or other detention areas within a drainage area. In order to reflect the associated hydrograph attenuation (i.e., flow reduction and delay) properties of these structures within the watershed, the associated storage-discharge relationships must be identified. It is not practical or cost effective to model every structure in the watershed. Therefore, criteria were used to determine whether a structure is hydrologically "significant." The initial criteria applied in this evaluation were as follows:

- o Identified as a significant flow obstruction in the stormwater questionnaires;
- o Has significant volume for stormwater storage (as identified on USGS quad maps) in that there was significant topographic differentiation (i.e., continuous) to allow development of required elevation storage relationships.

The application of these criteria resulted in the identification of eight obstructions for inclusion in the hydrologic modeling.

The necessary storage-discharge information required for the PSRM was collected for some of these structures during the Phase I study. The remainder of the "significant" structures storage information was obtained by planimetering the contour lines on the USGS quad mapping and determining the volume of storage for incremental elevations. Elevation-discharge curves were calculated based on orifice flow and weir flow using structure measurements obtained in the field. This data was combined with the elevation-storage curves to define the required storage-discharge relationships for input to the PSRM.

Calibration

All simulation models involve a significant degree of subjective input in their development. Values are chosen for various hydrologic parameters describing the runoff characteristics of a watershed which represent average or expected behavior in watersheds of similar soils, slopes, etc. The specific hydrologic characteristics of an individual watershed are not necessarily reflected in such average values. Therefore, the model needs to be fine tuned, or "calibrated", to provide a more accurate representation of the real runoff and timing conditions of a watershed. Calibration of a model often involves the adjustment of input parameters, within acceptable value ranges, to reproduce the recorded response of an actual storm event. To simulate a specific event, antecedent moisture conditions and rainfall distribution must be duplicated in the model input. Adjustments to other parameters are then made to attempt to duplicate hydrograph shapes and peak flow rates at points in the watershed where flow recordings were made.

In order to maximize the accuracy of the PSRM models developed for this Act 167 program, a calibration effort was undertaken. The preliminary PSRM, reflecting existing land use conditions within the Sawkill Creek Watershed, was compared to a previously developed hydrologic model developed in support of a proposed road crossing design in Milford Borough. This previous study utilized Snyder coefficients for runoff hydrograph computations within the U.S. Army Corps. of Engineers HEC-I, and reflected significantly larger sub-areas than those included in the current PSRM. Due to significant variation in the flows computed by these two models, a third hydrologic model was developed for the portion of the watershed draining to Savantine Creek. The model applied was the U.S. Soil Conservation Service TR20 (Reference 3). Table 2 presents the 100-year storm event peak flows computed by the three models at the point of confluence between Savantine and Sawkill Creeks.

TABLE 2

Computed Flow Summary

	Preliminary PSRM	HEC-I	TR20	Calibrated PSRM
PEAK (cfs)	837	1870	3719	1544
TIME (hours)	13.96	14.50	12.83	13.63

TABLE 1

SAWKILL CREEK WATERSHED

LAND USE CATEGORIES

Designation	Land Use Description	Average Pct. Impervious	Runoff Curve Number By Soil Group: A	B	C	D
H	1/4-acre residential	38	61	75	83	87
M	1/2-acre residential	25	54	70	80	85
L	1-acre residential	20	51	68	79	84
K	2-acre residential	12	46	65	77	82
O	Open Space includes: (agricultural land, landfills, junk yards, cemeteries, parks, golf courses, sports fields, sewage treatment plants, cleared land, schools with several acres of green areas	ND[1]	74	82	87	
X	Strip Mined Areas	ND[1]	77	86	91	94
F	Forest Cover	ND[1]	30	55	70	77
I	Industrial	72	81	88	91	93
C	Commercial	85	89	92	94	95
W	Water Surface	100	100	100	100	100

1 Not Defined by TR55, Reference 2

Since the peak flow from the HEC-I model was bracketed by the flows computed using the preliminary PSRM and the approximate TR20 models, it was selected as the "target" of this project's calibration effort. There are several potential calibration points within the PSRM. These include initial abstraction, surface roughness, overland flow widths, runoff curve numbers and hydrograph routing travel times. The preliminary PSRM hydrologic parameters reflecting overland flow width and initial abstraction were modified so as to yield increased peak flows. The preliminary overland flow widths were increased by a factor of 2.5 and the initial abstraction was decreased to 0.1 inch. These adjustments brought the PSRM flows at the Savantine/Sawkill Creek confluence to approximately 1544 CFS, which is within 17 percent of the HEC-I computed flow of 1870 CFS. However, the approximate nature of the travel times used in routing of the sub-area hydrographs through the Savantine creek sub-watershed by the PSRM and the lack of associated hydrograph routing and hydrologic structures within the HEC-I model were considered to be adequate justification for the variation in computed flows. This condition was highlighted by the increased disparity of computed flows found when comparing the calibrated PSRM to the HEC-I model at the proposed road crossing in Milford Borough.

The primary purpose of the hydrologic modeling effort within the Act 167 program is to estimate the impacts of future watershed development on existing flows. These assessments are generally directed at significant stream obstructions and existing flood-problem areas. Accordingly, the associated level of modeling detail is reduced from that which would be required for a detailed floodplain delineation. This reduced level of detail in the hydrologic model may lead to decreased accuracy in the computed peak flows. However, since the only modification to the calibrated PSRM made between existing and future land use conditions is the runoff curve number input parameter, use of these models to estimate potential peak flow impacts of future land use was considered appropriate. Rainfall events equivalent to the mean annual, 5-, 10-, 25-, 50-, and 100-year events were applied to the calibrated PSRM using the SCS Type II distribution.

4.4 Model of Future Conditions

4.4.1 Summary of Future Stormwater Characteristics

The potential stormwater impacts of anticipated development in the watershed were assessed by developing a model of expected future development conditions. The PCPC developed land use mapping of the projected future conditions based on a 10-year planning period. The items taken into consideration were as follows:

- Present land use configuration (USGS quads, tax mapping, municipal maps);
- Current zoning classification from municipal zoning ordinances;

- o Historical growth patterns determined through subdivision submissions, building permits and population projections; and,
- o Proposed development information from other agencies, periodicals, etc.

Data files for future conditions were prepared for input to PSRM by digitizing the future land use maps in the same manner as was applied to existing land use maps (see report Section 4.3.2). The GIS was then used to calculate composite runoff curve numbers based on this future land use information. For the purposes of this study, the soils and slope information for each subarea remained the same as under existing conditions. Table 3 shows the breakdown of land uses for each subarea under both existing and future conditions. The computed runoff curve numbers for both existing and future land use conditions used for each subarea in the models are listed in Table 4.

Model runs of future land use conditions were made for the mean annual, 5-, 10-, 25-, 50-, and 100-year SCS Type II storm events and compared to the associated existing conditions runs. Tables listing the existing and future flow rates at selected points of interest can be found in Appendix B.

4.4.2 Impact of Future Development Without Stormwater Management

As development takes place, significant changes in the stormwater generating characteristics of a watershed will occur. These are usually related to the increases of impervious surfaces and the modification of stormwater conveyance systems. These conditions combine to not only increase the volume of runoff that can be anticipated for a storm event, but also to increase the speed at which this runoff moves to the watershed outflow point. The increased volume and velocity of stormwater further increases erosion potentila, flooding, damage to existing water conveyance facilities and other property damage.

4.5 Summary of Modeling Results

As has been previously discussed, the primary application of the hydrologic model developed for the Sawkill Creek Watershed was to provide a basis for assessing the impacts of foreseeable development on stormwater related flows. To accomplish this, peak flows for the storm events of interest were developed for both existing and future land use conditions within the watershed. The associated resultant flows are compared in the tabulations included in Appendix B. Two sets of flow information are included in the tables associated with the detailed study areas. The first set, labelled "Watershed Flows", presents cumulative flows along the stream systems. The second set, labelled "Subarea Runoff", presents the individual subarea generated peak flow information.

By assessing the variation in peak flows, for both individual subareas and cumulative rates, it can be seen that the most significant future development stormwater impacts occur along the portion of Sawkill Creek above the confluence with Savantine Creek. This results from the fact that the majority of development potential for this watershed was defined by the PCPC to be in this watershed area. However, due to the buffering effects of floodplain storage these increases diminish as you move downstream towards the Delaware River.

Each of the provided subwatershed tabulations includes the mean annual, 5-, 10-, 25-, 50- and 100-year storm events. By evaluating these tables, it was noted that the percentage of variation between existing and future flows varies significantly between these storm events. This variation is a direct result of the initial existing condition flow to which the increase in future flows is compared. This information served as primary input for the development of stormwater management control recommendations which are discussed in detail in Section 6.0 of this report.

4.6 Additional Uses of the Sawkill Creek Watershed Model

Calibrated watershed models are a very useful "tool" for effectively managing water resources in a watershed. The calibrated PSRM for the Sawkill Creek Watershed can be utilized for the following types of evaluations, the results of which can serve as direct input into the water resources decision-making process.

o Development Impact Evaluations:

As part of this project a computer based geographic information system (GIS) was developed for the Sawkill Creek Watershed. The integral watershed database includes existing land use, hydrologic soil groups, surface slopes and subarea boundaries. It is accessed through a menu-driven, interactive program that allows users with a minimum degree of training to modify specific data so as to reflect potential developed conditions. The system can then be used to modify the existing condition PSRM input stream to reflect the "post-development" runoff curve numbers. Subsequent execution of this revised input stream will allow the planner to quantify the potential impacts on stormwater flows associated with the proposed development. This initial "quick look" at a proposed land use change can be very beneficial in providing direction to the developer concerning potential requirements for stormwater management.

o Encroachment Analyses:

In this case, the calibrated watershed PSRM can be used by land developers or municipalities to evaluate potential impacts that a stream encroachment may have on both contiguous flood elevations and downstream flows. Typically, when a stream encroachment application is made, the applicant, either the land developer or municipality must perform a hydraulic analysis to define the impacts the encroachment will have on flood elevations. To perform this analysis, a hydrologic analysis must first be performed to define the associated stream flows for input to the hydraulic model. Development of these models in lower portions of watersheds can be very costly and often will preclude development of a specific area. The availability of a calibrated hydrologic model can, therefore, significantly cut the cost of making a stream encroachment application. Additionally, varying the channel capacity and travel time parameters to reflect the proposed conditions will allow a municipality to evaluate/quantify the downstream hydrologic impacts of such activity, primarily those resulting from decreases in available floodplain storage.

o <u>Stormwater Management Facility Assessments:</u>

A significant problem associated with the implementation of stormwater detention facilities within a watershed is the potential for exacerbating downstream flows. This is a direct result of the extended duration of peak flows that result from attenuation of future land use condition flows to existing levels. These potential downstream impacts can be evaluated by modifying the calibrated PSRM to reflect the proposed facility. Although a preliminary assessment of this potential has been performed as part of this study, it can still be beneficial to assess these potential problems on a case by case basis.

o <u>Drainage Design:</u>

The calibrated PSRM model can also be used to provide design level data for:

- Highway design by counties or PennDOT;
- Verification of stormwater management plans for use by municipal engineers;
- Storm runoff characteristics data for use by land developers in the development of stormwater management plans.

TABLE 3

SAWKILL CREEK WATERSHED
EXISTING LAND USE DISTRIBUTION BY SUBAREA

SUBAREA NUMBER	1/4-ACRE RESIDENTIAL	1/2-ACRE RESIDENTIAL	1-ACRE RESIDENTIAL	2-ACRE RESIDENTIAL	OPEN SPACE	STRIP MINE	FOREST	INDUSTRIAL	COMMERCIAL	WATER	TOTAL ACRES
1	0.0	0.0	0.0	0.0	0.0	0.0	376.5	0.0	0.0	0.0	376.5
2	0.0	4.6	37.6	0.0	0.0	0.0	312.2	0.0	0.0	1.8	356.3
3	0.0	0.0	9.2	0.0	4.6	0.0	367.3	0.0	0.0	0.9	382.0
4	49.6	9.2	34.9	0.0	0.0	0.0	176.3	0.0	0.9	0.0	270.9
5	0.0	0.0	0.0	0.0	0.0	0.0	169.0	0.0	0.0	0.0	169.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	413.2	0.0	0.0	0.0	413.2
8	0.0	0.0	0.0	0.0	0.0	0.0	247.9	0.0	0.0	0.0	247.9
9	0.0	0.0	0.0	0.0	0.0	0.0	203.9	0.0	0.0	0.0	203.9
10	0.0	0.0	0.0	0.0	0.0	0.0	294.8	0.0	0.0	0.0	294.8
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	225.0	0.0	0.0	0.0	225.0
13	33.1	58.8	24.8	16.5	2.8	0.0	62.4	0.0	1.8	1.8	202.0
14	0.0	0.0	24.8	80.8	0.0	0.0	320.5	0.0	0.0	43.2	469.2
15	0.0	0.0	12.9	0.0	0.0	0.0	214.0	0.0	0.0	0.0	226.8
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.9	0.0	18.4	0.0	52.3	0.0	0.0	0.0	71.6
18	0.0	0.0	33.1	0.0	1.8	0.0	215.8	0.0	0.0	0.0	250.7
19	0.0	0.0	253.4	0.0	9.2	0.0	229.6	0.0	0.0	0.0	492.2
20	0.0	0.0	71.6	0.0	1.8	0.0	106.5	0.0	0.0	0.0	180.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.9	19.3	31.2	11.0	0.0	197.4	0.0	0.0	91.8	351.7
23	0.0	1.8	4.6	3.7	13.8	0.0	125.8	0.0	0.0	0.0	149.7
24	0.0	0.0	68.9	114.8	15.6	0.0	214.9	0.0	0.0	11.9	426.1
25	0.0	0.0	1.8	0.0	0.0	0.0	92.7	0.0	0.0	0.0	94.6
26	0.0	0.0	28.5	0.0	3.7	0.0	64.3	0.0	0.0	0.0	96.4
27	0.0	0.0	26.6	0.0	0.0	0.0	112.0	0.0	0.0	5.5	144.2
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	0.0	0.0	5.5	0.0	0.0	0.0	170.8	0.0	0.0	0.9	177.2
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31	0.0	0.0	0.9	25.7	0.0	39.5	676.8	0.0	0.0	0.0	742.9
32	0.0	0.0	0.0	0.0	31.2	0.0	367.3	0.0	0.0	4.6	403.1
33	0.0	0.0	0.0	0.0	0.0	0.0	158.9	0.0	0.0	0.0	158.9
34	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	0.0	0.0	0.0	0.0	3.7	0.0	376.5	0.0	0.0	20.2	400.4
36	0.0	0.0	0.0	0.0	7.3	0.0	233.2	0.0	0.0	0.0	240.6
37	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38	0.0	0.0	0.0	0.0	6.4	0.0	123.0	0.0	0.0	0.0	129.5
39	0.0	0.0	0.0	0.0	0.0	0.0	206.6	0.0	0.0	0.0	206.6
40	0.0	0.0	0.0	0.0	0.0	0.0	185.5	0.0	0.0	0.0	185.5
41	0.0	0.0	0.0	0.0	0.0	0.0	262.6	0.0	0.0	0.0	262.6
42	0.0	0.0	0.0	0.0	0.0	0.0	253.4	0.0	0.0	0.0	253.4
43	0.0	0.0	0.0	0.0	0.9	0.0	242.4	0.0	0.0	0.0	243.3
44	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
46	0.0	0.0	0.0	0.0	18.4	0.0	353.5	0.0	0.0	0.0	371.9
47	0.0	0.0	0.0	0.0	0.0	0.0	278.2	0.0	0.0	0.0	278.2
48	0.0	0.0	0.0	0.0	0.0	0.0	145.1	0.0	0.0	0.0	145.1
49	0.0	0.0	0.0	0.0	0.0	0.0	380.2	0.0	0.0	0.0	380.2

TABLE 3 (continued)

SAWKILL CREEK WATERSHED
EXISTING LAND USE DISTRIBUTION BY SUBAREA

SUBAREA NUMBER	1/4-ACRE RESIDENTIAL	1/2-ACRE RESIDENTIAL	1-ACRE RESIDENTIAL	2-ACRE RESIDENTIAL	OPEN SPACE	STRIP MINE	FOREST	INDUSTRIAL	COMMERCIAL	WATER	TOTAL ACRES
50	0.0	0.0	0.0	0.0	0.0	0.0	176.3	0.0	0.0	0.0	176.3
51	0.0	0.0	0.0	0.0	0.0	0.0	427.9	0.0	0.0	0.0	427.9
52	0.0	0.0	0.0	0.0	0.0	0.0	91.8	0.0	0.0	0.0	91.8
53	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
54	0.0	0.0	0.0	0.0	5.5	0.0	272.7	0.0	0.0	0.0	278.2
55	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
56	0.0	0.0	0.0	43.2	10.1	0.0	144.2	0.0	0.0	0.0	197.4
57	0.0	0.0	5.5	0.0	36.7	0.0	47.8	0.0	0.0	0.0	90.0
58	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
59	1.8	0.0	29.4	18.4	109.3	0.0	426.1	0.0	18.4	0.0	603.3
60	2.8	15.6	3.7	11.9	59.7	0.0	301.2	0.0	0.0	0.9	395.8
61	0.0	0.0	1.8	0.0	0.0	0.0	348.9	0.0	0.0	0.0	350.8
62	0.0	0.0	0.0	9.2	57.9	0.0	159.8	0.0	0.0	9.2	236.0
63	0.0	0.0	68.0	11.0	0.9	0.0	54.2	0.0	0.0	0.0	134.1
64	0.0	0.0	0.0	0.0	23.9	0.0	120.3	0.0	0.0	0.9	145.1
65	0.0	0.0	48.7	0.0	58.8	0.0	138.7	0.0	0.0	0.9	247.0
66	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
67	0.0	0.0	11.9	65.2	0.0	0.0	135.9	0.0	0.0	0.0	213.0
68	0.0	0.0	0.0	64.3	0.0	0.0	100.1	0.0	0.0	0.0	164.4
69	0.0	0.0	5.5	0.0	0.0	0.0	243.3	0.0	0.0	0.0	248.9
70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
72	0.0	0.0	17.4	0.0	45.0	0.0	291.1	0.0	0.0	4.6	358.1
73	4.6	0.0	20.2	0.0	0.0	0.0	126.7	0.0	0.0	0.0	151.5
74	8.3	24.8	48.7	0.0	76.2	0.0	108.4	0.0	2.8	0.0	269.1
75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
76	89.1	0.0	16.5	2.8	20.2	0.0	178.1	0.0	24.8	0.0	331.5
77	35.8	0.0	10.1	0.0	23.9	0.0	65.2	0.0	11.0	0.0	146.0

TABLE 3 (continued)

SAWKILL CREEK WATERSHED
FUTURE LAND USE DISTRIBUTION BY SUBAREA

SUBAREA NUMBER	1/4-ACRE RESIDENTIAL	1/2-ACRE RESIDENTIAL	1-ACRE RESIDENTIAL	2-ACRE RESIDENTIAL	OPEN SPACE	STRIP MINE	FOREST	INDUSTRIAL	COMMERCIAL	WATER	TOTAL ACRES
1	0.0	0.0	0.0	0.0	0.0	0.0	376.5	0.0	0.0	0.0	376.5
2	0.0	4.6	37.6	0.0	0.0	0.0	312.2	0.0	0.0	1.8	356.3
3	0.0	0.0	9.2	0.0	108.4	0.0	264.5	0.0	0.0	0.9	382.9
4	49.6	9.2	56.9	59.7	40.4	0.0	54.2	0.0	0.9	0.0	270.9
5	0.0	0.0	14.7	52.3	1.8	0.0	100.1	0.0	0.0	0.0	169.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	413.2	0.0	0.0	0.0	413.2
8	0.0	0.0	0.0	0.0	0.0	0.0	247.9	0.0	0.0	0.0	247.9
9	0.0	0.0	0.0	0.0	0.0	0.0	203.9	0.0	0.0	0.0	203.9
10	0.0	0.0	0.0	0.0	0.0	0.0	294.8	0.0	0.0	0.0	294.8
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	225.0	0.0	0.0	0.0	225.0
13	33.1	58.8	36.7	16.5	2.8	0.0	50.5	0.0	1.8	1.8	202.0
14	0.0	0.0	176.3	124.9	0.0	0.0	124.9	0.0	0.0	43.2	469.2
15	0.0	0.0	124.9	90.0	0.0	0.0	11.9	0.0	0.0	0.0	226.8
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	16.5	36.7	18.4	0.0	0.0	0.0	0.0	0.0	71.6
18	0.0	0.0	64.3	0.0	1.8	0.0	184.6	0.0	0.0	0.0	250.7
19	0.0	0.0	255.3	0.0	9.2	0.0	227.7	0.0	0.0	0.0	492.2
20	0.0	0.0	71.6	0.0	1.8	0.0	106.5	0.0	0.0	0.0	180.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.9	168.0	31.2	11.0	0.0	48.7	0.0	0.0	91.8	351.7
23	0.0	1.8	105.6	3.7	11.0	0.0	27.5	0.0	0.0	0.0	149.7
24	0.0	0.0	77.1	114.8	15.6	0.0	206.6	0.0	0.0	11.9	426.1
25	0.0	0.0	56.0	0.0	0.0	0.0	38.6	0.0	0.0	0.0	94.6
26	0.0	0.0	31.2	0.0	3.7	0.0	61.5	0.0	0.0	0.0	96.4
27	0.0	0.0	26.6	0.0	0.0	0.0	112.0	0.0	0.0	5.5	144.2
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	0.0	0.0	36.7	0.0	0.0	0.0	139.6	0.0	0.0	0.9	177.2
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31	0.0	0.0	0.9	25.7	0.0	39.5	676.8	0.0	0.0	0.0	742.9
32	0.0	0.0	0.0	0.0	31.2	0.0	367.3	0.0	0.0	4.6	403.1
33	0.0	0.0	0.0	0.0	0.0	0.0	158.9	0.0	0.0	0.0	158.9
34	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	0.0	0.0	0.0	0.0	3.7	0.0	376.5	0.0	0.0	20.2	400.4
36	0.0	0.0	0.0	0.0	7.3	0.0	233.2	0.0	0.0	0.0	240.6
37	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38	0.0	0.0	0.0	0.0	6.4	0.0	123.0	0.0	0.0	0.0	129.5
39	0.0	0.0	0.0	0.0	0.0	0.0	206.6	0.0	0.0	0.0	206.6
40	0.0	0.0	0.0	0.0	0.0	0.0	185.5	0.0	0.0	0.0	185.5
41	0.0	0.0	0.0	0.0	0.0	0.0	262.6	0.0	0.0	0.0	262.6
42	0.0	0.0	0.0	0.0	0.0	0.0	253.4	0.0	0.0	0.0	253.4
43	0.0	0.0	0.0	0.0	0.9	0.0	242.4	0.0	0.0	0.0	243.3
44	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
46	0.0	0.0	0.0	0.0	18.4	0.0	343.4	0.0	10.1	0.0	371.9
47	0.0	0.0	0.0	0.0	0.0	0.0	278.2	0.0	0.0	0.0	278.2
48	0.0	0.0	0.0	0.0	0.0	0.0	145.1	0.0	0.0	0.0	145.1
49	0.0	0.0	0.0	0.0	0.0	0.0	380.2	0.0	0.0	0.0	380.2

TABLE 3 (continued)

SAWKILL CREEK WATERSHED
FUTURE LAND USE DISTRIBUTION BY SUBAREA

SUBAREA NUMBER	1/4-ACRE RESIDENTIAL	1/2-ACRE RESIDENTIAL	1-ACRE RESIDENTIAL	2-ACRE RESIDENTIAL	OPEN SPACE	STRIP MINE	FOREST	INDUSTRIAL	COMMERCIAL	WATER	TOTAL ACRES
50	0.0	0.0	0.0	0.0	0.0	0.0	176.3	0.0	0.0	0.0	176.3
51	0.0	0.0	0.0	0.0	0.0	0.0	427.9	0.0	0.0	0.0	427.9
52	0.0	0.0	0.0	0.0	0.0	0.0	91.8	0.0	0.0	0.0	91.8
53	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
54	0.0	0.0	0.0	0.0	5.5	0.0	272.7	0.0	0.0	0.0	278.2
55	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
56	0.0	0.0	0.0	43.2	10.1	0.0	139.6	0.0	4.6	0.0	197.4
57	0.0	0.0	5.5	0.0	36.7	0.0	47.8	0.0	0.0	0.0	90.0
58	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
59	1.8	0.0	29.4	18.4	109.3	0.0	421.5	0.0	23.0	0.0	603.3
60	2.8	15.6	3.7	11.9	59.7	0.0	301.2	0.0	0.0	0.9	395.8
61	0.0	0.0	1.8	0.0	0.0	0.0	348.9	0.0	0.0	0.0	350.8
62	0.0	0.0	0.0	9.2	57.9	0.0	159.8	0.0	0.0	9.2	236.0
63	0.0	0.0	69.8	11.0	0.9	0.0	52.3	0.0	0.0	0.0	134.1
64	0.0	0.0	0.0	0.0	23.9	0.0	120.3	0.0	0.0	0.9	145.1
65	0.0	0.0	48.7	0.0	58.8	0.0	138.7	0.0	0.0	0.9	247.0
66	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
67	0.0	0.0	78.1	65.2	0.0	0.0	69.8	0.0	0.0	0.0	213.0
68	0.0	0.0	7.3	64.3	0.0	0.0	92.7	0.0	0.0	0.0	164.4
69	0.0	0.0	5.5	0.0	0.0	0.0	243.3	0.0	0.0	0.0	248.9
70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
72	0.0	0.0	17.4	0.0	45.0	0.0	290.2	0.0	0.0	4.6	357.2
73	4.6	0.0	38.6	0.0	0.0	0.0	109.3	0.0	0.0	0.0	152.4
74	8.3	24.8	67.0	0.0	76.2	0.0	90.0	0.0	2.8	0.0	269.1
75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
76	89.1	0.0	30.3	2.8	20.2	0.0	164.4	0.0	24.8	0.0	331.5
77	35.8	0.0	10.1	0.0	23.9	0.0	65.2	0.0	11.0	0.0	146.0

TABLE 4

SAWKILL CREEK WATERSHED
RUNOFF CURVE NUMBERS BY SUBAREA

SUBAREA NUMBER	LAND AREA (acres)	EXISTING CONDITIONS CURVE NUMBER	FUTURE CONDITIONS CURVE NUMBER
1	376.5	71	71
2	356.3	71	71
3	382.9	67	71
4	270.9	75	79
5	169.0	70	73
6	0.1	70	70
7	413.2	68	68
8	247.9	70	70
9	203.9	71	71
10	294.8	71	71
11	0.1	70	70
12	225.0	70	70
13	202.0	77	78
14	469.2	75	79
15	226.8	72	79
16	0.0	70	70
17	71.6	74	79
18	250.7	72	73
19	492.2	76	76
20	180.0	74	74
21	0.1	70	70
22	351.7	80	83
23	149.7	72	78
24	426.1	75	75
25	94.6	70	75
26	96.4	73	73
27	144.2	74	74
28	0.1	70	70
29	177.2	70	72
30	0.1	70	70
31	742.9	69	69
32	403.1	72	72
33	158.9	71	71
34	0.1	70	70
35	400.4	72	72
36	240.6	71	71
37	0.1	70	70
38	129.5	69	69
39	206.6	69	69
40	185.5	69	69

TABLE 4 (continued)

SAWKILL CREEK WATERSHED
RUNOFF CURVE NUMBERS BY SUBAREA

SUBAREA NUMBER	LAND AREA (acres)	EXISTING CONDITIONS CURVE NUMBER	FUTURE CONDITIONS CURVE NUMBER
41	262.6	70	70
42	253.4	71	71
43	243.3	70	70
44	0.1	70	70
45	0.1	70	70
46	371.9	65	65
47	278.2	70	70
48	145.1	68	68
49	380.2	70	70
50	176.3	71	71
51	427.9	70	70
52	91.8	70	70
53	0.1	70	70
54	278.2	64	64
55	0.1	70	70
56	197.4	65	66
57	90.0	71	71
58	0.1	70	70
59	603.3	64	64
60	395.8	67	67
61	350.8	69	69
62	236.0	72	72
63	134.1	66	66
64	145.1	73	73
65	247.0	71	71
66	0.1	70	70
67	213.0	68	71
68	164.4	68	69
69	248.9	70	70
70	0.1	70	70
71	0.1	70	70
72	357.2	70	70
73	152.4	66	67
74	269.1	69	70
75	0.1	70	70
76	331.5	68	69
77	146.0	64	64

SECTION 5

STORMWATER MANAGEMENT TECHNIQUES

5.0 STORMWATER MANAGEMENT TECHNIQUES

Underlying the goals and objectives of a comprehensive program of stormwater management are the following basic principles.

- The Drainage System is a Part of a Larger Environmental System -

  Surface streams within an urban watershed can be managed solely as a drainage system or they can be managed so as to provide a broad range of benefits (e.g., water supply, recreation, aesthetic value, etc.). The influence of any new development or land use change should be analyzed, and the potential for adverse impacts on the beneficial uses of the stream system should be minimized.

- Floodplains are Natural Storage Areas -

  All surface water streams have associated with them a prescribed natural easement, defined as the stream's floodplain. This area functions as a facility for the conveyance or storage of excess stormwater runoff. The act of encroaching on, or altering, the hydraulic and hydrologic characteristics of the land draining to the natural easement requires the implementation of compensating control/ management measures to maintain effective operation of the natural easement.

- Stormwater Requires Space -

  New development reduces the "space" within a watershed that is naturally allotted for stormwater runoff storage. If "artificial space" is not provided in coordination with the new development, alternate space will be claimed further downstream within the watershed.

- Stormwater Has Potential Uses -

  The "forgotten resource", stormwater, appreciates in value as existing water resources are contaminated or can no longer meet consumptive demands. The initial element of a program designed to develop this resource is storage areas from which the runoff can be withdrawn and conveyed to recharge areas. In addition, these storage areas may provide recreational opportunities.

- Water Pollution Control Measures are Essential -

  In order to derive the full potential available from streams, as well as from natural and artificial wetland areas, both point and non-point sources of pollution must be controlled.

- Comprehensive Planning and Preventive Measures are Less Costly -

  Planning for the future results in lower costs to taxpayers than implementation of corrective measures.

Utilizing these principles to achieve the stormwater management goals defined for the Sawkill Creek Watershed, applicable structural and non-structural stormwater management techniques were evaluated. Structural methods are those that employ physical facilities that are designed and constructed for the purpose of controlling stormwater flows. Non-structural control techniques, for the purposes of this plan, may be broadly classified as either floodplain management or comprehensive watershed management planning through implementation of applicable stormwater ordinances.

5.1 Non-Structural Stormwater Management Techniques

This section presents the technical evaluation of non-structural control techniques to determine if, and in what form, they are applicable for stormwater management in the Sawkill Creek Watershed.

5.1.1 The Release Rate Percentage Concept

For new development sites, the most common design criterion for stormwater management facilities is control of the peak discharge rate generated by the 10-25 year rainfall event in a post-development land use condition to the pre-development or "existing land use" rate. However, there is the potential for an increase in peak stormwater flow rates at downstream locations when stormwater from two or more tributary areas combine, even if stormwater runoff detention control facilities are being used. Unless the control facilities are designed with consideration for the dynamic interaction and combination of sub-drainage areas (subareas) within a watershed, these adverse flow combinations may occur. An example that illustrates this situation is provided in Appendix C, Example 1.

5.1.2 The Direct Discharge Concept

The "Direct Discharge Concept" provides an alternative to normal on-site stormwater management techniques/standards. It allows for the discharge without attenuation of flows from a developed area so as to get the associated runoff volume out of the adjacent stream prior to the peak flow from the remainder of the watershed reaching the site. This can be very significant when the extended duration of existing level peak flows from stormwater management facilities is considered.

For the purposes of this study, only those subareas contiguous to main stem stream segments were considered as candidates for direct discharge. The runoff generating characteristics of these subareas was evaluated in detail. Primarily, this evaluation centered around comparison of the "time to peak" for the individual subarea and for the cumulative flows along the contiguous stream segment. Those subareas which have peaks occurring significantly prior to the adjacent cumulative watershed peak were identified, and the impact of direct discharge from them was tested using the calibrated PSRM which reflected the preliminary distributed storage conditions. Those subareas which, through this detailed evaluation, were found to have no negative downstream impacts (i.e., exacerbation of existing stormwater problems) associated with their discharge have been identified for consideration by the municipalities and County for relief from specific on-site stormwater management attenuation facility controls.

The direct discharge concept relates only to the application of stormwater attenuation facilities. It does not relieve the developer from responsibility for ensuring that the associated discharges will not adversely affect the stream system through scour/erosion and degradation of water quality.

5.1.3 The Downstream Impact Evaluation

Many private developers feel that excessive regulations limit the potential for innovative site planning. In response to this concern for future development in the Sawkill Creek Watershed, an alternative to the release rate performance standard has been developed. It permits the party interested in land development to have a professional engineer, experienced in stormwater management planning and design, define the required level of stormwater runoff control. This level is to be defined by one of the following criteria.

a. In those areas of the watershed identified as "direct discharge candidates" where man-made stormwater conveyance channels (i.e., closed storm sewers, concrete-li channels, rip-rap protected channels, etc.) discharging directly into the main stem or primary watercourse exist or will be constructed, the total stormwater runoff flow may be directed through these channels without alteration of the post-development peak runoff rate if sufficient capacity in the conveyance channel is available. This criterion can allow for a condition where the post-development peak runoff rate does exceed the pre-development value -- when it can be shown that reasonable steps are being taken to reduce the potential for downstream storm runoff impacts, utilizing acceptable data and calculation procedures.

b. In any area of the Sawkill Creek Watershed, a post-development discharge rate which is greater than the prescribed release rate percentage may be allowed if it can be shown that there is no potential for exacerbating storm runoff damage to downstream areas of the watershed. However, in no case is the post-development discharge rate to exceed the pre-development discharge rate from the sub-area. A downstream impact evaluation must be performed which demonstrates that at any point in time, the flow rates on the existing conditions runoff hydrograph at the outlet of the subarea(s) are not increased for storm discharges resulting from future conditions runoff for the design rainfall events. An example of this process is detailed in Appendix C, Example 2.

5.1.4 On-Site Infiltration

Rainfall reaching the ground moves downward through the soil surface, a process which is called infiltration. Infiltration occurs both prior to and during the occurrence of surface runoff. Water which has infiltrated the surface passes first through the belt of soil water and then proceeds downward under the action of gravity until it reaches the water table. If water is added from above, the volume in underground storage increases, which is called groundwater recharge. The relatively slow movement of water from the zone of saturation to a stream channel is called groundwater or base flow. When the rate of rainfall exceeds the infiltration capacity, overland flow begins.

The process of urbanization has been observed to generate a number of detrimental changes to the hydrologic equilibrium, among others decreasing the base flow volumes in receiving streams and water quality. Mitigative measures such as infiltration in the past did not gain wide acceptance because they were not effective in controlling increases in the peak flow discharges. However, the application of infiltration practices in conjunction with various flow attenuation and detention practices can help to meet requirements for base flow, groundwater recharge, water quality control, low flow augmentation and ecological protection.

The incorporation of infiltration practices has been considerably hindered by the absence of detailed standards and specifications in the past. Presently, there are planning and design procedures, along with inspections and maintenance programs that can guide the planner and designer in the successful application of these practices. Structural techniques for providing infiltration capacity include:

- Infiltration basins;
- Infiltration trenches;
- Dry wells;
- Porous asphalt pavement;
- Vegetated swales with check dams; and
- Vegetative filters.

However, non-structural infiltration controls can be provided by limiting the amount of impervious cover that is placed on a development site and avoiding the paving over of soils with high infiltration rates.

5.2 Structural Stormwater Management Techniques

Structural stormwater management control techniques can be either on-site (serving one particular site) or off-site (collectively serving more than one site). This section includes a short discussion of on-site techniques which are applicable for use in the Sawkill Creek Watershed. The designer is not restricted to the listed on-site techniques and is encouraged to apply innovative techniques when appropriate and feasible, particularly in unique situations. A process for developing a coordinated on-site stormwater management system for a development site, incorporating some non-structural techniques is also presented.

5.2.1 On-Site Techniques

Table 5 presents a list of on-site stormwater management techniques that are considered to be appropriate for controlling increases in peak runoff rates and decreases in infiltration resulting from urban development in the Sawkill Creek Watershed. The reader is encouraged to refer to other texts and manuals for specific design details and limitations characteristic of each of the proposed techniques. Also, when evaluating the potential use of any of the infiltration systems, detailed soil and geologic investigations are required to define their applicability for any development site.

TABLE 5

ON-SITE STORMWATER CONTROL TECHNIQUES FOR THE SAWKILL CREEK WATERSHED

Type of Control Provided	Technique
Infiltration of precipitation 'at sorce' prior to concentration.	Dutch drains, gravel-filled ditches with optional drainage pipe in base. Infiltration Trench Porous paving - asphalt. Precast concrete lattice blocks and bricks.
Increase time of concentration by increasing length of overland flow.	Terraces, diversions, runoff spreaders,etc.
Infiltration of runoff after preliminary concentration.	Seepage pits or dry wells, unually filled with gravel or rubble, sometimes cased. Infiltration trenches. Seepage beds or ditches. Seepage areas (multi-use).
Peak runoff rate reduction.	Detention basins. Parking lot storage.

o French Drains

French drains are basicly gravel-filled ditches. The "drain" may be entirely gravel-filled or covered with topsoil and seeded. When the top surface area of the drain is very wide, the drain usually is covered with brick lattice or porous block (Figure 5-1). French drains are suggested for use as dividing strips between areas of impermeable paving to collect sheet runoff. Another location where French drains are often implemented is parallel to sidewalks where they are gently sloped to the drain.

If drains are set at the base of French drains and connected into the storm sewer system, an effective reduction of peak runoff rates will result during intense storms. This same benefit will result from providing longitudinal connections along the Dutch drain, allowing runoff to flow into other facilities in the development site's stormwater management system during excessively heavy rainfall.

o Infiltration Trenches

Infiltration trenches are similar to French drains in that they are an excavated trench backfilled with aggregate. However, they are generally much larger in terms of storage volume and are used for larger drainage areas. Additionally, they usually do not conduct water along their length. They are generally two to ten feet deep, located either at or below the ground surface. It is recommended that the soils contiguous to the trench have an infiltration rate greater than 0.27 in./hr. and have clay content less than 30%. For optimum performance, the slope of the site should be less than 5% for surface and less than 20% for underground trenches. It is recommended that calculations be based on the 2-year storm event and that the trenches drain within 72 hours following a storm event. The aggregate should consist of clean 1.5 to 3.0 inch stone. It is also recommended that filter fabric with a covering of topsoil be placed on top to protect the trench and to facilitate its maintenance.

o Porous Paving - Asphalt

Porous pavement is a special asphalt mixture designed to pass water to a specially prepared subbase. The special subbase is thicker than a normal gravel subbase and is composed of coarsely graded stone which supplies a large amount of void space for runoff storage capacity. Figure 5-2 shows a typical porous pavement cross-section and design elements.

The passage of runoff through porous pavement can significantly reduce runoff from paved areas. High infiltration rates have been reported through new porous pavement surfaces, and pavement and subbase storage may provide control for over seven inches of runoff. However, special attention must be given to maintaining the porous pavement. Under certain circumstances the surface may become clogged and its permeability and associated infiltration rates reduced. Inadequate maintenance, rain on a frozen surface, and certain conditions during snow melt may all result in runoff, even though porous paving is being used.

- Pre-Cast Concrete Lattice Blocks and Bricks

There are various types of pre-cast paving slabs which provide a hard surface and yet are porous to varying degrees. Perforated slabs may be used to cover Dutch drains or infiltration trenches between areas of impermeable paving (e.g., making a lattice of permeable paving through parking area). Tree pits covered with brick strips may be used in a similar manner. Various types are shown in Figure 5-3.

- Terraces, Diversions, and Runoff Spreaders

By increasing the time of concentration of runoff (that is, increasing the overland flow time), the runoff hydrograph from a development site can be flattened, thereby reducing associated peak runoff rates. This can be achieved by spreading runoff or by directing it into a system of trenches. The increased overland flow time may also significantly enhance the infiltration of runoff, particularly on well-drained sites.

- Seepage Pits or Dry Wells

Seepage pits collect runoff and store it until it infiltrates into the soil. However, unlike Dutch drains, seepage trenches do not conduct water along their length when filled. Unless the seepage pit is designed to take the total amount of anticipated runoff for a design storm, some provision for "positive" (i.e., directed toward some other source of defined discharge) overflow must be made. In order to have the maximum benefit in reducing peak runoff rates, the pit should overflow during intense storms before its capacity is reached (Figure 5-4).

- Seepage Beds or Ditches

Seepage beds (Figure 5-5) provide for infiltration of runoff into the soil via a system of drains set in ditches of gravel. These systems only reduce the volume and velocity of runoff and, therefore, require a positive overflow system for excess runoff. There are several advantages to seepage bed systems resulting from the fact that they distribute water over a larger area than can be achieved with other infiltration techniques. As a result, a lower potential exists for clogging. In fact, a seepage bed system may be placed under paved areas if the bearing capacity of the pavement is not decreased.

- Seepage Areas (Multi-Use)

Seepage areas allow for a percentage of annual rainfall to infiltrate into the ground, thereby recharging the groundwater system. Seepage areas serve to store excess runoff and to provide for multi-purpose use of such a facility through careful design for recreational use, parking or open space (Figure 5-6).

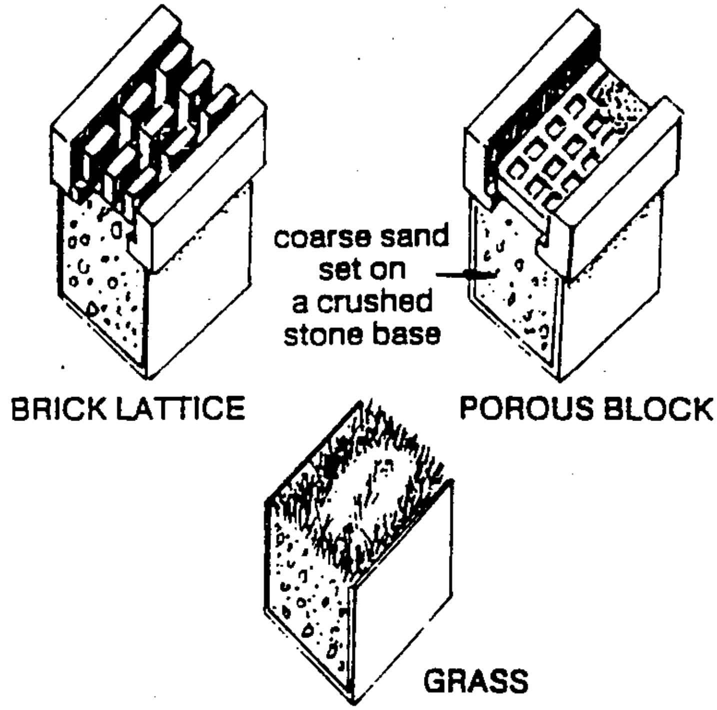


FIGURE 5-1
DUTCH DRAINS

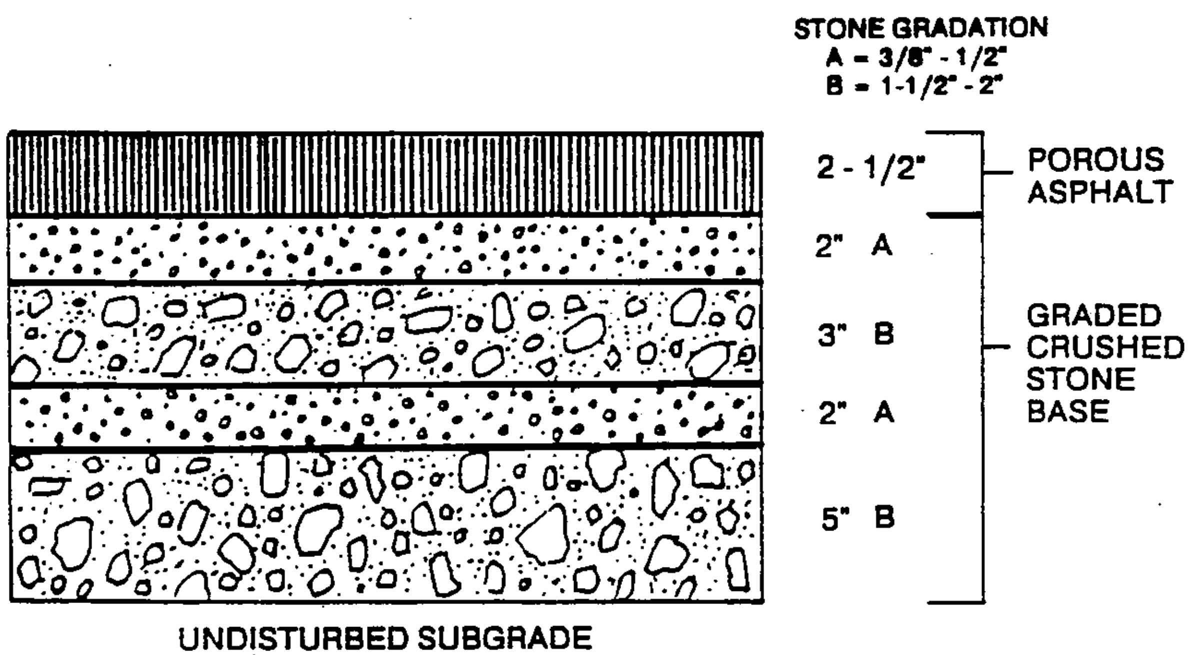


FIGURE 5-2
TYPICAL CROSS-SECTION OF POROUS PAVEMENT

o Detention Basins

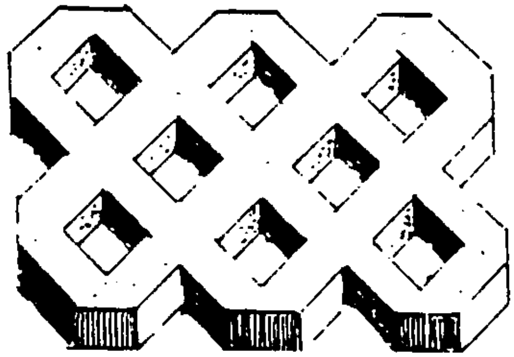
Properly designed detention basins reduce the peak rate of runoff discharging from a developed area by temporarily storing a portion of the stormwater runoff volume and attenuating the hydraulic response of the developed area. A term often confused with detention basins is "retention" basins. Retention basins require a significantly larger impoundment volume to provide permanent storage of stormwater, and are defined as any type of detention facility not provided with a positive outlet. The water that is stored in a retention facility either infiltrates or evaporates, but is not "discharged".

Because a detention basin or other facility providing similar runoff control is used as an element in most stormwater management plans for new development sites, additional information concerning their design and use in the Sawkill Creek Watershed is provided. A typical design procedure follows:

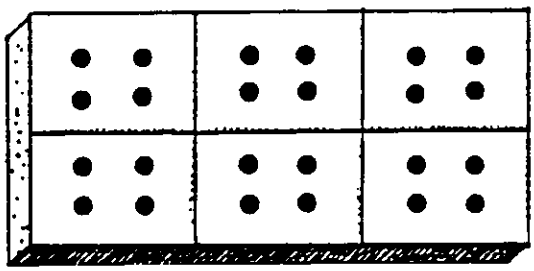
1. Define the site conditions (pre- and post-development);
2. Determine the total quantity of stormwater runoff that will arrive at the entrance of the detention facility for the design rainfall events. (NOTE: The post-development runoff quantity can be reduced by the amount proposed for on-site infiltration, where applicable.);
3. Develop pre- and post-developed runoff hydrographs, as opposed to only peak flow rates, for the design rainfall events (pre- and post-development);
4. Determine a preliminary basin size and develop a depth vs. storage relationship for the proposed basin configuration to satisfy defined performance (flow attenuation) standards;
5. Select an outlet control structure for the proposed detention basin (e.g., an outlet pipe and riser), and define its hydraulic characteristics (i.e., a headwater depth vs. discharge relationship);
6. Using the information developed in steps 4 and 5 (i.e., the relationship between storage and discharge), route the inflow hydrographs through the basin and develop associated outflow hydrographs; and,
7. Evaluate adequacy/effectiveness of the basin design, considering the impacts that the proposed basin will have on downstream areas.

o Parking Lot Storage

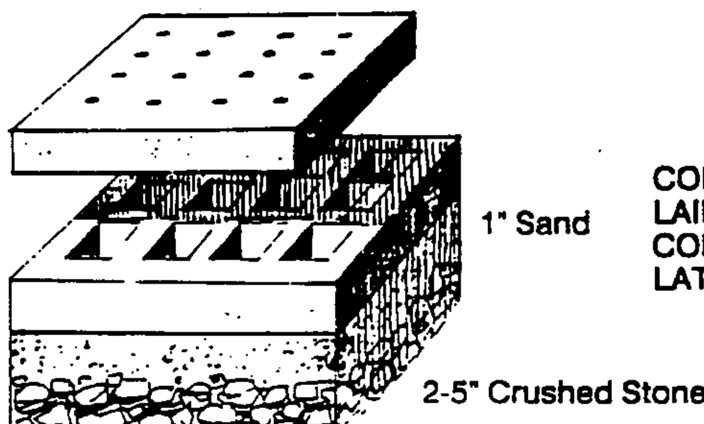
Parking lot storage involves the design of pavement surfaces, curbing, and stormwater inlet structures to temporarily detain stormwater runoff. Initial construction costs for implementing these measures are only a small percentage above the costs of constructing conventional parking lots. These measures should be designed to control runoff from the associated parking area, to drain completely and to avoid the formation of ice so as to minimize the impacts of the impounded water on vehicular movement.



CONCRETE
LATTICE
BLOCK



MODULE
PAVERS

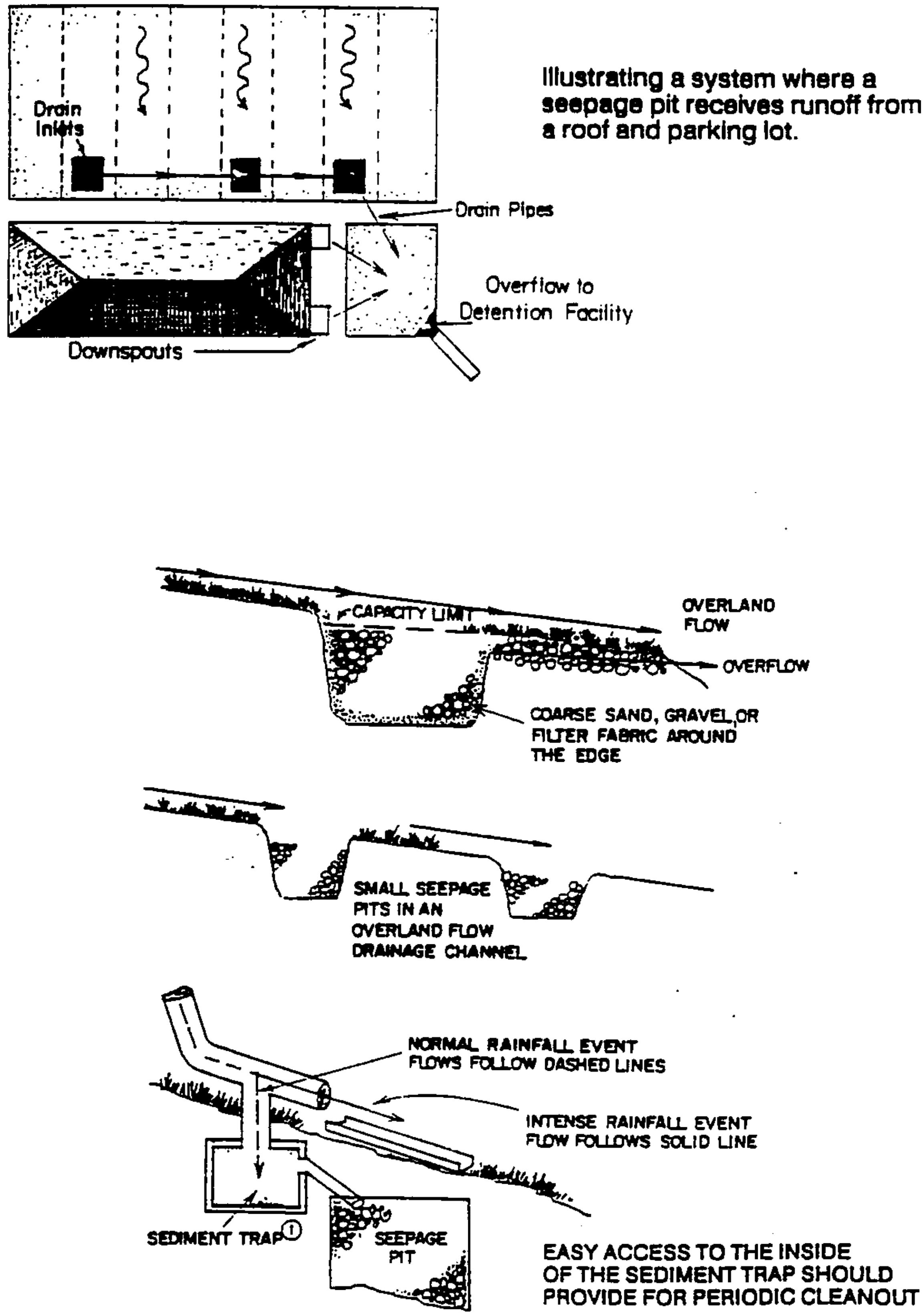


CONCRETE PAVER
LAID OVER
CONCRETE
LATTICE BLOCK

CONCRETE PAVERS

WALTER B. SATTERTHWAITE ASSOC., INC.
720 NORTH FIVE POINTS ROAD · WEST CHESTER, PA. 19380 · (215)692-5770

FIGURE 5-3



SEEPAGE PIT CONFIGURATIONS

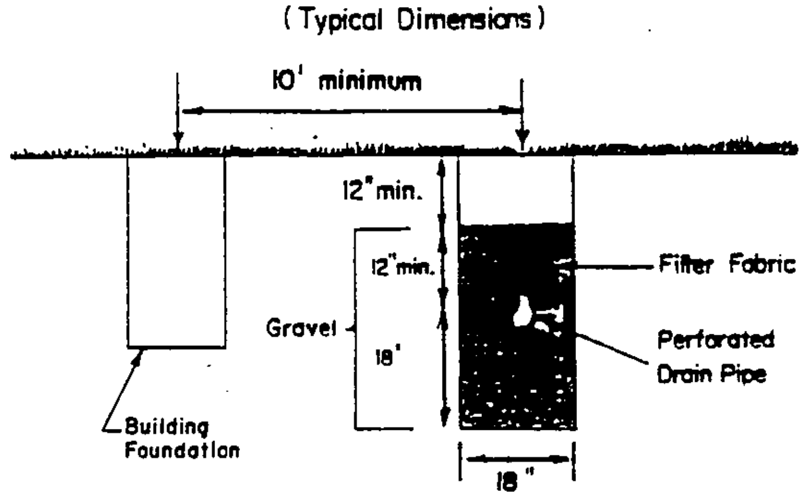


FIGURE 5-5
SEEPAGE BEDS

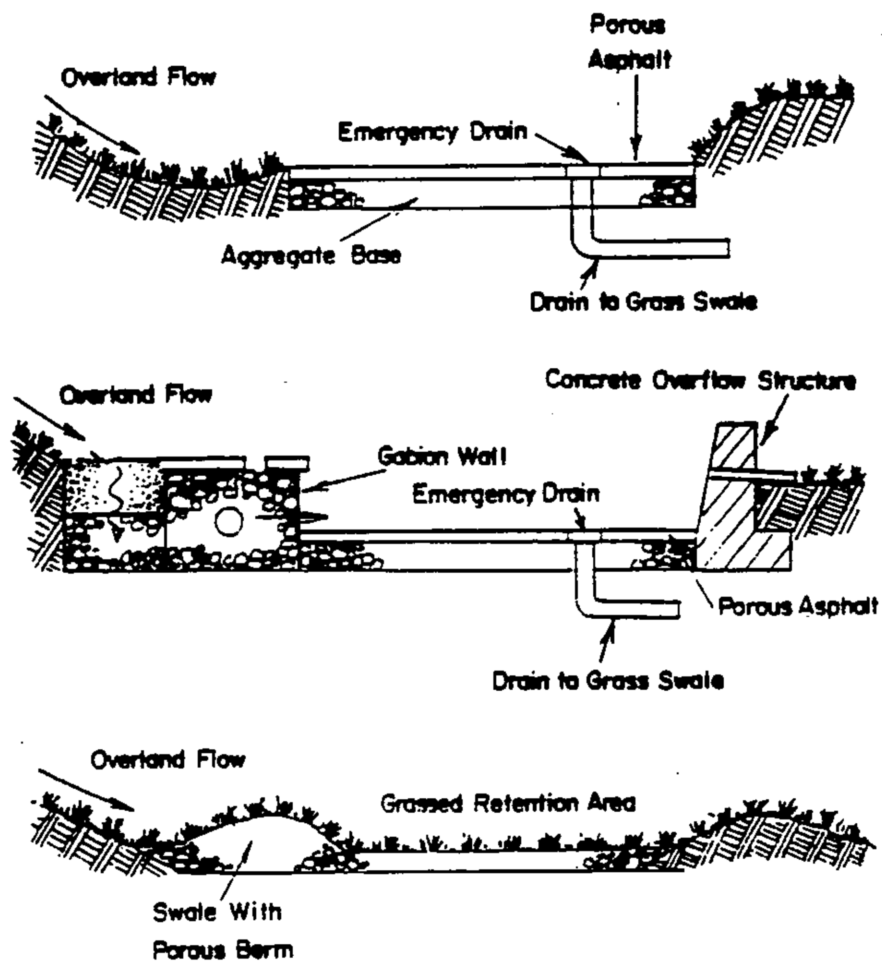


FIGURE 5-6
MULTI-PURPOSE SEEPAGE AREAS

5.2.2 Watershed-Level Stormwater Management Techniques

Watershed-level stormwater management systems represent a new direction for stormwater management and one that may be used more frequently in the future. One very key aspect of a watershed-level stormwater management alternative lies in its ability to provide an effective and coordinated system of runoff control facilities that is responsive to the specific hydrologic characteristics and needs of a watershed.

The distributed storage concept for watershed-level stormwater management relies on the selection of multiple detention facility locations by analyzing the specific characteristics of stormwater flow routing in the watershed. The trend of stormwater management in many locations has resulted in the construction of detention facilities in coordination with new development sites. The projected impact of these "randomly" located detention facilities is that an increase in flood flows may occur at downstream locations, i.e., at locations that are downstream from the development sites with the detention facilities.

In order to reduce the possibility of runoff flows from randomly placed detention facilities combining to increase downstream flows, the selection of sites that are hydrologically "most appropriate" for off-site (i.e., regional) detention facilities must be made. The ultimate selection of any stormwater storage area, however, will require a detailed assessment of potential advantages and disadvantages of desired facility locations and the associated assessment of downstream impacts.

SECTION 6

TECHNICAL STANDARDS AND CRITERIA FOR CONTROL OF STORMWATER RUNOFF

6.0 Technical Standards and Criteria for Control of Stormwater Runoff

Design rainfall events, or design storms, are defined and selected to provide a uniform basis for analyses of the flooding and runoff characteristics throughout an entire watershed. A design storm is identified by three basic properties:

- Return period or frequency;
- Duration; and,
- Rainfall distribution.

Frequency, or return period, refers to the likelihood of occurrence of the event in any year based on statistics from recorded events. A 10-year storm, for example, has a ten percent chance of occurring in any year, or may be expected once in every ten years. Duration refers to the length of time of rainfall in the event and is usually expressed in hours. It is equally important to know the pattern of rainfall distribution during the event in terms of the rainfall intensity during any time interval of the storm. Intensities are typically expressed in units of inches per hour.

Act 167 does not specify return periods to be used in the management of stormwater runoff. The stormwater management guidelines prepared by PADER recommend that complete flood frequency analysis ranging at least from a 2-year to a 100-year flood for both pre- and post-development conditions be performed in order to develop sound design frequency criteria for stormwater management. No State-level criteria has been adopted for stormwater management measures, so, therefore, they must be adopted by each municipality in accordance with approved watershed plans.

6.1 Design Storm Event Selection

A design storm event was chosen based on the analysis of the six assessed storm events. Basic rationales/considerations applied during the selection of the design storm event included the following:

- The selected event(s) should reflect significant increases under post-development conditions (in terms of quantity and quality) over existing conditions if control is not provided;
- The event(s) should be logically consistent with other existing watershed stormwater management programs so that compatible planning and adequate control measures can truly deter adverse future impacts including, in this case, impacts on the main stem of the Sawkill Creek; and,
- The impacts of the selected design storm event, as related to existing municipal controls, and potential cost increases to developers.

In order to allow for the selection of the principle design storm event for inclusion in proposed intermunicipal ordinances, peak flows resulting from various return interval storm events were computed using the calibrated PSRM. As was previously discussed, the storm events assessed were the mean annual, 10-, 25-, 50- and 100- year events. The tables in Appendix B reflect the resultant computed peak flows for both individual sub-areas and cumulative conditions, respectively. As can be seen by a review of these tables, the most dramatic increases over existing flow levels were found to occur during the 2.33- and 10-year storm events. This condition, coupled with the lack of identified existing flood problems and the expressed water quality concerns of watershed residents formed the primary rational for the selection of a recommended design storm event. The 2-year storm is the event considered to be most responsible for the configuration/size of stream channels. Additionally, the management of the 2- and 10-year storm events can have significant benefits in terms of water quality degradation mitigation. It should also be noted that most storm drain systems are designed with a 10-year capacity.

For the aforementioned reasons, the 10-year event has been selected as the design event for the release rate analysis, and it and the 2-year should event be included as the events for which peak flow attenuation is required. The 100-year future land use condition floodplains should be regulated so as to preclude development within their limits. Not only will this insure compliance with the FEMA program, but it will also provide a vegetative buffer around the exceptional value Sawkill Creek stream system.

In order to facilitate assessment of the potential impacts associated with defined development within the Sawkill Creek Watershed, Appendix B provides comparisons of stormwater runoff and stream flows which can be expected to occur under existing land use conditions and those which are anticipated in the future. It should be noted that both existing and future land use conditions were defined by the County as part of this project. The information presented in this appendix was developed using the calibrated PSRM, revised as necessary so as to reflect the required storm event and land use information as is discussed in Section 4.3 of this report.

For any analysis or facility design prepared in accordance with this Plan, the following rainfall frequency data shall be used with the selected methods of computation:

1. When the SCS Soil-Cover-Complex Method is used, storm runoff based on the following storm events and reflect the SCS Type II 24-hour rainfall distribution:

Storm Event	Inches of Rainfall
2.33 Year	2.94
5 Year	3.76
10 Year	4.43
25 Year	5.25
50 Year	5.89
100 Year	6.50

When the Rational Method is used, the Region 4 or Region 5 Rainfall Intensity-Duration-Frequency charts are shown in the PA DOT Design Manual, Part 2, August 1981 as amended, shall be used to determine the rainfall intensity,in inches per hour. The charts are shown on Figures 2.10.4.2(D) and 2.10.4.2(E) of the Manual. Figure 2.10.4.1 of the Manual should be used to determine if Region 4 or Region 5 curves are to be used.

6.2 Standards and Criteria Recommendations

As stormwater management facilities are constructed within a watershed, flows in contiguous downstream watercourse segments can be reduced to a pre-defined level. These facilities usually consist of detention basins which function by temporarily storing portions of the stormwater flow and subsequently releasing these flows over an extended period of time. Although this results in a reduction in peak flows at the facility, the extended duration of "high" flows can lead to increases in flows further downstream due to the timing of combination with flow from other portions of the watershed. This situation is discussed in detail in Section 5.1.1 of this report. In order to mitigate this potential negative impact of flow attenuation, a detailed release rate analysis was performed for the Sawkill Creek Watershed.

Individual subarea release rates are quantified by computing the ratio of the subarea's contribution to the peak flow at a downstream point of interest to its existing peak runoff rate. By setting release rates for detention facilities within the associated subarea at this level, it is possible to reduce the potential for the extended duration higher flows to increase flows within downstream watershed stream segments.

The work steps applied in the release rate evaluation of the Sawkill Creek detailed study area watersheds are as follows:

1. Identification of points of interest along each stream system, based on significant obstruction and flooding problem information provided by the County, with the potential for significant increases in existing land use condition peak flows due to the identified future development;

2. Identification of stream confluence points with the potential for significant existing land use condition flow increases due to identified future watershed development;

3. Computation of release rates for each subarea within the watershed associated with each downstream point of interest;

4. Identification of the most restrictive release rate for each subarea based on the associated downstream points of interest;

5. Hydrologic model based assessment/modification of defined release rates so as to maximize acceptable flows thereby minimizing associated control costs within each subarea; and,

6. Identification of those subareas where direct discharge (i.e., no flow attenuation requirement) is applicable.

In order to assess/modify the defined release rates, it was necessary to perform a preliminary distributed storage evaluation for the watershed. This was accomplished by modifying the watershed hydrologic models to reflect detention facilities within each subarea for which increases to peak flows are anticipated due to the defined future development. The Penn State Runoff Model was modified to "shave off" the portion of the subarea runoff hydrograph above the defined release rate. The associated runoff volume was then added to the receding limb of the runoff hydrograph so as to reflect a 24-hour draining time or "bleed off" period. Through this process, the impacts of extended duration high flows were approximated at downstream points of interest. Additionally, the initial computed release rates were adjusted so as to maximize allowable discharges from subarea detention facilities while still meeting the existing discharge flow rates. The recommended release rates developed through the aforementioned procedure are presented in Table 6. For ease of use, the release rates are also reflected on Plate No. 3 in the Model Ordinance.

6.3 Design Criteria for Detention Facilities

If a detention basin is an element in the stormwater management plan for any new development in the subject watershed, the following criteria should be used for the evaluation of the basin design:

1. The peak discharge from the basin shall be no greater than the pre-development peak runoff rate from the development site during the design rainfall events. (A person involved in the site design should be certain that all site runoff for these rainfall events is conveyed to the detention basin via storm sewers or appropriate surface drainage channels.) This may require that the detention basin outlet structures have multiple control capacity.

2. For development sites located in subareas for which release rate percentages of less than 100 percent were assigned, the peak discharge from the basin for post-development conditions shall be no greater than the peak runoff rate defined by applying the appropriate release rate percentage to the pre-development peak runoff rate from the development site during the design rainfall events illustrated by use of a routing procedure.

3. The stormwater detention basin shall have the capability of safely passing the 100-year peak stormwater runoff rate through an emergency spillway. "Safely" is being used here to mean "in a manner that will not result in physical damage" to the detention basin. This design provision will protect the structure if the primary outlet works become nonfunctional.

4. The water surface elevation in the detention basin during the 100-year rainfall event shall be designed to be at the crest of the emergency spillway. The minimum embankment height above the crest of the emergency spillway should be sufficient to pass the 100-year design storm flows "safely" through the

detention basin. One foot of free-board illustrated by use of a routing procedure shall be included inth design.

6.4 Sample Implementation of Recommended Performance Criteria

The recommended release rates within the Sawkill Creek Watershed (Table 6) are applied to each development site within the associated subarea. For example, if a development site is within a subarea with an 80 percent release rate then its maximum design event(s) discharge would be 80 percent of the associated existing land use conditions peak outflow or "discharge". Included as Appendix D is an example of applying the performance criteria on the site development level.

TABLE 6

PIKE COUNTY - SAWKILL CREEK WATERSHED

RELEASE RATE SUMMARY and DIRECT DISHARGE CANDIDATES

Release Rates	Subareas
70	4
80	13, 14, 15, 17, 18, 19, 20, 22
100	All others

Direct Discharge Candidates

Subareas 4, 23, 24, 26, 29, 31, 38, 56, 59, 60, 74, 76

SECTION 7

EXISTING INSTITUTION / REGULATORY SYSTEMS

7.0 EXISTING INSTITUTIONAL/REGULATORY SYSTEMS

This chapter covers two major topics: a review of existing municipal ordinances and a review of existing agencies and their current stormwater management functions. The first section reviews the stormwater provisions in the existing municipal land use and development ordinances. This analysis points out the areas where ammendments to the ordinances will be required to implement the plan. The second section provides a description of the agencies that are involved directly in stormwater management programs affecting the Sawkill Creek Watershed.

7.1 Review of Existing Ordinances

The stormwater provisions in the existing municipal ordinances were collected and reviewed by the Planning Commission. All of the municipalities in the Sawkill Creek have some type of stormwater control provisions in one or more of their land use or development ordinances. While there are a few common approaches and sometimes similar languages, there is no consistent pattern to the level of control or the particular type of regulatory approach taken to stormwater management.

Tables 7 and 8 indicate the types and variety of ordinances currently enforced by the watershed municipalities. As shown by the table, all the municipalities have zoning controls and all but Milford Borough have S/LD controls. The municipalities all enforce floodplain management controls, but Westfall Township utilizes a separate ordinance while the rest incorporate it into their zoning or building codes.

The municipal ordinances contain one or two types of stormwater standards. The first is the general performance standard which describes the end result the municipality desires to achieve. The associated statements may either be very broad or definite, such as the development shall "provide adequate drainage" or "no increasing the peak rate of runoff". The second type of stormwater standard is the technical standard which specifies exact conditions to be met. Examples are the storm frequency (e.g., 10-year) for which facilities must be designed or the method to be used to calculate runoff.

While broad standards may be sound in their intent, they present problems in their consistency with Act 167. For example, who is to decide what the definition of "adequate drainage" is? Can a municipality ever reject a site drainage plan if all its ordinances requires is "submit a plan showing existing and proposed facilities" without providing any standards for what is acceptable or unacceptablet drainage control?

TABLE 7

INVENTORY OF EXISTING REGULATORY CONTROLS
SAWKILL CREEK WATERSHED

			Controls are Addressed:			
Municipality	Ordinances Used	Comments on Ordinances	E&S	Floodplain Management	Drainage Control	Stormwater Management
Milford Borough	Zoning	Adopted 1989	Sec. 301.5(g)	Sections 5,6 & 7	Sections 4.01(b)	N/A
Milford Township	Zoning	Adopted 1986	Sects. 407.11	Sec. 412 Pg. 36	N/A	Sec. 407.11 Sec. 414.2 Sec. 414.3 Sec. 409.5, Pg.28 Sec. 503, Pg. 39
	Subdivision/ Land Devel.	Adopted 1987	Sects. 402.3 Pg. 31 403.3 Pg. 38 606 Pg. 69	N/A	N/A	Sec. 402.3, Pg.31 Sec. 403.3, Pg.38 Sec. 605, Pg. 66-69
Dingman Township	Zoning	Adopted 1983	N/A	Ord. 57	N/A	Sec. 410.3, Pg. 25 Sec. 413.1 Sec. 414.3 Sec. 415.9
	Subdivision/ Land Devel.	Adopted 1977	N/A	N/A	Sec. 704	N/A
	Planned Res.	Adopted 1976	Sec. 103c(2) Pg.4	N/A	N/A	Sec. 103c, Pg. 6
	Building Code	Adopted 1979	N/A	Ord. 37	Sec. 15.01	N/A
Shohola Township	Zoning	Adopted 1990	Sects. 512.11,Pg. 58 535.3(b),Pg.92	N/A	N/A	Sec. 512.11,Pg.58 Sec. 507.7(d) Pg. 44 Sec. 535.3(b)
	Subdivision/ Land Devel.	Adopted 1991	Sec.606	N/A	Sec. 605	Sec. 605
Westfall Township	Zoning	Adopted 1990	N/A	N/A	N/A	N/A
	Subdivision	Adopted 1989	Sec.402.7 502.301	N/A	Sec. 502.6 Sec.604.203	Sec. 402.9 Appendix B
	Floodplain	Adopted 1984	N/A	Ord. 44	Sec. 4.01b	N/A

TABLE 8

PIKE COUNTY

REVIEW OF EXISTING MUNICIPAL ORDINANCES

RELATIVE TO STORM RUNOFF RELATED CONTROLS

SAWKILL CREEK

Municipality	Milford Borough	Milford Township	Dingman Township	Shohola Township	Westfall Township
Stormwater Control Documents	Floodplain & Drainage from Zoning Ord. & Subdivision Ordinances Ordinances	Drainage, E&S Floodplain, & SWM from Zoning Building Code & Subdivision	Drainage, E&S Floodplain, & SWM from Zoning, & Subdivision Ordinances	Drainage Floodplain, & SWM from Zoning & Subdivision Ordinances	Drainage, E&S Floodplain& SWM from Zoning
Uses County Refers to SCS Standards	No	No	No	No Standards in Computing	Refer to SCS Conservation District or Stormwater Runoff
Who Reviews Plans for SW Management E/S Controls	No - Does Not Specify	Drainage System Improvements Approved by Township Engineer E/S County Cons. District	No - Does Not Specify	Drainage System Improvements Approved By Township Engineer E/S County Cons. District	Drainage System Improvements Approved By Twp. Engineer E/S County Cons. District
Fees for Plan Review	Set Fee Schedule	Set Fee Schedule	Set Fee Schedule	Set Fee Schedule	Set Fee Schedule
Regular Inspection Schedule and Who Performs	No	No	No	No	No
Maintenance Provisions for Facilities Identified	No	Yes - Owner of Facilities	No	Yes - Owner of Facilities	No
Land Use Planning Controls					
-Allows PRD, Cluster, etc.	No	Yes	Yes	Yes	Yes
-Steep Slope, Soil Stds.	No	No	Yes	No	Yes
-Impervious Cover Limits	Yes	Yes	Yes	Yes	Yes

TABLE 8

PIKE COUNTY

REVIEW OF EXISTING MUNICIPAL ORDINANCES

RELATIVE TO STORM RUNOFF RELATED CONTROLS

SAWKILL CREEK

(continued)

Municipality	Milford Borough	Milford Township	Dingman Township	Shohola Township	Westfall Township
Stormwater Control Documents	Floodplain & Drainage from Zoning Ord.	Drainage, E&S Floodplain, & SWM from Zoning & Subdivision Ordinances	Drainage, E&S Floodplain, & SWM from Zoning, Building Code & Subdivision Ordinances	Drainage Floodplain, & SWM from Zoning & Subdivision Ordinances	Drainage, E&S, Floodplain & SWM from Zoning & Subdivision Ordinances
Design Standards for Storm Sewers	No	Minimum Inside Diameter of Culverts 18"	Minimum Inside Diameter of Culverts 15"	No	No
Specifies Design Storm	No	10-Year-Resid. 25-Year-Comm. & Manufact.	No	25-Year	10-Year-Minor Streets 25-Year-Collector & Connector Streets
Specify Calculation Method	No	No	No	No	No
Uses Rate of Runoff Standard	No	Assure Postdev. Peak runoff ≤ Predevel. Peak Runoff	Mulit-family Assure Postdev. Peak Runoff ≤ Predevel. Peak Runoff or Manage Quantity, Velocity and Direction of Resulting Storm Water Runoff in a Manner which otherwise Adequately Protects Health and Property from Possibly Injury Single-Family Talbot's Formula	Talbot's Formula	Assure Postdevel. Peak Runoff ≤ Predevel Peak Runoff or Manage Quantity Velocity and Direction of Resulting Storm Water Runoff in a Manner which Otherwise Adequately Protects Health and Property from Possible Injury *Rational Formula
Emphasizes Groundwater Recharge On-Site	No	Yes	No	No	No
Has Design Standards for Detention Facility, Other Stormwater Measures	No	10-Year-Resid. 25-Year-Comm. & Manufac.	No	10-Year	PADER and PennDOT Regulations 10-Year-New Devel. & Minor Streets 25-Year Collector & Connector Streets

7.2.2 Department of Community Affairs

The Department of Community Affairs administers the Floodplain Management Act which is the companion act to the Stormwater Management Act. The Floodplain Management Act requires municipalities to participate in the National Flood Insurance Program. The watershed municipalities are presently participating in the flood insurance program and have adopted the required floodplain regulations.

7.2.3 Department of Environmental Resources (PADER)

The PADER, Division of Waterways and Stormwater Management, is the primary agency responsible for stormwater management in Pennsylvania. The Department is responsible for the administration of Act 167 watershed stormwater management plans as discussed previously. In addition, the Department upgraded the water quality in the Sawkill Creek from high quality to exceptional value (EV). At this time, the impact of the Exceptional Value status by PADER on the local municipalities is uncertain.

7.2.4 County Agencies

The Pike County Planning Commission is responsible for the preparation of the watershed stormwater plans with the local funding share provided by the Pike County Commissioners. The PCCD administers the state E/S regulations on behalf of PADER. The PCCD is responsible for education, plan reviews, handling complaints of E/S problems, assessing the problems and trying to obtain voluntary compliance. If legal actions are required, then PADER takes over the responsibility.

7.2.5 Local Municipalities

The local municipalities have a variety of functions under the existing institutional system. Their primary function is to adopt the stormwater management plan through local land use and development ordinances. The Stormwater Management Act states that a municipality must adopt and implement ordinances and regulations pertaining to proper stormwater management within six months following the adoption and approval of the watershed stormwater plan.

Three municipalities have adopted special stormwater ordinance provisions utilizing the "no increase in peak rate of runoff" standard which is consistent with the approach taken by Act 167. Several of the watershed municipalities go beyond the general performance language to establish various design standards. Two townships (Milford and Westfall) specify design storms for detention facilities. However, no design standards are given for detention/retention facilities. Culverts with minimum design standards are mentioned in Milford and Dingman Township Subdivision Ordinances. In addition, PennDOT regulations are referred to for culverts in one municipal ordinance. The method for calculating pre- and post-development stormwater runoff is identified in one municipal ordinance (Westfall Township) and is the "Rational Method".

Administrative and enforcement provisions of the existing ordinances generally cover procedures for plan reviews and approvals, reviews by the PCCD, site inspections, development fees, and facility maintenance. Two municipalities review stormwater control provisions as part of their S/LD plan review process. Two townships (Milford and Westfall) require separate E/S plans to be reviewed by the PCCD. The municipal engineer is usually responsible for the plan review, but the governing body maintains final approval power.

All the municipalities make provisions for fees to cover plan reviews and inspections through a fee schedule. In addition, the Pike County Planning Commission reviews all subdivisions and land development plans and charges fees to cover these reviews. Continuing maintenance of stormwater management facilities receives little attention in existing ordinances. Only one municipality (Milford Township) specifically mentions the responsibility an owner of a stormwater facility has for maintenance. Milford Township also allows a property owners' association to own and maintain such facilities through deed covenants and restrictions.

7.2 Existing Agencies and Their Stormwater Management Function

7.2.1 Federal Emergency Management Agency (FEMA)

This agency's involvement in local stormwater management is through its administration of the National Flood Insurance Program. Through the identification and mapping of 100-year floodplains and the adoption of local ordinances, it works with municipalities to reduce the potential for future flood damage.

SECTION 8

INSTITUTIONAL PLAN

DEVELOPMENT OF MODEL STORMWATER ORDINANCE PROVISIONS

8.0 INSTITUTIONAL PLAN - DEVELOPMENT OF MODEL STORMWATER ORDINANCE PROVISIONS

The Stormwater Management Act emphasizes locally administered stormwater programs with the watershed municipalities taking the lead role. Enforcement of the watershed plan standards and criteria will require the municipalities to incorporate them into their applicable ordinances which address land development. Provided as part of the plan is a model stormwater ordinance. This model ordinance is a single purpose stormwater ordinance that could be adopted by each municipality with minor changes to fulfill the needs of a particular municipality and time implement the Plan.

In addition to adopting the ordinance itself, the municipalities would also have to revise their existing subdivision, land development and zoning ordinances to incorporate the necessary linking provisions. These linking provisions would refer to any applicable regulated activities within the watershed to the single purpose ordinance. Key provisions of the model stormwater ordinance include the drainage standards and criteria, performance standards for stormwater management, and maintenance provisions for stormwater facilities.

Finally, the adopted stormwater ordinances should be understandable, applied fairly and uniformly throughout the watershed, and should not discourage creative solutions to stormwater management problems. It is advisable for the municipalities to adopt a uniform regulatory approach for the Sawkill Creek Watershed as this will assure consistent technical, construction implementation and enforcement aspects of stormwater management in the entire drainage.

SECTION 9

PRIORITIES FOR IMPLEMENTATION OF TECHNICAL STANDARDS AND CRITERIA

9.0 PRIORITIES FOR IMPLEMENTATION OF ACTION WITHIN THE PLAN

The regulatory approach for implementing the adopted plan utilizes the powers granted by Act 247, the Municipalities Planning Code (MPC). The MPC enables counties and municipalities to adopt zoning, subdivision and land development ordinances, and to address storm drainage concerns in these ordinances. In addition, the municipal codes enable the adoption of building codes. This section addresses several scenarios including adoption of a single purpose stormwater ordinance and incorporation of stormwater management provisions into existing ordinances.

As discussed in Section 8, a Model Stormwater Ordinance will be developed that could be adopted by each municipality with minor changes to fulfill the needs of a particular municipality and to implement the plan. The model ordinance would be referenced in the existing municipal land use ordinances.

Adoption of a single purpose stormwater ordinance is not required if a municipality chooses to incorporate the necessary provisions into their existing ordinances. It is important to note that the stormwater provisions in the local ordinance will override other developmental standards. The following guidelines identify some of the key additions and changes to the municipal ordinances that are needed to incorporate the standards and criteria of the Sawkill Creek Watershed Plan.

1. The existing subdivision and land development ordinance should address most of the stormwater provisions including drainage plan requirements and review procedures, design standards for stormwater management facilities, drainage easements, maintenance provisions and financial guarantees.

2. The stormwater management provisions in the existing subdivision and land development ordinance should be placed into one separate article.

3. The zoning ordinance should be amended to link the ordinance to the stormwater provisions as it relates to single lot/structure developments and changes or reuses of existing uses. Also, through the zoning ordinance, municipalities can protect sensitive environmental areas (e.g., steep slopes) which may contribute to stormwater problems or are subject to runoff damage.

4. The building code should be amended to reference sections of the subdivision and land development ordinance and/or zoning ordinance. This provides assurances that stormwater controls will be applied to all building construction. The building code should cover any standards for structurally related stormwater management techniques such as rooftop storage, porous pavement, parking lot storage, and storm drains.

SECTION 10

PLAN REVIEW ADOPTION AND UPDATING PROCEDURES

10.0 PLAN REVIEW ADOPTION AND UPDATING PROCEDURES

10.1 Plan Review and Adoption

This plan must undergo a local review process concurrent with a review by DER prior to adoption by the County. This local review will include the County, WAC, and the governing body of each municipality. Their review will include an evaluation of the Plan's consistency with other plans and programs affecting the watershed. All review comments must be documented by submitting to the County an official correspondence for the records. Below is a summary of the review requirements:

1. County Review - The Pike County Planning Commission, County Engineer, County Solicitor, and County Conservation District will review the plan and document their review. In addition, the County Planning Commission will receive official review comments from other agencies.

2. WAC Review - The committee formed, as required by Section 6 of the Act, to assist in the development of the Sawkill Creek Watershed Plan. The committee has provided the County and the consultant information during the data collection process. In addition, the committee has met on four occasions to review the progress of the Plan and provide this information to their respective municipalities. Act 167 specifies that prior to adoption of the plan by the County, the planning agency and the governing body of each municipality in the watershed must review the plan. The municipalities should review the draft Stormwater management Ordinance provisions of Section 8 which has been designed to implement the plan through adoption.

3. Department of Environmental Resources (DER) - The DER will review the plan to determine its consistency with the Act 167 requirements.

As a part of this plan adoption process, a final meeting will be held with each municipality to identify specific ordinance changes and methods of incorporation of the standards and criteria for the Plan into each municipality's existing ordinance framework. In addition, these meetings can also serve to provide clarification of any remaining questions or concerns each municipality may have concerning the implementation of the Plan for the particular municipality.

After the DER and local review of the Plan, the County will hold a public hearing concerning the Plan. The public hearing is to provide a forum for presenting the draft Plan and the review agency comments to the public for open discussion. A notice for the public hearing will be published at least two weeks before the hearing date. The County will prepare the hearing notice which will contain a brief summary of the principal provisions of the Plan and a reference to the places within each affected municipality where copies of the Plan may be examined or purchased at cost.

The County will review the comments made at the public hearing and modify the Plan if the comments are applicable. After all comments have been submitted and revisions to the plan made, the final Plan will be presented to the Pike County Commissioners to be adopted as a resolution. The resolution will have to be carried by an affirmative vote of at least a majority of the Pike County Board of Commissioners and shall refer expressly to the maps, charts, textual matter, and other materials intended to comprise the Plan. This action will then be recorded on the adopted plan.

The County will then submit to PADER a letter of transmittal, and three copies of the adopted plan, the review by the local official planning agency and governing body of each municipality, County Planning Commission, public hearing notice and minutes, and the resolution for adoption by Pike County. The letter of transmittal will state that Pike County has complied with all procedures outlined in Act 167 and request PADER to approve the adopted plan.

10.2 Procedure for Updating the Plan

The Act requires that the Plan be reviewed by Pike County and any necessary revisions be made at least every five (5) years after adoption by Pike County and approved by PADER. Any proposed revisions to the Plan would require municipal and public review prior to County adoption.

At this time, there are several check points that Pike County can use to assess the need for updating the Plan. These include:

1. Review of Subdivision/Land Development Plans.
2. Zoning revisions or curative amendments resulting in significant land use changes.
3. Concerns from developers and/or municipalities involving the impact or requirements of the watershed plan.
4. Changes in stream conditions that indicate that the Plan's stormwater management standards and criteria are ineffective.
5. Update of the flood insurance studies and maps.
6. Construction or modification of major stream obstructions, thus altering stormwater runoff flows and rates.

Pike County is to review the recommendations and determine if revisions are to be made. A revised Plan is subject to the same rules of adoption as the original Plan preparation. Should Pike County determine no revisions are required for five years, Pike County will adopt a resolution stating that the Plan has been reviewed and has been found satisfactory to meet the requirements of Act 167. This resolution shall then be forwarded to PADER.

The funding for plan updates will come from the PADER stormwater program. The counties and municipalities can establish a stormwater reserve fund using annual contributions from revenues from taxes (or general funds) and the drainage plan review fees. This fund could be allowed to accumulate to be used for plan updates and perhaps major capital projects to improve or correct stormwater problems in the watershed.

REFERENCES

REFERENCES

1. List of USGS Quadrangles used in this study:

   - United States Geological Survey Edgemere, PA Quadrangle Map, 1965; Photo-revised 1973
   - United States Geological Survey Milford, PA-NJ Quadrangle Map, 1958; Photo-revised 1983.
   - United States Geological Survey Pond Eddy, NY-PA Quadrangle Map, 1965; Photo-revised 1973.
   - United States Geological Survey Shohola, PA-NY Quadrangle Map, 1965; Photo-revised 1983.

2. United States Department of Agriculture Soil Conservation Service, Technical Release 55, "Urban Hydrology for Small Watersheds", June, 1986.

3. "TR-20, Project Formulation-Hydrology", Hydrology Unit, Engineering Division, Soil Conservation Service, 1982.

GLOSSARY OF TERMS

GLOSSARY OF TERMS

Confluence	The point at which two stream channels meet and combine into one.
Design Storm	The storm event or events to which performance standards are relocated.
Encroachment	An obstruction located within two stream's floodplain.
Erosion	The "washing away" of soils and other surface materials by stormwater runoff.
Evaporation	The process by which water is removed from an open surface by its conversion into water vapor.
Floodplain	The inundated portion of a stream valley during a storm event.
Gage	A device that records precipitation or stream flow rates.
Hydrograph	A recording of two stream's flow rate over time.
Hydrology	The science of evaluating the properties, distribution, and circulation of water on the surface of the land, in the soil, through fractures in underlying rocks, and in the atmosphere.
Hyetograph	A recording of a precipitation event over time.
Impervious	A surface that allows no water to penetrate.
Infiltration	The volume of precipitation that enters into the ground over a specific land area.
Initial Abstraction	The portion of rainfall that occurs prior to the beginning of stormwater runoff.
Permeability	The capacity of a soil to allow rainwater to pass through.
Pervious	A surface that allows water to penetrate
Precipitation	Water that falls to the earth as rain, snow, or hail.
Pressure Flow	The portion of flow that passes through a stream crossing structure.
Transpiration	The process by which vegetation returns water to the air.
Watercourse	Stream channel.
Weir Flow	The portion of flow that passes over a stream crossing structure.

APPENDIX A

APPENDIX A

EXAMPLE OF HYDROGRAPH DEVELOPMENT

To illustrate how a stream flow hydrograph is prepared, the following example using equal sized water tanks in place of watershed subbasins will be used (Figure A-1). The example presented here simulates ideal field conditions, which differ from those encountered in a watershed as follows.

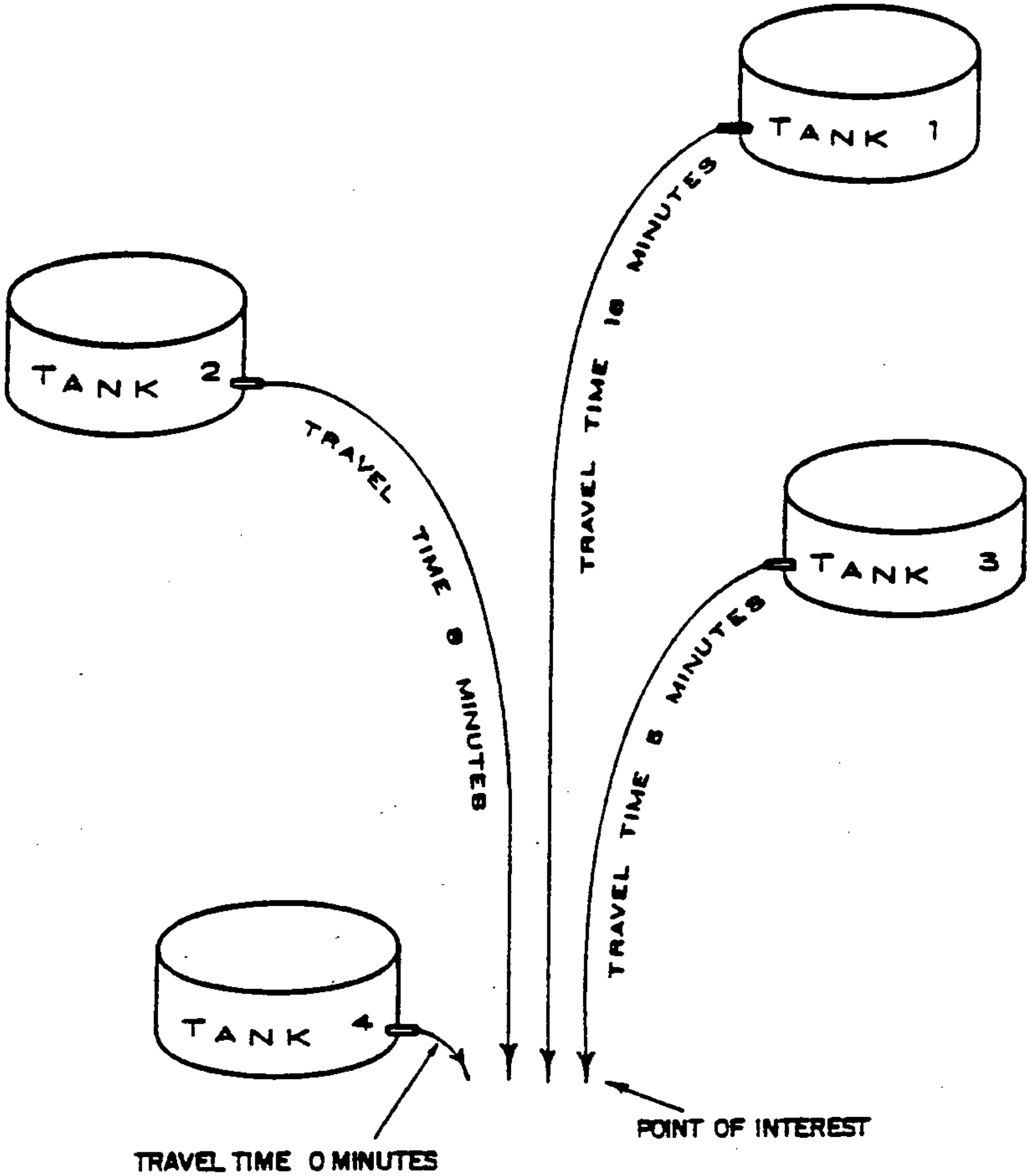
- o The total flow volume from each tank is the same. Within an actual watershed, the runoff quantity and rate vary significantly due to the influences of soil infiltration, storage, and size of the basin (and subbasins).

- o The rate of flow from each tank is uniform. In nature, however, the rainfall intensity values vary over time in a nonlinear fashion.

- o The travel time for the water from each tank to pass the point of interest has been assumed. In an actual watershed, these travel time values are determined from flow velocities that reflect the variations in the physical characteristics of the flow channels.

The key to understanding the formation of a watershed hydrograph is to realize that it is generated by runoff contributions from subbasins within the watershed. In the case of the water tank example, (Figure A-1), the total rate of flow passing the point of interest is a result of the contributions from the individual tanks. Figure A-2 is the hydrograph associated with Tank 3. In Figure A-2, it has been assumed that it takes five minutes (travel time) for the first drop of water released from the tank to reach the point of interest (Graph A). Figure A-2 also shows the increase (Graph B) and decrease (Graph C) in flow rate at the point of interest resulting from the opening of the valve (five minutes) and the draining of the tank (fifteen minutes). Thus, the maximum flow rate from Tank 3 occurs at the point of interest ten minutes after the valve for Tank 3 is opened. This time represents the combined time of travel (five minutes) and valve opening (five minutes).

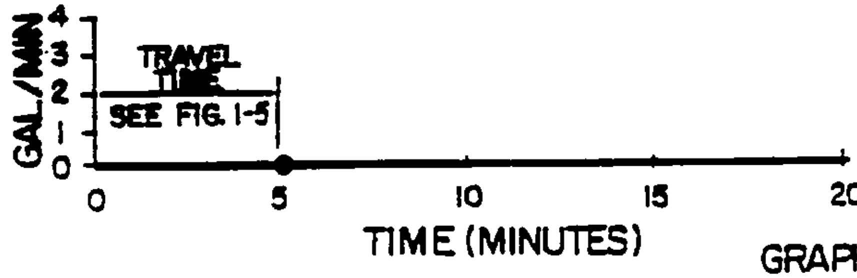
When all of the tank valves are opened simultaneously, similar graphs are created for the other tanks (see Figure A-3). For this example, because all flow rates and volumes are the same, the only variation among the hydrographs is the travel time for the first drops from the various tanks to reach the point of interest. It should be noted that the beginning point for each hydrograph in Figure A-3 represents that point in time when the flow from the associated tank begins to pass the point of interest.



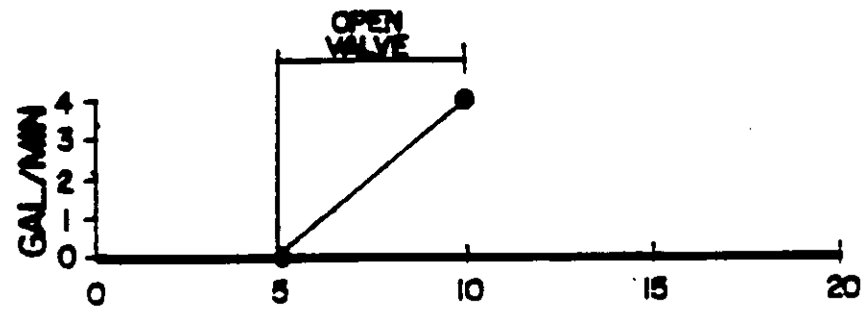
TANK TRAVEL TIMES

WALTER B. SATTERTHWAITE ASSOC., INC.

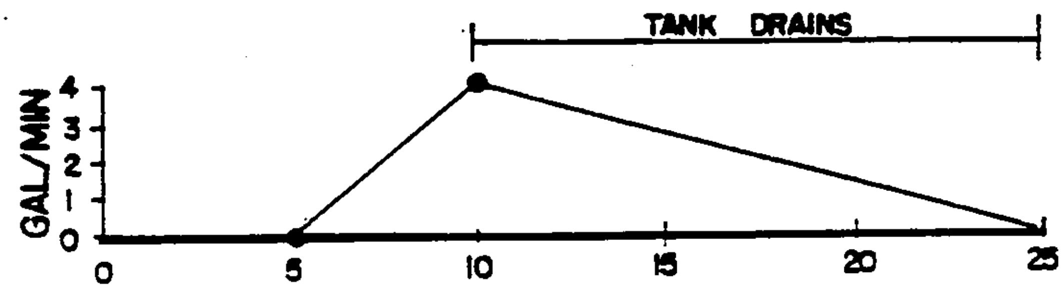
FIGURE A-1



GRAPH A



GRAPH B



GRAPH C

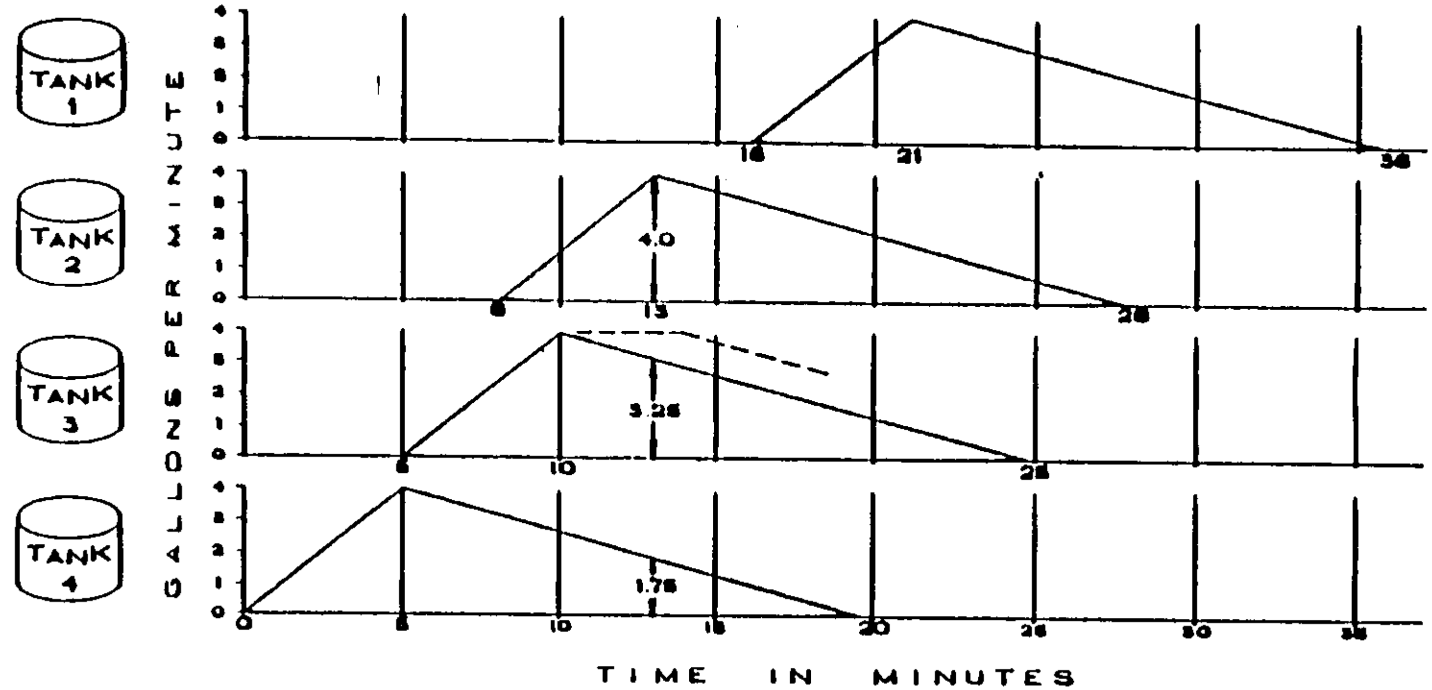
TIME (MINUTES)	0	5	6	7	8	9	10	15	20	25	30	35
FLOW RATE GAL/MIN	0	0	.8	1.6	2.4	3.2	4	2.7	1.3	0	0	0

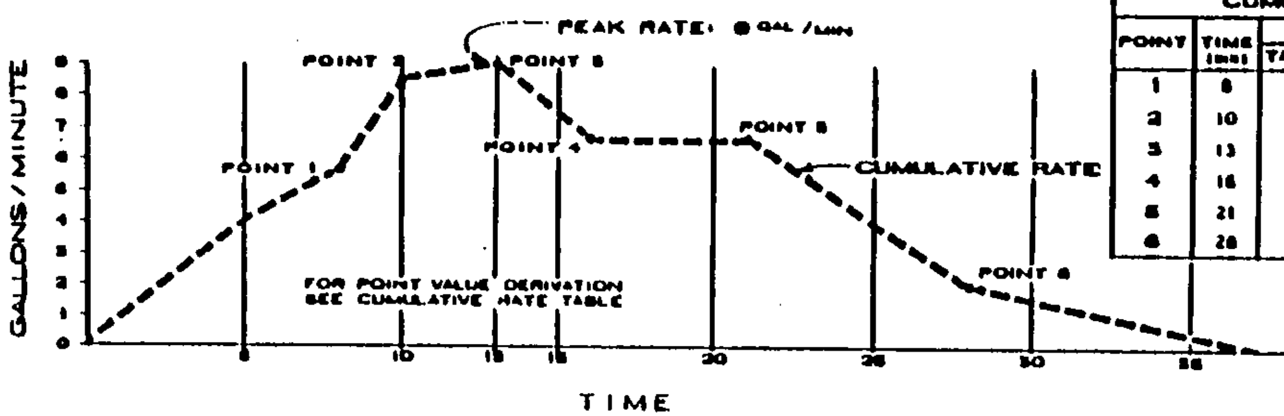
TANK 3 FLOW RATE GRAPH

As each tank drains, the decreasing volume of water in the tank reduces the gallons per minute discharging from the tank to zero. As shown in the hydrograph in Figure A-3, the last drop leaving Tank 3 passes the point of interest twenty-five minutes after the first drop leaves the tank. The figure also shows that the flow at the point of interest from Tank 3 reaches its maximum rate ten minutes into the overall storm runoff event.

Figure A-3 also shows the rates of flow for the other tanks, which were developed in a similar fashion. All of these hydrographs are then plotted over a common time span. To determine the cumulative rate of flow from each tank at the point of interest and for a selected point in time, the flow rates associated with each tank at the particular time of interest are totaled. Figure A-3 has a cumulative flow rate (or hydrograph) table which illustrates the contributing rate for various points along the hydrographs. The points are plotted, which furnished a graphical description of the cumulative flow rate at the point of interest. The "peak rate" is the highest value (point 3) which, for this example, is 9 gpm and occurs thirteen minutes after all the valves were opened.

This example uses ideal conditions with uniform values. If the sizes of the tanks vary, if the time required to open the valves varies, if the time of draining the tanks varies, or if the maximum rate from each tank varies, the overall system of flow rates would be very complex. This complexity is what actually occurs in a watershed. The concept used to develop the cumulative flow rate explained above, however, would be the same.





CUMULATIVE RATE TABLE						
POINT	TIME (min)	CONTRIBUTING GAL/min				
		TANK 1	TANK 2	TANK 3	TANK 4	TOTAL
1	8	0	0	2.4	3.25	5.65
2	10	0	1.6	4	2.75	8.35
3	13	0	4.0	3.25	1.75	9
4	16	0	3.25	2.5	1	6.75
5	21	4	1.75	1	0	6.75
6	28	2	0	0	0	2

CUMULATIVE FLOW RATE

APPENDIX B

SAWKILL CREEK WATERSHED PEAK FLOW TABLES

APPENDIX B (continued)
Sawkill Creek Watershed
Existing vs. Future Conditions Runoff Comparison
Individual Subarea Flows

Subarea No.	25 YEAR EVENT - SUBAREA RUNOFF					50 YEAR EVENT - SUBAREA RUNOFF					100 YEAR EVENT - SUBAREA RUNOFF					Subarea No.
	EXISTING		FUTURE			EXISTING		FUTURE			EXISTING		FUTURE			
	Runoff Peak (cfs)	Time of Peak (min)	Runoff Peak (cfs)	Time of Peak (min)	% DIFF-ERENCE	Runoff Peak (cfs)	Time of Peak (min)	Runoff Peak (cfs)	Time of Peak (min)	% DIFF-ERENCE	Runoff Peak (cfs)	Time of Peak (min)	Runoff Peak (cfs)	Time of Peak (min)	% DIFF-ERENCE	
46	107.7	717.5	107.7	717.5	0	195.2	717.5	195.2	717.5	0	300.1	717.5	300.1	717.5	0	46
47	186.8	717.5	186.8	717.5	0	289.0	717.5	289.0	717.5	0	400.4	717.5	400.4	717.5	0	47
48	104.1	717.5	104.1	717.5	0	168.3	717.5	168.3	717.5	0	237.0	717.5	237.0	717.5	0	48
49	200.5	717.5	200.5	717.5	0	310.1	717.5	310.1	717.5	0	436.7	717.5	436.7	717.5	0	49
50	186.3	717.5	186.3	717.5	0	274.9	717.5	274.9	717.5	0	371.6	717.5	371.6	717.5	0	50
51	194.4	717.5	194.4	717.5	0	302.3	717.5	302.3	717.5	0	427.2	717.5	427.2	717.5	0	51
52	89.7	717.5	89.7	717.5	0	135.2	717.5	135.2	717.5	0	185.2	717.5	185.2	717.5	0	52
53	0.4	717.5	0.4	717.5	0	0.4	717.5	0.4	717.5	0	0.5	717.5	0.5	717.5	0	53
54	71.6	717.5	71.6	717.5	0	137.9	717.5	137.9	717.5	0	215.9	717.5	215.9	717.5	0	54
55	0.4	717.5	0.4	717.5	0	0.4	717.5	0.4	717.5	0	0.5	717.5	0.5	717.5	0	55
56	88.3	717.5	105.7	717.5	20	157.5	717.5	178.9	717.5	14	240.9	717.5	264.3	717.5	10	56
57	106.1	717.5	106.1	717.5	0	155.0	717.5	155.0	717.5	0	208.3	717.5	208.3	717.5	0	57
58	0.4	717.5	0.4	717.5	0	0.4	717.5	0.4	717.5	0	0.5	717.5	0.5	717.5	0	58
59	87.4	762.5	87.4	762.5	0	152.9	747.5	152.9	747.5	0	237.3	717.5	237.3	717.5	0	59
60	155.4	717.5	155.4	717.5	0	261.2	717.5	261.2	717.5	0	386.5	717.5	386.5	717.5	0	60
61	166.9	717.5	166.9	717.5	0	264.9	717.5	264.9	717.5	0	378.3	717.5	378.3	717.5	0	61
62	184.1	717.5	184.1	717.5	0	274.2	717.5	274.2	717.5	0	369.0	717.5	369.0	717.5	0	62
63	73.4	717.5	73.4	717.5	0	124.2	717.5	124.2	717.5	0	183.2	717.5	183.2	717.5	0	63
64	225.4	717.5	225.4	717.5	0	318.0	717.5	318.0	717.5	0	412.6	717.5	412.6	717.5	0	64
65	234.8	717.5	234.8	717.5	0	348.8	717.5	348.8	717.5	0	473.5	717.5	473.5	717.5	0	65
66	0.4	717.5	0.4	717.5	0	0.4	717.5	0.4	717.5	0	0.5	717.5	0.5	717.5	0	66
67	116.4	717.5	166.9	717.5	43	188.4	717.5	252.5	717.5	34	271.7	717.5	342.9	717.5	26	67
68	57.6	717.5	66.3	717.5	15	95.9	717.5	105.8	717.5	10	138.5	717.5	151.7	717.5	10	68
69	164.4	717.5	164.4	717.5	0	254.6	717.5	254.6	717.5	0	352.9	717.5	352.9	717.5	0	69
70	0.4	717.5	0.4	717.5	0	0.4	717.5	0.4	717.5	0	0.5	717.5	0.5	717.5	0	70
71	0.4	717.5	0.4	717.5	0	0.4	717.5	0.4	717.5	0	0.5	717.5	0.5	717.5	0	71
72	190.2	717.5	190.2	717.5	0	294.0	717.5	294.0	717.5	0	414.0	717.5	414.0	717.5	0	72
73	86.2	717.5	98.4	717.5	14	145.4	717.5	163.6	717.5	13	214.0	717.5	235.3	717.5	10	73
74	182.4	717.5	206.2	717.5	13	288.7	717.5	317.6	717.5	10	403.2	717.5	436.7	717.5	8	74
75	0.4	717.5	0.4	717.5	0	0.4	717.5	0.4	717.5	0	0.5	717.5	0.5	717.5	0	75
76	193.7	717.5	218.8	717.5	13	312.4	717.5	346.3	717.5	11	445.4	717.5	484.8	717.5	9	76
77	64.2	717.5	64.2	717.5	0	121.2	717.5	121.2	717.5	0	187.2	717.5	187.2	717.5	0	77

Rainfall Taken From PA Bulletin For Region V

2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
2.94"	3.76"	4.43"	5.25"	5.89"	6.50"

APPENDIX B (continued)
Sawkill Creek Watershed
Existing vs. Future Conditions Runoff Comparison
Individual Subarea Flows

Subarea No.	25 YEAR EVENT - SUBAREA RUNOFF					50 YEAR EVENT - SUBAREA RUNOFF					100 YEAR EVENT - SUBAREA RUNOFF					Subarea No.
	EXISTING		FUTURE		% DIFF-ERENCE	EXISTING		FUTURE		% DIFF-ERENCE	EXISTING		FUTURE		% DIFF-ERENCE	
	Runoff Peak (cfs)	Time of Peak (min)	Runoff Peak (cfs)	Time of Peak (min)		Runoff Peak (cfs)	Time of Peak (min)	Runoff Peak (cfs)	Time of Peak (min)		Runoff Peak (cfs)	Time of Peak (min)	Runoff Peak (cfs)	Time of Peak (min)		
1	183.0	717.5	183.0	717.5	0	278.8	717.5	278.8	717.5	0	388.4	717.5	388.4	717.5	0	1
2	236.9	717.5	236.9	717.5	0	360.3	717.5	360.3	717.5	0	493.6	717.5	493.6	717.5	0	2
3	137.6	717.5	230.7	717.5	68	232.2	717.5	352.0	717.5	52	344.4	717.5	484.1	717.5	41	3
4	338.8	717.5	452.5	717.5	34	470.4	717.5	604.9	717.5	29	613.3	717.5	758.3	717.5	24	4
5	163.0	717.5	220.8	717.5	35	245.8	717.5	312.1	717.5	27	337.0	717.5	410.5	717.5	22	5
6	0.4	717.5	0.4	717.5	0	0.4	717.5	0.4	717.5	0	0.5	717.5	0.5	717.5	0	6
7	156.1	717.5	156.1	717.5	0	256.7	717.5	256.7	717.5	0	373.7	717.5	373.7	717.5	0	7
8	202.0	717.5	202.0	717.5	0	310.5	717.5	310.5	717.5	0	425.3	717.5	425.3	717.5	0	8
9	229.9	717.5	229.9	717.5	0	337.2	717.5	337.2	717.5	0	454.2	717.5	454.2	717.5	0	9
10	279.6	717.5	279.6	717.5	0	415.4	717.5	415.4	717.5	0	564.0	717.5	564.0	717.5	0	10
11	0.3	717.5	0.3	717.5	0	0.4	717.5	0.4	717.5	0	0.4	717.5	0.4	717.5	0	11
12	131.0	717.5	131.0	717.5	0	201.5	717.5	201.5	717.5	0	283.0	717.5	283.0	717.5	0	12
13	564.7	717.5	594.8	717.5	5	727.7	717.5	759.5	717.5	4	877.7	717.5	907.3	717.5	3	13
14	474.9	717.5	643.8	717.5	36	667.1	717.5	870.5	717.5	30	878.5	717.5	1102.0	717.5	25	14
15	282.2	717.5	476.7	717.5	69	404.8	717.5	626.0	717.5	55	537.8	717.5	768.7	717.5	43	15
16	0.0	717.5	0.0	717.5	0	0.0	717.5	0.0	717.5	0	0.0	717.5	0.0	717.5	0	16
17	126.8	717.5	176.9	717.5	40	175.0	717.5	229.0	717.5	31	223.5	717.5	277.3	717.5	24	17
18	247.3	717.5	272.3	717.5	10	361.2	717.5	389.8	717.5	8	485.0	717.5	518.0	717.5	7	18
19	474.1	717.5	474.1	717.5	0	660.4	717.5	660.4	717.5	0	868.1	717.5	868.1	717.5	0	19
20	153.4	717.5	153.4	717.5	0	221.2	717.5	221.2	717.5	0	292.1	717.5	292.1	717.5	0	20
21	0.4	717.5	0.4	717.5	0	0.4	717.5	0.4	717.5	0	0.5	717.5	0.5	717.5	0	21
22	602.9	717.5	720.3	717.5	19	797.4	717.5	918.9	717.5	15	992.1	717.5	1113.9	717.5	12	22
23	136.8	717.5	224.6	717.5	64	200.7	717.5	305.0	717.5	52	270.5	717.5	386.9	717.5	43	23
24	297.9	717.5	297.9	717.5	0	427.8	717.5	427.8	717.5	0	566.9	717.5	566.9	717.5	0	24
25	60.9	717.5	100.6	717.5	65	94.4	717.5	140.9	717.5	49	131.0	717.5	185.2	717.5	41	25
26	110.4	717.5	110.4	717.5	0	157.4	717.5	157.4	717.5	0	208.7	717.5	208.7	717.5	0	26
27	116.9	717.5	116.9	717.5	0	168.9	717.5	168.9	717.5	0	223.5	717.5	223.5	717.5	0	27
28	0.4	717.5	0.4	717.5	0	0.4	717.5	0.4	717.5	0	0.5	717.5	0.5	717.5	0	28
29	188.0	717.5	231.7	717.5	23	281.6	717.5	331.0	717.5	18	384.5	717.5	438.4	717.5	14	29
30	0.4	717.5	0.4	717.5	0	0.4	717.5	0.4	717.5	0	0.5	717.5	0.5	717.5	0	30
31	340.1	717.5	340.1	717.5	0	540.7	717.5	540.7	717.5	0	772.9	717.5	772.9	717.5	0	31
32	417.0	717.5	417.0	717.5	0	607.3	717.5	607.3	717.5	0	814.5	717.5	814.5	717.5	0	32
33	208.7	717.5	208.7	717.5	0	302.4	717.5	302.4	717.5	0	403.5	717.5	403.5	717.5	0	33
34	0.4	717.5	0.4	717.5	0	0.4	717.5	0.4	717.5	0	0.5	717.5	0.5	717.5	0	34
35	159.6	717.5	159.6	717.5	0	240.6	717.5	240.6	717.5	0	332.5	717.5	332.5	717.5	0	35
36	118.2	717.5	118.2	717.5	0	180.0	717.5	180.0	717.5	0	250.7	717.5	250.7	717.5	0	36
37	0.4	717.5	0.4	717.5	0	0.4	717.5	0.4	717.5	0	0.5	717.5	0.5	717.5	0	37
38	69.8	717.5	69.8	717.5	0	110.2	717.5	110.2	717.5	0	156.9	717.5	156.9	717.5	0	38
39	167.5	717.5	167.5	717.5	0	262.8	717.5	262.8	717.5	0	363.5	717.5	363.5	717.5	0	39
40	137.5	717.5	137.5	717.5	0	216.7	717.5	216.7	717.5	0	301.2	717.5	301.2	717.5	0	40
41	121.5	717.5	121.5	717.5	0	188.8	717.5	188.8	717.5	0	266.8	717.5	266.8	717.5	0	41
42	263.2	717.5	263.2	717.5	0	388.7	717.5	388.7	717.5	0	526.0	717.5	526.0	717.5	0	42
43	173.1	717.5	173.1	717.5	0	267.4	717.5	267.4	717.5	0	369.2	717.5	369.2	717.5	0	43
44	0.4	717.5	0.4	717.5	0	0.4	717.5	0.4	717.5	0	0.5	717.5	0.5	717.5	0	44
45	0.4	717.5	0.4	717.5	0	0.4	717.5	0.4	717.5	0	0.5	717.5	0.5	717.5	0	45

APPENDIX B (continued)
Sawkill Creek Watershed
Existing vs. Future Conditions Runoff Comparison
Cumulative Watershed Flows

Subarea No.	2.33 YEAR EVENT - WATERSHED OUTFLOW					5 YEAR EVENT - WATERSHED OUTFLOW					10 YEAR EVENT - WATERSHED OUTFLOW					Subarea No.
	EXISTING		FUTURE		% DIFF-ERENCE	EXISTING		FUTURE		% DIFF-ERENCE	EXISTING		FUTURE		% DIFF-ERENCE	
	Outflow Peak (cfs)	Time of Peak (min)	Outflow Peak (cfs)	Time of Peak (min)		Outflow Peak (cfs)	Time of Peak (min)	Outflow Peak (cfs)	Time of Peak (min)		Outflow Peak (cfs)	Time of Peak (min)	Outflow Peak (cfs)	Time of Peak (min)		
46	73.8	807.5	133.8	822.5	81	626.1	777.5	711.3	827.5	14	1190.5	767.5	1190.5	767.5	0	46
47	1.9	747.5	1.9	747.5	0	34.0	747.5	34.0	747.5	0	86.4	717.5	86.4	717.5	0	47
48	2.1	762.5	2.1	762.5	0	46.7	762.5	46.7	762.5	0	123.0	732.5	123.0	732.5	0	48
49	3.7	777.5	3.7	777.5	0	82.1	777.5	82.1	777.5	0	211.2	747.5	211.2	747.5	0	49
50	3.8	747.5	3.8	747.5	0	37.7	717.5	37.7	717.5	0	92.8	717.5	92.8	717.5	0	50
51	5.6	762.5	5.6	762.5	0	70.9	752.5	70.9	752.5	0	161.2	722.5	161.2	722.5	0	51
52	6.5	762.5	6.5	762.5	0	84.6	762.5	84.6	762.5	0	194.4	732.5	194.4	732.5	0	52
53	9.9	777.5	9.9	777.5	0	164.2	762.5	164.2	762.5	0	396.4	747.5	396.4	747.5	0	53
54	9.9	782.5	9.9	782.5	0	165.1	767.5	165.1	767.5	0	417.0	752.5	417.0	752.5	0	54
55	80.0	807.5	139.3	807.5	74	788.9	777.5	841.9	782.5	7	1587.6	767.5	1587.6	767.5	0	55
56	80.0	817.5	139.3	817.5	74	791.1	787.5	846.9	792.5	7	1601.7	812.5	1605.6	812.5	0	56
57	2.2	747.5	2.2	747.5	0	21.9	717.5	21.9	717.5	0	53.4	717.5	53.4	717.5	0	57
58	80.6	817.5	139.9	817.5	74	803.7	787.5	858.9	792.5	7	1617.4	812.5	1621.4	812.5	0	58
59	80.6	822.5	139.9	822.5	74	803.9	792.5	859.0	797.5	7	1568.5	817.5	1569.4	812.5	0	59
60	80.6	827.5	139.9	827.5	74	816.7	797.5	871.0	802.5	7	1605.8	822.5	1608.5	817.5	0	60
61	0.4	747.5	0.4	747.5	0	27.2	762.5	27.2	762.5	0	71.9	717.5	71.9	717.5	0	61
62	4.3	807.5	4.3	807.5	0	55.1	797.5	55.1	797.5	0	126.8	782.5	126.8	782.5	0	62
63	4.3	812.5	4.3	812.5	0	57.9	797.5	57.9	797.5	0	144.4	782.5	144.4	782.5	0	63
64	11.1	747.5	11.1	747.5	0	60.1	717.5	60.1	717.5	0	124.3	717.5	124.3	717.5	0	64
65	12.9	782.5	12.9	782.5	0	74.7	767.5	74.7	767.5	0	142.1	757.5	142.1	757.5	0	65
66	16.7	787.5	16.7	787.5	0	127.0	787.5	127.0	787.5	0	278.8	772.5	278.8	772.5	0	66
67	16.7	792.5	19.1	787.5	14	139.7	787.5	153.4	787.5	10	317.3	772.5	334.9	772.5	6	67
68	16.7	797.5	19.1	792.5	14	146.9	792.5	163.4	792.5	11	340.8	777.5	362.2	777.5	6	68
69	1.7	747.5	1.7	747.5	0	30.0	747.5	30.0	747.5	0	75.9	717.5	75.9	717.5	0	69
70	17.4	792.5	20.0	792.5	15	171.1	787.5	188.1	787.5	10	397.1	777.5	419.4	772.5	6	70
71	95.0	827.5	155.2	827.5	63	985.6	797.5	1052.2	802.5	7	1915.5	822.5	1946.0	817.5	2	71
72	0.8	797.5	0.8	797.5	0	22.6	827.5	22.6	827.5	0	51.6	822.5	51.6	822.5	0	72
73	0.8	802.5	0.8	802.5	0	24.3	807.5	26.9	807.5	11	65.7	792.5	69.1	792.5	5	73
74	0.8	807.5	2.6	762.5	225	46.2	777.5	56.1	777.5	21	122.2	762.5	136.6	752.5	12	74
75	95.7	827.5	155.9	827.5	63	1029.9	797.5	1103.8	802.5	7	2015.1	822.5	2055.6	817.5	2	75
76	95.7	827.5	155.9	827.5	63	1048.4	797.5	1127.7	802.5	8	2076.9	772.5	2127.2	772.5	2	76
77	95.7	832.5	155.9	832.5	63	1048.4	802.5	1127.7	807.5	8	2090.8	777.5	2141.1	777.5	2	77

Rainfall Taken From PA Bulletin For Region V

2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
2.94"	3.76"	4.43"	5.25"	5.89"	6.50"

APPENDIX B (continued)
Sawkill Creek Watershed
Existing vs. Future Conditions Runoff Comparison
Cumulative Watershed Flows

ubarea No.	2.33 YEAR EVENT - WATERSHED OUTFLOW					5 YEAR EVENT - WATERSHED OUTFLOW					10 YEAR EVENT - WATERSHED OUTFLOW					Subarea No.
	EXISTING Outflow Peak (cfs)	EXISTING Time of Peak (min)	FUTURE Outflow Peak (cfs)	FUTURE Time of Peak (min)	% DIFF-ERENCE	EXISTING Outflow Peak (cfs)	EXISTING Time of Peak (min)	FUTURE Outflow Peak (cfs)	FUTURE Time of Peak (min)	% DIFF-ERENCE	EXISTING Outflow Peak (cfs)	EXISTING Time of Peak (min)	FUTURE Outflow Peak (cfs)	FUTURE Time of Peak (min)	% DIFF-ERENCE	
1	3.6	762.5	3.6	762.5	0	39.0	762.5	39.0	762.5	0	87.2	717.5	87.2	717.5	0	1
2	7.6	782.5	7.6	782.5	0	84.5	767.5	84.5	767.5	0	181.2	757.5	181.2	757.5	0	2
3	7.6	787.5	11.7	777.5	54	98.8	772.5	130.0	767.5	32	235.3	762.5	278.5	757.5	18	3
4	26.2	747.5	63.2	717.5	141	98.2	717.5	167.0	717.5	70	191.0	717.5	283.9	717.5	49	4
5	1.8	747.5	10.8	747.5	500	27.9	717.5	56.0	717.5	101	77.7	717.5	118.2	717.5	52	5
6	29.9	777.5	71.4	717.5	139	179.8	777.5	249.7	767.5	39	319.5	817.5	402.4	717.5	26	6
7	29.9	797.5	71.5	737.5	139	189.0	842.5	261.1	837.5	38	361.9	817.5	460.3	787.5	27	7
8	30.5	802.5	73.1	742.5	140	201.7	847.5	274.9	837.5	36	383.7	822.5	501.2	812.5	31	8
9	4.7	747.5	4.7	747.5	0	47.0	717.5	47.0	717.5	0	115.1	717.5	115.1	717.5	0	9
10	10.3	762.5	10.3	762.5	0	96.0	732.5	96.0	732.5	0	224.3	732.5	224.3	732.5	0	10
11	39.5	772.5	78.9	742.5	100	270.4	772.5	338.3	792.5	25	503.3	792.5	598.6	812.5	19	11
12	40.6	777.5	80.2	747.5	98	292.7	777.5	357.6	797.5	22	544.3	797.5	633.3	817.5	16	12
13	76.9	717.5	95.2	717.5	24	220.7	717.5	247.1	717.5	12	366.0	717.5	394.1	717.5	8	13
14	109.3	737.5	171.9	737.5	57	337.6	737.5	430.6	737.5	28	574.1	737.5	682.4	737.5	19	14
15	9.9	747.5	70.1	717.5	608	65.8	717.5	183.6	717.5	179	145.1	717.5	303.1	717.5	109	15
16	116.8	737.5	227.2	737.5	95	390.7	737.5	550.5	737.5	41	675.8	737.5	858.5	737.5	27	16
17	124.3	742.5	246.9	742.5	99	415.3	742.5	589.2	742.5	42	716.2	742.5	912.0	742.5	27	17
18	8.6	762.5	13.3	747.5	55	55.4	717.5	68.6	717.5	24	126.8	717.5	145.9	717.5	15	18
19	11.1	932.5	12.1	932.5	9	37.5	952.5	39.1	952.5	4	79.5	922.5	82.6	917.5	4	19
20	10.0	762.5	10.0	762.5	0	40.3	717.5	40.3	717.5	0	83.1	717.5	83.1	717.5	0	20
21	15.5	807.5	16.1	822.5	4	53.2	807.5	54.4	807.5	2	101.8	862.5	105.1	862.5	3	21
22	22.1	1007.5	47.5	1002.5	115	84.5	1007.5	121.4	1002.5	44	155.7	1012.5	199.6	997.5	28	22
23	22.1	1012.5	50.9	942.5	130	86.0	972.5	129.6	957.5	51	160.7	982.5	211.8	962.5	32	23
24	35.2	807.5	63.4	822.5	80	129.7	792.5	172.7	807.5	33	232.6	792.5	283.8	787.5	22	24
25	0.6	747.5	7.9	747.5	1217	11.2	747.5	28.5	717.5	154	28.1	717.5	56.1	717.5	100	25
26	31.7	882.5	61.7	907.5	95	128.5	892.5	175.7	902.5	37	231.7	887.5	287.8	892.5	24	26
27	7.7	762.5	7.7	762.5	0	30.6	717.5	30.6	717.5	0	63.1	717.5	63.1	717.5	0	27
28	34.8	852.5	63.8	882.5	83	140.7	867.5	186.7	882.5	33	252.1	862.5	307.4	867.5	22	28
29	34.8	857.5	63.8	887.5	83	147.8	842.5	195.7	857.5	32	268.9	837.5	325.9	842.5	21	29
30	69.0	797.5	129.0	797.5	87	423.1	782.5	539.0	797.5	27	803.3	797.5	954.8	817.5	19	30
31	69.0	812.5	129.0	812.5	87	470.7	792.5	580.2	812.5	23	850.3	897.5	993.3	917.5	17	31
32	14.5	747.5	14.5	747.5	0	94.2	717.5	94.2	717.5	0	214.6	717.5	214.6	717.5	0	32
33	4.3	747.5	4.3	747.5	0	44.1	717.5	44.1	717.5	0	104.5	717.5	104.5	717.5	0	33
34	18.9	747.5	18.9	747.5	0	138.5	717.5	138.5	717.5	0	319.3	717.5	319.3	717.5	0	34
35	1.6	882.5	1.6	882.5	0	24.4	947.5	24.4	947.5	0	115.2	867.5	115.2	867.5	0	35
36	2.9	777.5	2.9	777.5	0	34.7	822.5	34.7	822.5	0	141.2	872.5	141.2	872.5	0	36
37	71.4	812.5	131.5	812.5	84	504.1	792.5	614.7	812.5	22	965.3	897.5	1091.2	917.5	13	37
38	71.4	817.5	131.5	817.5	84	513.0	797.5	622.0	817.5	21	946.6	912.5	1096.4	932.5	16	38
39	0.5	747.5	0.5	747.5	0	25.7	747.5	25.7	747.5	0	74.4	717.5	74.4	717.5	0	39
40	0.7	752.5	0.7	752.5	0	46.1	752.5	46.1	752.5	0	119.1	722.5	119.1	722.5	0	40
41	2.0	762.5	2.0	762.5	0	69.2	762.5	69.2	762.5	0	170.0	732.5	170.0	732.5	0	41
42	7.3	762.5	7.3	762.5	0	113.5	757.5	113.5	757.5	0	270.6	732.5	270.6	732.5	0	42
43	1.8	747.5	1.8	747.5	0	31.2	747.5	31.2	747.5	0	80.4	717.5	80.4	717.5	0	43
44	9.0	762.5	9.0	762.5	0	143.6	747.5	143.6	747.5	0	340.0	732.5	340.0	732.5	0	44
45	73.8	797.5	133.8	812.5	81	623.1	797.5	711.1	817.5	14	1155.7	757.5	1155.7	757.5	0	45

APPENDIX B (continued)
Sawkill Creek Watershed
Existing vs. Future Conditions Runoff Comparison
Cumulative Watershed Flows

Subarea No.	25 YEAR EVENT - WATERSHED OUTFLOW					50 YEAR EVENT - WATERSHED OUTFLOW					100 YEAR EVENT - WATERSHED OUTFLOW					Subarea No.
	EXISTING		FUTURE		% DIFF-ERENCE	EXISTING		FUTURE		% DIFF-ERENCE	EXISTING		FUTURE		% DIFF-ERENCE	
	Outflow Peak (cfs)	Time of Peak (min)	Outflow Peak (cfs)	Time of Peak (min)		Outflow Peak (cfs)	Time of Peak (min)	Outflow Peak (cfs)	Time of Peak (min)		Outflow Peak (cfs)	Time of Peak (min)	Outflow Peak (cfs)	Time of Peak (min)		
46	1968.8	897.5	2019.4	897.5	3	2741.2	822.5	2828.5	977.5	3	3472.3	832.5	3803.3	977.5	10	46
47	186.8	717.5	186.8	717.5	0	289.0	717.5	289.0	717.5	0	400.4	717.5	400.4	717.5	0	47
48	245.7	762.5	245.7	762.5	0	368.9	762.5	368.9	762.5	0	497.7	762.5	497.7	762.5	0	48
49	337.4	747.5	337.4	747.5	0	500.6	812.5	500.6	812.5	0	658.4	812.5	658.4	812.5	0	49
50	186.3	717.5	186.3	717.5	0	274.9	717.5	274.9	717.5	0	371.6	717.5	371.6	717.5	0	50
51	339.9	722.5	339.9	722.5	0	484.7	722.5	484.7	722.5	0	707.6	732.5	707.6	732.5	0	51
52	401.9	732.5	401.9	732.5	0	572.1	732.5	572.1	732.5	0	800.2	742.5	800.2	742.5	0	52
53	689.3	742.5	689.3	742.5	0	990.8	732.5	990.8	732.5	0	1308.8	742.5	1308.8	742.5	0	53
54	746.8	747.5	746.8	747.5	0	1095.6	757.5	1095.6	757.5	0	1440.5	767.5	1440.5	767.5	0	54
55	2300.0	837.5	2300.0	837.5	0	3461.7	822.5	3461.7	822.5	0	4389.0	832.5	4389.0	832.5	0	55
56	2317.1	792.5	2321.9	792.5	0	3485.1	867.5	3487.7	867.5	0	4416.8	877.5	4419.1	877.5	0	56
57	106.1	717.5	106.1	717.5	0	155.0	717.5	155.0	717.5	0	208.3	717.5	208.3	717.5	0	57
58	2347.1	792.5	2351.9	792.5	0	3500.8	867.5	3503.3	867.5	0	4434.0	877.5	4436.3	877.5	0	58
59	2414.3	822.5	2419.1	822.5	0	3566.7	897.5	3569.2	897.5	0	4522.3	907.5	4524.7	907.5	0	59
60	2485.7	827.5	2490.5	827.5	0	3484.5	922.5	3489.3	922.5	0	4573.6	932.5	4575.9	932.5	0	60
61	166.9	717.5	166.9	717.5	0	264.9	717.5	264.9	717.5	0	378.3	717.5	378.3	717.5	0	61
62	263.9	762.5	263.9	762.5	0	375.0	762.5	375.0	762.5	0	501.0	762.5	501.0	762.5	0	62
63	306.8	767.5	306.8	767.5	0	435.0	767.5	435.0	767.5	0	577.4	767.5	577.4	767.5	0	63
64	225.4	717.5	225.4	717.5	0	318.0	717.5	318.0	717.5	0	412.6	717.5	412.6	717.5	0	64
65	193.8	767.5	193.8	767.5	0	453.4	737.5	453.4	737.5	0	690.6	727.5	690.6	727.5	0	65
66	500.6	767.5	500.6	767.5	0	810.7	737.5	810.7	737.5	0	1055.3	732.5	1055.3	732.5	0	66
67	575.3	767.5	594.8	767.5	3	939.3	747.5	967.3	747.5	3	1229.2	742.5	1261.9	742.5	3	67
68	620.4	782.5	646.0	772.5	4	1011.9	762.5	1045.7	762.5	3	1327.2	757.5	1366.3	757.5	3	68
69	164.4	717.5	164.4	717.5	0	254.6	717.5	254.6	717.5	0	352.9	717.5	352.9	717.5	0	69
70	715.7	772.5	743.3	772.5	4	1157.1	762.5	1190.8	762.5	3	1515.2	757.5	1554.2	757.5	3	70
71	2993.9	827.5	3012.8	827.5	1	3754.0	922.5	3767.0	922.5	0	4877.7	932.5	4887.6	932.5	0	71
72	93.8	817.5	93.8	817.5	0	146.9	792.5	146.9	792.5	0	198.2	782.5	198.2	782.5	0	72
73	126.7	782.5	130.1	787.5	3	197.9	777.5	201.8	777.5	2	271.5	772.5	275.5	772.5	1	73
74	239.9	747.5	258.7	722.5	8	367.2	722.5	406.7	722.5	11	526.1	722.5	576.5	717.5	10	74
75	3168.7	827.5	3194.2	827.5	1	3879.3	922.5	3896.3	922.5	0	5017.7	932.5	5031.5	932.5	0	75
76	3232.8	827.5	3263.7	827.5	1	3913.8	922.5	3954.5	847.5	1	4884.9	932.5	4888.0	932.5	0	76
77	3247.9	832.5	3278.9	832.5	1	3926.7	852.5	3971.6	852.5	1	4893.6	937.5	4896.7	937.5	0	77

Rainfall Taken From PA Bulletin For Region V

2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
2.94"	3.76"	4.43"	5.25"	5.89"	6.50"

APPENDIX B (continued)
Sawkill Creek Watershed
Existing vs. Future Conditions Runoff Comparison
Cumulative Watershed Flows

Subarea No.	25 YEAR EVENT - WATERSHED OUTFLOW					50 YEAR EVENT - WATERSHED OUTFLOW					100 YEAR EVENT - WATERSHED OUTFLOW					Subarea No.
	EXISTING		FUTURE		% DIFF-ERENCE	EXISTING		FUTURE		% DIFF-ERENCE	EXISTING		FUTURE		% DIFF-ERENCE	
	Outflow Peak (cfs)	Time of Peak (min)	Outflow Peak (cfs)	Time of Peak (min)		Outflow Peak (cfs)	Time of Peak (min)	Outflow Peak (cfs)	Time of Peak (min)		Outflow Peak (cfs)	Time of Peak (min)	Outflow Peak (cfs)	Time of Peak (min)		
1	183.0	717.5	183.0	717.5	0	278.8	717.5	278.8	717.5	0	388.4	717.5	388.4	717.5	0	1
2	337.6	742.5	337.6	742.5	0	486.2	752.5	486.2	752.5	0	638.4	752.5	638.4	752.5	0	2
3	452.3	757.5	504.6	757.5	12	636.6	757.5	691.9	757.5	9	833.5	777.5	875.2	777.5	5	3
4	338.8	717.5	452.5	717.5	34	470.4	717.5	604.9	717.5	29	613.3	717.5	758.3	717.5	24	4
5	163.0	717.5	220.8	717.5	35	245.8	717.5	312.1	717.5	27	337.0	717.5	410.5	717.5	22	5
6	565.8	827.5	673.7	717.5	19	774.3	827.5	917.5	717.5	18	968.3	822.5	1175.8	717.5	21	6
7	615.1	787.5	786.6	787.5	28	872.4	787.5	1073.2	787.5	23	1149.8	787.5	1374.8	787.5	20	7
8	680.3	812.5	851.8	812.5	25	953.2	812.5	1154.1	812.5	21	1245.8	812.5	1470.8	812.5	18	8
9	229.9	717.5	229.9	717.5	0	337.2	717.5	337.2	717.5	0	454.2	717.5	454.2	717.5	0	9
10	430.0	732.5	430.0	732.5	0	519.6	732.5	519.6	732.5	0	619.8	727.5	619.8	727.5	0	10
11	841.3	732.5	997.3	812.5	19	1131.0	812.5	1331.8	812.5	18	1454.1	812.5	1679.1	812.5	15	11
12	945.3	737.5	1055.3	817.5	12	1231.0	737.5	1406.0	817.5	14	1543.8	817.5	1768.8	817.5	15	12
13	564.7	717.5	594.8	717.5	5	727.7	717.5	759.5	717.5	4	877.7	717.5	907.3	717.5	3	13
14	752.4	732.5	860.8	732.5	14	877.4	732.5	1021.1	727.5	16	1027.0	727.5	1234.9	717.5	20	14
15	282.2	717.5	476.7	717.5	69	404.8	717.5	626.0	717.5	55	537.8	717.5	768.7	717.5	43	15
16	936.6	732.5	1162.3	717.5	24	1139.0	717.5	1582.8	717.5	39	1532.6	717.5	2003.6	717.5	31	16
17	1000.5	737.5	1232.4	722.5	23	1230.2	722.5	1496.2	757.5	22	1477.0	757.5	2070.8	757.5	40	17
18	247.3	717.5	272.3	717.5	10	361.2	717.5	389.8	717.5	8	485.0	717.5	518.0	717.5	7	18
19	135.5	897.5	139.0	897.5	3	179.9	882.5	183.8	882.5	2	215.9	882.5	219.2	882.5	2	19
20	153.4	717.5	153.4	717.5	0	221.2	717.5	221.2	717.5	0	292.1	717.5	292.1	717.5	0	20
21	175.6	837.5	178.8	837.5	2	232.4	717.5	232.5	717.5	0	308.1	717.5	308.1	717.5	0	21
22	336.4	932.5	748.7	832.5	123	941.9	832.5	1243.7	782.5	32	1310.8	782.5	2079.6	767.5	59	22
23	351.2	937.5	793.2	837.5	126	985.1	837.5	1332.6	787.5	35	1396.7	787.5	1730.1	802.5	24	23
24	415.8	942.5	915.0	842.5	120	1132.8	842.5	1553.1	792.5	37	1658.1	792.5	1903.3	807.5	15	24
25	60.9	717.5	100.6	717.5	65	94.4	717.5	140.9	717.5	49	131.0	717.5	185.2	717.5	41	25
26	377.3	977.5	621.6	897.5	65	793.0	872.5	1035.2	857.5	31	1195.3	852.5	1497.3	847.5	25	26
27	116.9	717.5	116.9	717.5	0	168.9	717.5	168.9	717.5	0	223.5	717.5	223.5	717.5	0	27
28	406.3	867.5	647.5	892.5	59	829.9	872.5	1076.7	857.5	30	1244.6	852.5	1548.7	847.5	24	28
29	434.7	837.5	667.4	897.5	54	857.4	872.5	1111.0	857.5	30	1283.0	857.5	1596.8	842.5	24	29
30	1317.4	817.5	1572.7	817.5	19	1818.8	817.5	2348.1	817.5	29	2620.7	817.5	3207.9	817.5	22	30
31	1414.9	837.5	1649.0	917.5	17	1923.4	917.5	2452.7	917.5	28	2751.0	917.5	3338.2	917.5	21	31
32	417.0	717.5	417.0	717.5	0	607.3	717.5	607.3	717.5	0	814.5	717.5	814.5	717.5	0	32
33	208.7	717.5	208.7	717.5	0	302.4	717.5	302.4	717.5	0	403.5	717.5	403.5	717.5	0	33
34	626.1	717.5	626.1	717.5	0	910.1	717.5	910.1	717.5	0	1218.6	717.5	1218.6	717.5	0	34
35	437.6	772.5	437.6	772.5	0	828.4	757.5	828.4	757.5	0	1295.5	752.5	1295.5	752.5	0	35
36	523.2	777.5	523.2	777.5	0	907.0	777.5	907.0	777.5	0	1444.4	772.5	1444.4	772.5	0	36
37	1718.0	837.5	1809.7	917.5	5	2265.1	837.5	2660.2	917.5	17	3001.5	917.5	3588.7	917.5	20	37
38	1740.0	852.5	1820.6	932.5	5	2294.2	852.5	2675.4	932.5	17	3020.5	932.5	3607.8	932.5	19	38
39	167.5	717.5	167.5	717.5	0	262.8	717.5	262.8	717.5	0	363.5	717.5	363.5	717.5	0	39
40	271.7	732.5	271.7	732.5	0	413.7	732.5	413.7	732.5	0	563.3	732.5	563.3	732.5	0	40
41	360.1	777.5	360.1	777.5	0	534.3	777.5	534.3	777.5	0	716.0	777.5	716.0	777.5	0	41
42	464.7	777.5	464.7	777.5	0	665.6	777.5	665.6	777.5	0	885.5	717.5	885.5	717.5	0	42
43	173.1	717.5	173.1	717.5	0	267.4	717.5	267.4	717.5	0	369.2	717.5	369.2	717.5	0	43
44	576.6	717.5	576.6	717.5	0	892.9	717.5	892.9	717.5	0	1255.2	717.5	1255.2	717.5	0	44
45	1944.6	852.5	1995.2	852.5	3	2657.0	777.5	2810.9	932.5	6	3373.2	787.5	3776.4	932.5	12	45

APPENDIX B
Sawkill Creek Watershed
Existing vs. Future Conditions Runoff Comparison
Individual Subarea Flows

Subarea No.	2.33 YEAR EVENT - SUBAREA RUNOFF					5 YEAR EVENT - SUBAREA RUNOFF					10 YEAR EVENT - SUBAREA RUNOFF					Subarea No.
	EXISTING		FUTURE		% DIFF-ERENCE	EXISTING		FUTURE		% DIFF-ERENCE	EXISTING		FUTURE		% DIFF-ERENCE	
	Runoff Peak (cfs)	Time of Peak (min)	Runoff Peak (cfs)	Time of Peak (min)		Runoff Peak (cfs)	Time of Peak (min)	Runoff Peak (cfs)	Time of Peak (min)		Runoff Peak (cfs)	Time of Peak (min)	Runoff Peak (cfs)	Time of Peak (min)		
1	3.6	762.5	3.6	762.5	0	39.0	762.5	39.0	762.5	0	87.2	717.5	87.2	717.5	0	1
2	4.8	762.5	4.8	762.5	0	48.6	747.5	48.6	747.5	0	114.0	717.5	114.0	717.5	0	2
3	1.0	602.5	4.6	762.5	360	14.9	762.5	48.0	747.5	222	55.6	747.5	110.5	717.5	99	3
4	26.2	747.5	63.2	717.5	141	98.2	717.5	167.0	717.5	70	191.0	717.5	283.9	717.5	49	4
5	1.8	747.5	10.8	747.5	500	27.9	717.5	56.0	717.5	101	77.7	717.5	118.2	717.5	52	5
6	0.0	747.5	0.0	747.5	0	0.1	717.5	0.1	717.5	0	0.3	717.5	0.3	717.5	0	6
7	0.8	587.5	0.8	587.5	0	21.7	762.5	21.7	762.5	0	67.1	747.5	67.1	747.5	0	7
8	2.1	747.5	2.1	747.5	0	35.6	747.5	35.6	747.5	0	94.8	717.5	94.8	717.5	0	8
9	4.7	747.5	4.7	747.5	0	47.0	717.5	47.0	717.5	0	115.1	717.5	115.1	717.5	0	9
10	5.6	762.5	5.6	762.5	0	55.5	717.5	55.5	717.5	0	138.0	717.5	138.0	717.5	0	10
11	0.0	747.5	0.0	747.5	0	0.1	717.5	0.1	717.5	0	0.1	717.5	0.1	717.5	0	11
12	1.3	747.5	1.3	747.5	0	24.1	747.5	24.1	747.5	0	60.4	717.5	60.4	717.5	0	12
13	76.9	717.5	95.2	717.5	24	220.7	717.5	247.1	717.5	12	366.0	717.5	394.1	717.5	8	13
14	37.2	747.5	85.7	717.5	130	134.1	717.5	233.5	717.5	74	267.4	717.5	396.9	717.5	48	14
15	9.9	747.5	70.1	717.5	608	65.8	717.5	183.6	717.5	179	145.1	717.5	303.1	717.5	109	15
16	0.0	762.5	0.0	762.5	0	0.0	747.5	0.0	747.5	0	0.0	717.5	0.0	717.5	0	16
17	8.0	747.5	27.8	717.5	248	37.3	717.5	70.9	717.5	90	72.8	717.5	114.8	717.5	58	17
18	8.6	762.5	13.3	747.5	55	55.4	717.5	68.6	717.5	24	126.8	717.5	145.9	717.5	15	18
19	43.9	747.5	43.9	747.5	0	142.1	717.5	142.1	717.5	0	272.0	717.5	272.0	717.5	0	19
20	10.0	762.5	10.0	762.5	0	40.3	717.5	40.3	717.5	0	83.1	717.5	83.1	717.5	0	20
21	0.0	747.5	0.0	747.5	0	0.1	717.5	0.1	717.5	0	0.3	717.5	0.3	717.5	0	21
22	93.6	717.5	145.2	717.5	55	231.6	717.5	311.3	717.5	34	383.4	717.5	481.6	717.5	26	22
23	4.8	762.5	27.5	717.5	473	30.3	717.5	79.7	717.5	163	69.7	717.5	137.7	717.5	98	23
24	24.4	762.5	24.4	762.5	0	82.5	717.5	82.5	717.5	0	164.4	717.5	164.4	717.5	0	24
25	0.6	747.5	7.9	747.5	1217	11.2	747.5	28.5	717.5	154	28.1	717.5	56.1	717.5	100	25
26	5.4	747.5	5.4	747.5	0	27.4	717.5	27.4	717.5	0	58.5	717.5	58.5	717.5	0	26
27	7.7	762.5	7.7	762.5	0	30.6	717.5	30.6	717.5	0	63.1	717.5	63.1	717.5	0	27
28	0.0	747.5	0.0	747.5	0	0.1	717.5	0.1	717.5	0	0.3	717.5	0.3	717.5	0	28
29	2.1	747.5	8.1	747.5	286	32.8	717.5	53.1	717.5	62	90.5	717.5	119.6	717.5	32	29
30	0.0	747.5	0.0	747.5	0	0.1	717.5	0.1	717.5	0	0.3	717.5	0.3	717.5	0	30
31	0.9	747.5	0.9	747.5	0	55.9	762.5	55.9	762.5	0	147.7	747.5	147.7	747.5	0	31
32	14.5	747.5	14.5	747.5	0	94.2	717.5	94.2	717.5	0	214.6	717.5	214.6	717.5	0	32
33	4.3	747.5	4.3	747.5	0	44.1	717.5	44.1	717.5	0	104.5	717.5	104.5	717.5	0	33
34	0.0	747.5	0.0	747.5	0	0.1	717.5	0.1	717.5	0	0.3	717.5	0.3	717.5	0	34
35	5.8	762.5	5.8	762.5	0	38.9	762.5	38.9	762.5	0	79.9	747.5	79.9	747.5	0	35
36	2.3	762.5	2.3	762.5	0	25.1	762.5	25.1	762.5	0	56.4	717.5	56.4	717.5	0	36
37	0.0	747.5	0.0	747.5	0	0.1	717.5	0.1	717.5	0	0.3	717.5	0.3	717.5	0	37
38	0.2	747.5	0.2	747.5	0	11.2	747.5	11.2	747.5	0	30.3	717.5	30.3	717.5	0	38
39	0.5	747.5	0.5	747.5	0	25.7	747.5	25.7	747.5	0	74.4	717.5	74.4	717.5	0	39
40	0.4	747.5	0.4	747.5	0	21.4	747.5	21.4	747.5	0	60.6	717.5	60.6	717.5	0	40
41	1.2	747.5	1.2	747.5	0	23.2	762.5	23.2	762.5	0	55.3	717.5	55.3	717.5	0	41
42	5.3	747.5	5.3	747.5	0	53.1	717.5	53.1	717.5	0	130.9	717.5	130.9	717.5	0	42
43	1.8	747.5	1.8	747.5	0	31.2	747.5	31.2	747.5	0	80.4	717.5	80.4	717.5	0	43
44	0.0	747.5	0.0	747.5	0	0.1	717.5	0.1	717.5	0	0.3	717.5	0.3	717.5	0	44
45	0.0	747.5	0.0	747.5	0	0.1	717.5	0.1	717.5	0	0.3	717.5	0.3	717.5	0	45

APPENDIX B (continued)
Sawkill Creek Watershed
Existing vs. Future Conditions Runoff Comparison
Individual Subarea Flows

ubarea No.	2.33 YEAR EVENT - SUBAREA RUNOFF					5 YEAR EVENT - SUBAREA RUNOFF					10 YEAR EVENT - SUBAREA RUNOFF					Subarea No.
	EXISTING		FUTURE		% DIFF-ERENCE	EXISTING		FUTURE		% DIFF-ERENCE	EXISTING		FUTURE		% DIFF-ERENCE	
	Runoff Peak (cfs)	Time of Peak (min)	Runoff Peak (cfs)	Time of Peak (min)		Runoff Peak (cfs)	Time of Peak (min)	Runoff Peak (cfs)	Time of Peak (min)		Runoff Peak (cfs)	Time of Peak (min)	Runoff Peak (cfs)	Time of Peak (min)		
46	3.6	622.5	3.6	622.5	0	4.2	762.5	4.2	762.5	0	36.6	747.5	36.6	747.5	0	46
47	1.9	747.5	1.9	747.5	0	34.0	747.5	34.0	747.5	0	86.4	717.5	86.4	717.5	0	47
48	0.5	587.5	0.5	587.5	0	13.4	747.5	13.4	747.5	0	42.8	717.5	42.8	717.5	0	48
49	2.0	747.5	2.0	747.5	0	37.4	747.5	37.4	747.5	0	91.9	717.5	91.9	717.5	0	49
50	3.8	747.5	3.8	747.5	0	37.7	717.5	37.7	717.5	0	92.8	717.5	92.8	717.5	0	50
51	2.0	747.5	2.0	747.5	0	37.2	762.5	37.2	762.5	0	88.5	747.5	88.5	747.5	0	51
52	1.0	747.5	1.0	747.5	0	15.4	717.5	15.4	717.5	0	42.8	717.5	42.8	717.5	0	52
53	0.0	747.5	0.0	747.5	0	0.1	717.5	0.1	717.5	0	0.3	717.5	0.3	717.5	0	53
54	3.2	632.5	3.2	632.5	0	1.3	747.5	1.3	747.5	0	21.4	747.5	21.4	747.5	0	54
55	0.0	747.5	0.0	747.5	0	0.1	717.5	0.1	717.5	0	0.3	717.5	0.3	717.5	0	55
56	3.1	622.5	0.9	612.5	-71	3.5	747.5	7.4	747.5	111	27.9	747.5	35.7	747.5	28	56
57	2.2	747.5	2.2	747.5	0	21.9	717.5	21.9	717.5	0	53.4	717.5	53.4	717.5	0	57
58	0.0	747.5	0.0	747.5	0	0.1	717.5	0.1	717.5	0	0.3	717.5	0.3	717.5	0	58
59	3.3	632.5	3.3	632.5	0	1.4	747.5	1.4	747.5	0	25.3	762.5	25.3	762.5	0	59
60	1.2	602.5	1.2	602.5	0	16.6	762.5	16.6	762.5	0	61.7	747.5	61.7	747.5	0	60
61	0.4	747.5	0.4	747.5	0	27.2	762.5	27.2	762.5	0	71.9	717.5	71.9	717.5	0	61
62	6.5	762.5	6.5	762.5	0	40.1	747.5	40.1	747.5	0	92.8	717.5	92.8	717.5	0	62
63	0.6	612.5	0.6	612.5	0	5.1	747.5	5.1	747.5	0	24.6	747.5	24.6	747.5	0	63
64	11.1	747.5	11.1	747.5	0	60.1	717.5	60.1	717.5	0	124.3	717.5	124.3	717.5	0	64
65	4.7	762.5	4.7	762.5	0	46.6	717.5	46.6	717.5	0	115.9	717.5	115.9	717.5	0	65
66	0.0	747.5	0.0	747.5	0	0.1	717.5	0.1	717.5	0	0.3	717.5	0.3	717.5	0	66
67	0.6	587.5	3.3	762.5	450	15.3	747.5	33.2	747.5	117	47.3	717.5	81.1	717.5	71	67
68	0.3	587.5	0.2	747.5	-33	8.1	762.5	11.1	762.5	37	25.1	747.5	29.6	747.5	18	68
69	1.7	747.5	1.7	747.5	0	30.0	747.5	30.0	747.5	0	75.9	717.5	75.9	717.5	0	69
70	0.0	747.5	0.0	747.5	0	0.1	717.5	0.1	717.5	0	0.3	717.5	0.3	717.5	0	70
71	0.0	747.5	0.0	747.5	0	0.1	717.5	0.1	717.5	0	0.3	717.5	0.3	717.5	0	71
72	1.9	747.5	1.9	747.5	0	35.4	747.5	35.4	747.5	0	87.3	717.5	87.3	717.5	0	72
73	0.7	612.5	0.8	602.5	14	6.0	747.5	10.1	747.5	68	28.8	717.5	37.8	717.5	31	73
74	0.5	747.5	2.2	747.5	340	28.7	747.5	36.7	747.5	28	79.9	717.5	96.3	717.5	21	74
75	0.0	747.5	0.0	747.5	0	0.1	717.5	0.1	717.5	0	0.3	717.5	0.3	717.5	0	75
76	1.0	587.5	0.6	747.5	-40	25.3	747.5	34.6	747.5	37	79.1	717.5	95.7	717.5	21	76
77	3.0	632.5	3.0	632.5	0	1.2	747.5	1.2	747.5	0	17.6	747.5	17.6	747.5	0	77

Rainfall Taken From PA Bulletin For Region V

2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
2.94"	3.76"	4.43"	5.25"	5.89"	6.50"

APPENDIX C

APPENDIX C

EXAMPLE NO. 1:

THE RELEASE RATE PERCENTAGE CONCEPT

A sample watershed, with five subareas, is shown on Figure C-1. The figure also includes a hydrograph generated by a rainfall event on the watershed, which presents the individual hydrographs for Subarea No. 3 and the cumulative rate of runoff for the total watershed.

As can be seen by investigating Subarea 3, the travel time for runoff flow from Subarea 3 through Subarea Nos. 4 and 5 is 40 minutes. This represents the time at which Subarea 3 begins contributing flow to the downstream point of interest. Subarea 3's maximum discharge of 500 cfs arrives at the outlet point at 60 minutes, and the contributing rate to the watershed peak is 400 cfs, occurring at 70 minutes.

Now assume a land use modification within Subarea 3 increases the maximum discharge rate to 800 cfs (Figure C-2). After utilizing appropriate stormwater management techniques, the peak discharge rate is reduced to the pre-development peak discharge rate of 500 cfs. However, because of the attenuation of the runoff hydrograph from Subarea 3, which extends the time period during which the discharge rate is approximately 500 cfs, the combined runoff discharge peak at the point of interest is still above the pre-development peak rate of runoff. Therefore, although the development design may appear to be in compliance with Act 167, the actual impact of the stormwater management facility in the watershed is to increase the peak rate of runoff at the downstream point of interest.

A more complex situation is created if development is proposed for Subarea Nos. 4 or 5. Figure C-3 illustrates the effects of a proposed development site located in Subarea 5 which increased the peak subarea rate of runoff by 50 cfs. Also shown is the case where a potential development site is located in Subarea 4, which increases the peak subarea runoff by 100 cfs. Appropriate stormwater management techniques are implemented in both development areas to reduce the post-development peak runoff rate to the pre-development peak runoff rate. Through close inspection of Figure C-3, it can be seen that the stormwater management techniques implemented in Subarea 5 have no adverse impact at the outlet from the watershed (or point of interest). However, the stormwater management techniques implemented in Subarea 4 (Figure C-4) will generate an increase in the peak rate of runoff at the watershed outlet.

During the 30-minute period of time prior to and coincident with the occurrence of the watershed peak runoff rate, the projected post-development peak runoff rates from Subarea No. 3 and 4 will result in an increase of the peak flow rate at the watershed outlet. This same condition will occur in most watersheds. However, the duration of this sensitive time period prior to occurrence of the watershed peak runoff rate will vary for each watershed depending on its shape, size, slope, terrain, current land use, and projected development trends.

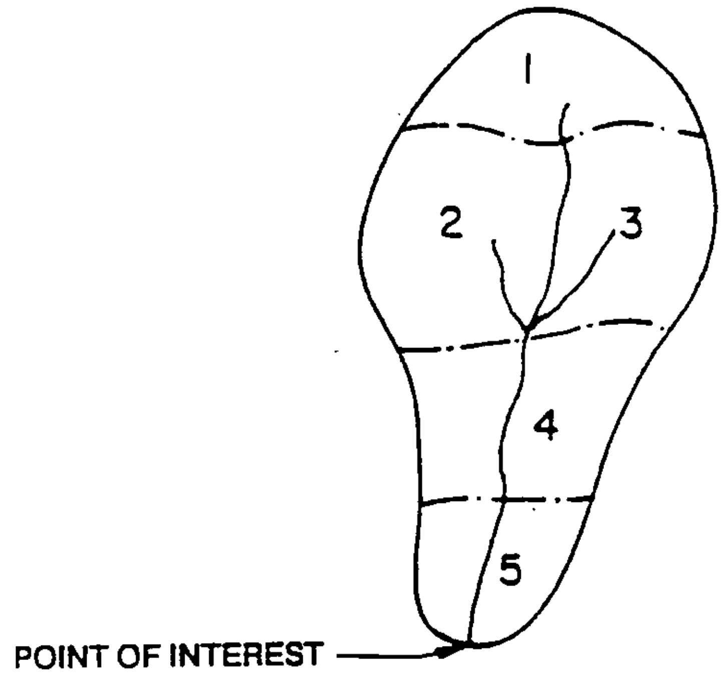


FIGURE C-1

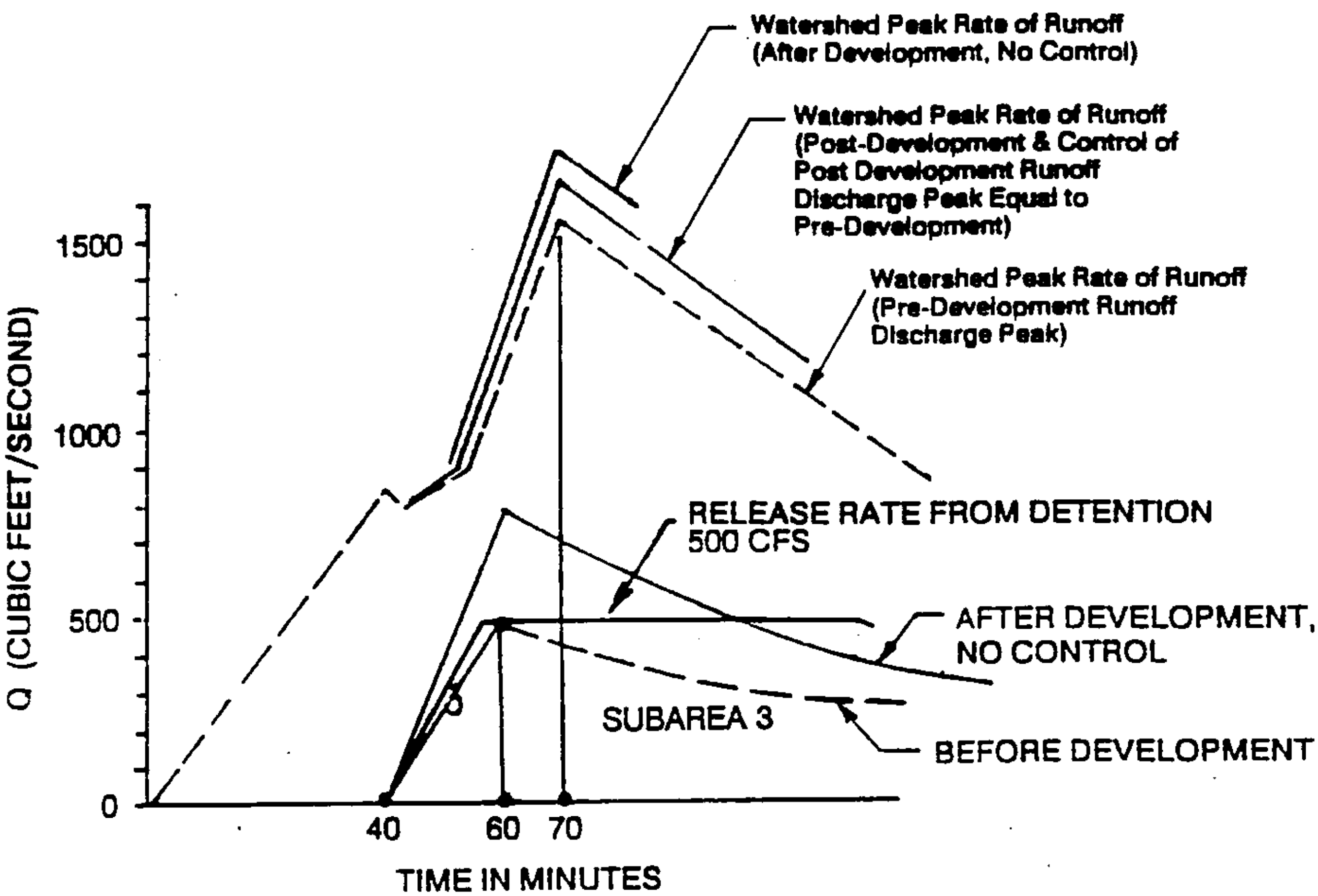
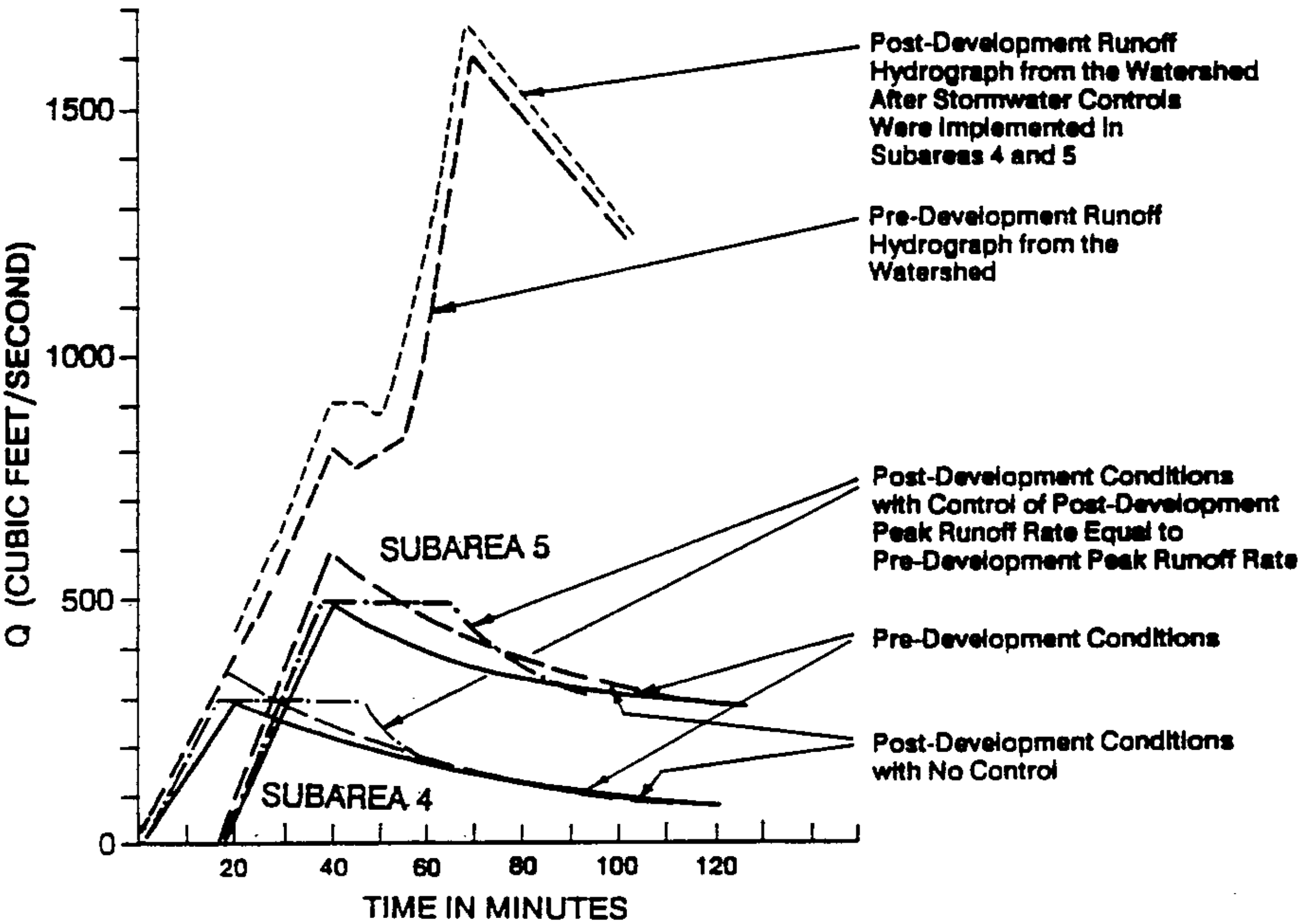
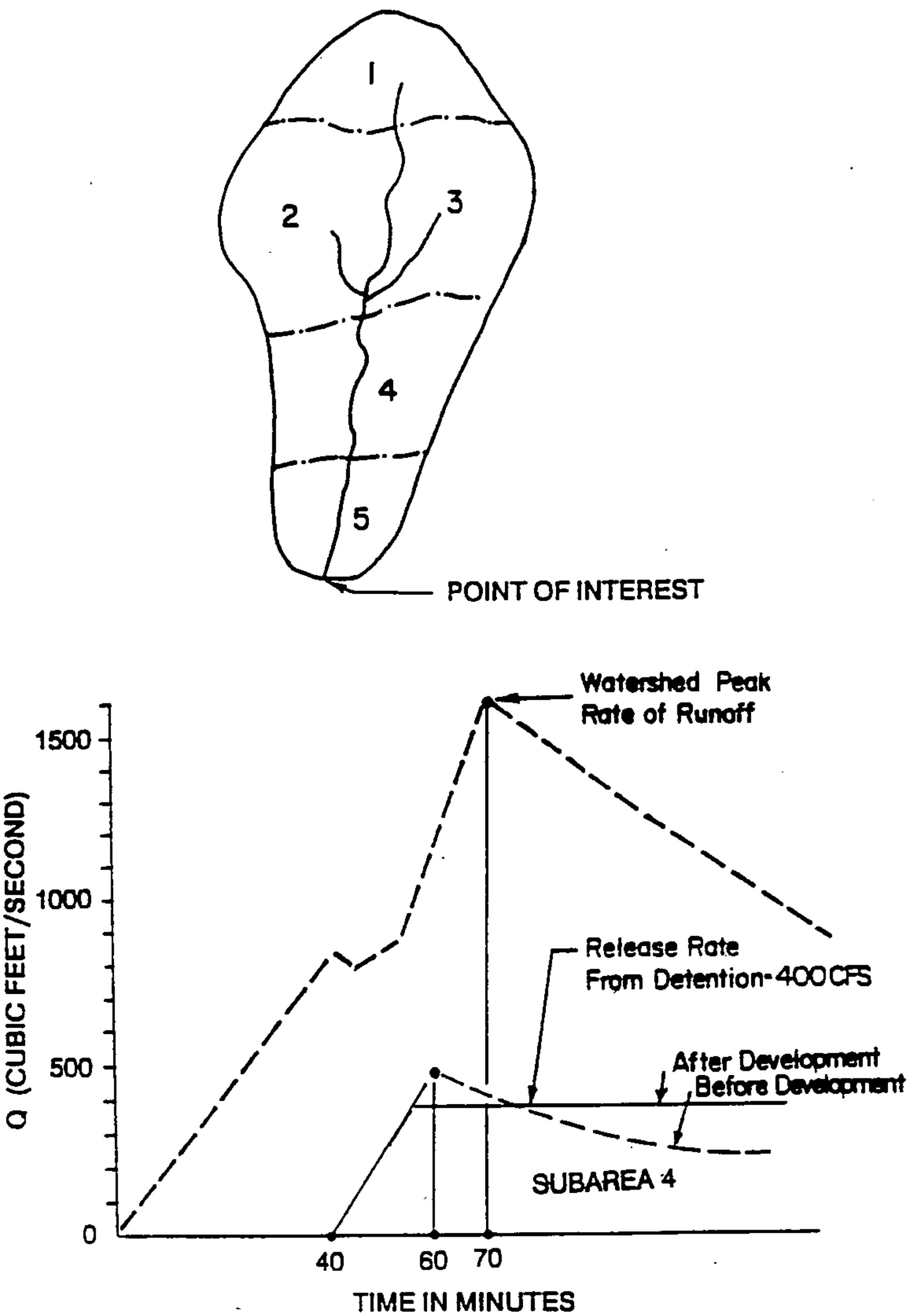


FIGURE C-2
WATERSHED HYDROGRAPH



WATERSHED IMPACT WITH CONTROL OF POST-DEVELOPMENT PEAK EQUAL TO PRE-DEVELOPMENT PEAK IN SUBAREAS 4 AND 5



WATERSHED AND SUBAREA HYDROGRAPHS

The release rate percentage, which is a form of comprehensive watershed management planning, was developed as a potential method for regulating the stormwater runoff rates from subareas within a watershed having runoff timing impacts similar to Subarea Nos. 3 and 4 illustrated in the example. A safe release rate for Subarea 3 is determined by computing the ratio of the subarea rate of runoff that is contributing to the peak at the downstream point of interest to the pre-development peak rate of runoff for the subarea itself.

$$\frac{\text{subarea contributing rate}}{\text{subarea pre-development peak rate of runoff}} = \text{release rate percentage}$$

$$\frac{400 \text{ cfs}}{500 \text{ cfs}} \times 100\% = 80 \text{ percent}$$

In order to demonstrate specifically how the release rate percentage is applied, an example is most effective.

A person interested in developing a tract of land located in Subarea 1 desires to preliminarily design his stormwater management system. First the pre-development peak runoff (Qpre) for all design rainfall events must be determined. Knowing that the 80% release rate was assigned to this subarea, the predevelopment peak discharges (Qpre) for all design events is then multiplied by 0.80 to define the maximum allowable peak runoff rates from the site after development. A stormwater management facility is, therefore, required to reduce the post-development uncontrolled peak runoff rates from the design rainfall events to 80 percent of the pre-development peak runoff rates prior to leaving the development site. This 80 percent release rate is the "performance standard" applied to Subarea 1.

APPENDIX C

EXAMPLE NO. 2:

DOWNSTREAM IMPACT EVALUATION

One method for completing Item b of the downstream impact evaluation involves the following steps.

1. Identify the subarea in which the proposed development site is located.

2. Calculate the full stormwater runoff hydrographs from the proposed development site (for the design rainfall events) for the following conditions:

    a. Pre-development conditions;

    b. Post-development conditions; and,

    c. Post-development conditions with a proposed stormwater management system;

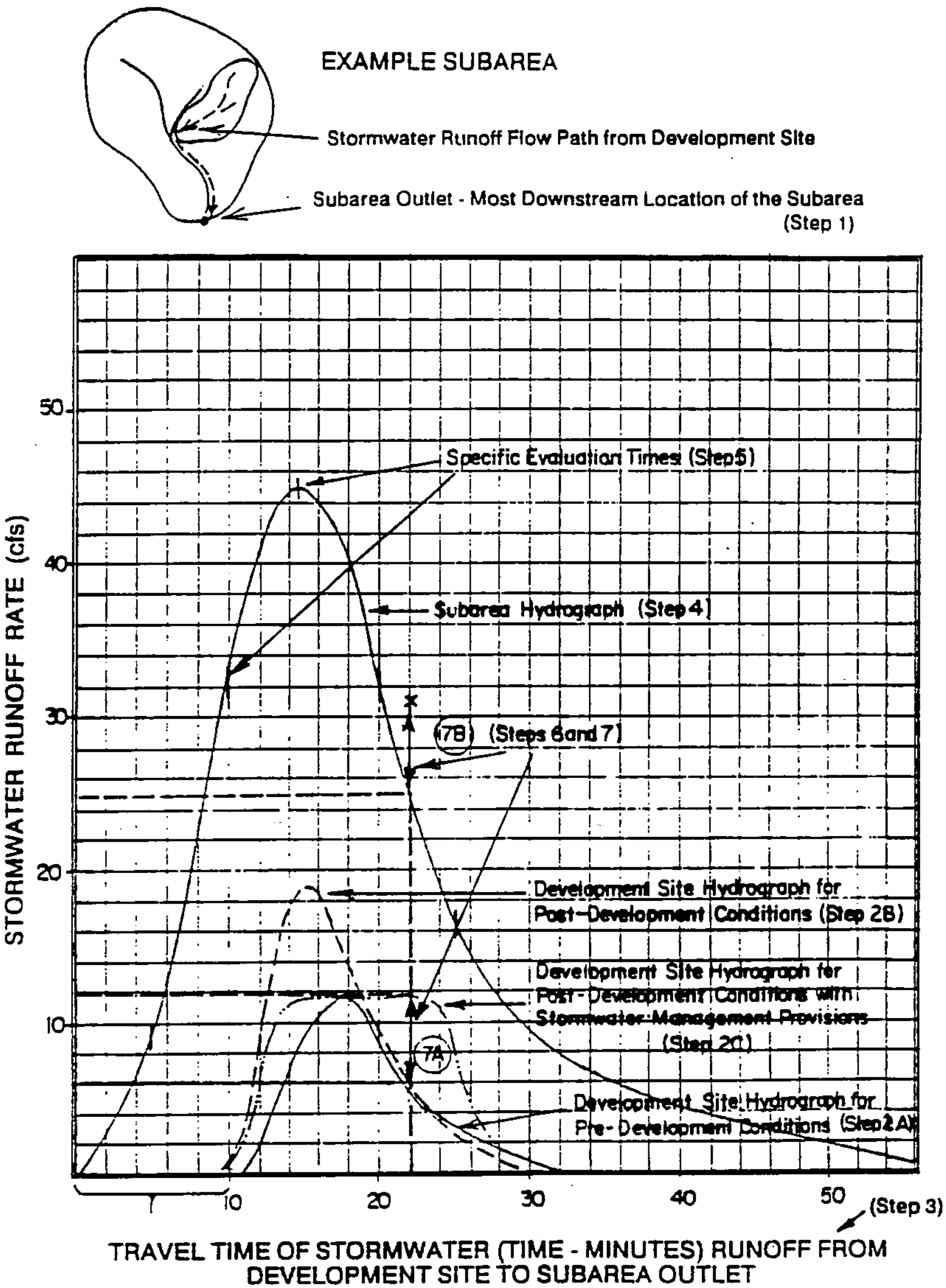
    A recommended method for developing these hydrographs is provided in the TR-55 document (Reference 3).

3. Determine the time required (i.e., the "travel time") for a unit or volume of stormwater to flow from the outlet point of the proposed development site to the outlet point of the subarea in which the site is located.

4. Prepare a graph that includes the runoff hydrographs for the proposed development site developed in Step 2 above. In addition, obtain the runoff hydrographs for the subarea in which the proposed development site is located for the design rainfall events from the Pike County Planning Commission (see Figure C-5). The subarea runoff hydrographs are a direct output of the watershed model that has been developed and calibrated for this study.

5. Calculate the difference in runoff rates, if any, between the pre- and post-development hydrographs for the development site (with a proposed stormwater management system) for at least five specific times spaced evenly throughout the duration of the design rainfall/runoff events (see Figure C-5).

6. If, at any specific time, a runoff rate on the development site post-development hydrograph (with a stormwater management system) is greater than therunoff rate at the same time on the pre-development hydrograph, this increase should be added to the subarea hydrograph at that specific time (see Figure C-5).



ILLUSTRATIONS OF THE HYDROGRAPHS REQUIRED FOR THE DOWNSTREAM IMPACT EVALUATION

7. If, at any specific time, the increase in runoff rate on the subarea hydrograph is calculated to be greater than the original runoff rate on the subarea hydrograph, then the proposed stormwater management system should be modified to eliminate the increase as required.

Example Computation:

A. At a point 22 minutes after the beginning of the runoff event, the contribution to the stormwater runoff rate from the development site has increased above pre-development conditions by approximately 6 cfs (with stormwater management provisions):

- The pre-development stormwater runoff rate from the development site that has traveled to the subarea outlet point 22 minutes after the beginning of the runoff event = 6 cfs;

- The subarea stormwater runoff rate 22 minutes after the beginning of the runoff event prior to new development conditions = 25 cfs;

- The post-development (with stormwater management provisions) stormwater runoff rate from the development site that has traveled to the subarea outlet point 22 minutes after the beginning of the runoff event = 12 cfs.

B. The increase in the subarea stormwater runoff rate at 22 minutes is 6 cfs with the proposed stormwater management provisions in place. Therefore, the percent increase in the subarea stormwater runoff rate at 22 minutes is greater than the pre-development stormwater runoff rate. In this illustration, the downstream impact criterion has not been attained and adjustments to the stormwater management system are required.

8. When the increase in the subarea runoff rate is eliminated for the post-development conditions (with the stormwater management system in place) at all five specific times during the rainfall/runoff event, the downstream impact evaluation standard is achieved.

The procedure described above is one of many appropriate engineering analyses for completing the downstream impact evaluation. Other procedures include computer modeling of the subarea divided into "sub-subareas", or the Tabular Method presented in SCS Technical Release No. 55, etc. The main objective of presenting this specific procedure was to better illustrate the general content of the downstream impact evaluation.

During the 30-minute period of time prior to and coincident with the occurrence of the watershed peak runoff rate, the projected post-development peak runoff rates from Subarea No. 3 and 4 will result in an increase of the peak flow rate at the watershed outlet. This same condition will occure in most watersheds. However, the duration of this sensitive time period prior to occurance of the watershed peak runoff rate will vary for each watershed depending on its shape, size, slope, terrain, current land use, and projected development trends.

The release rate percentage, which is a form of comprehensive watershed management planning, was developed as a potential method for regulating the stormwater runoff rates from subareas within a watershed having runoff timing impacts similar to Subarea Nos. 3 and 4 illystrated in the example. A safe release rate for Subarea 3 is determined by computing the ratio of the subarea rate of runoff that is contributing to the peak at the downstream point of interest to the pre-development peak rate of runoff for the subarea itself.

$$\frac{\text{subarea contributing rate}}{\text{subarea pre-development peak rate of runoff}} = \text{release rate percentage}$$

$$\frac{400 \text{ cfs}}{500 \text{ cfs}} \times 100\% = 80 \text{ percent}$$

In order to demonstrate specifically how the release rate percentage is applied, an example is most effective.

APPENDIX D

APPENDIX D

SAMPLE IMPLEMENTATION OF
RECOMMENDED PERFORMANCE CRITERIA

1.0 INTRODUCTION

In general, when sites become developed, the volume of water discharged and the rate of discharge (unit water volume per second) increase. This is due to a change in many factors that affect the length of time it takes for rainwater to drain from the site and the amount of water that infiltrates into the soils. Factors such as vegetation, soil permeability, leaf litter and other soil coverings, and stream meander all contribute to increasing the length of time over which water "concentrates" and runs off. For instance, vegetation has the effect of preventing precipitation from immediately reaching the ground. Leaves or grass "capture" water droplets and drip them at a regular rate, usually far below the peak rainfall rate. This slowing delays the buildup of standing water on soil surfaces. Leaf litter and thick ground covers impede water flow as it begins to concentrate on the ground surface. Naturally occurring soils have top layers that allow water to infiltrate easily. Streamlets and creeks tend to have winding irregular courses and natural obstacles such as rocks, fallen trees, and sand bars that slow the associated flows. During the course of development, these natural "controls" are reduced through the actions of clearing, soil stripping, paving and channelization of runoff. The results are that time for the peak runoff rate to develop is shortened and the volume of the runoff increases. The net effect is exacerbation of downstream flows and associated flooding.

A primary function of storm water management ponds is to restore the natural reduction and delay of runoff in a developed watershed by providing temporary storage for the storm water runoff in excess of the existing condition runoff. The following guidelines detail the steps normally applied in the design of storm water management basins.

I. Define Primary Basin Control/Design Requirements (Confirm Through Agency Coordination) -

   A. Basin Type (e.g. - wet or dry).

   B. Design Storm Event(s) (e.g. - 10-, 25- or 100-year).

   C. Performance Standards (e.g. - Post-development to pre-development peak runoff rate).

II. Estimate Existing and Proposed Land Use Condition Runoff Volume and Peak Flows from Development Site -

   A. Quantify runoff to basin by performing the following computations for both existing and proposed land use conditions.

1. Compute composite runoff curve numbers for the existing and proposed site conditions using the procedure outlined in Chapter 2 of the Soil Conservation Services Technical Release No. 55 (Reference 2). Generally, the applied steps are as follow:

a. Delineate the area draining to the proposed facility onsite topographic mapping;

b. Identify soil types on the site by applying U.S. Soil Conservation Service Soil Survey Mapping and associated hydrologic soil groups and using exhibit A-1 in Technical Release No. 55;

c. Overlay existing and proposed site land uses on the hydrologic soils and compute appropriate Composite Runoff Curve Numbers (CN) per Chapter 2 and Table 2-2G of TR-55.

2. Determine the total quantity of storm water runoff that arrives at the entrance of the detention facility.

After determining the weighted CN value for both pre- and post-development site conditions, use (Eq. 2-4, TR-55):

$$S = \frac{1,000}{CN} - 10$$

to determine the potential abstraction(s) for pre- and post-development conditions. Then substitute the value determined for the potential abstraction into (Eq. 2-3, TR-55):

$$Q = \frac{(P-0.2S)2}{P + 0.8S}$$

to determine the total runoff in inches (Q). P is the total precipitation for the design rainfall event(s). For this pilot study, the precipitation quantities for these events are given in Table D-1.

TABLE D-1

24-HOUR RAINFALL DEPTHS FOR SELECTED RETURN PERIODS IN A STUDY WATERSHED

	Return Periods	Depth In Inches
Mean Annual		
	5-year	3.9
	10-year	4.7
	25-year	5.2
	50-year	5.8
	100-year	6.5

The total runoff volume should be calculated for all rainfall events of interest over both pre-and post-development conditions. The total runoff volume that will be infiltrated through on-site infiltration facilities can be subtracted from the total runoff (Q) when the total runoff for post-development conditions is calculated.

B. Calculate travel time or "time of concentration" (tc) for both the existing and proposed conditions, if the flow paths are modified (e.g. - gutters, storm sewers).

1. Calculate the tc for each subarea using the methods shown in Chapter 3 of TR-55. Sum the travel time for sheet, concentrated and channel flow segments of each subarea's overland flow path.

C. Compute the peak discharge and associated runoff hydrograph from the facility drainage area for each storm event of interest.

1. Determine initial abstraction (Ia) for each subarea from RCN and Table 4-1 (TR-55).

2. Use the Graphical Peak Discharge method for single subarea watersheds within the limitations specified in Chapter 4 of TR-55.

3. Use the Tabular Hydrograph Method described in Chapter 5 of TR-55 for a multiple subarea watershed.

Additionally, computer based hydrologic models such as the Penn State Runoff Model, Soil Conservation Service TR20 and U.S. Army Corps of Engineers HEC I can be applied to input the hydrographs and associated runoff volumes and peak flows.

III. Estimate Required Storage Volume for Each Storm Event for Which Discharge Controls are Required (i.e. - Design Storm Events) -

A. Determine the maximum allowable pond discharge (qo) for each design storm event by applying the appropriate release rate (e.g. 80%) to the existing site discharge. Refer to the County watershed Stormwater Management Plan for the appropriate reduction factors and a description of the process.

B. Calculate the ratio of the allowable discharge (e.g. -qo existing x 80%) to the proposed condition peak runoff or "basin inflow".

C. Use the allowable discharge to proposed condition inflow ratio (from step B) with Figure 6-1 in TR-55 to obtain the required storage volume to runoff volume factor (Vs/Vr).

D. Calculate runoff volume (Vr) by converting Q in inches to runoff in acre-feet by the following equation: Vr = Q (53.33) Am where:

Vr = runoff volume (acre-ft.),

Q = runoff depth (in.),

Am = drainage area (in square miles), and

53.33 = conversion factor from in-mi2 to acre-ft.

E. Obtain the required storage volume by multiplying the Vs/Vr factor (Step C above) by the runoff volume (Vr) (Step D) for the design storm event(s).

F. Set up required storage/discharge curve for the site's facility.

IV. Develop Preliminary Pond Layout Based on the Required Storage Volume Needed to Satisfy the Maximum Design Storm Event Using the Storage/Discharge Curve Developed in Step II -

A. Establish the minimum base grade elevations for the pond if excavation is proposed.

1. Geotechnical investigation may be necessary to establish the elevation of top of rock or groundwater at the site.

2. Establish the minimum buffer between top of rock or groundwater to set the base grade for the pond.

B. Layout of Pond.

1. Site topography and the available base grade will dictate the naturally available storage volume for a given depth in the pond. Where the size of the pond is not constrained by site conditions or development requirements, natural contours can be followed if slope requirements are met (otherwise cutting or filling may be necessary).

2. If available space is limited, the required volume can be met through the use of embankment berms and/or excavation to yield more volume. However, the use of berms should be minimized since they detract from a natural appearance and add to project expense.

3. In all cases, the length of flow through the pond should be maximized to enhance water quality benefits.

4. Controlling Urban Runoff - A Practical Manual For Planning and Designing BMPs (Metropolitan Washington Council of Governments) is recommended as a guide to design of effective, efficient ponds to enhance water quality of discharges. The reference details considerations of length to width ratios, wetland creation in ponds, landscaping, and other design considerations.

C. Develop a detailed stage-area-storage table/curve from the preliminary layout by calculating the pool surface area at various water elevations. The incremental volume between various stages (elevations) can be calculated manually by the following formula:

$$Vs = \frac{h\ (A1 + A2 + (A1A2)0.5)}{3} \quad \text{where:}$$

Vs = incremental storage volume
h = elevation increment
A1 = surface area at lower elevation
A2 = surface area at upper elevation.

D. Select an outlet control structure.

The design on an outlet control structure is rather complex and time intensive. This structure often has to provide for a controlled discharge at multiple water level elevations, (e.g., the water level elevation for required 2-, 10-, and 25-year storage). An emergency spillway should be included to pass the peak post-development inflow rate of the 100-year rainfall while maintaining required minimum freeboard.

Some illustrations of outlet structures are shown in Figure D-1. Outlet structure is termed an "outlet control box". When the water surface is below the centroid of an opening, weir flow exists, and the following relationship can be used to calculate the discharge through the opening:

Q = CLH1.5 where:

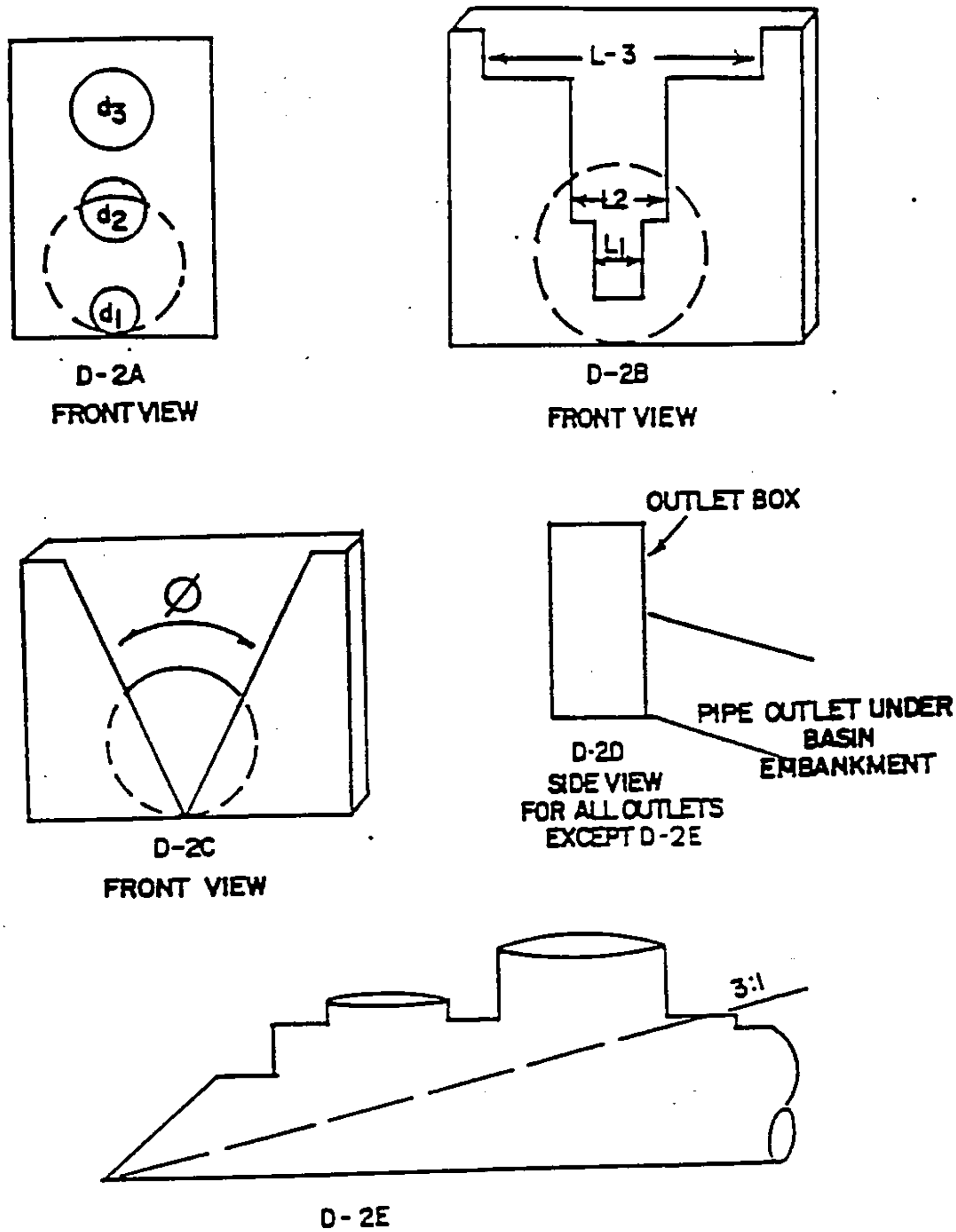
Q = weir flow (cfs)
C = discharge coefficient
L = length of weir, maximum L = D/2 (feet), where D is the diameter of the opening.
H = effective head (feet), the difference in elevation between the weir crest and the water surface measured upstream of the crest a short distance

In all the equations given above, a discharge coefficient (c) is required to solve for the desired flow. An excellent reference listing coefficients for various conditions is Brater and King's "Handbook of Hydraulics", Sixth Edition, McGraw Hill, 1976.

When the water surface is above the centroid of the opening, orifice flow exists, and the following relationship can be used to calculate the discharge through the opening:

Q = CA(2gHo)0.5 where:

Q = orifice flow (cfs)
C = discharge coefficient
A = cross-sectional area (ft2)
g = 32.2 ft/sec2
Ho = effective head to centroid (ft)



TYPICAL OUTLET CONTROL STRUCTURES

After the water surface is above the top of the box, the primary outlet culvert may define the controlling discharge capacity for the structure. That is, in that flow is ultimately discharged through the primary culvert, the maximum outflow cannot exceed that which could be handled by the primary culvert. Therefore, after water in the detention basin rises above the top of the box, the combination of total weir flow and orifice flow in the box cannot exceed the discharge capacity of the primary culvert.

Outlet structure D-2B is referred to as "broad-crested weirs in a headwall". The formula for discharge is:

$$Q = C(Ln-0.2H)H^{1.5} \quad \text{where:}$$

Q	=	weir flow (cfs)
C	=	discharge coefficient
Ln	=	length of particular weir (ft)
H	=	effective head

After the water surface is above the top of the box, weir flow over the top needs to be compared with the primary culvert capacity to determine the "controlling discharge" capacity of the structure.

Outlet structure D-2C is a "V-notched control structure". The flow through the V-notch structure is given by:

$$Q = C(8/15) \tan X \, (2g)^{0.5}H^{2.5} \quad \text{where:}$$

Q	=	V-notch weir flow (cfs)
C	=	discharge coefficient
X	=	$\phi/2$
ϕ	=	angle of V-notch
g	=	32.2 ft/sec2
H	=	effective head above notch opening

Again, as with all of these types of structures, when the water surface is above the top of the box, the total weir flow needs to be compared with the primary culvert capacity to determine the controlling discharge capacity.

Outlet structure D-2E is commonly referred to as a "multiple outflow structure". The flow through this structure is not as easily defined as the flow through the other three structures. The weir and orifice equations should be used in combination to accurately determine the flow associated with particular water level (stage) elevations in any impoundment.

E. Route the inflow hydrographs through the basin and develop outflow hydrographs.

The only proof of detention basin adequacy is to route a design inflow hydrograph through the storage volume and the proposed outlet structure. The procedure for hydrologic routing of a hydrograph through a detention facility is presented in "Introduction to Hydrology", by Viessman, Harbough, and Knapp, Intext Education Publishers, or many other hydrology texts. Additionally, this detailed assessment can be performed using readily available computer models such as the SCS TR-20 program, U.S. Army Corps of Engineers HEC I program or the Penn State Runoff Model.

F. Evaluate the basin design.

After completing the initial routing routine, determine if all of the criteria for the basin are attained. If not, change the configuration of the basin to alter storage characteristics or the dimensions of the outlet structure to alter the outflow characteristics. Specifically, the storage/outflow characteristics of the basin are altered in this fashion to provide for the required peak runoff rate control.

V. Financial Considerations -

A. The factors affecting costs of storm water management on a development site are numerous. The following constitute the primary cost impact areas.

1. Control requirements -

   a. Design storm events required to control.
   b. Performance standards (maximum release rate).

2. Development type -

   a. Change in impervious coverage.
   b. Density of development.

3. Site characteristics -

   a. Watershed drainage area.
   b. Topography/relief.
   c. Soils and depth to rock.
   d. Accessibility.
   e. Proximity to construction materials and haul distances.
   f. Wetland areas.

4. Type of controls that are proposed.

B. Factors affecting cost for construction of detention basins include:

1. Storage Volume;
2. Land Consumption;
3. Control structures;
4. Grading/excavation;
5. Design and permitting; and
6. Erosion and sediment control.

The impacts of these items on facility construction costs are highlighted in the following example.

VI. Example of Detention Facility Design Procedure -

The following example is based on a construction site with a 15.8 acre drainage area located in southern Pennsylvania, and for which 2-, 10- and 100-year controls were required. The existing land use conditions were "meadow" in good condition. Ultimate conditions called for the entire 15.8-acre drainage area to be paved.

A. Inflow hydrograph

Using the procedure outlined in Section II of this Appendix, pre- and post-development runoff hydrographs were developed. Figure D-2 shows the resultant hydrographs for the 10- and 100-year existing and proposed land use condition runoff for the development site. The graphs show how the proposed development results in an increased runoff that is roughly double the existing conditions rate and volume.

B. Pond design -

1. Stage Storage curve

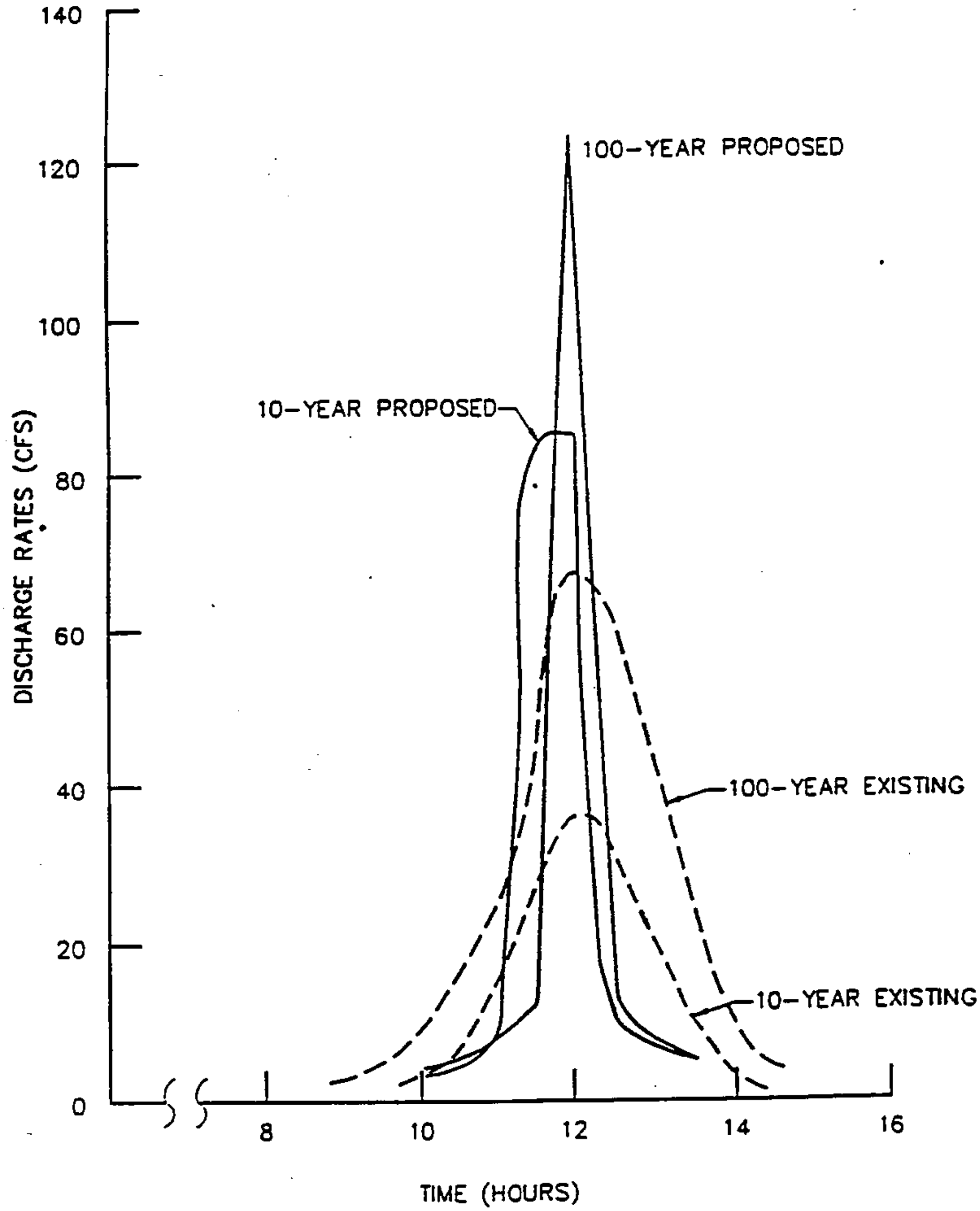
Figure D-3 shows the stage/storage curve for the pond design developed for the site. This curve shows the provided storage volume in the pond for a given stage (water surface elevation). It was developed by measuring the area and calculating the volume at various stages using the procedure outlined in Section III of this appendix.

2. Stage/discharge curves

Figure D-4 shows the stage/discharge curve for a 48-inch pipe under the embankment. Figure D-5 shows the stage/discharge curve for the box riser control structure. Examination of these two curves reveals that the pond discharge is controlled by the outlet structure, that is, the box riser weirs will pass less for a given stage than the pipe under the embankment would. These stage discharge relationships were developed using the procedures outlined in Section IV of this appendix.

3. Storm routing hydrograph

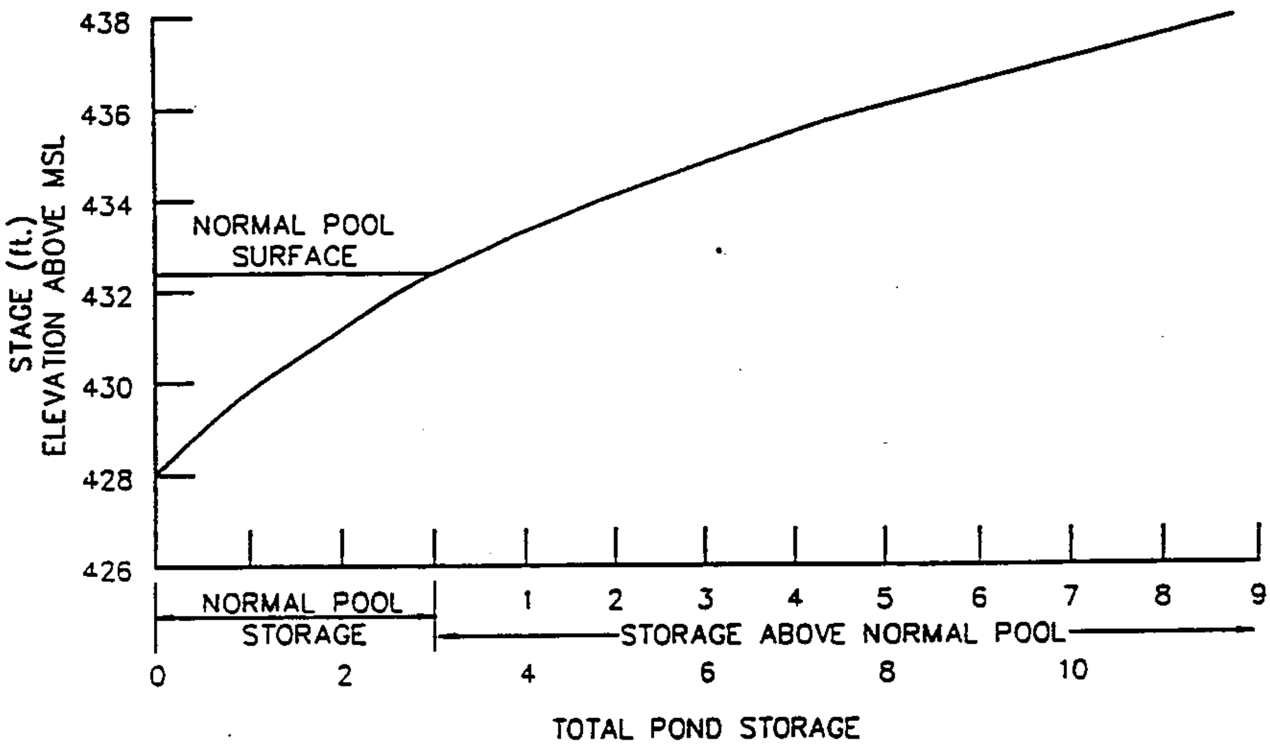
Figure D-6 shows the storm routing results from TR-20 modeling for the 100-year peak site discharge through the storm water management pond. The runoff from the 100-year storm for proposed site conditions is shown for comparison. The peak discharge from the pond, 54 cfs, is 80% of the existing site discharge, 67 cfs.



SITE DISCHARGE HYDROGRAPH

WALTER B. SATTERTHWAITE ASSOCIATES, INC.
720 NORTH FIVE POINTS ROAD · WEST CHESTER, PA. 19380 · (215)692-5770
BRANCH OFFICE: 9418 ANNAPOLIS ROAD · LANHAM, MD. 20706 · (301)731-0560

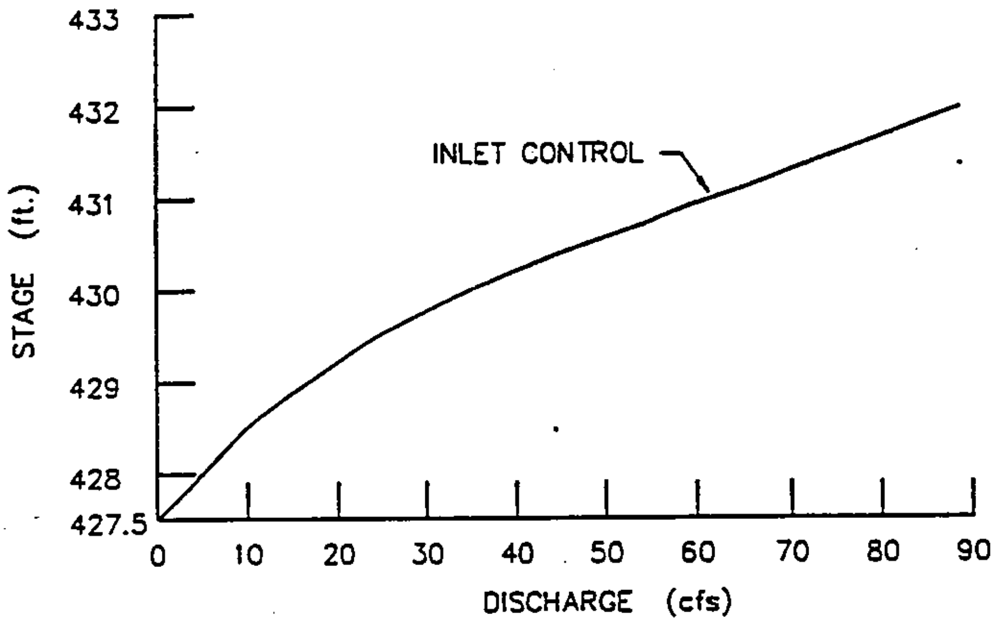
FIGURE D-2



STAGE/STORAGE CURVE

WALTER B. SATTERTHWAITE ASSOCIATES, INC.
720 NORTH FIVE POINTS ROAD · WEST CHESTER, PA. 19380 · (215)692-5770
BRANCH OFFICE: 9418 ANNAPOLIS ROAD · LANHAM, MD. 20706 · (301)731-0560

FIGURE D-3

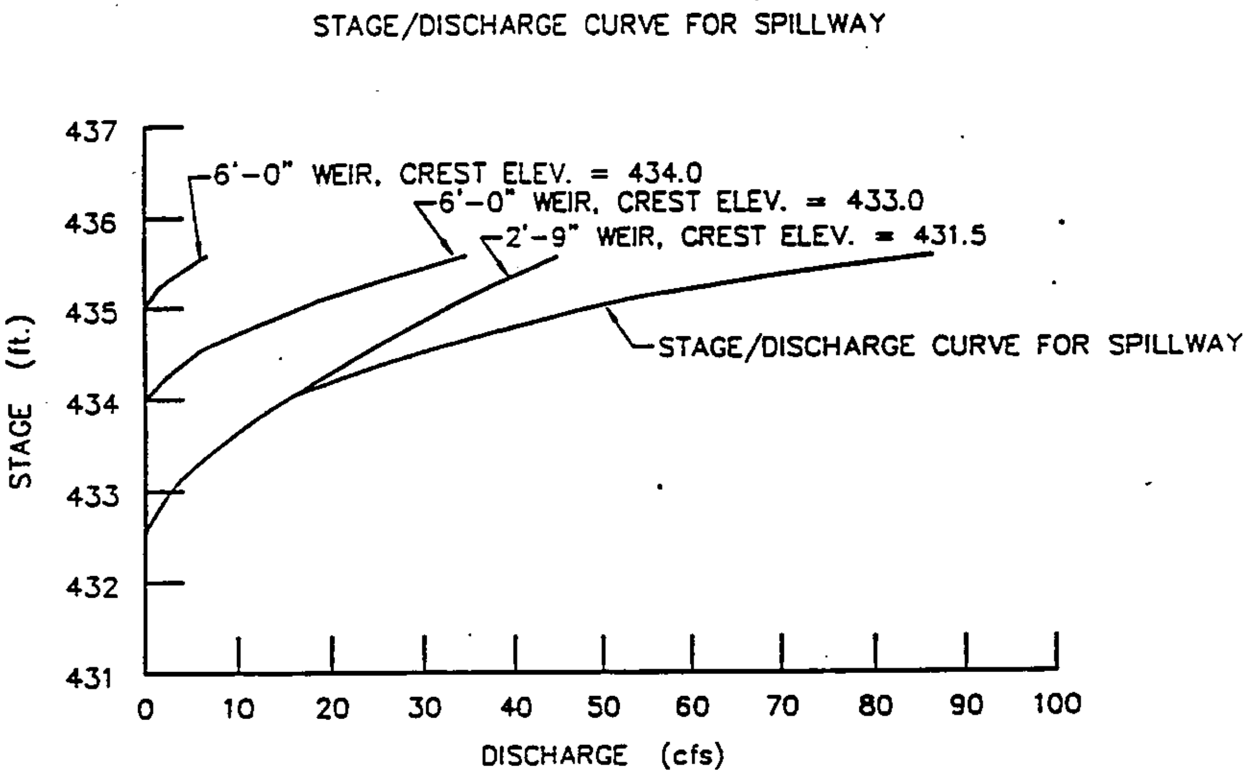


NOTE: THIS FIGURE SHOWS THE MAXIMUM DISCHARGE IN POND OUTLET PIPE FOR A GIVEN HYDRAULIC ELEVATION. USED WITH FIGURE TO DETERMINE WHETHER STRUCTURE WILL BE INLET OR OUTLET CONTROLLED (INLET CONTROLLED THIS EXAMPLE).

STAGE/DISCHARGE CURVE FOR 48" RCP

WALTER B. SATTERTHWAITE ASSOCIATES, INC.
720 NORTH FIVE POINTS ROAD · WEST CHESTER, PA. 19380 · (215)692-5770
BRANCH OFFICE: 9418 ANNAPOLIS ROAD · LANHAM, MD. 20706 · (301)731-0560

FIGURE D-4

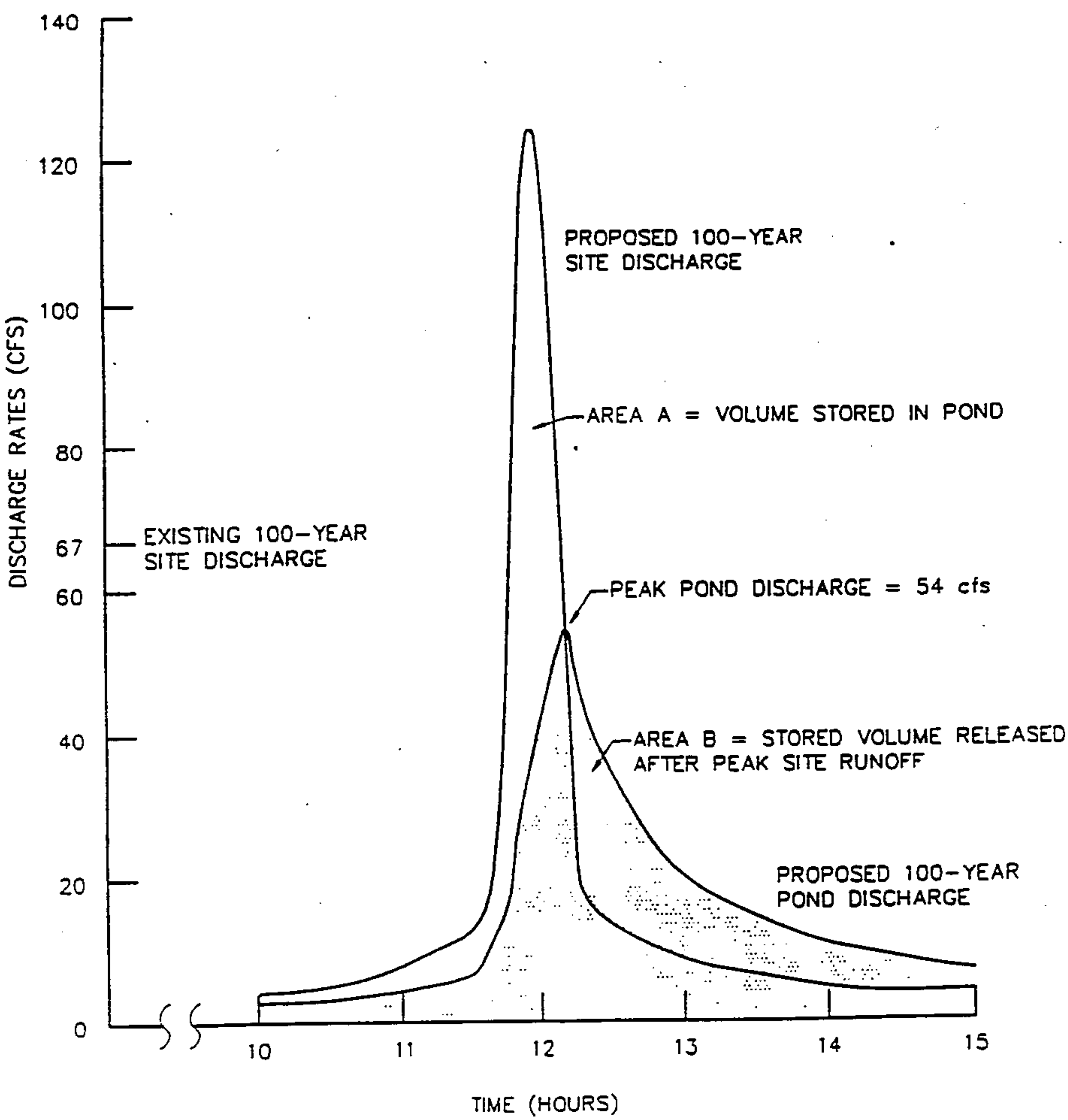


ELEV. ft.	Q cfs
432.5	0.0
433.0	3.1
433.5	8.7
434.0	16.0
434.5	31.4
435.0	53.4
435.5	86.9

STAGE DISCHARGE CURVE FOR CONTROL STRUCTURE

WALTER B. SATTERTHWAITE ASSOCIATES, INC.
720 NORTH FIVE POINTS ROAD · WEST CHESTER, PA. 19380 · (215)692-5770
BRANCH OFFICE: 9418 ANNAPOLIS ROAD · LANHAM, MD. 20706 · (301)731-0560

FIGURE D-5



INFLOW AND OUTFLOW HYDROGRAPHS FOR POND
SHOWING STORM ROUTING THROUGH BASIN

WALTER B. SATTERTHWAITE ASSOCIATES, INC.
720 NORTH FIVE POINTS ROAD · WEST CHESTER, PA. 19380 · (215)692-5770
BRANCH OFFICE: 9418 ANNAPOLIS ROAD · LANHAM, MD. 20706 · (301)731-0560

FIGURE D-6

C. Costs

1. Land area/storage relationship

Figure D-7 shows the land area/storage volume relationship. As shown by the curve, the rate of increase in pond area for increased storage decreases as storage volumes increase.

2. Construction cost/storage volume relationship

Figure D-8 shows the relative construction cost curves for wet and dry extended detention basins, based on cost estimation curves developed by the Metropolitan Washington Council of Governments (Wiegand et al, 1986). The equation used for dry ponds is:

$$C = 10.71Vs^{0.69}$$ where:

C = construction cost in 1985 dollars
Vs = volume of storage (cubic feet) of the pond up to the crest of the emergency spillway

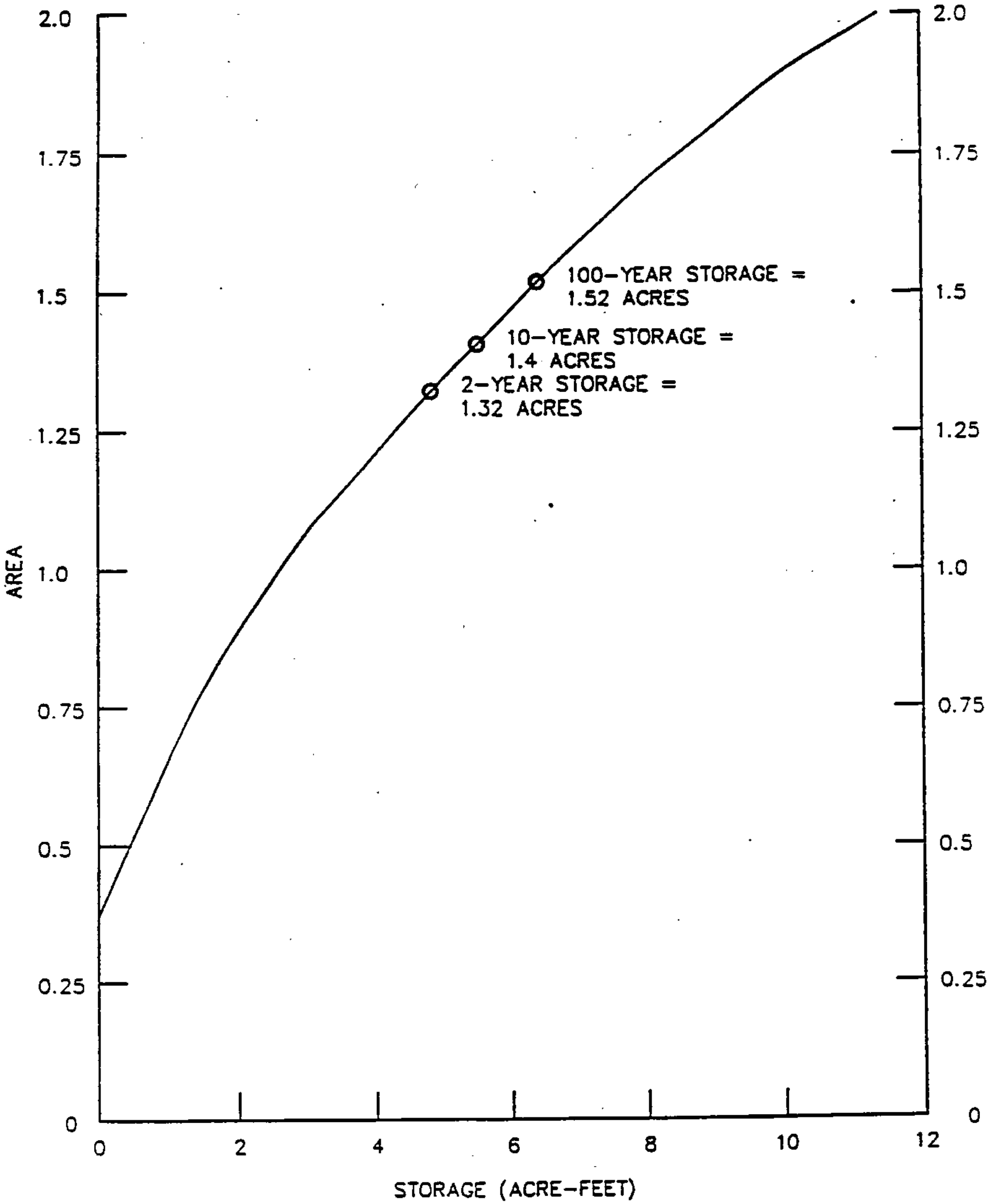
The equation used for wet ponds with volumes in excess of 100,000 cubic feet is:

$$C = 34Vs^{0.64}$$ where:

C = construction cost in 1985 dollars
Vs = volume of storage (cubic feet) of the pond up to the crest of the emergency spillway

It should be noted that the preceding equations represent only the cost of construction and are in 1985 dollars. MWCOG recommends that 25 percent be added for contingencies such as design, permitting, and overseeing construction.

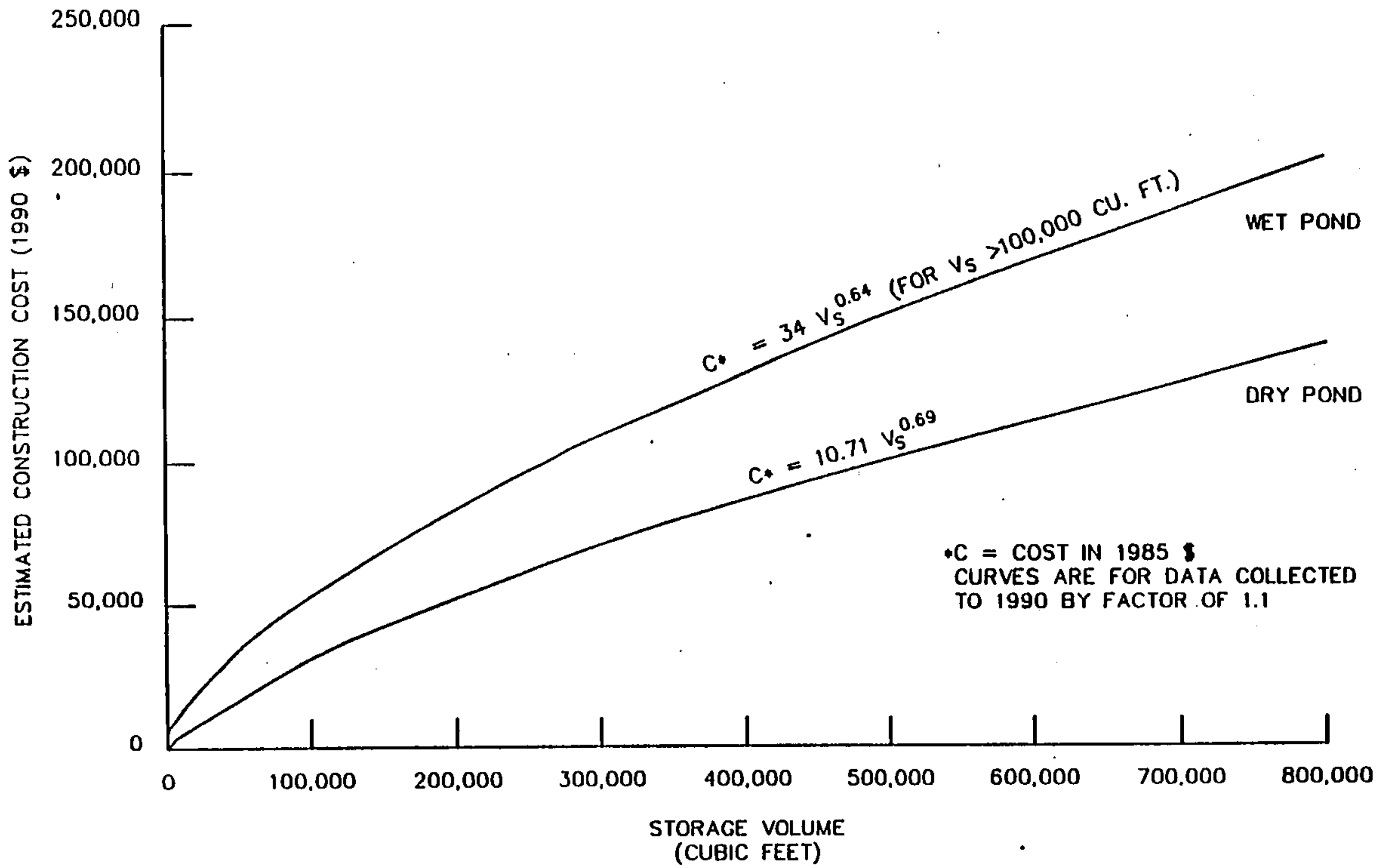
To adjust the 1985 costs to the 1990 costs used in Figure D-7 a factor of 1.1 was applied. Several observations can be made of the cost curves in Figure D-7. First, the curves become nearly linear above a volume of 400,000 cubic feet (about 9 acre feet). Second, the unit costs decrease with increasing pond size, indicating economies of scale with larger ponds. Third, wet ponds can cost from 45 to 60 percent more than dry ponds.



LAND AREA OCCUPIED TO VOLUME OCCUPIED

WALTER B. SATTERTHWAITE ASSOCIATES, INC.
720 NORTH FIVE POINTS ROAD · WEST CHESTER, PA. 19380 · (215)692-5770
BRANCH OFFICE: 9418 ANNAPOLIS ROAD · LANHAM, MD. 20706 · (301)731-0560

FIGURE D-7



STORAGE/COST RELATIONSHIP FOR WET AND DRY EXTENDED DETENTION PONDS

SOURCE: CONTROLLING URBAN RUNOFF – A PRACTICAL MANUAL FOR PLANNING AND DESIGNING URBAN BMP'S; MWCOG; 1987.

WALTER B. SATTERTHWAITE ASSOCIATES, INC.
720 NORTH FIVE POINTS ROAD · WEST CHESTER, PA. 19380 · (215)692-5770
BRANCH OFFICE: 9418 ANNAPOLIS ROAD · LANHAM, MD. 20706 · (301)731-0560

FIGURE D-8

VII. Cost Comparison of 2-, 10- and 100-Year Ponds -

Table D-2 shows the area occupied by the pool at the corresponding 2-, 10- and 100-year stages for the Pennsylvania site used to develop the stage/storage/discharge curves and TR-20 model. The estimated construction cost to build a pond meeting these events is also shown in Table D-2.

TABLE D-2

Comparison of Area and Estimated Construction Costs
For the 2-, 10- and 100-year Storm Events

Event	Storage Acre-feet	Storage Cubic feet	Area Acres	Construction Cost* 1990 Dollars
2-year	6.88	212,600	1.32	$87,000
10-year	5.58	243,100	1.40	$95,000
100-year	6.40	282,300	1.52	105,000

* Costs were derived from the equation shown for wet extended detention ponds and were adjusted from 1985 dollars to 1990 dollars using a factor of 1.1.

The actual land necessary to construct a pond for any of these control events is greater than the area shown due to the land needed for the impoundment structure, outfall and buffer areas. However, the areas shown give a relative measure of the area required to control various events.

Table D-2 shows that the 100-year event will require 0.12 acres more than the 10-year event, or an 8.6 percent increase in land required. Also shown is that a pond with 100-year event controls costs roughly 10,000 dollars more then the 10-year facility to construct, for a 10.5 percent increase in cost to control the 100-year event over the cost to control the 10-year event.

The actual increase in construction cost for this example might be less than 10.5 percent since in actual practice an emergency spillway would have to be provided for the 10-year controlled pond to prevent overtopping of the impoundment and possible breaching. The total increase due to the additional land and construction costs to meet 100-year controls depends on site specific factors, such as land cost, which precludes a meaningful estimate of the combined increase. It should be noted that the increase in land may or may not be meaningful for a given project site due to open space requirements, wetlands, or other factors that might otherwise prevent full development of the site. Additionally, an extended detention wet pond can be a good place to construct a wetland mitigation area required to develop other parts of a site.

VIII. Combining Effective Storm Water Management with Land Development Site Design -

The storm water management system is only one item in the total site development design which includes grading, building layout, landscaping, E/S control, sanitary wastewater facilities, water supply, streets, and other utilities. Many times the storm water system is treated as an add-on after the remainder of the site development design has been completed. Frequently, the result of the low priority given to storm water management design results in:

- Excessive Delays During the Municipal Review Process

  If adequate planning and evaluation of storm water management alternatives is not undertaken during the initial phases of the site planning process, the proposed storm water management system is often found to be inadequate by the municipal engineer. The delay which this may create can usually be avoided if the storm water management system is integrated into the overall site design during the initial planning phases.

- The Potential for Increased Construction Expense

  If integrated in the overall site design during the initial planning phases, the construction of the storm water management system can serve multiple functions (i.e., a road embankment may be used as an embankment for a detention basin, a seepage area may double as a recreation area, walk-ways may cover Dutch drains, etc.). If not, the storm water management system may only be viewed as a separate expense.

- The Unknown Impact of the Operation of the Storm Water Management System Within the Development Site on Downstream Areas

  When the storm water management system is a last-minute add-on, the only criterion used for it is a specific performance control (e.g., post-development peak runoff rate no greater than the pre-development peak runoff rate) at the development site boundary. The impact of redirected or increased storm water runoff on-site and in downstream areas may create future claims for damage by affected landowners. Minor revisions of the development site design and review procedure may provide for better coordination of the storm water management system design with other site development design phases.

  An alternative procedure for developing a storm water management system for a land development site may include the use of a "storm water management feasibility study". The feasibility study could be used to preliminarily define an "optimum" storm water management system for a site which can be more effectively designed and reviewed. The use of a feasibility approach can also help cut the overall costs for storm water management on a development site. The contents of a storm water management feasibility study for a land development site may include the items listed in Table D-3.

The benefits of the recommended procedure for incorporating the feasibility study approach into the site development review process include:

- o A potential reduction of wasted engineering fees resulting from detailed work which is determined to be inadequate by the reviewing agency(ies)at advanced stages of the review process;

- o A potential reduction in the overall time required for the review procedure because of early coordination between the applicant and the review agency(ies);

- o The definition of potential areas of environmental concern during the initial planning phases when cost-effective methods for eliminating this potential for adverse impact can best be determine; and,

- o Better overall coordination of the efforts of developers, technical consultants, municipal engineers, local municipal officials and agency representatives.

TABLE D-3

Typical Contents of a
Stormwater Management Feasibility Study
and Preliminary Site Sketch Plan

A. Feasibility Study

- o Existing ground cover conditions.
- o Soil descriptions, boundaries, seasonal high groundwater levels (SCS Soil Surveys can be used as a reference).
- o Underlying geologic conditions.
- o Definition of the existing natural drainage paths and drainage area boundaries.
- o Designation of any wetland areas.
- o 100-year floodplain boundaries.
- o Definition of existing on- or off-site drainage problems.
- o Appropriate stormwater management criteria as defined by the standards and criteria of the pilot stormwater management plan;
  - Release rate percentage,
  - Direct discharge,
  - Downstream impact evaluation.

B. Preliminary Site Sketch Plan

- o Architectural layout of streets, buildings, approximate building dimensions, parking areas, walkways, and other impervious areas.
- o Configuration of the storm and sanitary sewer system layout.
- o Approximate location and layout of the stormwater management system with a description of its proposed operation.
- o No detailed calculations are required at this time.

APPENDIX E

APPENDIX F

APPENDIX G

APPENDIX H

APPENDIX I

APPENDIX J

APPENDIX K