Beaverdam Branch Watershed
Act 167 Stormwater Management Plan
Volume 3: Training Manual

May 2000

Prepared for the:

Blair County Planning Commission

Prepared by:

Chester Engineers

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CHESTER ENGINEERS

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Act 167 Stormwater Management Plan
Volume 3: Training Manual

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Prepared for the:

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BEAVERDAM BRANCH STORMWATER MANAGEMENT PLAN TRAINING MANUAL

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BEAVERDAM BRANCH STORMWATER MANAGEMENT PLAN TRAINING MANUAL

SECTION I

INTRODUCTION

PURPOSE

This training manual has been designed to provide guidance to individuals who may be affected by stormwater management requirements in the Beaverdam Branch watershed. This manual is aimed at two general groups: those who are charged with implementing and enforcing stormwater management requirements; and those who will be required to comply with or will otherwise be affected by those requirements.

Individuals who will be involved in implementation and enforcement will include the following:

- Elected officials
- Municipal enforcement officers
- Municipal engineers and solicitors
- County Planning Department personnel

Personnel who will be affected by the administration of stormwater management requirements in the watershed include:

- Land developers
- Engineers serving land developers
- Individuals downstream of land development activities

APPROACH

The concepts associated with stormwater management range from "common sense" realizations of the potential impacts of land development activities to the use of sophisticated hydrologic/hydraulic models in the development of specific stormwater control criteria. Issues raised in conjunction with the implementation of stormwater management requirements encompass practical administrative and legal considerations as well as basic philosophical issues related to property rights and duties.

In short, there are various levels of understanding of stormwater management related issues. The extent and depth of understanding necessary for an individual to operate effectively under the adopted management system will depend upon his/her role in the system. The goal of this manual, therefore, is to provide a foundation of information upon which individuals can build to reach the level of understanding necessary to operate effectively under the Beaverdam Branch watershed stormwater management system. In order to accomplish this goal, an effort has been made to provide information spanning a range of topics without patronizing those familiar with the concepts presented nor intimidating persons new to this topic. As a result, this document is designed to introduce and provide a basic understanding or key concepts; present a back drop to the development of the Beaverdam Branch management system; and provide guidance to those involved in land development and the regulation of land development activities.

CONTENTS OF THIS MANUAL

This training manual is divided into the following sections:

- Introduction to Stormwater Management
- Basics of Hydrology
- Technical Approach to Stormwater Management
- Specific Beaverdam Branch Management Plan Requirements
- Catalog of Stormwater Management Techniques
- Institutional and Regulatory System
- Recommended Developer Plan Submission and Review Procedures
- Glossary of Terms

The first three (3) sections present general topics and contain information which is applicable to most watersheds. The next four (4) sections provide information specific to the Beaverdam Branch watershed and the stormwater management requirements developed for this watershed. The last section (contained in Appendix A) presents working definitions of frequently used stormwater management terms.

BEAVERDAM BRANCH STORMWATER MANAGEMENT PLAN TRAINING MANUAL

SECTION II

INTRODUCTION TO STORMWATER MANAGEMENT

INTRODUCTION

Stormwater management itself is not a new concept; however, the goals of approaches to and requirements for stormwater management have evolved over the past several decades. This section presents information designed to place a perspective on the current stormwater management requirements for the Beaverdam Branch watershed.

WHAT IS STORMWATER?

Stormwater is defined in the Water and Wastewater Control Engineering Glossary as follows:

> *Surface water from rain, snow or ice melting and running off from the surface of a drainage area.*

A similar definition of this term is contained in the Pennsylvania Stormwater Management Act. Clearly, stormwater is a natural phenomena and the primary concerns associated with stormwater relate to the effects of manmade changes to stormwater runoff rates, volumes, directs and quality.

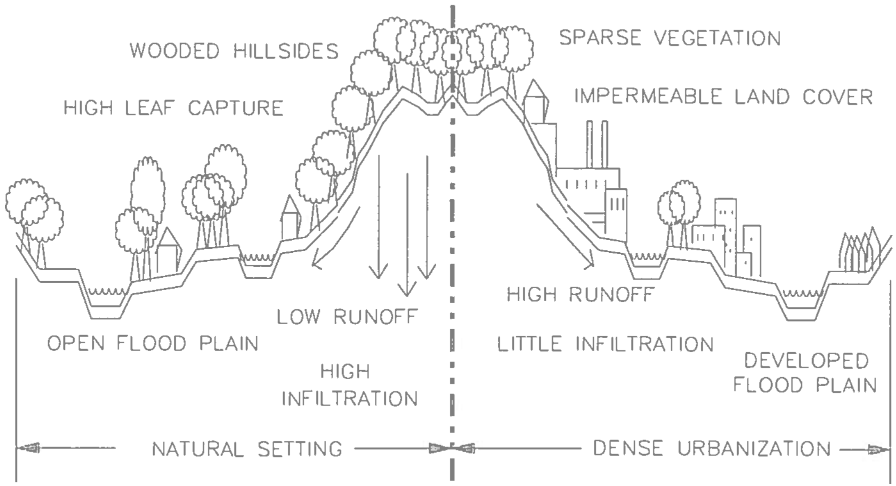
WHY IS STORMWATER RUNOFF A PROBLEM?

As was indicated above, stormwater runoff occurs as a natural consequence of precipitation. In a natural setting, land cover largely protects the land from erosion and stream channels have evolved with sufficient capacity to carry the runoff from all but the largest storms. Natural flood plains have developed as a corridor through which large floods are conveyed from the watershed. Stormwater runoff becomes a problem or concern when man's land development activities create changes in the natural setting which serve to decrease the carrying capacity of streams and floodways and/or modify ground cover an natural runoff regimes in ways that result in increased runoff.

Specifically, land development activities, or urbanization, typically results in a number of changes to the natural condition which can create stormwater runoff related problems. A number of the typically effects of urbanization upon the natural setting are illustrated in Figure II-1.

FIGURE II-1

URBANIZATION EFFECTS ON RUNOFF FACTORS



These effects include the following:

- Reducing the amount of water which is able to percolate to ground water by replacing permeable natural land cover with impermeable pavements.
- Reducing the amount of water which is trapped in and subsequently evaporated from leaves and plants by clearing wood and brush lands.
- Increasing the speed at. which runoff leaves the site(s) by replacing rough, irregular natural terrain with smooth, straight drainage gutters, swales and pipes.
- Concentrating and/or redirecting the discharge of stormwater runoff by reducing the extent of sheet flow through the construction of stormwater collection systems.
- Increasing soil erosion through the temporary or permanent removal of soil cover materials.
- Reducing natural channel carrying capacity through the subsequent sedimentation of eroded soil materials and the construction of culverts and bridges in the stream channel.
- Reducing the capacity of natural floodways and increasing the potential for property damage in floodplains through the construction of structures within the floodplain and floodway.

- Increasing the potential for pollution of stormwater contact through contact with sediment, oils, toxic chemicals and other materials deposited as a result of human activities.

These activities result in increased runoff volumes; higher peak rates of discharge; accelerated ground surface and stream bank erosion; reduced stream channel and floodway carrying capacity; degraded water quality and, ultimately, serious threats to public health and property.

Within the last fifty (50) years Pennsylvania has suffered numerous major floods resulting in billions of dollars of damages. Despite investments of over $1 billion in Federal and State flood control projects in the Commonwealth, the estimated average residual flood damage suffered in Pennsylvania is about $60 million each year. Ninety-five percent (95%) of the Commonwealth's 2,567 communities are designated as flood prone under the National Flood Insurance Program.

Clearly, land development can increase the potential for stormwater runoff related problems. Unless properly managed, future development may exacerbate existing problems and create new ones.

WHAT IS STORMWATER MANAGEMENT?

Stormwater management is generally defined as measures used by property owners and local governments to limit the amount of stormwater runoff from urban development and to control the path of runoff through space and time. Traditionally, stormwater management consisted essentially of the provision of curbs, gutters and underground pipes to remove stormwater from developed property as quickly as possible so as to minimize the possibility of **localized** flooding. Moreover, in the past little or no effort was expended to minimize increases in the amount of runoff generated and the rates at which the increased runoff occurred. Historically, stormwater management focused essentially upon the protection of the developing site with little or no consideration to the related, abeit more remote, downstream flooding effects.

Existing flooding problems to a large extent are a product of this narrow approach to managing stormwater runoff. Localized problems have simply been shifted downstream where they are magnified in combination with the effects of other upstream urbanization activities. Solutions to the resulting flooding problems have been largely remedial in nature i.e., increasing the capacity of critical stream reaches through channelization, construction of flood control reservoirs and flood protection though the construction of levees and flood walls.

Over the past several decades the focus of stormwater management has been broadened to address both local and downstream effects of land development activities. The thrust of stormwater management has shifted to the institution of preventative measures as development progress instead of constructing remedial improvements in response to problems as they develop. The modern approach to stormwater management, therefore, considers the entire watershed in the design of stormwater management systems for specific sites.

The primary advantage associated with this modern approach to stormwater management is realized when flooding and associated problems which would otherwise arise are avoided. The primary disadvantages of this approach are related to greater complexity in the development and administration of control standards and criteria. The principal difference between the traditional and historic approach to stormwater management are summarized below.

Comparison of Traditional and Modern
Stormwater Management Approaches

TRADITIONAL APPROACH	MODERN APPROACH
Remedial	Preventative
Single purpose	Multi-purpose
Site oriented	Watershed oriented
Conveyance oriented	Volume and rate control oriented

LEVELS OF STORMWATER MANAGEMENT

As the previous discussion indicated, effective stormwater management requires that the effects of stormwater discharges and alternative control methods be considered throughout the watershed. As a result, control requirements are designed to protect areas remote from the development site as well as properties immediately adjacent to the development. Furthermore, since hydrology and stream hydraulics do not respect municipal borders, to be effective stormwater management controls must be developed and applied consistently across municipal boundaries. Stormwater management planning in the modern context typically encompasses the development site, the community within which the development is occurring, the affected immediate drainage area and the watershed as a whole. It is the need for regional planning and application of stormwater management requirements that served as a basis for the passage of Pennsylvania's stormwater management act.

PENNSYLVANIA STORMWATER MANAGEMENT ACT

On October 4, 1978 the Pennsylvania General Assembly passed and the Governor signed into law the Pennsylvania "Storm Water Management Act, No. 167, P.L. 864" (Act 167). As stated in Act 167, the purpose of the legislation is to:

- Encourage planning and management of stormwater runoff in each watershed which is consistent with sound water and land use practices.

- Authorize a comprehensive program of stormwater management designated to preserve and restore the flood carrying capacity of Commonwealth streams, to preserve, to the maximum extent practicable, natural storm water runoff regimes and natural course, current and cross-section of water of the

Commonwealth; to protect and conserve ground waters and ground water recharge areas.

- Encourage local administration and management of storm water consistent with the Commonwealth's duty as trustee of natural resources and the people's constitutional right to the preservation of natural, economic, scenic, aesthetic, recreational and historical values of the environment.

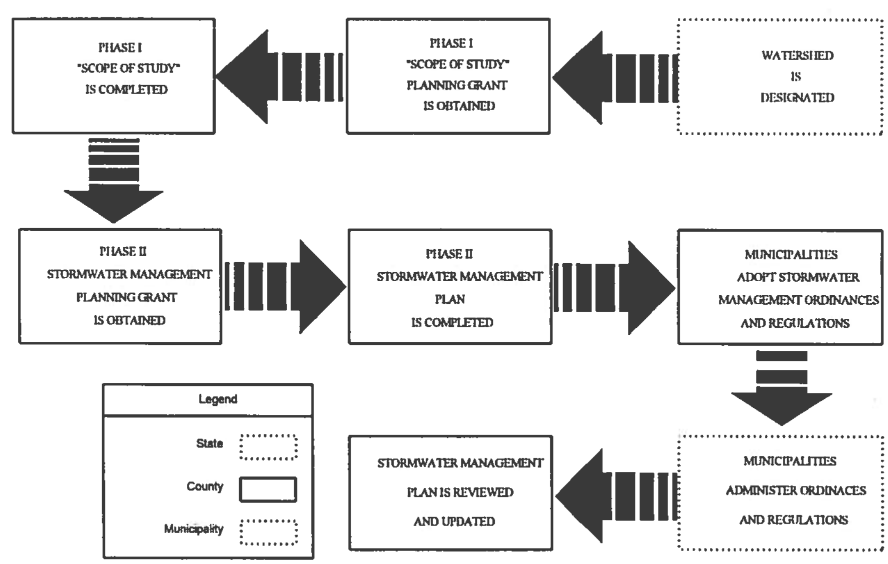
The basic mechanisms created by Act 167 for accomplishing these goals are the development and enforcement of watershed wide standards and criteria for the control of stormwater from developing areas such that development activities within the watershed do not adversely affect health, safety and property in other areas of the watershed and in basins to which the watershed is tributary. The appropriate criteria and standards as well as recommendations relative to the legal instruments and institutional arrangements necessary to enforce the standards are developed through the completion of watershed stormwater management plans. The general procedure for complying with the requirements of Act 167 is illustrated below in Figure II-2.

DUTIES UNDER ACT 167

Act 167 is explicit in outlining the duties which must be discharged by various levels of government and individuals involved in land development. These duties and responsibilities are outlined as follows.

FIGURE II-2

PROCEDURE FOR DISCHARGING PENNSYLVANIA STORMWATER MANAGEMENT RESPONSIBILITIES



STATE LEVEL RESPONSIBILITIES

At the state level, the agency charged with the primary responsibility for stormwater management is the Department of Environmental Protection (DEP). Specifically, Act 167 assigns the Department of Environmental Protection the responsibility for providing guidelines for county stormwater management plans; designating watersheds for which stormwater management plans should be prepared; review and approval of these plans; providing technical assistance and model local ordinances; developing grants and reimbursement regulations governing the disbursement of cost reimbursement moneys and generally coordinating stormwater management activities statewide.

COUNTY LEVEL RESPONSIBILITIES

Under Act 167, counties are required to prepare and adopt a watershed stormwater management plan for each designated watershed within the counties' jurisdictions.

MUNICIPALITIES

Municipalities are required to adopt new or to amend existing regulations as necessary to comply with and implement the stormwater management plans developed and adopted by the counties.

PERSONS ENGAGED IN LAND DEVELOPMENT

Act 167 states that any landowner and any person engaged in the alteration or development of land which may affect stormwater runoff characteristics must implement such measures consistent with the provisions of the applicable stormwater management plan as are reasonably necessary to prevent injury of health, safety or other property.

BEAVERDAM BRANCH STORMWATER MANAGEMENT PLANNING

The *Beaverdam Branch Watershed Stormwater Management Plan* presents specific recommendations relative to criteria and standards necessary to define the controls on runoff from land development activities required to achieve the goals of Act 167. The *Plan* also contains model stormwater ordinance provisions and recommendations concerning administrative and institutional arrangements necessary to implement and enforce the standards and criteria.

Sections V and VII of this manual address the specific recommendations of the *Beaverdam Branch Watershed Stormwater Management Plan*.

BEAVERDAM BRANCH STORMWATER MANAGEMENT PLAN TRAINING MANUAL

SECTION III

BASICS OF HYDROLOGY

RELEVANCE

Hydrology is the science that deals with storms and floods. An understanding of hydrology is, therefore, a key requirement for understanding the basic concepts of stormwater management. This section will review several hydrologic concepts and terms which are important in gaining an understanding of the subject of stormwater management and which will be encountered repeatedly as the Beaverdam Branch Stormwater Management Plan is implemented.

DEFINITION

Hydrology is defined as the applied science concerned with the waters of the earth in all their states - their occurrence, distribution, and circulation through the hydrologic cycle.

HYDROLOGIC CYCLE

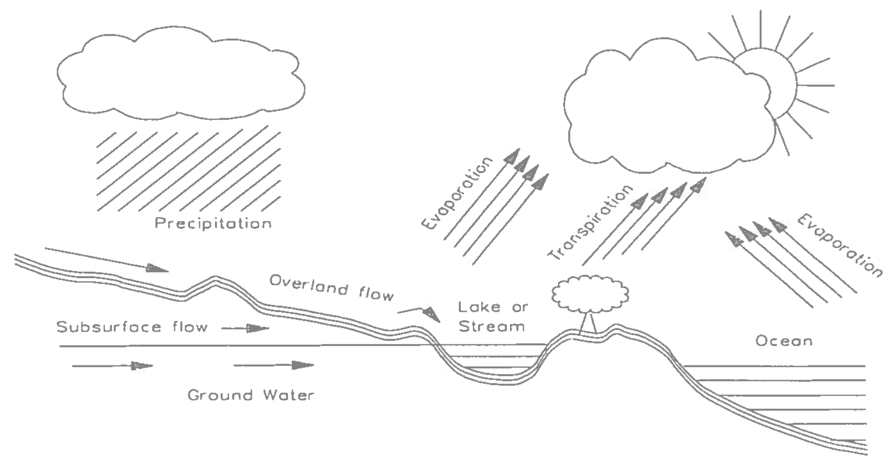
The hydrologic or water cycle is the continual flow of water between the atmosphere, the surface of the earth and under the ground. When rain falls on the land or when snow melts, it may soak into the soil (infiltration) or run off the surface of the land to nearby lakes, streams and wetlands (overland flow). Some rain water is typically trapped in depressions on the surface of the ground on a temporary basis.

Moisture on the surface of the ground is directly returned to the air as vapor (evaporation). As water is taken up by plants, it is released to the air through the plant's leaves (evaportranspiration). As much as 70 percent of all rain that falls re-enters the atmosphere in a short time.

Infiltration of stormwater into the soil is possible if the ground surface is not frozen or covered with pavement. Tiny openings between soil particles allow liquid water to pass through to lower soil levels. The spaces between the soil particles also allow moisture to evaporate into the air, a process which occurs rapidly when sunlight shines on open soil.

A portion of the stormwater entering the ground continues to flow downward where it may reach a saturated soil layer (ground water). The upper surface of the saturated layer is called the water table and the water below the water table surface is referred to as ground water. The process by which surface water replenishes ground water is called ground water recharge. Eventually, some of the ground water is discharged to lakes, stream and wetlands. Water from these areas evaporates, completing the water cycle. When clouds form and rain and snow falls the water cycle begins again.

Figure III-1
Hydrologic Cycle



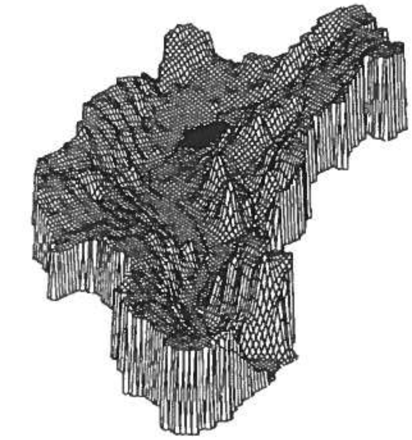
The most important component of the water cycle from the perspective of stormwater management is the overland flow or surface water runoff component. However, as is discussed in subsequent sections of this manual, the techniques which are used to estimate runoff do so by considering the effects of the other forms of water movement.

IMPORTANT TERMS

A comprehensive glossary of hydrologic, hydraulic and stormwater management terms is provided in Appendix A of this manual. Several essential terms essential to an understanding of basic stormwater management principles are defined here as a preface to our discussion of basic stormwater management principles.

WATERSHED

A watershed is an area of land which is drained by a particular river or lake. The surface of the ground within a watershed is sloped in directions which produce the result that all precipitation which falls on the watershed eventually drains through a identifiable stream. Essentially, all of the land within the watershed sheds water to the receiving stream. Drainage basin is a term synonymous with watershed. An illustration of the concept of a watershed or drainage basin is provided in Figure III-2.



For the purpose of hydrologic modeling and stormwater management planning, watersheds or drainage basins are frequently divided into smaller drainage areas which nest inside and together form the complete watershed. These small, component areas of a watershed are frequently referred to as subbasins.

INFILTRATION

Infiltration refers to the flow or movement of water generally downward through the pores of the soil ground water. Water which infiltrates generally does not contribute to stormwater runoff related problems. To the contrary, infiltration of precipitation results in beneficial recharge of ground water.

SURFACE OR DEPRESSION STORAGE

A portion of the rain falling on the ground surface neither runs off into streams nor infiltrates to ground water. A portion of the precipitation is retained in depressions in the ground surface from which it evaporates. A related phenomenon is the temporary capture of precipitation on and in vegetation.

FLOW REGIMES

Runoff flow regimes refers to the modes of travel of precipitation across the ground surface. There are two general modes or regimes of water runoff: overland flow and channel flow. Overland flow refers to the flow of water over the ground before it enters some defined channel or pipe. Channel flow is the movement of water through perceptible natural or artificial waterways which serve to convey water. This may include natural streams and manmade pipelines and canals.

TRAVEL TIME

Travel time is the time it takes runoff to travel from one location to another in a watershed. Travel time is determined by the distance runoff must travel and the speed at which it moves between the two locations.

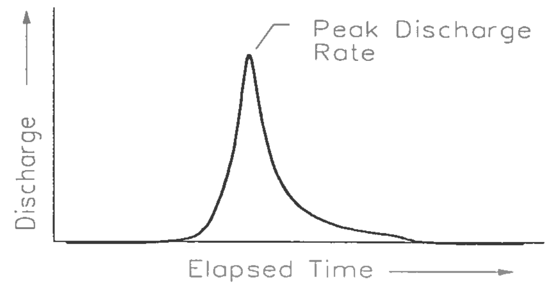
RUNOFF VOLUME AND RATE

Runoff volume is the total quantity of water which has run off of the land as a result of the precipitation event. Total runoff volume is usually expressed in terms of acre-feet. Runoff rate refers to the speed at which specified volumes of water are generated, moved or discharged. Runoff rates are typically measured in terms of cubic feet per second (cfs). One may envision runoff volume as the amount of water that has filled a rain barrel as a result of a rainstorm. The runoff rate can be pictured as how fast the barrel fills.

HYDROGRAPH

Runoff rates vary over time during and after precipitation events. Typically, the rate of runoff begins small and increases gradually or rapidly to a maximum value referred to as the peak flow and then gradually decreases to the originally starting value. A table or graph that displays this variation of discharge at a specific point over time is called a hydrograph. An example graphical illustration of a hydrograph is presented in Figure III-3.

Figure III–3
Runoff Hydrograph

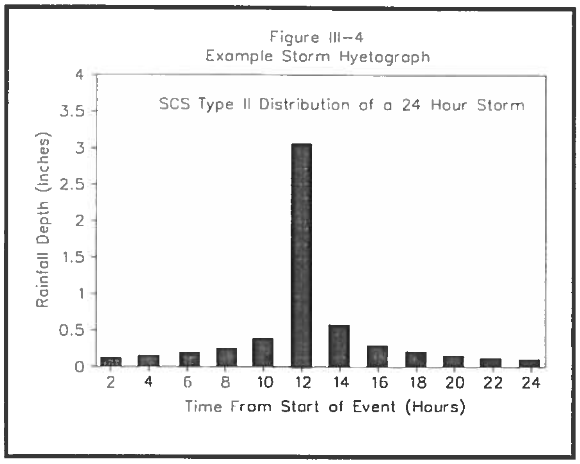


FACTORS AFFECTING STORMWATER RUNOFF

There are a number of factors which determine the amounts and rates of runoff resulting from precipitation. Some of these factors can be affected by man's development activities and others cannot. The quantification of the effects of these factors upon runoff is an important aspect of hydrology.

PRECIPITATION

As the definition of stormwater would lead one to expect, the primary determinants of runoff volumes and rates are the volume and rate of precipitation which trigger the runoff. Precipitation is also the most variable factor affecting stormwater runoff. The quantity of precipitation varies geographically, temporally and seasonally. Time variations of rainfall accumulation are normally presented in tabular or graphical forms called *hyetographs*. An example storm hyetograph is presented in Figure III-4.

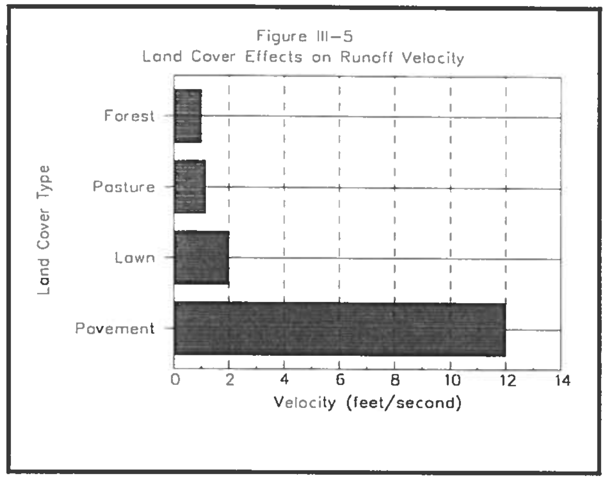


Stormwater and flood control facilities are designed to function properly under specified hypothetical design storm conditions. Design storms are developed from historical rainfall data to represent severe rainfall distribution patterns for given durations (expressed in hours) and frequency (defined in years). Storm *duration* refers to the length of time over which the precipitation falls. Storm *return frequency* refers to the average interval in years over which a storm event of a given precipitation volume can be expected to recur. For example, reference to a "10-year" storm means that a storm with the specified characteristics can be expected to occur *on average* once every ten years. Viewed another way, there is approximately a ten (10) percent chance that a "10-year" storm will occur in any given year.

LAND COVER / LAND USE

The type of land cover / land use in an area has a significant effect upon the volume and rate of runoff produced. *Land cover* relates to the type of feature present on the surface of the earth. Urban buildings, pavement, lakes, forests, grasslands and cultivated fields are all examples of land cover types. The term *land use* refers to the human activity associated with a specific piece of land. For example, a tract of land on the fringe of an urban area may be used for single family housing. Depending upon the level of mapping detail, its *land use* would be described as residential use or single family residential use. The same tract of land would have a *land cover* consisting of roofs, pavement, grass and trees. While it is land cover which ultimately affects runoff, the two terms are used somewhat interchangeably in hydrology to the extent that land use is descriptive of the associated typical land cover conditions.

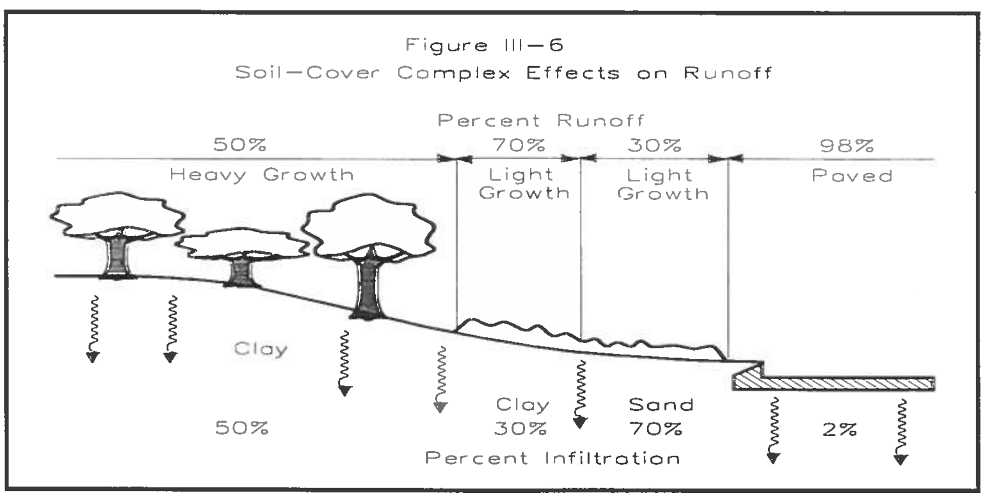
Land cover affects runoff in several ways. The type of land cover present affects the extent to which rain is captured and allowed to evaporate. Land cover has a significant impact upon the amount of water which moves as infiltration rather than direct runoff. Land cover also has a direct effect upon the speed at which the runoff moves across the ground surface. Changes to overland flow velocity can have two results. First, slowing the movement of runoff allows more water to infiltrate into the soil thereby reducing the runoff volume. Second, a reduction in flow velocity tends to reduce the peak rate of runoff. Typical overland flow velocities associated with various types of land cover are illustrated in Figure III-5. As is indicated in Figure III-5, the type of land cover has a major impact upon flow velocities, even between "natural" land cover types such as forests and lawn areas. This effect is even more pronounced when natural land cover types are paved. Paving a natural surface can increase overland flow velocities by a factor of as much as twelve.



SOIL CHARACTERISTICS

The effect soil conditions have on runoff relates to the extent infiltration occurs as opposed to direct runoff. The more highly permeable the soil, the more infiltration and the less direct runoff occurs. The United States Soil Conservation Service (SCS) (now the Natural Resources Conservation Service) classified soils into *hydrologic soil groups* to indicate the rate of infiltration rate for the soil and the resulting runoff potential of the soil. The SCS has identified four (4) hydrologic soils groups designated Groups A, B, C and D. The Group A soils are the most permeable and have the lowest runoff potential. Group D soils have the lowest permeability and highest runoff potential. Groups B and C characteristics fall within the two extremes.

As is indicated in Figure III-6, land cover and soil characteristics combine to affect infiltration and surface runoff volumes. The combination of land cover and soil characteristic is referred to as the *soil-cover complex*.



TERRAIN

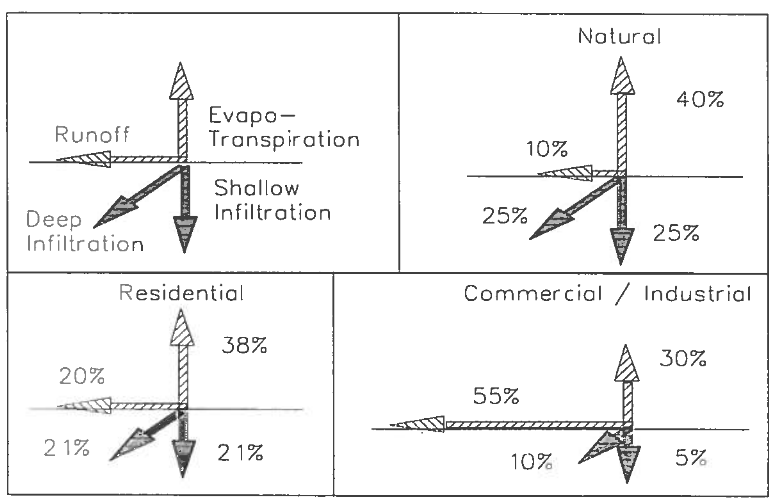
Terrain affects runoff rates principally by affecting the rate of overland flow and the overall time of travel. The steeper the slope, the more rapidly water will flow overland and in channels. In general, step slope areas produce higher resultant peak runoff rates. Terrain, as it affects the distance runoff must travel to the point of discharge or measurement, also affects peak discharge rates. As a rule, circuitous flow paths result in lower peak discharge rates.

EFFECTS OF LAND DEVELOPMENT ON STORMWATER RUNOFF

Land development frequently results in significant changes to two (2) of the four (4) factors affecting stormwater runoff presented above. While land development has no effect on precipitation and normally little effect on soil conditions, it usually produces major changes to land cover and perceptible changes to local terrain. From the standpoint of stormwater management these changes unfortunately tend to produce increased runoff volumes and peak rates of discharge.

Land development associated with urbanization normally includes paving and/or otherwise covering the ground with impervious surfaces. For example, a natural area has little or no paved surfaces. If this area is developed for a single family residential land use, the amount of impervious surface will increase to 10% to 20% of the area. If it is developed to a commercial or industrial land use, the amount of paved surface will increase to 75% to 100% of the area. As indicated previously, such a change from pervious to impervious surfaces will decrease infiltration and increase runoff volumes. This is illustrated in Figure III-7.

Figure III-7
Effects of Urbanization on Paved Surfaces and Runoff



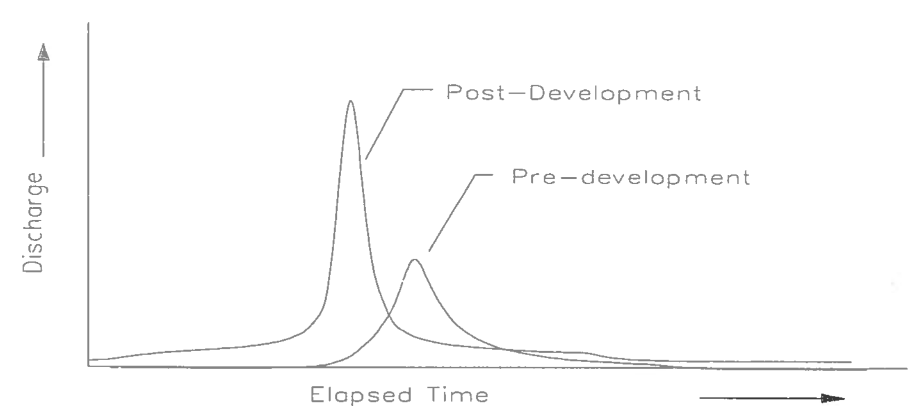
As is indicated in Figure III-7, the increase in impervious area which accompanies most land development activities reduces both infiltration and evapotranspiration rates. This produces more runoff volume than would result otherwise in the natural condition.

Land development also frequently results in increased runoff velocities. This occurs as a direct result of paving (see Figure III- 5). Increased flow velocities also occur as natural drainage channels are replaced with smooth lined channels, gutters and/or pipes. In addition, the associated stormwater collection systems frequently result in short travel distance by replacing the more circuitous natural flow paths with more direct man-made piped systems.

As was indicated previously, these types of changes to land cover and flow regimes tend to increase the volume of runoff generated and the peak rate of discharge of runoff from a given site. Clearly, the extent to which the increases in volumes and peak rates occur will depend upon the pre-development land cover characteristics and the specific type of land use / land cover in place following development. The more extreme the land cover changes are, the more extreme will be the change to runoff characteristics. Moreover, post development increases in runoff will be largest when a development which includes a large amount of paving occurs in an area underlain by soils with high permeability. In such a case, reductions in infiltration will be extreme because a highly permeable soil is isolated from the rainfall by an impervious layer. Recognizing that there is a great amount of site specific variability associated with the impacts of land development, the example hydrograph comparisons are presented in Figure III-8.

The hydrographs presented in Figure III-8 illustrate the overall effects of typical land development on stormwater runoff.

Figure III—8
Comparison of Pre and Post Development Hydrographs



The indicated increases in total runoff volume and peak rate of discharge are the results of decreased infiltration to ground water and decreased interception of rainfall in surface depressions and vegetation. The higher velocities and frequently shorter travel times associated with land development contribute to the higher peak discharge rate and more rapid rise and fall of the runoff hydrograph.

RUNOFF COMPUTATIONAL TOOLS

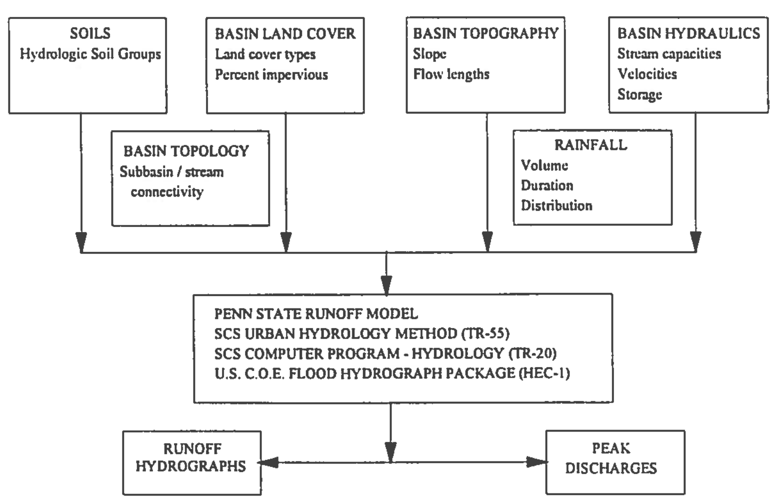
A number of methods for estimating stormwater runoff volume and rates have been developed. The most useful for stormwater management applications are rain-runoff methods which use the United State Soil Conservation Service (SCS) *soil-cover complex* estimating runoff. These methods offer the advantage of providing a means for estimating the stormwater runoff implications of changes in land use / land cover conditions under a range of site specific rainfall characteristics.

The *Beaverdam Branch Stormwater Management Plan* was formulated using the Penn State Runoff Model and recommends that stormwater calculations prepared under the requirements of the Plan be performed using one or more of the following methods:

- Penn State Runoff Model (PSRM)
- Soil Conservation Service Urban Hydrology Method (SCS TR-55)
- Soil Conservation Service Computer Program for Project Formulation-Hydrology (SCS TR-20)
- United States Army Corps of Engineers Flood Hydrograph Package (HEC-1)

These four recommended runoff computational techniques vary somewhat in terms of applicability to specific situations, data requirements, the algorithms used and data output. However, they all entail the same general procedure illustrated in Figure III-9. As is indicated in Figure III-9, the computational techniques recommended for use by the *Beaverdam Branch Stormwater Management Plan* use mathematical characterizations of the primary factors affecting stormwater runoff to produce estimates of runoff. Because of this they can be used to estimate stormwater runoff consequences of changes to watershed characteristics produced by land development activities.

FIGURE III-9
GENERALIZED RAINFALL RUNOFF COMPUTATIONAL PROCEDURE



SECTION IV

TECHNICAL APPROACH TO STORMWATER MANAGEMENT

INTRODUCTION

As was discussed previously in Section II, the basic standard for stormwater management as defined by Act 167 is that those involved in activities which can affect stormwater runoff characteristics are responsible for controlling and managing that runoff so that those changes will not cause harm to persons or property throughout the watershed. While a land developer is responsible for properly managing or controlling runoff from his site, it is the Counties' responsibility to establish criteria and standards which the developers can use as the basis for the design of any necessary control features.

The requirement for watershed wide as opposed to local protection demands comprehensive planning on a watershed level. This planning effort must develop such standards and criteria which, if followed, will provide for the control of stormwater so as to avoid adverse impacts not only at the particular site but everywhere downstream where the potential for harm can reasonably be identified.

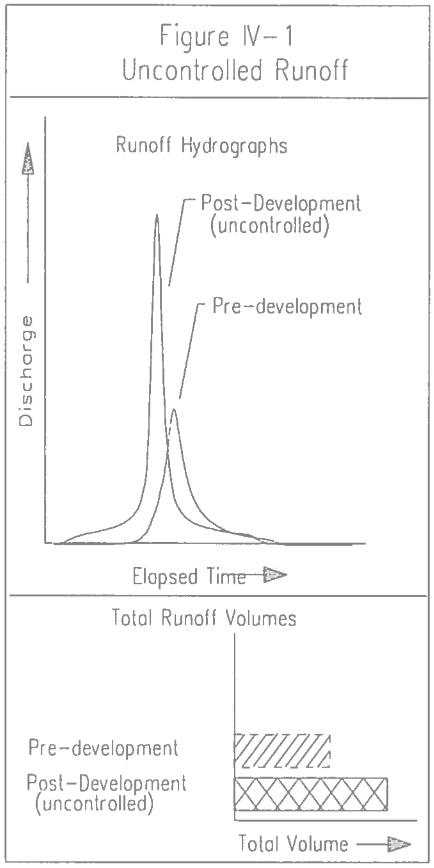
GENERAL APPROACH TO RUNOFF CONTROL

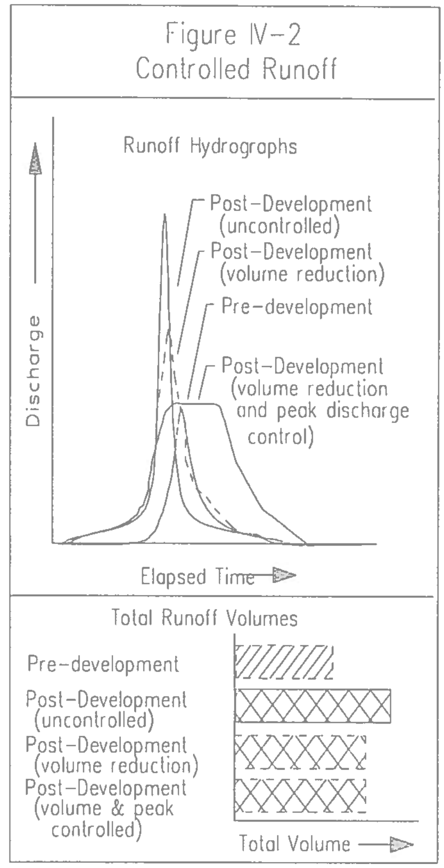
The most effective means of satisfying the basic requirements of Act 167 would be by controlling runoff from land development activities such that both the total volume and rate of runoff from new development are identical to that which occurred before the land was disturbed. In other words, the post-development runoff hydrograph would be identical to the pre-development hydrograph. If this could be accomplished, stormwater runoff from the new development would not produce any effect on downstream flows, eliminating any concern relative to the creation of downstream damage potentials.

Unfortunately, as was discussed in Section III, most land development activities involve the conversion of land use from a type which exhibits relatively low runoff potential a type which has a higher runoff potential. This results in increases to both total volume and peak rate of discharge.

Measures can be taken to manage stormwater runoff by reducing the total runoff volume and/or control peak rates of discharge. Techniques which may be used to minimize the increase in total runoff volume are described in Section VI of this manual. These techniques generally consist of measures which minimize the extent of land cover changes from pervious to impervious areas and/or artificially induce infiltration to ground water. While these measures can be effective in reducing increases in runoff volumes, it is usually impractical to entirely avoid runoff volume increases attendant to most land development activities. Consequently, as is indicated in Figures IV-1 and IV-

2, volume reduction measures typically produce hydrographs with peak rates of discharge and volumes falling between pre-development and uncontrolled post-development conditions.





Because it is impractical to entirely avoid increases in total runoff volume, the inevitability of some degree of runoff volume increases must be accepted and the primary emphasis of the stormwater control criteria must be placed on the control of peak discharge rates. In order to minimize the potential for damage, the basic *minimum* stormwater runoff control criteria to be applied is that post-development peak discharges must not exceed pre-development discharge rates.

This requirement that the post-development peak rate of discharge shall not exceed the pre-development peak rate of discharge is runoff control standard recommended for use in the Beaverdam Branch Watershed.

BEAVERDAM BRANCH STORMWATER MANAGEMENT PLAN TRAINING MANUAL

SECTION V

SPECIFIC PLAN REQUIREMENTS

INTRODUCTION

The *Beaverdam Branch Stormwater Management Plan* contains specific stormwater runoff control standards which are to be adhered to by individuals involved in land development activities. As was indicated earlier, these standards were developed so as to avoid the development of downstream flooding and erosion and sedimentation problems attributable to runoff from the land development.

The *Plan* also provides criteria to be used as the basis for the design and evaluation of proposed stormwater control facilities and or actions.

RUNOFF CONTROL STANDARDS

The *Beaverdam Branch Stormwater Management Plan* addresses the control of changes to both runoff volume and peak runoff rates. The standard for the control of increases to total runoff volume resulting from land development is essentially a "best practical technology" type of standard. That is, no specific numerical limit to runoff volume increases are presented. Instead, the *Plan* contains recommendations for encouraging the application techniques which serve to limit the extent of increases to total runoff volume. Site specific topographic, soils, ground water, space and land use conditions and requirements will largely dictate the extent to which volume reduction measures can be taken. Therefore, while the *Plan* calls for land developers to employ appropriate runoff volume reduction measures, the developer is free to select the methods to be used and the extent to which they are applied based upon site specific conditions. Section VI of this manual describes available volume reductions measures and their limitations.

The *Plan* establishes the following as the basic runoff control standard for the Beaverdam Branch Watershed: there shall be no increase in the peak rate of stormwater runoff discharge from any land development activity following the completion of the activity (post-development conditions) over the rate that would have occurred from the land prior to the activity (pre-development conditions

Under this approach, each developer can select and design drainage control measures that are most appropriate to the site as long as it can be demonstrated that the post-development peak discharge rate will not exceed the pre-development rate.

CONTROL STORM CRITERIA

The preceding discussion alludes to the use of specified *control storm characteristics criteria* during the application of the peak runoff control standard. These control storm characteristics criteria describe the rainfall events which the stormwater control measures must handle in conformance with the established runoff standards. The critical rainfall event characteristics are as follows:

- Rainfall Distribution
- Storm Duration
- Rainfall Volume

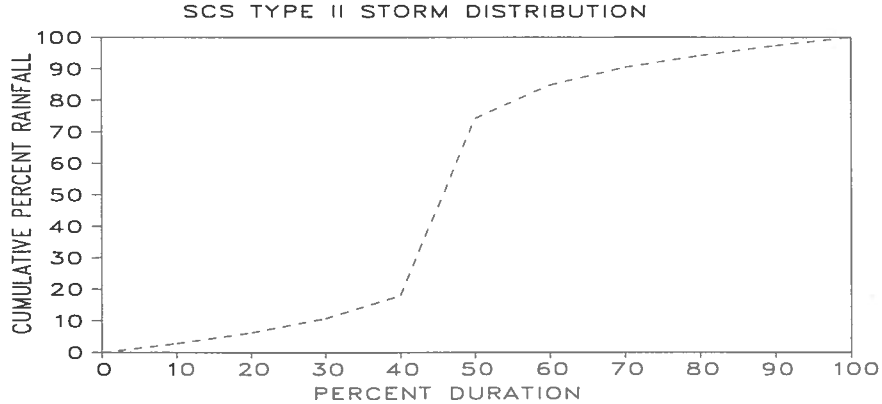
The Beaverdam Branch Stormwater Management Plan criteria describing each of these characteristics are presented below.

RAINFALL DISTRIBUTION

Rainfall does not fall at a uniform rate throughout a storm event. Within a single event, the rate at which rain falls can range from zero to several inches per hour (i.e., from a drizzle to a downpour). Rainfall distribution refers to the description of the variations in rainfall rates within the storm event. The U. S. Soil Conservation Service (SCS) Type II Storm Distribution has been selected for use in the Beaverdam Branch watershed. The SCS Type II distribution (Figure V-1) is a synthetic rainfall pattern arranged in a sequence that is critical for producing peak runoff. It is supported by significant research activity, it is widely used in stormwater runoff calculations throughout this area and its use is incorporated directly in the frequently employed runoff computational procedures referenced in Section III of this Manual.

FIGURE V-1

SCS TYPE II STORM DISTRIBUTION



STORM DURATION

Storm duration refers to the length of time over which the specified amount of precipitation falls. This factor is of concern because rainfall duration has a direct effect upon the resulting runoff volume and peak rate of discharge. The Beaverdam Branch Stormwater Management Plan recommends the use of the twenty-four (24) hours as the storm duration as the basis for stormwater management planning and control within the watershed.

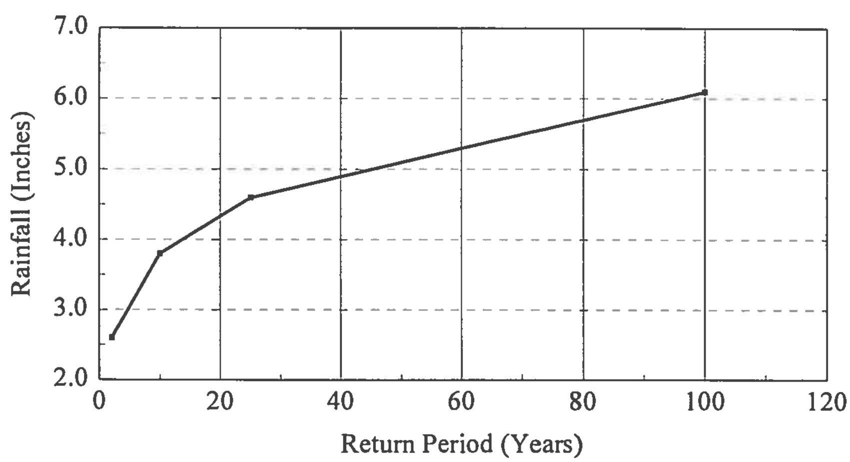
RAINFALL VOLUME

The selection of the appropriate rainfall volume(s) to be used in stormwater management planning is closely tied to an analysis of *storm frequency*. Storm frequency refers to the average interval in years over which a storm event of a given precipitation volume can be expected to recur. For example, reference to a "10-year" storm with an associated 3.8 inch, 24 hour duration storm volume indicates that a storm producing 3.8 inches of rainfall over a 24 hour period *on the average* can be expected to occur once every ten (10) years. Put another way, such a storm has a roughly ten (10) percent chance of occurring in any one year.

Data describing the relationship between rainfall volumes, durations and frequencies in Pennsylvania are presented in the *Field Manual of Pennsylvania Department of Transportation Storm Intensity - Duration - Frequency Charts*. These data were used to identify 24 hour rainfall volumes for the Beaverdam Branch watershed for frequencies ranging from 2 to 100 years (Figure V-2).

Figure V-2

24 Hour Storm Return Frequency Curve



The Beaverdam Branch Watershed Stormwater Management Plan requires that stormwater management/control systems demonstrate the ability to adequately control runoff from storms with the following return frequencies and associated volumes.

Storm Frequency	Rainfall Depth (inches)
2-year	2.6
10-year	3.8
25-year	4.6
100-year	6.1

The control storms were selected based upon an evaluation of conditions within the watershed and the consideration of the need for adequately controlling small and intermediate storms as well as large events. Consequently, stormwater control measures employed must be shown to be effective in controlling post-development runoff rates to the specified percentages of the pre-development rates under each of the four (4) specified control storms. It is not sufficient to control the most severe storm event without adequately controlling runoff from the smaller, more frequent events.

The characteristics of these control storms (arranged in the SCS Type II Distribution) are presented in Table V-1.

TABLE V-1
CONTROL STORM CHARACTERISTICS

	Rainfall Increment (Inches)			
	Storm Return Period			
Elapsed Time (Minutes)	2-Year	10-Year	25-Year	100-Year
60	0.031	0.046	0.055	0.073
120	0.031	0.046	0.055	0.073
180	0.031	0.046	0.055	0.073
240	0.031	0.046	0.055	0.073
300	0.042	0.061	0.074	0.098
360	0.042	0.061	0.074	0.098
420	0.052	0.076	0.092	0.122
480	0.062	0.091	0.110	0.146
540	0.073	0.106	0.129	0.171
600	0.094	0.137	0.166	0.220
660	0.146	0.213	0.258	0.342
720	1.175	1.718	2.079	2.757
780	0.218	0.319	0.386	0.512
840	0.114	0.167	0.202	0.268
900	0.083	0.122	0.147	0.195
960	0.062	0.091	0.110	0.146
1020	0.052	0.076	0.092	0.122

TABLE V-1
CONTROL STORM CHARACTERISTICS
(CONTINUED)

	Rainfall Increment (Inches)			
	Storm Return Period			
Elapsed Time (Minutes)	2-Year	10-Year	25-Year	100-Year
1080	0.052	0.076	0.092	0.122
1140	0.042	0.061	0.074	0.098
1200	0.042	0.061	0.074	0.098
1260	0.031	0.046	0.055	0.073
1320	0.031	0.046	0.055	0.073
1380	0.031	0.046	0.055	0.073
1440	0.031	0.046	0.055	0.073
TOTAL	2.60	3.80	4.60	6.10

PERMISSIBLE RUNOFF COMPUTATION TECHNIQUES

The Beaverdam Branch Stormwater Management Plan identifies the following runoff computation techniques for use in developing stormwater control plans:

- Soil Conservation Service Urban Hydrology Method (TR-55)
- Soil Conservation Service Computer Program for Project Formulation - Hydrology (TR-20)
- Penn State Runoff Model (PSRM)
- United States Army Corps of Engineers Flood Hydrograph Package (HEC-1)

Engineers involved in the preparation of stormwater control plans and reviewers of such plans should review the pertinent information relative to the use and applicability of each of these methods. It is important that the assumptions implicit and explicit in each of the techniques be understood and that the techniques are properly applied.

BEAVERDAM BRANCH STORMWATER MANAGEMENT PLAN TRAINING MANUAL

SECTION VI

STORMWATER MANAGEMENT TECHNIQUES

INTRODUCTION

One of the key features of the Stormwater Management Act 167 is its mandate to implement comprehensive stormwater runoff control practices. The Act requires stormwater planning at the watershed level in such a manner that adverse impacts of storm runoff are prevented, both at a particular site and at every potential flood prone location downstream from the watershed. Therefore, any stormwater management technique must consider runoff impacts on the watershed.

Studies in recent years have identified a number of methods of reducing the impact of development on storm peaks. Many management practices indicate the ingenuity of the planning, engineering and regulatory agencies. In particular, the publications of Soil Conservation Service (SCS) of Department of Agriculture (USDA), U.S. Environmental Protection Agency (EPA) and American Public Works Association (APWA) are quite comprehensive and aid in expanding some of the management practices reported in this section.

The present-day emphasis on detention or reduction of urban runoff within the contributing source area represents a remarkable shift in runoff control strategy that has occurred only just recently [Kibler and Aron, 1980]. This trend toward on-site runoff abatement includes control measures that either reduce the runoff directly at the source or delay the arrival of runoff contributions at some critical points downstream. Attesting to the strength of this trend is the large and growing number of publications describing various on-site control measures. Notable contributions in this regard include those by Poertner [1974, 78] on stormwater detention practices; Becker et al. [1973] on rooftop storage; Aron et al. [1976] on general runoff abatement measures including infiltration trench design; Montgomery County Soil Conservation District on storage detention ponds; ASCE, The Urban Land Institute, and the National Association of Homebuilders [1976] on residential runoff abatement measures; and Field [1978] and Field and Lager [1975] for comprehensive reviews of structural and non-structural measures.

Methods applicable to almost all watersheds are based on the principles of velocity reduction, infiltration enhancement, detention and retention storage, etc. However, site-specific conditions in a given watershed may lead to the development of innovative control measures. All the methods are designed to control sediment, pollution and stormwater within the watershed. Although the design of stormwater control facilities is usually completed by engineers and landscape architects, key policy questions should first be answered by local officials. Preferences of local residents concerning level of protection, aesthetics, maintenance responsibilities, and cost allocation should be assessed by local officials, not professionals. After community stormwater management policies have been established, detailed design or design review of particular controls and measures can be carried out [Clinton River Watershed Council, 1984]. Where practical, control measures should be designed to exploit the beneficial uses of the stormwater such as recreational and aesthetic benefits and recharge of underground aquifers. In many cases this can be the decisive factor in approval of a new land development. The intent of this chapter is to review the existing storm water management techniques and make recommendations on their applicability, from many different perspectives such as suitability for the study watershed, cost, effectiveness, advantages, disadvantages and maintenance etc.

CONCEPT OF STORMWATER MANAGEMENT

Early stormwater management efforts concentrated on transporting the runoff as quickly as possible from a storm location, by routing it through storm sewer systems. As the urban development increased in the watershed, such a flood control effort resulted in the worst flooding conditions downstream, due to increased total flow, peak flow rate, stream velocity, and flow depth. Land development causes an increase in the rate of runoff from the site, resulting in an increased peak flow rate. Changing a natural channel to a concrete-lined ditch or a storm sewer system increases the velocity and reduces the travel time to downstream locations. A reduction in the travel time may cause the peak flow rate from one watershed to contribute to, or, in the worst case, to coincide with the peak flow rate of some other watershed(s). This again results in an increased peak flow rate. Detaining the storm water and releasing the maximum rate over a longer period of time may also induce the same adverse effect.

It is now recognized that, due to above mentioned problems, the most logical and effective approach to control the storm runoff is to maintain the natural runoff flow characteristics. This can be accomplished in general by maximizing natural infiltration processes, reducing impervious surfaces, preserving floodplains, and controlling storm runoff in the watershed. There are numerous, technically acceptable techniques which have varying degrees of applicability in the study area, depending on the site and watershed characteristics. Some of the most widely used ones will be described here, along with a brief discussion of their key features, advantages and disadvantages, and typical costs. It will be up to each individual developer to select the techniques that are most appropriate to the project and site. It is most likely that, in most situations, a combination of on-site controls will be the most appropriate and least costly stormwater management system. Nevertheless, some alternatives must be carefully analyzed. For example, when several detention basins are used, their interaction must be considered, since a combination of the timing of their releases could aggravate downstream flooding rather than alleviating it. Also, the efficiency and costs of many of management alternatives vary from one location to another. Many of the alternatives, such as on site storage basins, erosion control, and flow reduction alternatives, may be feasible only for areas of new development [Kibler, 1982].

To determine the most appropriate set of techniques for a particular site, several factors should be evaluated:

1. Soil characteristics (i.e. soil permeability, erodibility)
2. Topography
3. Subsurface conditions
4. Drainage patterns (i.e. proximity to stream flooding problems)
5. Proposed land uses
6. Costs
7. General advantages and disadvantages of each technique.

STORMWATER RUNOFF PROBLEMS

FLOODING

During high intensity, or long duration storms the existing infiltration capacity of soils may be exceeded and surface storage filled to capacity. Once this happens, runoff occurs in the form of overland and channel flow. During some high runoff and relatively infrequent storm events, if the existing watercourses have insufficient capacity to convey surface flows, they get flooded. Natural floodplains provide some benefits by serving as reservoirs, natural recharge basins, collectors of pollutants, wildlife habitats etc. As floodplain or upstream areas are developed, this natural beneficial phenomenon, becomes a disaster due to its increased frequency and magnitude. Thus, new developments potentially create flood problems and potential downstream damages.

There are many ways to reduce the impact of new development on flooding. Some general concepts to consider in determining which solutions are applicable to a study area are listed below:

1. Limit development of floodplains and prohibit development in floodways
2. Increase infiltration
3. Reduce runoff rates
4. Store precipitation and runoff where it falls and release it slowly
5. Keep water confined in adequate pipes or channels
6. Protect areas subject to flood damages
7. Build flood control measures
8. Limit erosion and sediment transport

EROSION AND SEDIMENTATION

When raindrops hit bare soil, the cumulative effect is the splashing of the hundreds of tons of soil into the air. Some particles are washed into streams or downstream areas unless the velocity is very low or the soil is protected by some means. This phenomenon is called erosion. The runoff from new land developments can result in erosion both on-site and off-site. Once soil erosion begins, the soil particles transported by runoff and water currents begin to settle down in downstream drainage ways. This is called sedimentation. Sedimentation may result in blockages of natural watercourses, plugging of culverts and storm sewers, smothering of vegetation, filling of reservoirs, etc. Sedimentation occurs at increased rates during and following land development because graded areas are left in an unprotected state. Data collected by Brandt [1972] shows that erosion rates on land undergoing development can be 2,000 times larger than the erosion rate of forested lands.

Erosion problems in the Beaverdam Branch Watershed are particularly significant in areas downstream of large developments. Unless properly collected and transported, runoff in large developments can collect on the surface and run through downstream property. This ultimately can lead to loss of property and threats of damage to residential, commercial, and industrial properties.

General concepts to be followed for minimizing erosion and sedimentation include the following:

1. Protect the soil surface to withstand effects of rainfall and runoff
2. Limit soil erosion through site management practices
3. Store rainfall and runoff where it originates and release it slowly
4. Catch sediment before it enters natural drainage channels

Activities specifically appropriate to drainage in the vicinity of the shore line bluff areas include:

1. Collection of surface runoff in properly designed stormwater collection and conveyance systems.
2. Conveyance of surface water runoff to the base of the bluffs thorough outfalls equipped with energy dissipation devices.

POLLUTANT TRANSPORT

Runoff from developed areas contains more pollutants than from natural watersheds. These pollutants include heavy metals, BOD, and high concentrations of suspended solids. Heavy metals and BOD generally increase as the area is developed and reach a plateau when the development has stabilized. The impacts of these pollutants depend on the existing quality and use of the receiving waters. If the newly developed area drains into a supply reservoir, an increase in the amount of pollutants could be very significant. In other cases, the impacts may be difficult to determine and are often long-term, subtle, and persuasive rather than immediate.

ON-SITE STORMWATER FLOW MANAGEMENT

Many methods are available to alleviate the impact of urbanization on the quantities and rates of stormwater runoff. Maryland Interim Watershed Management Policy [APWA, 1981] states, "When engineering a site for stormwater management, two overall concepts must be considered: 1) the perviousness of the system should be maintained or enhanced, and 2) the rate of runoff should be slowed. Land development methods which tend to reduce the volume of runoff are preferred over methods which tend to increase the volume of runoff." Many of the steps taken to reduce flooding also have significant effects in reducing erosion, sedimentation, and stream pollution and may reduce the need for capital-intensive storm sewer systems.

All things considered, the most advantageous means of controlling stormwater runoff from new developments is by minimizing the amount of increased runoff volumes produced. If it were possible to complete the new development in a manner such that there would be no change in either the volume or peak rate of discharge after development, there would be essentially no stormwater related impacts. While it is recognized that, in most cases, it may not be possible to accomplish the goal of making both post-development runoff volumes and peak rates of runoff match pre-development conditions, reasonable efforts should be made to minimize increases in total runoff volumes prior to the design of supplemental controls designed to control peak discharge rates.

It is recommended that land developers be encouraged to take reasonable and applicable steps to incorporate features into their developments which will serve to minimize increases in stormwater runoff volumes.

RUNOFF VOLUME REDUCTION MEASURES

Following are brief descriptions of measures which may be taken to limit increases in total runoff volumes resulting from new developments. The applicability of these measures is highly site specific and dependent upon the nature of the development. However, it is recommended that the potential application of these techniques be seriously considered early in the design of land development activities.

Limit the Amount of Land Disturbed

The added volume of runoff produced as a result of the development of "virgin" land is directly related to the amount of land cover changed from its natural state to a more impervious condition (usually paved). Consequently, increases in runoff volumes can be minimized to the extent that land cover disturbances can be minimized. Individuals involved in land development activities, should, therefore, be encouraged to optimize their development activities from the standpoint of accomplishing the basic objectives of the development while minimizing the amount of paved areas used and natural areas disturbed.

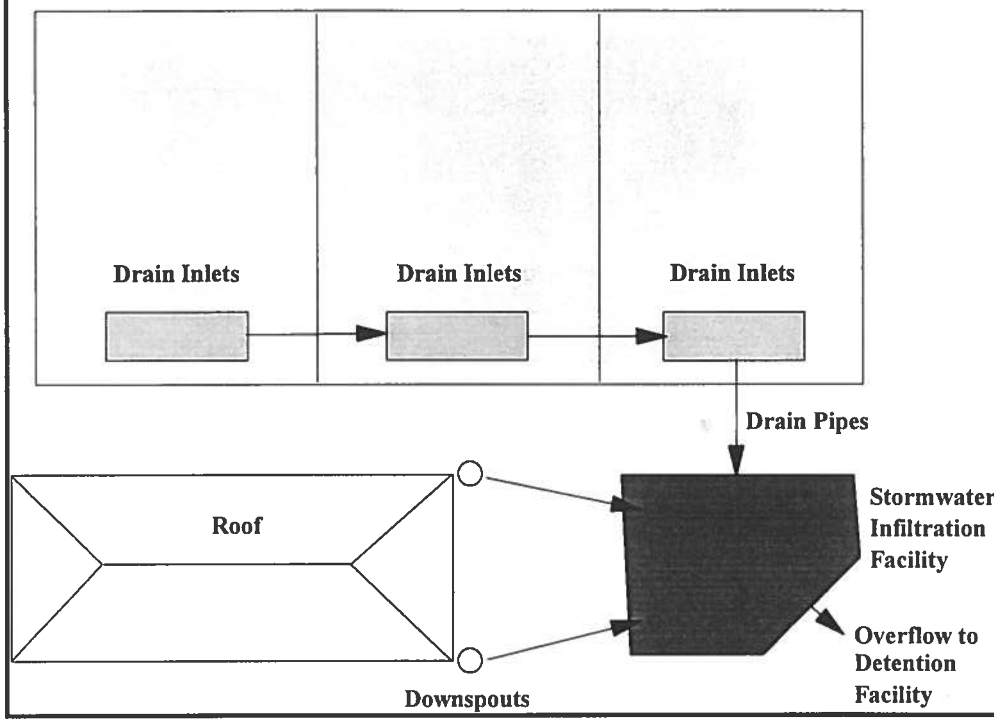
Utilize Terraces, Contoured Landscapes, Runoff Spreaders, Diversions and Grassed or Rock-Lined Waterways

These measures increase the time of concentration by increasing length of overland flow, and thus lowering the flood peak. They provide the additional benefit of reducing total runoff through infiltration if the site has well-drained soils. Runoff spreaders spread runoff or direct it into a system of terraces. Terraces are more suitable for reducing erosion from agricultural and non-urban areas and conserving soil moisture. They reduce effective slope length and avoid runoff concentration. About 90% of the soil that is moved is deposited in the terrace channels. In contouring, crop rows follow field contours to prevent erosion and runoff. Contouring can reduce average soil loss by 50% on moderate slopes and less on steep slopes. There are no soil or climatic limitations on practicing contouring, but it is not feasible on very irregular topography. Grassed waterways or swales stabilize vegetation on drainage channels. For velocities of up to eight feet per second, runoff is reduced by grass channels, if correctly graded and stabilized. Detailed design information for this category of alternatives can be obtained from the Soil Conservation Service's Engineering Field Manual for Conservation Practices.

Use of Infiltration Devices

Infiltration devices are used to reduce flood peaks by releasing all or part of the stored runoff into the ground water. The infiltrated water may appear a short distance downstream as surface water at a later time. However, the runoff hydrograph at the outlet point should be much lower and drawn out in time than that from runoff delay techniques [Aron, 1975]. An example application of infiltration storage techniques is provided in Figure VI-1.

Figure VI-1
Example Application of Roof and Parking Lot Infiltration Facility



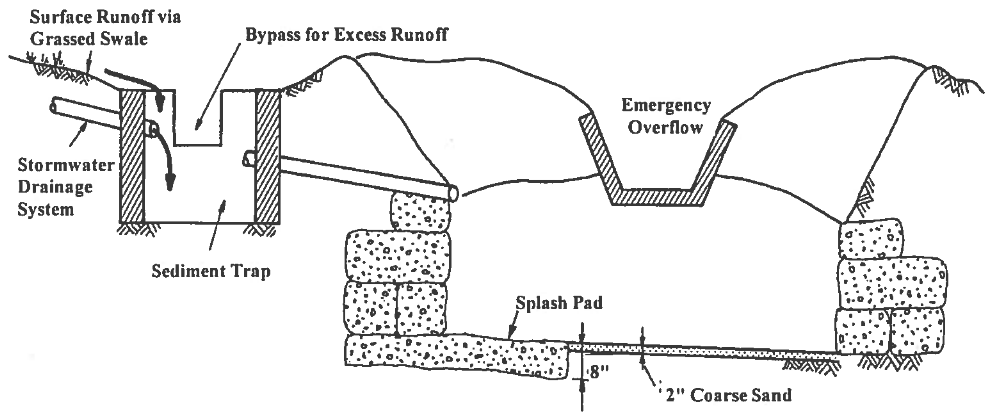
Soils comprised of sands and/or silty sands have high infiltration capacities, and therefore are well suited for infiltration storage. Soils comprised of fine silts and clays have low infiltration capacities and, therefore, are not suitable for constructing infiltration devices over them. Deep soil sampling should be performed to assess the feasibility of water loading the various geological strata for purposes of stormwater disposal. Percolation tests, pumping tests, and soil sampling should provide useful data about the depth, size, and location where subsurface storage is practical. In the Beaverdam Branch Watershed, a number of the soils have properties which can limit the applicability of infiltration storage. Therefore, this alternative should be used with caution. If this method is proposed as the primary means to reduce runoff for large development sites or for sites located in landslide-prone soil locations, a soil engineer's report should be obtained. Moreover, infiltration systems should not be used where there is a reasonable probability the runoff may be contaminated (e.g. industrial sites, commercial parking lots, etc.).

The following techniques for stormwater control are based on the principle of encouraging infiltration to ground water.

Seepage or Recharge Basins

Figure VI-2 shows a typical design of a seepage or recharge basin. In this method, runoff is collected in various storm drainage systems and then passed into large excavations called seepage or recharge basins designed to allow a large percentage of annual rainfall to recharge an underlying aquifer. In addition to reducing runoff volumes, this method offers to put the stormwater to beneficial use by allowing a large percentage of runoff to recharge an aquifer.

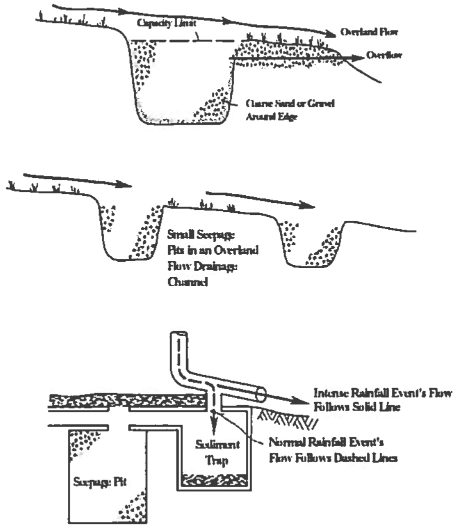
Figure VI-2
Seepage or Recharge



Generally, the infiltration basins must be located in aquifer recharge areas, but they may be used whenever the water table is more than 48" below the ground surface. If they are used as the only means of stormwater control, their size must be sufficient to store the area's maximum design rainfall from all paved areas. However, seepage or recharge basins are economically more feasible if designed to recharge a limited amount of the runoff that is produced by rainfall events and to overflow relatively early during intense rainfall events. Control of this overflow may require the use of additional stormwater management facilities. As indicted above, when seepage basins are used there is a need to consider the impacts of the type and quality of runoff being infiltrated; e.g., water quality impacts on ground water, and possibility of the pit being sealed by salts in the water. Seepage basins should not be used where there is a significant potential for pollution of the ground water. In order to maintain good infiltration rates, the bottom of the basin should be kept silt free by using a sediment trap. In addition, an emergency overflow structure is required to bypass excess runoff.

Seepage Pits or Dry Wells

Figure VI-3
Seepage Pits

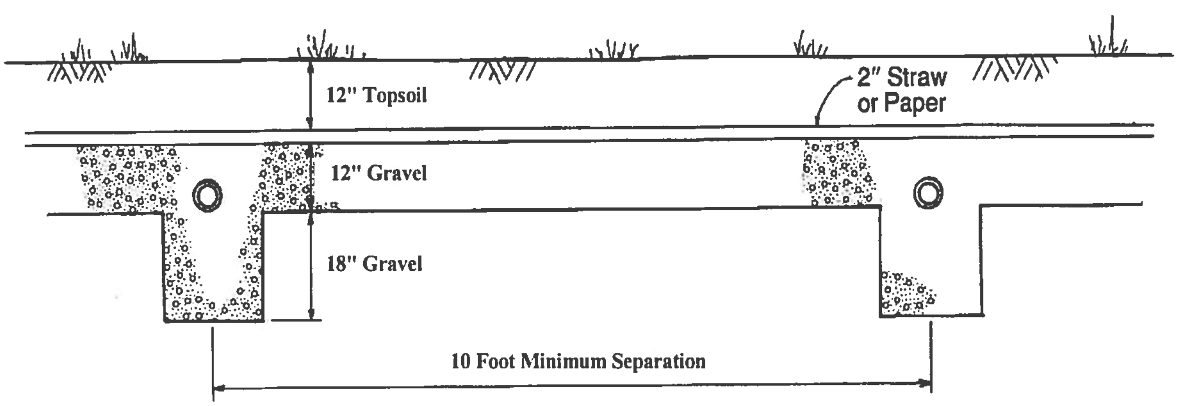


Seepage pits are small excavations designed to overflow during intense storms, but reduce flood peaks by encouraging infiltration to ground water. They can be effectively used at sites where soil permeability is over 0.15 ft/day and water table is more than 48" below the bottom of the pit. There are two important design considerations associated with seepage pits: (1) the minimum size (which depends on porosity of the soil and design storm) should be sufficient to maintain the pre-development infiltration rate; (2) the side area should be at least two times larger than the bottom area. Figure VI-3 shows three seepage pit designs each with an alternative overflow mechanism.

Seepage Beds or Ditches

Seepage beds dispose of runoff by infiltration into the soil through a system of perforated pipes laid in ditches. They are not suitable for sites with water tables less than 48" deep and extremely low permeability. A typical design of a seepage bed is shown in Figure VI-4.

Figure VI-4
Seepage Bed

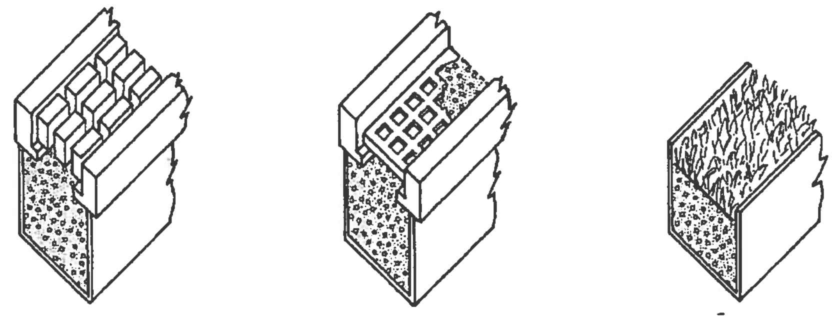


Dutch Drains

Dutch drains are employed in residential developments. They are simply ditches either filled entirely with gravel or covered with top soil and seeded. Very wide drains are usually covered with brick lattice or porous block as shown in Figure VI-5. The drains may either be located directly under the roof eaves along the length of a building, or runoff can be routed from downspouts to the dutch drain.

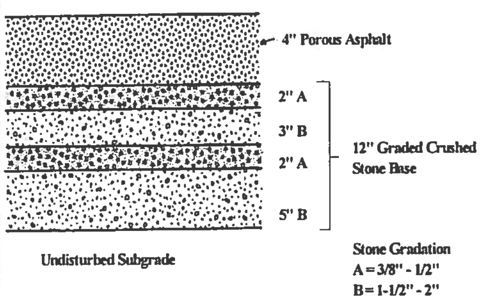
If dutch drains are the only means of stormwater disposal in a development, they should be able to drain the area's design rainfall alone and would be impractally large. More often, dutch drains are combined with other control alternatives for partial stormwater management using dutch drains.

Figure VI-5
Dutch Drains



Porous Pavement

Figure 6
Typical Cross Section of
Porous Pavement



Porous pavement is a special asphalt mixture designed to pass water at a high rate to a specially prepared subbase. The special subbase is thicker than a normal gravel subbase and is composed of coarse graded stone supplying large void spaces to store infiltrated runoff. Figure VI-6 shows a typical porous pavement cross-section. The base aggregate is designed to have about 40% voids ratio.

Regardless of design traffic number (DTN), a minimum surface thickness of 4" should be provided. Also, the combined surface and base thickness should not be less than anticipated frost penetration. Porous pavements have shown very positive results in regard to permeabilities, wear resistance and freezing - thawing effects. However, the main problem with porous pavements is that of pore clogging by muddy tires.

PEAK DISCHARGE CONTROL DEVICES

Peak discharge control devices are those which control peak discharges rates by either lengthening the runoff path of the storm water or storing it and releasing it at a controlled rate. The runoff delay may vary between 15 to 30 minutes for very small areas to several hours for drainage basins of larger extent. A common goal of delay devices is, however, the disposal of all stored water before a second storm might hit. The stored water must be allowed to release at a flow rate that is designed not to cause harm.

Delay of runoff is accomplished by two basic principles of detention and retention. Detention is defined as detaining a large portion of the runoff from a storm, for a time period approximately equal to the natural runoff duration. Retention, on the other hand, is defined as holding of runoff for some time period longer than the natural runoff period. There are following alternatives available based on the principle of runoff delay.

There are a number of on-site locations for temporary storage of precipitation and runoff are generally considered:

1. Storage in ponds and lakes
2. Rooftop storage
3. Underground storage
4. Parking lot storage
5. Blue-green storage
6. Multiple use storage areas

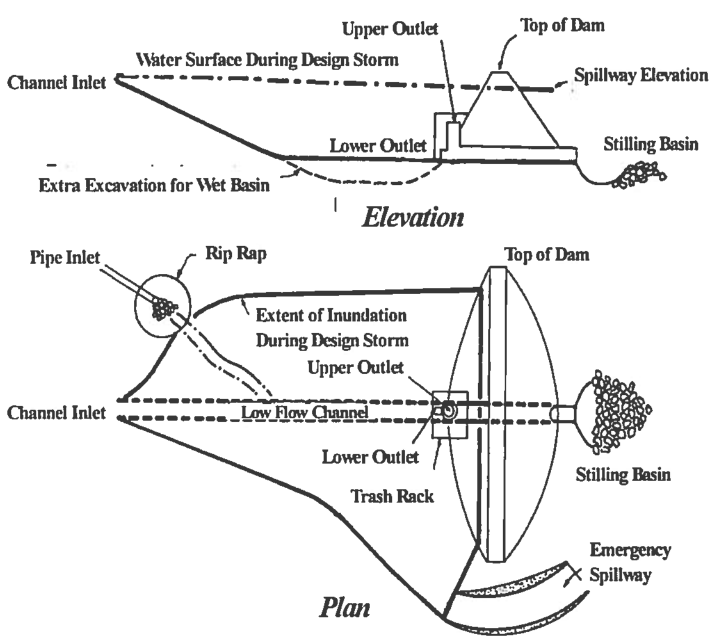
In planning on-site storage methods, one should consider existing physical, social and economic limitations of the area. What may be a good solution at one site, may be inappropriate at another.

Detention and Retention Basins

Detention and retention basins take a variety of forms. Some are wet (filled with water all of the time) and some are dry (filled with water only during storms).

Some basins are designed as a continuation of a stream or river (on-stream basins) while others are separate from the river (off-site basins). Off-stream basins are usually connected to the water course by pipes or swales.

Figure VI-7
Typical Detention Basin Design



Dry Ponds

As the name implies, dry ponds are designed to be normally dry with the ability store a portion of the stormwater during a storm event and then release the stored volume slowly and safely. Typically they, are used in areas where runoff volume has been increased and it is desirable to reduce the runoff rate.

Retention basins are used when extreme limits on downstream flow rate or velocity are required. The outflow rate will be relatively low and extended over a longer period of time as compared to the outflow period of detention basin. This requires large amounts of storage for detaining stormwater for periods greater than 24 hours. Figure VI-7 shows a typical detention basin design. One detention basin can be designed to control the stormwater from 2, 10, 25 and 100-year design storm events, by constructing multi-stage outlet structures. The outlet flow discharge rate from the basin will depend on the return period of the design storm.

Rooftop Detention

Rooftop detention utilizes the built-in structural capabilities of rooftops to store a certain amount of rainfall that falls on them. In many cases, existing roof structures require little modification to function as detention structures. On flat rooftops, drains must be designed with proper outlet capacities to control release rates to the design level. Overflow mechanisms should be provided to preclude danger from overloading.

Figure VI-8
Examples of Rooftop Detention Devices

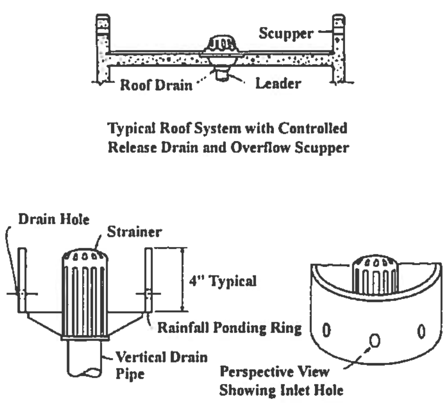
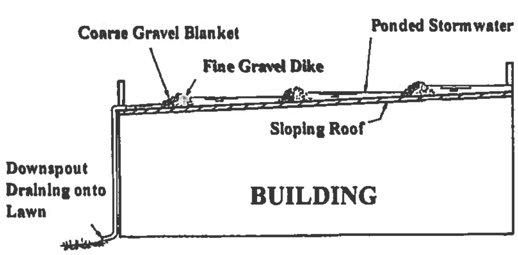


Figure VI-9
Roof Ponding With Gravel Dikes



Special considerations of roof water tightness may be necessary when water is to be detained for longer time periods or where frequent freezing and thawing are prevalent. Figure VI-8 illustrates several types of rooftop retention devices. On sloping roofs, the retention can be achieved by providing findams. Findams are actually about 4" high gravel ridges at 15 to 30 ft spacing as shown in Figure VI-9. Individual wedge-shaped ponds would build up behind these "minidikes". Through laboratory studies it was found that a series of five dikes of 1/4 inch gravel placed on roofs of 1% slope will cut the peak runoff rate by 50% and extend the runoff time by about 30 minutes [Aron, 1975]. Finer gravel would naturally delay the runoff further. The effectiveness of the rooftop storage is a function of the actual area affected by such storage. It is most effective when used as an integral part of a larger stormwater runoff control plan. Detailed structural analyses of the structure should be completed to assure that the added roof load represented by stored water can be safely supported. Moreover, additional maintenance should be anticipated on roofs subject to leaf accumulation.

Wet Ponds

Permanent or wet ponds are detention/retention structures filled with water all the time with adequate detention capacity to store the design floods above normal ponds level. Overflow spillways must be provided to bypass or discharge flows into floodways on the peripheries of the ponds so that safe water-storage elevations are not exceeded nor banks breached.

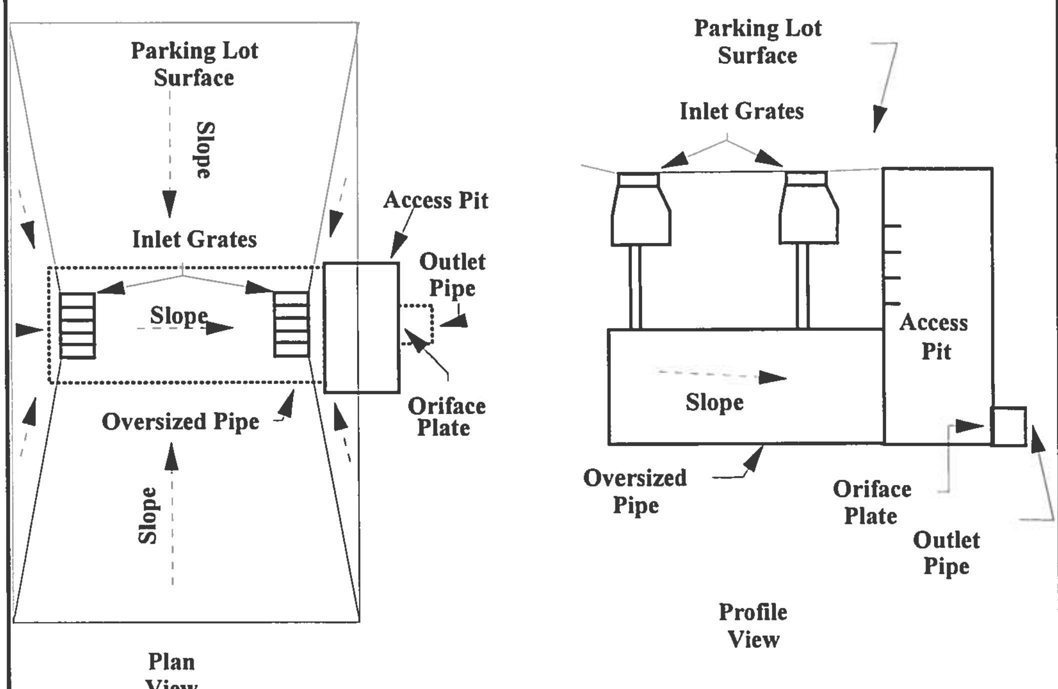
For extremely large ponds, adequate design precautions should be taken to minimize possible shoreline erosion due to ice, wind, and wave action. Sediment accumulation and water pollution due to roadside accumulations of salts, copper, and asbestos from brake linings, grease, oil, and heavy metals are the disadvantages associated with wet ponds. Such deleterious material should be screened out from the drainage system by interception and disposition before it reaches stormwater storage ponds. In some locations, municipal, state, or federal safety standards regarding the depth and volume of water will have to be met. These ponds are unquestionably more aesthetically appealing than a typical dry detention basin. In addition, they can be designed to provide some recreational benefits.

The main difficulty with wet ponds lies in the frequent unavailability of land. Dry ponds can be made rather inconspicuous as an integral part of the landscaping or as lawn areas for office buildings. For example, depressed front lawn areas can be designed to detain runoff from intense storms and to serve as buildings' green space in dry season. The outlet pipes allow the ponds to drain in 12 to 24 hours, and a certain amount of water undoubtedly filters into the ground [Aron, 1975] - thus drying the areas and returning them to a suitable condition for dry weather uses.

Underground Detention/Retention Tanks

This alternative involves the construction of underground holding tanks or large sized pipes as a means of providing controlled runoff from the site. In areas where land is expensive or surface topography is not suitable, these tanks can serve the same function as basins, while conserving land area. Outflow control devices may consist of small gravity pipes, or weirs. In some applications pumping may be required to discharge the stored runoff. This method can be quite expensive because of high material construction costs and possible pumping requirements; however, they may be appropriate in situations where land area is at a premium. An example general design of an underground stormwater detention facility is illustrated in Figure VI-10.

Figure VI-10
Underground Detention Facility



Parking Lot Detention

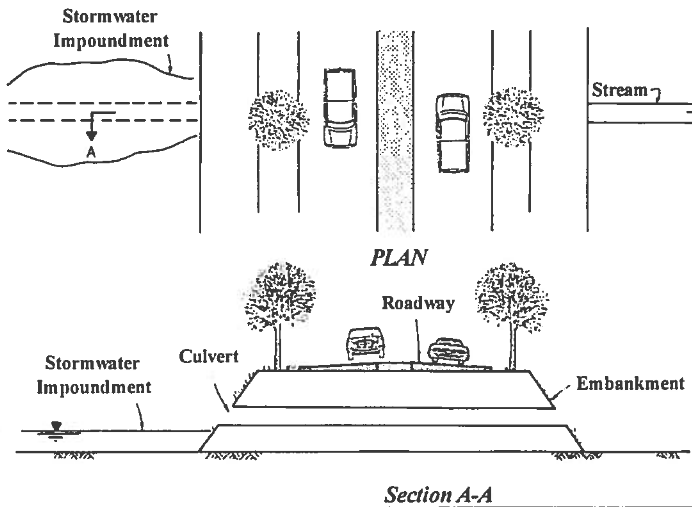
Parking lots cover a major portion of commercial developments and are, therefore, large contributors of stormwater runoff. Stormwater runoff can be detained on parking lot sites by shallow basins or swales. If properly designed, this measure can be quite effective. Initial construction costs for implementing these measures are only a small percentage above the construction cost of conventional parking lots. Arrangements of areas in a parking lot to accept ponding should be planned so that pedestrians are inconvenienced as little as possible. A 7" design depth is not unreasonable for parking locations in the remote areas of lots [APWA, 1981]. The facility should be designed to drain completely and avoid formation of ice.

Design considerations should recognize the possible use of porous asphalt, provided the subgrade has an adequate infiltration capability. Expansive and/or collapsing type soils may preclude this solution. An alternative to impervious paving of parking areas is the substitution of grassy strips. The ground surface of the planting strip is depressed and driving lanes are graded to direct the storm runoff into the depressions. The strips should be filled with pervious soil to allow a maximum of infiltration, and planted with a Fescue-type grass which is both resistant to occasional swamping and dry soil conditions. The strips should be oriented perpendicular to the parking lot slope and surrounded by broken curbs to protect them from being overrun by cars.

Blue-Green Storage

Incorporation of stormwater storage in urban drainage ways traversing roadways is a version of detention ponding that has been identified as the blue green concept. Topographical characteristics of many land areas adjacent to roadway embankments make them very much adaptable for use as detention facilities. This can be achieved by designing the culverts to pond where appropriate, as shown in Figure VI-11. Many drainage structures can be designed to operate in this fashion. Roadway embankments at control points should be stabilized and protected to minimize erosion effects of retained water.

Figure VI-11
Road Embankment Stormwater Detention



Detention within Pedestrian Plazas and Malls

On-site detention in heavily congested areas can be incorporated effectively in the design of pedestrian plazas, malls, and other similar type developments. The ponding requirement can be accomplished at selected locations with very shallow depths (1 to 3 in) to avoid public inconvenience. Frequent maintenance and suitable discharge control devices designed to satisfy the architectural objectives of the land development are necessary in developments of this type.

Multiple Use Impoundment Areas

These areas utilize sites having primary functions other than runoff control. In new developments, such multiple use should be incorporated into the primary design. For example, open space and grassed areas provided in the land development to enhance the aesthetic appeal can also be used as stormwater detention facilities. This can be accomplished by providing stormwater release controls such as weirs, orifices, small diameter pipes, gates, etc.

A hard-surface basketball or tennis court can be designed to drain adjacent grassed or paved areas. The stormwater would collect in grass swales around the edge of the court, seep through a gravel drain to retain the sediment load, and discharge onto a porous asphalt surface. Some type of emergency drain should be provided. Positive drainage toward the control devices is essential to avoid the swampy conditions, weed growth and increased maintenance costs. For optimum operation of control structures, it is also essential to screen out the floating debris from the inlet stormwater.

RELATIVE ADVANTAGES AND DISADVANTAGES

Table VI-1 gives a brief summary of principal urban runoff abatement practices and their associated relative advantages and disadvantages. As was expressed previously, the runoff volume reduction measures which simultaneously reduce runoff peaks offer significant advantages from the perspective of both local and watershed wide effects. However, since there are limitations inherent in the volume reduction techniques, it is likely that an overall stormwater control plan will include a combination of applicable volume reduction features and peak discharge control features (i.e. detention and/or retention facilities).

Selection of the best combination of techniques to be used in a particular instance should be made by the developer in consultation, or at least with the concurrence, of the municipal reviewer.

Table VI-1
Advantages and Disadvantages of On-Site Control Methods

METHOD	ADVANTAGES	DISADVANTAGES
REDUCTION OF RUNOFF / INFILTRATION STORAGE		
Dutch Drains	- Reduces the total volume of runoff. - Reduces the peak runoff discharge rate. - Enhances the groundwater supply. - Provides additional water for vegetation in the area. - Reduces the size of down-slope stormwater control facilities.	- Looses efficiency if intensive storms follow in rapid succession. - Subject to clogging by sediment. - Limited to application for small sources of run-off only, i.e., roof drains, small parking lots, tennis courts. - Maintenance is difficult when the facility becomes clogged. - Limited application in poor infiltration soils.
Porous Pavement	- Reduces the total volume of runoff. - Reduces the peak runoff discharge rates. - Enhances the groundwater supply. - Provides additional water for vegetation in the area. - Reduces the size of down-slope stormwater control facilities. - Less costly than conventional pavements for most	- More prone to water stripping than conventional mixtures. - Subject to clogging by sediment. - Water freezing within the pores takes longer to thaw and limits infiltration. - Motor oil drippings and gasoline spillage may pollute groundwater. - Limited application in poor infiltration soils. - recent studies suggest

Table VI-1
Advantages and Disadvantages of On-Site Control Methods (continued)

METHOD	ADVANTAGES	DISADVANTAGES
Porous Pavement (continued)	applications. - Safety features - superior skid resistance and visibility of pavement markings. - Provides pavement drainage without contouring. - Prevents pudding on the surface.	that porous pavement's advantage will reduce with time.
Seepage/Recharge Basins	- Reduces the total volume of runoff. - Reduces the peak runoff discharge rates. - Enhances the groundwater supply. - Construction borrow pits often can be converted to a large seepage basin to serve multiple areas.	- Must be fenced and regularly maintained. - If porosity is greatly reduced, it may be necessary to bore seepage holes or pits in the base. - No filtering supplied by the topsoil. - Usefulness limited in poor infiltration soils.
Seepage Pits	- Reduces the total volume of runoff. - Reduces the peak runoff discharge rates. - Enhances the groundwater supply. - Provides additional water for vegetation in the area. - Reduces the size of down slope stormwater control facilities	- Looses efficiency if intensive storms follow in rapid succession. - Subject to clogging by sediment. - Maintenance is difficult when the facility becomes clogged. - Limited utility in poor soils.

Table VI-1
Advantages and Disadvantages of On-Site Control Methods (continued)

METHOD	ADVANTAGES	DISADVANTAGES
Seepage Beds/Ditches	- Reduces the total volume of runoff. - Reduces the peak runoff discharge rates. - Enhances groundwater supply. - Reduces the size of down-slope stormwater control facilities. - Distributes stormwater over a larger area than other infiltration techniques. - May be placed under paved areas if the bearing capacity of the paved area is not affected. - Safer than seepage or recharge basins.	- More expensive than other infiltration techniques. - Replacement of entire system if clogging by sediment should occur. - Maintenance of sediment traps must be frequent and consequently more expensive.
Terraces, Diversions, Runoff Spreaders, Grassed Waterways, and Contoured Landscapes	- Increases the overland flow time, increasing the time of concentration and allowing for increased infiltration. - Vegetative swales are less expensive than curb and gutter systems.	- On poorly drained soils, these techniques may leave ground waterlogged for extended periods after storms. - vegetative channels may require more maintenance than curb and gutter systems. - Roadside swales become less feasible as the

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Table VI-1
Advantages and Disadvantages of On-Site Control Methods (continued)

METHOD	ADVANTAGES	DISADVANTAGES
		number of driveway entrances requiring culverts increase
DELAY OF RUNOFF		
Rooftop Retention	- No additional land requirements. - Not unsightly or a safety hazard. - May be adapted to existing structures.	- Leaks may cause damage to buildings and contents. - Stored runoff will greatly increase the load imposed on structural support. This increased construction expense may be greater than the savings resulting from reducing the size of downslope stormwater management facilities.
Parking Lot Detention	- Adaptable to both existing and proposed parking facilities. - Parking lot storage is usually easy to incorporate into parking lot design and construction.	- May cause an inconvenience to people. - Ponding areas are prone to icing, requiring more frequent maintenance.
Multiple Use Impoundment Areas	- Serves more than one purpose. Employing areas of grass, a certain amount of stormwater will infiltrate	- Difficult to maintain the porosity of multi-use areas.

Table VI-1
Advantages and Disadvantages of On-Site Control Methods (continued)

METHOD	ADVANTAGES	DISADVANTAGES
	and improve the quantity of water recharged by natural filtering processes. - If porous pavement is used on basketball or tennis courts, additional infiltration will be provided.	
Detention/Retention Basins	- Offers design flexibility for adapting to a variety of uses. - Construction of ponds is relatively simple. - May allow significant reduction in the size of downslope stormwater management facilities. - May have some recreational and aesthetic benefits if runoff is not carrying heavy sediment loads.	- Facilities that empty out completely can have an unsightly nature and be a detriment to the developments. - Difficulty in establishing a regular maintenance program. - In a residential development, it may be difficult to determine whose responsibility it is to pay for the maintenance program. - Consumes land area which could be used for other purposes.
Permanent Ponds	- Will provide both a reduction in peak runoff rates and a source of recreation in any residential area. - Only minor modifications may be required to adapt an existing	- Stormwater runoff having a high sediment or pollutant load should not be controlled in existing ponds because of its adverse impact on the natural conditions.

Table VI-1
Advantages and Disadvantages of On-Site Control Methods (continued)

METHOD	ADVANTAGES	DISADVANTAGES
	pond for use as a permanent stormwater management facility. - Wildlife habitat and wetlands may be preserved	
Underground Retention/ Detention Tanks	- Minimal interference with traffic or people. - Can be used in existing as well as newly developed areas. - Potential for using storm-water for nonpotable uses.	- Subsurface excavation could be extremely expensive depending upon the type and amount of rock encountered. - Access for maintenance may be difficult if proper design features are not provided.

STORMWATER QUALITY BEST MANAGEMENT PRACTICES

The volumes and rates of stormwater runoff from land developments are a major concern in stormwater management. However, they are not the only consideration. The impacts of stormwater runoff upon water quality are becoming of increasing concern. The predominant categories of pollutants that have been identified in stormwater runoff from developed areas are listed below.

- sediments
- nutrients
- pathogens
- organic enrichment
- toxic pollutants
- salts

There are a number of methods through which the negative effects of stormwater runoff pollution can be minimized. These methods are generally referred to as *best management practices for stormwater quality control (BMPs)*. These best management practices are generally low cost, relatively low technology methods of reducing the pollutant content of stormwater runoff. The following sections describe the most commonly employed stormwater quality BMPs. As is indicated by the following information, most of the stormwater quality BMPs also are effective in controlling the volumes and rates of stormwater runoff produced by new land developments and were presented previously in the context of stormwater flow control. It is fortunate that the most effective stormwater management controls have the dual benefits of reducing stormwater quantities and improving runoff quality.

VEGETATIVE BEST MANAGEMENT PRACTICES

All of the following practices rely on various forms of vegetation to enhance the pollutant removal, habitat value, or appearance of a development site. Although, in practice, each technique, by itself, is usually not capable of entirely controlling increased runoff and pollutant export for a development site, they can improve the performance and amenity value of other BMPs. These practices, therefore, should be considered as an integral part of every development site plan.

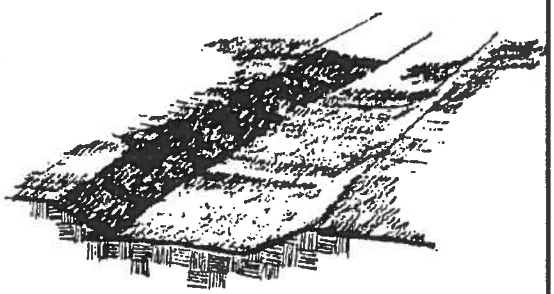
Limiting the Amount of Land Disturbed (Urban Forestry)

Limiting the amount of land disturbed and/or replanting vegetation following completion of construction can reduce pollutants in stormwater runoff in several ways: 1) through plant uptake and storage, 2) by reducing the volume of stormwater runoff and the associated pollutants, 3) through filtering, and 4) by preventing soil erosion. With careful landscape design, as much as 50% of a residential lot can be converted into an attractive natural setting of trees, shrubs, and ground covers. The extent to which pervious, vegetated areas can be preserved and/or created will have a direct effect upon the volume of stormwater runoff and the quantities of associated pollutants that will be produced. Moreover, the cost of maintaining the vegetated areas is relatively low and the aesthetic value to the overall development can be quite high.

Grassed Swales

Grassed swales are typically applied in residential developments and highway medians as an alternative to curb and gutter drainage systems. Figure VI-12 presents an example of a grassed swale. Grassed swales remove pollutants through the filtering action of the grass, deposition in low velocity areas, and by infiltration into the subsoil. These mechanisms are most effective in removing particulate pollutants and have a negligible effect on soluble pollutants. Swales are generally less expensive to construction than curb and gutter systems and maintenance is relatively low cost, generally consisting of normal lawn maintenance activities such as mowing and watering as needed.

Figure VI-12
Illustration of Grassed Lined Swale



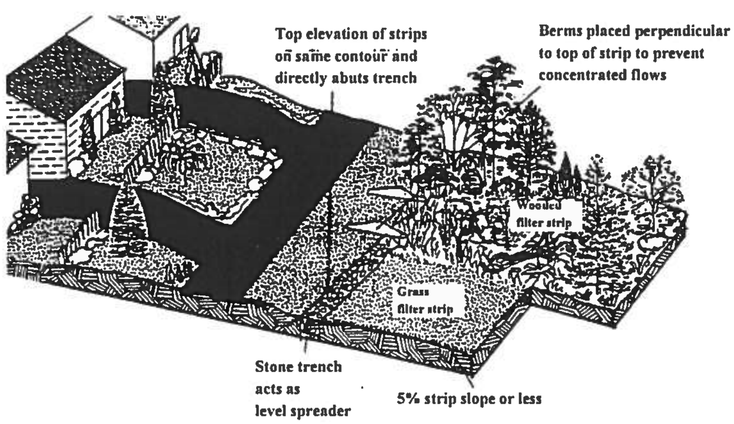
An alternative to grassed swales are rock lined waterways (Figure VI-13). A rock lined waterway consists of a channel lined with rock. These channels are generally less effective than grassed swales in the removal of pollutants due to a reduced filtering through the grass. However, some suspended pollutants are removed through deposition in low velocity areas.

Figure VI-13
Illustration of Rock Lined Channel

Filter Strips

Filter strips are similar to grassed swales in many respects. However, they differ in that they are designed to only accept overland sheet flow and are not intended to serve a dual purpose as a conveyance facility. In practice, runoff from an adjacent impervious area is evenly distributed across the filter strips. To perform properly, a filter strip must be: 1) equipped with some sort of level spreading device; 2) densely vegetated with a mix of erosion resistant plant species that effectively bind the soil; 3) graded to a uniform, even, and relatively low slope, and 4) be at least as long as the contributing runoff area. Filter strips are especially effective when constructed as a buffer between the development activities and adjacent streams, curbs, and swales. They can also be used to protect surface infiltration trenches from clogging by sediment. An example of an application of filter strips is presented in Figure VI-14. The pollutant removal mechanisms in filter strips are similar to those presented previously for grassed swales. As is the case with grassed swales, filter strips are particularly effective in removing particulate pollutants such as sediment, organic material, and many

Figure VI-14
Example Application of Vegetated Filter Strips

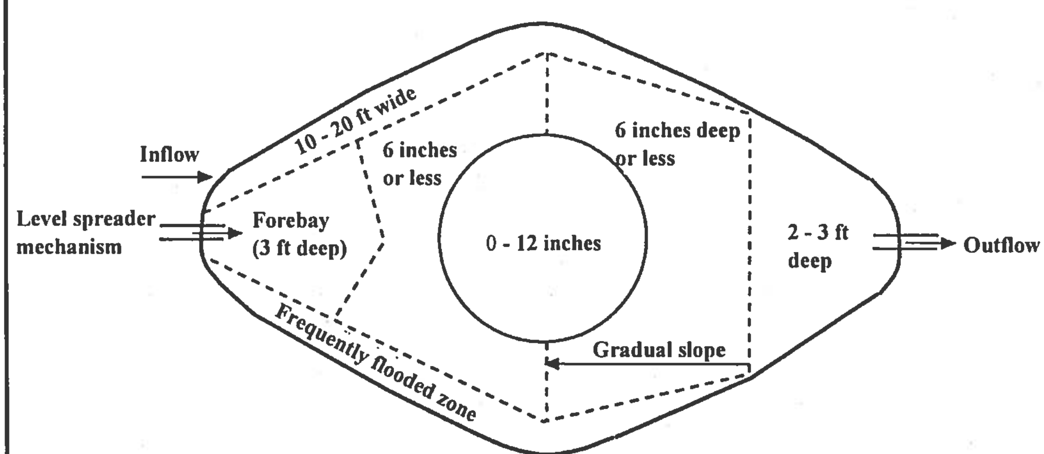


trace metals. Filter strips are relatively inexpensive to establish and cost almost nothing if preserved during site development. A creatively landscaped filter strip can become a valuable community amenity, providing wildlife habitat, screening, and stream protection. The open space created by the filter strips can also be applied toward meeting established development density limitations that may be contained in local ordinances.

Constructed Wetlands

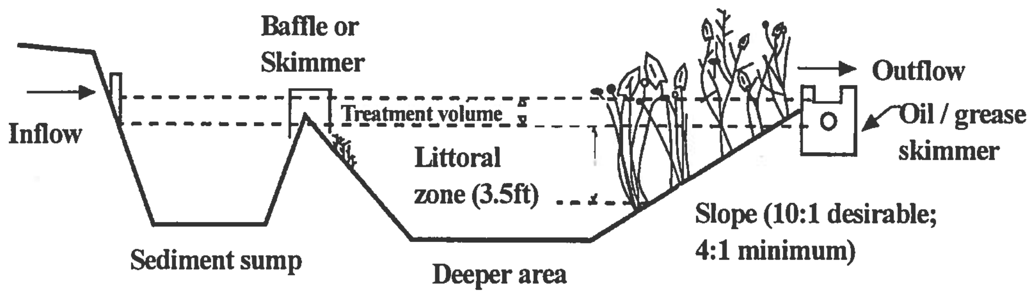
There are two prevalent types of constructed wetlands in use: 1) shallow constructed wetlands (Figure VI-15) and 2) wet detention systems (Figure VI-16). Constructed wetland systems perform a series of pollutant mechanisms, including sedimentation, filtration, adsorption, microbial decomposition, and vegetative uptake to remove sediment, nutrients, oil and grease, bacteria, and metals. While constructed wetlands can be very effective in the removal of the broad range of pollutants encountered in stormwater runoff, it is important that they be properly designed, sited, and maintained. The critical design consideration is the maximization of the detention time in the wetland through proper sizing and configuration to prevent short circuiting.

Figure VI-15
Schematic of a Shallow Constructed Wetland



Siting of wetlands can be difficult due to the importance of soil properties (chiefly permeability) to performance, size requirements, and concerns relative to potential nuisance insect breeding. In addition, created wetlands become a resource area that will subsequently be protected by federal and state laws.

Figure VI-16
Example Wet Detention Wetland System



INFILTRATION FACILITIES

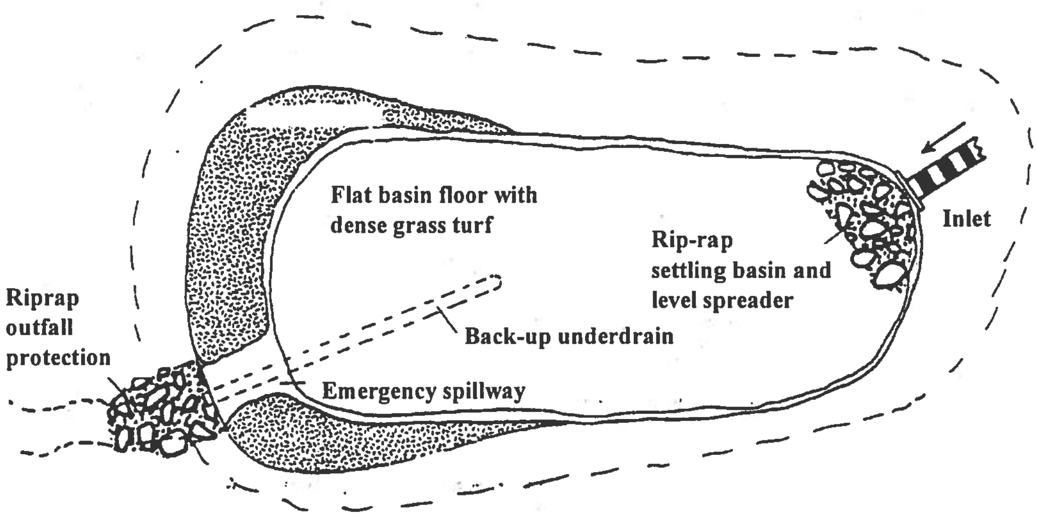
Infiltration facilities permanently capture runoff so that it soaks to the ground water. As was presented previously, to the extent of their capacity to handle the volumes of stormwater runoff produced, they are very effective in controlling stormwater runoff flows. They also can be very effective in removing pollutants. Pollutant removal in these BMPs occurs primarily through infiltration, which eliminates the runoff volume or lowers it by the capacity of the facility. Currently, the three types of facilities commonly employed to remove pollutants from stormwater runoff through infiltration are: 1) infiltration basins; 2) infiltration trenches / dry wells; and 3) porous pavements (grassed swales, which also promote infiltration were discussed previously under vegetative practices).

Infiltration Basins

Infiltration basins are similar to dry ponds, except that infiltration basins have only an emergency spillway and no standard outlet structure (see Figure VI-17). All flow entering an infiltration basin (up to the capacity of the basin) is retained and allowed to infiltrate into the soil. Infiltration basins provide pollutant removal through volume reduction, filtration, and settling. They are particularly effective in removing bacteria, suspended solids, insoluble nutrients, oil and grease, and floating wastes. They are less effective in removing dissolved nutrients, some toxic pollutants, and chlorides. Therefore, infiltration basins should not be used in cases where the runoff can be suspected to contain significant amounts of those pollutants.

Infiltration basins often have relatively large land requirements and require a suitable soil to be effective. Accumulating runoff must be able to infiltrate the soil in the bottom of the basin. Typically sand and loam, with infiltration rates greater that or equal to 0.27 inches per hour are the preferred soils. Soils with percolation rates meeting this criteria exist throughout the watershed. However, high or seasonally high water tables predominate throughout most of the watershed. For infiltration to occur, ground water levels should be located at least 2 to 4 feet below the bottom of the basin. Consequently, the use of infiltration basins will not be practical throughout most of the Beaverdam Branch Watershed.

Figure VI-17
Example Infiltration Basin Layout



Infiltration Trenches / Dry Wells

Subsurface infiltration practices, such as infiltration trenches or dry wells force runoff into the soil to recharge ground water and remove pollutants. Filtration is the primary pollutant removal mechanism active in these facilities. They effectively remove suspended sediments, floating materials, and bacteria. They are less effective at removing dissolved materials.

The soil infiltration rate and structure size are the most important considerations in the design of infiltration structures. The soils underlying the structures must be tested to determine their infiltration capacity and the ground water level. The soil must neither be too impermeable to runoff nor to rapidly permeable. Moreover, a distance of at least 2 feet should be maintained between the bottom of the infiltration structure and the mean high ground water elevation. Due to the nature of prevailing conditions in the area, siting of infiltration facilities must be made carefully throughout the Beaverdam Branch Watershed.

Porous Pavement

By allowing stormwater to infiltrate into the soil, porous pavements can reduce runoff volume and pollutant discharge. Porous pavements can remove significant amounts of both soluble and particulate pollutants. Porous pavement is primarily designed to remove pollutants deposited from the atmosphere, as coarse solids can clog the pavement pores. As a result, porous pavements are generally designed into parking areas that receive light traffic.

As is the case with all of the infiltration systems, the effectiveness of porous pavements for pollutant removal is highly dependent upon soil characteristics and ground water levels. The soils under the pavement system must produce adequate infiltration and ground water levels should be 2 to 4 feet below the bottom of the paving and subbase system. Proper maintenance of porous pavements is important and can be extensive. The pavement must be kept free of coarse particles that can clog the pavement and prevent runoff from infiltrating. The pavement must, therefore, be regularly inspected and cleaned with a vacuum sweeper and high pressure jet.

DETENTION FACILITIES

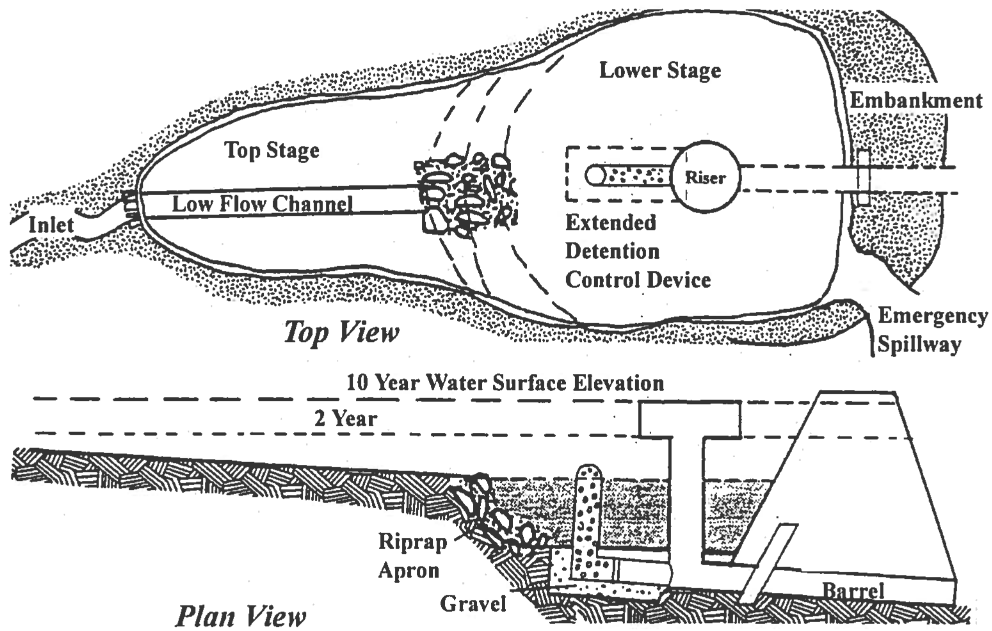
One of the most common structural methods of controlling runoff is through the construction of ponds to collect runoff, detain it, and release it to receiving waters at a controlled rate. Pollution reduction during the temporary period of runoff storage results primarily from the settling of solids. Detention facilities, therefore, are most effective at reducing the concentrations of solids and the pollutants that adhere to solids, and less effective at removing dissolved pollutants.

The three types of detention facilities commonly used to remove pollutants from stormwater runoff are extended detention dry ponds, wet ponds, and constructed wetlands. The first two types of facilities are discussed below. Constructed wetlands were introduced previously under the topic of vegetative methods.

Extended Detention Dry Ponds

As was discussed previously in regard to flow control devices, dry ponds are frequently used to control peak discharges by temporarily detaining runoff. They are designed to completely drain at the conclusion each rainstorm event. When designed to achieve pollutant load reductions, the design of the ponds are modified to achieve longer detention times than are necessary solely to adequately control peak discharges. Generally, the ponds are designed to retain a specified runoff volume for a period of time sufficient to achieve the desired pollutant removal. This requires sufficient storage volume and an outlet flow control devices to accomplish the desired flow detention. Dry ponds should also include a low flow channel designed to reduce erosion; vegetation on the bottom of the pond to promote filtering, sedimentation, and uptake of pollutants. In addition, dry pond designs frequently include upstream structures to remove coarse sediments and reduce sedimentation and clogging of the outlet. An example of a layout of an extended detention pond is illustrate in Figure VI-18.

Figure VI-18
Schematic of a Dry Extended Detention Pond



Maintenance of water quality dry ponds is important. Regular mowing, inspection, erosion control, and debris and litter removal are necessary to prevent excessive sediment buildup and vegetative overgrowth. Also, periodic nuisance and pest control could be required. The primary constraints to siting dry ponds are land requirements, topography, and depth to bedrock.

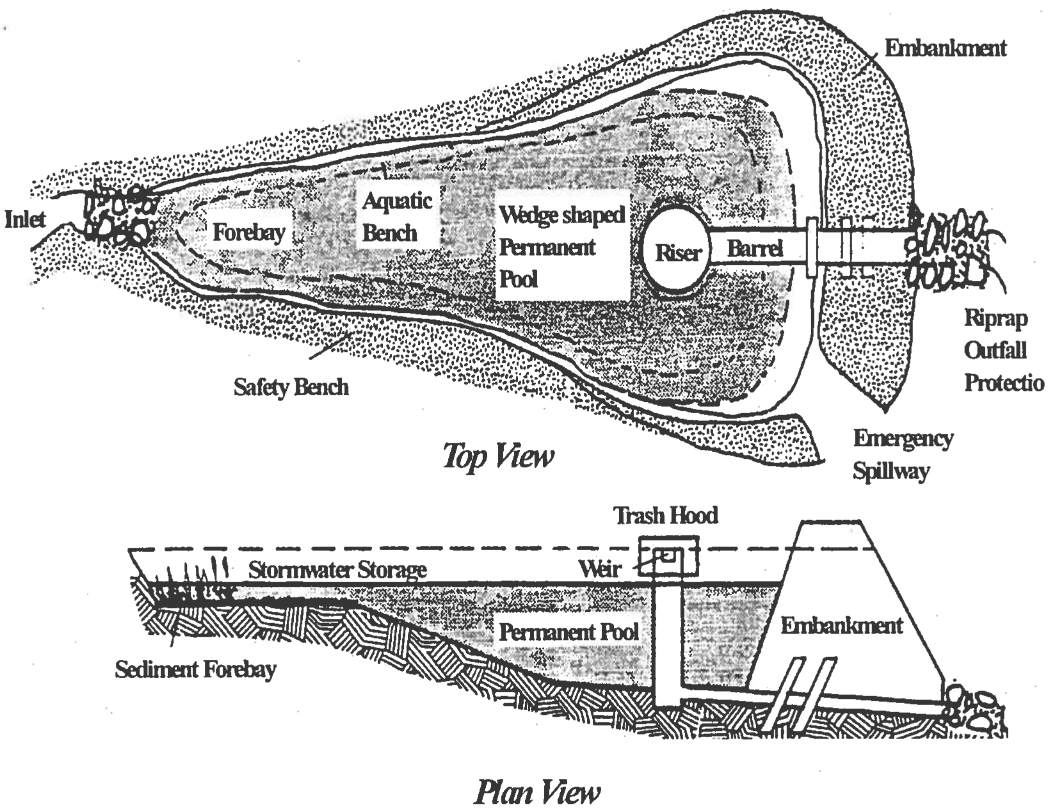
WET PONDS

The design of wet ponds is similar to that of dry ponds. In wet ponds, however, stormwater runoff is directed into a constructed pond or enhanced natural pond, in which a permanent pool of water is maintained. Once the capacity of a wet pond is exceeded, collected runoff is discharged through an outlet structure or emergency spillway. An example of a wet pond system is presented in Figure VI-19.

The primary pollutant removal mechanism in wet ponds is settling. The ponds are designed to collect stormwater runoff during rainfall and detain it until additional stormwater enters the pond and displaces it. While the runoff is detained, settling of particulates and associated pollutants takes place in the pond. Wet ponds can also remove pollutants from runoff through vegetative uptake. Wet ponds should be vegetated with native emergent aquatic plant species, which can remove dissolved pollutants such as nutrients from the runoff before it is discharged to the receiving water.

Wet ponds are typically designed with a number of different water levels. One level has a permanent poll of water. The next level periodically is inundated with water during storm. This level should be vegetated and relatively flat to promote settling and filtering of sediments and vegetative uptake of nutrients. The highest level will be inundated only during extremely heavy rainfall. This level should also be vegetated. Sizing of wet ponds is determined by requirements for storage volumes and desired detention times.

Figure VI-19
Schematic of a Wet Pond



Maintenance requirement for wet ponds include periodic sediment removal (approximately once every 10 to 20 years), mowing, and litter removal. Factors affecting siting include land requirements, soil conditions (soils should not be excessively porous and ground water tables should be relatively high), and topography.

WATER QUALITY BEST MANAGEMENT PRACTICES SUMMARY

As was indicated in the preceding discussion, there are a number of techniques that represent best management practices for reducing pollution associated with stormwater runoff. These techniques all also have application in efforts to control runoff volumes and peak rates of discharge. Consequently, appropriately designed stormwater management facilities can improve runoff water quality while achieving the required control of stormwater discharge flows. Table IV-2 contains a comparison of the pollutant removal effectiveness for the range of BMPs discussed under various design approaches. As is indicated in Table VI-2, the effectiveness of the BMPs varies. It is important, however, to recognize the water quality benefits that are offered and to consider these benefits in the overall selection and design of stormwater management controls.

EROSION AND SEDIMENTATION CONTROL MEASURES

The ability of storm water runoff to transport material is a function of flow velocity and the erosion resistance of the material. As stormwater runoff flow rates increase, the flow velocity increases and more eroded material is transported. As the water travels down the watershed, channel gradients reduce flow velocity and sediment begins to be deposited in streams and storm sewers. This process, known as sedimentation, continues as the flow rate and flow velocity reduces. New developments further increase the sedimentation problem by removing natural vegetation and making the bare ground susceptible to erosion.

The following principles should be practiced for urban soil erosion and sedimentation control.

1. Keep disturbed areas small: Areas vulnerable to erosion should be disturbed the minimum amount possible. As much natural cover as possible should be retained and protected. The construction plan should be phased whenever possible in small units and in sequence such that only the area being developed is exposed. All other areas should have a good cover of vegetation or mulch.

2. Stabilize and Protect Disturbed Areas: Mechanical and/or structural methods and vegetative methods are available for stabilizing disturbed areas. These methods include seeding, mulching, sodding, retaining walls, terracing, use of chemical stabilizers, and others.

3. Keep Runoff Velocities Low: Removal of existing vegetative cover and the resulting increase in impermeable surface during development increase both the volume and velocity of runoff. Short slopes, low gradients and the preservation of natural vegetation cover help to keep stormwater velocities low and thus limit soil erosion.

4. Protect Disturbed Areas from Runoff: Protective measures that can be utilized to prevent water from entering and running over disturbed areas are diversions, waterways, structures etc.

5. Retain Sediment within the Site Area: Sediment can be retained by two methods: filtering runoff as it flows, and detaining sediment laden runoff for a period of time large enough to allow the soil particle settle. Sediment basins, vegetative filter strips, terraces and sediment barriers may be used to retain sediment. However one should not rely solely upon vegetation filter strips, since sediment may rapidly render such areas useless by killing the vegetation.

Table VI-2
Comparative Pollutant Removal of Stormwater BMP Designs

Best Management Practice / Design	Suspended Sediment	Total Phosphorus	Total Nitrogen	Oxygen Demand	Trace Metals	Bacteria	Overall Effectiveness
Grassed Swale							
Design 1	0 to 20%	0 to 20%	0 to 20%	0 to 20%	0 to 20%	Insufficient Knowledge	Low
Design 2	20 to 40%	20 to 40%	20 to 40%	20 to 40%	0 to 20%	Insufficient Knowledge	Low
Filter Strip							
Design 3	20 to 40%	0 to 20%	0 to 20%	0 to 20%	20 to 40%	Insufficient Knowledge	Low
Design 4	80 to 100%	40 to 60%	40 to 60%	60 to 80%	80 to 100%	Insufficient Knowledge	Moderate
Porous Pavement							
Design 5	40 to 60%	60 to 80%	40 to 60%	60 to 80%	40 to 60%	60 to 80%	Moderate
Design 6	80 to 100%	60 to 80%	60 to 80%	60 to 80%	80 to 100%	80 to 100%	High
Design 7	80 to 100%	60 to 80%	60 to 80%	80 to 100%	80 to 100%	80 to 100%	High
Infiltration Basin							
Design 5	80 to 100%	40 to 60%	40 to 60%	60 to 80%	80 to 100%	60 to 80%	Moderate
Design 6	80 to 100%	40 to 60%	40 to 60%	60 to 80%	80 to 100%	60 to 80%	High
Design 7	80 to 100%	60 to 80%	60 to 80%	80 to 100%	80 to 100%	80 to 100%	High
Infiltration Trench							
Design 5	60 to 80%	40 to 60%	40 to 60%	60 to 80%	60 to 80%	60 to 80%	Moderate
Design 6	60 to 80%	40 to 60%	40 to 60%	60 to 80%	80 to 100%	60 to 80%	High
Design 7	80 to 100%	60 to 80%	60 to 80%	80 to 100%	80 to 100%	80 to 100%	High
Wet Pond							
Design 8	60 to 80%	40 to 60%	20 to 40%	20 to 40%	20 to 40%	Insufficient Knowledge	Moderate
Design 9	80 to 100%	40 to 60%	20 to 40%	20 to 40%	60 to 80%	Insufficient Knowledge	Moderate
Design 10	80 to 100%	60 to 80%	40 to 60%	40 to 60%	60 to 80%	Insufficient Knowledge	High
Extended Detention Pond							
Design 11	60 to 80%	20 to 40%	20 to 40%	20 to 40%	40 to 60%	Insufficient Knowledge	Moderate
Design 12	80 to 100%	40 to 60%	20 to 40%	40 to 60%	60 to 80%	Insufficient Knowledge	Moderate
Design 13	80 to 100%	60 to 80%	40 to 60%	40 to 60%	60 to 80%	Insufficient Knowledge	High

Key

- 0 to 20% Removal
- 20 to 40% Removal
- 40 to 60% Removal
- 60 to 80% Removal
- 80 to 100% Removal
- Insufficient Knowledge

Source: Schueler, Thomas R., Controlling Urban Runoff: <u>A Practical Manual For Planning and Designing Urban BMP's</u>.

Design 1: High slope swales with no check dams
Design 2: Low gradient swales with check dams
Design 3: 20 foot wide turf strip
Design 4: 100 foot wide forested strip with level spreader
Design 5: Facility exfiltrates first - flush: 0.5 inch runoff / impervious acre
Design 6: Facility exfiltrates one inch runoff volume per impervious acre
Design 7: Facility exfiltrates all runoff up to 2 year design storm
Design 8: Permanent pool equal to 0.5 inch storage per impervious acre
Design 9: Permanent pool equal to 2.5 (Vr); where Vr equals the mean storm runoff
Design 10: Permanent pool equal to 4.0 (Vr); where Vr equals the mean storm runoff
Design 11: First - flush runoff volume detained 6-12 hours
Design 12: Runoff volume produced by 1.0 inch detained for 24 hours
Design 13: As in design 12, but with shallow marsh in bottom stage

6. In-stream Control: After precipitation and runoff has concentrated, an outlet channel is needed for safe release of the water off the site. This outlet channel needs to be protected from erosion. A wide, shallow grassed water way can be a very good method. Channels with steeper gradients need structural protection along with, or instead of vegetative measures. Typical structural measures include: earth dams with a full flow pipe through the fill, weirs, flood gates, and check dams. In designing such facilities, it is important to consider the effects of the dam or embankment on upstream properties. The design must include safety features in the form of spillways and bypasses to prevent overtopping which can cause embankment failure.

The details on the design and implementation of practices described above and many others can be obtained from the Soil Conservation Service and the County Conservation District.

SOIL CHARACTERISTICS VERSUS STORMWATER MANAGEMENT ALTERNATIVES

It was mentioned earlier that the soil characteristics at the development site, such as soil permeability, water capacity, frost penetration etc. play an important role in the selection of stormwater management alternatives. This section gives specific soil information for the Beaverdam Branch Watershed and discusses the soil characteristics and their impact on alternative stormwater management techniques.

Soil information for Blair County can be obtained from the publications, "Soil Survey of Blair County, Pennsylvania". These publications are prepared by the Natural Resources Conservation Service of U.S. Department of Agriculture. The survey has a general soil map showing in color, the soil associations in the county. A soil association is a landscape that has a distinct pattern of soils in defined proportions. The soil association map should not be used to determine the soil type, for selecting stormwater water management alternatives. The reason is that, a general soil map is intended to be a general guide in evaluating large areas such as a watershed, or in county-wide planning for community development. It is not a suitable map for selecting a site for locating a stormwater detention or retention facility. For example, this map can be used to establish a generalized idea, that Berks Channery Silt Loam soils occur in the Beaverdam Branch Watershed. Also, the survey tells that these soils have seasonal high water tables ranging from zero to six inches below the surface, thus having severely limitations for infiltration storage. Thus, a general rule can be established that infiltration storage alternative should not be approved in the Berks Channery Silt Loam soils unless the occurrence of the ground water table at shallow depths has been ruled out by on-site engineering tests.

Table VI-3 presents some relevant properties of the Beaverdam Branch Watershed soils significant to the use of various stormwater management techniques. Table VI-4 indicates the suitability of the soils for some generalize construction activities associated with stormwater management alternatives. General conclusions that can be drawn from the information contained in Tables VI-3 and VI-4 include the following.

1. Activities designed to minimize the creation of impervious surfaces will be appropriate throughout the watershed.
2. The construction and operation of dry and wet ponds will generally be feasible throughout the watershed, although consideration must be given to site specific soil conditions.
3. The use of large scale induced infiltration systems will generally be limited by soil and ground water conditions that frequently are not suitable for those techniques.

Table VI-3
Beaverdam Branch Watershed: Relevant Soil Properties

Soil Name	Depth to Seasonal High Ground Water (Feet)	Depth To Bedrock (Inches)	Permeability (Inches/Hour)
Albrights gravelly silt loam	0.5 - 3.0	>60	0.2 - 2.0
Andover variant extremely stony loam	0.0 - 0.5	>60	0.06 - 2.0
Basher soils	0.5 -2.0	>60	0.6 - 6.0
Berks channery silt loam	0.0 - 0.5	20 - 40	0.6 - 2.0
Berks-Weikert channery silt loam	>6.0	20 - 40	0.6 - 6.0
Blairton silt loam	0.5 - 3.0	20 - 40	0.2 - 2.0
Brinkerton silt loam	0.0 - 0.5	>60	0.06 - 2.0
Buchanan gravelly silt loam	1.0 - 2.0	>60	0.06 - 2.0
Cavode silt loam	0.5 - 1.5	>40 - 60	0.06 - 2.0
Clarksburg silt loam	1.5 - 3.0	>60	0.06 - 2.0
Clymer loam	>6.0	>40	0.06 - 2.0
Clymer very stony loam	>6.0	>40	0.6 - 2.0
Ernest silt loam	1.5 - 3.0	>60	0.06 - 2.0
Gilpin channery silt loam	>6.0	20 - 40	0.6 - 2.0
Hagerstown-Rock outcrop complex	>6.0	>40	0.6 - 2.0
Hazleton channery sandy loam	>6.0	>40	0.2 - 2.0
Hazleton very stony sandy loam	>6.0	>40	2.0 - 20.0
Hublersburg very silty clay loam	>6.0	>60	0.6 - 2.0
Laidig channery loam	3.0 - 4.0	>60	0.2 - 6.0
Leck Kill channery silt loam	>6.0	>40	0.6 - 6.0
Leetonia flaggy loamy sand	>6.0	>60	6.0 - 20.0
Lehew very stony loam	>6.0	>20 - 40	0.6 - 20.0
Meckesville gravelly silt loam	3.0 - 6.0	>60	0.2 - 2.0
Meckesville very stony silt loam	3.0 - 6.0	>60	0.2 - 2.0
Mertz channery silt loam	>6.0	>60	0.2 - 2.0
Monongahela silt loam	1.5 - 3.0	>60	0.06 - 2.0
Morrison sandy loam	>6.0	>60	0.6 - 6.0
Murrill gravelly silt loam	>6.0	>60	0.6 - 2.0
Opequon-Hagerstown-Rock outcrop	>6.0	>12 - 20	0.2 - 2.0
Purdy silt loam	0.0 - 0.5	>48	0.0.62 - 0.6
Tyler silt loam	0.5 - 1.5	>60	0.0.62 - 0.6
Urban land - Berks complex	>6.0	20 - 40	0.06 - 0.12
Urban land - Edom complex	>6.0	>40	0.2 - 2.0
Wharton silt loam	1.5 - 3.0	>48	0.06 - 2.0

Table VI-4
Beaverdam Branch Watershed
Soil Limitations to Selected Stormwater Management Techniques

Soil Name	Ponds	Terraces and Diversions	Grassed Waterways
Albrights gravelly silt loam	Slope	Slope, percs slowly	Percs slowly, wetness
Andover variant extremely stony loam	Slope	Percs slowly, erodes easily, wetness	Percs slowly, wetness, large stones
Basher soils	Seepage	None	Erodes easily
Berks channery silt loam	Depth to rock, seepage	Depth to rock, slope, small stones	Depth to rock, droughty, slope
Berks-Weikert channery silt loam	Depth to rock, seepage	Depth to rock, slope, small stones	Depth to rock, droughty, slope
Blairton silt loam	Depth to rock	Depth to rock, percs slowly, wetness	Rooting depth, percs slowly, wetness
Brinkerton silt loam	Slope	Percs slowly, erodes easily, wetness	Percs slowly, wetness, erodes easily
Buchanan gravelly silt loam	Slope	Slope, percs slowly	Slope, wetness
Cavode silt loam	Slope, depth to rock	Wetness, percs slowly	Wetness, percs slowly
Clarksburg silt loam	Slope	Slope, erodes easily, percs slowly	Wetness, percs slowly
Clymer loam	Slope, depth to rock, seepage	Slope, small stones	Slope
Clymer very stony loam	Depth to rock, large stones, slope	Large stones, slope	Large stones, slope
Ernest silt loam	Slope	Slope, erodes easily, percs slowly	Slope, erodes easily, percs slowly
Gilpin channery silt loam	Slope, depth to rock, seepage	Slope, depth to rock	Slope, depth
Hagerstown-Rock outcrop complex	Seepage, slope	None	None
Hazleton channery sandy loam	Slope, depth to rock, seepage	Slope, depth to rock	Slope

Table VI-4
Beaverdam Branch Watershed
Soil Limitations to Selected Stormwater Management Techniques
(continued)

Soil Name	Ponds	Terraces and Diversions	Grassed Waterways
Hazleton very stony sandy loam	Slope, seepage	Slope, large stones	Slope, large stones
Hublersburg very silty clay loam	Slope	Slope, erodes easily	Slope, erodes easily
Laidig channery loam	Slope, seepage	Slope, rooting depth	Large stones, slope, rooting depth
Leck Kill channery silt loam	Seepage, slope	Slope	Slope
Leetonia flaggy loamy sand	Seepage, slope	Too sandy, piping, slope	Droughty, slope
Lehew very stony loam	Depth to rock, seepage, slope	Depth to rock, large stones	Droughty, depth to rock, large stones
Meckesville gravelly silt loam	Slope	Slope	Slope
Meckesville very stony silt loam	Slope, large stones	Large stones, slope	Large stones, slope
Mertz channery silt loam	Slope	Slope, piping	Slope
Monongahela silt loam	Slope, seepage	Percs slowly, piping, rooting depth	Slope, percs slowly, erodes easily
Morrison sandy loam	Seepage	Slope, erodes easily	Slope, erodes easily
Morrison very stony sandy loam	Seepage	Slope, erodes easily, large stones	Slope, erodes easily, large stones
Murrill gravelly silt loam	Slope	Slope	Slope
Opequon-Hagerstown-Rock outcrop	Depth to rock, slope	Depth to rock	Slope, rooting depth, depth to rock
Purdy silt loam	None	Wetness	Wetness
Tyler silt loam	None	Erodes easily, wetness, rooting depth	Wetness, erodes easily, rooting depth
Urban land - Berks complex	Depth to rock, seepage	Depth to rock, slope, small stones	Depth to rock, droughty, slope
Urban land - Edom complex	Slope	Erodes easily, slope	Erodes easily, slope
Wharton silt loam	Slope	Slope, percs slowly, erodes easily	Slope, percs slowly, erodes

OPERATION AND MAINTENANCE CONSIDERATIONS

Most stormwater control facilities or systems must be monitored and maintained regularly following construction to assure effective operation, long life and compatibility with the local setting. Table VI-5 contains a summary of key operation and maintenance considerations for the stormwater management alternatives discussed previously.

As is indicated in Table VI-5, there is range of operation / maintenance items which must be performed depending upon the type of stormwater management techniques employed. It is recommended that individual municipal stormwater management ordinance require that the enumeration of specific recommended operation and maintenance activities be outlined by the design engineer at the time applications for permit approval are made. The designer of the facilities should be in the best position to define the maintenance requirements associated with the facilities being proposed. However, operation and maintenance plan should be reviewed in consideration of the general requirements presented in Table VI-5. The approved set of operation and maintenance activities should then be used as the basis of an on-going operation and maintenance plan. Also, provisions should be made in the appropriate ordinances or regulations to provide for effective mechanisms through which the completion of critical maintenance can be assured.

PUBLIC ACCEPTANCE OF ON-SITE DETENTION

On-site detention, also has the disadvantage of not having wide spread public acceptance. This is mostly because the individuals have to spend extra dollars to satisfy the runoff control regulations. Also, they are concerned about the safety of their children also, which are usually attracted toward the ponds. Therefore, it is highly recommended to employ multi-purpose use of detention facilities. In the minds of a community, the multi-purpose use of such a detention facility greatly improves the perception that such a facility is a justifiable expense by the public or by the private developer [APWA, 1981]. Detention ponds are excellent examples of multi-purpose adaptability. When conceived and designed artistically, they can support different kind of activities throughout the year, such as, water sports and fishing. During winter months, shallow detention ponds with a permanent pool of water provide opportunities for ice skating.

Table VI-5
Operation and Maintenance Considerations

	Dredging	Debris / Sedimentation Removal	Weed Control	Insect Control	Mechanical Maintenance	Mowing	Cleaning	Repair	Inspection
Detention/Retention Basins		★	★	★		★		★	★
Detention/Retention Tanks				★	★		★	★	★
Ponds	★	★	★	★				★	★
Parking Lot Detention							★	★	★
Roof-top Retention							★	★	★
Open Space Detention		★				★			★
Road Embankment Detention		★	★	★			★	★	★
Infiltration Strips			★				★		★
Infiltration Beds *		★					★		★
Porous Pavement							★	★	★
Open Channels **		★	★			★			★
Pipe Systems		★					★	★	★

* Includes dutch drains, seepage pits and seepage beds.
** Includes grassed and rock lined channels

A detention basin that is dry between runoff events can be used for field sports such as football, soccer, baseball, and various passive recreational pursuits such as badminton, model airplane operation, shuffleboard, croquet, and picnicking. Some detention basins may double as tennis or baseball courts. It might be difficult to convince some developers that the benefits derived from recreation outweighs the cost of the land plus construction costs. However, should the recreation area be redesigned as a multi-purpose recreational/detention basin, the cost would look insignificant compared to the cost of upgrading a storm drainage system or the amount of potential flood damages.

Detention facilities may also contribute to the protection and preservation of wildlife habitats and other natural resources. One example is a 602 ha (244 ac) tract in Chester County, Pennsylvania, where 315 homes were to be constructed. Approximately 84 ha (34 ac) of open space were provided containing two detention ponds designed to store runoff from the 100-year rainstorm. One year following the completion of the detention ponds, wildlife was observed returning to its former habitat. Geese have nested and fish have returned to the streams and newly constructed channels. The dual purpose utilization of stormwater detention facilities as wetlands represents a potential useful means of coping with the increasingly stringent wetland protection requirements and associated wetland replacement activities.

Although multiple uses are a better alternative for securing the community acceptance, maintenance costs for such facilities may be higher. Therefore, when considering multiple uses, it is important to look at all the associated costs and intangible benefits, to determine if it is practical to proceed with the multiple use concept.

SAFETY CONSIDERATIONS

A survey conducted by APWA in 1980, based on 325 respondents, revealed that there have been two drownings reported at the detention facilities. It is, therefore, essential to take precautions in design and selection of storm water management alternatives, to minimize hazards. Embankment slopes, railings, fencing and other features are obvious considerations. The importance of designing and constructing outflow structures and dams with safety considerations in mind should never be ignored. In general, the approaches that can be used to promote safety are [APWA, 1981]:

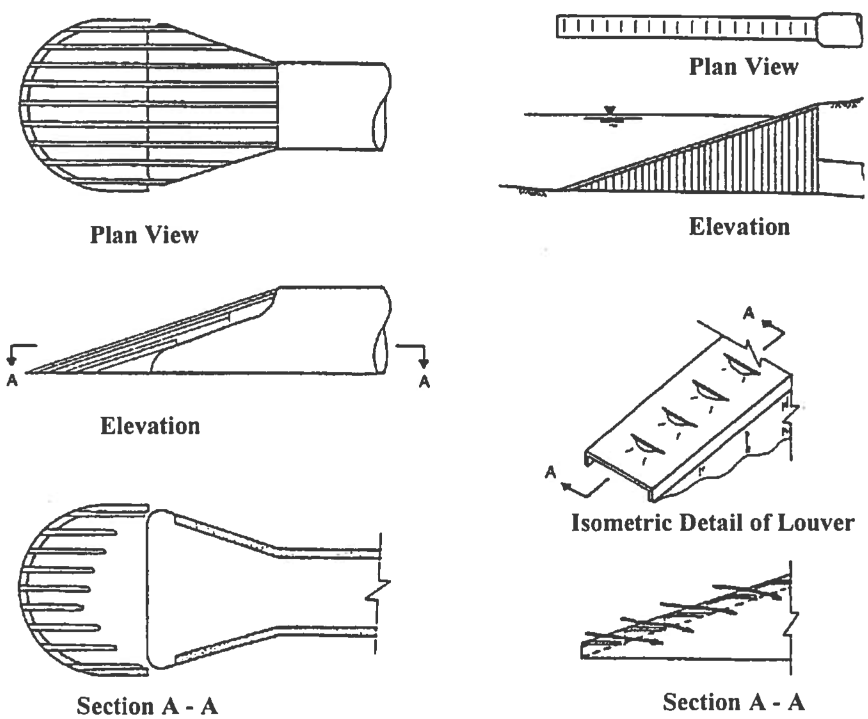
1. Keep people off the detention facility site
2. Provide escape aids
3. Make the onset of the hazards gradual
4. Eliminate the hazards

The designers and reviewers of stormwater control facilities, particularly those using detention / retention facilities should pay particular attention to incorporating appropriate safety features in the design of the facilities.

Special attention must be given to the design of outflow structures to satisfy the safety considerations. Water currents constitute a distinct hazard to persons who enter a detention pond or basin during periods when stormwater is being discharged. The force of the currents may push a person into an outflow structure or may hold a victim under the water where a bottom discharge is used. Several features designed to either eliminate or reduce such hazards are illustrated in Figures VI-20 and VI-21.

Figure VI-20 illustrates two versions of designs for non-submerged outlets: 1) curvilinear trash/safety racks for standard flared end sections and 2) narrow flume outlets. Both of these designs represent methods which tend to reduce the potential for persons to be drawn into or trapped against the outlet devices.

Figure VI-20
Suggested Safety Features for Non-Submerged Outlets

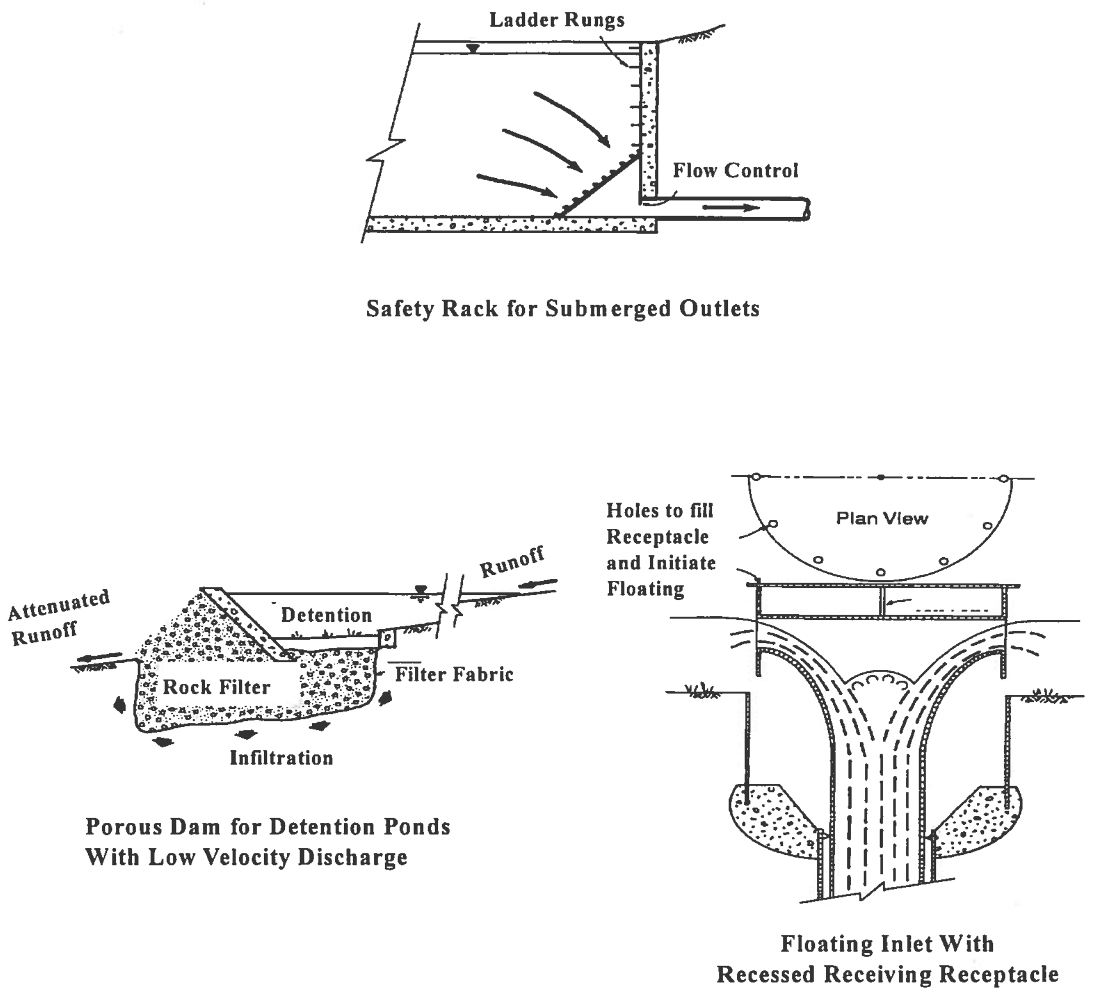


Curvilinear Trash/Safety Rack for Standard Flared End Sections

Narrow Flume Outlet For Detention Ponds

Figure VI-21 presents suggested safety features for submerged outlets: 1) outflow velocities and hence the associated hazards can be reduced through the use of a porous dam type of outlet facility; and 2) the illustrated safety rack for submerged outlets reduces the entrapment potential and provides a means of egress from the basin. As is also illustrated in Figure VI-21, drowning hazards can also be reduced by using a floating inlet for a basin outlet structure. The floating inlet reduces the drowning hazard by eliminating the water force which could trap a person at the outflow structure.

Figure VI-21
Suggested Safety Features for Submerged Outlets



DISTRIBUTED STORAGE

The stormwater management techniques discussed thus far have been geared primarily to on-site control methods. It is likely that on-site controls will be the predominant form of stormwater management in the Beaverdam Branch watershed. Off-site, distributed storage is, however, an alternative or adjunct to on-site control techniques which should be recognized and considered for use where appropriate. Simply defined, distributed storage is the process of utilizing the most suitable site or sites for regional detention facilities.

The combination of on-site detention and distributed storage approaches may significantly improve the capability of land developers and communities to control stormwater on a watershed basis. Distributed storage may also offer a means of accommodating development in a manner which minimizes total costs and optimizes land utilization through the sharing of a single, strategically located detention or retention facility. Finally, the use of distributed storage may increase the feasibility of dual or multi-purpose facilities. For example, certain recreation areas might easily be used to provide temporary stormwater storage; natural or artificial ponds and lakes can serve both recreation and stormwater management objectives; and stormwater management facilities may be constructed as replacement wetlands.

SUMMARY

The institution of stormwater management regulations throughout the watershed will require that land developers include provisions in their land development plans to limit increases in the volume of runoff and to control peak rates of stormwater discharges to levels specified in the local ordinances. These standards will be presented as performance standards. That is, the standards will set limits on the peak rate of discharge permitted from the development site without specifying the exact methods to be used in order to meet the standards. The owner of the development will be afforded a high degree of flexibility in the selection and design of the specific measures to be incorporated into the design of the development. This will permit the developer to select and arrange the various available control techniques in a manner that is most efficient for the particular information and that best accommodates the intended use of the development.

Nevertheless, the various stormwater control techniques offer differing degrees of benefit. For example, measures such as the preservation of pervious areas, the use of filter strips and buffers, and the use of vegetated swales offer the following significant advantages:

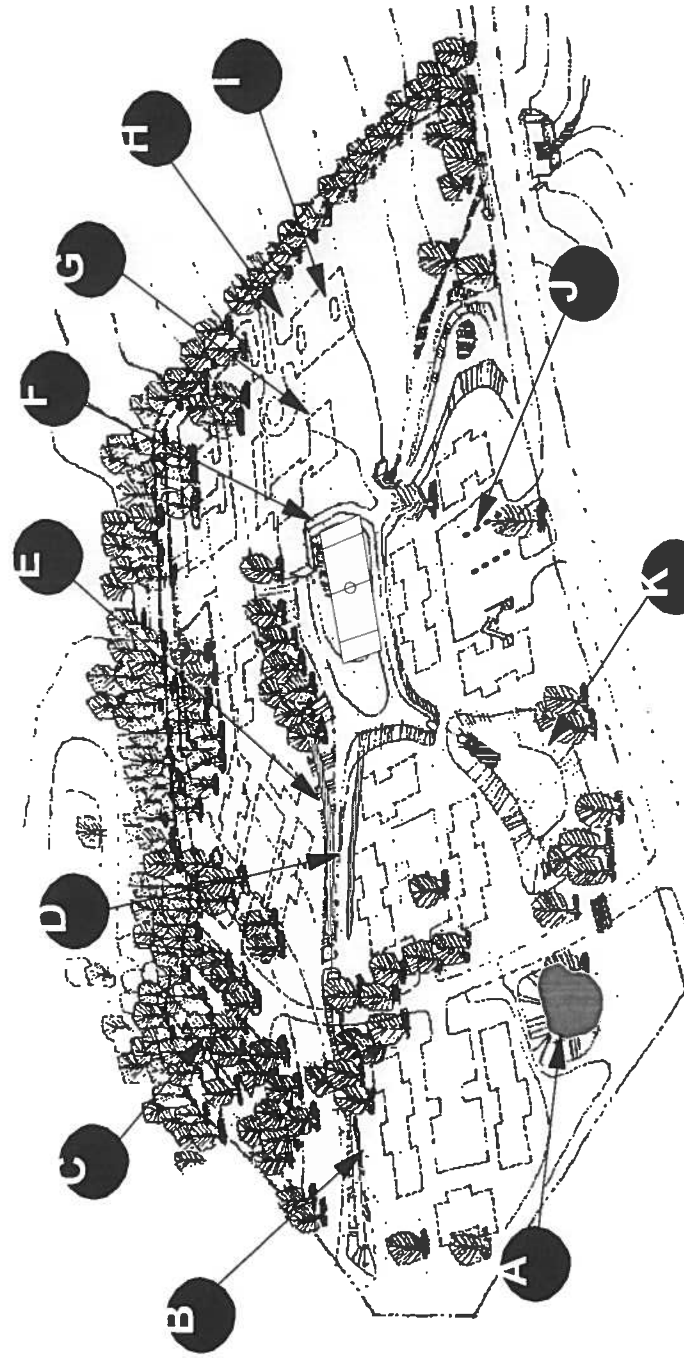
1. Minimization of total runoff volumes
2. Promotion of aquifer recharge
3. Stormwater pollution reduction
4. Ease of construction and maintenance
5. Low construction and maintenance costs
6. Preservation of open space

The opportunity for realizing these benefits is lost if no effort is made to utilize these techniques and the stormwater performance standards are satisfied solely through the construction of detention facilities. It is important, therefore, that the land developers be encouraged to make use of the full range of available control techniques in an integrated approach that maximizes the attributes of each. To that end, the municipal stormwater ordinances should encourage the land developers to select the general types of stormwater controls used in his/her stormwater management plan in the general order of preference:

1. Maximization of infiltration on-site by minimizing land disturbance, maximizing the amount of pervious surfaces incorporated in the development, and creating vegetated strips and buffer areas.
2. Flow attenuation through the use of open vegetated swales, rock lined channels, and natural depressions
3. Stormwater detention / retention structures (dry, wet, multi-purpose)

An example of a land development that employs the broad range of applicable control techniques is present in Figure VI-22. The concept illustrated in Figure VI-22 is an approach to providing stormwater management techniques in a manner that incorporates them into the overall design of the development while using the flow and pollution control capabilities of each technique in an integrated stormwater management and overall land development plan.

Figure VI-22
Example of Development Integrating Variety of Stormwater Control Techniques



Techniques Employed

A: Wet detention pond
B: Grassed swale
C: Original growth woodlands preserved
D: Rock-lined channel
E: Grassed strips
F: Multi-use dry detention area
G: Dutch drains under roof eves
H: Pervious surface walkways
I: Parking lot detention storage
J: Grassed strips in parking area
K: Dry detention pond

BEAVERDAM BRANCH STORMWATER MANAGEMENT PLAN TRAINING MANUAL

SECTION VII

INSTITUTIONAL AND REGULATORY SYSTEM

STORMWATER MANAGEMENT FUNCTIONS

The stormwater activities necessary to implement the *Beaverdam Branch Watershed Stormwater Management Plan* are implied by Section 11 of Act 167 and by the *Plan* itself. The basic functions inherent in the implementation of watershed stormwater management in the Beaverdam Branch watershed consist of the following:

- Planning
- Development Regulation
- Construction
- Inspection
- Maintenance
- Financing

PLANNING

Act 167 requires watershed stormwater management plans to be reviewed, revised and updated at least once every five (5) years. This requirement for period planning activities creates a need for an agency or organization with the authority and ability to complete the plan updates. Under Act 167, counties are given the planning responsibility.

The need for periodic plan updates implies the need for maintaining the hydraulic and hydrologic database and rainfall/runoff models assembled during the preparation of the original *Plan*. There is also a need for monitoring conditions within the watershed and assessing the effectiveness of plan implementation so as to provide the basis for determining the need for updating the plan in advance of the statutory five (5) year period.

DEVELOPMENT REGULATION

For the *Plan* to be effective, the stormwater control standards and criteria must be mandatory. Act 167 charges each municipality with the responsibility for adopting and enforcing such regulations as are necessary to require conformance with the *Plan*. Each municipality must adopt and enforce ordinances serving to implement the recommended standards and criteria, and apply them to all types of development activity. For example, subdivision plans that are routinely reviewed by the local and county planning agencies must include review and approval relative to compliance with the ordinance provisions enforcing the requirements of the *Beaverdam Branch Stormwater Management Plan*.

CONSTRUCTION

This function refers to the actual construction of any stormwater control facilities or features. Responsibility for construction will normally rest with the land developer. In most cases, the developer will be part of the private sector, although, if the land development activity is performed by an agency of government, that agency will be responsible for the construction of the required associated stormwater control facilities.

INSPECTION

Inspection is a vital component of the overall management system in that it provides the means for verifying that the stormwater control measures approved during the plan review process are actually constructed as approved. In order to be effective, it is necessary that inspectors have the legal right of entry onto private property and the right to stop work if conditions are found to be different than represented in the plan application or if the stormwater controls are not being constructed as approved. In general, since inspection is an prerequisite for effective enforcement, inspection responsibility is most appropriately assigned to the local municipalities. Inspection of the stormwater control provisions can be completed by the same individuals who provide inspection of roads and utilities as otherwise required by the subdivision / land development ordinances.

MAINTENANCE

Stormwater maintenance includes such tasks as clearing debris from and mowing grass in detention basins, cleaning catch basins, dredging creeks and repairing stream embankments. The responsibility for maintaining publicly owned facilities clearly rests with the agencies or municipalities which own the facilities. The delineation of responsibilities associated with maintaining facilities constructed by private sector developers can be addressed by ordinance. In the event that the responsibility for maintenance is left with the private sector, effective means of requiring that the necessary maintenance is performed must be available the municipality. Stream channel maintenance projects generally require close cooperation between state, local and county agencies. The responsibility for such maintenance is often poorly defined its accomplishment frequently requires the efforts of all three levels of government.

FINANCING

This function includes such items as funding for the costs associated with the administration of stormwater ordinance provisions, facilities construction, inspections, maintenance and long term stormwater management planning. Funding of these costs is spread across the private sector and the local, county and state levels. Ordinances requiring the provision of adequate controls, and the establishment of stormwater management permit fees and escrowed maintenance funds place the responsibility for most construction, and a portion of the administrative and maintenance costs associated with stormwater management on the private developers. The local municipalities generally bear a portion of these costs as well as the cost of maintaining public facilities. A portion of the cost for long term stormwater management planning is borne by the county government. The State will reimburse the counties and municipalities a portion of eligible planning and administrative expenses.

ENFORCEMENT

Enforcement is a police function that is essential to any stormwater management program. Municipalities under Act 167 are charged with exercising their police powers to take a variety of enforcement actions such as fines, the use of permits, court actions and civil penalties. With regard to the enforcement of erosion and sedimentation controls, the county conservation district has the power to enforce compliance with Pennsylvania Department of Environmental Protection's regulations.

PERFORMANCE OF FUNCTIONS

The recommended delineation of stormwater management responsibilities of the various governmental and quasi-governmental agencies active in the watershed is as follows:

LOCAL MUNICIPALITIES

Primary responsibility for the administration and enforcement of stormwater management ordinances and regulation, including plan review and approval; inspections; and either performing or requiring the performance of routine maintenance.

COUNTY AGENCIES

The role of Blair County, as defined by Act 167 is to perform periodic reviews and updates of the Beaverdam Branch Watershed Stormwater Management Plan.

STORMWATER MANAGEMENT ORDINANCES

Under the provisions of Act 167 and the recommendations of the *Beaverdam Branch Stormwater Management Plan*, local municipalities must take the lead in implementing stormwater management through the adoption, administration and enforcement of various regulatory controls. While certain management functions may be collectively performed, each municipality will have the responsibility for initiating the ordinances which provide the legal basis for stormwater management in the Beaverdam Branch Watershed.

The *Beaverdam Branch Stormwater Management Plan* presents model ordinances as a guide to be used by the Beaverdam Branch watershed municipalities for constructing a workable regulatory approach using the legal authorities that are presently available to Pennsylvania municipalities.

The model stormwater management provisions are presented as a unit in the form of a separate stormwater management ordinance that can be incorporated by reference in existing subdivision and land development ordinances and zoning ordinances. The ordinance can stand alone in instances where the municipality has no local zoning or subdivision and land development ordinances.

As described above, a municipal stormwater management ordinance may be implemented by incorporating it as an amendment to the existing development ordinances (zoning, S/LD, etc.) or by adopting it as a single purpose ordinance. Regardless of how it is created, the stormwater management ordinance must include the following key provisions:

- Control storm characteristics
- Control standards
- Exemptions
- Computational techniques
- Applicable control techniques
- Site plan requirements
- Plan review procedures
- Continuing maintenance agreements
- Fees
- Enforcement remedies and penalties

The following are brief descriptions of the approaches taken by the *Plan's* model ordinance in regard to these issues.

CONTROL STORM CHARACTERISTICS

The control storm characteristics developed in the *Beaverdam Branch Watershed Stormwater Management Plan* are defined in the model ordinance. Storm rainfall distribution, duration and total rainfall volumes are provided for the 2, 10, 25 and 100 year storms. The ordinance specifies that the measures employed must adequately control each of these storms in accordance with the specified standards.

CONTROL STANDARDS

The model ordinance spells out the specific stormwater control standards established by the *Plan*. . The basic control standard is that post-development peak rates of runoff shall not exceed the pre-development peak runoff rate from any development site.

EXEMPTIONS

The model ordinance describes specific activities that are exempt from the ordinance requirements.

COMPUTATIONAL TECHNIQUES

In order to facilitate review and provide some standardization, the model ordinance specifies by name the allowable runoff computation techniques to be used in the development of stormwater control plans.

APPLICABLE CONTROL TECHNIQUES

Each land developer is permitted to select the runoff control technique or combination of techniques that are most appropriate to the site. However, model ordinance requires the developer to consider and apply control techniques which first limit increases in total runoff volume and encourage ground water recharge. Detention/retention techniques should then be employed to the extent that these measures are inappropriate or fail to meet the established control standards.

The model ordinance also contains language which outlines specific features to be incorporated into the design of control facilities as well as identifying conditions which require supplemental geotechnical investigations.

SITE PLAN REQUIREMENTS

Local ordinances should precisely describe site plan submission requirements for stormwater management. For example, the model ordinance requires stormwater plans to be prepared by a registered professional engineer, surveyor or landscape architect and sets forth the content and form of information that must be included in the plan. Generally, the stormwater plan submission is made in two stages: preliminary and final. The ordinance also contains provisions allowing simplified plan submission requirements for small developments or certain special uses.

PLAN REVIEW PROCEDURE

The model ordinance contains a recommended procedure for reviewing developer's stormwater management plan submission. The responsibility for plan reviews lies with the municipality, which specifies its own procedures.

CONTINUING MAINTENANCE AGREEMENTS

The model ordinance leaves open to the discretion of each municipality the option for continued private ownership of the facilities or transfer of ownership to the municipality. Regardless of ultimate ownership, as a condition of plan approval, the developer must submit a maintenance plan for all proposed stormwater control facilities. The maintenance plan should describe the following:

- the proposed ownership arrangement,
- the type and frequency of required maintenance activities,
- personnel and equipment requirements,
- estimated annual cost and

- method of financing the cost of maintenance if the facilities are not publicly owned.

Under the provisions of the model ordinance, the developer must submit a signed maintenance agreement if the facilities will be publicly owned. The plan must be approved by the municipality.

The model ordinance also contains suggested language through which a system of financing maintenance activities through a special fund. In the case of privately owned facilities, the ordinance may require developers to deposit fees to cover municipal inspections for a specified time period. In addition to the maintenance agreement, the model ordinance also provides for the submission of construction or performance bonds and maintenance bonds consistent with the Municipal Planning Code.

FEES

The model ordinance contains provisions for instituting a schedule of fees to cover the cost of administering the stormwater program and implementing the requirements of the ordinance. A system of flat fees or direct reimbursement for costs may be imposed if consistent with the Municipalities Planning Code.

INSPECTIONS

A recommended schedule for periodic inspections of stormwater facilities during the course of construction is provided in the model ordinance. The purpose of these inspections is to assure that the facilities are installed as described in the approved stormwater plan application.

ENFORCEMENT, REMEDIES AND PENALTIES

The model ordinance contains enforcement provisions as prescribed by the Municipalities Planning Code. Municipalities may also use the enforcement remedies of Act 167 whereby action to enforce the provisions of the watershed plan or stormwater management ordinance can be instituted by the municipality or any "aggrieved person."

SECTION VIII

SUGGESTED PLAN SUBMISSION AND REVIEW PROCESS

RECOMMENDED PROCEDURES

Figure VIII-1 presents a suggested stormwater control plan submission and review procedure. This procedure, which is included in the model ordinance, is designed to be used under normal circumstances involving most subdivision and land development activities. This process is presented a guidance for municipalities that currently do not use a formalized review process. If they so choose, the municipalities may adopt a procedure such as the one illustrated in Figure VIII-1. However, the procedure to be followed is at the discretion of the individual municipalities.

The three (3) phase process consists of: 1) preliminary planning submission; 2) design and engineering; and 3) inspection. The purpose of the first two phases is to a save engineering fees resulting from the need to redesign controls to satisfy the reviewer's requirements. Keep in mind that design engineering costs are often four (4) to five (5) times higher than preliminary planning costs.

The first phase submission creates a checkpoint for both the developer and the reviewer. At this stage in the development of the plan, prior to design, a general agreement can be reached concerning existing conditions, applicable control standards and criteria, appropriate runoff computation techniques and permissible control methods. This will serve to expedite the plan submission and review process.

STORMWATER CONTROL PLAN CONTENT

The purpose of the stormwater control plan required to be submitted by the land developer is to present information describing site specific conditions including general location, topography, hydrologic characteristics, runoff control requirements, and the proposed runoff control measures. This information must be supplied in sufficient detail to permit the reviewer to determine whether the proposed plan meets the requirements of the stormwater management ordinance.

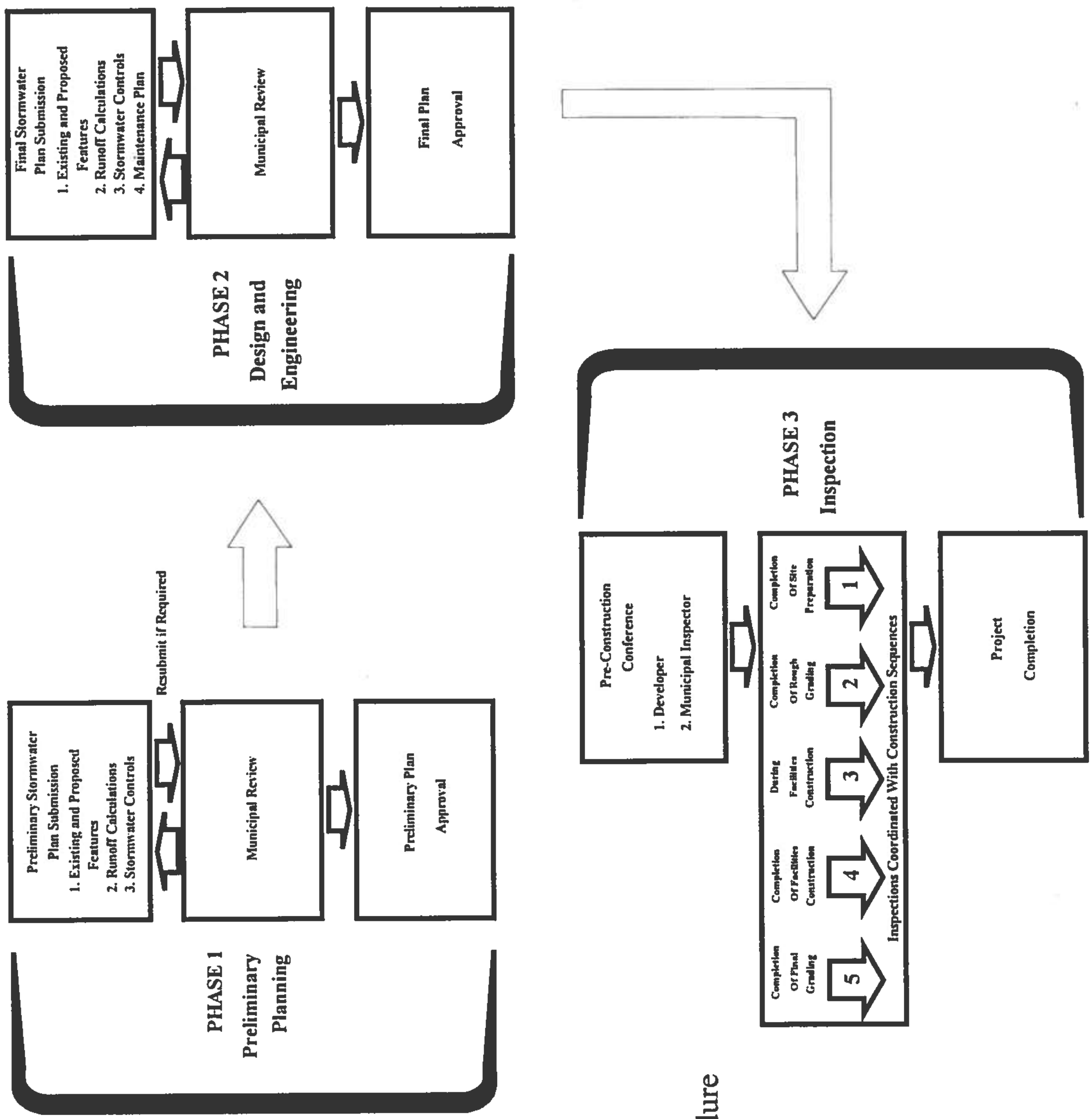


Figure VIII-1
Suggested Stormwater Plan
Submission and Review Procedure

In general, stormwater control plans should provide the following information:

- Site location
- Topographic information
- Soils
- Land cover
- Drainage area delineations
- Runoff calculations
- Stormwater control design calculations
- Description of stormwater control features
- Identification of easements, rights-of-way and deed restrictions
- Listing of other required permits/approvals
- Description of maintenance program
- Financial guarantees
- Professional certification

This information should be furnished in the form of maps and drawings and a written report containing narrative descriptions of the plan and summaries of the computations completed in support of the plan.

An example stormwater management plan report submission is provided in Appendix B of this manual.

SITE LOCATION

The location of the development site should be identified on a United States Geological Survey (USGS) 1:24000 scale topographic maps. The general site location information depicted on the USGS topographic map will be used by the reviewer to:

- Physically locate the site
- Verify the soils characteristics employed
- Determine the proximity to streams and other surface waters

TOPOGRAPHIC INFORMATION

Topographic information is of particular importance to the stormwater plan review process. This information is used to complete the runoff calculations, identify drainage areas and site stormwater control facilities. The following topographic information an associated natural features should be depicted on a suitably scaled map.

- Existing and final contours should be displayed at intervals as specified by the municipality.

- Floodplain boundaries for the 100-year floodplains (if any) in the development site should be displayed.

- All bodies of water (natural or artificial) should be shown. This includes watercourses (permanent or intermittent), swales, wetlands and other drainage courses with will be affected by runoff from the development.

- Any special features such as buildings, water supply wells, etc. which may effect the siting of stormwater control facilities.

SOILS INFORMATION

The areas underlain by soils of the various hydrologic soils groups should be delineated on a copy of the topographic map. This information, coupled with land cover descriptions is used to calculate runoff. The necessary soils information is found in two general sources. Soil survey reports and maps have been prepared for Blair County by the U.S. Soil Conservation Service. The soil survey includes a set of maps on which the location and extent of different soil types are outlined and identified by symbols. The soil survey report also includes a legend which identifies each symbol and describes each type of soil.

Another U.S. Soil Conservation Service document, *Urban Hydrology for Small Watersheds (TR-55)* contains a classification of each soil series as listed in the soil surveys according to hydrologic soils groups. The distribution of the various hydrologic soils groups within the development site can be determined by cross referencing the soils surveys and TR-55. This information should be transferred to the topographic map supplied as part of the stormwater control plan.

LAND COVER

Existing and future land cover types should be identified on the same topographic map as the hydrologic soil groups as necessary to support and illustrate the runoff computations performed. Land cover classes should correspond to those for which runoff curve numbers are provided in TR-55.

DRAINAGE AREA DELINEATIONS

The drainage areas delineated and used in the runoff computations should be displayed as a third overlay on the soil - land cover map. Consideration should be given to color coding the various themes to more clearly illustrate the required information.

RUNOFF AND DESIGN CALCULATIONS

Calculations for determining pre- and post-development runoff rates and for designing proposed stormwater control facilities must be submitted as a part of the stormwater control plan. The plan should include a narrative description of the procedures employed, a statement of the control standards used in the development of the plan (release rate percentage) and a summary of the computations performed. This information should be provided in sufficient detail to permit the reviewer to verify that the requirements of the stormwater management ordinance will be satisfied.

The plan should also contain a description and summary of the calculations used in the design of the facilities employed. This information may include: runoff hydrograph routings, infiltration rates, storage volume calculations, outlet structure design, etc.

STORMWATER CONTROL FEATURES

All proposed stormwater runoff control measures to be used both during and after construction should be shown in the plan. This includes methods for collecting, conveying and storing stormwater runoff on-site. Erosion and sedimentation controls should be shown in accordance with applicable County Conservation District requirements. The plan should provide information on the exact type, location, sizing, design and construction of all proposed facilities and their relationship to the existing watershed drainage system. If appropriate, a justification should be submitted as to why any preferred stormwater management techniques are not proposed for use.

If the development is to be constructed in stages, the applicant should demonstrate that stormwater facilities will be installed to manage stormwater runoff safely during each stage of development. A schedule for the installation of all temporary and permanent stormwater control measures and devices should be submitted.

IDENTIFICATION OF EASEMENTS, RIGHTS-OF-WAY AND DEED RESTRICTIONS

All existing and proposed easements and rights-of- way for drainage and/or access to stormwater control facilities shall be shown and the proposed owner identified. Necessary easements and rights-of-way should be designated as required to facilitate on going maintenance activities. Any areas subject to special deed restrictions relative to or affecting stormwater management should be delineated.

OTHER PERMITS/APPROVALS

A list of any approvals/permits relative to stormwater management that will be required from other governmental agencies and anticipated dates of submission/receipt should be included with the stormwater plan submission.

MAINTENANCE PROGRAM

The application should contain a proposed maintenance plan for all stormwater control facilities. The plan should identify the proposed owner and the proposed method of financing continuing operation and maintenance if the facility is to be owned by other than the municipality or other governmental agency. The maintenance program should outline the type of maintenance activities required, probable frequency of maintenance, personnel and equipment requirements and estimated annual maintenance costs. The plan should include copies of any legal agreements required to implement the maintenance program and copies of the maintenance agreement as required by the stormwater management ordinance.

FINANCIAL GUARANTEES

The plan submission should contain evidence of satisfaction of the completion guarantees required by the stormwater management ordinance.

PROFESSIONAL CERTIFICATION

The stormwater management plan (including all calculations) must be prepared and sealed by a registered professional engineer or licensed land surveyor with training and expertise in hydrology and hydraulics. Documentation of qualifications may be required by the municipality.

SUMMARY

The stormwater management plan is a integral part of the land development permit application review process. As such, any problems and/or delays in securing approval of the stormwater play may result in delays to the development project. It is important to consider that, in order to be approved, the plan must be judged by a reviewer to satisfy the specific stormwater control criteria and standards in a technically sound manner. Therefore, land developers should make an effort to file complete, accurate and clear stormwater management plans.

PLAN REVIEWERS' RESPONSIBILITIES

In most cases, the local municipality will receive and review the developers' submissions in two (2) phases. The following discussion is offered as guidance as to how the submissions should be reviewed.

PHASE 1 REVIEW

The reviewer should have three (3) primary questions in mind as he reviews the developer's Phase 1 submission:

- Do the conclusions documented by the site analysis accurately describe the conditions found on the site?
- Did the preparer of the plan accurately interpret and apply the proper standards and criteria to his site?
- Does the stormwater management plan adequately provide for controls complying with the standards and criteria?

An important step in accurately answering these questions is a visit to the site. Such an on-site inspection can help to answer questions regarding drainage and the type and condition of existing land cover. In some cases, problem areas may not show up on maps and drawings. However, by actually inspecting the site, the reviewer will get a first hand view of site conditions.

The first phase review presents the opportunity to insure that the proper standards and criteria are being applied and that approved computational methods and control techniques are being proposed for use. Any misunderstandings in regard to the basis of plan development should be resolved prior to the preparation of the Phase 2 submission.

PHASE 2 REVIEW

The second phase of the review involves a final checking to insure that the stormwater control plan complies with the applicable standards and criteria and specific requirements of the stormwater ordinance. The developer is responsible for the sizing and design of all control measures. The reviewer, however, should check to make sure that the proposed control measures make sense as an overall system and that no apparent errors have been made. A suggested check list for use by the plan reviewer is provided as Figure VIII-2. This check list can be used to organize the technical review of the plan submissions as a means for verifying the completeness of proposed stormwater management plans.

The reviewer also should verify that the plan is complete and that it complies in substance with specific requirements of the governing ordinance.

The purpose of the review and the reviewer's comments is to identify potential problems rather that to recommend solutions because solutions are the responsibility of the developer. Review comments should always be documented in writing to lessen confusion and to provide a record of correspondence between the developer and the municipality.

The review of the second phase involves a comparison of the applicable standards and criteria to the recommended controls to insure that the plan is adequate and effective. The proposed control measures must be considered as a system to make sure that all the proposed control measures work together to meet the applicable standards.

The multi-phase submission and review process provides a framework for developing a working relationship between the developer and the reviewer. It helps to define responsibility and minimizes arbitrary decisions concerning plan approval. Another important benefit of this process is that it forms the basis for worthwhile on-site inspections where both the developer and the reviewer know what to expect before construction begins. This knowledge can help to minimize costly construction delays as well as to insure compliance with the requirements of the *Beaverdam Branch Watershed Stormwater Management Plan* and associated municipal ordinances.

SITE INSPECTION

The responsibility of the municipality continues after the developer receives his permit. The stormwater management plan just be implemented and associated facilities must be constructed as designed and approved.

Table VIII-2
Suggested Stormwater Management Plan Review Checklist

GENERAL COMPLETENESS REVIEW

Is the owner's name and address identified? .... Yes ☐ No ☐

Is the preparer of the plan's name and address identified? .... Yes ☐ No ☐

Is a site location map on a U.S.G.S topographic
base map provided? .... Yes ☐ No ☐

Are stormwater plan drawings at an appropriate scale provided
containing the following information:?

- Watershed location .... Yes ☐ No ☐
- Floodplain boundaries .... Yes ☐ No ☐
- Water bodies, watercourses, drainage courses..................... Yes ☐ No ☐
- Soil types and boundaries .... Yes ☐ No ☐
- Contours at an appropriate contour interval .... Yes ☐ No ☐
- Land cover .... Yes ☐ No ☐
- Drainage area delineations... Yes ☐ No ☐
- Stormwater management control facilities .... Yes ☐ No ☐

Are the runoff calculations presented in a form and detail
sufficient to enable them to be critically reviewed?.......................... Yes ☐ No ☐

Are the proposed stormwater controls described in sufficient detail
to permit the review to assess the following?

- Appropriateness of the general stormwater
management approach .... Yes ☐ No ☐
- Facilities sizing and design approach .... Yes ☐ No ☐
- Compliance with design standards contained
in the ordinance .... Yes ☐ No ☐

Are required easments, right-of-ways, and deed
restrictions identified?.. Yes ☐ No ☐

Are other required permits and approvals identified?....................... Yes ☐ No ☐

Is an operation and maintenance plan provided?.............................. Yes ☐ No ☐

Is the proposed ownesrship arrangement for the
storrmwater management facilities defined? .... Yes ☐ No ☐

Are the financial guarantees required by the
Ordinance provided?.. Yes ☐ No ☐

Does the plan contain a acceptable erosion and
sedimentation control plan? .... Yes ☐ No ☐

Table VIII-2
Suggested Stormwater Management Plan Review Checklist
(Continued)

Is the plan certified by a qualified individual as defined
by the Ordinance?.. Yes ☐ No ☐

REVIEW OF CONTENT

Plan drawings:
- Are the drawings legible?... Yes ☐ No ☐
- Are the drawing scales and contour intervals appropriate?.. Yes ☐ No ☐
- Are the delineated drainage areas reasonable based upon topography?.. Yes ☐ No ☐

Runoff calculations:
- Are the runoff calculations performed using approved procedures?... Yes ☐ No ☐
- Are the rainfall characteristics used in the calculations those specified in the Ordinance?.................. Yes ☐ No ☐
- Have soils on the site been assigned to the proper hydrologic groups?.. Yes ☐ No ☐
- Are the runoff curve numbers used in the analysis with acceptable for the pre- and post-development land cover characteristics and soil characteristics?.. Yes ☐ No ☐
- Do the time of concentration and travel time estimates used in the runoff calculations appear to be reasonable? .... Yes ☐ No ☐

Stormwater management facilities design:
- Is the post-development not to exceed pre-development peak discharge control standard properly applied?... Yes ☐ No ☐
- Has the applicant demonstrated the incorporation the amount of impervious surfaces has been minimized to the extent feasible? .... Yes ☐ No ☐
- Has the applicatant demonstrated the use of flow attenuation to the extent feasible? .... Yes ☐ No ☐
- Are the facilities sized using appropriate techniques?........ Yes ☐ No ☐
- Are the facilites designed in accordance with the requirements of the Ordinance?........................... Yes ☐ No ☐

Operation and maintenance plan:
- Is the proposed ownership arrangement acceptable to the municipality? .... Yes ☐ No ☐
- Does the operation and maintenance plan outline appropriate and effective maintenance activities? .... Yes ☐ No ☐

There are two general kinds of inspections that should be used in the inspection program:

- Scheduled inspections: inspections related to construction operations and other existing scheduled inspections

- Random inspections: impromptu site checks to assure continuing compliance with and maintenance of control measures

Initially, a pre-construction conference should be held in which the stormwater management plan is discussed to insure that the municipality and the developer are in agreement about the control procedures and measures to be followed. The developer should be informed of local inspection schedules and notified that it is usually his responsibility to request inspections.

The scheduled inspections should be coordinated with the existing construction inspections. Generally, existing building inspections provide reasonable check points for stormwater runoff control. As a precautionary measure, however, random checks on construction sites should be made in addition to scheduled inspections to further verify compliance.

BEAVERDAM BRANCH WATERSHED STORMWATER MANAGEMENT PLAN

TRAINING MANUAL

APPENDIX A: GLOSSARY OF TERMS

CHESTER ENGINEERS

GLOSSARY OF TERMS

acre - A measure of land equivalent to 43,560 square feet.

acre-foot - A quantity of water that would cover one acre to a depth of one foot.

annual flood - The maximum 24-hour average rate of flow occurring in a stream during any period of 12 consecutive months. It is usual practice to consider the 12-month period as extending from October 1 of one year to September 30 of the following year.

antecedent moisture - The degree of wetness of the soil at the beginning of a runoff period, frequently expressed as an index determined by summation of weighted daily rainfalls for a period preceding the runoff in question.

antecedent precipitation - Rainfall that occurred prior to the particular rain storm under consideration.

area drain - In plumbing, a drain installed to collect surface or storm water from an open area of a building.

artificial watercourse - A surface watercourse constructed by human agencies.

assessment district - The land or area created by statute within the boundaries of which the cost of an improvement is assessed.

automatic spillway - Device for wasting water into natural drainage courses built along canal sides. It may be an uncontrolled overflow crest, a crest equipped with automatic gates, or an enclosed crest designed for siphon operation.

average annual flood - A flood discharge equal to the mean of the discharges of all of the maximum annual floods during the period of record.

average velocity - The average velocity of a stream flowing in a channel of conduit at a given cross section or in a given reach. It is equal to the discharge divided by the cross-sectional area of the section of the average cross-sectional area of the reach. Also called mean velocity.

avulsion - The sudden breaking of a stream through its banks in an unexpected manner, accompanied by formation of another channel or the cutting off of a large quantity of land.

back of levee - The side of a levee away from the river, facing the protected area. Sometimes called the land side or inside of the levee.

backwater effect - The effect which a dam or other obstruction has in raising the surface of the water upstream from it.

bank - (1) The continuous margin along a river or stream where all upland vegetation ceases. (2) The elevation of land which confines waters of a stream to their natural channel in their normal course of flow. (3) The rising land bordering a river, lake or sea.

bank protection - Riprap, paving, brush, concrete, or other material placed to prevent erosion on a stream, reservoir, or lake shore: usually extends to and beyond the thalweg of the channel.

bank revetment - A type of bank protection that covers continuously the entire slope of a bank or an embankment, including the portions extending to the deepest point in the river bed, to keep the bank from receding landward because of erosion. Bank revetment somewhat resembles canal lining in appearance, but whereas the latter is intended to stop or lessen the seepage of water from a canal into the ground, the former is not much concerned with the seepage flow except in regard to the drainage of underground water from land to the river, which may reduce the stability of the banks.

bank storage - Water absorbed and stored in the voids of the soil cover of the bed and banks of a stream, lake, or reservoir and returned in whole or in part as the surface of the water body falls.

base flood - A term used in the National Flood Insurance Program to indicate the minimum size flood to be used by a community as a basis for its floodplain management regulations; presently required by regulation to be that flood which has a one-percent chance of being equaled or exceeded in any given year. Also known as a 100-year flood.

base flow - That part of the stream discharge that is not attributable to direct runoff from precipitation of melting snow; it is usually sustained by water draining from natural storage in groundwater bodies, lakes, or swamps.

base flow depletion curve - The characteristic rate, expressed as a curve, at which the base flow of a stream at a given point diminishes until supplemented by precipitation or snowmelt.

basic hydrologic data - Records of measurements and observations of the quantity per unit of time of precipitation, including snowfall; streamflow; evaporation from water; the elevation of natural water planes, both surface and underground and the change thereof from time to time; and of any related phenomena and natural conditions necessary to allow estimates to be made of past, present, and probable future occurrence of water. The unit of time involved in recording the quantities may vary from seconds to years, and depends on custom, convenience, and method of compilation of the data.

basin - (1) The surface area within a given drainage system. (2) An area upstream from an obstruction to the flow of water. (3) A shallow tank or depression through which liquids may be passed or in which they are detained for treatment or storage.

bed - The bottom of a watercourse of any body of water.

bed load - Sediment that moves by sliding, rolling or skipping on or very near the stream bed; sediment that is moved by tractive or gravitational forces, or both, but at velocities less than that of the adjacent flow.

bed material - In a stream system, the geologic formations and the alluvial deposits through which the stream channel is cut.

bed ripple - Undulating ridges and furrows or crests and troughs formed by the action of flow on the bed of a channel.

bond - A warranty by an underwriting organization, such as an insurance company, guaranteeing honesty, performance, or payment by a contractor.

border strip - A grassed or thickly vegetated strip located at the edge of a field, along outlet channels, or at ends of rows to check or prevent erosion.

box culvert - A culvert with a rectangular cross section.

bridge - A structure erected over a watercourse, depression, or other obstacle consisting of a deck or superstructure supported on abutments and/or piers. As distinguished from a culvert, it spans a watercourse the bed of which is left comparatively undisturbed.

broad crested weir - A weir having a substantial width of crest in the direction parallel to the direction of flow of water over it. This type of weir supports the nappe for an appreciable length and produces no bottom contraction of the nappe. Also called wide crested weir.

brook - A small shallow stream, usually in continuous, somewhat turbulent flow.

building code - Regulations adopted by a governmental body which set forth standards for the construction of buildings and other structures for the purpose of protecting the health, safety and general welfare of the public.

building drainage system - In plumbing, all piping provided for carrying wastewater or other drainage from the building to the street sewer or place of disposal.

building storm sewer - The extension from the building storm drain to the public storm sewer, combined sewer, or other place of disposal.

buttress dam - A fixed dam consisting of a water-supporting upstream face supported by buttresses, which are equally spaced walls or struts proportioned to transmit to the foundations the water load and weight of the structure.

bypass channel - A channel constructed to carry flood water in excess of the quantity that can safely be carried in the stream. Sometimes called flood-relief channel, floodway.

calibration - (1) The determination, checking or rectifying the model outputs to observed conditions. (2) The determination, checking or rectifying of the graduation of any instrument giving quantitative measurements. (3) The process of taking measurements or of observations to establish the relationship between two quantities.

canal - An artificial open channel or waterway constructed for one or more of the following purposes: (a) transporting water, (b) connecting two or more bodies of water, and (c) serving as a waterway for watercraft.

canal section - (1) The shape of the cross section of a canal at right angles to its axis. (2) The data, either in graphic or tabular form, which describe the shape, dimensions, side and bank slopes, normal depth of water, slope of bottom, thickness and kind of lining material (if any), and other such characteristics of a canal at a given point.

capacity - (1) The quantity that can be contained exactly, or the rate of flow that can be carried exactly.

capacity curve - A curve expressing the relationship between the volume of a space and the upper elevation of the material occupying the space. In the case of a reservoir, it is the relationship between the elevation of the water surface in the reservoir and the volume of water below that elevation. Also called storage-capacity curve.

carrying capacity - The maximum rate of flow that a conduit, channel, or other hydraulic structure is capable of passing.

catch basin - A chamber or well, usually built at the curbline of a street which admits surface water for discharge into a stormwater drain.

catchment area - The area draining into a river, reservoir, etc. Also catchment, catchment basin.

cfs - The rate of flow of a material in cubic feet per second.

channel - A perceptible natural or artificial waterway which
periodically or continuously contains moving water or which forms a connecting link between two bodies of water. It has a definite bed and banks which confine the water.

channel accretion - The gradual building up of a channel bottom or bank as a result of sediment deposition.

channel flow depletion - The gradual downstream decrease in the flow of a stream due to seepage from the stream to an adjacent of underlying groundwater body.

channelization - Manmade modification of a channel to increase flow capacity and/or eliminate bank erosion.

channel line - The route of strongest flow of a river. It usually coincides, or nearly coincides with the thalweg.

channel of approach - That reach of a channel immediately upstream from control structure such as a dam, weir, sill, or bridge.

channel roughness - That roughness of a channel, including the extra roughness due to local expansion or contraction and obstacles, as well as the roughness of the stream bed proper; that is, friction offered to the flow by the surface of the bed of the channel in contact with the water. It is expressed as roughness coefficient in the velocity formulas.

channel storage - The in-channel storage volume depending on the stage of water surface in the channel.

climatic year - A continuous 12-month period during which a complete annual cycle occurs, arbitrarily selected from the presentation of data relative to hydrologic or meteorological phenomena. The U.S. Geological Survey uses the period October

1 September 30 in the publication of its records of streamflow. Also called water year.

clustering - Clustering is a fairly broad concept which generally implies the grouping of homes together on smaller lots (and sometimes at a higher density) than normally provided by the local zoning ordinance, in exchange for the reservation of permanent common open space.

combined sewer - A sewer intended to receive both wastewater and storm or surface water.

common law - That body of law developed in England prior to the establishment of the United States. It refers principally to rights and privileges and, while generally followed in the United States, has in some of its applications been abrogated or modified, as in the case of riparian rights to water in some jurisdictions in the United States.

complex surface - In hydrology, a specified combination of soil, crops, or vegetation, and tillage. Also called complex cover.

composite unit hydrograph - A tabular presentation of unit hydrographs for the important subdivisions of a large area, with the times of beginning of rise appropriately lagged by the times of travel from the outlets of the subareas to the major gauging station. The runoff is computed independently for each area multiplied by unit-graph ordinates for that area. The sum of all flows thus computed in a vertical column gives the flow to be expected at the outlet of the basin.

compound hydrograph - The hydrograph of an intermittent storm when the flow resulting from one substorm continues during the next substorm.

concentration time - (1) The period of time required for storm runoff to flow from the most remote point of a catchment or drainage area to the outlet or point under consideration. It is not a constant, but varies with depth of flow and condition of channel. (2) The time at which the rate of runoff equals the rate of rainfall of a storm of uniform intensity.

condensed time - The foreshortening of the time base in hydrological studies in deriving an infiltration-capacity curve. Time condensation is applied, for a period during a storm when the rain intensity is less than infiltration capacity, to meet the requirement that the volume of infiltration under the curve of infiltration capacity must equal the observed volume of infiltration.

confluence - A junction or flowing together of streams; the place where streams meet.

consequent stream - A stream the course of which has been controlled in direction and location by the general slope of the surface topography.

constriction - In a waterway, an obstruction that confines the flow to a narrower section or to a smaller area, thus throttling the flow. Natural gorges, bridge piers, weirs, and orifices are examples of constrictions. Also obstruction.

contour - A line of equal elevation above a specified datum, usually mean sea level.

contour interval - The difference in elevation between adjacent contours on a map.

contour map - A map showing the configuration of the surface by means of contour lines drawn a regular intervals of elevation.

contracted-opening discharge measurement - A determination (by indirect measurement) of peak discharge following a flood by field survey of high-water marks and channel and bridge geometry at a bridge constriction. Discharge is computed on the basis of an evaluation of energy changes between the approach section and the downstream side of the constriction.

contracting reach - A reach of channel wherein flow is accelerating; the velocity head at the downstream cross section exceeds the velocity head at the upstream cross section in a slope-area determination.

control works - (1) All the structures, devices, etc., located at the head or diversion point of a conduit or canal. Practically synonymous with diversion works; and intake heading. (2) Structures and reservoirs constructed to reduce the flood peaks on streams subject to damaging floods.

crest - (1) The top of a dam, dike, spillway, or weir, to which water must rise before passing over the structure. (2) The summit or highest point of a wave. (3) The highest elevation reached by flood waters flowing in a channel.

cross section - A graph or plot of ground elevation across a stream valley or a portion of it, usually along a line perpendicular to the stream or direction of flow.

cubic foot per second (cfs) - A unit of measure of the rates of liquid flow past a given point equal to one cubic foot in one second.

culvert - (1) A closed conduit for the free passage of surface drainage water under a highway, railroad, canal, or other embankment. (2) In highway usage, a bridge waterway structure having a span of less than 20 feet.

curb inlet - An intake structure to allow storm water to enter a storm sewer from a roadway gutter. It is configured to the shape of the curb and gutter to provide for easy installation and efficient operation. See also catch basin.

current - (1) The flowing of water or other fluid. (2) That portion of a stream of water which is moving with a velocity much greater than the average or in which the progress of the water is principally concentrated.

cutoff - A more direct channel, formed either naturally or artificially, connecting two points on a stream channel, which shortens the original length of the channel and increases its slope.

daily flood peak - The maximum mean daily discharge occurring in a stream during a given flood event.

dam - A barrier constructed across a watercourse for the purpose of (a) creating a reservoir, (b) diverting water into a conduit of channel, (c) creating a head which can be used to generate power, and/or (d) improving river navigability.

dam site - a location where the topographical and other physical conditions are favorable for the construction of a dam, or any site where a dam has been built, is being built, or is contemplated.

Darcy-Weisbach Roughness Coefficient - The roughness coefficient in the Darcy-Weisbach formula. It is dimensionless.

debris basin - A basin formed behind a low dam or excavated in a stream channel to trap debris or bed load carried by the stream. Such a basin requires periodic cleaning of debris by excavation to restore capacity.

Debris dam - a fixed dam built across a stream channel to catch and retain debris such as sand, gravel, silt, driftwood.

denudation - The erosion, by rain, frost, wind, running water, and other agencies, of the solid matter of the earth so that strata formerly covered are exposed and elevations are worn down.

depletion curve - That part of a hydrograph extending from the point of termination of the recession curve to a subsequent rise or alteration of inflow when additional water becomes available for streamflow; that part of the hydrograph representing the rate of water flow or seepage from groundwater storage into the stream channels.

depletion hydrograph - The drainage from groundwater, swamps, and lakes during long rainless periods of no recharge, expressed in a hydrograph of discharge from the water bodies maintaining base flow. The rate of this drainage is an indication of the rate at which storage in those water bodies is being depleted and the rates of drainage as well as storage decrease with time.

depression storage - The volume of water, expressed as depth on the entire water surface of the area, which is required to fill natural depressions, large or small, to their overflow levels. Also called pocket storage.

depth of runoff - The total runoff from a drainage basin divided by its area. For convenience in comparing runoff with precipitation, the term is usually expressed in inches of depth over the drainage area during a given period of time.

design analysis - In engineering reports, the tabulation and consideration of the physical data, present requirements, and probable future requirements pertaining to an engineering project. It should include the main features and principles of the design.

designated floodway - The channel of a stream and that portion of the adjoining floodplain designated by a regulatory agency to be kept free of further development to provide for unobstructed passage of flood flows.

design criteria - (1) Engineering guidelines specifying construction details and materials. (2) Objectives, results, or limits which must be met by a facility, structure, or process in performance of its intended functions.

design flood - (1) The largest flow which a reservoir, channel, or other works can accommodate without damage or with limited damage. (2) The flood adopted for use in determining the hydraulic proportions of a structure such as the outlet works of a dam, the height of a dam, the size of culverts, etc..

design storm - (1) The storm for which a hydraulic structure such as a bridge, culvert, or dam is designed. (2) The rainfall estimate corresponding to an enveloping depth-duration curve for the selected frequency.

desilting basin - A settling basin for removal of silt from river or stormwater flows.

detention - The slowing, dampening, or attenuating of runoff flows entering the natural drainage pattern or storm drainage system by temporarily holding water on a surface area in a detention basin or within the drainage system.

detention pond - A pond or reservoir, usually small, constructed to impound or retard surface runoff temporarily.

detention time - The period of time that a water flow is retained in a basin, tank, or reservoir for storage.

developer - The person, persons, or any corporation, partnership, association, or other entity or any responsible person therein or agent therefor that undertakes the activities associated with changes in land use. The term "developer" is intended to include, but not necessarily be limited to, the terms, "subdivider", "owner", and "builder" even though the individuals involved in successive stages of a project may vary.

development - Any activity, construction, alteration, change in land use or practice that affects stormwater runoff characteristics.

dike - An embankment constructed to prevent overflow of water from a stream or other body of water.

dimensionless unit hydrograph - A unit graph useful for comparing unit hydrographs of different drainage areas or those resulting from different storm patterns. It is derived either from an observed storm flow hydrograph of flood event or from a unit hydrograph, or it can be constructed from a summation graph.

direct bank protection - A kind of works done on the bank itself, such as slope protection of the embankment and upper bank and toe protection of the lower bank against erosion, and grading of the sloping surface or provision of drainage layers to ensure stability against seepage and saturation. A revetment.

direct runoff - The runoff that enters stream channels promptly by flow over the ground surface or through the ground without entering the main water table, or that portion of the runoff which is directly associated with causative rainfall or snow melt.

discharge - The flow or rate of flow from a canal, conduit, channel or other hydraulic structure.

discharge capacity - The maximum rate of flow that a conduit, channel or other hydraulic structure is capable of passing.

discharge coefficient - A coefficient by which the theoretical discharge of a fluid through an orifice, weir, nozzle, or other passage must be multiplied to obtain the actual discharge.

discharge curve - A curve that expresses the relationship between the discharge of a stream or open conduit at a given location and the stage or elevation of the liquid surface at or near that location. Also called rating curve, discharge rating curve.

discharge hydrograph - The hydrograph of the discharge or flow of a stream or conduit.

discharge rating curve - A curve that expresses the relationship between the discharge of a stream or open conduit at a given location and the stage or elevation of the liquid surface at or near that location. Also called rating curve.

distribution graph - In hydrology, a unit hydrograph in which the ordinates of flow are expressed as percentages of the volume of the hydrograph. Also unit hydrograph.

ditch - An artificial open channel or waterway constructed through earth or rock to convey water. A ditch usually has sharper curvature than does a canal, is not constructed to such refinement or uniformity of grade or cross section, and is seldom lined with impervious material to prevent seepage.

dive culvert - A culvert in which the outlet is lower than the inlet and the middle is lower than either. Also inverted siphon.

diversion - (1) The taking of water from a stream or other body of surface water into a canal, pipeline, or other conduit. (2) A channel with a supporting ridge on the lower side constructed across the slope to intercept runoff and minimize erosion or to prevent excess runoff from flowing onto lower lying areas

diversion area - That portion of an adjacent area beyond the normal watershed divide which contributes water to the watershed under discussion.

diversion canal - A canal to divert water from one point to another.

diversion chamber - A chamber which contains a device for drawing off all or part of a flow or for discharging portions of the total flow to various outlets.

diversion channel - An artificial channel constructed around a town or other point of high potential flood damages to divert flood water from the main channel for the critical reach.

downspout - In plumbing, the water conductor from the roof to the storm drain or other means of disposal.

drain - (1) A conduit or channel constructed to carry off, by gravity, liquids. It may be an open ditch, lined or unlined, or a buried pipe. (2) In plumbing, any pipe which carries water or wastewater in a building drainage system.

drainage - (1) In general, the removal of surface water from a given area either by gravity or by pumping. Commonly applied to surface water and groundwater. (2) The area from which water occurring at a given point of location on a stream originates. In such cases, synonymous with "drainage area" and "watershed."

drainage area - (1) The area of a drainage basin or watershed, expressed in acres, square miles, or other unit of area. Also called catchment area, watershed, river basin. (2) The area served by a sewer system receiving storm and surface water, or by a watercourse.

drainage basin - An area from which surface runoff is carried away by a single drainage system. Also called catchment area, watershed, drainage area.

drainage canal - A canal built and used primarily to convey water from an area where surface and soil conditions provide no natural outlet for precipitation.

drainage culvert - A closed conduit for the free passage of surface drainage water under a highway, railroad, canal, or other embankment.

drainage district - (1) An organization created and operating under statutory enactment for the purpose of financing, constructing, and operating a drainage system. (2) The land or area within the boundaries of a drainage district, as delimited in the organizing statute.

drainage divide - The line which follows the ridges or summits forming the exterior boundary of a drainage basin and which separates one drainage basin from another.

drizzle - Relatively uniform precipitation consisting exclusively of minute and numerous drops of water which seem to float in the air and are usually less than 0.02 inches in diameter. It is distinguished from light rain by the fact that visibility is poor during a drizzle. A drizzle frequently occurs simultaneously with fog or mist.

drowned weir - A weir which, when in use has the water level on the downstream side at an elevation equal to, or higher than the weir crest; the rate of discharge is affected by the tail water. Also submerged weir.

dry weather flow - (1) The flow of wastewater in a combined sewer during dry weather. Such flow consists mainly of wastewater with no storm water included. (2) The flow of water in a stream during dry weather. Also base flow.

duration-area curve - A curve which shows the area beneath a duration curve at any value of the flow, and is therefore the integral of duration with respect to streamflow. When the duration curve is plotted as a percentage of time, the resulting duration area shows the average flow available below a given discharge.

duration curve - A curve that expresses the relationships of all the units of some item such as head, flow, load, power, etc., arranged in order of magnitude as the ordinate, to time, frequently expressed in percentage, as the abscissa; a graphical representation of the number of times given quantities are equaled or exceeded during a certain period of record.

effective rainfall - Rain that produces surface runoff.

effective storage - The volume of water available for a designated purpose. In flood control reservoirs, the effective storage is the difference between actual capacity above outlet elevation and valley storage.

energy dissipation - The transformation of mechanical energy into heat energy. In fluids, this is accomplished by viscous shear. The rate of energy dissipation in flowing fluids varies with the scale and the degree of the turbulence. Baffles, the hydraulic jump, and other damping methods are used to dissipate energy in water.

ephemeral stream - (1) A stream that flows only in direct response to precipitation. Such a stream receives no water from springs and no long continued supply from melting snow or other surface source. Its channel is above the water table at all times. (2) The term may be arbitrarily restricted to streams or stretches of streams that do not flow continuously during periods of as much as one month.

erosion - Wearing away of the lands by running water, glaciers, winds, and waves; can be subdivided into three process: corrasion, corrosion, and transportation. Weathering, although sometimes included in erosion, is a distinct process which does not imply removal of any material.

erosion control - The application of measures to reduce erosion of land surfaces.

erosive velocity - that velocity of water in a stream or canal which, when exceeded, will cause erosion of banks or bed.

escarpment - A more or less continuous line of cliffs or steep slopes facing in one general direction and caused by erosion.

excess rainfall - That part of the rain of a given storm which falls at intensities exceeding the infiltration capacity and is thus available for direct runoff.

fall - (1) A sudden difference in elevation in the bed of a stream of sufficient extent to cause the entire stream of water passing over it to drop vertically for some distance before it resumes its course. (2) The vertical distance between the water-surface elevations of the two points on a stream or conduit.

flash flood - A flood of short duration with a relatively high peak rate of flow, usually resulting from a high-intensity rainfall over a small area.

flashy stream - A stream in which flows collect rapidly from the steep slopes of the catchment and thus flood peaks occur soon after the rain. The flows in such a stream usually subside as rapidly as the collect.

flat - A level surface with little or no change in elevation; a level tract along the banks of a river.

flat-crested weir - A weir the crest of which is horizontal in the direction of flow and of appreciable length when compared with the depth of water passing over it.

flood - A relatively high flow as measured by either gage height or discharge quantity. Also, any flow equal to or greater than a designated base flow.

flood basin - The part of a river valley that is outside the natural stream bank and is subject to flooding, particularly where the bank is higher than the valley floor and where a basin is formed between the bank and the sidehill.

flood benefits - The value of the flood protection as estimated in terms of damage eliminated or other advantageous effects of the proposed works.

flood-control storage - Storage of water during floods for later release as rapidly as channel capacities permit.

flood-control works - Structures and reservoirs constructed to reduce the flood peaks on streams subject to damaging floods.

flood duration - The length of time a stream is above flood stage or overflowing its banks.

flood event - The series of flows of water in a stream constituting a distinct progressive rise, culminating in a peak, crest, or summit, together with the recession that follows the peak or crest.

flood frequency - The frequency with which the maximum flood may be expected to occur at a site in any average interval of years. Frequency analysis defines the "N-year flood" as being the flood which will, over a long period of time, be equaled or exceeded on the average once every N years. Sometimes expressed in terms of percentage of probability; for example, a probability of 1 percent would be a 100-year flood; a probability of 10 percent would be a 10-year flood.

flood fringe - The portion of the floodplain outside of the floodway but still subject to flooding. Sometimes referred to as "floodway fringe". Also used to refer to areas subject to flooding by water with little or no velocity.

flood hazard boundary map - An official map of a community issued by the Federal Insurance Administration on which the boundaries of the floodplain, mudslide and/or flood-related erosion areas having special hazards have been drawn.

flood insurance - Insurance on structures and/or their contents for their restoration or replacement if damaged by flood water. The term is usually applied to flood insurance under the National Flood Insurance Act of 1968, as administered by the Federal Insurance Administration.

flood insurance rate map - An official map of a community on which the Federal Insurance Administration has delineated the area in which the purchase of flood insurance is required under the Flood Insurance Regular Program and the actuarial rate zones applicable to each area.

flood level - The stage of a stream at time of flood.

flood of record - The greatest flood recorded for a location. Usually referred to as the "maximum flood of record".

flood peak - Maximum rate of flow, usually expressed in cubic feet per second, that occurred during a flood.

flood plain - The area described by the perimeter of the probable limiting flood. That portion of a river valley which has been covered with water when the river overflowed its banks at flood stage.

flood plain management - The operation of a program intended to lessen the damaging effects of floods, maintain and enhance natural values, and make effective use of related water and land resources with the floodplain. It is an attempt to balance values obtainable from use of the flood plains with potential losses arising from such use.

floodplain regulations - A general term for the full range of codes, ordinances, and other regulations relating to the use of land and construction within stream channels and floodplain areas. The term encompasses zoning ordinances, subdivision regulations, building and housing codes, encroachment line statutes, open-space regulations, and other similar methods of control affecting the use and development of these sites.

flood probability - The probability of a flood of a given size being equaled or exceeded in a given period; a probability of 1 percent would be a 100-year flood; a probability of 10 percent would be a 10-year flood.

floodproofing - A combination of structural changes and adjustments to new or existing structures and facilities, their contents and/or their sites for the purpose of reducing or eliminating flood damages by protecting against structural failure, keeping water out, or reducing the effect of water entry.

flood-protection works - Structures built to protect lands and property from damage by floods.

flood-relief channel - A channel constructed to carry flood water in excess of the quantity that can be carried safely in the stream.

flood routing - The process of determining progressively the timing and shape of a flood wave at successive points along a river.

flood-source area - That portion of a drainage basin where conditions of precipitation and cover, topography, or land use favor frequent flooding.

flood stage - An arbitrarily fixed and generally accepted gage height or elevation above which a rise in the water surface elevation is termed a flood. It is commonly fixed as the stage at which overflow of the normal banks or damage to property would begin.

flood wave - A rise in streamflow to a crest in response to runoff generated by precipitation and its subsequent recession after the precipitation ends.

floodway - (1) A channel constructed to carry flood water in excess of the quantity that can be carried safely in the stream. Also bypass channel, flood-relief channel. (2) That portion of the 100-year floodplain which serves as a flood channel to pass the deeper, faster moving waters. (3) As used in the National Flood Insurance Program, floodways must be large enough to pass the 100-year flood without causing an increase in elevation of more that a specified amount (on foot in most areas).

flotsam - Debris from natural sources or human activity that floats on oceans, lakes, rivers and streams.

flow - (1) The movement of a stream of water or other fluid from place to place; movement of silt, water, sand or other material. (2) The fluid which is in motion. (3) The quantity or rate of movement of a fluid; discharge; total quantity carried by a stream. (4) To issue forth or discharge. (5) The liquid amount of liquid per unit time passing a given point.

flow augmentation - The release of water stored in a reservoir or other impoundment to increase the natural flow in a stream.

flow-duration curve - A duration curve of streamflow.

flow line - (1) The position of the water surface in a flowing stream or conduit for a normal or specified rate of discharge. (2) A contour or line around a reservoir, pond, or lake, or along a stream, corresponding to some definite water level, for example, maximum, mean, low, spillway crest. The term is generally used in this connection in the acquisition of rights to flood lands for the purpose of water storage. (3) The hydraulic grade line in an open channel. (4) Adjective applied to a closed conduit laid on the hydraulic grade line and designed to flow less than full.

flow rate - Volume or mass of a gas, liquid or solid material that passes through a cross-section of conduit in a given time.

flow recording - Documentation of the quantity or rate of the flow of a fluid past a given point.

fluvial deposit - Sediment deposited by the action of streams. Also called alluvial deposit.

fluvial erosion - Erosion caused by the action of streams.

freeboard - The vertical distance between the normal maximum level of the surface of the liquid in a conduit, reservoir, tank, canal, etc., and the top of the sides of and open conduit, the top of a dam or levee, etc., which is provided so that waves and other movements of the liquid will not overflow the confining structure.

free flow - A condition of flow through or over a structure where such flow is not affected by submergence or the existence of tail water.

free weir - A weir that is not submerged; a weir in which the tail water is below the crest or where the flow is not in any way affected by tail water.

frequency - (1) The number of occurrences of a certain phenomenon in a given time. (2) The number of occasions on which the same numerical measure of a particular quantity has occurred between definite limits.

frequency curve - A graphical representation of the frequency of occurrence of specific events.

frequency distribution - An arrangement of distribution of quantities pertaining to a single element in order of their magnitude and frequency of occurrence.

front - A meteorological term for a line or narrow belt marking the intersection of a frontal surface with the surface of the earth.

frontal precipitation - Precipitation occurring at the frontal surface.

frontal surface - The surface of separation between two adjacent air masses of different characteristics, usually temperature and humidity, normally associated with a belt of clouds and precipitation.

front of levee - The side of the levee next to the river, facing away from the protected area. Sometimes called the river side.

gabion - A long basket filled with earth or stones used in building dams, dikes, and bank protection structures.

gage - (1) A device for indicating the magnitude or position of an element in specific units when such magnitude or position is subject to change. (2) The act or operation of registering or measuring the magnitude or position of a thing when these characteristics are subject to change. (3) The operation of determining the discharge in a waterway by using both discharge measurements and a record of stage.

gage datum - The elevation of the zero of the gage above a certain datum.

gage height - The height of a water surface as measured on a gage, the zero of the gage being referred to same datum.

gauging - The determination of the quantity of water flowing per unit of time in a stream channel, conduit, or orifice at a given point by means of current meters, rod floats, weirs, pitot tubes, or other measuring device.

gauging station - A location on a stream or conduit where measurements of discharge are customarily made. The location includes a stretch of channel through which the flow is uniform and a control downstream from this stretch exists. The station usually has a recording or other gage for measuring the elevation of the water surface in the channel or conduit.

gpd - The rate of water, wastewater, or other flow measured in U.S. gallons per day.

gpm - The rate of water, wastewater, or other flow measured in U.S. gallons per minute.

grade - (1) The inclination or slope of a stream channel, conduit, or natural ground surface, usually expressed in terms of the ratio or percentage of number of units of vertical rise or fall per unit of horizontal distance. (2) To establish a profile by cuts and fills or earthwork. (3) To range by size, broken stone, gravel, sand or combinations of such materials.

graded stream - A condition of stream in which its channel has reached a stable form as a result of its flow characteristics.

grassed waterway - A vegetated natural waterway used to conduct the accumulated runoff from cultivated land or fields in strip-crop systems.

grating - A screen consisting of parallel bars, two sets being transverse to each other in the same plane.

ground cover - Any vegetation producing a protecting mat on or just above the soil surface.

groundwater - Subsurface water occupying the saturation zone, from which wells and springs are fed. In a strict sense, the term applies only to water below the water table.

groundwater recharge - Replenishment of groundwater naturally by precipitation or runoff or artificially by spreading or injection.

groundwater table - (1) The upper surface of a body of unconfined groundwater. (2) The elevation of depth below the ground surface of such a water surface. In a confined aquifer, it is defined by the static levels in wells that draw from the aquifer.

gumbel distribution - A statistical distribution used in flood frequency analysis, to determine the probability that a given flow will occur within a given time interval.

headwall - A wall of stone, metal, concrete, or wood at the end of a culvert or drain to serve one or all of the following purposes: protect fill from scour or undermining, increase hydraulic efficiency of conduit, divert direction of flow, retard disjointing of short sectional pipe, and serve as a retaining wall.

height of dam - The difference in elevation between the roadway, walkway, or spillway crest and the lowest part of the excavated foundation along the axis of a fixed dam.

high water mark - A mark on a structure or natural object, indicating the maximum stage of tide or flood.

histogram - (1) A graph of computations furnishing the data for plotting a histograph. (2) A bar diagram representing a frequency distribution. A graphical representation of a frequency distribution by means of rectangles whose widths are the class intervals and whose heights are the corresponding frequencies.

histograph - A map or chart of a river, drainage, or sewer system on which a series of time lines is placed. These time lines give the time of transit of water originating on a time line between that line and the outlet of the system.

hydraulically sensitive area - An area where the runoff has a potential to cause problems or is already causing problems. Future development could result in a significant increase in the subarea peak flow, or a change in the timing of the subarea peak could result in an increase in the downstream flows.

hydraulic elements - The depth of water, cross-sectional area of the water, hydraulic radius, wetted perimeter, mean depth of water, velocity, energy head, friction factor, and other similar quantities pertaining to a particular stage of flowing water or to a particular cross section of a conduit or stream channel.

hydraulic friction - The resistance to flow exerted on the perimeter or contact surface of a body of water moving in a stream channel or conduit due to the roughness characteristic of the confining surface, which induces turbulence and consequent loss of energy. Energy losses arising from excessive turbulence, impact at obstructions, curves, eddies, and pronounced channel changes are not ordinarily ascribed to hydraulic friction.

hydraulic fiction coefficient - The ratio of actual discharge to the theoretical discharge in a frictionless conduit or open channel free of turbulence. Also roughness coefficient.

hydraulic grade line - A hydraulic profile of the piezometric level of water at all points along a line. The term is usually applied to water moving in a conduit, open channel, or stream.

hydraulic head - The height of the free surface of a body of water above a given point beneath the surface.

hydraulic jump - (1) The sudden and usually turbulent passage of water in an open channel under conditions of free flow, from low stage below critical depth to high stage above critical depth; during this passage the velocity changes from supercritical to subcritical. It represents the limiting condition of the surface curve, in which that curve tends to become perpendicular to the stream bed. (2) A device to dissipate energy in an open channel, in a sewer, or at the toe of a spillway section of a dam. (3) A device to promote turbulence. (4) An abrupt rise in water surface which may occur in an open channel when water flowing at a high velocity is retarded.

hydraulic loss - The loss of head attributable to obstructions, friction, changes in velocity, and changes in the form of the conduit.

hydraulic profile - (1) A profile along the axis of flow of a stream or conduit showing elevations of the bottom and of the energy line.

hydraulic radius - The right cross-sectional area of a stream of water divided by the length of that part of its periphery in contact with its containing conduit; the ratio of area to wetted perimeter.

hydraulics - That branch of science or of engineering which deals with water or other fluid in motion.

hydraulic slope - The slope of the hydraulic grade line.

hydraulic structure - Any engineering structure designed to control water.

hydrograph - A graph showing, for a given point on a stream or conduit, the discharge, stage, velocity, or other property of water with respect to time.

hydrologic cycle - The circuit of water movement from the atmosphere to the earth and return to the atmosphere through various stages or process such as precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transpiration. Also water cycle.

hydrologic data station - A site at which information applicable to hydrologic studies is collected.

hydrologic properties - Those properties of soils and rocks which control the entrance of water and the capacity to hold, transmit, and deliver water. They include porosity, specific yield, specific retention, permeability, infiltration capacity, and direction of maximum and minimum permeability.

hydrology - The applied science concerned with the waters of the earth in all their states - their occurrence, distribution, and circulation through the hydrologic cycle.

hyetograph - A graphical representation of average rainfall, rainfall excess rates, or volumes over specified areas during successive units of time during a storm.

ice gorge - The choking of a stream channel due to the piling up of ice against some obstruction, forming a temporary dam, and the subsequent release of the water impounded behind the dam due to its sudden bursting, with a resultant flood of water so released.

impermeability - The property of material which prevents perceptible movement of water through it under pressure ordinarily encountered.

impervious - Not allowing, or allowing only with great difficulty, the movement of water; impermeable.

impounding dam - A barrier constructed across a watercourse to create a reservoir.

impounding reservoir - A reservoir in which surface water is retained for a considerable period of time and from which it is released for use at a time when the ordinary flow is insufficient to satisfy requirements.

impoundment - A pond, lake, tank, basin, or other space, either natural or created in whole or part by the building of engineering structures which is used for storage, regulation, and control of water.

infiltration - (1) The flow or movement of water through the interstices or pores of a soil or other porous medium. (2) The absorption of liquid by the soil, either as it falls as precipitation or from a stream flowing over the surface.

initial abstraction retention - Total amount of rainfall that may fall without causing a significant amount of direct runoff.

initial detention - The volume of water on the ground, either in depression or in transit at the time active runoff begins. Also depression storage.

initial loss - In hydrology, rainfall preceding the beginning of surface runoff. It includes interception, surface wetting, and the infiltration unless otherwise specified.

initial rain - The rain that falls in the beginning of a storm before the depression storage is completely filled.

inlet - (1) A surface connection to a drain pipe. (2) A structure at the diversion end of a conduit. (3) The upstream end of any structure through which water may flow. (4) A form of connection between the surface of the ground and a drain or sewer for the admission of surface or storm water.

inlet control - Control of the relationship between headwater elevation and discharge by the inlet or upstream end of any structure through which water may flow.

intercepting channel - A channel excavated at the top of earth cuts, at the foot of slopes, or at other critical places to intercept surface runoff or flow.

interception - (1) The process by which precipitation is caught and held by foliage, twigs, and branches of trees, shrubs, and other vegetation, and lost by evaporation, never reaching the surface of the ground. (2) The amount of precipitation intercepted.

interception loss - That portion of precipitation caught by foliage, twigs, and branches of trees, shrubs, and other vegetation, and lost by evaporation, never reaching the surface of the ground. (2) The amount of precipitation intercepted.

intermittent stream - A stream or portion of a stream that flows only in direct response to precipitation.

invert - The floor, bottom, or lowest portion of the internal cross section of a closed conduit.

isohyet - An imaginary line on the earth's surface, as presented on a map, connecting all points of equal precipitation. A line or contour representing equal concentration.

isohyetal map - A map that shows, through the use of isohyets, the variation and distribution of precipitation occurring over an area during a given period.

jetsam - Floating discarded material.

Kutter roughness coefficient - The roughness coefficient in the formula published by Ganguillet and Kutter for determining the discharge coefficient in the Chezy formula.

land development - As devined by the Municipalities Planning Code [Section 107(11)]: "(i) the improvement of one lot or two or more contiguous lots, tracts or parcels of land for any purpose involving (a) a group of two or more buildings, or (b) a division or allocation of land or space between or among two or more existing or prospective occupants by means of, or for the purpose of, streets, common areas, leaseholds, and condominiums, building groups, or other features; (ii) a division of land."

land disturbance - Any activity involving the changing, grading, transportation, fill and any other activity which causes land to be exposed to the danger of erosion.

land use - (1) The culture of the land surface which has a determining effect on the broad social and economic conditions of a region and which determines the amount and character of the runoff and erosion. (2) Existing or zoned economic use of land, such as residential, industrial, commercial, open, etc.

levee - A dike or embankment, generally constructed on or parallel to the banks of a stream, lake, or other body of water, intended to protect the land side from inundation by flood waters or to confine the stream flow to its regular channel.

lined canal - A canal of which the sides and bottom have been lined or covered with some watertight material to prevent leakage or erosion, to improve carrying capacity, or to minimize growth of vegetation.

log Pearson distribution - A statistical distribution used in flood frequency analysis to determine the probability that a given flow will occur within a given time.

lot averaging - In a single family subdivision, a developer may average the size of the lots (reducing some and increasing others), provided that the total number of units for the entire site does not exceed the number specified by the zoning ordinance. This approach provides design flexibility, but does not result in the reservation of commonly-owned open spaces.

made land - An area artificially filled with soil material.

main channel - The middle, deepest, or most navigable channel.

maintenance - The upkeep necessary for efficient operation of physical properties. It involves labor and materials, but is not to be confused with replacement or retirement.

Manning formula - A formula for open-channel flow, published by Manning in 1890, which gives the value of c in the Chezy formula.

Manning roughness coefficient - The roughness coefficient in the Manning formula for determination of the discharge in the Chezy formula.

marsh - A tract of soft, wet land, usually vegetated by reeds, grasses, and occasionally small shrubs. Also swamp.

mass diagram - A diagram, curve, or graph plotted with rectangular coordinates and representing a summation of all preceding quantities up to a point, each ordinate being equal to the sum of preceding terms in the series, with the corresponding abscissa representing elapsed time or other appropriate variable. Also mass curve.

maximum computed flood - The largest momentary flood discharge from a watershed believed possible from a consideration of meteorological conditions such as probable maximum rainfall and snow cover and geomorphic conditions such as stream gradients or land slope. Also probable maximum flood.

maximum discharge - The maximum rate of flow that a stream, conduit, channel, pipe, or other hydraulic structure is capable of passing.

maximum probable rainfall - Precipitation of a given amount and duration that can reasonable be expected to occur in a drainage basin.

mean - (1) The arithmetic average of a group of data. (2) The statistical average (50% point) determined by a probability analysis.

mean annual precipitation - The average over a period of years of the annual amounts of precipitation.

mean annual runoff - The average over a period of years of the annual amounts of runoff discharged by a stream.

mean depth - The average depth of water in a stream channel or conduit. It is equal to the cross-sectional area divided by the surface width.

meander - In connection with streams, a tortuous or winding stream channel, usually in an erodible, alluvial valley, formed in a reverse or S-shaped curve by erosion of the concave bank. It is characterized by curved flow and alternating shoals and bank erosion.

median - In a statistical array, the value having as many cases larger in value as cases smaller in value.

mgd - Million gallons per day.

model - (1) A scaled reproduction or representation of an entity, treatment process or environmental domain. (2) A series of mathematical equations approximating a real situation.

modeling - The simulation of some physical or abstract phenomenon or system with another system believed to obey the same physical laws or abstract rules of logic, in order to predict the behavior of the former.

nappe - The sheet or curtain of water overflowing a weir or dam.

natural stormwater runoff regime - A watershed where natural surface configurations, runoff characteristics and defined drainage conveyances have attained the conditions of equilibrium.

navigable water - Any stream, lake, or other natural body of water which is actually navigable and that, by itself or by its connections with other waters, is of sufficient capacity to float watercraft for the purposes of commerce, trade, transportation, or pleasure for a period long enough to be of commercial value; or any water which has been declared navigable by the Congress of the United States.

net rainfall - Rainfall minus infiltration and other deductions from surface runoff. Also excess rainfall.

n factor - Values of the roughness factor in Manning's formula or Kutter's formula.

nonfrontal precipitation - Precipitation which may occur in any kind of barometric depression. The lifting of air is caused by horizontal convergence resulting from inflow into the low pressure area.

obstruction - Any structure or assembly of materials including fill above or below the surface of land or water, any activity which might impede, retard, or change flood flow capacities.

occasional storm - A rainfall of an intensity that may be expected to occur once in 10 to 25 years. Also extraordinary storm.

open channel - Any natural or artificial waterway or conduit in which water flows with a free surface.

open-channel constriction - (1) Any obstruction that reduces the normal cross section of a channel. (2) In a general sense, any type of constriction in an open channel, whether natural or man-made, such as a dam, bridge, culvert. (3) In application, a width constriction, such as a highway bridge with long approach fills across a flood plain.

open-channel flow - Flow of a fluid with its surface exposed to atmosphere.

orifice - An opening with closed perimeter, usually of regular form, in a plate, wall, or partition, through which water may flow, generally used for the purpose of measurement or control of such water.

orifice plate - A plate containing an orifice.

orographic precipitation - Precipitation caused by the interference of rising land in the path of moisture-laden wind. A horizontal air current striking a mountain slope is deflected upward and the consequent dynamic cooling associated with the expansion of the air produces precipitation if the air contains sufficient aqueous vapor.

outfall - (1) The point, location or structure where wastewater or drainage discharges from a sewer, drain or other conduit. (2) The conduit leading to the ultimate discharge location.

outlet - Downstream opening or discharge end of a pipe, culvert, or canal.

outlet control structure - The means of controlling the relationship between the headwater elevation and the discharge, placed at the outlet or downstream end of any structure through which water may flow.

overbank flow - That portion of streamflow which exceeds the carrying capacity of the normal channel and overflows the adjoining flood plain.

overflow - The water that exceeds the ordinary limits, such as the stream banks, the spillway crest, or ordinary level of a basin.

overflow channel - An artificial waterway provided to conduct away from the structure the water overflowing from a reservoir, basin, or canal by way of an overflow device provided for the purpose.

overland flow - The flow of water over the ground before it enters some defined channel. Also overland runoff.

peak flow - Maximum flow.

Penn State Runoff Model - A computer stormwater runoff simulation model developed by the Pennsylvania State University for application in stormwater management planning efforts.

perennial stream - A stream that flows continuously at all seasons of the year and during dry as well as wet years.

performance zoning - The intent of performance zoning is to provide more flexibility than traditional zoning. Instead of establishing specific standards, such as lot size, setbacks, etc., various performance criteria or end results to be achieved are established. If the proposed use can meet these performance standards, then it is permitted in the district. Performance standards could relate to density, amount and type of open space, preservation of sensitive environmental areas, and similar items.

permit program - An authoritative or official program of licensing the conduct of an activity.

pervious - Possessing a texture that permits water to move through perceptibly under normal head differences.

planned residential development - As defined by the Municipalities Planning Code [Section 107(14)]: "an area of land, controlled by a landowner, to be developed as a single entity for a number of dwelling units, the development plan for which does not correspond in lot size, bulk or type of dwelling, density, lot coverage and required open space to the regulations established in any one residential district created, from time to time, under the provisions of a municipal zoning ordinance.

plumbing system - The distributing pipes for the water supply; the fixtures and fixture traps; the soil, waste and vent pipes; the building drain and building sewer; and the stormwater drainage pipes; with their devices, appurtenances and connections within and adjacent to the building.

point of interest - A point of hydraulic concern such as a bridge, culvert, or channel section, at which the rate of runoff is computed or measured.

pond - A body of water of limited sizes, either naturally or
artificially confined and usually smaller that a lake.

ponded stream - A section or stretch of stream flowing through an area which has been warped upward or uplifted at a geological period subsequent to the time when the stream channel was originally established.

pool - (1) A small and rather deep body of relatively quiet water, as a pool in a stream. (2) A small body of standing or stagnant water.

precipitation - (1) The total measurable supply of water received directly from clouds as rain, hail, or sleet; usually expressed as depth in an hour, day, or other time period. (2) The process by which atmospheric moisture is discharged onto a land or water surface.

precipitation mass curve - A graph showing accumulated precipitation as a function of time.

precipitation rate - The amount of precipitation occurring in a unit of time, generally expressed in inches per hour.

probable maximum flood - The most severe flood that may be expected from a combination of the most critical meteorological and hydrological conditions that are reasonably possible in the drainage basin. It is used in designing high-risk flood protection works and siting of structures and facilities that must be subject to almost no risk of flooding.

proportional weir - A special type of weir in which the discharge through the weir is directly proportional to the head.

rain - Particles or liquid water that have become too large to be held by the atmosphere.

rainfall - (1) A fall of rain; precipitation in the form of water. (2) The amount of rain, usually expressed in inches depth of water on an area, that reaches the surface of the earth.

rainfall index - The average rainfall intensity above which the volume of rainfall equals the volume of observed runoff. It represents the combined effects of interception and depression storage as well as of infiltration.

rainfall intensity - Amount of rainfall occurring in a unit of time, converted to its equivalent in inches per hour at the same rate.

rainfall-intensity curve - A curve that expresses the relation of rates of rainfall and their duration. Each curve is generally for a period of years during which time the intensities shown will not, on the average, be exceeded more than once.

rain gage - A device for catching and measuring the depth of rainfall.

rainstorm - A meteorological disturbance accompanied by rain.

rare storm - A rainfall of such intensity as may be expected to occur once in 100 years.

rating curve - (1) A curve which expresses graphically the relation between mutually dependent quantities. (2) A graphic representation of a rating table. (3) A curve showing the relation between gage height and discharge of a stream or conduit at a given station.

rational method - A method of estimating the runoff in a drainage basin at a specific point and time by means of the rational runoff formula.

rational runoff formula - A formula used to relate rainfall intensity to runoff. It is based on the approximation that one inch per hour per acre equals one cubic foot per second.

recession curve - On a hydrograph, that part of the descending line from the point of inflection to the time when direct runoff has ceased.

recharge - Addition of water to the zone of saturation from precipitation, infiltration from surface streams, and other sources.

recharge basin - A basin excavated in the earth to receive the discharge from streams or storm drains for the purpose of replenishing ground water supply.

recurrence interval - (1) The average time interval between actual occurrences of hydrological event of a given or greater magnitude. (2) In an annual flood series, the average interval in which a flood of a given size recurs as an annual maximum. (3) In a partial duration series, the average interval between floods of a given size, regardless of their relationship to the year or any other period of time. This distinction holds even though for large floods recurrence intervals are nearly the same on both scales.

regimen of a stream - The condition of a stream and its channel with respect to its stability.

regulated activities - Actions or proposed actions which impact upon proper management of stormwater runoff and which are regulated by provisions of the stormwater management plan, regulations and ordinances.

release rate percentage - The watershed factor determined by comparing the maximum rate of runoff from a subbasin to the contributing rate of runoff to the watershed peak rate at specific points of interest.

reservoir - A pond, lake, basin or other space, either natural or created in whole or in part by the building of engineering structures, which is used for storage, regulation and control of water, recreation, power, flood control or drinking. Also impoundment.

retention pond - A basin, usually enclosed by artificial dikes, that is used to retard stormwater runoff by temporarily storing the runoff and releasing it at a predetermined rate.

return period - The average interval in years over which an event of a given magnitude can be expected to recur.

revetment - A facing of stone, concrete, or other material placed to protect an embankment or structure against erosion by wave action or currents, normally extending from top of bank to the thalweg or beyond the deepest part of the channel.

revetment wall - A wall constructed along the toe of an embankment to protect the slope against erosion.

right-of-way - A right of passage over another persons land.

riparian - (1) Of, pertaining to, or situated or dwelling on, the bank of a river or other body of water. (2) One who owns land on the bank of a natural watercourse or body of water.

riprap - Broken stone or boulders placed compactly or irregularly on dams, levees, dikes, or similar embankments for protection of earth surfaces against the action of waves or currents.

river - A larger stream of water that serves as the natural drainage channel for a drainage basin of considerable area.

rivulet - A very small stream. Also rill, streamlet.

roof drain - Stormwater flowing from the roofs of buildings.

roof storage - The storage of rainwater on the roof top to permit
release at a controlled rate.

roughness - A measure of the resistance to fluid flow of a channel, pipe, or other conduit.

roughness coefficient - A factor, in the Chezy, Darcy-Weisbach, Hazen-Williams, Kutter, Manning, and other formulas for computing the average velocity of flow of water in a conduit or channel, which represents the effect of roughness of the confining material on the energy losses in the flowing water.

routing - (1) The derivation of an outflow hydrograph for a given reach of a stream from known values of upstream inflow. The procedure uses wave velocity or the storage equation, sometimes both. (2) Estimating the flood at a downstream point from the inflow at an upstream point.

runoff - That part of precipitation which flows over the land.

runoff characteristics - The surface components of any watershed which affect the rate, amount, and direction of stormwater runoff. These may include but not be limited to: vegetation, soils, slopes and man-made landscape alterations.

runoff coefficient - (1) The ration of the maximum rate of the runoff to the uniform rate of rainfall with a duration equaling or exceeding the time of concentration which produced this rate of runoff. (2) The ration of the depth of runoff from the drainage basin to the depth of rainfall.

runoff-distribution curve - A graph showing the typical distribution of runoff from a drainage basin in terms of the percentage of the total runoff, expressed as the average discharge in a given time interval.

runoff volume - The total quantity or volume of runoff during a specified time.

SCS - Soil Conservation Service, U.S. Department of Agriculture.

scour - The action of a flowing liquid as it lifts and carries away the material on the sides or bottom of a waterway, conduit, or pipeline.

scouring velocity - The minimum velocity necessary to dislodge stranded material from the boundary of a waterway, conduit or pipeline by a fluid in motion.

sediment - Mineral or organic solid material that is being transported or has been moved from its site of origin by air, water or ice and has come to rest.

seepage pit/trench - An area of excavated earth filled with loose stone or similar material and into which surface water is directed for infiltration into the ground.

sediment erosion - Detachment of sediment particles by water, wind, ice or gravity.

sediment-transport curve - A graph showing the relationship between the water discharge and the amount of sediment in transport in a stream channel.

sheet erosion - The gradual uniform removal of the earth's surface without the formation of rills or gullies. This type of erosion may occur when water flows in a sheet down a sloping surface.

sheet flow - Flow in a relatively thin sheet of uniform thickness.

silt - Deposits of waterborne material in a reservoir, on a delta, or on overflowed lands.

silting - The process of filling up or raising the bed of a body of water through deposition of sediment.

slack water - In streams, a place where there is very little current.

slope - The inclination or gradient from the horizontal of a line or surface.

slope area discharge measurement - A determination, by indirect measurement, of the peak discharge by field survey of a reach of channel and high-water marks, usually after a flood has passed.

soil - Earth material which has been so modified and acted upon by physical, chemical, and biological agents that it will support rooted plants.

soil-cover complex method - A method of runoff computation developed by the SCS which is based upon relating soil type and land use/cover to a runoff parameter called a Curve Number.

spillway - A waterway in or about a dam or other hydraulic structure for the escape of excess water.

squall- Sudden and violent or successive gusts of wind, especially with rain, snow, or sleet.

stabilized channel - An earth channel or canal in which, over a period of time, no appreciable erosion or deposition of silt or sediment occurs.

staff gage - A graduated scale, vertical unless otherwise specified, on a plank, metal plate, pier, wall, etc., used to indicate the height of a fluid surface above a specified point or datum plane.

stage - The elevation of a water surface above its minimum or above or below an established low-water plane or datum of reference.

stage-discharge relation - The relationship between gage height and discharge of a stream or conduit at a gauging station. This relation is shown by the rating curve for such station.

storage - The impounding of water for future use. The term differs from pondage and regulation in that the latter refer to more or less temporary retention of the water, while storage involves retention for much longer periods.

storage capacity curve - A curve expressing the relation between the volume of a space and the upper level of elevation of the material occupying the space. In the case of a reservoir, it is the relationship between the water surface elevation in the reservoir and the volume of water below that elevation.

storage indication method - A reservoir routing procedure based on solution of the continuity equation (inflow minus outflow equals the change in storage for a given time interval) and based on outflow being an unique function of storage volume.

storm - Usually an occurrence of such phenomena as rain, snow, hail, and wind.

storm center - The center of the area covered by a storm, especially the place of lowest pressure in a cyclonic storm, or the place where wind velocities approach zero.

storm distribution pattern - The manner in which depth of rainfall varies from station to station throughout and area.

storm drain - A drain used for conveying rainwater to a storm sewer or combined sewer.

storm sewer - A sewer that carries stormwater and surface water, street wash and other wash waters or drainage but excludes domestic wastewater and industrial wastes.

stormwater - Drainage runoff from the surface of the land resulting from precipitation or snow or ice melt.

stormwater collection system - Natural or man-made structures which collect and transport stormwater.

stormwater district - (1) An organization, created and operating under statute, for the purpose of regulating activities affecting stormwater runoff and financing, constructing and operating stormwater protection/control facilities. (2) The land or area within the boundaries of a stormwater management district as delimited in the organizing statute.

stormwater management plan - The plan for managing storm water runoff as required by the Act of October 4, 1978, P.L. 864, (Act 167), and known as the "Stormwater Management Act".

stream - A course of running water usually flowing in a particular direction in a definite channel and discharging into some other stream or body of water.

stream banks - The side slopes of a natural channel between which the normal flow of the stream is confined.

stream bed - The bottom of a stream below the usual water surface. It is the area which is kept practically bare of vegetation by the wash of the waters of the stream.

streamflow - The water which is flowing in a stream channel.

subbasin - A portion of the watershed that has similar hydrological characteristics and drains to a common point.

subdivision - The division or redivision of a lot, tract or parcel of land by any means into two or more lots, tracts, parcels or other divisions of land including changes in existing lot lines for the purpose, whether immediate or future, of lease, transfer of ownership or building or lot development.

subdivision regulations - Ordinances or regulations governing the subdivision of land with respect to such things as adequacy and suitability of building sites, utilities and public facilities.

subwatershed - A hydrologically defined area within a designated watershed which drains to a specific point. Also subbasin.

sump - A tank or pit which receives drainage and stores it temporarily, and from which the discharge is pumped or ejected.

surcharge - The height of wastewater in a sewer manhole above the crown of the sewer when the sewer is flowing completely full.

surface detention - That part of the rain which remains on the ground surface during rainfall and either runs off or infiltrates after the rain ends; does not include depression storage. The detention depth increases until discharge reaches equilibrium with rate of supply equal to surface runoff.

surface runoff - The water that reaches a stream by traveling over the soil surface or falls directly into the stream channels.

suspended load - The sediment in suspension in a stream, which is transported at essentially the velocity of the water.

swale - A wide, shallow ditch, usually grassed or paved which gathers or carries surface water runoff.

synthetic unit hydrograph - A unit graph developed for an ungaged drainage area, based on known physical characteristics of the basin.

tail water - Water discharged at the downstream end of a structure.

terrace - A low embankment or ridge of earth constructed across a slope to control surface runoff and minimize soil erosion.

terrace system - A system of terraces constructed on sloping ground for the purpose of retarding erosion resulting from surface flow of water.

thalweg - (1) The line following the lowest part of a valley, whether under water or not. Usually the line following the deepest part or middle of the bed or channel of a river. (2)The middle or chief navigable channel of a waterway; the thread of a stream.

thermal convection storm - A storm, caused by local inequalities in the temperature, in which the rainfall is intense, short-lived and limited to only a small area.

thread of stream - The line equidistant from the edge of the water on the two sides of the stream at the ordinary stage of the water.

time lag - (1) Referring to discharge or water level, the time elapsing between the occurrence of corresponding changes in discharge or water level at two points in a river. (2) Referring to runoff of rainfall, the time between the center of mass, or beginning, of rainfall to the peak or center of mass of runoff.

time of flow - (1) The time required for water to flow in a storm drain from the point of entrance to any given location beyond the inlet. (2) The time required for water flowing in a stream to travel from a given point to some other downstream point.

topographic map - A map showing the various topographic features of a given area, such as hills, valleys, mountains, and slope of the land surfaces, usually by means of contours or lines connecting points of equal elevation, and including other pertinent information.

trace of rain - Precipitation of an amount of rain too small to be measured.

transpiration - The process by which plants release water vapor into the air.

transporting erosive velocity - Velocity that is high enough not only to maintain sediment in movement, but also to scour the bed of a stream or canal.

travel time - The time required for water flowing in a stream to travel from a given point to some other downstream point.

TR-20 - "Technical Release 20: Project Formulation - Hydrology", computer model which computes direct runoff resulting from any synthetic or natural rainstorm developed by the U.S. Department of Agriculture Soil Conservation Service.

TR-55 - "Technical Release 55: Urban Hydrology for Small Watersheds", procedures for estimating runoff and peak discharges in small watersheds developed by the U.S. Department of Agriculture Soil Conservation Service.

unit hydrograph - The hydrograph of the storm runoff at a given point o a given stream which will result from an isolated rainfall excess of unit duration occurring over the contributing drainage area and resulting in a unit of runoff.

unit hydrograph method - A procedure for determining the rates of surface runoff within a drainage basin by analogy from observed rainfalls and the corresponding observed hydrographs of surface runoff from the same basin. It is based on the hypothesis that in a given drainage basin, surface runoff from rainfall occurring in a unit of time will produce hydrographs of approximately equal bases and with ordinates varying with the quantity of rainfall minus infiltration and other subtractions.

useful storage - (1) Storage between top of gates and minimum downward level. Usual unit is the acre-foot. (2) Storage used for regulation of flow.

utility - A public or private concern engaged in the performance of some critical service. Such a concern usually has a monopoly position in providing its service to a defined geographical area.

valley storage - (1) The volume below the water surface profile. (2) The natural storage capacity or volume occupied by a stream in flood after it has overflowed its banks. It includes the quantity of water within the main channel (channel storage) and that which has overflowed its banks (lateral storage).

velocity-area method - A method used to determine the discharge of a stream or any open channel by measuring the velocity of the flowing water at several points within the cross section of the stream and summing up the products of these velocities and their respective fractions of the total area.

velocity meter - A vaned water meter which operates on the principle that the vanes of the wheel move at approximately the same velocity as the flowing water.

watercourse - (1) A natural or artificial channel for passage of water. (2) A running stream of water. (3) A natural stream fed from permanent or natural sources, including rivers, creeks, runs and rivulets.

water cycle - The circuit of water movement from the atmosphere to the earth and return to the atmosphere through various stages or processes such as precipitation, interception, runoff, infiltration, percolation, storage, evaporation and transpiration. Also hydrologic cycle.

water pollution - The addition of wastewater or other harmful material to water in concentrations or quantities that result in measurable degradation of water quality.

water rights - The legal powers or privileges recognized as validly existing under the applicable system of law, concerning waters, as such powers or privileges held by nations, states, corporations, or individuals exist in the light of the powers and privileges of others in the same waters.

watershed divide - The line that follows the ridges or summits forming the exterior boundary of a drainage basin and separates one drainage basin from another. Also drainage divide.

waterway - (1) Any body of water, other than the open sea, which is or can be used by boats as a means of travel. (2) Any natural or artificial channel or depression in the surface of the earth which provides a course for water flowing either continuously or intermittently.

water year - A continuous 12-month period during which a complete annual cycle occurs, arbitrarily selected from the presentation of data relative to hydrologic or meteorological phenomena. The U.S. Geological Survey uses the period October 1 to September 30 in the publication of its records of streamflow.

wetland - Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions, including swamps, marshes, bogs, and similar areas.

zoning ordinance - An ordinance which divides an area into districts and, within each district, regulates the use of land and buildings, and bulk of buildings or other structures, and the density of population.

BEAVERDAM BRANCH WATERSHED STORMWATER MANAGEMENT PLAN

TRAINING MANUAL

APPENDIX B: EXAMPLE STORMWATER MANAGEMENT PLAN

CHESTER ENGINEERS

STORMWATER MANAGEMENT PLAN REPORT

FOR THE

EXAMPLE BUILDING

Located in Spruce Township, Pennsylvania

Date

Seal of
Registered
Professional Engineer
John Doe

John Doe, P.E.

Prepared for:

Spruce Athletic Association

Prepared by:

John Doe Engineering Associates

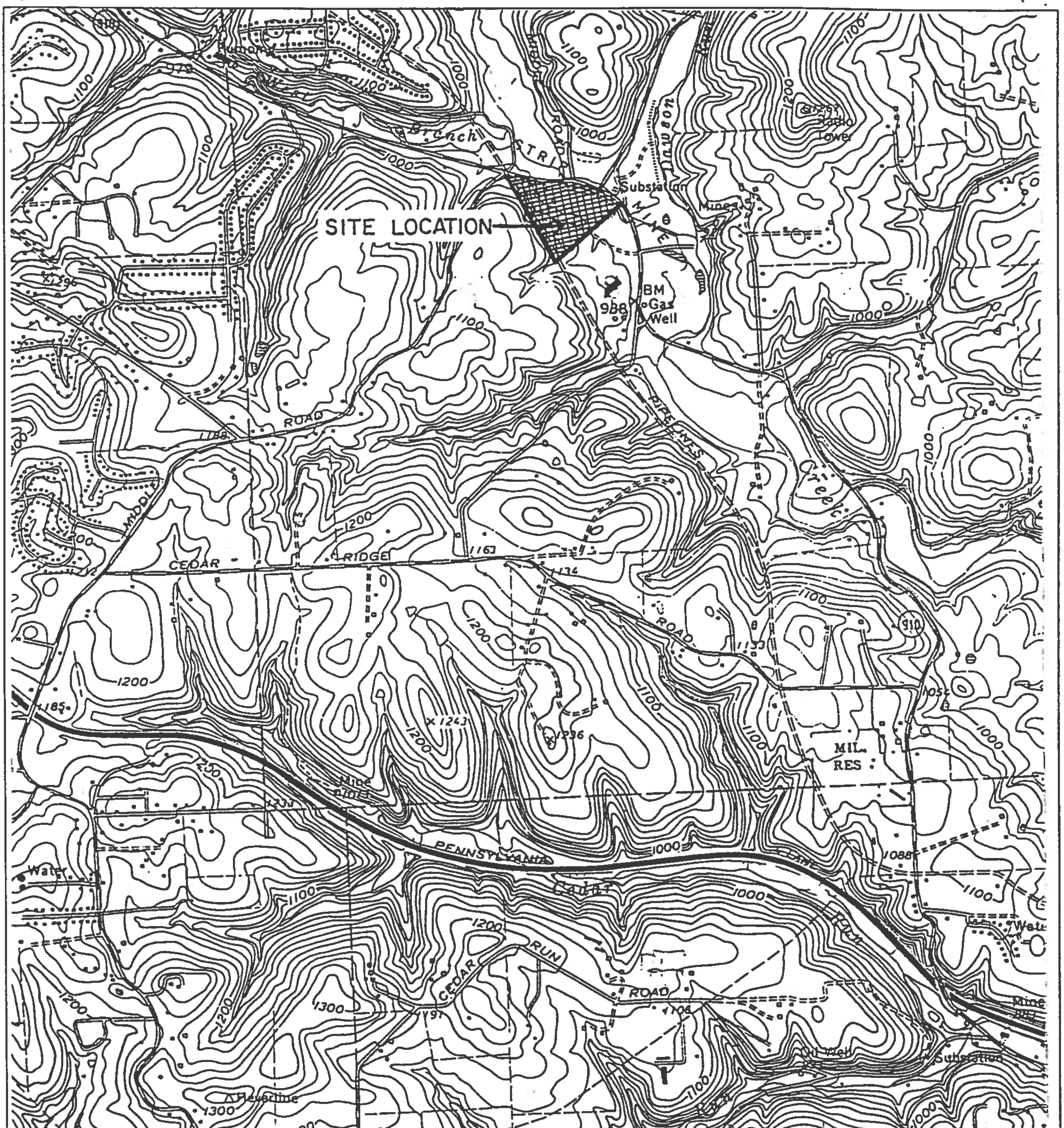


FIGURE 1
PROJECT LOCATION MAP: EXAMPLE BUILDING
SPRUCE TOWNSHIP, PA

N
W E
S

SCALE: 1" = 2,000'
SOURCE: NEWTOWN, PA 7 1/2 MINUTE U.S.G.S. QUADRANGLE

STORMWATER MANAGEMENT PLAN
FOR
EXAMPLE BUILDING

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STORMWATER MANAGEMENT PLAN
PROJECT NARRATIVE FOR
EXAMPLE BUILDING

I. GENERAL DESCRIPTION AND PROJECT OVERVIEW

The Spruce Athletic Association proposes to develop an 18.4 acre site in Spruce Township, Blair County. The proposed development will consist of a recreational building and outdoor playing fields.

II. SITE LOCATION

The site is located south of S.R. 5222, immediately east of Spruce Road. Spruce Road Extension and Pine Road extend north from S.R. 5222 across from the site. The site will have access via a drive located about 300 feet west of Spruce Road Extension. The general location of the Example Building development site is illustrated on a copy of a section of a United States Geological Survey (U.S.G.S.) 7-1/2 Minute Quadrangle Map presented as Figure 1.

III. TOPOGRAPHIC INFORMATION

Topographic information relative to the area in the vicinity of the development site is provided at a 1"=2,000 foot scale at 20' contour intervals on the U.S.G.S. map presented in Figure 1. Development site specific topographic mapping at a scale of 1"=30' and a 2' contour interval is provided on Drawings 1 and 2, attached.

Spruce Creek flows from west to east on the north side of the development site. The stream approaches from the north, crosses beneath S.R. 5222 just west of Spruce Road Extension and flows east in its natural channel between S.R. 5222 and the proposed development. The floodway of the stream, as delineated in the Spruce Township Flood Information Study is illustrated on Drawing 1. As is indicated on Drawing 1, the floodway of the stream will not be disturbed.

Much of the development site was previously disturbed by a strip mining operation. This work resulted in the creation of a relatively shallow pond that is located west of the site. This pond will be incorporated into the stormwater plan as a retention basin and subsequently discussed in more detail.

IV. SOILS INFORMATION

The soils information presented in this report was obtained from the Soil Survey for Blair County, published by the U.S. Natural Resources Conservation Service. The following soil types are located in the development site.

Soil Map Symbol	Soil Name	Hydrologic Soil Group
SmD	Strip mined land	D
UWB	Urban Land-Wharton	C
WHC	Wharton Silt Loam	C
WHB	Wharton Silt Loam	C
GSF	Gilpin,Wiekert & Culleoka Shaley Silt Loam	C

The locations of these soils in the development site are illustrated on Drawing 1. Additional information concerning the distribution of soils within the development site is provided in Table 1.

V. LAND COVER INFORMATION

Pre-development land cover is summarized as follows:

Pre-development Land Cover	
Land Cover Type	Percentage of Total Development Site
Open space - poor condition	29.4%
Open space - fair condition	4.5%
Impervious surfaces	3.4%
Gravel surfaces	1.2%
Pasture - fair condition	61.5%

Post development land cover is summarized as follows:

Post Development Land Cover	
Land Cover Type	Percentage of Total Development Site
Open space - good condition	30.7%
Impervious surfaces	12.7%
Gravel surfaces	3.2%
Pasture - fair condition	53.4

Additional information describing pre-development and post-development land cover is provided in Table 1.

VI. DRAINAGE AREA DELINEATIONS

Seven drainage areas have been delineated on Drawing 2 and have been designated as Subareas A through G.

VII. DESIGN CRITERIA

The Spruce Township Stormwater Management Ordinance stipulates that the peak rate of runoff from the development site after development must be limited to eighty-five percent of the peak rates that occurred prior to development. This regulation applies to storms with return frequencies of 2, 10, 25, and 100 years. The Ordinance further stipulates that the stormwater management facilities be designed based upon the following 24 hour precipitation volumes. The distribution of rainfall during the 24 hour event is to follow the United States Soil Conservation Service Type II Synthetic Rainfall Distribution.

Table 1
Curve Number Data Table

Hydraulic Area	Soil Type	Soil Group	Cover Description	Area (Acres)
Subarea A: Predeveloped Watershed to Basin A	SmD	D	Open - Poor condition (100%) CN = 89	0.11
	UwB GSF WhC WhB	C C C C	Pasture Fair Condition (100%), CN=79	7.35
Subarea B: Developed Watershed to Basin A	SmD	D	Open - Good Condition (21%), CN=80 / Impervious (79%), NC=98	0.53
	UwB GSF WhC WhB	C C C C	Open-Good Condition (5.2%), CN=74 / Impervious (1.6%), CN=98, CN=89/ Pasture-Fair Condition(91%), CN=79	9.06
Subarea C: Addtitional Offsite Watershed to Basin A-Retained	SmD	D	Impervious (100%)	0.42
	UwB GSF WhC WhB	C C C C	Open-Good Conditin (13%), CN=74/ Impervious (8.2%), NC=98/ Gravel (11.7%), CN=89, Pasture-Fair Condition (67.1%), CN=79	1.71
Subarea D: Additional Offsite Watershed to Basin A After Development	UwB GSF WhC WhB		Pasture-Fair Condition (100%), CN=79	1.15
Subarea E: Developed Disturbed Uncontrolled	SmD	D	Open-Good Condtion (88%), CN=80/ Impervious (12%), CN= 98	1.98
	UwB	C	Open-Good Condition (100%), CN=98	0.55
	WhC	C	Impervious (100%), CN=98	0.02
Subarea F: Watershed to Basin B	SmD	D	Open-Good Condition (55.3%), CN=74/ Impervious (42.4%), CN=98/ Gravel (2.3%) CN=91	2.28
	UwB	C	Open-Good Condition (52.3%), CN=74/ Impervious (23.8%), CN=98/ Gravel (2.6%), CN=89/ Pasture-Fair Conditon (21.3%), CN=79	.34
Subarea G: Offsite Watershed to Basin B	UwB	C	Pasture-Fair Conditon (100%), CN=79	0.07

Design Rainfall Volumes	
Return Period (Years)	24- Hour Precipitation (Inches)
2	2.14
10	3.24
25	3.55
100	4.59

VIII. STORMWATER MANAGEMENT CONCEPT

Stormwater runoff from the site will be controlled using two basins. Basin A, will be designed as a retention basin with a permanent pool. Basin B, will function as a detention basin. When a storm occurs, the retention basin will receive runoff, and temporarily store the water above the permanent pool elevation. The detention facility, which will be dry prior to the onset of a storm, will receive the runoff and store the water for a relatively short period of time. The two basins will release the flow at controlled rates so that the total peak discharge from the development site will not exceed eight-five percent of the pre-development peak discharge rates. The maximum allowable discharge rate from the basins will equal eighty-five percent of the pre-development rate from the area to be developed, less the runoff from that portion of the developed site that will be uncontrolled, plus runoff from the watershed area above the site that will bass through the site.

IX. METHOD OF ANALYSIS

The methods contained in the Soil Conservation Service Technical Release No. 55 (TR 55) have been used in determining runoff values. The Modified Puls Routing Method from the Penn State Urban Hydrology Model was used to analyze flow through the basins. These methods are specified as allowable in the Stormwater Management Ordinance. Design of the stormwater conveyance system was accomplished using the rational method to compute runoff.

Data used to develop the runoff curve numbers employed by the TR-55 procedure are summarized in Table 1, introduced previously. The basic hydrologic and hydraulic data developed and used during the preparation of this plan are summarized in Table 2. Printouts of the results of the TR-55 runs are presented in Appendix A. Basin design details, stage-storage data, and Modified Puls Routing results are provided in Appendix B.

X. FINAL OVERALL STORMWATER MANAGEMENT SYSTEM DESIGN

As specified in the Stormwater Management Ordinance, the overall development plan has incorporated the following features to reduce the amount of runoff to the extent feasible and compatible with the use of the development:

1. Minimization of impervious surfaces during site design

   The following features have been incorporated into the site design in order to minimize increased runoff.

   a. The total parking area has been sized as small as possible to accommodate anticipated parking needs and comply with established zoning ordinances.

TABLE 2: SUMMARY OF HYDROLOGIC AND HYDRAULIC ANALYSES

Design Parameters	Storm Return Frequency			
	2 yr.	10 yr.	25 yr.	100 yr.
1. Runoff from disturbed area of 6.4 Acres				
a. Predevelopment Flow	7.9	15.9	18.2	26.3
b. Eighty-Five Percent of Predevelopment	6.7	13.5	15.5	22.4
c. Developed Flow	8.8	18.0	20.7	30.1
2. Required Detention (Line 1.c. - Line 1.b.)	2.1	4.5	5.2	7.7
3. Actual Detention (line 6 - Line 5)	2.7	5.0	5.6	8.7
4. Allowable Basin Discharge Rate #				
a. Predeveloped Flow from Disturbed Area	6.7	11.1	12.7	18.3

	2 Yr.	10 Yr.	25 Yr.	100 Yr.
Total Disturbed	7.9	13.0	14.9	21.5
At 85% R.R.	6.7	11.1	12.7	18.3

Design Parameters	2 yr.	10 yr.	25 yr.	100 yr.
b. Runoff from Uncontrolled Area (Area = 2.6 ac)	-2.7	-3.6	-4.3	-6.6

	2 Yr.	10 Yr.	25 Yr.	100 Yr.
Developed	2.7	3.6	4.3	6.6

Design Parameters	2 yr.	10 yr.	25 yr.	100 yr.
c. Off-Site Runoff (Basin A)	0.5	1.4	1.7	2.6
c. Off-Site Runoff (Basin B)	0.0	0.1	0.1	0.2

	2 Yr.	10 Yr.	25 Yr.	100 Yr.
Runoff increase to Basin A (1.2 ac)	0.6	1.7	2.0	3.1
At 85% R.R.	0.5	1.4	1.7	2.6
Basin B (0.07 ac)	0.0	0.1	0.1	0.2
At 85% R.R.	0.0	0.1	0.1	0.2

Design Parameters	2 yr.	10 yr.	25 yr.	100 yr.
d. Allowable Discharge from Site - Total	4.5	9.0	10.2	14.5
5. Increase in Total Developed Inflow to Basin A (Area = 2.1 ac.)	1.9	4.1	4.7	7.0 *
6. Actual Discharge from Basin A	0.2	0.5	0.6	0.8
7. Total Developed Inflow to Basin B (Area = 2.6 ac)	3.2	6.4	7.3	10.4 **
8. Actual Discharge from Basin B	2.2	5.0	5.8	7.9
BASIN A - PARAMETERS				
9. Storage Volume Required, cubic feet	3,485	7,405	8,712	12,632
10. Storage volume provided to proposed pool elevation, cu. ft.				24,938
11. Maximum ponded depth at each storm event	0.21 ft.	0.45 ft.	0.51 ft.	0.64 ft.
12. Maximum ponded elevation at each storm event	936.21	936.45	936.51	936.64
13. Maximum Ponded Depth when emergency spillway is functioning.				941.00
BASIN B - PARAMETERS				
14. Storage Volume Required, cubic feet	1,307	2,614	2,614	4,356
15. Storage volume provided to top of embankment, cubic feet				9,175
16. Maximum ponded depth at each storm event	1.72 ft.	2.57 ft.	2.74 ft.	3.37 ft.
17. Maximum ponded elevation at each storm event	932.72	933.57	933.74	934.37
18. Maximum Ponded Depth when emergency spillway is functioning with principle spillway blocked.				935.00

All flow rates are in cubic feet per second

* Emergency spillway for basin A designed for a 100-year flow of 7.0 cfs.

** Emergency spillway for basin B designed for a 100-year flow of 10.4 cfs.

\# Allowable discharge rate based upon hydrograph comparisons.

b. The parking area will be gravel so as to provide a pervious surface that is suitable for use as a parking area.

c. Vegetative strips have been designed into the parking area to serve as dividers.

d. The number and size of sidewalks have been minimized and constructed of gravel.

2. Accomplish flow attenuation by the use of open vegetated swales and natural depressions

   An open vegetative swale has been designed to serve as the primary conduit for flows into Basin B from the southern side of the development.

The effects of these design features have been accounted for in the calculation of post-development runoff rates.

The overall stormwater management system design incorporates the construction of a detention basin (Basin B) and the modification of an existing pond for use as a retention basin (Basin A).

A. Retention Basin A

In order to achieve a significant portion of the required detention, the existing pond, identified as Basin No. A, located on the west side of the building and access road, will be modified to detain additional runoff. The basin and related watersheds are shown on Drawing 1. As a result of the existing topography on the site, the pond has a permanent water surface elevation of 936.0.

Runoff that will flow to Basin A includes runoff from the building roof, parking lot area located behind the building, and off-site runoff from above the basin. This basin watershed will have an area of about 2.1 acres. The runoff from the remainder of the developed site will flow either from the site uncontrolled, thus requiring compensation in the allowable discharge rate from the two facilities or to the downstream detention Basin B.

An outlet structure and outlet pipe system will be installed that will regulate the additional storage and rate of discharge. The water will be permitted to pond to an elevation of 936.64 at the occurrence of the 100 year storm. An emergency spillway will be constructed to discharge larger flows from larger storms.

A portion of the watershed tributary to the retention basin, approximately 0.3 acres of disturbed land located adjacent to the pond, overlaps between the pre- and post-development conditions. The runoff from this area is considered a contribution watershed to the existing permanent pool elevation and not included in the additional increase in runoff from the developed watershed to Basin A. This consideration is based upon the fact that the development, while altering the grade of the affected area, will improve the ground cover when compared to the existing conditions. Therefore it will pose no adverse effects in the difference in runoff between pre- and post-development conditions.

B. Detention Basin B

The second proposed facility consists of a detention basin located east of the parking area. The basin will measure approximately 80 feet in width and 140 feet in length with an available depth of 4.0 feet. These dimensions provide a usable storage of about 9,175 cubic feet.

Runoff that will flow to Basin B includes runoff from the parking lot area, on-site runoff from the disturbed area above the basin, and a small amount of off-site runoff. A routing analysis was completed on the basin and discharge rates were computed. The discharge rates from Basin B will be controlled to insure that the total system detains the required amount of stormwater runoff. Refer to Table 1 for further detailed information pertaining to the performance of the two basins with respect to the entire site stormwater management plan.

XI. FINAL BASIN DESIGN

A. Summary of Basin Watershed Areas

1. Area that will be disturbed as a result of development		
a. Area from which runoff flows are controlled	=	3.50 acres
b. Area from which runoff flows are uncontrolled	=	2.60 acres
c. Disturbed area in Basin A watershed	=	6.40 acres
Total	=	**3.50 acres**
2. Detention / Retention Basin Watershed Areas		
a. Off-site above Basin A; undisturbed	=	1.15 acres
b. Off-site above Basin B; undisturbed	=	0.07 acres
c. On-site; see 1.a. above	=	3.50 acres
Total	=	**4.70 acres**
3. Make-up of Example Building		
a. Developed area	=	6.40 acres
b. Undeveloped area	=	12.00 acres
Total	=	**18.40 acres**

B. Basin A Outlet Design

After runoff rates were computed for the developed portion of the site and the undeveloped areas that are within the basin watershed, storage volume requirements were determined and an outlet structure design was selected.

In order to achieve the allowable discharge rates attainable with the basin's configuration for the design storms, a 15-inch diameter outlet pipe and single stage outlet structure with a required storage capacity of 12,632 cubic feet, was selected as the most efficient design combination. The basin has a potential storage capacity of in excess of 24,938 cubic feet to the 937.0 elevation.

C. Basin B Outlet Design

After runoff rates were computed for the developed portion of the site and the undeveloped areas that are within the basin watershed, storage volume requirements were determined and an outlet structure design was selected.

In order to achieve the allowable discharge rates attainable with the basin's configuration for the design storms, a 15-inch diameter outlet pipe and two-stage outlet structure with a required storage capacity of 4,356 cubic feet below the 100 year emergency spillway was selected as the most efficient combination design. The basin has a potential storage capacity of in excess of 9,175 cubic feet to the crest of the embankment.

D. Emergency Spillways

In order to provide protection in the event that the outlet structures should become blocked, an overflow channel will be installed to have sufficient entrance capacity to intercept the 100 year inflow rate with the normal outlets blocked while providing one foot of freeboard below the crest of the basins. Basin A will have a channel situated at an elevation of 940.0 and a capacity to pass the 100-year inflow of 7.0 cfs. Basin B will be placed at the 100-year ponded elevation of 934.37 and a capacity to pass the 100-year inflow of 10.4 cfs.

XII. OPERATION AND MAINTENANCE PLAN

The Spruce Athletic Association will own, operate and maintain the stormwater management facilities. The Association will implement the following operation and maintenance program.

The Association will operate and maintain the stormwater control facilities in a safe operating condition so as to protect life, health, safety, and property and to maintain the aesthetic appearance of the facilities. The Association will be responsible for the evaluation of the facilities and all appurtenant structures and the modification thereof to ensure the protection of life and property as specified below.

The Association will inspect each facility and all appurtenant works according to the following schedule:

1. The facilities and their appurtenant works will be inspected at least once every three months and immediately after heavy storms.

2. The Association will retain records of such inspections, including records of actions taken to correct conditions found during such inspections.

The period inspection of each facility will be completed in a manner so as to detect any of the following conditions which may occur during the normal operation of the facility:

1. Sliding of upstream or downstream slopes or abutments contiguous to the embankment.

2. Sudden subsidence of the embankment.

3. Longitudinal or transverse cracking of the crest of the embankment.

4. Any other unusual conditions at the downstream slope of the embankment.

5. Significant landslides in the impoundment area.

6. Obstruction or significant debris accumulation interfering with the outlet control structure.

7. The accumulation of significant amounts of sediment in the basins so as to interfere with the proper operation of the facilities and reduce available storage volumes.

8. Excessive growth of vegetation.

9. Appearance of significant populations of nuisance insects and animal pests.

Should any of the above mentioned conditions exist at the time of such an inspection, immediate action will be taken to correct the same and a full report of all actions taken will be retained by the Association.

XIII. IDENTIFICATIONS OF REQUIRED EASEMENTS AND RIGHTS-OF-WAY

As is indicated on the drawings, all of the stormwater management facilities will be located on the development site and no easements or rights-of-way are required.

XIV. EROSION AND SEDIMENTATION CONTROL PLAN

A soil erosion and sedimentation plan for this project is presented on Drawing 2. The plan has been developed in accordance with the Pennsylvania Erosion/Sedimentation Regulations and the standards and guidelines of the County Conservation District.

XV. OTHER PERMITS / APPROVALS

All work will be performed on the development site as indicated on the drawings and no state or federal agency permits are required for the implementation of this stormwater management plan.

XVI. PROFESSIONAL CERTIFICATION

This stormwater management plan has been prepared by the undersigned registered professional engineer.

____

John Doe. P.E.
PA Professional Engineer Registration No. 123456

APPENDIX A
HYDROLOGIC AND HYDRAULIC CALCULATION RESULTS
TR-55 METHODOLOGY

```
*******************************************************
* PSUHM: MODULE _1-A¢ - Curve Number Weighting        *
*******************************************************
```

File Name: A:kbpre.CN

1 Description: - PREDEVELOPED DISTURBED

Landuse	Soil Group	CN	Area (acres)	% Total Area
SmD-Strip Mine	D	89	4.7	74.2
UWB-Urban Land-Wharton	C	79	1.3	19.6
WhC-Wharton Silt Loam	C	79	0.4	6.2
Weighted result ---¢		86	6.4	100

```
*********************************************************************
* TRAVEL TIME CALCULATIONS - SCS Segmental Approach, TR-55 (1986) *
*********************************************************************
```

SUMMARY for PREDEVELOPED CONDITIONS

Segment 1: OVERLAND FLOW
L = 100 ft, S = .17 ft/ft, n = .15, P(2yr/24hr) = 2.14 in
Travel Time = 5.1 minutes

Segment 2: CONCENTRATED FLOW
L = 354 ft, S = .0169 ft/ft, UNPAVED surface
Travel time = 2.8 minutes

TOTAL TRAVEL TIME = 7.9 min.

****
PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD *
****

WATERSHED TITLE: PREDEVELOPED DISTURBED

2 YR. TYPE STORM: PRECIPITATION = 2.14 in.

==

SUMMARY OF INPUT PARAMETERS

'BAREA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC ( )	ADJ. TC (hrs)	TT ( )	ADJ. TT (hrs)
1	6.382	86	0.152	0.96	7.900	0.100	0.000	0.032
)MPOSITE	6.382	86		0.96				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

JBAREA	TIME (hrs) 11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.2	2.2	6.4	1.5	0.8	0.6	0.5	0.4	0.3	0.2	0.1	0.0
)MPOS.	0.2	2.2	6.4	1.5	0.8	0.6	0.5	0.4	0.3	0.2	0.1	0.0

THE PEAK FLOW IS 7.9 cfs - OCCURS AT 12.1 hrs

==

****
PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD *
****

WATERSHED TITLE: PREDEVELOPED DISTURBED

10 YR. TYPE STORM: PRECIPITATION = 3.24 in.

SUMMARY OF INPUT PARAMETERS

JBAREA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC ( )	ADJ. TC (hrs)	TT ( )	ADJ. TT (hrs)
1	6.382	86	0.100	1.87	7.900	0.100	0.000	0.032
)MPOSITE	6.382	86		1.87				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

JBAREA	TIME (hrs) 11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.4	5.0	13.0	2.9	1.5	1.1	0.9	0.7	0.5	0.4	0.2	0.0
)MPOS.	0.4	5.0	13.0	2.9	1.5	1.1	0.9	0.7	0.5	0.4	0.2	0.0

THE PEAK FLOW IS 15.9 cfs - OCCURS AT 12.1 hrs

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*****************************************************************************
PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD                              *
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WATERSHED TITLE: PREDEVELOPED DISTURBED

25 YR. TYPE STORM: PRECIPITATION = 3.55 in.

SUMMARY OF INPUT PARAMETERS

BAREA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC ( )	ADJ. TC (hrs)	TT ( )	ADJ. TT (hrs)
1	6.382	86	0.100	2.14	7.900	0.100	0.000	0.032
MPOSITE	6.382	86		2.14				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

BAREA	TIME (hrs) 11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.5	5.8	14.9	3.3	1.8	1.3	1.0	0.8	0.6	0.4	0.3	0.0
MPOS.	0.5	5.8	14.9	3.3	1.8	1.3	1.0	0.8	0.6	0.4	0.3	0.0

THE PEAK FLOW IS 18.2 cfs - OCCURS AT 12.1 hrs

****

PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD *

****

WATERSHED TITLE: PREDEVELOPED DISTURBED

100 YR. TYPE STORM: PRECIPITATION = 4.59 in.

===

SUMMARY OF INPUT PARAMETERS

)BAREA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC ( )	ADJ. TC (hrs)	TT ( )	ADJ. TT (hrs)
1	6.382	86	0.100	3.09	7.900	0.100	0.000	0.032
)MPOSITE	6.382	86		3.09				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

)BAREA	TIME (hrs)											
	11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.7	8.3	21.5	4.8	2.6	1.8	1.5	1.2	0.9	0.6	0.4	0.0
)MPOS.	0.7	8.3	21.5	4.8	2.6	1.8	1.5	1.2	0.9	0.6	0.4	0.0

THE PEAK FLOW IS 26.3 cfs - OCCURS AT 12.1 hrs

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*************************************************************
* PSUHM: MODULE _1-A¢ - Curve Number Weighting             *
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File Name: A:kbdev.CN

Description: - DEVELOPED DISTURBED

Landuse	Soil Group	CN	Area (acres)	% Total Area
SmD-Strip Mine	D	86	4.7	74.2
UWB-Urban Land-Wharton	C	81	1.3	19.6
WhC-Wharton Silt Loan	C	81	0.4	6.2
Weighted result ---¢		85	6.4	100

****
PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD *
****

WATERSHED TITLE: DEVELOPED DISTURBED

2 YR. TYPE STORM: PRECIPITATION = 2.14 in.

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SUMMARY OF INPUT PARAMETERS

BAREA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC ( )	ADJ. TC (hrs)	TT ( )	ADJ. TT (hrs)
1	6.382	85	0.165	0.90	5.000	0.100	0.000	0.000
MPOSITE	6.382	85		0.90				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

BAREA	TIME (hrs) 11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.1	2.5	5.3	1.2	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0.0
MPOS.	0.1	2.5	5.3	1.2	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0.0

THE PEAK FLOW IS 8.8 cfs - OCCURS AT 12.1 hrs

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PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD *

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WATERSHED TITLE: DEVELOPED DISTURBED

10 YR. TYPE STORM: PRECIPITATION = 3.24 in.

SUMMARY OF INPUT PARAMETERS

JBAREA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC ( )	ADJ. TC (hrs)	TT ( )	ADJ. TT (hrs)
1	6.382	85	0.109	1.79	5.000	0.100	0.000	0.000
)MPOSITE	6.382	85		1.79				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

JBAREA	TIME (hrs) 11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.4	5.8	11.1	2.2	1.4	1.0	0.8	0.7	0.5	0.4	0.2	0.0
)MPOS.	0.4	5.8	11.1	2.2	1.4	1.0	0.8	0.7	0.5	0.4	0.2	0.0

THE PEAK FLOW IS 18.0 cfs - OCCURS AT 12.1 hrs

****

PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD *

****

WATERSHED TITLE: DEVELOPED DISTURBED

25 YR. TYPE STORM: PRECIPITATION = 3.55 in.

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SUMMARY OF INPUT PARAMETERS

JBAREA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC ( )	ADJ. TC (hrs)	TT ( )	ADJ. TT (hrs)
1	6.382	85	0.100	2.06	5.000	0.100	0.000	0.000
)MPOSITE	6.382	85		2.06				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

JBAREA	TIME (hrs) 11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.5	6.9	12.9	2.5	1.6	1.2	0.9	0.8	0.6	0.4	0.3	0.0
MPOS.	0.5	6.9	12.9	2.5	1.6	1.2	0.9	0.8	0.6	0.4	0.3	0.0

THE PEAK FLOW IS 20.7 cfs - OCCURS AT 12.1 hrs

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*****************************************************************************
 PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD                              *
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WATERSHED TITLE: DEVELOPED DISTURBED

100 YR. TYPE STORM: PRECIPITATION = 4.59 in.

SUMMARY OF INPUT PARAMETERS

JBAREA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC ( )	ADJ. TC (hrs)	TT ( )	ADJ. TT (hrs)
1	6.382	85	0.100	2.99	5.000	0.100	0.000	0.000
)MPOSITE	6.382	85		2.99				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

JBAREA	TIME (hrs) 11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.7	10.0	18.7	3.7	2.3	1.7	1.4	1.1	0.9	0.6	0.4	0.0
)MPOS.	0.7	10.0	18.7	3.7	2.3	1.7	1.4	1.1	0.9	0.6	0.4	0.0

THE PEAK FLOW IS 30.1 cfs - OCCURS AT 12.1 hrs

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*****************************************************
* PSUHM: MODULE _1-A¢ - Curve Number Weighting      *
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File Name: A:kbun.CN

Description: - DEV. UNCONTROLLED

Landuse	Soil Group	CN	Area (acres)	% Total Area
SmD-Strip Mine	D	82	2.0	77.6
UwB-Urban Land-Wharton	C	74	0.5	21.5
WhC-Wharton Silt Loam	C	98	0.0	0.9
Weighted result ---¢		81	2.5	100

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PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD *
****

WATERSHED TITLE: DEVELOPED UNCONTROLLED

2 YR. TYPE STORM: PRECIPITATION = 2.14 in.

SUMMARY OF INPUT PARAMETERS

BAREA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC ( )	ADJ. TC (hrs)	TT ( )	ADJ. TT (hrs)
1	2.550	81	0.219	0.70	5.000	0.100	0.000	0.000
MPOSITE	2.550	81		0.70				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

BAREA	TIME (hrs) 11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.0	0.6	1.6	0.4	0.2	0.2	0.2	0.1	0.1	0.1	0.0	0.0
MPOS.	0.0	0.6	1.6	0.4	0.2	0.2	0.2	0.1	0.1	0.1	0.0	0.0

THE PEAK FLOW IS 2.7 cfs - OCCURS AT 12.1 hrs

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 PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD                             *
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WATERSHED TITLE: DEVELOPED UNCONTROLLED

10 YR. TYPE STORM: PRECIPITATION = 3.24 in.

SUMMARY OF INPUT PARAMETERS

BAREA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC ( )	ADJ. TC (hrs)	TT ( )	ADJ. TT (hrs)
1	2.550	81	0.145	1.50	5.000	0.100	0.000	0.000
MPOSITE	2.550	81		1.50				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

BAREA	TIME (hrs) 11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.1	1.8	3.6	0.8	0.5	0.4	0.3	0.2	0.2	0.1	0.1	0.0
MPOS.	0.1	1.8	3.6	0.8	0.5	0.4	0.3	0.2	0.2	0.1	0.1	0.0

THE PEAK FLOW IS 5.9 cfs - OCCURS AT 12.1 hrs

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PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD *
****

WATERSHED TITLE: DEVELOPED UNCONTROLLED

25 YR. TYPE STORM: PRECIPITATION = 3.55 in.

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SUMMARY OF INPUT PARAMETERS

BAREA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC ( )	ADJ. TC (hrs)	TT ( )	ADJ. TT (hrs)
1	2.550	81	0.132	1.75	5.000	0.100	0.000	0.000
MPOSITE	2.550	81		1.75				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

BAREA	TIME (hrs) 11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.1	2.1	4.3	0.9	0.6	0.4	0.3	0.3	0.2	0.2	0.1	0.0
MPOS.	0.1	2.1	4.3	0.9	0.6	0.4	0.3	0.3	0.2	0.2	0.1	0.0

THE PEAK FLOW IS 7.0 cfs - OCCURS AT 12.1 hrs

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PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD *
****

WATERSHED TITLE: DEVELOPED UNCONTROLLED

100 YR. TYPE STORM: PRECIPITATION = 4.59 in.

SUMMARY OF INPUT PARAMETERS

BAREA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC ( )	ADJ. TC (hrs)	TT ( )	ADJ. TT (hrs)
1	2.550	81	0.102	2.63	5.000	0.100	0.000	0.000
MPOSITE	2.550	81		2.63				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

BAREA	TIME (hrs) 11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.2	3.5	6.6	1.3	0.8	0.6	0.5	0.4	0.3	0.2	0.1	0.0
MPOS.	0.2	3.5	6.6	1.3	0.8	0.6	0.5	0.4	0.3	0.2	0.1	0.0

THE PEAK FLOW IS 10.6 cfs - OCCURS AT 12.1 hrs

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*************************************************************
* PSUHM: MODULE _1-A¢ - Curve Number Weighting             *
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File Name: A:KBOFFDEV.CN
Description: ADDITIONAL OFFSITE WS. TO BASIN A - AFTER DEV.

Landuse	Soil Group	CN	Area (acres)	% Total Area
UWB/GSF/WhC/WhB	C	79	1.1	100.0
Weighted result ---¢		79	1.1	100

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**********************************************************************
* TRAVEL TIME CALCULATIONS - SCS Segmental Approach, TR-55 (1986) *
**********************************************************************
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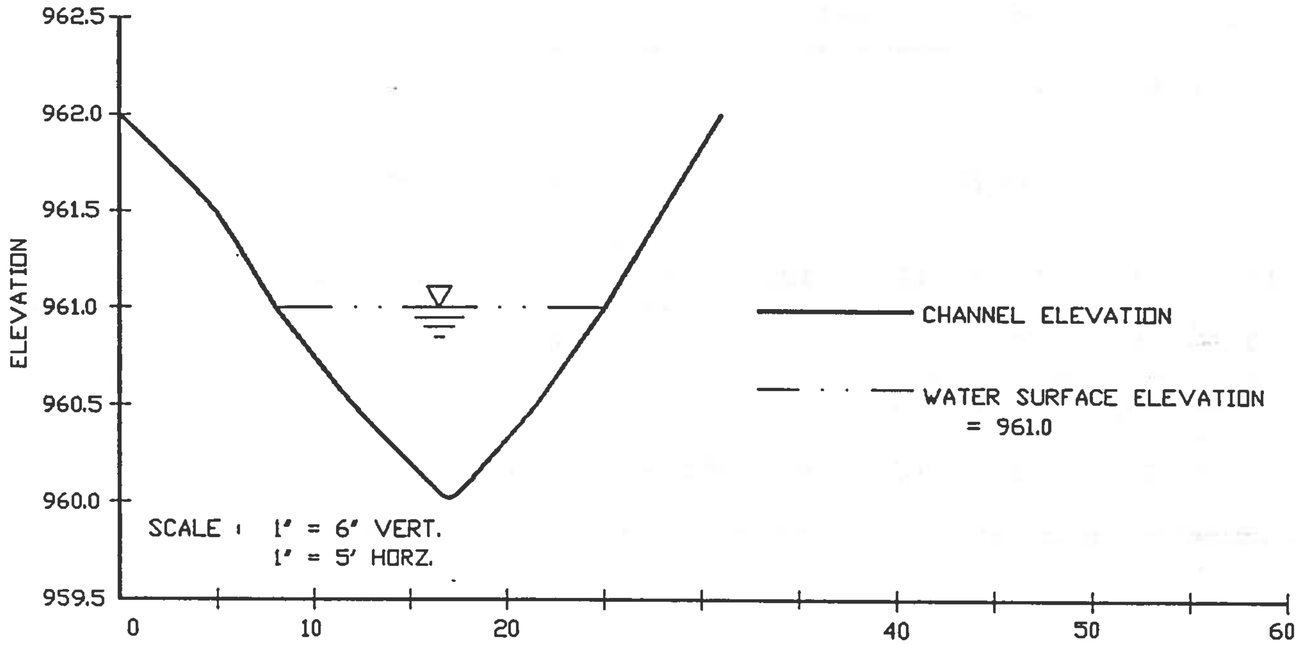
SUMMARY for ADDITIONAL OFFSITE WS. TO BASIN - AFTER DEV.

Segment 1: OVERLAND FLOW
L = 100 ft, S = .15 ft/ft, n = .4, P(2yr/24hr) = 2.14 in
Travel Time = 11.7 minutes

Segment 2: CONCENTRATED FLOW
L = 820 ft, S = .139 ft/ft, UNPAVED surface
Travel time = 2.3 minutes

Segment 3: CHANNEL FLOW
A = 7.25 ft©2, P = 15.5 ft, L = 64.5 ft, S = .33 ft/ft, n = .15
Travel Time = .3 minutes

TOTAL TRAVEL TIME = 14.3 min.



Tc: CHANNEL SECTION A-A

SCALE: AS NOTED

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*********************************************************************************
PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD                                   *
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WATERSHED TITLE: ADD. OFFSITE TO BASIN AFTER DEV.

2 YR. TYPE STORM: PRECIPITATION = 2.14 in.

SUMMARY OF INPUT PARAMETERS

BAREA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC ( )	ADJ. TC (hrs)	TT ( )	ADJ. TT (hrs)
1	1.146	79	0.248	0.61	14.300	0.200	0.000	0.038
MPOSITE	1.146	79		0.61				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

BAREA	TIME (hrs) 11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.0	0.1	0.7	0.3	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
MPOS.	0.0	0.1	0.7	0.3	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0

THE PEAK FLOW IS 0.7 cfs - OCCURS AT 12.2 hrs

****
PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD *
****

WATERSHED TITLE: ADD. OFFSITE TO BASIN AFTER DEV.

10 YR. TYPE STORM: PRECIPITATION = 3.24 in.

SUMMARY OF INPUT PARAMETERS

SUBAREA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC ( )	ADJ. TC (hrs)	TT ( )	ADJ. TT (hrs)
1	1.146	79	0.164	1.37	14.300	0.200	0.000	0.038
COMPOSITE	1.146	79		1.37				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

SUBAREA	TIME (hrs) 11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.0	0.3	1.7	0.6	0.3	0.2	0.1	0.1	0.1	0.1	0.0	0.0
COMPOS.	0.0	0.3	1.7	0.6	0.3	0.2	0.1	0.1	0.1	0.1	0.0	0.0

THE PEAK FLOW IS 1.7 cfs - OCCURS AT 12.2 hrs

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*******************************************************************************
 PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD                                *
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WATERSHED TITLE: ADD. OFFSITE TO BASIN AFTER DEV.

25 YR. TYPE STORM: PRECIPITATION = 3.55 in.

SUMMARY OF INPUT PARAMETERS

JBAREA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC ( )	ADJ. TC (hrs)	TT ( )	ADJ. TT (hrs)
1	1.146	79	0.150	1.60	14.300	0.200	0.000	0.038
OMPOSITE	1.146	79		1.60				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

JBAREA	TIME (hrs) 11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.0	0.4	2.0	0.7	0.3	0.2	0.2	0.1	0.1	0.1	0.0	0.0
OMPOS.	0.0	0.4	2.0	0.7	0.3	0.2	0.2	0.1	0.1	0.1	0.0	0.0

THE PEAK FLOW IS 2.0 cfs - OCCURS AT 12.2 hrs

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*****************************************************************************
* PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD                            *
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WATERSHED TITLE: ADD. OFFSITE TO BASIN AFTER DEV.

100 YR. TYPE STORM: PRECIPITATION = 4.59 in.

SUMMARY OF INPUT PARAMETERS

UBAREA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC ( )	ADJ. TC (hrs)	TT ( )	ADJ. TT (hrs)
1	1.146	79	0.116	2.45	14.300	0.200	0.000	0.038
OMPOSITE	1.146	79		2.45				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

UBAREA	TIME (hrs) 11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.1	0.7	3.1	1.1	0.4	0.3	0.2	0.2	0.1	0.1	0.1	0.0
OMPOS.	0.1	0.7	3.1	1.1	0.4	0.3	0.2	0.2	0.1	0.1	0.1	0.0

THE PEAK FLOW IS 3.1 cfs - OCCURS AT 12.2 hrs

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**************************************************************
* PSUHM: MODULE _1-A¢ - Curve Number Weighting              *
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5

File Name: A:KBPREWS.CN
Description: PREDEVELOPED WATERSHED TO BASIN A

Landuse	Soil Group	CN	Area (acres)	% Total Area
SmD	D	89	0.1	1.5
UWB/GSF/WhC/WhB	C	79	7.4	98.5
Weighted result ---¢		79	7.5	100

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***************************************************************************
* TRAVEL TIME CALCULATIONS - SCS Segmental Approach, TR-55 (1986) *
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SUMMARY for PREDEVELOPED WATERSHED TO BASIN A

Segment 1: OVERLAND FLOW
L = 100 ft, S = .15 ft/ft, n = .4, P(2yr/24hr) = 2.14 in
Travel Time = 11.7 minutes

Segment 2: CONCENTRATED FLOW
L = 820 ft, S = .139 ft/ft, UNPAVED surface
Travel time = 2.3 minutes

Segment 3: CHANNEL FLOW
A = 7.25 ft©2, P = 15.5 ft, L = 64.5 ft, S = .33 ft/ft, n = .15
Travel Time = .3 minutes

TOTAL TRAVEL TIME = 14.3 min.

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PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD *

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WATERSHED TITLE: PREDEV. WS. TO BASIN

2 YR. TYPE II STORM: PRECIPITATION = 2.14 in.

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SUMMARY OF INPUT PARAMETERS

UBAREA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC (min)	ADJ. TC (hrs)	TT (min)	ADJ. TT (hrs)
1	7.460	79	0.248	0.61	14.300	0.200	0.000	0.038
OMPOSITE	7.460	79		0.61				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

UBAREA	TIME (hrs) 11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.0	0.4	4.4	1.8	0.8	0.6	0.5	0.4	0.3	0.2	0.1	0.0
OMPOS.	0.0	0.4	4.4	1.8	0.8	0.6	0.5	0.4	0.3	0.2	0.1	0.0

THE PEAK FLOW IS 4.4 cfs - OCCURS AT 12.2 hrs

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*****************************************************************************
 PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD                              *
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WATERSHED TITLE: PREDEV. WS. TO BASIN

10 YR. TYPE II STORM: PRECIPITATION = 3.24 in.

SUMMARY OF INPUT PARAMETERS

JBAREA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC (min)	ADJ. TC (hrs)	TT (min)	ADJ. TT (hrs)
1	7.460	79	0.164	1.37	14.300	0.200	0.000	0.038
)MPOSITE	7.460	79		1.37				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

JBAREA	TIME (hrs) 11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.2	1.9	10.8	3.9	1.7	1.1	0.9	0.7	0.6	0.4	0.3	0.0
)MPOS.	0.2	1.9	10.8	3.9	1.7	1.1	0.9	0.7	0.6	0.4	0.3	0.0

THE PEAK FLOW IS 10.8 cfs - OCCURS AT 12.2 hrs

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* PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD *
****

WATERSHED TITLE: PREDEV. WS. TO BASIN

25 YR. TYPE II STORM: PRECIPITATION = 3.55 in.

SUMMARY OF INPUT PARAMETERS

UBAREA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC (min)	ADJ. TC (hrs)	TT (min)	ADJ. TT (hrs)
1	7.460	79	0.150	1.60	14.300	0.200	0.000	0.038
OMPOSITE	7.460	79		1.60				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

UBAREA	TIME (hrs) 11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.3	2.4	12.9	4.6	2.0	1.3	1.0	0.8	0.6	0.4	0.3	0.0
OMPOS.	0.3	2.4	12.9	4.6	2.0	1.3	1.0	0.8	0.6	0.4	0.3	0.0

THE PEAK FLOW IS 12.9 cfs - OCCURS AT 12.2 hrs

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*****************************************************************************
PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD                              *
*****************************************************************************
```

WATERSHED TITLE: PREDEV. WS. TO BASIN

100 YR. TYPE II STORM: PRECIPITATION = 4.59 in.

SUMMARY OF INPUT PARAMETERS

BAREA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC (min)	ADJ. TC (hrs)	TT (min)	ADJ. TT (hrs)
1	7.460	79	0.116	2.45	14.300	0.200	0.000	0.038
MPOSITE	7.460	79		2.45				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

BAREA	TIME (hrs) 11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.6	4.3	20.4	6.8	2.9	1.9	1.5	1.2	0.9	0.6	0.4	0.0
MPOS.	0.6	4.3	20.4	6.8	2.9	1.9	1.5	1.2	0.9	0.6	0.4	0.0

THE PEAK FLOW IS 20.4 cfs - OCCURS AT 12.2 hrs

```
************************************************************
* PSUHM: MODULE _1-A¢ - Curve Number Weighting             *
************************************************************

  File Name: A:KBDEVWS.CN
Description: DEVELOPED WATERSHED TO BASIN A
```

Landuse	Soil Group	CN	Area (acres)	% Total Area
SmD	D	94	0.5	5.5
UWB/GSF/WhC/WhB	C	79	9.1	94.5
Weighted result ---¢		80	9.6	100

6

```
***************************************************************************
* TRAVEL TIME CALCULATIONS - SCS Segmental Approach, TR-55 (1986) *
***************************************************************************

SUMMARY for DEVELOPED WATERSHED TO BASIN

Segment 1: OVERLAND FLOW
     L = 100 ft, S = .15 ft/ft, n = .4, P(2yr/24hr) = 2.14 in
     Travel Time = 11.7 minutes

Segment 2: CONCENTRATED FLOW
     L = 820 ft, S = .139 ft/ft, UNPAVED surface
     Travel time = 2.3 minutes

Segment 3: CHANNEL FLOW
     A = 7.25 ft©2, P = 15.5 ft, L = 64.5 ft, S = .33 ft/ft, n = .15
     Travel Time = .3 minutes

TOTAL TRAVEL TIME = 14.3 min.
```

```
*********************************************************************************
 PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD                                  *
*********************************************************************************
```

WATERSHED TITLE: DEV. WS. TO BASIN

2 YR. TYPE STORM: PRECIPITATION = 2.14 in.

SUMMARY OF INPUT PARAMETERS

JBAREA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC ( )	ADJ. TC (hrs)	TT ( )	ADJ. TT (hrs)
1	9.590	80	0.234	0.65	14.300	0.200	0.000	0.038
OMPOSITE	9.590	80		0.65				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

JBAREA	TIME (hrs) 11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.1	0.7	6.2	2.5	1.1	0.8	0.6	0.5	0.4	0.3	0.2	0.0
OMPOS.	0.1	0.7	6.2	2.5	1.1	0.8	0.6	0.5	0.4	0.3	0.2	0.0

THE PEAK FLOW IS 6.2 cfs - OCCURS AT 12.2 hrs

```
****************************************************************************************
 PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD                                        *
****************************************************************************************
```

WATERSHED TITLE: DEV. WS. TO BASIN A

10 YR. TYPE STORM: PRECIPITATION = 3.24 in.

SUMMARY OF INPUT PARAMETERS

BAREA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC ( )	ADJ. TC (hrs)	TT ( )	ADJ. TT (hrs)
1	9.590	80	0.154	1.43	14.300	0.200	0.000	0.038
MPOSITE	9.590	80		1.43				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

BAREA	TIME (hrs) 11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.3	2.7	14.7	5.2	2.3	1.5	1.2	1.0	0.7	0.5	0.3	0.0
MPOS.	0.3	2.7	14.7	5.2	2.3	1.5	1.2	1.0	0.7	0.5	0.3	0.0

THE PEAK FLOW IS 14.7 cfs - OCCURS AT 12.2 hrs

```
*****************************************************************
* PSUHM: MODULE _1-A¢ - Curve Number Weighting                 *
*****************************************************************
```

File Name: A:KBWSA.CN
Description: ADDITIONAL WS. TO BASIN A - TO BE RETAINED

Landuse	Soil Group	CN	Area (acres)	% Total Area
SmD- Strip Mine	D	98	0.4	19.8
UWB/GSF/WhC/WhB	C	81	1.7	80.2
Weighted result ---¢		84	2.1	100

```
***********************************************************************
* TRAVEL TIME CALCULATIONS - SCS Segmental Approach, TR-55 (1986) *
***********************************************************************
```

SUMMARY for ADD. WS. TO BASIN A

Segment 1: OVERLAND FLOW
L = 100 ft, S = .15 ft/ft, n = .4, P(2yr/24hr) = 2.14 in
Travel Time = 11.7 minutes

Segment 2: CONCENTRATED FLOW
L = 820 ft, S = .139 ft/ft, UNPAVED surface
Travel time = 2.3 minutes

Segment 3: CHANNEL FLOW
A = 7.25 ft©2, P = 15.5 ft, L = 64.5 ft, S = .33 ft/ft, n = .15
Travel Time = .3 minutes

TOTAL TRAVEL TIME = 14.3 min.

****
PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD *
****

WATERSHED TITLE: ADDITIONAL WS. TO BASIN A

2 YR. TYPE STORM: PRECIPITATION = 2.14 in.

SUMMARY OF INPUT PARAMETERS

JBAREA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC ( )	ADJ. TC (hrs)	TT ( )	ADJ. TT (hrs)
1	2.130	84	0.178	0.84	14.300	0.200	0.000	0.038
)MPOSITE	2.130	84		0.84				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

JBAREA	TIME (hrs) 11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.0	0.3	1.9	0.7	0.3	0.2	0.2	0.1	0.1	0.1	0.0	0.0
)MPOS.	0.0	0.3	1.9	0.7	0.3	0.2	0.2	0.1	0.1	0.1	0.0	0.0

THE PEAK FLOW IS 1.9 cfs - OCCURS AT 12.2 hrs

****
PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD *
****

WATERSHED TITLE: ADDITIONAL WS. TO BASIN A

10 YR. TYPE STORM: PRECIPITATION = 3.24 in.

===

SUMMARY OF INPUT PARAMETERS

BAREA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC ( )	ADJ. TC (hrs)	TT ( )	ADJ. TT (hrs)
1	2.130	84	0.118	1.72	14.300	0.200	0.000	0.038
MPOSITE	2.130	84		1.72				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

BAREA	TIME (hrs) 11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.1	0.9	4.1	1.4	0.6	0.4	0.3	0.2	0.2	0.1	0.1	0.0
MPOS.	0.1	0.9	4.1	1.4	0.6	0.4	0.3	0.2	0.2	0.1	0.1	0.0

THE PEAK FLOW IS 4.1 cfs - OCCURS AT 12.2 hrs

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*******************************************************************************
PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD                                *
*******************************************************************************
```

WATERSHED TITLE: ADDITIONAL WS. TO BASIN A

25 YR. TYPE STORM: PRECIPITATION = 3.55 in.

SUMMARY OF INPUT PARAMETERS

BAREA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC ( )	ADJ. TC (hrs)	TT ( )	ADJ. TT (hrs)
1	2.130	84	0.107	1.98	14.300	0.200	0.000	0.038
MPOSITE	2.130	84		1.98				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

BAREA	TIME (hrs) 11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.1	1.0	4.7	1.6	0.7	0.4	0.3	0.3	0.2	0.1	0.1	0.0
MPOS.	0.1	1.0	4.7	1.6	0.7	0.4	0.3	0.3	0.2	0.1	0.1	0.0

THE PEAK FLOW IS 4.7 cfs - OCCURS AT 12.2 hrs

****
PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD *
****

WATERSHED TITLE: ADDITIONAL WS. TO BASIN A

100 YR. TYPE STORM: PRECIPITATION = 4.59 in.

SUMMARY OF INPUT PARAMETERS

BAREA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC ( )	ADJ. TC (hrs)	TT ( )	ADJ. TT (hrs)
1	2.130	84	0.100	2.90	14.300	0.200	0.000	0.038
MPOSITE	2.130	84		2.90				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

BAREA	TIME (hrs) 11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.2	1.6	7.0	2.3	1.0	0.6	0.5	0.4	0.3	0.2	0.1	0.0
MPOS.	0.2	1.6	7.0	2.3	1.0	0.6	0.5	0.4	0.3	0.2	0.1	0.0

THE PEAK FLOW IS 7.0 cfs - OCCURS AT 12.2 hrs

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***********************************************************
* PSUHM: MODULE _1-A¢ - Curve Number Weighting            *
***********************************************************
```

File Name: A:kboffb.CN
Description: OFFSITE WATERSHED TO BASIN B

Landuse	Soil Group	CN	Area (acres)	% Total Area
8 UWB-Urban Land-Wharton	C	79	0.1	100.0
Weighted result ---¢		79	0.1	100

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****************************************************************************
* TRAVEL TIME CALCULATIONS - SCS Segmental Approach, TR-55 (1986) *
****************************************************************************
```

SUMMARY for OFFSITE WATERSHED TO BASIN B

Segment 1: OVERLAND FLOW
L = 100 ft, S = .205 ft/ft, n = .15, P(2yr/24hr) = 2.14 in
Travel Time = 4.7 minutes

Segment 2: CHANNEL FLOW
A = 11 ft©2, P = 23 ft, L = 298.5 ft, S = .0201 ft/ft, n = .15
Travel Time = 5.8 minutes

TOTAL TRAVEL TIME = 10.5 min.

****
PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD *
****

WATERSHED TITLE: OFFSITE WATERSHED TO BASIN B

2 YR. TYPE STORM: PRECIPITATION = 2.14 in.

SUMMARY OF INPUT PARAMETERS

BARеA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC ( )	ADJ. TC (hrs)	TT ( )	ADJ. TT (hrs)
1	0.073	79	0.248	0.61	10.500	0.200	0.000	0.000
)MPOSITE	0.073	79		0.61				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

TIME (hrs)

JBAREA	11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OMPOS.	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

THE PEAK FLOW IS 0.1 cfs - OCCURS AT 12.2 hrs

****
PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD *
****

WATERSHED TITLE: OFFSITE WATERSHED TO BASIN B

10 YR. TYPE STORM: PRECIPITATION = 3.24 in.

SUMMARY OF INPUT PARAMETERS

BAREA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC ( )	ADJ. TC (hrs)	TT ( )	ADJ. TT (hrs)
1	0.073	79	0.164	1.37	10.500	0.200	0.000	0.000
MPOSITE	0.073	79		1.37				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

BAREA	TIME (hrs) 11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MPOS.	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

THE PEAK FLOW IS 0.1 cfs - OCCURS AT 12.2 hrs

****
PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD *
****

WATERSHED TITLE: OFFSITE WATERSHED TO BASIN B

25 YR. TYPE STORM: PRECIPITATION = 3.55 in.

SUMMARY OF INPUT PARAMETERS

JBAREA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC ( )	ADJ. TC (hrs)	TT ( )	ADJ. TT (hrs)
1	0.073	79	0.150	1.60	10.500	0.200	0.000	0.000
)MPOSITE	0.073	79		1.60				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

JBAREA	TIME (hrs) 11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
)MPOS.	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

THE PEAK FLOW IS 0.1 cfs - OCCURS AT 12.2 hrs

****
PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD
****

WATERSHED TITLE: OFFSITE WATERSHED TO BASIN B

100 YR. TYPE STORM: PRECIPITATION = 4.59 in.

SUMMARY OF INPUT PARAMETERS

JBAREA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC ( )	ADJ. TC (hrs)	TT ( )	ADJ. TT (hrs)
1	0.073	79	0.116	2.45	10.500	0.200	0.000	0.000
)MPOSITE	0.073	79		2.45				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

'BAREA	TIME (hrs) 11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MPOS.	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

THE PEAK FLOW IS 0.2 cfs - OCCURS AT 12.2 hrs

9

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*******************************************************
* PSUHM: MODULE _1-A¢ - Curve Number Weighting       *
*******************************************************
```

File Name: A:KBWSB.CN
Description: WATERSHED TO BASIN B

Landuse	Soil Group	CN	Area (acres)	% Total Area
SmD-Strip Mine	D	88	2.3	86.9
UWB-Urban Land-Wharton	C	81	0.3	13.1
Weighted result ---¢		87	2.6	100

```
********************************************************************
* TRAVEL TIME CALCULATIONS - SCS Segmental Approach, TR-55 (1986) *
********************************************************************
```

SUMMARY for WATERSHED TO BASIN B

Segment 1: OVERLAND FLOW
L = 100 ft, S = .205 ft/ft, n = .15, P(2yr/24hr) = 2.14 in
Travel Time = 4.7 minutes

Segment 2: CHANNEL FLOW
A = 11 ft©2, P = 23 ft, L = 298.5 ft, S = .0201 ft/ft, n = .15
Travel Time = 5.8 minutes

TOTAL TRAVEL TIME = 10.5 min.

```
*********************************************************************************
  PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD                                *
*********************************************************************************
```

WATERSHED TITLE: WATERSHED TO BASIN B

2 YR. TYPE STORM: PRECIPITATION = 2.14 in.

SUMMARY OF INPUT PARAMETERS

JBAREA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC ( )	ADJ. TC (hrs)	TT ( )	ADJ. TT (hrs)
1	2.623	87	0.140	1.02	10.500	0.200	0.000	0.000
)MPOSITE	2.623	87		1.02				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

JBAREA	TIME (hrs) 11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.1	0.7	3.2	0.7	0.4	0.3	0.2	0.2	0.1	0.1	0.1	0.0
)MPOS.	0.1	0.7	3.2	0.7	0.4	0.3	0.2	0.2	0.1	0.1	0.1	0.0

THE PEAK FLOW IS 3.2 cfs - OCCURS AT 12.2 hrs

****
PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD *
****

WATERSHED TITLE: WATERSHED TO BASIN B

10 YR. TYPE STORM: PRECIPITATION = 3.24 in.

===

SUMMARY OF INPUT PARAMETERS

;AREA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC ( )	ADJ. TC (hrs)	TT ( )	ADJ. TT (hrs)
1	2.623	87	0.100	1.95	10.500	0.200	0.000	0.000
IPOSITE	2.623	87		1.95				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

TIME (hrs)

BAREA	11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.2	1.7	6.4	1.3	0.7	0.5	0.4	0.3	0.2	0.2	0.1	0.0
MPOS.	0.2	1.7	6.4	1.3	0.7	0.5	0.4	0.3	0.2	0.2	0.1	0.0

THE PEAK FLOW IS 6.4 cfs - OCCURS AT 12.2 hrs

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****
PSUHM: MODULE _3-B¢ - SCS TR-55 TABULAR METHOD *
****

WATERSHED TITLE: WATERSHED TO BASIN B

25 YR. TYPE STORM: PRECIPITATION = 3.55 in.

SUMMARY OF INPUT PARAMETERS

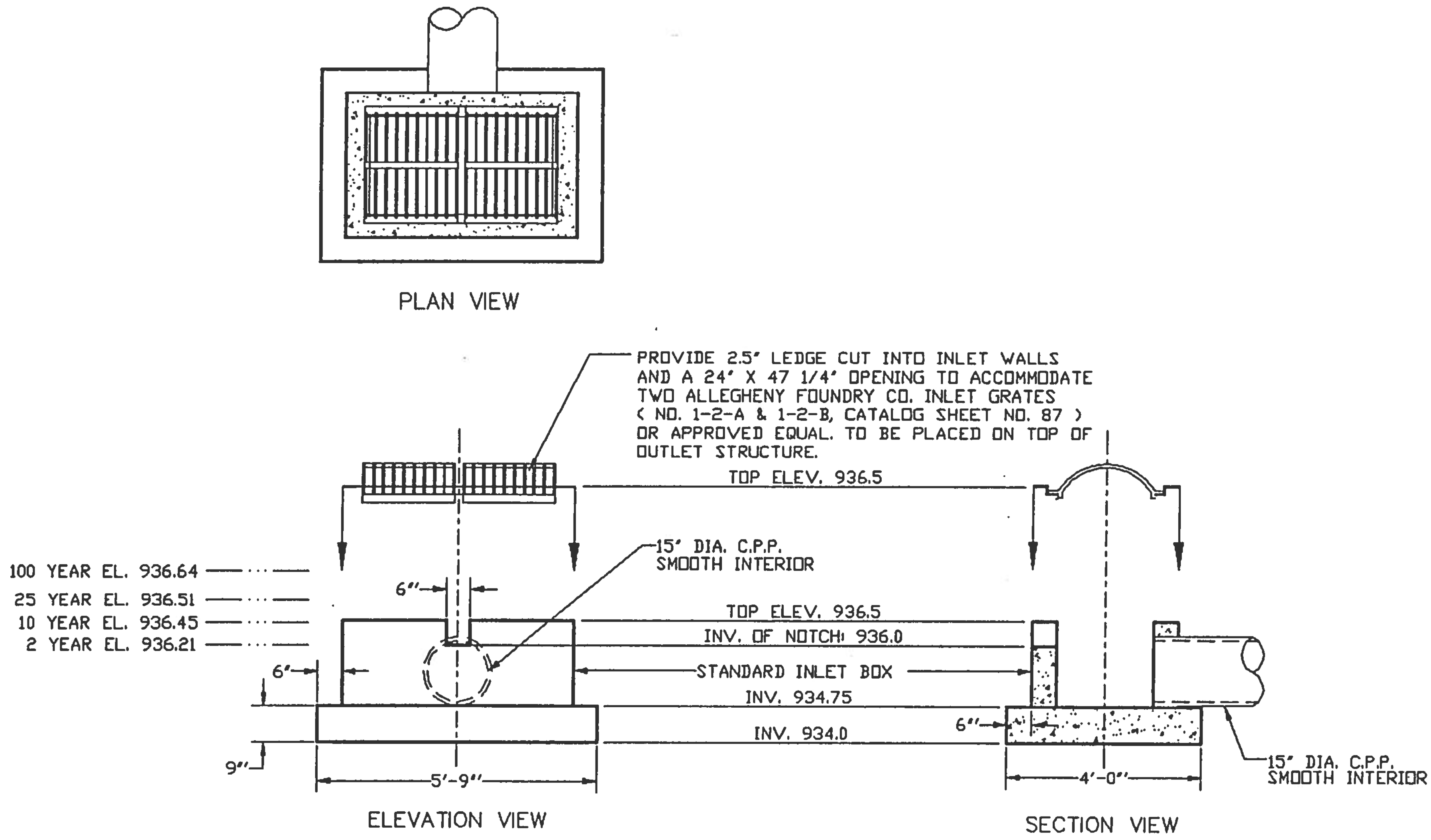
BAREA	AREA (acre)	CURVE NUMBER	IA/P	RUNOFF (in)	TC ( )	ADJ. TC (hrs)	TT ( )	ADJ. TT (hrs)
1	2.623	87	0.100	2.23	10.500	0.200	0.000	0.000
MPOSITE	2.623	87		2.23				

INDIVIDUAL SUBAREA & COMPOSITE HYDROGRAPHS

BAREA	TIME (hrs) 11.0	11.9	12.2	12.5	12.8	13.2	13.6	14.0	15.0	17.0	20.0	26.0
1	0.2	1.9	7.3	1.5	0.8	0.6	0.4	0.4	0.3	0.2	0.1	0.0
MPOS.	0.2	1.9	7.3	1.5	0.8	0.6	0.4	0.4	0.3	0.2	0.1	0.0

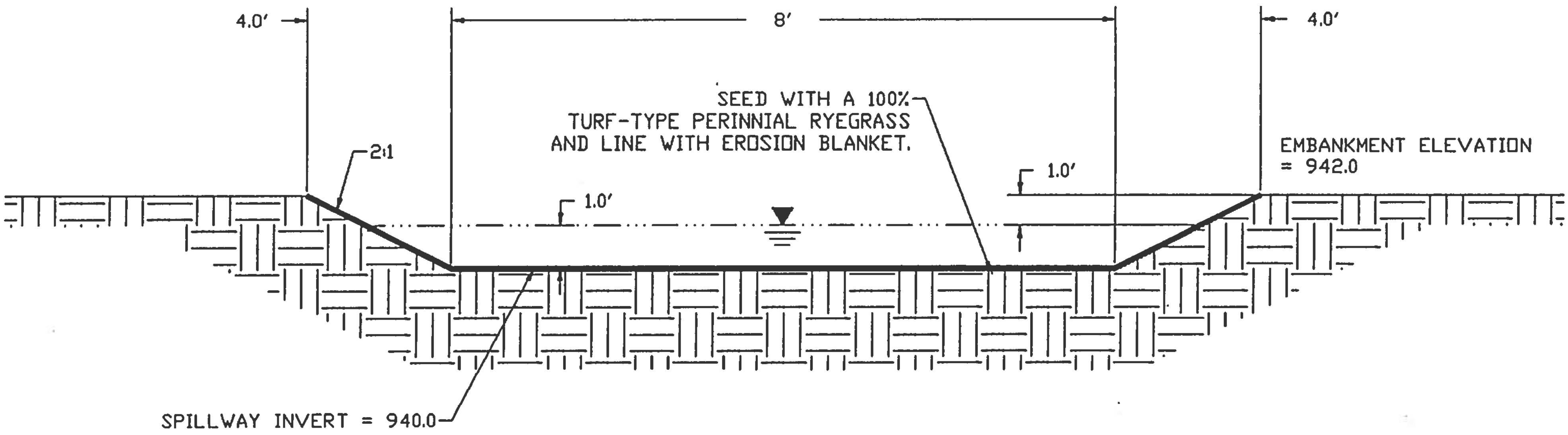
THE PEAK FLOW IS 7.3 cfs - OCCURS AT 12.2 hrs

APPENDIX B
BASIN DESIGN DETAILS, STAGE STORAGE DATA AND MODIFIED PULS ROUTING RESULTS



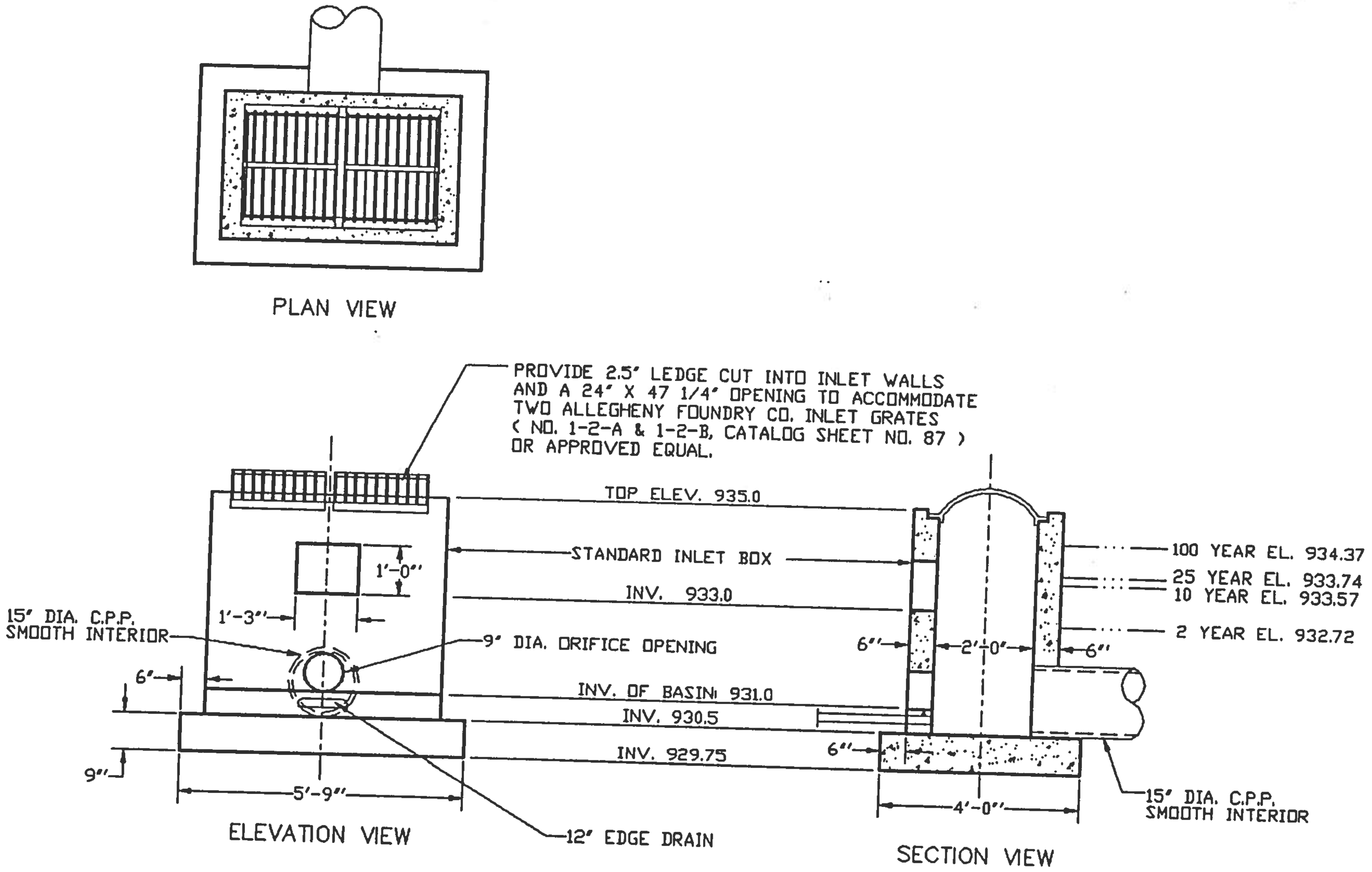
OUTLET CONTROL STRUCTURE
FOR BASIN 'A'
MODIFIED PENNDOT STANDARD INLET BOX
REFER TO RC-34

SCALE: NONE



EMERGENCY SPILLWAY
AT BASIN 'A' EMBANKMENT

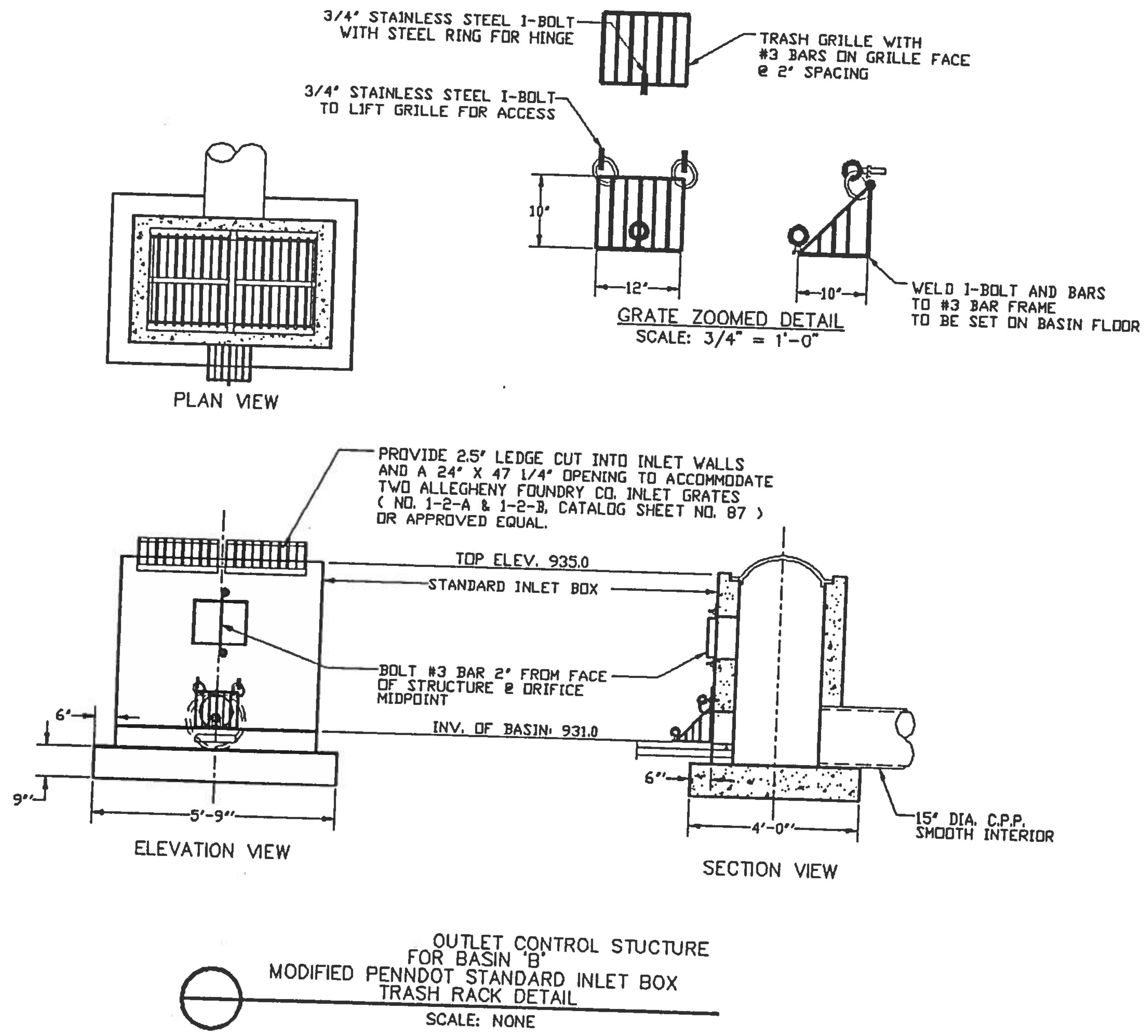
SCALE: NONE

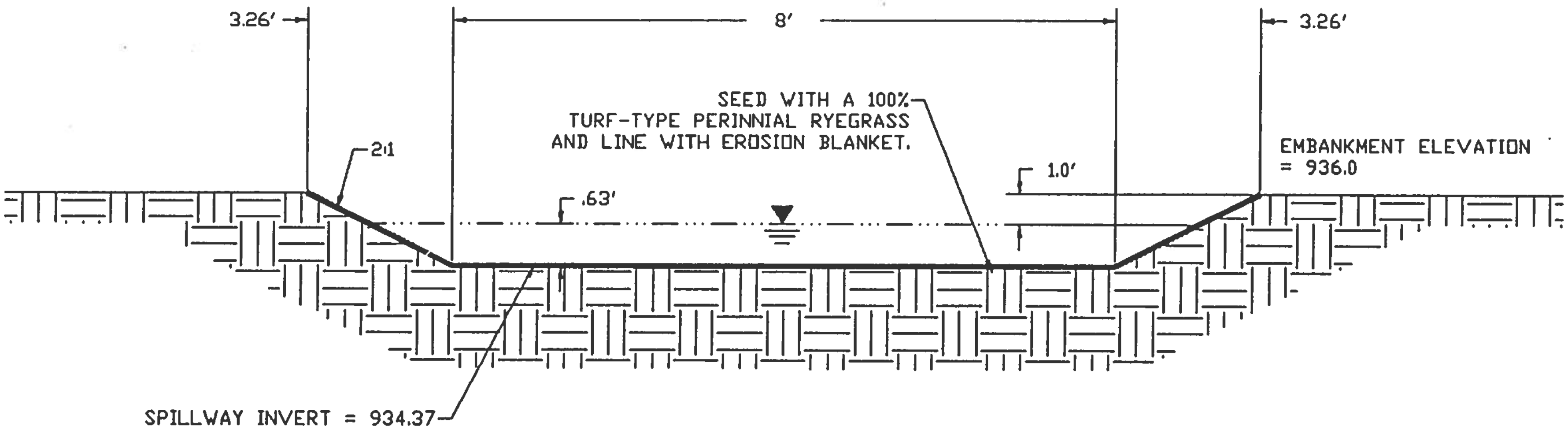


OUTLET CONTROL STRUCTURE
FOR BASIN 'B'
MODIFIED PENNDOT STANDARD INLET BOX
REFER TO RC-34

SCALE: NONE

NOTE: For trash rack details see the following page.


3/4" STAINLESS STEEL I-BOLT WITH STEEL RING FOR HINGE
TRASH GRILLE WITH #3 BARS ON GRILLE FACE @ 2" SPACING
3/4" STAINLESS STEEL I-BOLT TO LIFT GRILLE FOR ACCESS
10"
12"
10"
WELD I-BOLT AND BARS TO #3 BAR FRAME TO BE SET ON BASIN FLOOR
GRATE ZOOMED DETAIL
SCALE: 3/4" = 1'-0"
PLAN VIEW
PROVIDE 2.5" LEDGE CUT INTO INLET WALLS AND A 24" X 47 1/4" OPENING TO ACCOMMODATE TWO ALLEGHENY FOUNDRY CO. INLET GRATES (NO. 1-2-A & 1-2-B, CATALOG SHEET NO. 87) OR APPROVED EQUAL.
TOP ELEV. 935.0
STANDARD INLET BOX
BOLT #3 BAR 2" FROM FACE OF STRUCTURE @ ORIFICE MIDPOINT
INV. OF BASIN: 931.0
6"
9"
5'-9"
ELEVATION VIEW
6"
4'-0"
15" DIA. C.P.P. SMOOTH INTERIOR
SECTION VIEW
OUTLET CONTROL STUCTURE
FOR BASIN 'B'
MODIFIED PENNDOT STANDARD INLET BOX
TRASH RACK DETAIL
SCALE: NONE



KRIGGER BUILDING EMERGENCY SPILLWAY
AT BASIN 'B' EMBANKMENT

SCALE: NONE

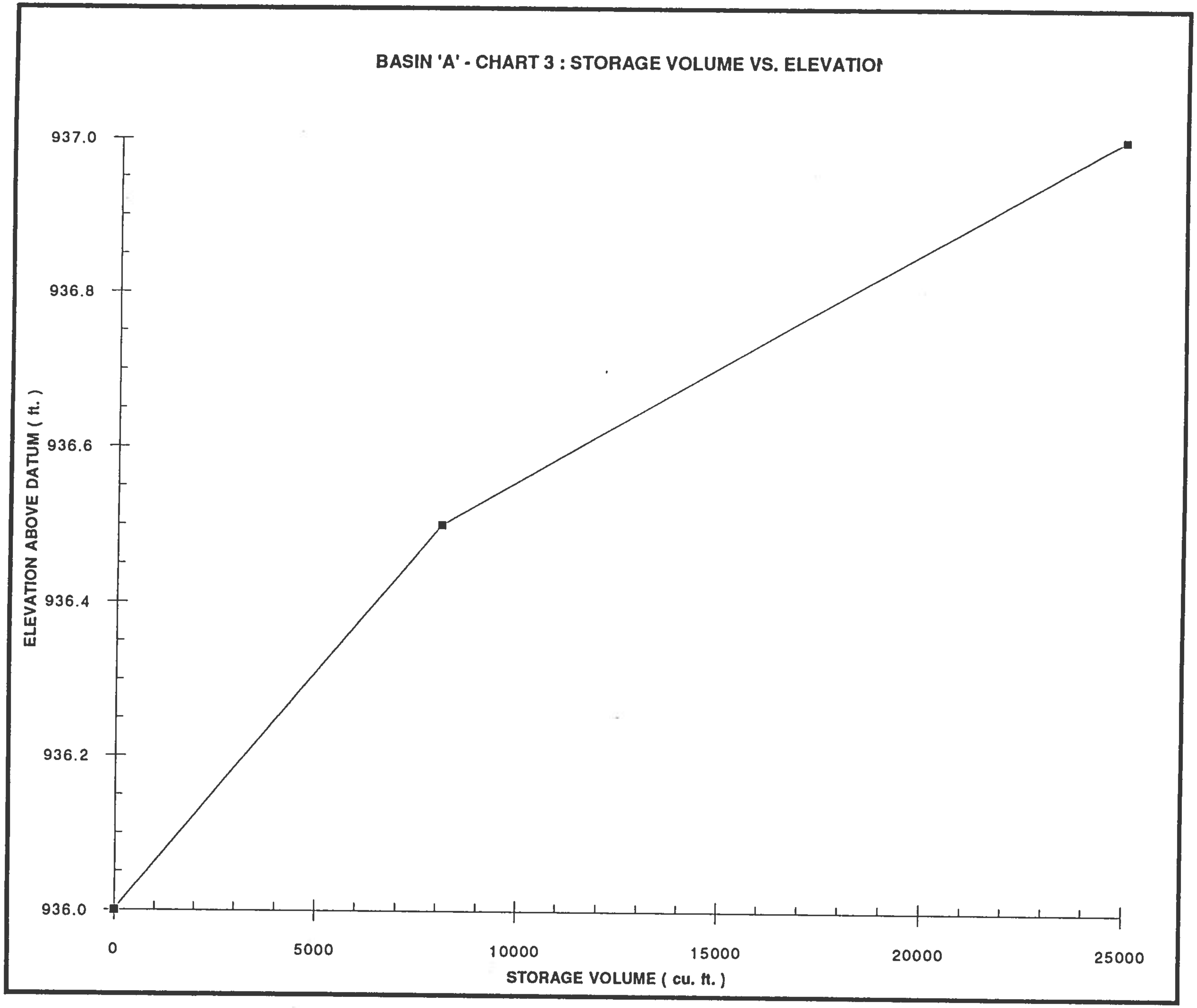
PROJECT NAME:
LOCATION:
PREPARED BY:
CHECKED BY:

STAGE STORAGE DATA:

RETENTION BASIN 'A' DATA SUMMARY

Existing Pool Elev.=	936.0
Top of 100 yr. Pool =	936.7
Proposed Pool Elev. =	937.0

Elevation (Feet)	Area (Sq. Feet)	Average Area (Sq. Feet)	Difference in Elevation (Feet)	Storage Volume (Cu. Ft.)		Ac/Ft	Discharge
				Incremental	Total	Total	CFS
936.0	0				0	0	0.00
		16,117	0.5	8,059			
936.5	32,234				8,059	0.1850	0.56
		33,759	0.5	16,880			
937.0	35,284				24,938	0.5725	1.58


BASIN 'A' - CHART 3 : STORAGE VOLUME VS. ELEVATIOI
ELEVATION ABOVE DATUM (ft.)
937.0
936.8
936.6
936.4
936.2
936.0
0
5000
10000
15000
20000
25000
STORAGE VOLUME (cu. ft.)

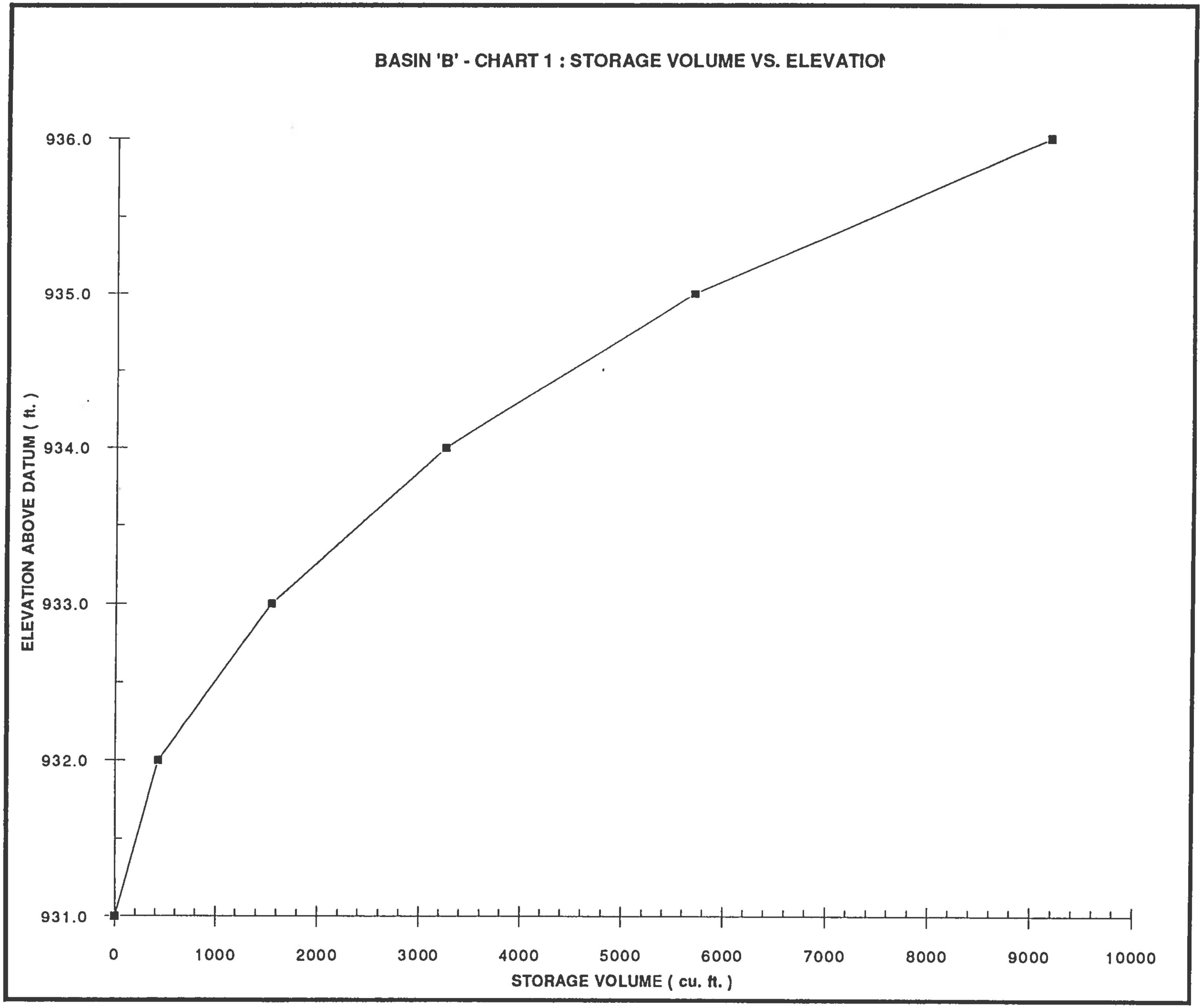
PROJECT NAME:
LOCATION:
PREPARED BY:
CHECKED BY:

STAGE STORAGE DATA:

DETENTION BASIN 'B' DATA SUMMARY

Invert of Basin =	931.0
Top of 100 yr. Pool =	934.4
Top of Embank. =	936.0

Elevation (Feet)	Area (Sq. Feet)	Average Area (Sq. Feet)	Difference in Elevation (Feet)	Storage Volume (Cu. Ft.)		Ac/Ft	Discharge
				Incremental	Total	Total	CFS
931.0	0				0	0	0.00
		430	1	430			
932.0	860				430	0.0099	1.44
		1,115	1	1,115			
933.0	1,370				1,545	0.0355	2.48
		1,700	1	1,700			
934.0	2,030				3,245	0.0745	6.90
		2,450	1	2,450			
935.0	2,870				5,695	0.1307	9.47
		3,480	1	3,480			
936.0	4,090				9,175	0.2106	


BASIN 'B' - CHART 1 : STORAGE VOLUME VS. ELEVATIOI
ELEVATION ABOVE DATUM (ft.)
936.0
935.0
934.0
933.0
932.0
931.0
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
STORAGE VOLUME (cu. ft.)

HYDROGRAPH COMPARISON FOR THE 2 YR STORM EVENT

Date	Time (min.)	Predev. Disturbed Hydrograph		Devel. Uncontr. Hydro. (-)	Basin 'A' Add. Offsite Hydro.		Basin 'B' Offsite Hydro.		Maximum Allowable Discharge (cfs)
		1 (cfs)	@ 85% R. R. (cfs)	3 (cfs)	4 (cfs)	@ 85% R. R. (cfs)	8 (cfs)	@ 85% R. R. (cfs)	
1/15/96	0000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1/15/96	0006	0.20	0.17	0.00	0.00	0.00	0.00	0.00	0.17
1/15/96	0012	0.20	0.17	0.00	0.00	0.00	0.00	0.00	0.17
1/15/96	0018	0.20	0.17	0.00	0.00	0.00	0.00	0.00	0.17
1/15/96	0024	0.30	0.26	0.00	0.00	0.00	0.00	0.00	0.26
1/15/96	0030	0.30	0.26	0.10	0.00	0.00	0.00	0.00	0.16
1/15/96	0036	0.40	0.34	0.10	0.00	0.00	0.00	0.00	0.24
1/15/96	0042	1.00	0.85	0.20	0.10	0.09	0.00	0.00	0.74
1/15/96	0048	1.60	1.36	0.40	0.20	0.17	0.00	0.00	1.13
1/15/96	0054	2.20	1.87	0.60	0.50	0.43	0.00	0.00	1.70
1/15/96	0100	4.80	4.08	1.70	0.70	0.60	0.10	0.09	3.06
1/15/96	0106	7.90	6.72	2.70	0.60	0.51	0.00	0.00	4.53
1/15/96	0112	6.40	5.44	1.60	0.40	0.34	0.00	0.00	4.18
1/15/96	0118	3.50	2.98	0.60	0.30	0.26	0.00	0.00	2.63
1/15/96	0124	2.10	1.79	0.40	0.20	0.17	0.00	0.00	1.56
1/15/96	0130	1.50	1.28	0.40	0.20	0.17	0.00	0.00	1.05
1/15/96	0136	1.20	1.02	0.30	0.10	0.09	0.00	0.00	0.81
1/15/96	0142	1.00	0.85	0.30	0.10	0.09	0.00	0.00	0.64
1/15/96	0148	0.80	0.68	0.20	0.10	0.09	0.00	0.00	0.57
1/15/96	0154	0.80	0.68	0.20	0.10	0.09	0.00	0.00	0.57
1/15/96	0200	0.70	0.60	0.20	0.10	0.09	0.00	0.00	0.48
1/15/96	0206	0.70	0.60	0.20	0.10	0.09	0.00	0.00	0.48
1/15/96	0212	0.60	0.51	0.20	0.10	0.09	0.00	0.00	0.40
1/15/96	0218	0.60	0.51	0.20	0.10	0.09	0.00	0.00	0.40
1/15/96	0224	0.50	0.43	0.20	0.10	0.09	0.00	0.00	0.31
1/15/96	0230	0.50	0.43	0.20	0.10	0.09	0.00	0.00	0.31
1/15/96	0236	0.50	0.43	0.00	0.10	0.09	0.00	0.00	0.51
1/15/96	0242	0.00	0.00	0.00	0.10	0.09	0.00	0.00	0.09
1/15/96	0248	0.00	0.00	0.00	0.10	0.09	0.00	0.00	0.09
1/15/96	0254	0.00	0.00	0.00	0.10	0.09	0.00	0.00	0.09
1/15/96	0300	0.00	0.00	0.00	0.10	0.09	0.00	0.00	0.09
1/15/96	0306	0.00	0.00	0.00	0.10	0.09	0.00	0.00	0.09
1/15/96	0312	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1/15/96	0318	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1/15/96	0324	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1/15/96	0330	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1/15/96	0336	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1/15/96	0342	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1/15/96	0348	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1/15/96	0354	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1/15/96	0400	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1/15/96	0406	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1/15/96	0412	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1/15/96	0418	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

HYDROGRAPH COMPARISON FOR THE 25 YR STORM EVENT

Date	Time (min.)	Predev. Disturbed Hydrograph		Devel. Uncontr. Hydro. (-)	Basin 'A' Add. Offsite Hydro.		Basin 'B' Offsite Hydro.		Maximum Allowable Discharge (cfs)
		1 (cfs)	@ 85% R. R. (cfs)	3 (cfs)	4 (cfs)	@ 85% R. R. (cfs)	8 (cfs)	@ 85% R. R. (cfs)	
1/15/96	0000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1/15/96	0006	0.60	0.51	0.20	0.10	0.09	0.00	0.00	0.40
1/15/96	0012	0.60	0.51	0.20	0.10	0.09	0.00	0.00	0.40
1/15/96	0018	0.70	0.60	0.20	0.10	0.09	0.00	0.00	0.48
1/15/96	0024	0.80	0.68	0.20	0.10	0.09	0.00	0.00	0.57
1/15/96	0030	0.90	0.77	0.30	0.10	0.09	0.00	0.00	0.55
1/15/96	0036	1.10	0.94	0.30	0.10	0.09	0.00	0.00	0.72
1/15/96	0042	2.60	2.21	0.90	0.20	0.17	0.00	0.00	1.48
1/15/96	0048	4.20	3.57	1.50	0.30	0.26	0.00	0.00	2.33
1/15/96	0054	5.80	4.93	2.10	0.40	0.34	0.00	0.00	3.17
1/15/96	0100	11.20	9.52	4.40	0.80	0.68	0.10	0.09	5.89
1/15/96	0106	18.20	15.47	7.00	1.50	1.28	0.10	0.09	9.83
1/15/96	**0112**	**14.90**	**12.67**	**4.30**	**2.00**	**1.70**	**0.10**	**0.09**	**10.15**
1/15/96	0118	7.90	6.72	1.50	1.60	1.36	0.10	0.09	6.66
1/15/96	0124	4.70	4.00	1.10	1.10	0.94	0.00	0.00	3.83
1/15/96	0130	3.30	2.81	0.90	0.70	0.60	0.00	0.00	2.50
1/15/96	0136	2.60	2.21	0.70	0.50	0.43	0.00	0.00	1.94
1/15/96	0142	2.10	1.79	0.60	0.40	0.34	0.00	0.00	1.53
1/15/96	0148	1.80	1.53	0.60	0.30	0.26	0.00	0.00	1.19
1/15/96	0154	1.60	1.36	0.50	0.30	0.26	0.00	0.00	1.12
1/15/96	0200	1.50	1.28	0.50	0.20	0.17	0.00	0.00	0.95
1/15/96	0206	1.40	1.19	0.50	0.20	0.17	0.00	0.00	0.86
1/15/96	0212	1.30	1.11	0.40	0.20	0.17	0.00	0.00	0.88
1/15/96	0218	1.20	1.02	0.00	0.20	0.17	0.00	0.00	1.19
1/15/96	0224	1.10	0.94	0.00	0.20	0.17	0.00	0.00	1.11
1/15/96	0230	1.10	0.94	0.00	0.20	0.17	0.00	0.00	1.11
1/15/96	0236	0.00	0.00	0.00	0.20	0.17	0.00	0.00	0.17
1/15/96	0242	0.00	0.00	0.00	0.20	0.17	0.00	0.00	0.17
1/15/96	0248	0.00	0.00	0.00	0.10	0.09	0.00	0.00	0.09
1/15/96	0254	0.00	0.00	0.00	0.10	0.09	0.00	0.00	0.09
1/15/96	0300	0.00	0.00	0.00	0.10	0.09	0.00	0.00	0.09
1/15/96	0306	0.00	0.00	0.00	0.10	0.09	0.00	0.00	0.09
1/15/96	0312	0.00	0.00	0.00	0.10	0.09	0.00	0.00	0.09
1/15/96	0318	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1/15/96	0324	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

©STAGE/DISCHARGE TABLE FOR - BASIN 'A'

BASIN WATER ©ELEVATION,ft.	BASIN OUTFLOW,cfs.	RISER BOX WATER ELEVATION,ft.	TAILWATER ELEVATION,ft.	OUTLET CULV. CONTROL
936.00	0.00	934.75	N/A	N/A
936.25	0.20	934.99	N/A	ORIFICE CONT
936.50	0.56	935.16	N/A	ORIFICE CONT
936.75	1.03	935.31	N/A	ORIFICE CONT
937.00	1.58	935.45	N/A	ORIFICE CONT

©OUTLET STRUCTURE GEOMETRY FOR KRIGGER BUILDING - BASIN 'A'

STAGE 1 ---> RECTANGULAR WEIR

CREST ELEVATION = 936.00 CREST LENGTH = 0.50 ft. DISCHARGE COEFF. = 3.100

---> OUTFALL CULVERT

UPSTREAM INVERT ELEVATION = 934.75 DIAMETER = 1.25 ft. LENGTH = 80.00 ft. SLOPE = 0.0156 ft/ft.
MANNING'S n = 0.0120 ENTRANCE CONDITION = SOH, K = 0.20

---> NO OUTFALL CHANNEL

Penn State Urban Hydrology Model
MODULE _4-B¢ - MODIFIED PULS ROUTING

Name of reservoir or channel: RETENTION BASIN 'A' - 2 YR STORM
Filename of inflow hydrograph: A:KBWSA2.HYD
Filename of rating matrix: A:KBWSA.ESO

Date	Time	Inflow (cfs)	I1+I2 (cfs)	2ST/DT-O (cfs)	2ST/DT+O (cfs)	Outflow (cfs)	Storage (AcFt)	Elevation (ft MSL)
		0.0	0.0	0.0	0.0	0.0	0.00	936.00
00/00/0	0006	0.0	0.1	0.0	0.0	0.0	0.00	936.00
00/00/0	0012	0.1	0.2	0.1	0.1	0.0	0.00	936.00
00/00/0	0018	0.1	0.2	0.3	0.3	0.0	0.00	936.00
00/00/0	0024	0.1	0.2	0.5	0.5	0.0	0.00	936.01
00/00/0	0030	0.1	0.2	0.7	0.7	0.0	0.00	936.01
00/00/0	0036	0.1	0.3	0.8	0.9	0.0	0.00	936.01
00/00/0	0042	0.2	0.5	1.1	1.1	0.0	0.00	936.01
00/00/0	0048	0.3	0.6	1.6	1.6	0.0	0.01	936.02
00/00/0	0054	0.3	1.1	2.1	2.2	0.0	0.01	936.02
00/00/0	0100	0.8	2.4	3.1	3.2	0.0	0.01	936.04
00/00/0	0106	1.6	3.7	5.4	5.5	0.1	0.02	936.06
00/00/0	0112	2.1	3.9	8.9	9.1	0.1	0.04	936.10
00/00/0	0118	1.8	3.0	12.5	12.8	0.2	0.05	936.14
00/00/0	0124	1.2	2.0	15.1	15.5	0.2	0.06	936.17
00/00/0	0130	0.8	1.4	16.7	17.1	0.2	0.07	936.19
00/00/0	0136	0.6	1.0	17.6	18.1	0.2	0.07	936.20
00/00/0	0142	0.4	0.7	18.2	18.6	0.2	0.08	936.21
00/00/0	0148	0.3	0.6	18.4	18.9	0.2	0.08	936.21
00/00/0	0154	0.3	0.6	18.5	19.0	0.2	0.08	936.21
00/00/0	0200	0.3	0.5	18.6	19.1	0.2	0.08	936.21
00/00/0	0206	0.2	0.4	18.7	19.1	0.2	0.08	936.21
00/00/0	0212	0.2	0.4	18.6	19.1	0.2	0.08	936.21
00/00/0	0218	0.2	0.4	18.5	19.0	0.2	0.08	936.21
00/00/0	0224	0.2	0.4	18.5	18.9	0.2	0.08	936.21
00/00/0	0230	0.2	0.4	18.4	18.9	0.2	0.08	936.21
00/00/0	0236	0.2	0.4	18.3	18.8	0.2	0.08	936.21
00/00/0	0242	0.2	0.4	18.3	18.7	0.2	0.08	936.21
00/00/0	0248	0.2	0.4	18.2	18.7	0.2	0.08	936.21
00/00/0	0254	0.2	0.4	18.1	18.6	0.2	0.08	936.21
00/00/0	0300	0.2	0.3	18.1	18.5	0.2	0.08	936.20
00/00/0	0306	0.1	0.2	17.9	18.4	0.2	0.08	936.20
00/00/0	0312	0.1	0.2	17.7	18.1	0.2	0.07	936.20
00/00/0	0318	0.1	0.2	17.4	17.9	0.2	0.07	936.20
00/00/0	0324	0.1	0.2	17.2	17.6	0.2	0.07	936.19
00/00/0	0330	0.1	0.2	17.0	17.4	0.2	0.07	936.19
00/00/0	0336	0.1	0.2	16.8	17.2	0.2	0.07	936.19
00/00/0	0342	0.1	0.2	16.5	17.0	0.2	0.07	936.19
00/00/0	0348	0.1	0.2	16.3	16.7	0.2	0.07	936.18
00/00/0	0354	0.1	0.2	16.1	16.5	0.2	0.07	936.18
00/00/0	0400	0.1	0.2	15.9	16.3	0.2	0.07	936.18
00/00/0	0406	0.1	0.2	15.7	16.1	0.2	0.07	936.18
00/00/0	0412	0.1	0.2	15.5	15.9	0.2	0.06	936.18
00/00/0	0418	0.1	0.2	15.3	15.7	0.2	0.06	936.17
00/00/0	0424	0.1	0.2	15.1	15.5	0.2	0.06	936.17
00/00/0	0430	0.1	0.2	15.0	15.3	0.2	0.06	936.17
00/00/0	0436	0.1	0.2	14.8	15.2	0.2	0.06	936.17
00/00/0	0442	0.1	0.2	14.6	15.0	0.2	0.06	936.17
00/00/0	0448	0.1	0.2	14.5	14.8	0.2	0.06	936.16
00/00/0	0454	0.1	0.2	14.3	14.7	0.2	0.06	936.16
00/00/0	0500	0.1	0.2	14.1	14.5	0.2	0.06	936.16

00/00/0	0506	0.1	0.2	14.0	14.3	0.2	0.06	936.16
00/00/0	0512	0.1	0.2	13.8	14.2	0.2	0.06	936.16
00/00/0	0518	0.1	0.2	13.7	14.0	0.2	0.06	936.15
00/00/0	0524	0.1	0.2	13.5	13.9	0.2	0.06	936.15
00/00/0	0530	0.1	0.2	13.4	13.7	0.2	0.06	936.15
00/00/0	0536	0.1	0.2	13.3	13.6	0.2	0.06	936.15
00/00/0	0542	0.1	0.2	13.1	13.5	0.2	0.06	936.15
00/00/0	0548	0.1	0.2	13.0	13.3	0.2	0.05	936.15
00/00/0	0554	0.1	0.2	12.9	13.2	0.2	0.05	936.15
00/00/0	0600	0.1	0.2	12.8	13.1	0.2	0.05	936.14
00/00/0	0606	0.1	0.2	12.6	13.0	0.2	0.05	936.14
00/00/0	0612	0.1	0.2	12.5	12.8	0.2	0.05	936.14
00/00/0	0618	0.1	0.2	12.4	12.7	0.2	0.05	936.14
00/00/0	0624	0.1	0.2	12.3	12.6	0.2	0.05	936.14
00/00/0	0630	0.1	0.2	12.2	12.5	0.2	0.05	936.14
00/00/0	0636	0.1	0.2	12.1	12.4	0.2	0.05	936.14
00/00/0	0642	0.1	0.2	12.0	12.3	0.2	0.05	936.14
00/00/0	0648	0.1	0.2	11.9	12.2	0.2	0.05	936.13
00/00/0	0654	0.1	0.2	11.8	12.1	0.1	0.05	936.13
00/00/0	0700	0.1	0.2	11.7	12.0	0.1	0.05	936.13
00/00/0	0706	0.1	0.2	11.6	11.9	0.1	0.05	936.13
00/00/0	0712	0.1	0.2	11.5	11.8	0.1	0.05	936.13
00/00/0	0718	0.1	0.2	11.4	11.7	0.1	0.05	936.13
00/00/0	0724	0.1	0.2	11.3	11.6	0.1	0.05	936.13
00/00/0	0730	0.1	0.2	11.2	11.5	0.1	0.05	936.13
00/00/0	0736	0.1	0.2	11.2	11.4	0.1	0.05	936.13
00/00/0	0742	0.1	0.2	11.1	11.4	0.1	0.05	936.13
00/00/0	0748	0.1	0.2	11.0	11.3	0.1	0.05	936.12
00/00/0	0754	0.1	0.2	10.9	11.2	0.1	0.05	936.12
00/00/0	0800	0.1	0.2	10.8	11.1	0.1	0.05	936.12
00/00/0	0806	0.1	0.2	10.8	11.0	0.1	0.05	936.12
00/00/0	0812	0.1	0.2	10.7	11.0	0.1	0.04	936.12
00/00/0	0818	0.1	0.2	10.6	10.9	0.1	0.04	936.12
00/00/0	0824	0.1	0.2	10.6	10.8	0.1	0.04	936.12
00/00/0	0830	0.1	0.2	10.5	10.8	0.1	0.04	936.12
00/00/0	0836	0.1	0.2	10.4	10.7	0.1	0.04	936.12
00/00/0	0842	0.1	0.2	10.4	10.6	0.1	0.04	936.12
00/00/0	0848	0.1	0.2	10.3	10.6	0.1	0.04	936.12
00/00/0	0854	0.1	0.2	10.2	10.5	0.1	0.04	936.12
00/00/0	0900	0.1	0.2	10.2	10.4	0.1	0.04	936.12
00/00/0	0906	0.1	0.2	10.1	10.4	0.1	0.04	936.11
00/00/0	0912	0.1	0.2	10.1	10.3	0.1	0.04	936.11
00/00/0	0918	0.1	0.2	10.0	10.3	0.1	0.04	936.11
00/00/0	0924	0.1	0.2	10.0	10.2	0.1	0.04	936.11
00/00/0	0930	0.1	0.2	9.9	10.2	0.1	0.04	936.11
00/00/0	0936	0.1	0.2	9.9	10.1	0.1	0.04	936.11
00/00/0	0942	0.1	0.2	9.8	10.1	0.1	0.04	936.11
00/00/0	0948	0.1	0.2	9.8	10.0	0.1	0.04	936.11
00/00/0	0954	0.1	0.2	9.7	10.0	0.1	0.04	936.11
00/00/0	1000	0.1	0.2	9.7	9.9	0.1	0.04	936.11
00/00/0	1006	0.1	0.2	9.6	9.9	0.1	0.04	936.11
00/00/0	1012	0.1	0.2	9.6	9.8	0.1	0.04	936.11
00/00/0	1018	0.1	0.2	9.6	9.8	0.1	0.04	936.11
00/00/0	1024	0.1	0.2	9.5	9.8	0.1	0.04	936.11
00/00/0	1030	0.1	0.2	9.5	9.7	0.1	0.04	936.11
00/00/0	1036	0.1	0.2	9.4	9.7	0.1	0.04	936.11
00/00/0	1042	0.1	0.2	9.4	9.6	0.1	0.04	936.11
00/00/0	1048	0.1	0.2	9.4	9.6	0.1	0.04	936.11
00/00/0	1054	0.1	0.2	9.3	9.6	0.1	0.04	936.11
00/00/0	1100	0.1	0.2	9.3	9.5	0.1	0.04	936.11

00/00/0	1106	0.1	0.2	9.3	9.5	0.1	0.04	936.10
00/00/0	1112	0.1	0.2	9.2	9.5	0.1	0.04	936.10
00/00/0	1118	0.1	0.2	9.2	9.4	0.1	0.04	936.10
00/00/0	1124	0.1	0.2	9.2	9.4	0.1	0.04	936.10
00/00/0	1130	0.1	0.2	9.1	9.4	0.1	0.04	936.10
00/00/0	1136	0.1	0.2	9.1	9.3	0.1	0.04	936.10
00/00/0	1142	0.1	0.2	9.1	9.3	0.1	0.04	936.10
00/00/0	1148	0.1	0.2	9.0	9.3	0.1	0.04	936.10
00/00/0	1154	0.1	0.2	9.0	9.2	0.1	0.04	936.10
00/00/0	1200	0.1	0.2	9.0	9.2	0.1	0.04	936.10
00/00/0	1206	0.1	0.2	9.0	9.2	0.1	0.04	936.10
00/00/0	1212	0.1	0.2	8.9	9.2	0.1	0.04	936.10
00/00/0	1218	0.1	0.2	8.9	9.1	0.1	0.04	936.10
00/00/0	1224	0.1	0.2	8.9	9.1	0.1	0.04	936.10
00/00/0	1230	0.1	0.2	8.9	9.1	0.1	0.04	936.10
00/00/0	1236	0.1	0.2	8.8	9.1	0.1	0.04	936.10
00/00/0	1242	0.1	0.2	8.8	9.0	0.1	0.04	936.10
00/00/0	1248	0.1	0.2	8.8	9.0	0.1	0.04	936.10
00/00/0	1254	0.1	0.2	8.8	9.0	0.1	0.04	936.10
00/00/0	1300	0.1	0.2	8.7	9.0	0.1	0.04	936.10
00/00/0	1306	0.1	0.2	8.7	8.9	0.1	0.04	936.10
00/00/0	1312	0.1	0.2	8.7	8.9	0.1	0.04	936.10
00/00/0	1318	0.1	0.2	8.7	8.9	0.1	0.04	936.10
00/00/0	1324	0.1	0.2	8.7	8.9	0.1	0.04	936.10
00/00/0	1330	0.1	0.2	8.6	8.9	0.1	0.04	936.10
00/00/0	1336	0.1	0.2	8.6	8.8	0.1	0.04	936.10
00/00/0	1342	0.1	0.2	8.6	8.8	0.1	0.04	936.10
00/00/0	1348	0.1	0.2	8.6	8.8	0.1	0.04	936.10
00/00/0	1354	0.1	0.2	8.6	8.8	0.1	0.04	936.10
00/00/0	1400	0.1	0.2	8.6	8.8	0.1	0.04	936.10
00/00/0	1406	0.1	0.2	8.5	8.8	0.1	0.04	936.10
00/00/0	1412	0.1	0.2	8.5	8.7	0.1	0.04	936.10
00/00/0	1418	0.1	0.2	8.5	8.7	0.1	0.04	936.10
00/00/0	1424	0.1	0.2	8.5	8.7	0.1	0.04	936.10
00/00/0	1430	0.1	0.2	8.5	8.7	0.1	0.04	936.10
00/00/0	1436	0.1	0.2	8.5	8.7	0.1	0.04	936.10
00/00/0	1442	0.1	0.2	8.4	8.7	0.1	0.04	936.10
00/00/0	1448	0.1	0.2	8.4	8.6	0.1	0.04	936.10
00/00/0	1454	0.1	0.2	8.4	8.6	0.1	0.04	936.10

Peak inflow = 2.1 cfs occurred at 0112 on 00/00/0
Peak outflow = .2365049 cfs occurred at 0206 on 00/00/0
Number of hydrograph points = 149
Time step = .1 hrs.
Change in storage =-.04 ac.ft.
Summation of DT * (INFLOW - OUTFLOW) = 0 ac.ft.

Penn State Urban Hydrology Model
MODULE _4-B¢ - MODIFIED PULS ROUTING

Name of reservoir or channel: RETENTION BASIN 'A' - 10 YR STOR
Filename of inflow hydrograph: A:KBWSA10.HYD
Filename of rating matrix: A:KBWSA.ESO

Date	Time	Inflow (cfs)	I1+I2 (cfs)	2ST/DT-O (cfs)	2ST/DT+O (cfs)	Outflow (cfs)	Storage (AcFt)	Elevation (ft MSL)
		0.1	0.2	0.0	0.0	0.0	0.00	936.00
00/00/0	0006	0.1	0.3	0.2	0.2	0.0	0.00	936.00
00/00/0	0012	0.2	0.4	0.5	0.5	0.0	0.00	936.01
00/00/0	0018	0.2	0.4	0.9	0.9	0.0	0.00	936.01
00/00/0	0024	0.2	0.4	1.2	1.3	0.0	0.01	936.01
00/00/0	0030	0.2	0.5	1.6	1.6	0.0	0.01	936.02
00/00/0	0036	0.3	0.8	2.0	2.1	0.0	0.01	936.02
00/00/0	0042	0.5	1.2	2.8	2.8	0.0	0.01	936.03
00/00/0	0048	0.7	1.7	3.9	4.0	0.0	0.02	936.04
00/00/0	0054	1.0	2.9	5.4	5.6	0.1	0.02	936.06
00/00/0	0100	1.9	5.5	8.1	8.3	0.1	0.03	936.09
00/00/0	0106	3.6	8.2	13.3	13.6	0.2	0.06	936.15
00/00/0	0112	4.6	8.3	21.0	21.5	0.3	0.09	936.24
00/00/0	0118	3.7	6.1	28.5	29.3	0.4	0.12	936.32
00/00/0	0124	2.4	3.9	33.8	34.6	0.4	0.14	936.38
00/00/0	0130	1.5	2.6	36.7	37.7	0.5	0.15	936.42
00/00/0	0136	1.1	1.9	38.4	39.3	0.5	0.16	936.43
00/00/0	0142	0.8	1.5	39.3	40.3	0.5	0.16	936.44
00/00/0	0148	0.7	1.3	39.8	40.8	0.5	0.17	936.45
00/00/0	0154	0.6	1.1	40.1	41.1	0.5	0.17	936.45
00/00/0	0200	0.5	1.0	40.1	41.2	0.5	0.17	936.45
00/00/0	0206	0.5	0.9	40.1	41.1	0.5	0.17	936.45
00/00/0	0212	0.4	0.8	40.0	41.0	0.5	0.17	936.45
00/00/0	0218	0.4	0.8	39.8	40.8	0.5	0.17	936.45
00/00/0	0224	0.4	0.8	39.6	40.6	0.5	0.17	936.45
00/00/0	0230	0.4	0.7	39.4	40.4	0.5	0.16	936.45
00/00/0	0236	0.3	0.6	39.1	40.1	0.5	0.16	936.44
00/00/0	0242	0.3	0.6	38.7	39.7	0.5	0.16	936.44
00/00/0	0248	0.3	0.6	38.4	39.3	0.5	0.16	936.43
00/00/0	0254	0.3	0.6	38.0	39.0	0.5	0.16	936.43
00/00/0	0300	0.3	0.6	37.6	38.6	0.5	0.16	936.43
00/00/0	0306	0.3	0.6	37.3	38.2	0.5	0.16	936.42
00/00/0	0312	0.3	0.6	37.0	37.9	0.5	0.15	936.42
00/00/0	0318	0.3	0.6	36.6	37.6	0.5	0.15	936.41
00/00/0	0324	0.3	0.6	36.3	37.2	0.5	0.15	936.41
00/00/0	0330	0.3	0.6	36.0	36.9	0.5	0.15	936.41
00/00/0	0336	0.3	0.6	35.7	36.6	0.5	0.15	936.40
00/00/0	0342	0.3	0.6	35.4	36.3	0.4	0.15	936.40
00/00/0	0348	0.3	0.6	35.1	36.0	0.4	0.15	936.40
00/00/0	0354	0.3	0.6	34.8	35.7	0.4	0.15	936.39
00/00/0	0400	0.3	0.6	34.6	35.4	0.4	0.14	936.39
00/00/0	0406	0.3	0.6	34.3	35.2	0.4	0.14	936.39
00/00/0	0412	0.3	0.6	34.0	34.9	0.4	0.14	936.38
00/00/0	0418	0.3	0.6	33.8	34.6	0.4	0.14	936.38
00/00/0	0424	0.3	0.6	33.5	34.4	0.4	0.14	936.38
00/00/0	0430	0.3	0.6	33.3	34.1	0.4	0.14	936.38
00/00/0	0436	0.3	0.6	33.0	33.9	0.4	0.14	936.37
00/00/0	0442	0.3	0.6	32.8	33.6	0.4	0.14	936.37
00/00/0	0448	0.3	0.6	32.6	33.4	0.4	0.14	936.37
00/00/0	0454	0.3	0.6	32.4	33.2	0.4	0.14	936.37

00/00/0	0500	0.3	0.6	32.1	33.0	0.4	0.13	936.36
00/00/0	0506	0.3	0.6	31.9	32.7	0.4	0.13	936.36
00/00/0	0512	0.3	0.6	31.7	32.5	0.4	0.13	936.36
00/00/0	0518	0.3	0.6	31.5	32.3	0.4	0.13	936.36
00/00/0	0524	0.3	0.6	31.3	32.1	0.4	0.13	936.35
00/00/0	0530	0.3	0.6	31.2	31.9	0.4	0.13	936.35
00/00/0	0536	0.3	0.6	31.0	31.8	0.4	0.13	936.35
00/00/0	0542	0.3	0.6	30.8	31.6	0.4	0.13	936.35
00/00/0	0548	0.3	0.6	30.6	31.4	0.4	0.13	936.35
00/00/0	0554	0.3	0.6	30.4	31.2	0.4	0.13	936.34
00/00/0	0600	0.3	0.6	30.3	31.0	0.4	0.13	936.34
00/00/0	0606	0.3	0.6	30.1	30.9	0.4	0.13	936.34
00/00/0	0612	0.3	0.6	30.0	30.7	0.4	0.13	936.34
00/00/0	0618	0.3	0.6	29.8	30.6	0.4	0.12	936.34
00/00/0	0624	0.3	0.6	29.6	30.4	0.4	0.12	936.34
00/00/0	0630	0.3	0.6	29.5	30.2	0.4	0.12	936.33
00/00/0	0636	0.3	0.6	29.4	30.1	0.4	0.12	936.33
00/00/0	0642	0.3	0.6	29.2	30.0	0.4	0.12	936.33
00/00/0	0648	0.3	0.6	29.1	29.8	0.4	0.12	936.33
00/00/0	0654	0.3	0.6	28.9	29.7	0.4	0.12	936.33
00/00/0	0700	0.3	0.6	28.8	29.5	0.4	0.12	936.33
00/00/0	0706	0.3	0.6	28.7	29.4	0.4	0.12	936.32
00/00/0	0712	0.3	0.6	28.6	29.3	0.4	0.12	936.32
00/00/0	0718	0.3	0.6	28.4	29.2	0.4	0.12	936.32
00/00/0	0724	0.3	0.6	28.3	29.0	0.4	0.12	936.32
00/00/0	0730	0.3	0.6	28.2	28.9	0.4	0.12	936.32
00/00/0	0736	0.3	0.6	28.1	28.8	0.4	0.12	936.32
00/00/0	0742	0.3	0.6	28.0	28.7	0.4	0.12	936.32
00/00/0	0748	0.3	0.6	27.9	28.6	0.4	0.12	936.32
00/00/0	0754	0.3	0.6	27.8	28.5	0.4	0.12	936.31
00/00/0	0800	0.3	0.6	27.7	28.4	0.4	0.12	936.31
00/00/0	0806	0.3	0.6	27.6	28.3	0.3	0.12	936.31
00/00/0	0812	0.3	0.6	27.5	28.2	0.3	0.12	936.31
00/00/0	0818	0.3	0.6	27.4	28.1	0.3	0.11	936.31
00/00/0	0824	0.3	0.6	27.3	28.0	0.3	0.11	936.31
00/00/0	0830	0.3	0.6	27.2	27.9	0.3	0.11	936.31
00/00/0	0836	0.3	0.6	27.1	27.8	0.3	0.11	936.31
00/00/0	0842	0.3	0.6	27.0	27.7	0.3	0.11	936.31
00/00/0	0848	0.3	0.6	27.0	27.6	0.3	0.11	936.30
00/00/0	0854	0.3	0.6	26.9	27.6	0.3	0.11	936.30
00/00/0	0900	0.3	0.6	26.8	27.5	0.3	0.11	936.30
00/00/0	0906	0.3	0.6	26.7	27.4	0.3	0.11	936.30
00/00/0	0912	0.3	0.6	26.6	27.3	0.3	0.11	936.30
00/00/0	0918	0.3	0.6	26.6	27.2	0.3	0.11	936.30
00/00/0	0924	0.3	0.6	26.5	27.2	0.3	0.11	936.30
00/00/0	0930	0.3	0.6	26.4	27.1	0.3	0.11	936.30
00/00/0	0936	0.3	0.6	26.4	27.0	0.3	0.11	936.30
00/00/0	0942	0.3	0.6	26.3	27.0	0.3	0.11	936.30
00/00/0	0948	0.3	0.6	26.2	26.9	0.3	0.11	936.30
00/00/0	0954	0.3	0.6	26.2	26.8	0.3	0.11	936.30
00/00/0	1000	0.3	0.6	26.1	26.8	0.3	0.11	936.30
00/00/0	1006	0.3	0.6	26.0	26.7	0.3	0.11	936.29
00/00/0	1012	0.3	0.6	26.0	26.6	0.3	0.11	936.29
00/00/0	1018	0.3	0.6	25.9	26.6	0.3	0.11	936.29
00/00/0	1024	0.3	0.6	25.9	26.5	0.3	0.11	936.29
00/00/0	1030	0.3	0.6	25.8	26.5	0.3	0.11	936.29
00/00/0	1036	0.3	0.6	25.8	26.4	0.3	0.11	936.29
00/00/0	1042	0.3	0.6	25.7	26.4	0.3	0.11	936.29
00/00/0	1048	0.3	0.6	25.7	26.3	0.3	0.11	936.29
00/00/0	1054	0.3	0.6	25.6	26.3	0.3	0.11	936.29

00/00/0	1100	0.3	0.6	25.6	26.2	0.3	0.11	936.29
00/00/0	1106	0.3	0.6	25.5	26.2	0.3	0.11	936.29
00/00/0	1112	0.3	0.6	25.5	26.1	0.3	0.11	936.29
00/00/0	1118	0.3	0.6	25.4	26.1	0.3	0.11	936.29
00/00/0	1124	0.3	0.6	25.4	26.0	0.3	0.11	936.29
00/00/0	1130	0.3	0.6	25.3	26.0	0.3	0.11	936.29
00/00/0	1136	0.3	0.6	25.3	25.9	0.3	0.11	936.29
00/00/0	1142	0.3	0.6	25.3	25.9	0.3	0.11	936.29
00/00/0	1148	0.3	0.6	25.2	25.9	0.3	0.11	936.29
00/00/0	1154	0.3	0.6	25.2	25.8	0.3	0.11	936.28
00/00/0	1200	0.3	0.6	25.2	25.8	0.3	0.11	936.28
00/00/0	1206	0.3	0.6	25.1	25.8	0.3	0.11	936.28
00/00/0	1212	0.3	0.6	25.1	25.7	0.3	0.10	936.28
00/00/0	1218	0.3	0.6	25.0	25.7	0.3	0.10	936.28
00/00/0	1224	0.3	0.6	25.0	25.6	0.3	0.10	936.28
00/00/0	1230	0.3	0.6	25.0	25.6	0.3	0.10	936.28
00/00/0	1236	0.3	0.6	24.9	25.6	0.3	0.10	936.28
00/00/0	1242	0.3	0.6	24.9	25.5	0.3	0.10	936.28
00/00/0	1248	0.3	0.6	24.9	25.5	0.3	0.10	936.28
00/00/0	1254	0.3	0.6	24.9	25.5	0.3	0.10	936.28
00/00/0	1300	0.3	0.6	24.8	25.5	0.3	0.10	936.28
00/00/0	1306	0.3	0.6	24.8	25.4	0.3	0.10	936.28
00/00/0	1312	0.3	0.6	24.8	25.4	0.3	0.10	936.28
00/00/0	1318	0.3	0.6	24.7	25.4	0.3	0.10	936.28
00/00/0	1324	0.3	0.6	24.7	25.3	0.3	0.10	936.28
00/00/0	1330	0.3	0.6	24.7	25.3	0.3	0.10	936.28
00/00/0	1336	0.3	0.6	24.7	25.3	0.3	0.10	936.28
00/00/0	1342	0.3	0.6	24.6	25.3	0.3	0.10	936.28
00/00/0	1348	0.3	0.6	24.6	25.2	0.3	0.10	936.28
00/00/0	1354	0.3	0.6	24.6	25.2	0.3	0.10	936.28
00/00/0	1400	0.3	0.6	24.6	25.2	0.3	0.10	936.28
00/00/0	1406	0.3	0.6	24.6	25.2	0.3	0.10	936.28
00/00/0	1412	0.3	0.6	24.5	25.2	0.3	0.10	936.28
00/00/0	1418	0.3	0.6	24.5	25.1	0.3	0.10	936.28
00/00/0	1424	0.3	0.6	24.5	25.1	0.3	0.10	936.28
00/00/0	1430	0.3	0.6	24.5	25.1	0.3	0.10	936.28
00/00/0	1436	0.3	0.6	24.5	25.1	0.3	0.10	936.28
00/00/0	1442	0.3	0.6	24.4	25.1	0.3	0.10	936.28
00/00/0	1448	0.3	0.6	24.4	25.0	0.3	0.10	936.28
00/00/0	1454	0.3	0.6	24.4	25.0	0.3	0.10	936.28

Peak inflow = 4.599999 cfs occurred at 0112 on 00/00/0
Peak outflow = .5084742 cfs occurred at 0200 on 00/00/0
Number of hydrograph points = 149
Time step = .1 hrs.
Change in storage =-.1 ac.ft.
Summation of DT * (INFLOW - OUTFLOW) = .1 ac.ft.

Penn State Urban Hydrology Model
MODULE _4-B¢ - MODIFIED PULS ROUTING

Name of reservoir or channel: RETENTION BASIN 'A' - 25 YR STOR
Filename of inflow hydrograph: A:KBWSA25.HYD
Filename of rating matrix: A:KBWSA.ESO

Date	Time	Inflow (cfs)	I1+I2 (cfs)	2ST/DT-O (cfs)	2ST/DT+O (cfs)	Outflow (cfs)	Storage (AcFt)	Elevation (ft MSL)
		0.2	0.4	0.0	0.0	0.0	0.00	936.00
00/00/0	0006	0.2	0.4	0.4	0.4	0.0	0.00	936.00
00/00/0	0012	0.2	0.4	0.8	0.8	0.0	0.00	936.01
00/00/0	0018	0.2	0.4	1.1	1.2	0.0	0.00	936.01
00/00/0	0024	0.2	0.5	1.5	1.5	0.0	0.01	936.02
00/00/0	0030	0.3	0.6	2.0	2.0	0.0	0.01	936.02
00/00/0	0036	0.3	0.9	2.5	2.6	0.0	0.01	936.03
00/00/0	0042	0.6	1.5	3.3	3.4	0.0	0.01	936.04
00/00/0	0048	0.9	2.1	4.7	4.8	0.1	0.02	936.05
00/00/0	0054	1.2	3.5	6.6	6.8	0.1	0.03	936.07
00/00/0	0100	2.3	6.6	9.9	10.1	0.1	0.04	936.11
00/00/0	0106	4.3	9.6	16.1	16.5	0.2	0.07	936.18
00/00/0	0112	5.3	9.6	25.0	25.7	0.3	0.10	936.28
00/00/0	0118	4.3	7.0	33.8	34.6	0.4	0.14	936.38
00/00/0	0124	2.7	4.5	39.8	40.8	0.5	0.17	936.45
00/00/0	0130	1.8	3.0	43.2	44.3	0.5	0.18	936.49
00/00/0	0136	1.2	2.1	45.0	46.2	0.6	0.19	936.50
00/00/0	0142	0.9	1.6	46.0	47.1	0.6	0.19	936.51
00/00/0	0148	0.7	1.4	46.4	47.6	0.6	0.19	936.51
00/00/0	0154	0.7	1.3	46.6	47.8	0.6	0.20	936.51
00/00/0	0200	0.6	1.1	46.8	47.9	0.6	0.20	936.51
00/00/0	0206	0.5	1.0	46.7	47.9	0.6	0.20	936.51
00/00/0	0212	0.5	1.0	46.5	47.7	0.6	0.19	936.51
00/00/0	0218	0.5	0.9	46.3	47.5	0.6	0.19	936.51
00/00/0	0224	0.4	0.8	46.1	47.2	0.6	0.19	936.51
00/00/0	0230	0.4	0.8	45.7	46.9	0.6	0.19	936.51
00/00/0	0236	0.4	0.8	45.4	46.5	0.6	0.19	936.51
00/00/0	0242	0.4	0.7	45.0	46.2	0.6	0.19	936.50
00/00/0	0248	0.3	0.6	44.6	45.7	0.6	0.19	936.50
00/00/0	0254	0.3	0.6	44.1	45.2	0.6	0.18	936.50
00/00/0	0300	0.3	0.6	43.6	44.7	0.6	0.18	936.49
00/00/0	0306	0.3	0.6	43.1	44.2	0.5	0.18	936.49
00/00/0	0312	0.3	0.6	42.6	43.7	0.5	0.18	936.48
00/00/0	0318	0.3	0.6	42.2	43.2	0.5	0.18	936.48
00/00/0	0324	0.3	0.6	41.7	42.8	0.5	0.17	936.47
00/00/0	0330	0.3	0.6	41.3	42.3	0.5	0.17	936.47
00/00/0	0336	0.3	0.6	40.8	41.9	0.5	0.17	936.46
00/00/0	0342	0.3	0.6	40.4	41.4	0.5	0.17	936.46
00/00/0	0348	0.3	0.6	40.0	41.0	0.5	0.17	936.45
00/00/0	0354	0.3	0.6	39.6	40.6	0.5	0.17	936.45
00/00/0	0400	0.3	0.6	39.2	40.2	0.5	0.16	936.44
00/00/0	0406	0.3	0.6	38.8	39.8	0.5	0.16	936.44
00/00/0	0412	0.3	0.6	38.4	39.4	0.5	0.16	936.43
00/00/0	0418	0.3	0.6	38.1	39.0	0.5	0.16	936.43
00/00/0	0424	0.3	0.6	37.7	38.7	0.5	0.16	936.43
00/00/0	0430	0.3	0.6	37.4	38.3	0.5	0.16	936.42
00/00/0	0436	0.3	0.6	37.0	38.0	0.5	0.15	936.42
00/00/0	0442	0.3	0.6	36.7	37.6	0.5	0.15	936.42
00/00/0	0448	0.3	0.6	36.4	37.3	0.5	0.15	936.41
00/00/0	0454	0.3	0.6	36.1	37.0	0.5	0.15	936.41

00/00/0	0500	0.3	0.6	35.8	36.7	0.5	0.15	936.40
00/00/0	0506	0.3	0.6	35.5	36.4	0.4	0.15	936.40
00/00/0	0512	0.3	0.6	35.2	36.1	0.4	0.15	936.40
00/00/0	0518	0.3	0.6	34.9	35.8	0.4	0.15	936.39
00/00/0	0524	0.3	0.6	34.6	35.5	0.4	0.14	936.39
00/00/0	0530	0.3	0.6	34.3	35.2	0.4	0.14	936.39
00/00/0	0536	0.3	0.6	34.1	34.9	0.4	0.14	936.39
00/00/0	0542	0.3	0.6	33.8	34.7	0.4	0.14	936.38
00/00/0	0548	0.3	0.6	33.6	34.4	0.4	0.14	936.38
00/00/0	0554	0.3	0.6	33.3	34.2	0.4	0.14	936.38
00/00/0	0600	0.3	0.6	33.1	33.9	0.4	0.14	936.37
00/00/0	0606	0.3	0.6	32.9	33.7	0.4	0.14	936.37
00/00/0	0612	0.3	0.6	32.6	33.5	0.4	0.14	936.37
00/00/0	0618	0.3	0.6	32.4	33.2	0.4	0.14	936.37
00/00/0	0624	0.3	0.6	32.2	33.0	0.4	0.13	936.36
00/00/0	0630	0.3	0.6	32.0	32.8	0.4	0.13	936.36
00/00/0	0636	0.3	0.6	31.8	32.6	0.4	0.13	936.36
00/00/0	0642	0.3	0.6	31.6	32.4	0.4	0.13	936.36
00/00/0	0648	0.3	0.6	31.4	32.2	0.4	0.13	936.35
00/00/0	0654	0.3	0.6	31.2	32.0	0.4	0.13	936.35
00/00/0	0700	0.3	0.6	31.0	31.8	0.4	0.13	936.35
00/00/0	0706	0.3	0.6	30.8	31.6	0.4	0.13	936.35
00/00/0	0712	0.3	0.6	30.6	31.4	0.4	0.13	936.35
00/00/0	0718	0.3	0.6	30.5	31.2	0.4	0.13	936.34
00/00/0	0724	0.3	0.6	30.3	31.1	0.4	0.13	936.34
00/00/0	0730	0.3	0.6	30.1	30.9	0.4	0.13	936.34
00/00/0	0736	0.3	0.6	30.0	30.7	0.4	0.13	936.34
00/00/0	0742	0.3	0.6	29.8	30.6	0.4	0.12	936.34
00/00/0	0748	0.3	0.6	29.7	30.4	0.4	0.12	936.34
00/00/0	0754	0.3	0.6	29.5	30.3	0.4	0.12	936.33
00/00/0	0800	0.3	0.6	29.4	30.1	0.4	0.12	936.33
00/00/0	0806	0.3	0.6	29.2	30.0	0.4	0.12	936.33
00/00/0	0812	0.3	0.6	29.1	29.8	0.4	0.12	936.33
00/00/0	0818	0.3	0.6	29.0	29.7	0.4	0.12	936.33
00/00/0	0824	0.3	0.6	28.8	29.6	0.4	0.12	936.33
00/00/0	0830	0.3	0.6	28.7	29.4	0.4	0.12	936.32
00/00/0	0836	0.3	0.6	28.6	29.3	0.4	0.12	936.32
00/00/0	0842	0.3	0.6	28.5	29.2	0.4	0.12	936.32
00/00/0	0848	0.3	0.6	28.3	29.1	0.4	0.12	936.32
00/00/0	0854	0.3	0.6	28.2	28.9	0.4	0.12	936.32
00/00/0	0900	0.3	0.6	28.1	28.8	0.4	0.12	936.32
00/00/0	0906	0.3	0.6	28.0	28.7	0.4	0.12	936.32
00/00/0	0912	0.3	0.6	27.9	28.6	0.4	0.12	936.32
00/00/0	0918	0.3	0.6	27.8	28.5	0.4	0.12	936.31
00/00/0	0924	0.3	0.6	27.7	28.4	0.4	0.12	936.31
00/00/0	0930	0.3	0.6	27.6	28.3	0.3	0.12	936.31
00/00/0	0936	0.3	0.6	27.5	28.2	0.3	0.12	936.31
00/00/0	0942	0.3	0.6	27.4	28.1	0.3	0.11	936.31
00/00/0	0948	0.3	0.6	27.3	28.0	0.3	0.11	936.31
00/00/0	0954	0.3	0.6	27.2	27.9	0.3	0.11	936.31
00/00/0	1000	0.3	0.6	27.1	27.8	0.3	0.11	936.31
00/00/0	1006	0.3	0.6	27.1	27.7	0.3	0.11	936.31
00/00/0	1012	0.3	0.6	27.0	27.7	0.3	0.11	936.31
00/00/0	1018	0.3	0.6	26.9	27.6	0.3	0.11	936.30
00/00/0	1024	0.3	0.6	26.8	27.5	0.3	0.11	936.30
00/00/0	1030	0.3	0.6	26.7	27.4	0.3	0.11	936.30
00/00/0	1036	0.3	0.6	26.7	27.3	0.3	0.11	936.30
00/00/0	1042	0.3	0.6	26.6	27.3	0.3	0.11	936.30
00/00/0	1048	0.3	0.6	26.5	27.2	0.3	0.11	936.30
00/00/0	1054	0.3	0.6	26.4	27.1	0.3	0.11	936.30

00/00/0	1100	0.3	0.6	26.4	27.0	0.3	0.11	936.30
00/00/0	1106	0.3	0.6	26.3	27.0	0.3	0.11	936.30
00/00/0	1112	0.3	0.6	26.2	26.9	0.3	0.11	936.30
00/00/0	1118	0.3	0.6	26.2	26.8	0.3	0.11	936.30
00/00/0	1124	0.3	0.6	26.1	26.8	0.3	0.11	936.30
00/00/0	1130	0.3	0.6	26.1	26.7	0.3	0.11	936.29
00/00/0	1136	0.3	0.6	26.0	26.7	0.3	0.11	936.29
00/00/0	1142	0.3	0.6	25.9	26.6	0.3	0.11	936.29
00/00/0	1148	0.3	0.6	25.9	26.5	0.3	0.11	936.29
00/00/0	1154	0.3	0.6	25.8	26.5	0.3	0.11	936.29
00/00/0	1200	0.3	0.6	25.8	26.4	0.3	0.11	936.29
00/00/0	1206	0.3	0.6	25.7	26.4	0.3	0.11	936.29
00/00/0	1212	0.3	0.6	25.7	26.3	0.3	0.11	936.29
00/00/0	1218	0.3	0.6	25.6	26.3	0.3	0.11	936.29
00/00/0	1224	0.3	0.6	25.6	26.2	0.3	0.11	936.29
00/00/0	1230	0.3	0.6	25.5	26.2	0.3	0.11	936.29
00/00/0	1236	0.3	0.6	25.5	26.1	0.3	0.11	936.29
00/00/0	1242	0.3	0.6	25.4	26.1	0.3	0.11	936.29
00/00/0	1248	0.3	0.6	25.4	26.0	0.3	0.11	936.29
00/00/0	1254	0.3	0.6	25.4	26.0	0.3	0.11	936.29
00/00/0	1300	0.3	0.6	25.3	26.0	0.3	0.11	936.29
00/00/0	1306	0.3	0.6	25.3	25.9	0.3	0.11	936.29
00/00/0	1312	0.3	0.6	25.2	25.9	0.3	0.11	936.29
00/00/0	1318	0.3	0.6	25.2	25.8	0.3	0.11	936.28
00/00/0	1324	0.3	0.6	25.2	25.8	0.3	0.11	936.28
00/00/0	1330	0.3	0.6	25.1	25.8	0.3	0.11	936.28
00/00/0	1336	0.3	0.6	25.1	25.7	0.3	0.10	936.28
00/00/0	1342	0.3	0.6	25.1	25.7	0.3	0.10	936.28
00/00/0	1348	0.3	0.6	25.0	25.7	0.3	0.10	936.28
00/00/0	1354	0.3	0.6	25.0	25.6	0.3	0.10	936.28
00/00/0	1400	0.3	0.6	25.0	25.6	0.3	0.10	936.28
00/00/0	1406	0.3	0.6	24.9	25.6	0.3	0.10	936.28
00/00/0	1412	0.3	0.6	24.9	25.5	0.3	0.10	936.28
00/00/0	1418	0.3	0.6	24.9	25.5	0.3	0.10	936.28
00/00/0	1424	0.3	0.6	24.8	25.5	0.3	0.10	936.28
00/00/0	1430	0.3	0.6	24.8	25.4	0.3	0.10	936.28
00/00/0	1436	0.3	0.6	24.8	25.4	0.3	0.10	936.28
00/00/0	1442	0.3	0.6	24.8	25.4	0.3	0.10	936.28
00/00/0	1448	0.3	0.6	24.7	25.4	0.3	0.10	936.28
00/00/0	1454	0.3	0.6	24.7	25.3	0.3	0.10	936.28

Peak inflow = 5.3 cfs occurred at 0112 on 00/00/0
Peak outflow = .5880549 cfs occurred at 0200 on 00/00/0
Number of hydrograph points = 149
Time step = .1 hrs.
Change in storage =-.1 ac.ft.
Summation of DT * (INFLOW - OUTFLOW) = .1 ac.ft.

Penn State Urban Hydrology Model
MODULE _4-B¢ - MODIFIED PULS ROUTING

Name of reservoir or channel: RETENTION BASIN 'A' - 100 YR STO
Filename of inflow hydrograph: A:KBWSA100.HYD
Filename of rating matrix: A:KBWSA.ESO

Date	Time	Inflow (cfs)	I1+I2 (cfs)	2ST/DT-O (cfs)	2ST/DT+O (cfs)	Outflow (cfs)	Storage (AcFt)	Elevation (ft MSL)
		0.2	0.5	0.0	0.0	0.0	0.00	936.00
00/00/0	0006	0.3	0.6	0.5	0.5	0.0	0.00	936.01
00/00/0	0012	0.3	0.6	1.1	1.1	0.0	0.00	936.01
00/00/0	0018	0.3	0.7	1.6	1.7	0.0	0.01	936.02
00/00/0	0024	0.4	0.8	2.3	2.3	0.0	0.01	936.03
00/00/0	0030	0.4	0.9	3.0	3.1	0.0	0.01	936.03
00/00/0	0036	0.5	1.4	3.8	3.9	0.0	0.02	936.04
00/00/0	0042	0.9	2.2	5.1	5.2	0.1	0.02	936.06
00/00/0	0048	1.3	3.1	7.1	7.3	0.1	0.03	936.08
00/00/0	0054	1.8	5.2	9.9	10.2	0.1	0.04	936.11
00/00/0	0100	3.4	9.7	14.8	15.1	0.2	0.06	936.17
00/00/0	0106	6.3	14.2	23.9	24.5	0.3	0.10	936.27
00/00/0	0112	7.9	14.2	37.1	38.1	0.5	0.16	936.42
00/00/0	0118	6.3	10.3	50.1	51.3	0.6	0.21	936.53
00/00/0	0124	4.0	6.6	58.9	60.4	0.7	0.25	936.58
00/00/0	0130	2.6	4.4	64.0	65.5	0.8	0.27	936.61
00/00/0	0136	1.8	3.2	66.7	68.4	0.8	0.28	936.62
00/00/0	0142	1.4	2.5	68.3	69.9	0.8	0.29	936.63
00/00/0	0148	1.1	2.0	69.1	70.8	0.8	0.29	936.63
00/00/0	0154	0.9	1.7	69.5	71.1	0.8	0.29	936.64
00/00/0	0200	0.8	1.6	69.5	71.2	0.8	0.29	936.64
00/00/0	0206	0.8	1.5	69.4	71.1	0.8	0.29	936.64
00/00/0	0212	0.7	1.4	69.2	70.9	0.8	0.29	936.64
00/00/0	0218	0.7	1.3	69.0	70.6	0.8	0.29	936.63
00/00/0	0224	0.6	1.2	68.6	70.3	0.8	0.29	936.63
00/00/0	0230	0.6	1.1	68.2	69.8	0.8	0.29	936.63
00/00/0	0236	0.5	1.0	67.6	69.3	0.8	0.28	936.63
00/00/0	0242	0.5	1.0	67.0	68.6	0.8	0.28	936.62
00/00/0	0248	0.5	1.0	66.4	68.0	0.8	0.28	936.62
00/00/0	0254	0.5	1.0	65.8	67.4	0.8	0.28	936.62
00/00/0	0300	0.5	1.0	65.2	66.8	0.8	0.27	936.61
00/00/0	0306	0.5	1.0	64.6	66.2	0.8	0.27	936.61
00/00/0	0312	0.5	1.0	64.1	65.6	0.8	0.27	936.61
00/00/0	0318	0.5	1.0	63.5	65.1	0.8	0.27	936.60
00/00/0	0324	0.5	1.0	63.0	64.5	0.8	0.26	936.60
00/00/0	0330	0.5	1.0	62.5	64.0	0.8	0.26	936.60
00/00/0	0336	0.5	1.0	62.0	63.5	0.8	0.26	936.60
00/00/0	0342	0.5	1.0	61.5	63.0	0.8	0.26	936.59
00/00/0	0348	0.5	1.0	61.0	62.5	0.7	0.26	936.59
00/00/0	0354	0.5	1.0	60.5	62.0	0.7	0.25	936.59
00/00/0	0400	0.5	1.0	60.0	61.5	0.7	0.25	936.59
00/00/0	0406	0.5	1.0	59.6	61.0	0.7	0.25	936.58
00/00/0	0412	0.5	1.0	59.1	60.6	0.7	0.25	936.58
00/00/0	0418	0.5	1.0	58.7	60.1	0.7	0.25	936.58
00/00/0	0424	0.5	1.0	58.3	59.7	0.7	0.24	936.58
00/00/0	0430	0.5	1.0	57.8	59.3	0.7	0.24	936.57
00/00/0	0436	0.5	1.0	57.4	58.8	0.7	0.24	936.57
00/00/0	0442	0.5	1.0	57.0	58.4	0.7	0.24	936.57
00/00/0	0448	0.5	1.0	56.6	58.0	0.7	0.24	936.57
00/00/0	0454	0.5	1.0	56.3	57.6	0.7	0.24	936.57

00/00/0	0500	0.5	1.0	55.9	57.3	0.7	0.23	936.56
00/00/0	0506	0.5	1.0	55.5	56.9	0.7	0.23	936.56
00/00/0	0512	0.5	1.0	55.1	56.5	0.7	0.23	936.56
00/00/0	0518	0.5	1.0	54.8	56.1	0.7	0.23	936.56
00/00/0	0524	0.5	1.0	54.4	55.8	0.7	0.23	936.56
00/00/0	0530	0.5	1.0	54.1	55.4	0.7	0.23	936.55
00/00/0	0536	0.5	1.0	53.8	55.1	0.7	0.22	936.55
00/00/0	0542	0.5	1.0	53.5	54.8	0.7	0.22	936.55
00/00/0	0548	0.5	1.0	53.1	54.5	0.7	0.22	936.55
00/00/0	0554	0.5	1.0	52.8	54.1	0.7	0.22	936.55
00/00/0	0600	0.5	1.0	52.5	53.8	0.7	0.22	936.54
00/00/0	0606	0.5	1.0	52.2	53.5	0.6	0.22	936.54
00/00/0	0612	0.5	1.0	51.9	53.2	0.6	0.22	936.54
00/00/0	0618	0.5	1.0	51.7	52.9	0.6	0.22	936.54
00/00/0	0624	0.5	1.0	51.4	52.7	0.6	0.21	936.54
00/00/0	0630	0.5	1.0	51.1	52.4	0.6	0.21	936.54
00/00/0	0636	0.5	1.0	50.8	52.1	0.6	0.21	936.54
00/00/0	0642	0.5	1.0	50.6	51.8	0.6	0.21	936.53
00/00/0	0648	0.5	1.0	50.3	51.6	0.6	0.21	936.53
00/00/0	0654	0.5	1.0	50.1	51.3	0.6	0.21	936.53
00/00/0	0700	0.5	1.0	49.8	51.1	0.6	0.21	936.53
00/00/0	0706	0.5	1.0	49.6	50.8	0.6	0.21	936.53
00/00/0	0712	0.5	1.0	49.4	50.6	0.6	0.21	936.53
00/00/0	0718	0.5	1.0	49.1	50.4	0.6	0.21	936.53
00/00/0	0724	0.5	1.0	48.9	50.1	0.6	0.20	936.53
00/00/0	0730	0.5	1.0	48.7	49.9	0.6	0.20	936.52
00/00/0	0736	0.5	1.0	48.5	49.7	0.6	0.20	936.52
00/00/0	0742	0.5	1.0	48.3	49.5	0.6	0.20	936.52
00/00/0	0748	0.5	1.0	48.1	49.3	0.6	0.20	936.52
00/00/0	0754	0.5	1.0	47.9	49.1	0.6	0.20	936.52
00/00/0	0800	0.5	1.0	47.7	48.9	0.6	0.20	936.52
00/00/0	0806	0.5	1.0	47.5	48.7	0.6	0.20	936.52
00/00/0	0812	0.5	1.0	47.3	48.5	0.6	0.20	936.52
00/00/0	0818	0.5	1.0	47.1	48.3	0.6	0.20	936.52
00/00/0	0824	0.5	1.0	46.9	48.1	0.6	0.20	936.51
00/00/0	0830	0.5	1.0	46.7	47.9	0.6	0.20	936.51
00/00/0	0836	0.5	1.0	46.6	47.7	0.6	0.19	936.51
00/00/0	0842	0.5	1.0	46.4	47.6	0.6	0.19	936.51
00/00/0	0848	0.5	1.0	46.2	47.4	0.6	0.19	936.51
00/00/0	0854	0.5	1.0	46.1	47.2	0.6	0.19	936.51
00/00/0	0900	0.5	1.0	45.9	47.1	0.6	0.19	936.51
00/00/0	0906	0.5	1.0	45.8	46.9	0.6	0.19	936.51
00/00/0	0912	0.5	1.0	45.6	46.8	0.6	0.19	936.51
00/00/0	0918	0.5	1.0	45.5	46.6	0.6	0.19	936.51
00/00/0	0924	0.5	1.0	45.3	46.5	0.6	0.19	936.51
00/00/0	0930	0.5	1.0	45.2	46.3	0.6	0.19	936.51
00/00/0	0936	0.5	1.0	45.0	46.2	0.6	0.19	936.50
00/00/0	0942	0.5	1.0	44.9	46.0	0.6	0.19	936.50
00/00/0	0948	0.5	1.0	44.8	45.9	0.6	0.19	936.50
00/00/0	0954	0.5	1.0	44.6	45.8	0.6	0.19	936.50
00/00/0	1000	0.5	1.0	44.5	45.6	0.6	0.19	936.50
00/00/0	1006	0.5	1.0	44.4	45.5	0.6	0.19	936.50
00/00/0	1012	0.5	1.0	44.3	45.4	0.6	0.19	936.50
00/00/0	1018	0.5	1.0	44.2	45.3	0.6	0.18	936.50
00/00/0	1024	0.5	1.0	44.0	45.2	0.6	0.18	936.50
00/00/0	1030	0.5	1.0	43.9	45.0	0.6	0.18	936.50
00/00/0	1036	0.5	1.0	43.8	44.9	0.6	0.18	936.50
00/00/0	1042	0.5	1.0	43.7	44.8	0.6	0.18	936.49
00/00/0	1048	0.5	1.0	43.6	44.7	0.6	0.18	936.49
00/00/0	1054	0.5	1.0	43.5	44.6	0.6	0.18	936.49

00/00/0	1100	0.5	1.0	43.4	44.5	0.5	0.18	936.49
00/00/0	1106	0.5	1.0	43.3	44.4	0.5	0.18	936.49
00/00/0	1112	0.5	1.0	43.2	44.3	0.5	0.18	936.49
00/00/0	1118	0.5	1.0	43.1	44.2	0.5	0.18	936.49
00/00/0	1124	0.5	1.0	43.0	44.1	0.5	0.18	936.49
00/00/0	1130	0.5	1.0	42.9	44.0	0.5	0.18	936.49
00/00/0	1136	0.5	1.0	42.9	43.9	0.5	0.18	936.48
00/00/0	1142	0.5	1.0	42.8	43.9	0.5	0.18	936.48
00/00/0	1148	0.5	1.0	42.7	43.8	0.5	0.18	936.48
00/00/0	1154	0.5	1.0	42.6	43.7	0.5	0.18	936.48
00/00/0	1200	0.5	1.0	42.5	43.6	0.5	0.18	936.48
00/00/0	1206	0.5	1.0	42.5	43.5	0.5	0.18	936.48
00/00/0	1212	0.5	1.0	42.4	43.5	0.5	0.18	936.48
00/00/0	1218	0.5	1.0	42.3	43.4	0.5	0.18	936.48
00/00/0	1224	0.5	1.0	42.2	43.3	0.5	0.18	936.48
00/00/0	1230	0.5	1.0	42.2	43.2	0.5	0.18	936.48
00/00/0	1236	0.5	1.0	42.1	43.2	0.5	0.18	936.48
00/00/0	1242	0.5	1.0	42.0	43.1	0.5	0.18	936.48
00/00/0	1248	0.5	1.0	42.0	43.0	0.5	0.18	936.47
00/00/0	1254	0.5	1.0	41.9	43.0	0.5	0.18	936.47
00/00/0	1300	0.5	1.0	41.9	42.9	0.5	0.18	936.47
00/00/0	1306	0.5	1.0	41.8	42.9	0.5	0.17	936.47
00/00/0	1312	0.5	1.0	41.7	42.8	0.5	0.17	936.47
00/00/0	1318	0.5	1.0	41.7	42.7	0.5	0.17	936.47
00/00/0	1324	0.5	1.0	41.6	42.7	0.5	0.17	936.47
00/00/0	1330	0.5	1.0	41.6	42.6	0.5	0.17	936.47
00/00/0	1336	0.5	1.0	41.5	42.6	0.5	0.17	936.47
00/00/0	1342	0.5	1.0	41.5	42.5	0.5	0.17	936.47
00/00/0	1348	0.5	1.0	41.4	42.5	0.5	0.17	936.47
00/00/0	1354	0.5	1.0	41.4	42.4	0.5	0.17	936.47
00/00/0	1400	0.5	1.0	41.3	42.4	0.5	0.17	936.47
00/00/0	1406	0.5	1.0	41.3	42.3	0.5	0.17	936.47
00/00/0	1412	0.5	1.0	41.2	42.3	0.5	0.17	936.47
00/00/0	1418	0.5	1.0	41.2	42.2	0.5	0.17	936.47
00/00/0	1424	0.5	1.0	41.2	42.2	0.5	0.17	936.47
00/00/0	1430	0.5	1.0	41.1	42.2	0.5	0.17	936.46
00/00/0	1436	0.5	1.0	41.1	42.1	0.5	0.17	936.46
00/00/0	1442	0.5	1.0	41.0	42.1	0.5	0.17	936.46
00/00/0	1448	0.5	1.0	41.0	42.0	0.5	0.17	936.46
00/00/0	1454	0.5	1.0	41.0	42.0	0.5	0.17	936.46

Peak inflow = 7.9 cfs occurred at 0112 on 00/00/0
Peak outflow = .8382187 cfs occurred at 0200 on 00/00/0
Number of hydrograph points = 149
Time step = .1 hrs.
Change in storage =-.17 ac.ft.
Summation of DT * (INFLOW - OUTFLOW) = .2 ac.ft.

⊖STAGE/DISCHARGE TABLE FOR EMERGENCY SPILLWAY - BASIN 'A'

BASIN WATER ⊖ELEVATION,ft.	BASIN OUTFLOW,cfs.	RISER BOX WATER ELEVATION,ft.	TAILWATER ELEVATION,ft.	OUTLET CULV. CONTROL
940.00	0.00	N/A	N/A	N/A
940.20	1.88	N/A	N/A	N/A
940.40	5.32	N/A	N/A	N/A
940.60	9.78	N/A	N/A	N/A
940.80	15.06	N/A	N/A	N/A
941.00	21.04	N/A	N/A	N/A

⊖OUTLET STRUCTURE GEOMETRY FOR EMERGENCY SPILLWAY - BASIN 'A'

STAGE 1 ---> EMERGENCY SPILLWAY

CREST ELEVATION = 940.00   CREST LENGTH = 8.00 ft.   DISCHARGE COEFF. = 2.630

---> NO OUTFALL CULVERT, NO OUTFALL CHANNEL, NO OUTLET STRUCTURE SUBMERGENCE

©STAGE/DISCHARGE TABLE FOR - BASIN 'B'

BASIN WATER ©ELEVATION,ft.	BASIN OUTFLOW,cfs.	RISER BOX WATER ELEVATION,ft.	TAILWATER ELEVATION,ft.	OUTLET CULV. CONTROL
931.00	0.00	930.50	N/A	N/A
931.50	0.61	930.93	N/A	ORIFICE CONT
932.00	1.44	931.15	N/A	ORIFICE CONT
932.50	2.00	931.31	N/A	ORIFICE CONT
933.00	2.48	931.39	N/A	ORIFICE CONT
933.50	4.21	931.68	N/A	ORIFICE CONT
934.00	6.90	932.02	N/A	ORIFICE CONT
934.50	8.70	932.91	N/A	ORIFICE CONT
935.00	9.47	933.29	N/A	ORIFICE CONT

©OUTLET STRUCTURE GEOMETRY FOR KRIGGER BUILDING - BASIN 'B'

STAGE 1 ---> CIRCULAR ORIFICE

INVERT ELEVATION = 931.00 DIAMETER = 0.75 ft. DISCHARGE COEFF. = 0.600

STAGE 2 ---> RECTANGULAR ORIFICE

INVERT ELEVATION = 933.00 WIDTH = 1.25 FT. HEIGHT = 1.00 ft. DISCHARGE COEFF. = 0.600

---> OUTFALL CULVERT

UPSTREAM INVERT ELEVATION = 930.50 DIAMETER = 1.25 ft. LENGTH = 57.00 ft. SLOPE = 0.0260 ft/ft.
MANNING'S n = 0.0120 ENTRANCE CONDITION = SOH, K = 0.20

---> NO OUTFALL CHANNEL

Penn State Urban Hydrology Model
MODULE _4-B¢ - MODIFIED PULS ROUTING

Name of reservoir or channel: DETENTION BASIN 'B' - 2 YR STORM
Filename of inflow hydrograph: A:KBWSB2.HYD
Filename of rating matrix: A:KBWSB.ESO

Date	Time	Inflow (cfs)	I1+I2 (cfs)	2ST/DT-O (cfs)	2ST/DT+O (cfs)	Outflow (cfs)	Storage (AcFt)	Elevation (ft MSL)
		0.1	0.2	0.0	0.0	0.0	0.00	931.00
00/00/0	0006	0.1	0.2	0.0	0.2	0.1	0.00	931.05
00/00/0	0012	0.1	0.2	0.1	0.2	0.1	0.00	931.07
00/00/0	0018	0.1	0.2	0.1	0.3	0.1	0.00	931.07
00/00/0	0024	0.1	0.2	0.1	0.3	0.1	0.00	931.07
00/00/0	0030	0.1	0.3	0.1	0.3	0.1	0.00	931.07
00/00/0	0036	0.2	0.5	0.1	0.4	0.1	0.00	931.10
00/00/0	0042	0.3	0.8	0.1	0.6	0.2	0.00	931.15
00/00/0	0048	0.5	1.2	0.2	0.9	0.4	0.00	931.25
00/00/0	0054	0.7	2.2	0.4	1.4	0.5	0.00	931.37
00/00/0	0100	1.5	4.4	0.6	2.6	1.0	0.01	931.67
00/00/0	0106	2.9	6.1	1.8	5.0	1.6	0.01	932.17
00/00/0	0112	3.2	5.2	3.9	7.9	2.0	0.02	932.56
00/00/0	0118	2.0	3.1	4.7	9.1	2.2	0.03	932.72
00/00/0	0124	1.1	1.8	3.8	7.8	2.0	0.02	932.54
00/00/0	0130	0.7	1.3	2.2	5.6	1.7	0.02	932.24
00/00/0	0136	0.6	1.0	0.9	3.5	1.3	0.01	931.91
00/00/0	0142	0.4	0.8	0.5	1.9	0.7	0.00	931.49
00/00/0	0148	0.4	0.7	0.3	1.3	0.5	0.00	931.33
00/00/0	0154	0.3	0.6	0.3	1.0	0.4	0.00	931.26
00/00/0	0200	0.3	0.6	0.2	0.9	0.3	0.00	931.22
00/00/0	0206	0.3	0.6	0.2	0.8	0.3	0.00	931.21
00/00/0	0212	0.3	0.6	0.2	0.8	0.3	0.00	931.21
00/00/0	0218	0.3	0.5	0.2	0.8	0.3	0.00	931.21
00/00/0	0224	0.2	0.4	0.2	0.7	0.3	0.00	931.18
00/00/0	0230	0.2	0.4	0.1	0.6	0.2	0.00	931.15
00/00/0	0236	0.2	0.4	0.1	0.5	0.2	0.00	931.14
00/00/0	0242	0.2	0.4	0.1	0.5	0.2	0.00	931.14
00/00/0	0248	0.2	0.4	0.1	0.5	0.2	0.00	931.14
00/00/0	0254	0.2	0.4	0.1	0.5	0.2	0.00	931.14
00/00/0	0300	0.2	0.4	0.1	0.5	0.2	0.00	931.14
00/00/0	0306	0.2	0.4	0.1	0.5	0.2	0.00	931.14

Peak inflow = 3 cfs occurred at 0112 on 00/00/0
Peak outflow = 2 cfs occurred at 0118 on 00/00/0
Number of hydrograph points = 31
Time step = .1 hrs.
Change in storage = 0 ac.ft.
Summation of DT * (INFLOW - OUTFLOW) = 0 ac.ft.

Penn State Urban Hydrology Model
MODULE _4-B¢ - MODIFIED PULS ROUTING

Name of reservoir or channel: DETENTION BASIN 'B' - 10 YR STOR
Filename of inflow hydrograph: A:KBWSB10.HYD
Filename of rating matrix: A:KBWSB.ESO

Date	Time	Inflow (cfs)	I1+I2 (cfs)	2ST/DT-O (cfs)	2ST/DT+O (cfs)	Outflow (cfs)	Storage (AcFt)	Elevation (ft MSL)
		0.2	0.4	0.0	0.0	0.0	0.00	931.00
00/00/0	0006	0.2	0.4	0.1	0.4	0.2	0.00	931.10
00/00/0	0012	0.2	0.4	0.1	0.5	0.2	0.00	931.13
00/00/0	0018	0.2	0.5	0.1	0.5	0.2	0.00	931.14
00/00/0	0024	0.3	0.6	0.2	0.6	0.2	0.00	931.16
00/00/0	0030	0.3	0.7	0.2	0.8	0.3	0.00	931.20
00/00/0	0036	0.4	1.2	0.2	0.9	0.3	0.00	931.23
00/00/0	0042	0.8	2.0	0.4	1.4	0.5	0.00	931.37
00/00/0	0048	1.2	2.9	0.6	2.4	0.9	0.01	931.61
00/00/0	0054	1.7	4.9	0.9	3.5	1.3	0.01	931.91
00/00/0	0100	3.2	9.1	2.3	5.8	1.7	0.02	932.27
00/00/0	0106	5.9	12.3	6.2	11.4	2.6	0.04	933.03
00/00/0	0112	6.4	10.2	8.9	18.5	4.8	0.06	933.53
00/00/0	0118	3.8	5.8	9.0	19.1	5.0	0.06	933.57
00/00/0	0124	2.0	3.3	7.5	14.8	3.7	0.05	933.27
00/00/0	0130	1.3	2.3	5.9	10.8	2.4	0.03	932.96
00/00/0	0136	1.0	1.8	4.1	8.2	2.1	0.03	932.61
00/00/0	0142	0.8	1.5	2.4	5.9	1.7	0.02	932.28
00/00/0	0148	0.7	1.3	1.0	3.9	1.5	0.01	932.01
00/00/0	0154	0.6	1.2	0.6	2.3	0.9	0.01	931.60
00/00/0	0200	0.6	1.1	0.4	1.8	0.7	0.00	931.46
00/00/0	0206	0.5	1.0	0.4	1.5	0.6	0.00	931.40
00/00/0	0212	0.5	1.0	0.3	1.4	0.5	0.00	931.36
00/00/0	0218	0.5	0.9	0.3	1.3	0.5	0.00	931.35
00/00/0	0224	0.4	0.8	0.3	1.2	0.5	0.00	931.32
00/00/0	0230	0.4	0.8	0.3	1.1	0.4	0.00	931.29
00/00/0	0236	0.4	0.8	0.3	1.1	0.4	0.00	931.28
00/00/0	0242	0.4	0.8	0.3	1.1	0.4	0.00	931.28
00/00/0	0248	0.4	0.8	0.3	1.1	0.4	0.00	931.28
00/00/0	0254	0.4	0.8	0.3	1.1	0.4	0.00	931.28

Peak inflow = 6 cfs occurred at 0112 on 00/00/0
Peak outflow = 5 cfs occurred at 0118 on 00/00/0
Number of hydrograph points = 29
Time step = .1 hrs.
Change in storage = 0 ac.ft.
Summation of DT * (INFLOW - OUTFLOW) = 0 ac.ft.

Penn State Urban Hydrology Model
MODULE _4-B¢ - MODIFIED PULS ROUTING

Name of reservoir or channel: DETENTION BASIN 'B' - 25 YR STOR
Filename of inflow hydrograph: A:KBWSB25.HYD
Filename of rating matrix: A:KBWSB.ESO

Date	Time	Inflow (cfs)	I1+I2 (cfs)	2ST/DT-O (cfs)	2ST/DT+O (cfs)	Outflow (cfs)	Storage (AcFt)	Elevation (ft MSL)
		0.2	0.4	0.0	0.0	0.0	0.00	931.00
00/00/0	0006	0.2	0.5	0.1	0.4	0.2	0.00	931.10
00/00/0	0012	0.3	0.6	0.1	0.6	0.2	0.00	931.16
00/00/0	0018	0.3	0.6	0.2	0.7	0.3	0.00	931.20
00/00/0	0024	0.3	0.7	0.2	0.8	0.3	0.00	931.21
00/00/0	0030	0.4	0.8	0.2	0.9	0.3	0.00	931.23
00/00/0	0036	0.4	1.3	0.3	1.0	0.4	0.00	931.27
00/00/0	0042	0.9	2.3	0.4	1.6	0.6	0.00	931.41
00/00/0	0048	1.4	3.3	0.7	2.7	1.0	0.01	931.70
00/00/0	0054	1.9	5.6	1.1	4.0	1.5	0.01	932.02
00/00/0	0100	3.7	10.4	3.0	6.7	1.8	0.02	932.39
00/00/0	0106	6.7	14.0	7.0	13.4	3.2	0.04	933.16
00/00/0	0112	7.3	11.7	9.7	21.0	5.6	0.06	933.71
00/00/0	0118	4.4	6.7	9.9	21.4	5.8	0.06	933.74
00/00/0	0124	2.3	3.8	8.2	16.6	4.2	0.05	933.40
00/00/0	0130	1.5	2.7	6.4	12.0	2.8	0.04	933.06
00/00/0	0136	1.2	2.1	4.7	9.1	2.2	0.03	932.73
00/00/0	0142	0.9	1.7	3.1	6.8	1.9	0.02	932.41
00/00/0	0148	0.8	1.5	1.6	4.8	1.6	0.01	932.13
00/00/0	0154	0.7	1.3	0.8	3.1	1.2	0.01	931.82
00/00/0	0200	0.6	1.2	0.5	2.1	0.8	0.01	931.54
00/00/0	0206	0.6	1.2	0.4	1.7	0.6	0.00	931.45
00/00/0	0212	0.6	1.1	0.4	1.6	0.6	0.00	931.42
00/00/0	0218	0.5	1.0	0.4	1.5	0.6	0.00	931.39
00/00/0	0224	0.5	1.0	0.3	1.4	0.5	0.00	931.36
00/00/0	0230	0.5	0.9	0.3	1.3	0.5	0.00	931.35
00/00/0	0236	0.4	0.8	0.3	1.2	0.5	0.00	931.32
00/00/0	0242	0.4	0.8	0.3	1.1	0.4	0.00	931.29
00/00/0	0248	0.4	0.8	0.3	1.1	0.4	0.00	931.28
00/00/0	0254	0.4	0.8	0.3	1.1	0.4	0.00	931.28
00/00/0	0300	0.4	0.8	0.3	1.1	0.4	0.00	931.28
00/00/0	0306	0.4	0.8	0.3	1.1	0.4	0.00	931.28

Peak inflow = 7 cfs occurred at 0112 on 00/00/0
Peak outflow = 6 cfs occurred at 0118 on 00/00/0
Number of hydrograph points = 31
Time step = .1 hrs.
Change in storage = 0 ac.ft.
Summation of DT * (INFLOW - OUTFLOW) = 0 ac.ft.

Penn State Urban Hydrology Model
MODULE _4-B¢ - MODIFIED PULS ROUTING

Name of reservoir or channel: DETENTION BASIN 'B' - 100 YR STO
Filename of inflow hydrograph: A:KBWSB100.HYD
Filename of rating matrix: A:KBWSB.ESO

Date	Time	Inflow (cfs)	I1+I2 (cfs)	2ST/DT-O (cfs)	2ST/DT+O (cfs)	Outflow (cfs)	Storage (AcFt)	Elevation (ft MSL)
		0.3	0.6	0.0	0.0	0.0	0.00	931.00
00/00/0	0006	0.3	0.7	0.1	0.6	0.2	0.00	931.16
00/00/0	0012	0.4	0.8	0.2	0.8	0.3	0.00	931.22
00/00/0	0018	0.4	0.9	0.3	1.0	0.4	0.00	931.26
00/00/0	0024	0.5	1.0	0.3	1.2	0.4	0.00	931.30
00/00/0	0030	0.5	1.1	0.3	1.3	0.5	0.00	931.34
00/00/0	0036	0.6	1.9	0.4	1.4	0.5	0.00	931.37
00/00/0	0042	1.3	3.3	0.6	2.3	0.8	0.01	931.59
00/00/0	0048	2.0	4.7	1.0	3.9	1.4	0.01	932.00
00/00/0	0054	2.7	8.0	2.3	5.7	1.7	0.02	932.25
00/00/0	0100	5.3	14.9	5.5	10.3	2.4	0.03	932.89
00/00/0	0106	9.6	20.0	9.6	20.4	5.4	0.06	933.67
00/00/0	0112	10.4	16.7	14.3	29.6	7.6	0.09	934.28
00/00/0	0118	6.3	9.6	15.3	31.0	7.9	0.10	934.37
00/00/0	0124	3.3	5.5	11.2	24.9	6.9	0.07	933.99
00/00/0	0130	2.2	3.9	8.2	16.7	4.3	0.05	933.40
00/00/0	0136	1.7	3.0	6.5	12.1	2.8	0.04	933.07
00/00/0	0142	1.3	2.4	5.0	9.5	2.3	0.03	932.78
00/00/0	0148	1.1	2.1	3.5	7.4	1.9	0.02	932.49
00/00/0	0154	1.0	1.9	2.2	5.6	1.7	0.02	932.24
00/00/0	0200	0.9	1.8	1.1	4.1	1.5	0.01	932.04
00/00/0	0206	0.9	1.7	0.7	2.9	1.1	0.01	931.77
00/00/0	0212	0.8	1.6	0.6	2.4	0.9	0.01	931.63
00/00/0	0218	0.8	1.5	0.5	2.2	0.8	0.01	931.58
00/00/0	0224	0.7	1.4	0.5	2.0	0.8	0.01	931.53
00/00/0	0230	0.7	1.3	0.5	1.9	0.7	0.00	931.50
00/00/0	0236	0.6	1.2	0.4	1.8	0.7	0.00	931.46
00/00/0	0242	0.6	1.2	0.4	1.6	0.6	0.00	931.43
00/00/0	0248	0.6	1.2	0.4	1.6	0.6	0.00	931.42
00/00/0	0254	0.6	1.2	0.4	1.6	0.6	0.00	931.42
00/00/0	0300	0.6	1.2	0.4	1.6	0.6	0.00	931.42
00/00/0	0306	0.6	1.2	0.4	1.6	0.6	0.00	931.42

Peak inflow = 10 cfs occurred at 0112 on 00/00/0
Peak outflow = 8 cfs occurred at 0118 on 00/00/0
Number of hydrograph points = 31
Time step = .1 hrs.
Change in storage = 0 ac.ft.
Summation of DT * (INFLOW - OUTFLOW) = 0 ac.ft.