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March 14, 1980

W11717.BO

Ms. Florence Beck Kurdle
Office of Planning and Zoning
Anne Arundel County
Arundel Center
Annapolis, Maryland 21401

Dear Ms. Kurdle:

CH2M HILL is very pleased to present this final report, "Severn Run Watershed Management Study" to Anne Arundel County. It was both a pleasure and an honor to work with the County on their first watershed management study.

This report presents one of the two major products of the study effort. The second product, flood plain plan and profile sheets, have been previously sent to the County.

The conceptual and technical information as well as the recommendations contained in the report has many applications to watershed management and can help lay the foundation for the County's continuing watershed management program.

We have enjoyed working with the County and greatly appreciate the opportunity for providing our services.

Sincerely yours,

Wesley H. Blood

Wesley H. Blood, Ph.D.
Project Director

Skip Ellis

Skip Ellis
Project Manager

cs
Enclosures

TW79/Y

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ACKNOWLEDGEMENTS

This study represents the combined efforts of many individuals either in a working or review capacity. All contributions to the study and preparation of this report are gratefully acknowledged.

Considerable information and guidance was provided by staff members from the Anne Arundel County Office of Planning and Zoning, Department of Public Works, Department of Inspections and Permits, and the Soil Conservation District. Valuable input was also obtained from the Maryland Water Resources Administration, the Maryland Geological Survey, and interested citizens of Anne Arundel County.

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This report is provided under Agreement 1084 dated March 1, 1978 between Anne Arundel County, Maryland and CH2M HILL Southeast, Inc.. The information contained herein and any conclusions or recommendations offered represent the findings and opinions of the consultant based on his knowledge and understanding of the facts as they existed at the time this report was prepared.

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Chapter 1

CHAPTER 1
INTRODUCTION

This watershed management study of Severn Run was undertaken to help fulfill the following goals:

1. Protection of human and animal life;
2. Elimination of property losses from stormwaters and floods;
3. Preservation of the natural character of streams, stream valleys, wetlands, and aquifer recharge areas;
4. Preservation of the natural aesthetics of the stream valleys, including characteristic flora and fauna; and
5. Enhancement of the watershed's water quality.
6. To act as prototype study and identify watershed management concerns on a countywide basis.

To do this, the following tasks were performed:

1. The watershed hydrology was simulated using the Soil Conservation Services (SCS) computer model TR20 for the 2-, 5-, 10-, 25-, 50-, and 100-year storms. Forty-six subbasins and 35 cross sections were used.
2. Hydraulic backwater analysis was performed, using the Corps of Engineers HEC2 model. All flows were analyzed for 22 miles of stream.
3. Based on the hydrology and hydraulic analysis, flooding problems were determined, and the 2- and 100-year storms were plotted on plan and profile sheets for existing and ultimate land use conditions. In addition, the floods that just topped existing roads and bridges were determined.
4. An inventory of physical characteristics and resources was performed, as well as biologic field work.

5. Problems were identified in four major areas: flooding, land surface erosion, stream channel erosion, and water quality and environmental concerns.

6. Various management alternatives were determined for flooding, construction site erosion, and stream channel erosion.

7. Alternatives to control the identified problems were determined, and a recommended program described.

8. A case study showing possible problems resulting from urbanization is presented. The effects of the existing Stormwater Management Ordinance and other control alternatives are discussed.

The following are not considered in detail in the study:

1. The effect of urbanization on groundwater recharge, as TR20 has no groundwater capabilities.

2. Water quality modeling or monitoring. Existing data is very limited and sampling was beyond the scope of work. Most pollution sources in Severn Run are nonpoint in nature and need detailed study.

3. Determination of the exact location, size or impacts of storm runoff control structures. This is the responsibility of the Department of Public Works in conjunction with the Soil Conservation District. However, recommendations regarding stormwater runoff controls are made.

4. Changes in land use. This is a function of the Office of Planning and Zoning. The study considers only the projected land use as determined from currently approved zoning maps, but does indicate where future land use problems may exist.

This study considers the spectrum of watershed management, covering various problems, watershed characteristics, and means to deal with some of the problems. Watershed management includes land use planning, flooding, stream channel erosion (stormwater management), land surface erosion, sedimentation, water quality, environmental features, groundwater and ecological concerns. The common thread uniting all these various concerns deals with their response to rainfall and the natural surroundings and how man's activities change this response. The study attempts to deal with these concerns in sufficient detail so that knowledgeable watershed management can be made possible.

The report consists of 12 chapters as given below:

Chapter 1	Introduction
Chapter 2	Findings and Recommendations - a summary of the most pertinent findings and recommendations of the study
Chapter 3	General Basin Description, Technical Tools and Goals - briefly describes the Severn Run watershed, computer models used, and goals of the report.
Chapter 4	Environmental Features and Land Use - describes in detail environmental features such as soils, slopes, geology, ecology, and groundwater of the watershed as well as existing and ultimate land use.
Chapter 5	Hydrology - presents the results of the hydrologic analysis of the watershed.
Chapter 6	Hydraulic Analysis - covers the hydraulic (backwater--depth of flooding, flood plain boundaries) analysis of 22 stream miles of Severn Run and its tributaries.
Chapter 7	Assessment of Problems and Opportunities - describes identified problems or opportunities related to flooding, construction site erosion, stream channel erosion, and water quality and the environment.
Chapter 8	Management Alternatives - presents possible management alternatives.

Chapter 9	Policies - reviews federal, state and county laws, ordinances and policies that impact watershed management.
Chapter 10	Evaluation Criteria - covers criteria to evaluate the management alternatives.
Chapter 11	Alternative Analysis, Recommendations and Implementation - presents an analysis of four concepts: existing ordinances and policies, new policies, highway improvements, and large scale impoundments, along with a case study showing the effects of the alternatives. The chapter also describes the recommendations of the previous chapters and identifies the key agencies to implement them, as well as approximate costs.
Chapter 12	Additional Considerations - presents ideas for future studies, water quality, and groundwater concerns.

Chapter 2

CHAPTER 2
FINDINGS AND RECOMMENDATIONS

This chapter presents a very brief summary of the more important findings and recommendations of the Severn Run Study. The chapters containing the detailed descriptions are listed.

FINDINGS

Environmental Features (Chapters 3 and 4)

Eighty-seven percent of the Severn Run Watershed is composed of soils with low or moderate runoff potential. The southeastern portion of the watershed generally has a higher runoff potential and steeper slopes than the rest of the watershed.

The watershed has an abundance of groundwater from four major aquifer formations: the Patuxent, Patapsco, Magothy, and Aquia.

A wide variety of vegetation was found. There are several small upland wetlands which exhibit different vegetation than is found in other areas of the watershed. No endangered species were found but a rare plant, the sheep laurel (Kalmia angustifolia), was observed. Also, two species that are protected in western states were observed; the stiff club moss Lycopodium obscurum and Lady's Slipper (Cypripedium).

Land Use (Chapter 4)

Eighty percent of the watershed's 24.21-square-mile area is presently undeveloped. The developed areas consist of 16 percent residential and 4 percent commercial or industrial land use. Substantial growth is expected in the vicinity of Fort Meade and the northern section of the watershed. Based on development in accordance with the zoning map and the General Development Plan, 47 percent of the land, located largely in the southeastern portion of the watershed, will remain undeveloped.

Hydrology (Chapter 5)

Input data to the hydrologic model, TR20, is given in Chapter 5. Calibration of the model was not possible because streamflow records do not exist for Severn Run. A regional analysis based on nearby gaged streams indicates that reasonable flows were simulated. Noncalibration means that the simulated flows are estimates and cannot be shown to be correct or incorrect.

A sensitivity analysis of TR20 showed it to be extremely sensitive to the antecedent moisture condition used. It was also very sensitive to the runoff curve number and time distribution of the rainfall.

The results of the simulation show extremely large increases in peak flows for future commercial and industrial areas. Peak flows within some sections of Severn Run could increase by a factor of 5.5 for the 2-year storm and 2.6 for the 100-year storm. Peak flows at the most downstream section, Route 3, do not increase appreciably because Jabez Branch, which undergoes minimal urbanization, determines the peak flows.

Hydraulics (Chapter 6 and Plan and Profile sheets)

The existing and ultimate land use condition 2-, 5-, 10-, 25-, 50- and 100-year flood elevations for 22 miles of stream were determined using HEC2. The 2- and 100-year elevations were plotted on plan and profile sheets, which have been given to the Office of Planning and Zoning. The plan and profile sheets were used in the determination of flooding problems and the flood that just tops a road or reaches a building is shown on the sheets.

Problems (Chapter 7)

Flooding, construction site erosion, stream channel erosion, and water quality and environmental concerns were the basic problems discovered during the course of the study.

Flooding. There are 13 roads and several private drives that are flooded. Of these roads (Table 2-1), Reece Road (Rt. 554), Telegraph Road (Rt. 170) and Burns Crossing Road are considered the most important, since they are the primary north-south routes through the watershed.

Other flooding problems include six houses, two trailers, and several sheds which are within the 100-year flood plain. Five houses are within the existing 100-year flood plain in the Reece Road Branch subbasin upstream of Reece Road. One house on Rogers Lane, off Telegraph Road, is flooded by Beaver Creek.

Two municipal wastewater pump houses are located in the watershed. Both are just out of the 100-year flood plain, but if more intensive urbanization than currently planned should occur upstream of the pump houses, flooding would be likely.

Table 2-1
Roadway Flooding
(See Figure 4-10)

Name of Road	Stream	Depth of Flooding For 100-Year Flood (ft) Existing	Depth of Flooding For 100-Year Flood (ft) Ultimate	Chance of Being Flooded in Any Year (%) Existing	Chance of Being Flooded in Any Year (%) Ultimate
STATE ROADS					
Telegraph Road (170)	Beaver Creek	1.2	1.7	2-4	>50
Reece Road (554)	Reece Road Br.	0.2	2.2	4-10	20-50
COUNTY ROADS					
Burns Crossing Road	Beaver Creek	1.4	2.0	4-10	20-50
Burns Crossing Road	Severn Run	1.8	3.5	4-10	>50
Old Mill Road	Severn Run	1.0	4.0	10-20	>50
New Cut Road	Broad Branch	0.5	0.6	2-4	2-4
Upton Road	Broad Branch	0.6	0.9	2-4	10-20
Lokus Road	Picture Frame Br.	-	0.3	<1	>50
Gambrills Road	Jabez Branch	1.0	1.5	4-10	4-10
Hog Farm Road	Jabez Branch	1.1	1.2	20-50	>50
Dicus Mill Road	Severn Run	3.8	5.0	4-10	10-20
Private Road	Reece Road Br.	0.8	0.9	4-10	20-50
Jackson Grove Road	Jackson Grove Br.	0.6	1.9	4-10	>50
WB&A Road	Beaver Creek	-	0.7	<1	10-20

The proposed town center west of the Penn Central railroad tracks in the Picture Frame Branch watershed will drain through two small culverts under the railroad tracks. These culverts cannot pass the increased runoff resulting from the town center, and will pond water behind the tracks. This requires either enlarging the culverts or incorporating the storage area needed for the backed-up water into the town center design as a multiple use facility. The northernmost culvert floods an area of around 3.2 acres to a depth of 5 feet, while the lower culvert floods 2.5 acres

Construction Site Erosion. Control of construction site erosion has received considerable attention following the unsatisfactory rating given the county by the Maryland Department of Natural Resources (DNR) letter dated April 20, 1979. Inadequate implementation and enforcement of sediment control plans were the main reasons for the unsatisfactory rating. It should be noted that DNR's inspection took place shortly after a major change by the county in inspection and enforcement responsibilities and procedures, and is not necessarily a true assessment of the new program.

Construction site erosion has a very high likelihood to cause in-stream problems for Severn Run, because the area planned for the heaviest urbanization has the soils with the highest erosion potential. A very rough estimate of the soil loss due to uncontrolled (i.e., no control program at all and assuming a high percentage of eroded sediment will eventually reach the stream system) construction site erosion over the next 20 years is 650,000 to 950,000 tons, or 7.8 million to 12 million cubic feet.

Stream Channel Erosion. The potential for severe stream channel erosion is great, with some tributaries possibly experiencing an increase in channel width by a factor of 8 and a doubling of Severn Run's width. It is estimated that 360,000 tons (4.3 million cubic feet) or 25 acres of land could be lost to uncontrolled (i.e., no stormwater management at all) stream channel erosion.

The estimates for construction site and stream channel erosion are probably high since natural processes will remove some of the sediment before it reaches the stream system. The heavier sediment particles will settle in the stream, while the rest are carried into the Severn River estuary. The complex tidal hydraulic and salinity regime of an estuary make it impossible to predict--without a detailed study--the effects of the sediment on the estuary. However, very heavy sediment deposits were noticed just downstream from Route 3. The sediment had formed sand bars and covered most of the stream bottom to a depth of 6 inches to a foot. Heavy sediment loads can smother bottom organisms, adversely impact fish propogation, and act to the detriment of other aquatic organisms. Preventing adverse impact of the sediment on the estuary may be the most important reason for controlling construction site and stream channel erosion.

Water Quality and Environmental Concerns. Severn Run is classified as a Class IV Recreational Trout Stream. Only sporadic water quality data exists, which makes an analysis of water quality conditions difficult. Comparing the observed data to the Maryland State standards indicated three potential problems--high water temperatures, low pH, and high fecal coliform values. The high water temperatures were caused in the past by thermal discharges from Midway Industrial Park. The industries now have holding ponds to allow the effluent to cool, but there is no existing data to evaluate their effectiveness.

The low pH values, which occur throughout the Severn Run, may be a natural condition. The observed values are just below the Maryland standards. Five of the six fecal coliform values are well in excess of the standard. Potential sources of the bacteriological contamination include: failing septic systems, leaking sanitary sewers, pumping station overflows, wild animals, and domestic animals. Failing septic systems and domestic animals with direct access to streams were observed during the course of the study. Occasional pump house overflows, as well as failing septic systems in the Ridgeway, Elmhurst, Oakdale and Clark Heights subdivisions, have been reported.

Numerous dumps are located throughout the watershed. Tributaries are filled with tires, cars, motorcycles, toys, lumber, refrigerators, and other trash resulting from dumping and a general disregard for the aesthetics of the streams. The trash can degrade and add organics and toxins to the water, which can severely stress local and downstream ecosystems.

<u>Policies</u> (Chapters 9 and 11)

Various federal, state, and county laws, ordinances and policies apply to watershed management. The problems addressed by state and county ordinances and policies are summarized in Table 2-2.

Table 2-2
Problems Addressed by Existing Ordinances and Policies

Ordinance or Policy	Problems Addressed: Flooding	Land Surface Erosion	Stream Channel Erosion	Water Quality and Environment
COUNTY				
General Development Plan	X	X	X	X
Storm Waters 16-77	X		X	
Grading and Sediment Control		X	X	
Subdivision Regulations	X			X
Zoning Ordinance	X		X	X
Storm Water Management Order No. 1	X			
STATE				
Sediment Control Act		X	X	
Watershed Management Policy	X	X	X	X
Construction on Flood Plains	X		X	X

X indicates that ordinance addresses problem.

RECOMMENDATIONS (Chapters 11 and 12)

The recommendations presented in this study are based on a consultant's viewpoint of problems noted within the Severn Run watershed and the county as a whole. The county should decide which recommendations warrant implementation, then initiate appropriate programs or changes.

Those recommendations that the consultant feels are most important will be given first, followed by recommendations for each problem area and general recommendations. For the sake of completeness within each section, some repetition may occur.

Priority Recommendations

The most essential recommendations to consider are:

1. An active, multiagency and broad-based watershed management program should be formed that will consider all the topics discussed in this report. The program should be under the leadership of the Office of Planning and Zoning, which has already undertaken the appropriate steps to begin such a program. Other participants should include the Department of Public Works, the Department of Inspections and Permits, the Public Health Department, a staff member from the Baltimore Regional Planning Council 208 program, interested citizens, appropriate state agencies, the Soil Conservation District, and other desired groups.

   The purpose of the watershed management program would be to ensure that decisions and plans for the county take full consideration of watershed problems and characteristics. A key element of the program is the commitment to provide a trained staff knowledgeable in watershed concerns and the necessary computer simulation models. The Department of Public Works and the Office of Planning and Zoning should have such personnel on a permanent staff basis. The single most important aspect of a watershed management program is the dedication and desire of all involved to work together to preserve and protect the county's watershed resources. A program that just "goes through the motions" will not succeed, while a program that embodies the spirit of watershed management will.

2. Several roads and homes are flooded. Corrective action must be taken to ensure the protection of the county's citizens--its most important resource.

3. The stormwater ordinance needs substantial revision to fulfill its goal of protecting citizens from flood hazards and preventing stream channels from erosion beyond natural conditions.

4. A stormwater management program that allows onsite, offsite, or regional controls should be considered. The effects of controls on downstream flows must be taken into account.

5. The county's sediment control program must continue to improve. The intent of the State's and County's sediment control laws can be fulfilled. To help achieve this goal, Public Works and Capital Improvement Projects should be treated the same as all other projects especially regarding inspection and enforcement procedures.

6. An active public education program regarding water quality and ecology must be initiated. The adverse impacts of trash dumps and litter in streams must be stressed, as well as the need for preserving upland swamps that provide unique ecological systems.

7. Future efforts should include water quality and other watershed studies.

Flooding

Improvements as given in Table 2-3 should be made for Reece Road (Rt. 554), Telegraph Road (Rt. 170), and Burns Crossing Road to enable them to safely pass floodwaters. Due to the large number of homes that are flooded by the restrictive culvert, Reece Road improvements should have

Table 2-3
Summary of Recommended Roadway Improvements

Road	Stream	Necessary Increase in Culvert Opening (sq ft)	Necessary Increase in Top of Roadway Elevation (ft)	Resultant Increase in Flow Capacity (cfs)
STATE ROADS				
Reece Road	Reece Road Branch	79	-	475
Telegraph Road	Beaver Creek	74	1.2	690
COUNTY ROADS				
Burns Crossing Road	Severn Run	255	2.2	2150
Burns Crossing Road	Beaver Creek	87	-	450

the highest priority. Telegraph Road and Burns Crossing Road will require that the road be raised and the culvert under the road increased in size.

Despite these improvements, two houses, two trailers, and a barn will still be within the 100-year flood plain. The trailers should be moved to higher ground. One of the houses (Rogers Lane) is on the fringe of the flood plain, so minor flood proofing or flood insurance should be considered. The other house (Reece Road Branch) is well within the flood plain. Purchase of the house by the county, flood proofing, and/or flood insurance are the more feasible alternatives.

The county should consider modifying the subdivision regulations to ban development within the ultimate land use 100-year flood plain for those areas that have undergone detailed hydrologic and hydraulic studies. The Stormwater Ordinance should be changed to allow onsite, offsite, in-stream or off-stream flood control structures and alternatives. The proposed town center will need to provide for the required storage volume of the water impounded by the restrictive railroad culverts, approximately 3.2 acres for the northernmost culvert and 2.5 acres for the lower culvert.

Construction Site Erosion

Recommendations from DNR, the county's 208 Soil Erosion Committee, and this report should be given serious consideration. Specific recommendations of this study include:

1. The number of unscheduled construction site inspections should be increased. This requires that manpower requests be met.

2. The Grading and Sediment Control Ordinance should be revised to require that Anne Arundel County Capital Improvements and Public Works Projects be treated like all other projects. This is the case with the Stormwater Ordinance. All sediment control plans should undergo the same review, inspection, and enforcement procedures. Complete inspection responsibility should be shifted to the Department of Inspections and Permits.

3. An index to the Grading and Sediment Control Ordinance would be helpful. Provisions for construction site entrance mud and dirt removal should be included for sites near environmentally sensitive areas.

4. Sediment control plans should be more preventive than curative. Stopping or reducing erosion by proper planning and vegetative measures is more desirable than the sole use of straw bales or settling basins to trap eroded sediment. Inherent in this philosophy is minimizing the amount of land bared of vegetation.

5. The Grading and Sediment Control Ordinance should be revised to include the Office of Planning and Zoning's Environmental Resources Section as a reviewing agency for development on slopes greater than 15 percent. This approval would ensure that small developments on steep slopes do not adversely impact critical areas or unique ecologic systems. Also, revisions to the Subdivision Regulations which would prohibit construction on steep slopes without retaining a ground cover buffer zone should be considered.

<u>Stream Channel Erosion</u>

The most important improvement that could be made is control of 100 percent of the increase in the flow of the 2-year storm, rather than the current 70 percent control. Other recommendations are:

1. Onsite, offsite and regional controls should be allowed. Regional offsite controls could serve several developments, either existing or planned, and would be funded by the county. Eventual users would contribute to a regional offsite management

program as their developments are built. Multiple use facilities could be encouraged by the regional offsite management program.

2. The effect of control measures on downstream peak flows should be considered in the design and choice of control alternatives.

3. Hydrographs, rather than just peak flows, will be required to allow for detailed reservoir routing. TR20 or other acceptable methods of obtaining runoff hydrographs should be used.

4. The Department of Public Works and the Office of Planning and Zoning should become familiar with hydrologic and hydraulic modeling and analysis techniques.

Water Quality and Environmental Concerns

The programs of the Office of Planning and Zoning and the 208 agency should be given continued support. A water quality study that obtains physical-chemical and biological data should be initiated for the Severn Run.

If the number of dumps and amount of litter were reduced, the aesthetic value of the Severn Run and its tributaries would greatly improve. The general public should be advised that our streams are not garbage receptacles, but are instead a valuable resource that must be protected.

A means of preserving the unique biota of some of the upland swamps should be determined. One suggestion is the inclusion of these areas as open space in low-density residential developments.

The Subdivision Regulations should be modified to prevent the clearing of trees adjacent to streams, particularly for headwater tributaries which often are not subject to the ban on development within the 100-year flood plain.

Exceptions to the rule should allow for the development of stream valley parks and recreational areas. Clearing trees raises the temperature of the water and stresses the fish population.

General

General recommendations include:

1. The Anne Arundel Office of Planning and Zoning is the appropriate lead agency to coordinate watershed management studies.

2. Future studies should be conducted. The next watershed should have a gaged stream so that the hydrologic computer model used may be calibrated. The use of a continuous hydrologic model should be considered, along with the development of a methodology to address the needs of the Department of Public Works and the Soil Conservation District.

3. The Office of Planning and Zoning and the Department of Public Works should make a commitment to training permanent staff in the theory and use of appropriate computer models (TR20 and HEC-2). A staff member of the Environmental Resources Section should be provided to run the models in conjunction with a staff member from the Department of Public Works.

4. The Office of Planning and Zoning should follow up watershed management studies with water quality studies designed to obtain adequate data to determine problems, pollution sources, and possible control alternatives. Nonpoint sources as well as point sources should be considered. Computer modeling may or may not be a part of a water quality study, depending upon the goals and needs of the study.

5. Groundwater is an abundant resource in Anne Arundel County that needs to be properly managed. Potential problems include saltwater intrusion into the Magothy aquifer and reduction in recharge potential for all aquifers due to urbanization, both within and outside of the county. A potential also exists for pollution

of some aquifers from failing septic systems, improperly designed and operated landfills, and wastewater injection. Anne Arundel County should continue to study its groundwater system and implement comprehensive management of its primary potable water source.

6. Current county and state laws call for county government agencies to perform a majority of the design, review, approval, inspection and enforcement of the numerous programs that influence watershed management. The appropriate agencies must carry out and follow through on their existing responsibilities and those additional responsibilities they may acquire in the future.

IMPLEMENTATION AND COSTS

The agencies and their areas of concern for implementing the recommendations are summarized in Table 2-4.

A detailed breakdown of costs is presented in Table 11-12. It is anticipated that the following costs could be incurred to implement the recommendations of this report.

Item	Approximate Cost
Roadway Improvements	
State	$ 304,000
County	579,000
Manpower additions, training, and ordinance revision	$ 233,230
Additional studies or programs	68,266
TOTAL	$1,184,496

Table 2-4
Summary of Areas of Concern and Appropriate Agencies

	Agencies of Concern							
Area of Concern	Office of Planning and Zoning	Department of Public Works	Department of Inspections and Permits	Soil Conservation District	County 208 Program	Maryland Department of Natural Resources	Health Department	State Highway Department
Roadway Improvements	P	P						P
Houses in Flood Plain	P	P	S					
Subdivision Regulations	P		S					
Grading and Sediment Control Ordinance	S	P	P	P	S	S		
Sediment Inspection Procedures	S	S	P	S	S	S		
Sediment Control Plans	S	P	S	P	S	S		
Stormwater Ordinance	P	P	P	P	S	S		
Future Water Quality Studies	P	S	S	S	P	S	P	
Environmentally Sensitive Areas	P	S	S	S	S	P		
Future Watershed Studies	P	P	S	S	S	S	S	S
Watershed Management Program	P	P	P	P	P	S	S	S

P = primary interest or responsibility
S = secondary interest or responsibility

Chapter 3

CHAPTER 3
GENERAL BASIN DESCRIPTION, TECHNICAL TOOLS, AND GOALS

BASIN DESCRIPTION

Location

The Severn Run watershed is located in the northwestern portion of Anne Arundel County, Maryland. The watershed is approximately 4 miles south of Baltimore-Washington International Airport, 14 miles northwest of Annapolis, and 23 miles northeast of Washington, D.C.. Severn Run is the primary source of fresh water inflow to the Severn River, a tidal estuary of the Chesapeake Bay. Severn Run watershed has an area of approximately 24.2 square miles or 15,500 acres. Figure 3-1 is a general location map of the watershed.

The watershed's boundary is roughly defined by Route 3 on the east and Route 175 on the south. Route 175 and Fort George Meade establish the western boundary, while the northern boundary is generally comprised of Severn Road and Clark Station Road.

Topography

The elevation within the watershed ranges from 5 feet to 283 feet, with an overall channel slope of 0.55 percent. A majority of the watershed has a slope of less than 5 percent, although there are areas beside the stream channels in the southeastern section of the watershed with slopes in excess of 15 percent.

Soils

The watershed is generally divided into two areas with predominant soil types. The southeastern section consists mainly of Sassafras and Rumford soils which belong to the Soil Conservation Service hydrologic soil group B classification. These soils have moderate infiltration rates when thoroughly wetted. On the other hand, group A soils, which comprise a majority of the rest of the watershed, have high infiltration rates even when thoroughly wetted. The group A soils are primarily of the Evesboro classification and have a lesser runoff potential than group B soils.

Stream System

Figure 3-2 shows the Severn Run watershed boundaries and stream system. The main channel of the Severn Run is approximately 9 miles in length, originating from Lake Marion in the northwest section of the watershed. There are six major tributaries to the Severn Run, with Jabez Branch in the southeast portion of the basin having the largest tributary area.

Development

The General Development Plan for Anne Arundel County intends to leave the southeast section of the watershed generally undeveloped. The remainder of the watershed will consist primarily of residential land use, with some commercial and industrial centers.

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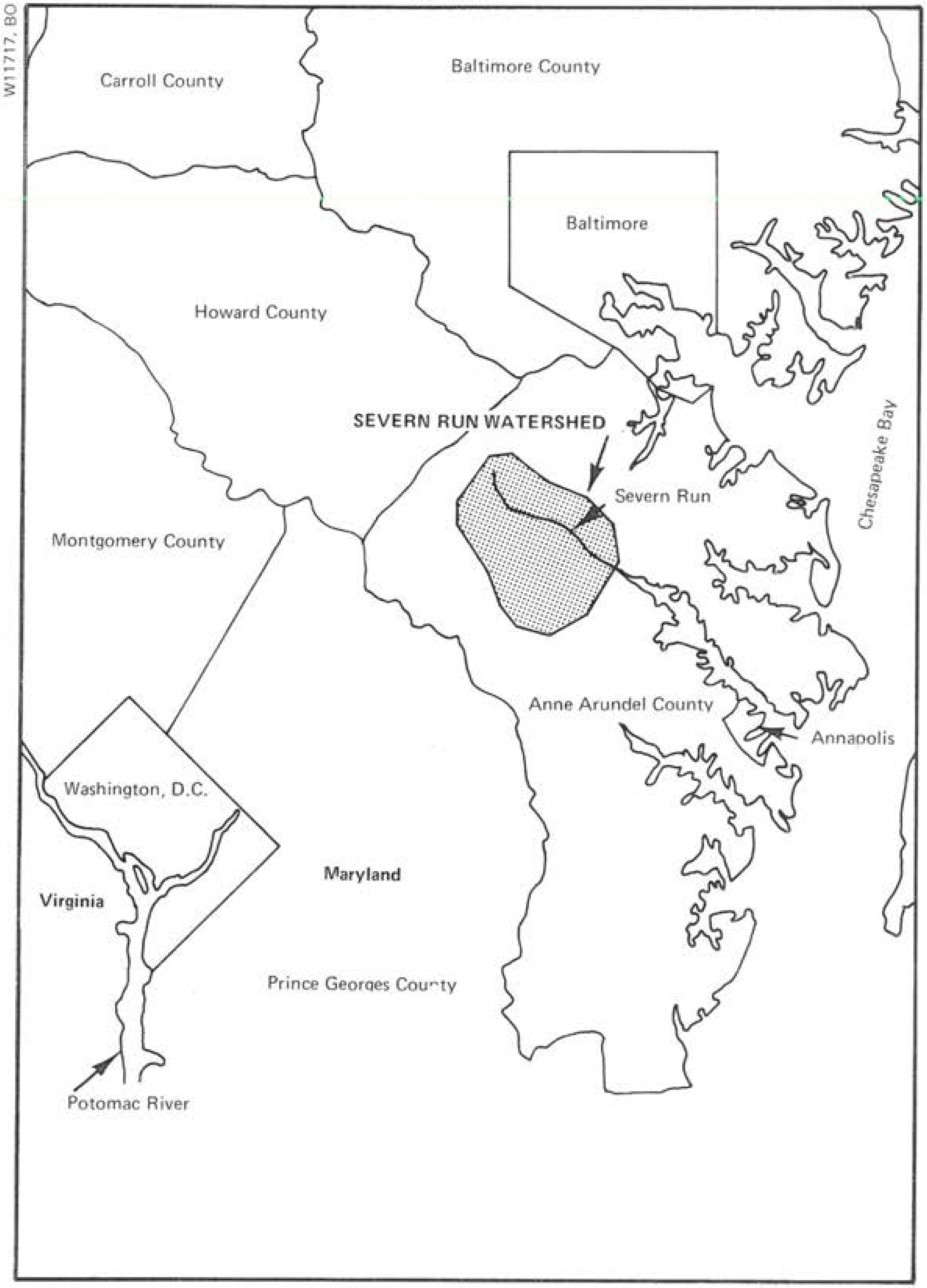

FIGURE 3-1: General Location Map of Severn Run Watershed

TECHNICAL TOOLS

Hydrology

Flood flows are a necessary element of a watershed management study and are obtained by computer simulation of the hydrologic process (Figure 3-3) or from long-term streamflow records. A computer model was used in this study for three primary reasons:

1. Severn Run is not gaged, so no streamflow records exist.
2. Estimates of the hydrologic impacts of future land use conditions were desired.
3. The effectiveness of many control alternatives can be determined.

The Soil Conservation Service's Technical Release No. 20, "Computer Program for Project Formulation Hydrology, TR20" was used as the hydrology model. TR20 is a single event, rainfall-to-runoff computer model. Its major input data consist of the area, time of concentration and curve number for each subbasin and either a stage-discharge relationship for stream cross sections or a routing coefficient. Curve numbers, which are based on land use and soil types, determine the amount of rainfall that becomes overland flow. TR20 does not explicitly consider evaporation, transpiration, interflow or groundwater flow.

In order to apply TR20 to the Severn Run watershed, numerous smaller subbasins had to be established as well as stream cross sections. Forty-six subbasins, shown in Figure 3-4, were used to accurately reflect the changes that future development will have on the flood flows. Thirty-five stream cross sections were used to account for channel routing effects on the flood peaks. These cross sections were taken from the 175 cross sections used in the hydrulic analysis.

The hydrologic simulation schematic of the watershed is given in Figure 3-5. The schematic and the subbasin map are invaluable aids in interpreting the results of the hydrology simulation, and will be frequently referenced.

Hydraulics

Hydraulic analyses were performed to determine flood elevations along each stream studied. Flood elevations were simulated using the U.S. Army Corps of Engineers HEC-2 computer program.

The required information used by the HEC-2 program includes the following:

A. Description of Floodplain

1. Valley cross section geometry
2. Bridge geometry
3. Roughness values (Manning's "n")
4. Length and slope between cross sections

B. Description of Flood

1. Peak flood discharge for each recurrence interval of interest
2. Starting water surface elevation

The HEC-2 program progresses upstream in determining the total flow energy (for subcritical flow) by applying Bernoulli's Theorem at each cross section. Bernoulli's

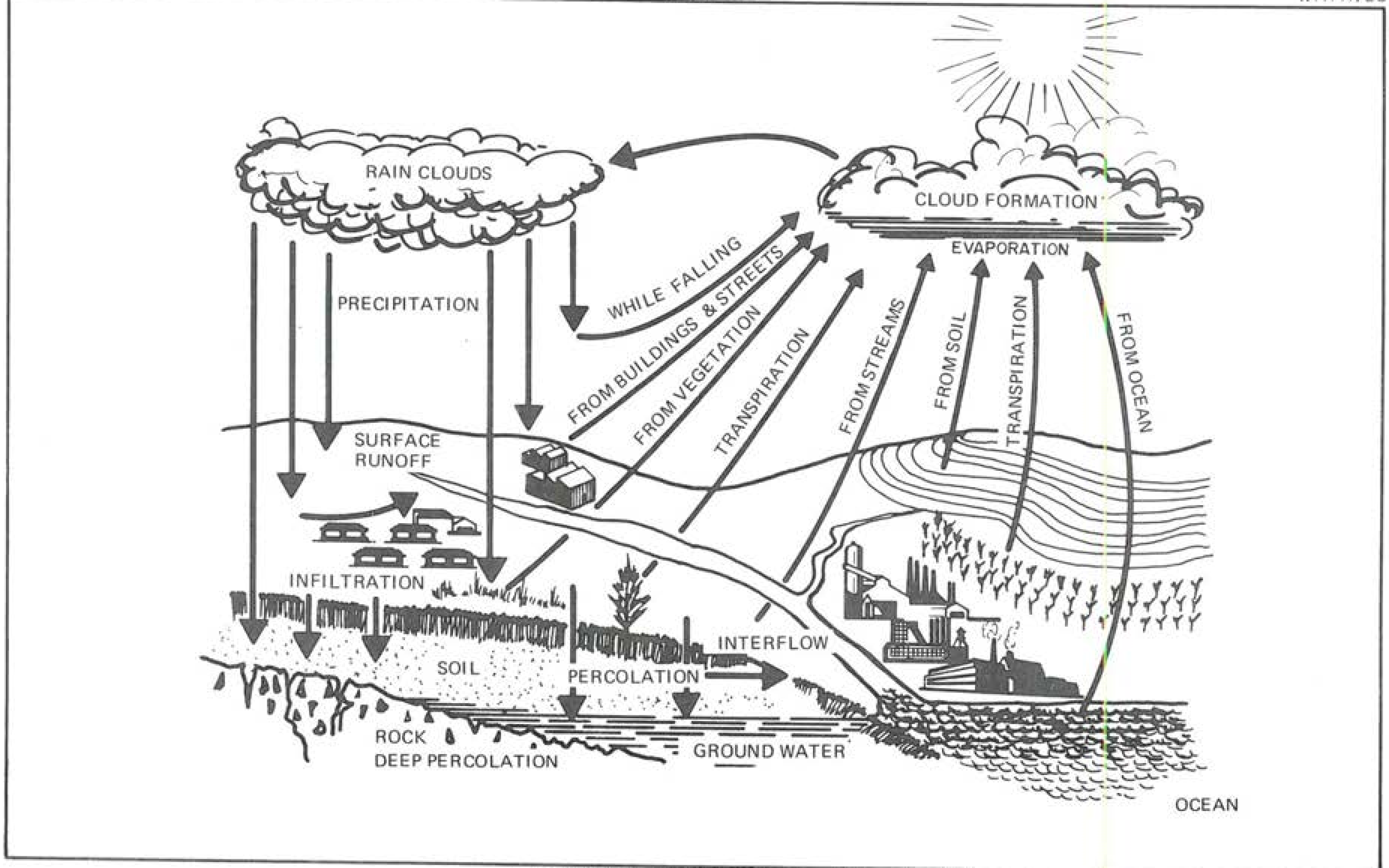

FIGURE 3-3: Hydrologic Cycle – Urban Condition

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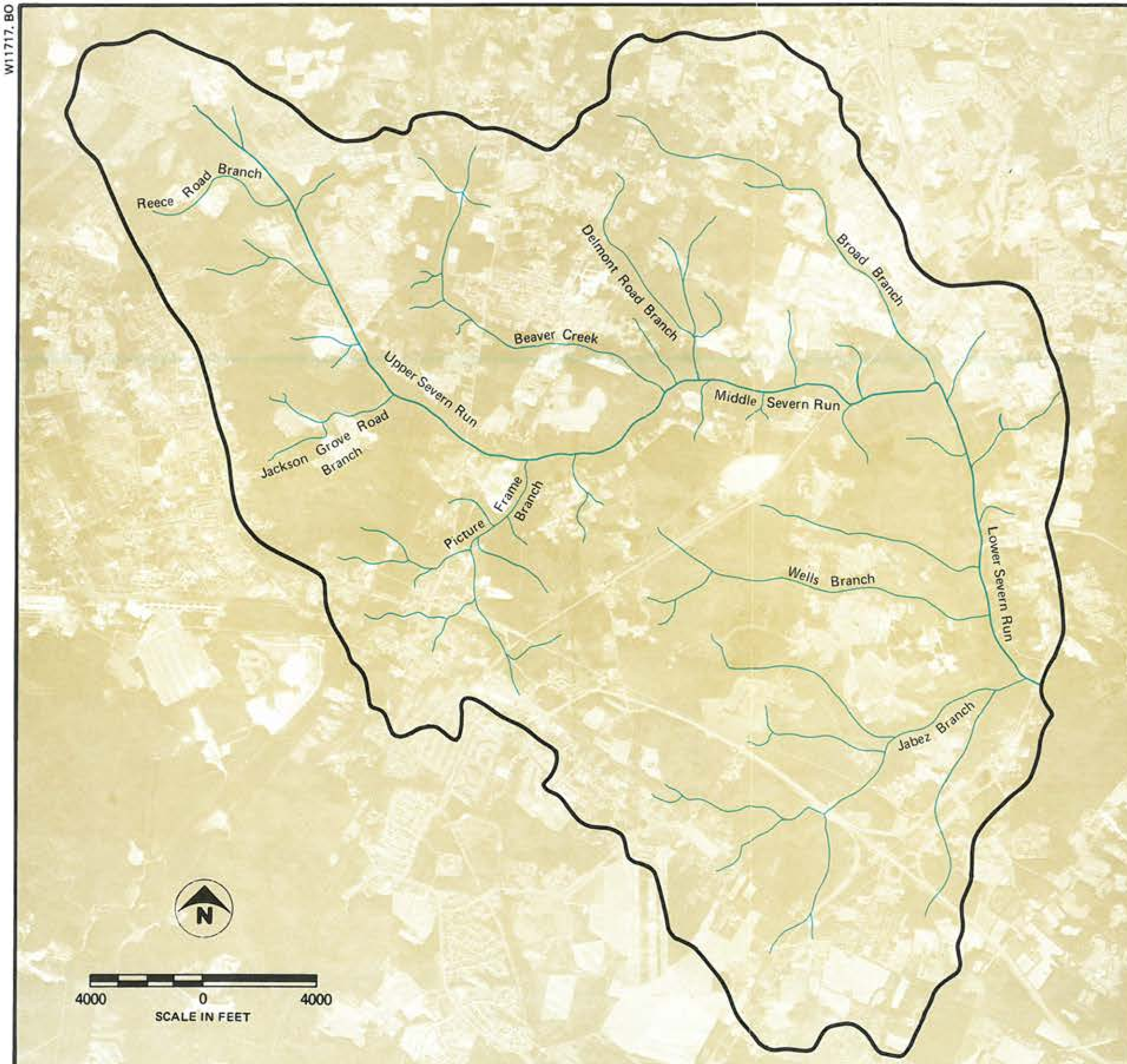

FIGURE 3-2: Severn Run Watershed And Stream System

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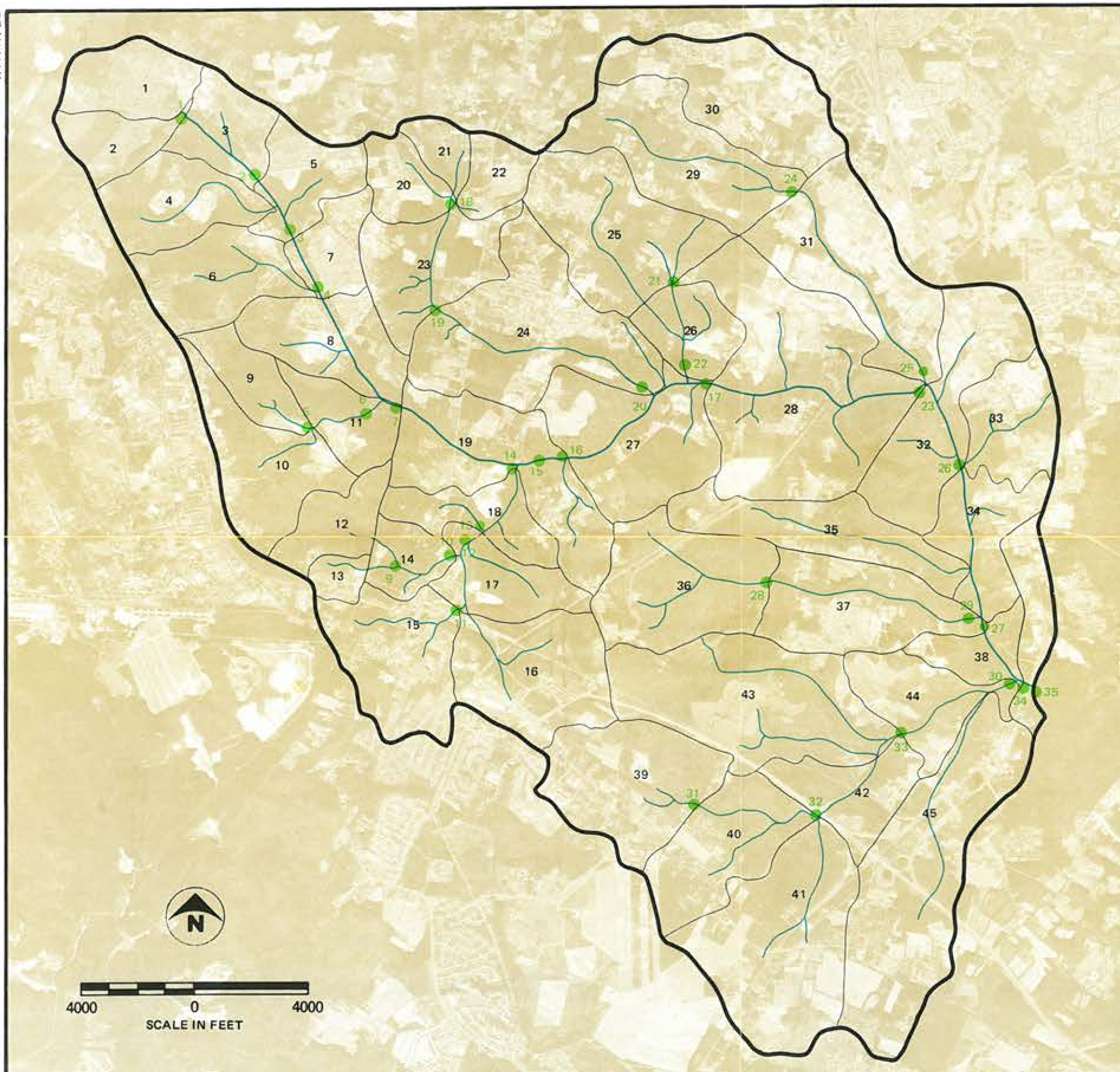

SUBBASINS AND CROSS SECTIONS

LEGEND

1 ● TR-20 Stream Cross Sections

1 Subbasin Number

FIGURE 3-4: Hydrology Subbasin Map

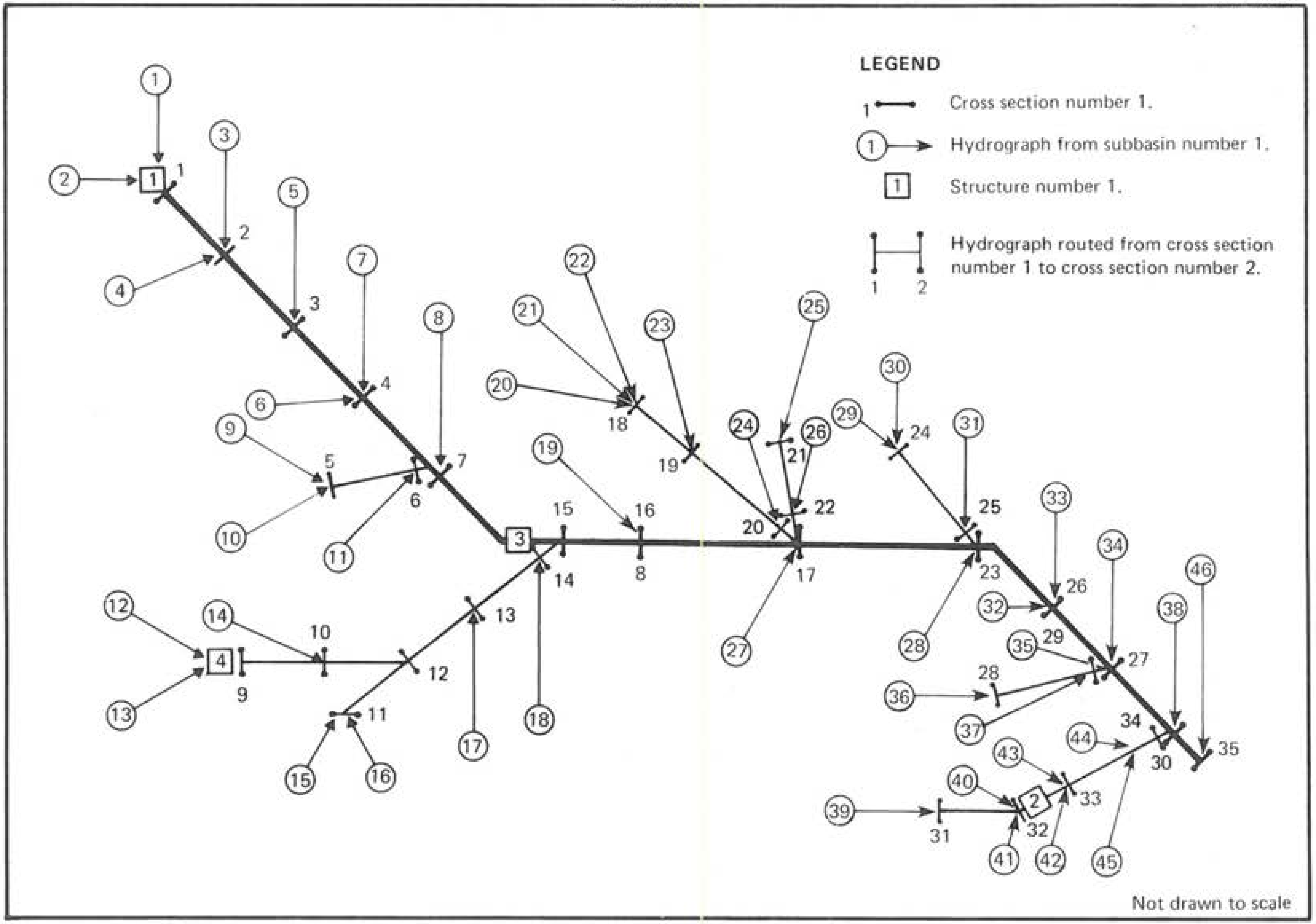

FIGURE 3-5: Hydrologic Model Schematic of Severn Run

Theorem describes how the nature of the energy balances for the flow. Friction head losses between cross sections are computed using Mannings's formula, which relates flow to channel cross sectional area, hydraulic radius, the slope of the energy grade line, and a roughness coeffecient. Energy losses other than friction are also considered. At bridges or other flood plain obstructions, HEC-2 has the capability of applying weir flow and pressure flow computations in addition to the normal flood plain routing. The principal output from HEC-2 is water surface elevations for the flows considered at each cross section. Flood elevations between cross sections are interpolated to produce a continuous flood profile.

HEC-2 is an excellent tool for testing hypothetical changes in the watershed being studied. After the program is set up for existing conditions, future conditions can be analyzed with a minimum of effort. Changing flood flows for future land use, removing or rearranging bridges, straightening or clearing the channel, widening culverts and filling in parts of the flood plain are some of the changes which could be considered.

A more complete discussion of the hydraulic analyses follows in Chapter 6.

Flood Plain Mapping

Flood plains are the land areas adjoining a stream or watercourse which become inundated during or after a storm. Flood plain delineation is a prerequisite to any management strategy designed for the protection of watersheds. Such mapping delineation not only defines present and potential problem areas, but also allows for their regulation and management, thereby precluding expensive public works or disaster relief measures.

A sound flood plain management program will provide for:

1. Protection of life, health and general welfare of the residents of the watershed;
2. Reduction in losses to public and private property;
3. Reduction in surface and underground water pollution;
4. Reduction of flood damages (which can reduce local taxes); and
5. Enhancement of the environmental integrity of the area.

Flood plain maps have been prepared for major streams within the Severn Run watershed and, by reference, are incorporated as a part of this study. A typical flood plain map shows streambed profiles, location and hydraulic characteristics of structural crossings (bridges), water surface profiles, and areas inundated by 2-year and 100-year water surface profiles. Profiles were also computed for 50-year, 25-year, 10-year and 5-year design floods. Figure 3-6 shows the steps involved in preparing flood plain maps depicting existing and ultimate land use conditions. These flood plain maps are available for review at the Office of Planning and Zoning. Figure 3-7 shows the streams studied in Severn Run for which flood plain maps were prepared, and provides an index to the flood plain maps.

GOALS AND OBJECTIVES OF WATERSHED PLANNING

Goals and policies for Anne Arundel County are contained in Resources for Future Growth and the General

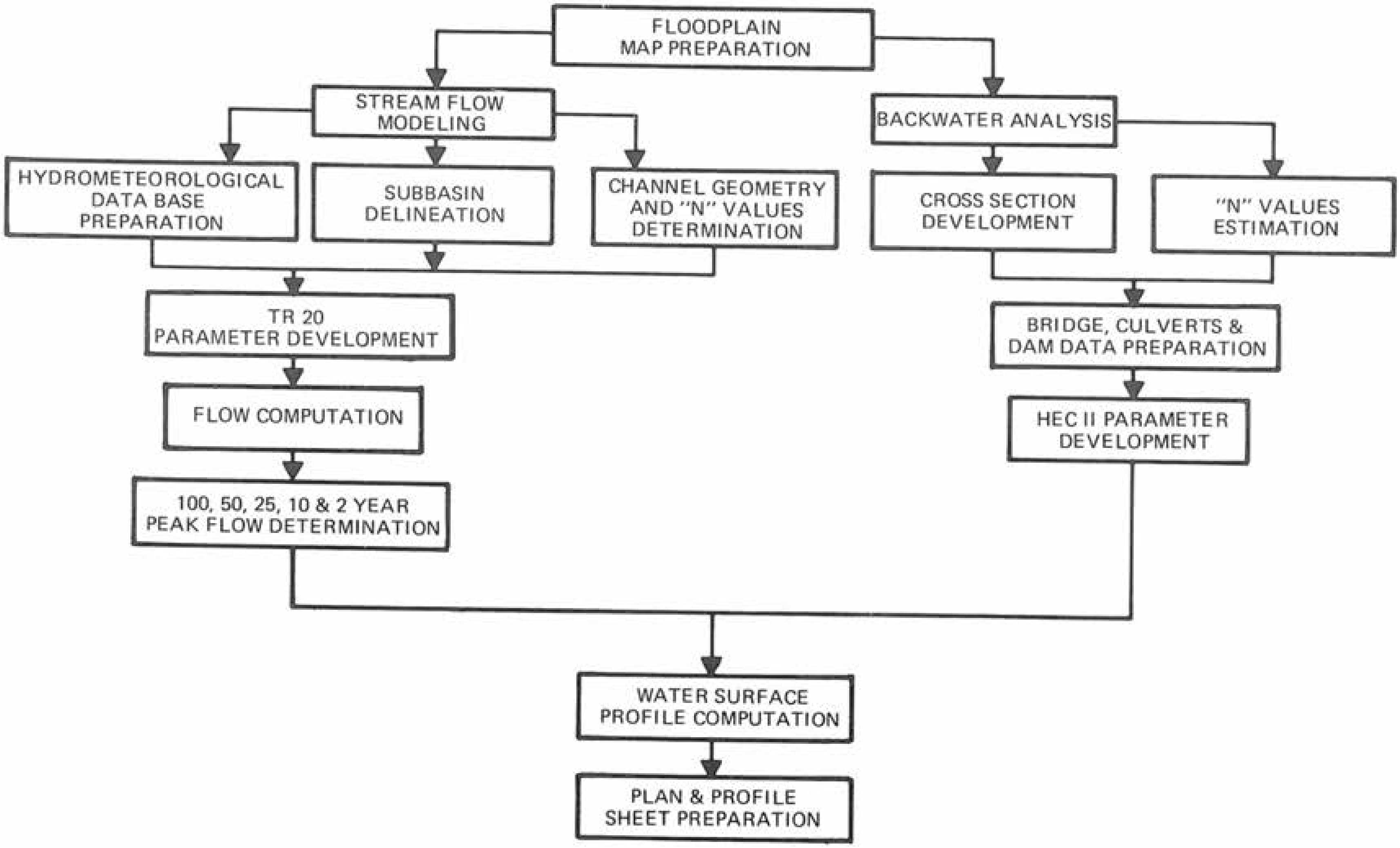

FIGURE 3-6: Floodplain Map Preparation Diagram

Development Plan of 1978. The goals cover a wide range of social, economic and environmental considerations. A watershed management plan should also consider the same issues.

Specific objectives of the Severn Run Watershed Management Study are:

1. Protection of Public Health, Safety and Welfare.

   - Protection of human life and reduction of property losses from stormwater and floods.

   - Reduction of soil erosion and sedimentation resulting from development and agricultural activities.

   - Management of flood plains to restrict development within the 100-year flood plain.

   - Enhancement of water quality.

2. Conservation of Aesthetic and Environmental Qualities

   - Maintenance and/or improvement of the ecological balance of the existing environment.

   - Conservation to the greatest degree feasible of the natural character of streams, stream valleys, wetlands and aquifer recharge areas.

   - Preservation of the natural beauty of stream valleys and unique archaeological, historic, architectural and geologically significant areas. Enhancement of habitat for flora and fauna with regard for their position in the ecosystem.

   - Reclamation of natural floodways, sediment deposition zones and aquifer recharge areas in those places where inappropriate development has occurred or is anticipated.

3. Development of Resources and Protection of Opportunities.

- o Creation of areas for fishing, swimming, and other recreational pursuits.
- o Control of stormwater through land use policies and regulations in areas subject to future inundation, with emphasis on preventive measures such as zoning, subdivision regulations, building codes, development policies, open space, tax incentives, and conservation easements.
- o Where man-made impoundments are necessary or desirable, designing them as multiuse facilities, taking full advantage of their recreational and aesthetic values, as well as their flood control value. Special attention should be given to the use of water as an enhancement of the natural and man-made environment.

4. Guidance to Land Use Policies and Regulations.

- o Use of the watershed management plan as a basis for land planning and regulation.
- o Development of watershed models to identify areas which should not be developed, and to identify stormwater management problems and/or requirements.
- o Assistance in the development and amendment of master and sector plans which are more sensitive to the environmental impact of alternative densities and uses.
- o Provision of data on which to base acquisition of stream valley parks and development of other recreational activities.
- o Provision of the factual and conceptual basis for modification, as necessary, of zoning laws, subdivision regulations and other local or state codes pertaining to stormwater, erosion and sediment control.
- o Provision of the information and local policies needed to coordinate and implement the National Flood Insurance Program in Anne Arundel County.

5. Guidance to Capital Projects Programming.

Chapter 4

CHAPTER 4
ENVIRONMENTAL FEATURES AND LAND USE

GEOPHYSICAL DATA

Soils

Soils data was obtained from the 1973 Anne Arundel County Soil Survey conducted by the Soil Conservation Service. Hydrologically, the Soil Conservation Service (1972) defines and classifies soils in four groups as follows:

Group A. "(Low runoff potential). Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravels. These soils have a high rate of water transmission.

Group B. Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

Group C. Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.

Group D. (High runoff potential). Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission."

Infiltration rate is the rate at which water enters the soil from the soil surface while transmission rate is the rate at which water moves within the soil.

The soil types found within the Severn Run watershed and their associated hydrologic soil group are given in Table 4-1. The predominant soils are Sassafras, Rumford, and Evesboro. Figure 4-1 is a map of the watershed by hydrologic soil group, while Table 4-2 gives the percent of each soil group for the various subbasins. Forty-three percent of the basin is comprised of soil group A, and 44 percent is group B. Over 85 percent of the basin has soils with moderate to high infiltration rates. Notice in Figure 4-1 that most of the group B soils are located in the Jabez Branch drainage area. The impact this has on stormwater runoff will be discussed in Chapter 5.

Table 4-1
Hydrologic Soil Groups for Soil Types
Within the Severn Run Watershed

Group A	Group B	Group C	Group D
Evesboro	Adelphia	Beltsville	Bibb
	Collington	Butlertown	Elkton
	Klej	Chillum	Fallsington
	Matapeake	Christiana	Osier
	Muirkirk	Croom	Shrewsbury
	Rumford	Donlonton	
	Sassafras	Keyport	
		Mattawan	
		Mattapex	
		Woodstown	

Slopes

The slopes within the watershed were determined by using the Soil Survey, USGS quad sheets, the county

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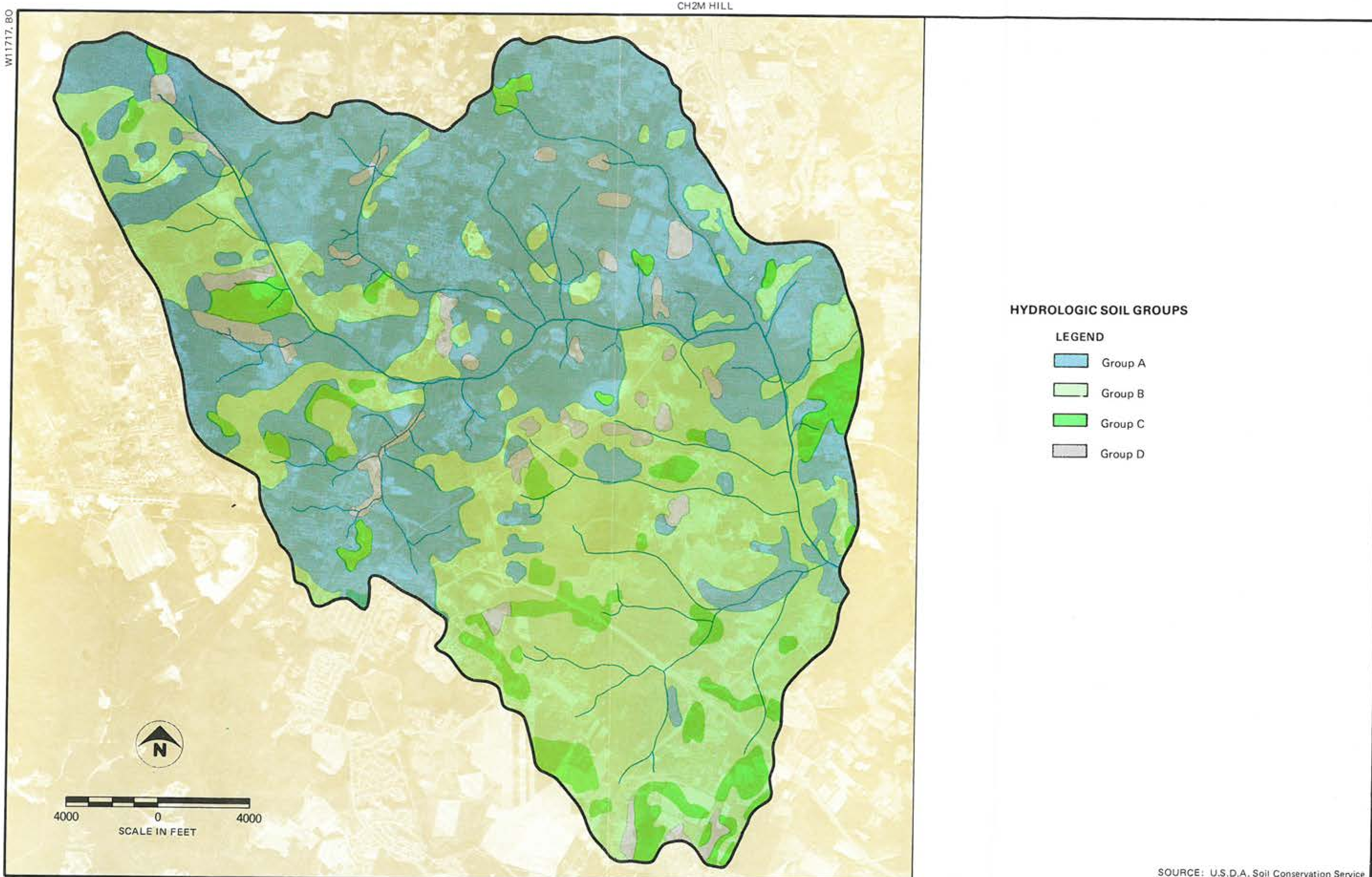

FIGURE 4-1: Soils Map

Table 4-2
Soils and Slope Data

Subbasin Number	Area (Square Miles)	Soils: Group A (percent)	Soils: Group B (percent)	Soils: Group C (percent)	Soils: Group D (percent)	Slope: 0-5%	Slope: 5-10%	Slope: 10-15%	Slope: Greater Than 15%
1	0.41	88	4	7	1	78	22		
2	0.18	23	43	23	11	68	12	7	3
3	0.32	70	25		5	28	68	4	
4	0.50	42	46		12	85	5	4	6
5	0.25	89	11			64	36		
6	0.47	13	76		11	99			1
7	0.17	100				81	19		
8	0.46	16	48	17	18	97			3
9	0.22	48	21	17	14	100			
10	0.62	74	24	2		93	7		
11	0.31	60	7	19	13	77	14		9
12	0.19	25	52	17	6	90	10		
13	0.11	32	68			95	5		
14	0.23	60	27	6	7	100			
15	0.59	64	6	28	2	90		10	
16	0.70	49	51			74	15	3	8
17	0.35	48	28		24	33	57		10
18	0.28	61	35		4	66	22		12
19	0.79	48	47	5		90			10
20	0.21	98			2	90	10		
21	0.16	95			5	87	13		
22	0.22	78	22			96	4		
23	0.61	86	11		3	89	11		
24	1.10	74	20	1	5	90	6		4
25	0.57	95	5			92	8		
26	0.25	75	25			72			28
27	0.87	76	18		6	53	21		26
28	1.20	53	41	1	5	83	11	1	5
29	0.69	89		6	5	90	10		
30	0.85	91	8		1	71	27	2	
31	0.99	84	9		7	85	7		9
32	0.55	66	33		1	79	3	6	12
33	0.56	15	58	26		95			5
34	0.44	27	46	24	3	84	5		11
35	0.52	4	81	3	12	70	25		5
36	0.92	12	76	8	4	71	21	8	
37	0.45	2	89	6	3	50	33	9	8
38	0.38	43	57			54	19	2	25
39	0.72		76	21	3	88			12
40	0.56		86		14	65	23		12
41	1.02	1	74	19	6	80	9		11
42	0.33		91		9	66	16		18
43	1.08	2	91	7		66	15	19	2
44	0.37	27	73			58	20		22
45	1.23		77	23		76	8	1	15
46	0.11	52	40	8		75	7	3	15

slope map, and 1" = 200' topographic maps provided by the county. The percentage of slope is a measure of the change in elevation over a horizontal distance. This provides a useful means of evaluating the suitability of land for urban development. The following list shows various slope percentages and the limitations they impose on development.

Percent Slope	Land Use Limitation
0-5	Very little limitation
5-10	Little limitation
10-15	Impractical for extensive commercial and industrial development. Restricted agriculture, residential, and intensive recreational development
15 & over	Very limited residential, nonintensive recreation (hiking, native study, scenic areas)

Most of the watershed is very flat; the steeply sloped areas are adjacent to the streams, as shown in Figure 4-2. The percent area on a subbasin basis with slopes in the ranges 0-5%, 5-10%, 10-15%, and greater than 15% are contained in Table 4-2.

Minerals

The watershed has minimal mining or quarry operations. A few sand and gravel operations have existed as well as borrow pits (Figure 4-3).

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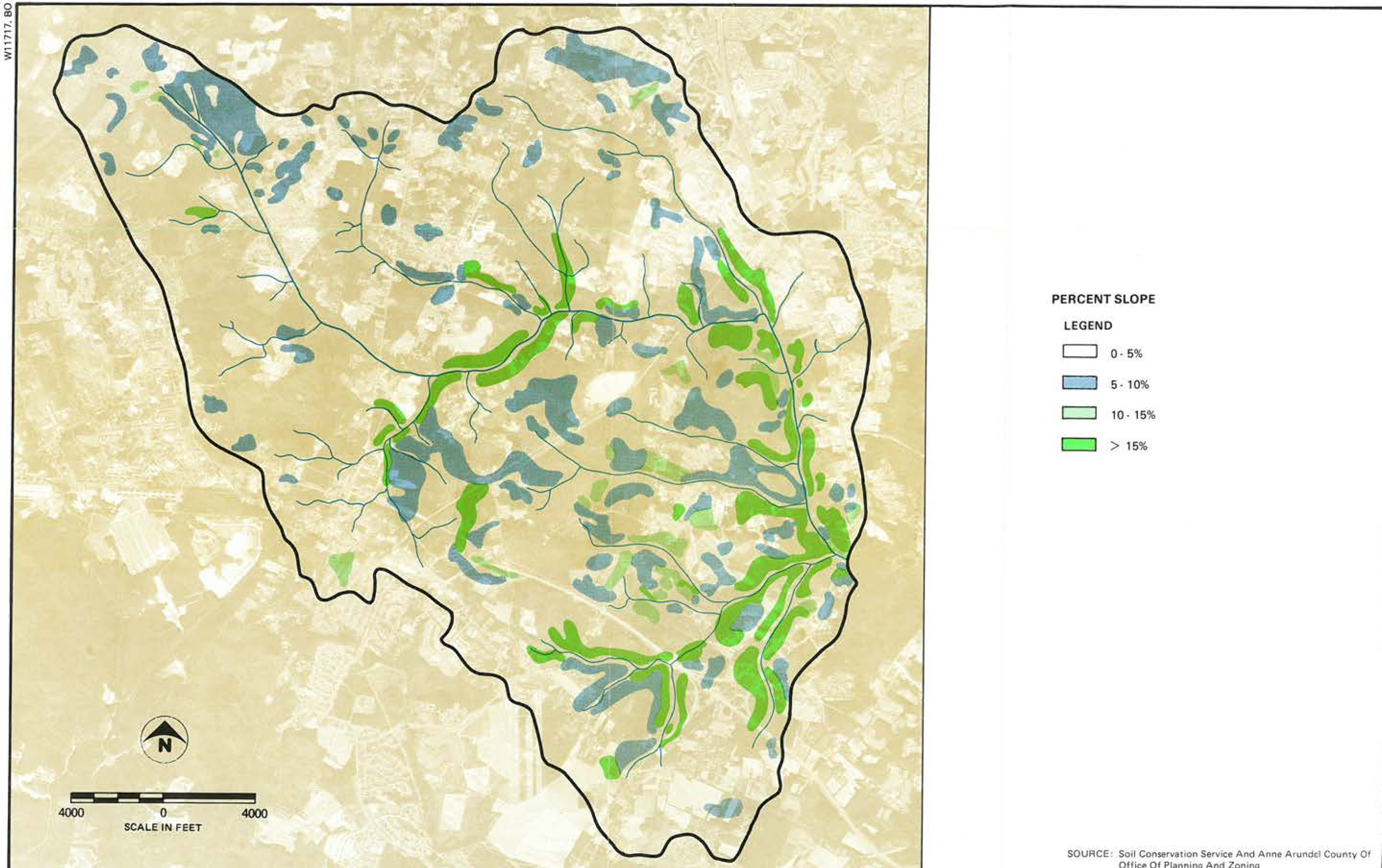

SOURCE: Soil Conservation Service And Anne Arundel County Of Office Of Planning And Zoning

FIGURE 4-2: Slope Map

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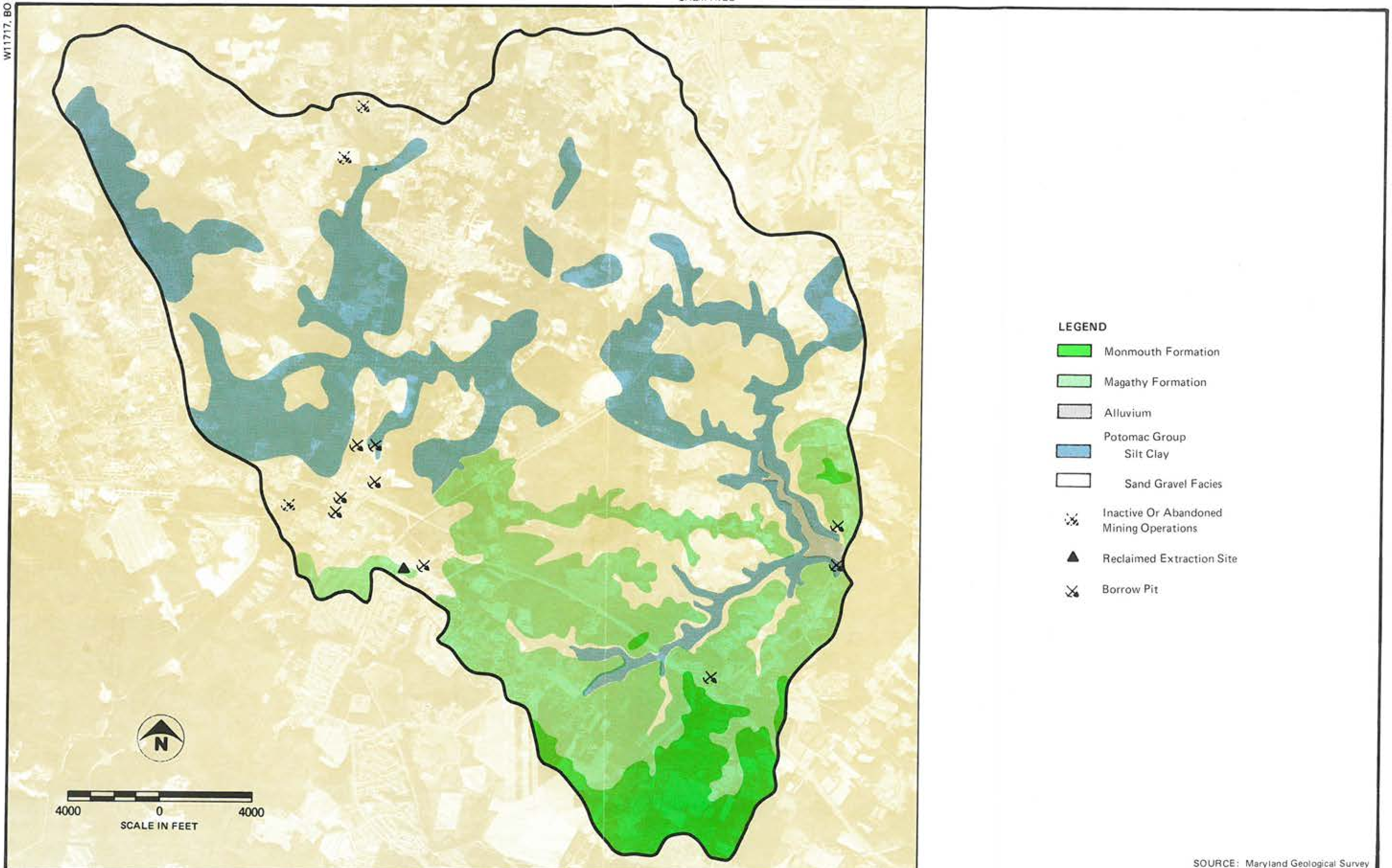


FIGURE 4-3: Geology And Mineral Operations

Geology

Severn Run lies within the Coastal Plain Physiographic region of Maryland. The watershed consists primarily of the Potomac Group sand-gravel or silt-clay facies. These sediments were deposited during the Cretaceous period in river flood plain back-swamp environments and are from 50 to 1,600 feet thick. The sand-gravel facies consists of quartz sand, pebbly sand, gravel and subordinate silt-clay while the silt-clay facies consists of clay, silt and subordinate firm to medium-grained muddy sand. (Glaser, 1976)

The Jabez branch drainage area, particularly around Gambrills Road, is composed of the Magothy Formation. This formation, also from the Cretaceous period, is 3 to 150 feet thick and was formed from shoreline environments. It consists predominantly of fine to medium grained quartz sand with some silt-clay and pebbly sand or gravel.

A very small area near Route 3, north of the mouth of the Severn Run, is made of the Monmouth and Matawan formations. This very fine to fine grained sand with some clayey silt is 3 to 55 feet thick.

The lower section of the Severn Run stream channel area consist of alluvial deposits that resulted from the erosion of the upstream areas. Figure 4-3 gives the geologic location of the formations within the watershed.

Groundwater

The Severn Run watershed has an abundance of groundwater from four major aquifer formations: the Patuxent, Patapsco, Aquia, and Magothy.

An aquifer is a geologic formation capable of transmitting water in useful quantities. There are two kinds of aquifers, confined and unconfined. As its name suggests, a confined aquifer is a permeable bed restricted by impermeable layers of material. When the permeable bed fills with water, the confining layers restrict the water's movement and the pressure rises. In an unconfined aquifer, there is no restricting impervious layer and the water is allowed to rise and fall. Figure 4-4 illustrates two types of aquifers.

A general schematic aquifer geology within a portion of the watershed is given in Figure 4-5. Figure 4-6 shows the locations of aquifer outcroppings and recharge as well as the location of the major wells. Data on the wells are presented in Table 4-3.

ENVIRONMENTAL FEATURES

Parks and Historic Sites

The locations of county and state parks in the watershed are given in Figure 4-7, as well as the location of Bill Himer's residence and barn, the only known historic site within the Severn Run basin. The Severn Run Environmental Area is the major park and is owned by the state. It is not intensively developed as a recreational area and future plans are for it to remain a scenic wildlife area. Another major recreation area will be the Millerville Sanitary Landfill (3 in Figure 4-7). When individual cells are filled, they will be converted to a variety of

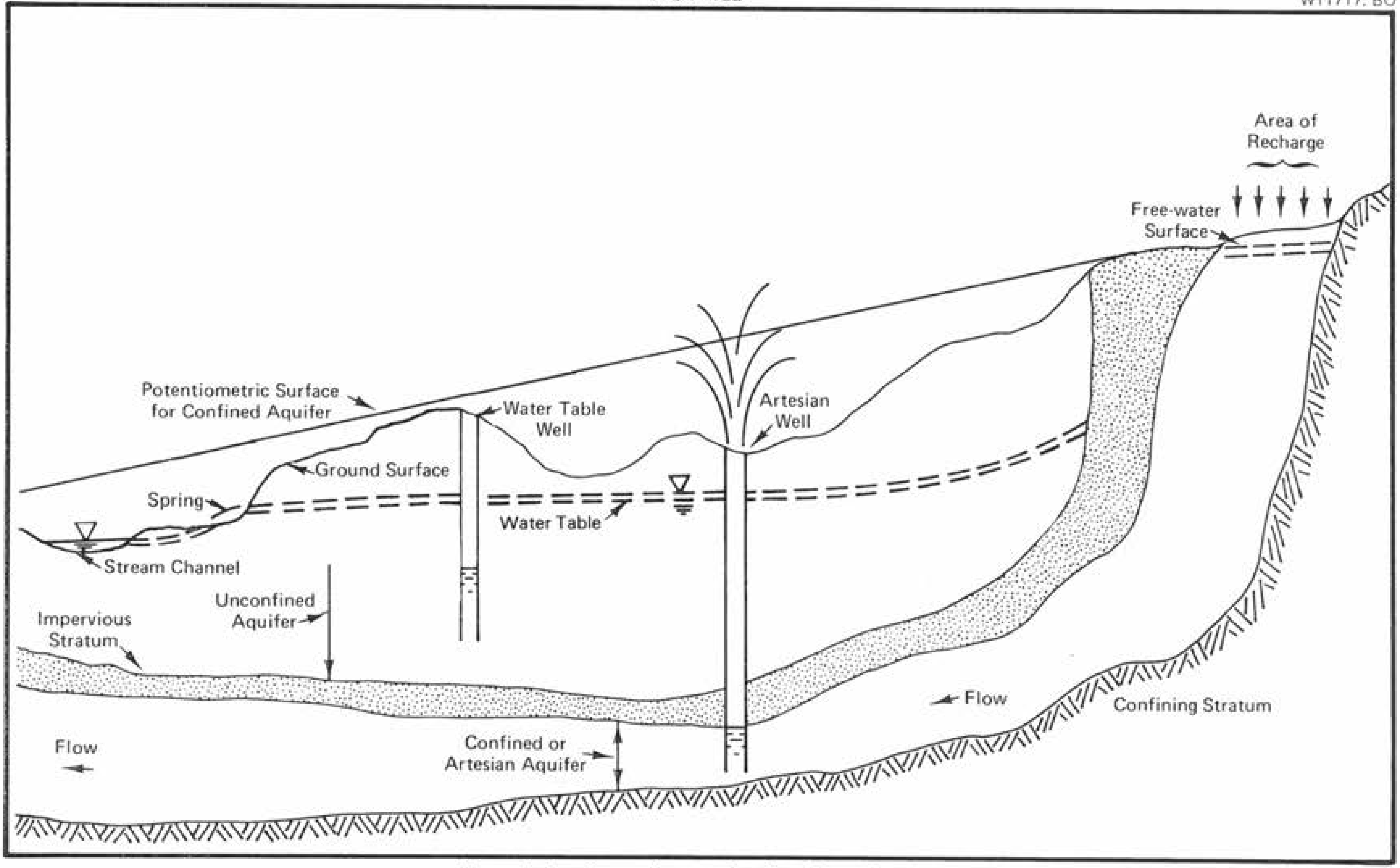
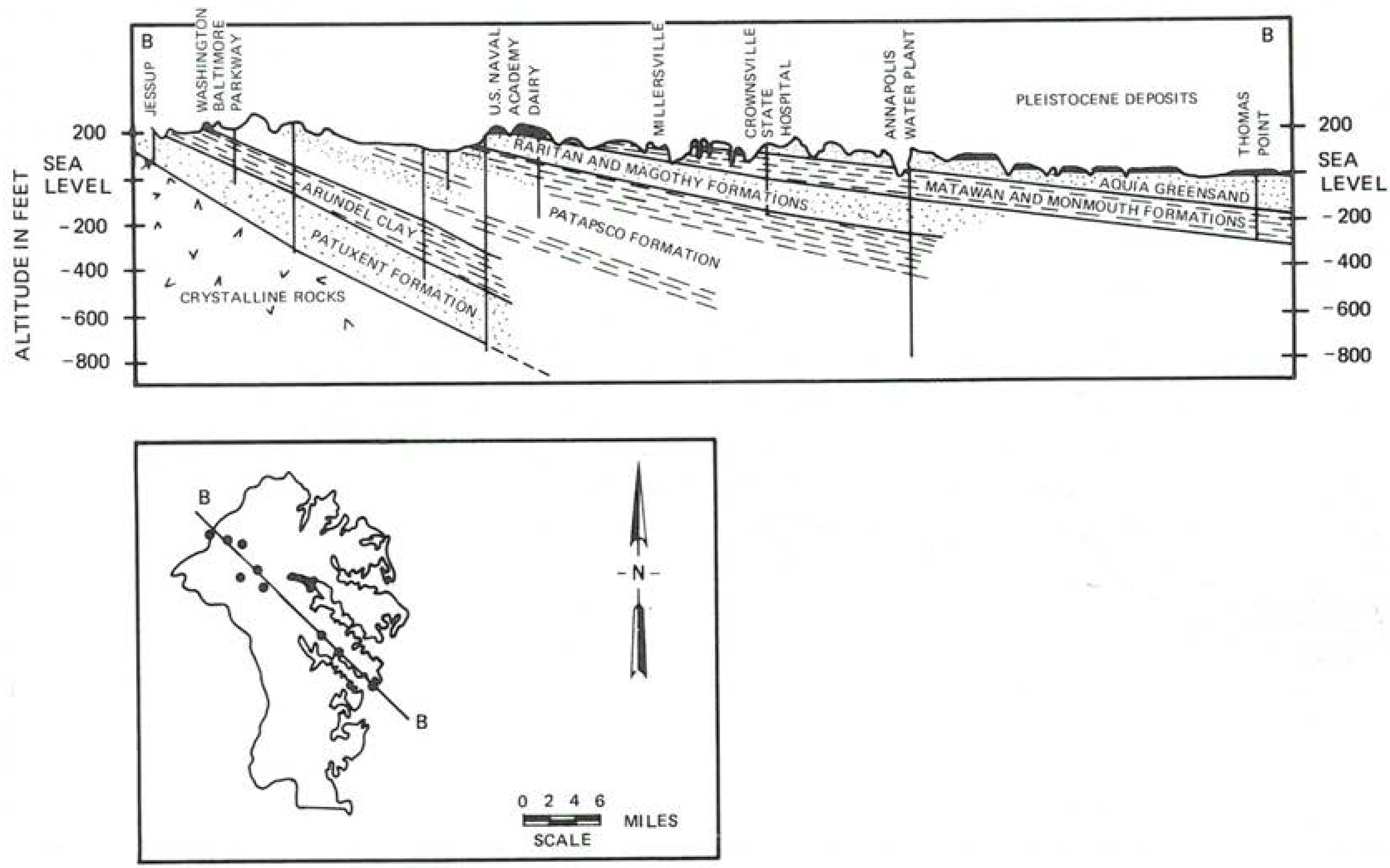


Figure 4-4: Groundwater Aquifer Classification



Points of Test Wells Used to Determine Upper Figure
Maryland Geologic Survey

FIGURE 4-5: Groundwater Aquifer Geology

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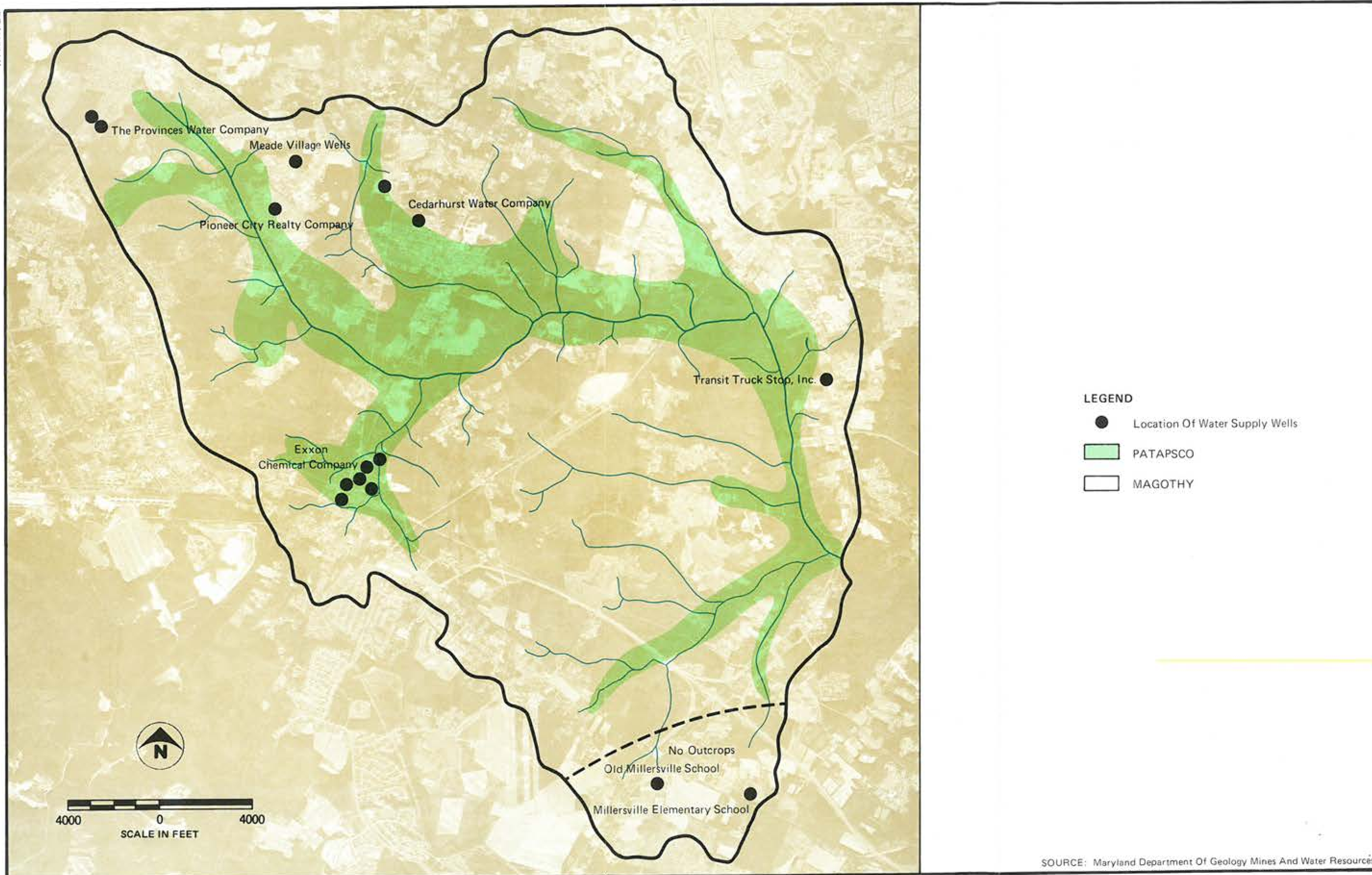

SOURCE: Maryland Department Of Geology Mines And Water Resources

FIGURE 4-6: Aquifer Outcrops And Major Wells

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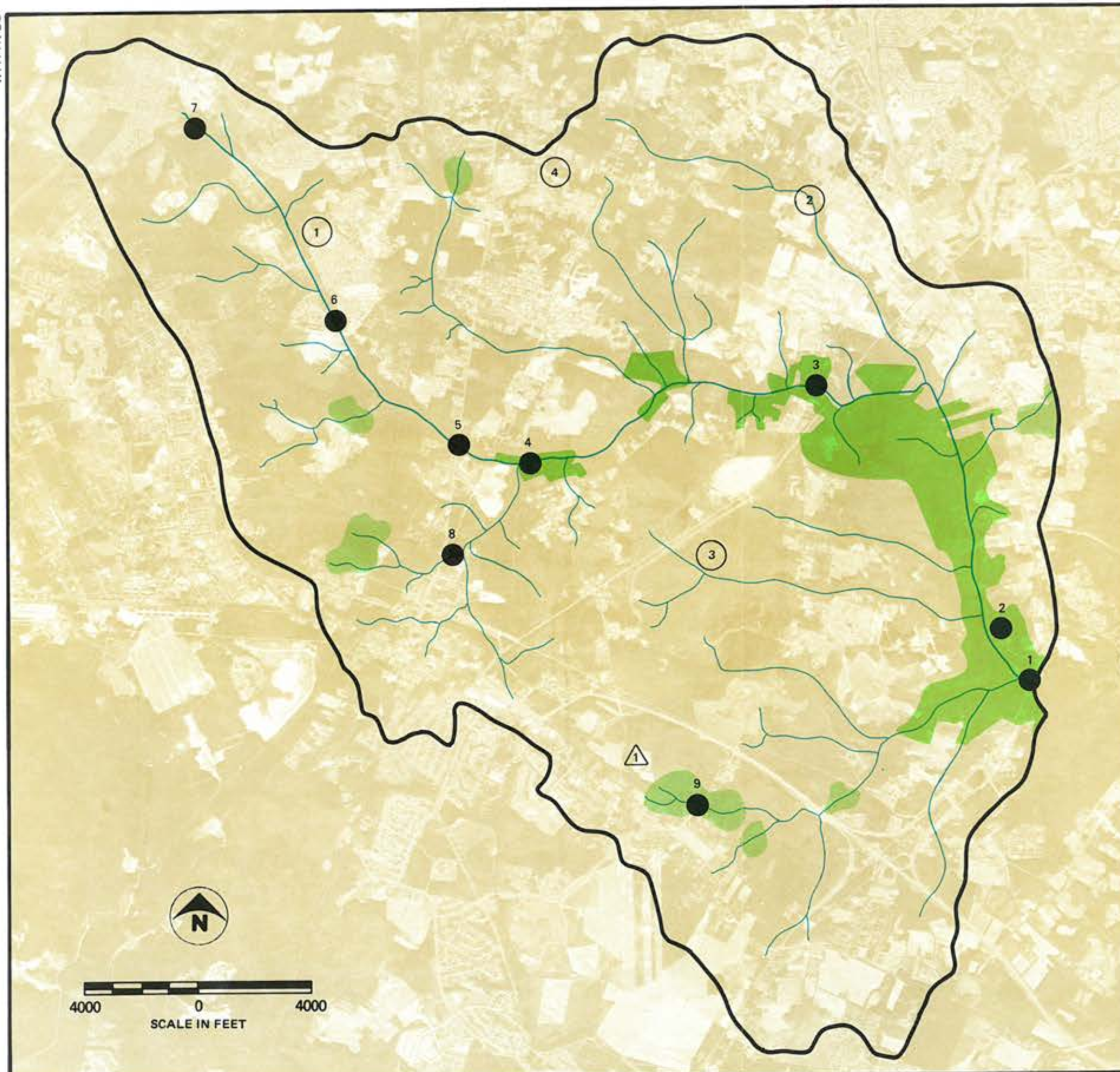

LEGEND

△	Historic Site
①	Parks
▭	Environmentally Sensitive Areas
▭	Severn Run Environmental Area
●	Biological Sampling Sites

Refer To Table 4-4

SOURCE: Anne Arundel County Office Of Planning And Zoning

FIGURE 4-7: Parks, Historic Sites, And Environmentally Sensitive Areas

Table 4-3
Major Wells

Name	Well Number	Aquifer Used	Average Annual Pumpage GPD
Exxon Chemical Company	BC1	Patapsco	2,469,270
	BC2	Patapsco	
	BC20	Patapsco	
	BC40	Patapsco	
	BC47	Patapsco	
	BC157	Patapsco	
	BC165	Patapsco	
	BC171	Patapsco	
	BC173	Patuxent	
Pioneer City Realty Co.	BC169	Patapsco	176,151
	BC195	Patapsco	
The Provinces Water Co.	BC192	Patuxent	130,855
	BC193	Patuxent	
Transit Truck Stop, Inc.	BD111	Patapsco	29,795
Millersville Elementary School	CD61	Magothy	11,900
Old Millersville School	CD51	Magothy	
Meade Village Wells	BC175	Patapsco	92,000
	BC176	Patapsco	
Cedarhurst Water Co.	BC142	Patapsco	15,000
	BC191	Patapsco	

recreational uses. Other parks or recreational areas include the Meade Village Recreation Center (1), the Upton Road Recreational Center (2), and the Severn-Danza Recreation Center (4).

Wildlife and Plants

In the fall of 1978 a section of Severn Run and its watershed was studied from Lake Marion downstream to slightly below the Route 3 bridge (Crain Highway). The biological information gathered is presented in the sections below.

Several previous biological studies were conducted by the State of Maryland, Department of Natural Resources in 1965, 1973 and 1976, and portions of these studies are summarized and discussed along with results from the present study to provide a unified and readily accessible "picture" of the prevailing biological conditions of the run and its watershed.

In the present study, major natural features of the Severn Run watershed were identified. Environmentally significant and sensitive natural areas were identified and studied. Biological data were collected to delineate the characteristic floral and faunal elements in the immediate area of Severn Run. Also, all organisms observed, collected, or known to occur in the area were further studied to determine whether or not they are an endangered or threatened species.

Methods. The Severn Run watershed was visited on five occasions from mid-September to early November, 1978. Nine stations were established in the area

(Table 4-4, Figure 4-7). Each station was visited on at least two occasions during the study period. Unfortunately, it was not possible to establish more stations or visit the existing stations earlier in 1978. If this had been possible, more biological data would have been gathered, and seasonal floral and faunal occurrences and trends could have been documented. Also, the tables of plants and animals found in the watershed would have been more comprehensive. The 9 stations were selected because they represented sites that would give the most information in order to satisfy the objectives of this study. Several of the stations were located in the same areas as those of the previous Maryland state studies. In this way, a continuity in collected information was established. In addition, general biological observations were made in other areas of the watershed during this study. Notes based on observations at each station were made on each visit.

Had this study been more extensive, the plant and animal species could have been grouped and studied by watershed habitat type instead of by station. It is hoped that the composite station data presented in the tables will serve as a preliminary description of the watershed and its species.

Terrestrial, marsh and semi-aquatic plants were either identified in the field or taken back to the laboratory for later identification. Texts and monographs used in the identifications included Brockman (1968), Cobb (1956), Courtenay and Zimmerman (1972), Cuthbert (1948), Grimm (1962, 1966, 1968), Hotchkiss (1970), Jaques (1959), Justice and Bell (1968), Massey (1969), and USDA (1971).

Table 4-4
Location of Biological Sampling Stations
Studied in the Severn Run Watershed,
September-November, 1978

Station 1 - Severn Run at Route 3 Bridge (Crain Highway). A 200 foot portion of the run was sampled.

Station 2 - Severn Run at Dicus Mill Road and marsh adjacent to run on north side of road.

Station 3 - Severn Run at New Cut Road.

Station 4 - Severn Run at Burns Crossing Road.

Station 5 - Severn Run at Telegraph Road.

Station 6 - Severn Run at Still Meadow residential development and construction area off Jacobs Road.

Station 7 - Lake Marion, "headwaters" of Severn Run and area immediately downstream from the lake overflow culvert.

Station 8 - Severn Run at industrial park on east side of Route 170 (Telegraph Road).

Station 9 - Marshy area and Jabez Branch at Gambrills Road off Route 175.

Aquatic plants were collected from the run itself and its stream bank, and were later identified. References used in the aquatic identifications were Beal (1977), Fassett (1966), Hotchkiss (1967) and Mitchell (1971).

Selected samples of algae were collected at several stations and identified with a compound microscope at 100x magnification. Texts used for these algal identifications were Prescott (1962, 1970) and Whitford and Schumacher (1969).

Due to constraints on time and materials, only the more common, dominant plants were collected. Also, emphasis was placed on the plants rather than the animals, because of their greater abundance and ease of collection.

Lists of aquatic invertebrates and fish occurring in the Severn Run were prepared from previous state studies and Eddy (1969). Also, lists were prepared of reptiles, amphibians and mammals which could potentially occur in the watershed or had previously been reported from Maryland and Anne Arundel County.

<u>Terresterial Plants Found in the Watershed</u>. A portion of the Severn Run watershed from Burns Crossing Road (Station 4) to below the Route 3 bridge (Station 1) was studied by the Department of Natural Resources, State of Maryland, in June 1976. Their biological observations, plus the additional observations made in the fall of 1978 are presented below.

Plants and trees were observed and collected from the banks of the Severn Run, its associated flood plain, and from one freshwater wetland (Station 9). Table 4-5 lists the hardwood and softwood trees of the watershed.

Table 4-5
Trees (Hardwood and Softwood)
Found in The Severn Run Watershed

Species Name	Common Name
Pinus virginiana	Virginia Pine
P. rigida	Pitch Pine
Nyssa sylvatica	Black Gum
Betula nigra	River Birch
Alnus serrulata	Common Alder
Acer rubrum	Red Maple
Salix sericea	Silky Willow
S. nigra	Black Willow
Liquidambar styraciflua	Sweet Gum
Tilia americana	American Basswood
Quercus alba	White Oak
Q. palustris	Pin Oak
Q. stellata	Post Oak
Q. prinus	Chestnut Oak
Q. falcata	Southern Red Oak
Q. coccinea	Scarlet Oak
Q. velutina	Black Oak
Q. marilandica	Blackjack Oak
Carya glabra	Pignut Hickory
C. tomentosa	Mockernut Hickory
C. cordiformis	Bitternut Hickory
Liriodendron tulipifera	Yellow Poplar
Sassafras albidum	Sassafras
Ilex opaca	American Holly
Ulmus americana	American Elm
Morus rubra	Red Mulberry
Cornus florida	Flowering Dogwood
Prunus serotina	Black Cherry
Fagus grandifolia	American Beech
Carpinus caroliniana	American Thornbeam
Platanus occidentalis	Americn Sycamore
Cercis canadensis	Redbud
Fraxinus americana	White Ash
F. pennsylvanica var. subintegerrina	Green Ash

A rich variety of shrubs, smaller trees, and vines are present in the watershed (Table 4-6). Flowering plants and those making up the herbal layer at the various stations in the watershed are listed in Table 4-7.

A general description of the Severn Run watershed's trees and shrubs follows, based on Brown and Brown (1972). The Severn Run can be included in the coastal zone and transition region between it and the midland region of Maryland. Predominant forest types are oak-pine (coastal zone) and oak-hickory (midlands). In well drained areas the most abundant trees are Virginia pine (Pinus virginiana), pitch pine (P. rigida), sweet gum (Liquidambar styraciflua), pin oak (Quercus palustris) and post oak (Q. stellata). Sweet gum, bitternut hickory (Carya cordiformis), sweet bay (Magnolia spp.), and American holly (Ilex opaca) are found in moister and in slightly lower areas. Often these are associated with tulip tree (Liriodendron tulipfera), beech (Fagus grandifolia) and in wetter areas, river birch (Betula nigra). Shrubs such as blueberry (Vaccinium spp.) and dangleberry (Gaylussacia frondosa) are present in drier areas, with bayberry (Myrica spp.), sweet pepperbush (Clethra alnifolia), azalea (Rhododendron spp.), and fetterbush (Leucothoe racemosa) found in slightly moister areas. Swampy coastal zone areas also contain a distinct group of trees and shrubs; black gum (Nyssa sylvatica), red maple (Acer rubrum), and sweet bay (Magnolia virginica).

Also present are red chokeberry (Aronia arbutifolia), smooth witherod (Viburnum nudum), and bayberry (myrica spp.). Trees characteristic of the midlands region are found in the upper portion of the Severn Run watershed. Pitch pine, hickory (Carya spp.), and a variety of oaks including the chestnut oak (Quecus prinus), scarlet

Table 4-6
Other Trees, Shrubs and Vines
Found in the Severn Run Watershed

Species Name	Common Name
Sambucus canadensis	Common Elder
Ilex laevigata	Winterberry
Symphoricarpos orbiculatus	Coralberry
Lonicera sp.	Honeysuckle
Lonicera sempervirens	Trumpet Honeysuckle
Itea virginica	Virginia Willow
Rubus occidentalis	Black Raspberry
Rhus glabra	Smooth Sumac
R. vernix	Poison Sumac
R. copallina	Dwarf Sumac
R. typhina	Staghorn Sumac
R. radicans	Poison Ivy
Smilax rotundifolia	Common Greenbrier
Rhododendron sp.	Rhododendron
R. nudiflorum	Pink Azalea
R. viscosum	Swamp Azalea
Amelanchier sp.	Juneberry
Vitus riparia	Riverbank Grape
Magnolia virginica	Sweet Bay
Rosa palustris	Swamp Rose
Aronia arbutifolia	Red Chokeberry
Lindera benzoin	Spicebush
Clethra alnifolia	Sweet Pepperbush
Castanea spp. (probably C. pumila and C. dentata)	Chinquapin
Myrica cerifera	Wax Mytle
M. pensylvanica	Bayberry
Leucothoe racemosa	Fetterbush
Kalmia latifolia	Mountain Laurel
K. angustifolia	Sheep-Laurel: RARE
Hibiscus syriacus	Rose-of-Sharon
Aralia spinosa	Hercules' Club
Celtis occidentalis	Hackberry
Cephalanthus occidentalis	Buttonbush
Parthenocissus quinquefolia	Virginia Creeper
Chimaphila maculata	Spotted Wintergreen
Vaccinium corymbosum	Highbush Blueberry
V. stamineum	Deerberry
V. vacillans	Blueberry
Gaylussacia frondosa	Dangleberry
G. baccata	Black Huckleberry
Viburnum acerifolium	Maple-leaved Arrow-wood
V. recognitum	Smooth Arrow-wood
V. nudum	Smooth Witherod
V. prunifolium	Black Haw

Table 4-7
Flowering Plants Found in the
Severn Run Watershed

Species Name	Common Name
Impatiens sp.	Jewel-weed
I. capensis	Spotted Touch-Me-Not
Bidens aristosa	Western Tickseed - Sunflower
Desmodium canadense	Showy Tick - Trefoil
Similacina stellata	Star-Flowered Solomons Seal
Eupatorium pupureum	Joe-Pye Weed
Daucus carota	Wild Carrot
Aster tradescanti	Tradescants Aster
A. novae-angliae	New England Aster
Muhlenbergia racemosa	Wild Timothy
Dalibarda repens	Dalibarda
Rumex crispus	Curled Pock
Solidago nemoralis	Common Goldenrod
Arisaema triphyllum	Jack-In-The-Pulpit
Symplocarpus foetidus	Skunk Cabbage
Medeola virginiana	Indian Cucumber-Root
Cichorium intybus	Chicory
Galium sp.	Bedstraw
Cypripedium sp.	Ladies'-Slipper
C. acaule	Mocasin Flower

oak (*Q. coccinea*), white oak (*Q. alba*), black oak (*Q. velutina*), blackjack oak (*Q. marilandica*), and southern red oak (*Q. falcata*). Common shrubs of this region include flowering dogwood (*Cornus florida*), black haw (*Viburnum prunifolium*), chinquapin (*Castanea* spp.), sassafras (*Sassafras albidum*), redbud (*Cercis Canadensis*), mountain laurel (*Kalmia latifolia*), blueberry (*Vaccinium* spp.), and pink azalea (*Rhododendron nudiflorum*). Spicebush (*Linden benzoin*) and maple-leaved arrow-wood (*Viburnum acerifolium*) are common in moist areas.

Only a single specimen of American basswood (*Tilia americana*) was found in Severn Run watershed and it was probably deliberately or accidentally introduced here by man or his activities.

Station 9, the wetland area near Gambrills Road, was rather unique. *Arisaema triphyllum* (jack-in-the-pulpit), *Medeola virginiana* (Indian cucumber-root), *Sphagnum* sp. (sphagnum moss), and *Symplocarpus foetidus* (skunk cabbage) were found only at this station in 1978. Also, the mushroom *Calbovista subsculpta* was commonly found here and at no other station in 1978.

Freshwater wetlands can be classified into many different types (Goodwin and Niering, 1975). Table 4-8 lists those types which match to some extent stations on the Severn Run watershed. Species for each type present at various stations are also listed.

Also, these types can be expanded to wet areas not normally thought of as wetlands: flood plains, along watercourses, and waterlogged areas, to name a few examples. Table 4-8 indicates that much of the Severn Run watershed falls into one or another of the wetland types.

Table 4-8
Freshwater Wetland Types Found
in Severn Run Watershed

Type and Description	Characteristic Species	Areas in Watershed Matching the Types
1) SEASONALLY FLOODED BASINS AND FLATS. (SOUTHEAST U.S.): Sites are inundated periodically, but not flooded during growing season. Along water courses and on flood plains.	*Polygonum* spp. (Smartweeds) *Nyssa* spp. (Gums) *Quercus* spp. (Oaks) *Liquidambar styraciflua* (Sweet Gum)	Stations 1 to 5, 9
2) SHALLOW FRESH MARSHES: Soil waterlogged throughout season. Sites often covered with water.	*Typha* sp. (cattails) *Sagittaria* sp. (Arrowheads) *Sparganium* sp. (Burweed) *Polygonum* sp.	Area adjacent to Station 2. Below Station 1.
3a)*SHRUB SWAMPS: Water table at or near the surface throughout much of the year, may be flooded at certain periods.	*Salix* spp. (Willows) *Alnus* spp. (Alders) *Cornus* spp. (Dogwoods) *Clethra alnifolia* (Sweet Pepperbush)	Stations 1 to 5
3b)*WOODED SWAMPS: Water table at or near the surface throughout the year, standing water common during the year.	*Acer rubrum* (Red Maple) *Nyssa sylvatica* (Black Gum) *Quercus* spp. (Oaks)	Stations 3 to 5, 8

* Types 3a and 3b may intergrade.

Source: Goodwin and Niering, 1975

Collection of plants during other times of the year would undoubtedly increase the list of species. It is hoped that this will be done in any followup studies, as well as studying the plant species by habitat type instead of by station.

Aquatic, Semi-Aquatic and Marsh Plants. Plants collected from an aquatic or semi-aquatic habitat at the stations are listed in Table 4-9. One obvious trend was that the number of species present at a station decreased as one progressed toward the headwaters of Severn Run. For example, 11 species were found or occurred at Station 1 (Route 3) but only 2 at Station 5 (Telegraph Road). This is probably due to the changing substrate of the stream and the velocity of the current. At the lower stations sediment was an important consideration, with large thick sediment layers deposited in the stream bed and along the edges of the run. Also, the current was slower at the lower stations, and therefore fine sediments introduced from upstream construction and other land-disturbing activities near Station 6 (Jacobs Road) would tend to settle out. The marsh area adjacent to Station 2 (Dicus Mill Road) contained two species not collected elsewhere, Peltandra virginica (arrow arum) and Nuphar advena (yellow water lily). Sparganium androcladum (bur reed), and Callitriche verna (water starwart), were found at most stations.

Spirodela polyrhiza (Big Duck Weed) and the species of Potamogeton (Pondweeds) were mostly restricted to the lower stations. This is due to their preference for slower-moving stream habitats. Some Potamogeton species occur where there is a thick layer of deposited sediments. When a plant attaches to the substrate a

Table 4-9
Aquatic and Marsh Plants Found
at the Severn Run Stations 1-9
September-November, 1978

	Stations								
	1	2	3	4	5	6	7	8	9
Spirodela polyrhiza (Big Duckweed)	+	+	+	NONE PRESENT	-	-	NONE PRESENT	-	-
Typha latifolia (Cattail)	+	+	-		-	-		+	-
Sparganium androcladum (Bur Reed)	+	+	+		-	+		+	+
Callitriche verna (Water Starwort)	+	+	+		+	-		+	-
Ludwigia palustris var. *americanus* (False Loosestrife)	+	+	-		-	-		+	-
Scirpus sp. (Bullrush)	+	-	-		-	-		-	-
Potamogeton filiformis (Threadleaf Pondweed)	+	-	+	NONE PRESENT	-	-	NONE PRESENT	-	-
P. foliosus (Leafy Pondweed)	+	-	-		+	-		-	-
P. gramineus (Variable Pondweed)	+	-	-		-	-		-	-
Sagittaria sp. (Arrow-Head)	+	-	-		-	-		-	-
Peltandra virginica (Arrow Arum)	+	+	-		-	-		-	-
Nupha advena (Yellow Water Lily)	-	+	-		-	-		-	-
Cyperus sp. (Sedge)	-	+	+		-	-		-	-
Carex sp. (Sedge)	-	-	-		-	+		-	-
Total number of spp.	11	8	5	0	2	2	0	4	1

+ = present
- = absent

local reduction in current velocity results. This in turn causes more sediment to be deposited (Hynes, 1970). The aquatic plants then expand onto the newly deposited sediment, eventually forming long luxuriant beds. This is especially true at Station 1 near the Route 3 bridge. Over a period of time the beds of aquatic plants may shift over the stream channel bottom due to the changing conditions of flow and sedimentation.

A 1973 study of the Severn Run indicated that Callitriche heterophylla, Potamogeton americanus, and Sagittaria were collected at Station 1. There are some differences between this study and the present one. Callitriche verna was found here in 1978. Hotchkiss (1967) combines both C. heterophylla and C. palustris in this species. Because of the absence of fruits at the time of the year of this study's field trips (October-November) it was impossible to determine whether C. verna was, in fact, C. heterophylla. Sagittaria was not collected in 1978 but was in 1973 and 1976, earlier in the year. Identification of species of Potamogeton is very difficult. Leaves are often of two kinds, the floating ones of firm texture, and the submersed ones, thin and membranous. Complexes or combinations of species are formed through hydridization and subsequent morphological intergradation. In the present study it was felt that one of the Potamogeton species occurring at Station 1 (Route 3) more closely matched P. gramineus instead of the earlier reported P. americanus. The floating leaves were not long and tapering to a point as is evident in P. americanus. Of the other pond weeds, P. filiformis and P. foliosus, the former was much less abundant in quantity of plant material.

Three species of smartweed, Polygonum, were collected throughout the watershed. The species of this semi-aquatic or marsh plant were P. arifolium (halbard-leaved tear-thumb), P. coccineum (marsh smartweed) and P. punctatum (dotted smartweed).

Collecting aquatic and semi-aquatic plants earlier in the year when growth is maximal and reproduction is occurring would help to determine more precisely which species are found in Severn Run.

Algae. Table 4-10 lists the types of algae found in Severn Run in October, 1978. Algae are important because they may accumulate in numbers sufficient to form blooms or mats. Many of the attached algae may form continuous carpets of growth on submerged substrates in rivers (Palmer, 1977). Fragments of the algal carpet may become detached due to changes in streamflow. These fragments may cause taste and odor problems and present an unpleasant appearance to the stream, especially to people using the stream for recreational purposes. Large amounts of Rhizoclonium and Microspora were present in Lake Marion. These algae are commonly found in polluted and nutrient enriched conditions. During periods of high stormwater flow, it is highly likely that the algae is washed out of the lake into Severn Run, thus compounding the problem of excessive algal growth and lessened water quality on the Run. While not the intent of the present study, future studies should be directed to Lake Marion. Nutrient levels (presumed to be high) should be determined and the algae studied on a seasonal basis to delineate abundance and composition of the algal species. Aquatic habitats which produce excessive amounts of plant materials and have high levels of nutrients (phosphorus and nitrogen) are

Table 4-10
Algae Collected at Several Stations
in the Severn Run Watershed
October, 1978

Species	Stations					
	1	3	4	5	7 (Lake)	8
Ulothrix sp.	+	-	-	-	-	-
Spirogyra sp.	-	+	-	+	-	+
Rhizoclonium sp.	-	-	-	+	+	-
Eunotia sp.	-	-	-	+	-	-
Microspora sp.	-	-	-	-	+	-
Stigeoclonium tenue	-	-	+	-	-	+

+ = present
- = absent

termed eutrophic. Lake Marion appears to be highly eutrophic. In fact, algae were so abundant that large clumps were floating around the margins of the lake.

Algae collected at the other stations are also sometimes found in polluted situations (Palmer, 1977). Algal abundance at these stations was not nearly as great as at Lake Marion, and could not be considered a problem, at least not in October.

Ferns and Fern Allies. Ferns and allied groups such as club mosses were found only at four stations (Table 4-11). A total of 8 species were collected in this study. Had the study begun earlier in 1978, additional species would have been collected. Station 9, a marshy wetland, had all eight species, indicative of the favorable growing conditions there for these plants. *Lycopodium obscurum*, the stiff club moss, was the only allied fern group collected in the watershed. *Lygodium palmatum* is considered rare by some in Maryland (Rucker, 1979). This occurrence should be positively verified by additional collecting earlier in the season. Table 4-12 lists more species of ferns which presumably could occur in the watershed at other times of the year.

Aquatic Invertebrates. Emphasis was not placed on this group in the study due to constraints on time and equipment. In 1976 the Maryland Department of Natural Resources, Water Quality Services, conducted a water quality study in which invertebrates were collected from artificial substratas placed in Severn Run. Table 4-13 gives a summary of the organisms collected at some of the stations.

Table 4-11
Ferns and Allied Groups Collected on the Flood Plain and Along the Banks of Severn Run
September-November 1978

Species	Stations 1	6	8	9
Onoclea sensibilis (Sensitive Fern)	+	-	-	+
Woodwardia areolata (Netted Chain Fern)	-	+	+	+
Osmunda cinnamomea (Cinnamon Fern)	-	+	+	+
O. regalis (Royal Fern)	-	-	-	+
Thelypteris palustris (Marsh Fern)	-	-	-	+
Dryopteus sp. (Wood Fern)	-	-	-	+
D. noveboracensis (New York Fern)	+	-	-	-
Polypodium vulgare (Common Polypody)	-	-	-	+
Lycodium obscurum (Stiff Club Moss)	-	-	-	+
Lygodium palmatum (Climbing Fern)	+	-	-	-

+ = present
- = absent

Table 4-12
Other Ferns and Fern Allies
Possibly ocurring at Severn Run
Watershed, Based on Distributions
and Similar Habitat Type

Species Name	Common Name
Selaginella apoda	Meadow Spikemoss
Lycopodium complanatum	Running Pine
Equisetum arvense	Field Horsetail
Polystichum acrostichoides	Christmas Fern
Adiantum pedatum	Maidenhair-Fern
Asplenium platyneuron	Ebony Spleenwart
Athyrium filix-femina	Northern Lady-Fern
A. thelypterioides	Silvery Spleenwart
Dennstaedtia punchtilobula	Hay-Scented Fern
Dryopteris hexagonoptera	Winged Wood-Fern
Pteridium aquilinum	Braken Fern
Botrychium dissectum	Cutleaf Grape-Fern
B. virginianum	Rattlesnake fern

Source: Based on Massey (1969), Rucker (personal communication).

Table 4-13
Aquatic Invertebrates Collected at
Some Stations on Severn Run,
from June 23, 1976 to August 2, 1976

Organism	Station 1	2	3	4	8
Diptera (Flies)					
Chironomidae (midges					
Rheotanytarsus sp.	+	+	+	-	-
Polypedilum sp.	+	+	+	+	+
Labrundinia sp.	+	-	-	-	-
Cricotopus sp.	+	+	+	-	-
Eukiefferiella sp.	+	+	-	-	-
Trichocladius sp.	+	-	+	-	-
Procladius sp.	-	-	+	+	-
Pentaneurini	+	+	+	-	+
Orthocladinae	-	+	-	-	-
Simulidae (Black Flies)	+	-	-	-	-
Empidae (Dance Flies)	+	+	+	-	-
Tipulidae (Crane Flies)					
Antocha sp.	-	-	-	-	+
Trichoptera (Caddis Flies)					
Cheumatopsyche sp.	+	+	+	-	-
Hydropsyche sp.	+	+	+	+	-
Brachycentrus numerosus	+	-	-	-	-
Polycentropus sp.	-	-	+	-	-
Plecoptera (Stone Flies)					
Acroneuria sp.	-	+	-	-	-
Ephemeroptera (May Flies)					
Stenonema sp.	+	+	+	-	-
Pseudocloeon sp.	+	+	-	-	-
Baetis sp.	+	+	-	-	-

Table 4-13
(Continued)

Organism	Station 1	2	3	4	8
Odonata (Damsel & Dragon Flies)					
Aeschnidae					
Boyeria sp.	+	+	+	+	-
Agrionidae					
Agrion sp.	-	+	+	-	-
Coeagrionidae	+	-	+	+	-
Coleoptera (Beetles)					
Dineutes sp.	+	-	+	-	-
Helichus sp.	+	-	-	-	-
Macronychus glabratus	+	+	-	-	-
Ancryonyx variegata	+	+	+	-	-
Oligochaeta (Segmented Worms)	-	-	-	+	+
Hirudinea (Leeches)	-	-	-	-	+
Gastropoda (Snails)					
Lymnaea sp.	-	-	-	-	+
Helisoma sp.	-	-	-	+	+
Physa sp.	+	+	+	+	-
Ferrissia sp.	-	+	+	-	-
Summary (Based on two samples at each station)					
Total No. of Organisms	309,329	221,208	145,606	12,7	57,85
Number of Taxa	18,21	10,16	16,14	7,4	5,6
Diversity Index	2.49,2.45	1.98,2.48	2.41,1.48	2.45,1.66	0.97,1.43

+ = present
- = absent

Source: Department of Natural Resources, Water Quality Services, unpublished studies.

The importance of invertebrates as indicators of water quality has been documented in many studies (Hynes, 1970; Mackenthun and Ingram, 1967). Invertebrates respond to their immediate aquatic environment (favorable or unfavorable) by producing a population best suited for the particular environment in which they exist. Also, invertebrates respond to changes due to pollution which takes place in their environment with shifts in the kinds and numbers of species. Because of this response, invertebrates can serve as an accurate characterization of water quality.

Station 8 (Picture Frame Branch), near the industrial area, was severely depressed in terms of numbers of organisms, taxa and diversity when compared to stations below the confluence of Picture Frame Branch with Severn Run. This may be due to discharge from the Exxon lagoon, which is located directly upstream from Station 8.

During the 1978 study oyster shells were found below Station 1. It is very unlikely that oysters occur this far up the Severn River estuary. They may have been deposited with the gravel fill used in construction of the Route 3 bridges.

At Station 4, the Old Mill area, snails (*Helisoma* sp.) were seen grazing on the organic silt, algae, and debris found there. These organisms are tolerant of these conditions.

Fishes. Table 4-14 compares collections of fishes obtained in 1965 and 1973. The total number of species decreased from 14 to 10 in the 8 years between the two studies. Three of the five species not present in 1973 are game fish and it is possible that fishing activities may

Table 4-14
Fishes of the Severn Run in 1965 and 1973

	1965	1973
Perca flavescens (Yellow Perch)	+	+
Roccus americanus (White Perch)	+	-
Catostomus commersoni (White Sucker)	+	+
Esox niger (Eastern Chain Pickerel)	+	+
Micropterus salmoides (Largemouth Bass)	+	-
Ictalurus nebulosus (Brown Bullhead)	+	+
Lepomis gibbosus (Pumpkin Seed)	+	+
L. macrochirus (Blue Gill)	+	-
L. auritus (Redbreast Sunfish)	-	+
Notemigonus crysoleucas (Golden Shiner)	+	+
Umbra pygmaea (Mud Minnow)	+	+
Etheostoma nigrum (Johnny Darter)	+	+
Fundulus diaphanus (Banded Killifish)	+	-
Alosa pseudoharengus (Alewife)	+	-
Anguilla rostrata (Eel)	+	+
Total No. of spp.	14	10 (5 lost 1 gained)

+ = present
- = absent

Source: State of Maryland, Department of Natural Resources have depleted populations of these fish. Also, changes caused by the sediment problem in Severn Run (especially at Stations 1 and 2) may also have contributed to their absence. Logging, grazing, and road construction activities have been shown to have harmful effects on fish (Swift and Messer, 1971). Removal of plant cover over the stream can cause the water temperature to increase above the critical limits of such fish as trout, thus adding additional stress. Changes or decreases in sources of food may indirectly limit certain fish species.

Other Vertebrates. Lists of reptiles, amphibians, and mammals (Tables 4-15 and 4-16) were prepared. Species listed are those which might reasonably be expected to occur in the Severn Run watershed. The species are distributed in the eastern United States (including Maryland) and are found in similar habitats to those in the watershed.

Table 4-17 lists birds which were observed by personnel from the Department of Natural Resources in their 1976 survey.

Environmentally Sensitive Areas

Environmentally sensitive areas include unique ecological vegetation, mature forestland, special land forms and deposits of minerals, waterfowl and fish sanctuaries, fish and wildlife habitats, unique scenic vistas, historic structures, and archeological sites.

Environmentally sensitive areas are given in Figure 4-7. The Severn Run Environmental Area is the largest sensitive or critical area and the only one within the watershed officially designated by the county. The other sensitive

Table 4-15
Reptiles and Amphibians Which Could Potentially Occur in the Severn Run Watershed Based on Distributions and Habitat Similarities

Species Name	Common Name
Ambystoma maculatum	Spotted Salamander
A. opacum	Marbled Salamander
Notophthalmus viridescens viridescens	Central Newt
Plethodon cinereus cinereus	Red-Backed Salamander
Desmognathus fuscus fuscus*	Northern Dusky Salamander
Pseudotriton ruber ruber*	Northern Red Salamander
Scaphiopus holbrooki holbrooki	Eastern Spadefoot Toad
Bufo americanus americanus	American Toad
B. woodhousei fowleri	Fowler's Toad
Acris crepitans crepitans	Cricket Frog
Pseudacris triseriata triseriata	Chorus Frog
Hyla crucifer crucifer	Northern Spring Peeper
H. cinerea	Green Tree Frog
H. versicolor	Eastern Gray Tree Frog
Rana ultricularia ultricularia	Northern Leopard Frog
R. palustris	Pickeral Frog
R. sylvatica sylvatica	Wood Frog
R. clamitans clamitans*	Bronze Frog
R. catesbaeiana*	Bull Frog
Terrapene carolina carolina	Eastern Box Turtle
Clemmys guttata	Spotted Turtle
Kinosternon subrubrum subrubrum*	Eastern Mud Turtle
Chelydra serpentina serpentina*	Common Snapping Turtle
Chrysemys picta picta*	Eastern Painted Turtle
Sceloporus undulatus hyacinthinus	Northern Fence Lizard
Cnemidophorus sexlineatus sexlineatus	Six-Lined Skink
Scincella lateralis	Ground Skink
Eumeces fasciatus	Five-Line Skink
E. laticeps	Broad-Headed Skink
Diadophis punctatus	Rinkneck Snake
Coluber constrictor constrictor	Northern Black Racer
Lampropeltis alligaster rhombomaculata	Mole Snake
L. getulus getulus	Eastern King Snake
L. triangulum triangulum	Eastern Milk Snake
Thamnophis sauritus sauritus	Eastern Ribbon Snake
T. sirtalis sirtalis	Eastern Garter Snake
Storeria occipitomaculata	Red-Bellied Snake
S. dekayi dekayi	Northern Brown Snake
Carphophis amoenus amoenus	Eastern Worm Snake
Opheodrys aestivus*	Rough Green Snake
Elaphe obsoleta obsoleta*	Corn Snake
E. guttata guttata*	Black Rat Snake
Natrix sipedon sipedon*	Northern Water Snake
N. septemvittata*	Queen Snake
Virginia valeriae valeriae*	Eastern Earth Snake

Table 4-15
(Continued)
Reptiles and Amphibians Which Could Potentially Occur in the Severn Run Watershed Based on Distributions and Habitat Similarities

Species Name	Common Name
Heterodon platyrhinos*	Eastern Hognose Snake
Agkistrodon contortrix mokasen*	Northern Copperhead

*Collected by C. Rucker at Arnold, MD (personal communication).

Source: Based on Conant (1975), Harris (1975), and Smith (1961).

Table 4-16
Mammals Which Could Potentially
Occur in the Severn Run Watershed Based on
Distributions and Habitat Similarities

Species Name	Common Name
Didelphis marsupialis	Opossum
Blarina brevicauda	Short-tailed Shrew
Cryptotis parva	Little Short-tailed Shrew
Scalopus aquaticus	Eastern Mole
Myotis lucifugus	Big Myotis Bat
M. keeni	Keens Myotis
Pipistrellus subflavus	Pipistrelle Bat
Eptesicus fuscus	Big Brown Bat
Nycticeius humeralis	Evening Bat
Lasionycteris noctivagans	Silvery-Haired Bat
Lasiurus cinereus	Horney Bat
L. borealis	Red Bat
Corynorhinus townsendii	Long-Eared Bat
Sylvilagus floridanus	Eastern Cottontail
Sciurus carolinensis	Gray Squirrel
S. niger	Fox Squirrel
Marmota monax	Woodchuck
Tamias striatus	Eastern Chipmunk
Glaucomys volans	Southern Flying Squirrel
Peromyscus maniculatus	Deer Mouse
P. leucopus	Wood Mouse
Neotoma floridana	Eastern Wood Rat
Synaptomys cooperi	Southern Leming-Mouse
Microtus pinetorum	Pine Vole
Rattus norvegicus	Norway Rat
Mus musculus	House Mouse
Zapus hudsonius	Meadow Jumping Mouse
Procyon lotor	Raccoon
Mephitus mephitis	Striped Skunk
Odocoileus virginianus	White-tailed Deer

Source: Based on Hall (1955).

Table 4-17
Birds Observed in the Severn Run
Watershed, June 1976

Species Name	Common Name
Bombycilla cedrorum	Cedar Waxwing
Parula americana	Parula Warbler
Helmitheros vermivorus	Worm-Eating Warbler
Progne subis	Purple Martin
Butorides virescens	Green Heron
Buteo platypterus	Broad-Winged Hawk
Colaptes auratus	Yellow Shafted Flicker
Wilsonia citrina	Hooded Warbler
Seiurus aurocapillus	Ovenbird
Passerina cyanea	Indigo Bunting
Geothlypis trichas	Yellow Throat
Polioptila caerulea	Blue gray Gnatcatcher
Vireo griseus	White-eyed Vireo
Vermivora pinus	Blue Winged Warbler
Toxostoma rufum	Brown Thrasher
Myiarchus crinitus	Great Crested Flycatcher

Source: Maryland Department of Natural Resources areas on Figure 4-7 are several small wetland areas in the tributaries to Severn Run. These areas were found during field investigations by the consultant and their area is approximate.

Freshwater wetlands are unique areas because of the distinctive flora they contain, as was noted previously in the discussion of plants found at Station 9 (Gambrills Road). Wetlands, because of their water-holding ability, act as storage basins. They lower flooding water levels, minimize erosion, and reduce the severity of floods. Since urbanization intensifies the rate of runoff, this function is important in populated areas. Wetlands and flood plains function as catchment basins by slowing the speed of floodwaters. By decreasing the velocity of flow, wetlands minimize erosion and also act as siltation basins. Niering (1966) estimated that a 6-inch rise in water level in a 10-acre wetland placed more than 1.5 million gallons of water in storage and did not harm the surrounding biota.

Freshwater wetlands are among the most productive biological systems on earth in terms of gross productivity (Odum, 1971). Wetlands are commonly associated with waterfowl (Alexander et al., 1953; Linduslen, 1964). Some are important as migratory feeding areas as well as the actual breeding areas for many species. Others are essential as wintering grounds and resting areas along the major flyways (Errington, 1966; Niering, 1966).

As well as exhibiting a distinctive flora and fauna adapted to the wet conditions and periodic flooding, wetlands also act to remove pollutants such as BOD, phosphorus and ammonia, and nitrate nitrogen, (Grant and Patrick, 1970).

The area between Stations 3 (New Cut Road) and 5 (Telegraph Road) is also environmentally sensitive. The Severn Run watershed is relatively undeveloped in this area. There are no housing developments along this portion of Severn Run. Perhaps the State Environmental Area could be enlarged by additional state purchases of land in this area. Station 4 (Old Mill Road) is the site of an old mill. The mill run is still in evidence. Severn Run here has a earthen uniform bed of gravel and small rocks and sedimentation is minimal. The substrate appears to be favorable for aquatic invertebrates and fish, and occurs only at this section of Severn Run.

The Severn Run is also important as a stocked trout and a yellow perch spawning area. If the State of Maryland desires to continue trout stocking in this stream, then sedimentation and further disturbances in the watershed must be lessened or minimized.

Endangered Species

In 1973 Public Law 93-205, the Endandered Species Act, was passed. It charges the Secretary of the Interior with maintaining lists of those animals and plants throughout the United States that are either in danger of extinction or likely to become so (threatened species) within the foreseeable future. Once a species has been determined to be endangered or threatened, it is placed on an official list published in the Federal Register. Restrictions of interstate and international commerce are placed on each species.

All plants and animals found in the Severn Run watershed were compared to lists of endangered and threatened species. References such as Ayensu and DeFilipps

(1978) and Berger and Neuner (1979) were consulted. In no case were any organisms in the watershed found to be endangered or threatened. The sheep laurel, *Kalmia angustifolia*, was considered rare in the 1976 Department of Natural Resources Survey. *Lycopodium obscurum*, the stiff club moss, and species of *Cypripedium* (lady's-slipper) are protected from collection in many midwestern states. At present, this is not the case in Maryland.

PUBLIC FACILITIES

Water and Sewer System

Based on the Anne Arundel County Water and Sewerage Plan of 1976, the existing and projected sanitary sewer system is presented in Figure 4-8, and the water supply system in Figure 4-9. The planned extensions of the water and sewer systems play a significant role in the staging of development in accordance with the *General Development Plan* recommendations.

The delineated service areas approximate the sections of most intense urbanization. Land outside the service areas is intended for low-density residential, rural or open land use.

Transportation

Highways. Figure 4-10 presents the major existing highways and streets in the Severn Run basin, plus planned extensions. Route 3 (Crain Highway) and Route 32 (Patuxent Freeway) have been designated as primary routes by the State and have been added to the Interstate Highway Program. Route 3 provides the major north-south access through the watershed, while Route

32 runs in an east-west direction. Route 175 (Annapolis Road) carries considerable traffic from Fort George Meade, and is heavily congested during the rush hours.

Proposed roads include an extension of Route 32 by the state, Nevada Avenue by the county, Mapes Road by the county, and the finishing of Donaldson Avenue by the county. In addition, changes in access and possible elimination of some interchanges or ramps may be required to bring Routes 3 and 32 up to Interstate standards.

Railroads. The Penn Central Railroad crosses the watershed in a north-south direction, running nearly parallel to Route 170, Telegraph Road. There are no passenger stations in the watershed. The Baltimore and Ohio Railroad has a spur line originating in the southern portion of the watershed and running to the major line that connects Washington, D.C. and Baltimore. There are several miles of abandonded railroad line beds in the watershed. The WB&A Road is built on an abandonded railroad bed.

LAND USE

Existing Land Use

The Severn Run basin covers an area of 24.21 square miles or 15,494 acres. This is approximately 6 percent of the total county area. The watershed's land use is comprised of 16 percent residential, 4 percent commercial or industrial, 17 percent open or agricultural, and 63 percent forest. As can be seen from Figure 4-11, no major urban areas exist within the watershed. Most of the development has taken place in the vicinity

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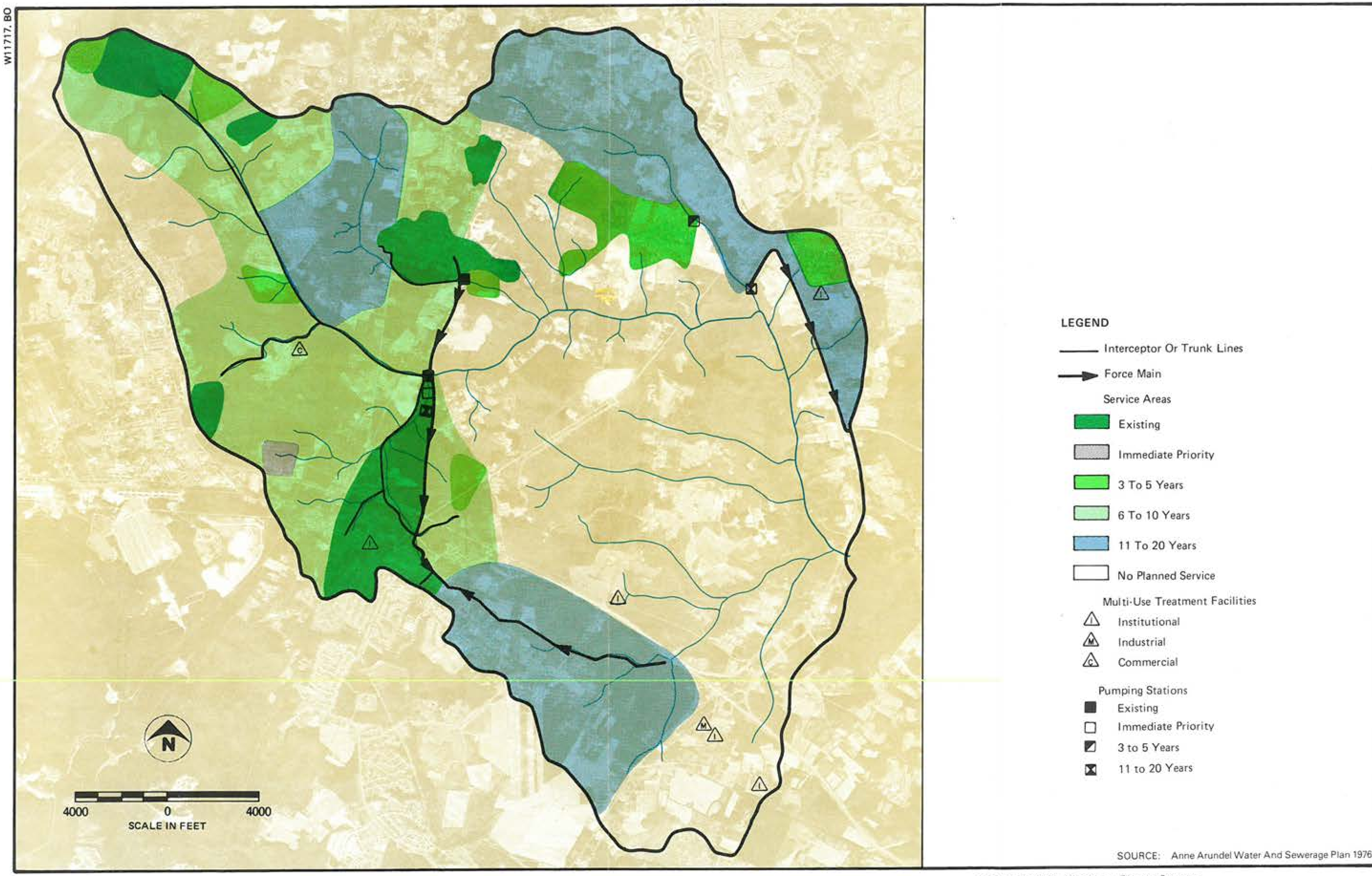

FIGURE 4-8: Sanitary Sewer System

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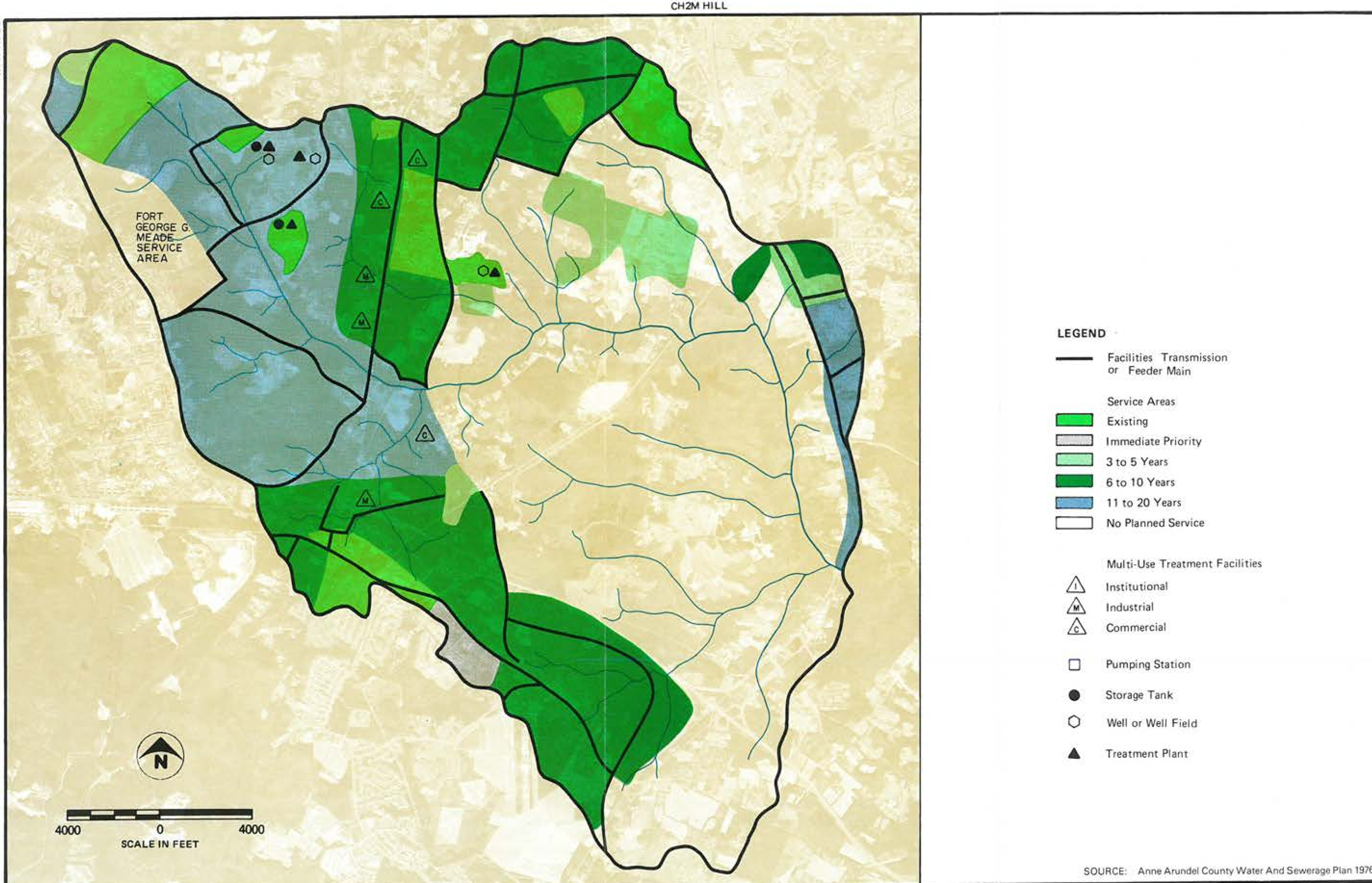

SOURCE: Anne Arundel County Water And Sewerage Plan 1976

FIGURE 4-9: Water Supply System

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HIGHWAYS

LEGEND

State Highway

Planned Extensions

SOURCE: Anne Arundel County Office Of Planning And Zoning

FIGURE 4-10: Transportation System

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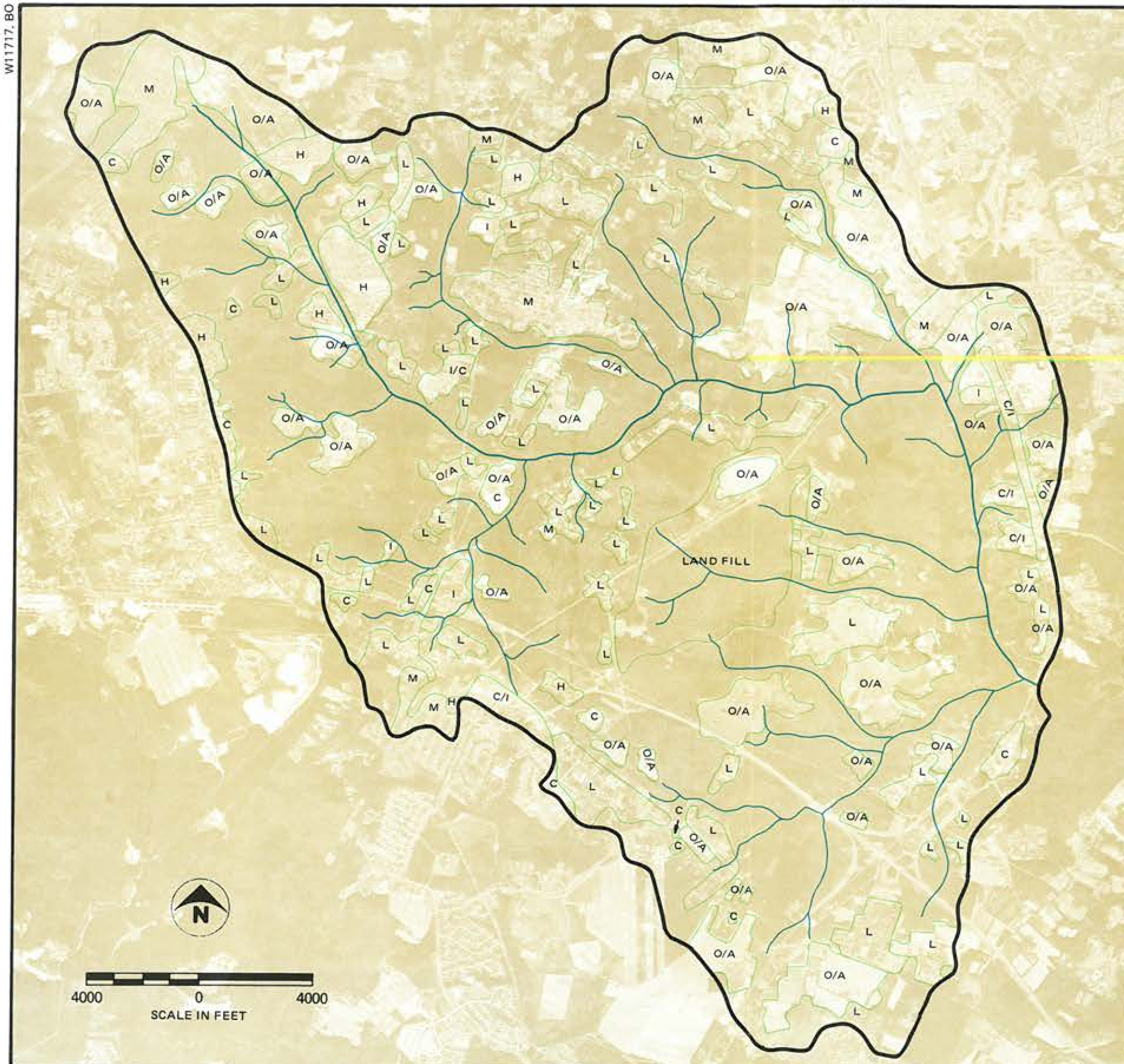

EXISTING LAND USE

LEGEND

Residential

L — Low Density — 2-5 dwelling units/acre

M — Medium Density — 5-10 dwelling units/acre

H — High Density — 10 or more dwelling units/acre

C — Commercial

I — Industrial

C/I — Mixed Commercial/Industrial

O/A — Open Area

Forests Are Dark Unlabeled Areas

FIGURE 4-11: Existing Land Use

of Fort Meade, Odenton, Millersville, and Glen Burnie. Eighty percent of the land is undeveloped.

Table 4-18 gives the existing land use for the sub-basins used in the hydrology simulation. The land use was determined from aerial photographs and field trips to the area. The aerial photograph used for the land use determinations forms the base map to the graphics used in the report and was taken on 24 March 1977.

General Development Plan

The General Development Plan, prepared by Anne Arundel County Office of Planning and Zoning, calls for future growth in a contained pattern that encourages most new growth in and near existing developed areas. The plan also encourages growth in the western part of the county which would result in large employment at Fort Meade. This growth policy impacts the Severn Run watershed since the southwestern portion of the basin borders Fort Meade and industrial growth would be expected at the Midway Industrial Park. Industrial areas such as this are encouraged by the General Development Plan.

The plan discourages strip commercial development along major highways which will slow down the growth of such establishments along Route 3 and prevent them on Route 32. Further, agricultural activity and rural areas will be preserved as much as possible.

The intent of the General Development Plan is reflected in the county's land use zoning and the projection of future land uses within the watershed.

Table 4-18
Existing Land Use

Subbasin Number	Residential: Low Density (percent)	Residential: Medium Density (percent)	Residential: High Density (percent)	Commercial (percent)	Industrial (percent)	Agricultural (percent)	Open Space (percent)	Forest (percent)
1	2	45				13		40
2		27		8		29		36
3		4				56		40
4				2		24		74
5	2		29			27		42
6	6		3	1		15		75
7			64	3		20		13
8	9		34			4		53
9				5		2		93
10			7	7		15		71
11						14		86
12								100
13	22			16				62
14	13			1	7	2		77
15	21		24		11	6		38
16	2	4	5	15		7		67
17					10	8		72
18			3	9		6		82
19	14				4	15		67
20						69		31
21		9						91
22	24	19	23					34
23	5	8	7	1	7	11	2	59
24	12	41		2	4			41
25	7					15		78
26	7					17		76
27	3					7		90
28	3					50		47
29	8	10				12		70
30	15	15	12	5		18		35

Table 4-18
(Continued)

Subbasin Number	Residential Low Density (percent)	Residential Medium Density (percent)	Residential High Density (percent)	Commercial (percent)	Industrial (percent)	Agricultural (percent)	Open Space (percent)	Forest (percent)
31	3	17		2		38	2	38
32	1			5	4	28	3	59
33	3				27	21		49
34	1			8		6	5	80
35	5					5		90
36	2					2		96
37	29						3	68
38	2					5		93
39	14	18		3		10	1	54
40	25			5		7	2	61
41	8			3	1	32	3	53
42	9						5	86
43	2					15		83
44	2					42		56
45	21			6		18		55
46	10			5		14	10	61

Ultimate Land Use

Ultimate hydrologic land use based on the county's land use zoning map is shown in Figure 4-12. The western and northern areas of the basin will be experiencing the most development. The drainage basin for Picture Frame Branch in particular will be very highly developed, including a proposed town center, industrial growth, and high density residential growth. Based on this projected growth, 36 percent of the watershed will be forested compared to an existing 63 percent, and 11 percent will be open or agricultural lands compared to an existing 17 percent. The undeveloped area will decrease from 80 percent to 47 percent of the watershed.

In order to obtain hydrologic future land uses to compare to existing land use, it was necessary to make some adjustments to the zoned land use. For example, an area zoned R5 or medium density residential does not specifically include any open areas or forested lands. Based on the county's zoning ordinance, it was decided to assign 90 percent of R5 areas to medium density residential and 10 percent to forest, open space or agriculture. The 10 percent was split among these land uses according to their existing ratios for each subbasin. The following distribution of zoned land uses was used:

1. Forest, agriculture and open space consists of:

   100% of the land zoned RA and OS
   70% of the land zoned R1
   15% of the land zoned R2
   10% of the land zoned R5
   5% of the land zoned R15 and R22

   The division of land in this category between forest, agriculture and open space was based on the existing ratios of these land uses for each subbasin.

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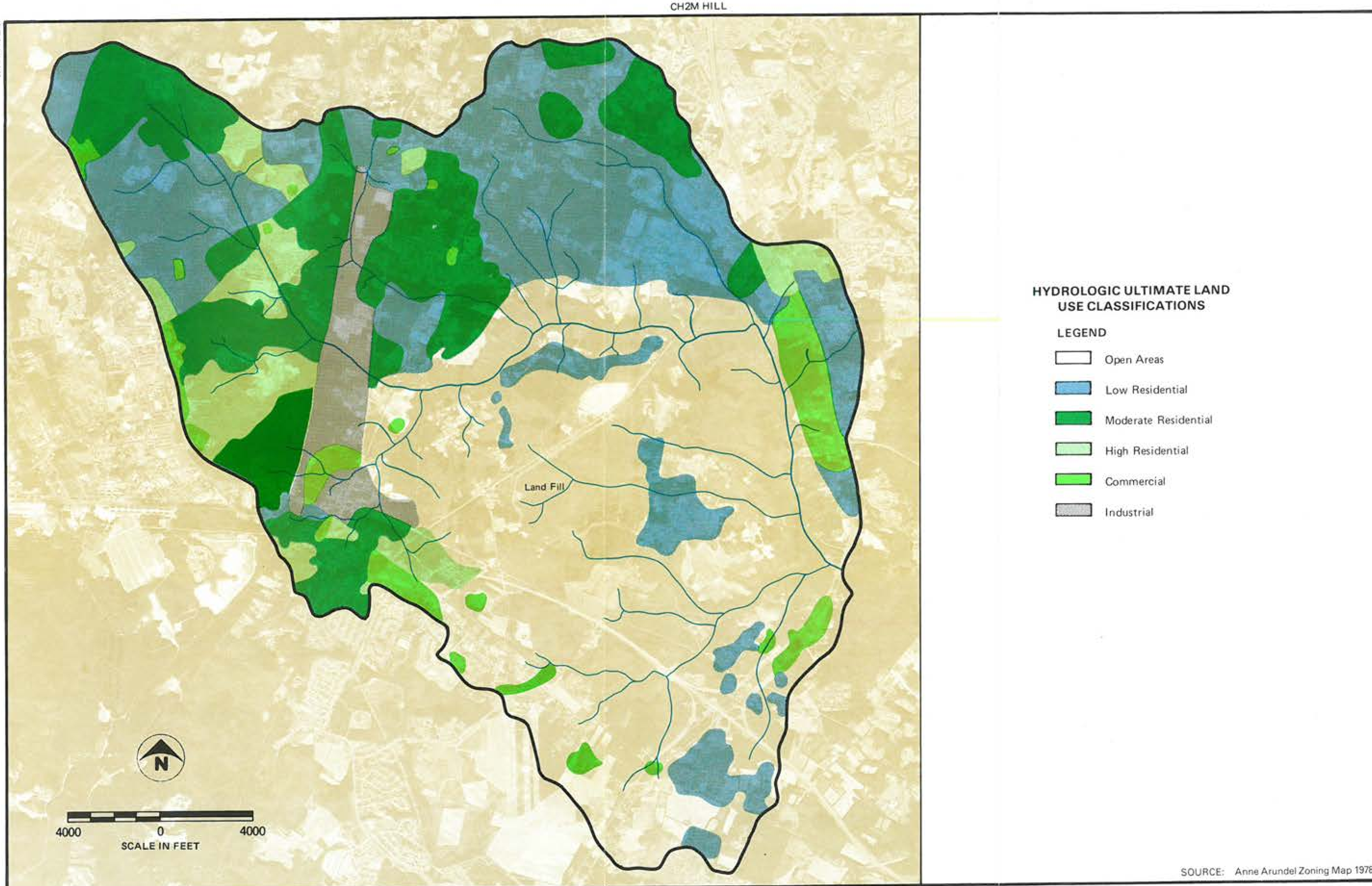

FIGURE 4-12: Ultimate Land Use

2. Low density consists of:

   30% of the land zoned R1
   85% of the land zoned R2

3. Medium density residential consists of 90 percent of the land zoned R5.

4. High density residential consists of 95 percent of the land zoned R15 and R22.

5. Commercial and industrial consists of 100 percent of the land zoned commercial and industrial, respectively.

Based on these distributions of zoned lands, Table 4-19 presents the ultimate (year 2000) land use for each subbasin. This table and Table 4-2 were used to determine runoff curve numbers, CN, for the subbasins. The details of the calculations will be given in Chapter 5, Hydrology, but for now it is sufficient to say that a CN reflects soil types and land uses. More developed areas have higher curve numbers for similar soils and more runoff than undeveloped areas. Figure 4-13 shows those subbasins that experience large increases in urbanization and hence their curve numbers. Most of the changes are in the southwestern portion of the basin in the vicinity of Fort Meade and the Midway Industrial Park. These areas can be expected to have dramatic increases in flood peak flows. The increase in the percent of developed land for each subbasin is given by Table 4-20. For example, 15 percent of a subbasin will change from forest, agricultural or open space land use to residential, commercial, or industrial land use.

Table 4-19
Ultimate Land Use

Subbasin Number	Residential: Low Density (percent)	Residential: Medium Density (percent)	Residential: High Density (percent)	Commercial (percent)	Industrial (percent)	Agricultural (percent)	Open Space (percent)	Forest (percent)
1	4	58				9	5	24
2	6	65		27			1	1
3	1	91					3	5
4	10			2		3	17	68
5	5		49			3	15	28
6	71	8	3	2		2	4	10
7	3		65	5		2	13	12
8		18	62				4	16
9		89	11					
10		34	55	11				
11		32	35		13		1	19
12			21	8	70			1
13		10		19	71			
14		8		36	56			
15	2	26	28	21	16	1		6
16	25	23	25	12	7	1		7
17	75				12	1		12
18	70		2		15			13
19	25	13			29	6		27
20	34	38		13	4	7		4
21	64	22						14
22	63	20			2			15
23	12	46	8		25	1		8
24	21	48		2	11			18
25	25	26		1		8		40
26	30					13		57
27	4	16				6		74
28	11					47		42
29	58	10				4		28
30	44	27	12	5		4		8

Table 4-19
(Continued)

Subbasin Number	Residential Low Density (percent)	Residential Medium Density (percent)	Residential High Density (percent)	Commercial (percent)	Industrial (percent)	Agricultural (percent)	Open Space (percent)	Forest (percent)
31	39	18		2		21		20
32	1			5	13	26	7	48
33	13				41	14		32
34	1			4	37	6	5	47
35	5	8				8		79
36	2	33		1				64
37	3	22				6		69
38	2					5		93
39	25	30		10		5		30
40	26			11		6	2	55
41	16			9		28	2	45
42	10					5		85
43	2	10				5		83
44	2					42		56
45	21			8		17		52
46	10			5	55	15		15

Table 4-20
Differential Increase in Percent of Developed Land From Existing Land Use to Ultimate Land Use

Subbasin	Increase	Subbasin	Increase
1	15	24	23
2	63	25	49
3	88	26	23
4	13	27	17
5	23	28	8
6	74	29	50
7	6	30	41
8	37	31	37
9	95	32	9
10	86	33	24
11	80	34	33
12	99	35	8
13	62	36	34
14	77	37	0
15	37	38	0
16	66	39	30
17	77	40	7
18	75	41	13
19	49	42	6
20	89	43	10
21	77	44	0
22	19	45	4
23	63	46	55

Increase determined by subtracting percent developed for existing land use from percent developed ultimate land use.

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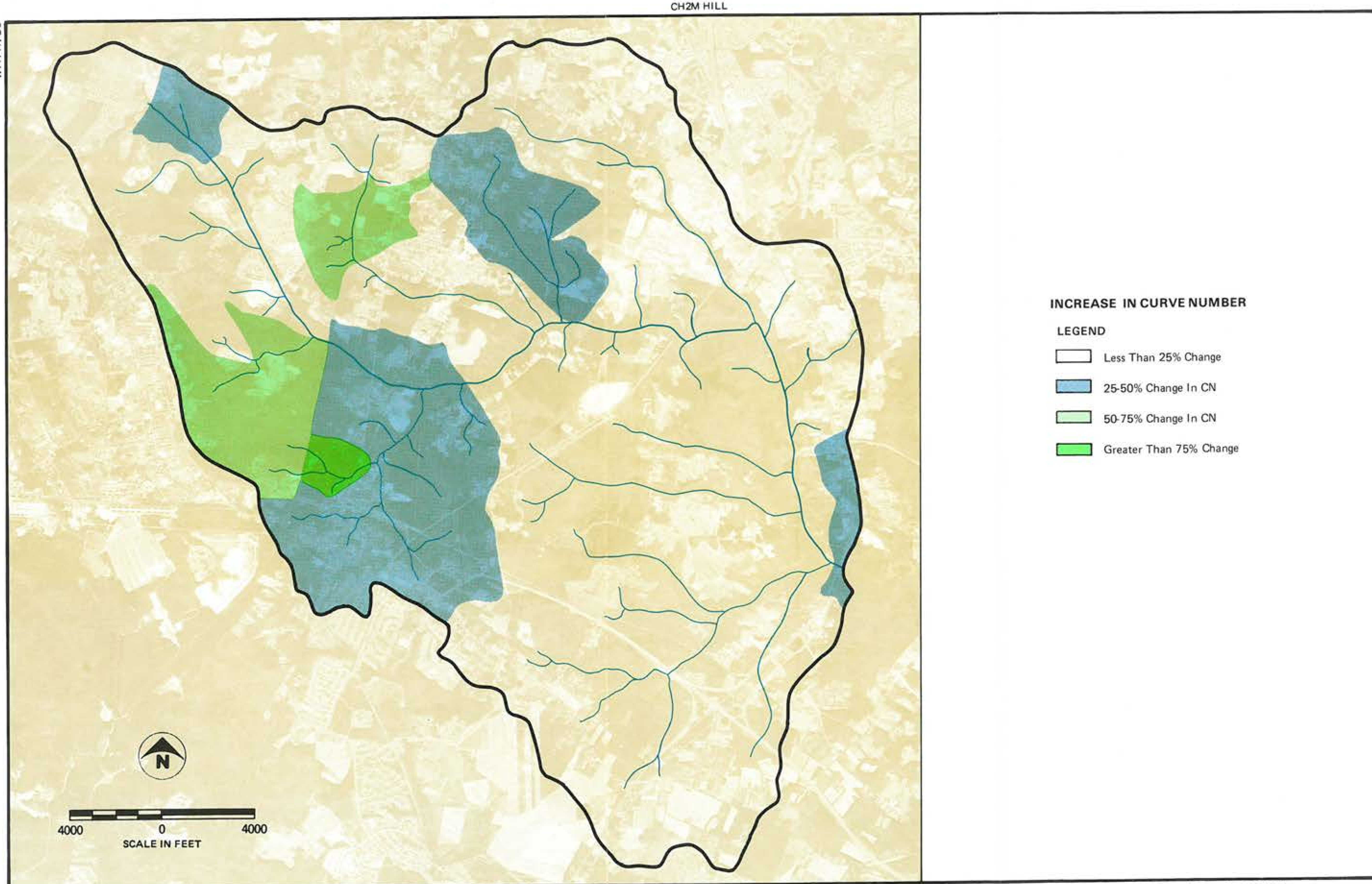

FIGURE 4-13: Increase In CN's As A Result Of Ultimate Urbanization

Chapter 5

CHAPTER 5
HYDROLOGY

At the heart of any watershed management plan is an understanding of the hydrology of the area. It is commonly known that the hydrologic, stream channel, and water quality regime in a drainage basin will change as development progresses within the basin. However, the extent of these changes is not known. This chapter addresses the existing hydrologic conditions and what those conditions will be if land development progresses according to existing plans.

HYDROLOGY MODEL

In order to predict existing and future streamflows--recall that Severn Run is an ungaged stream--a computerized mathematical model was used to simulate the hydrologic response of the watershed. The Soil Conservation Service's (SCS) Computer Program for Project Formulation: Hydrology (TR20) was used. The model computes only surface runoff from input rainstorms. It considers some of the conditions that affect runoff and can route the flow through stream channels and reservoirs. TR20 can combine the routed hydrograph with those from other tributaries and output the hydrograph, peak discharge, time of peak, and peak water surface elevation. Details of the model are given in SCS publications TR20, TR55, and NEH-4.

Hydrologic Data

All computer models require some input data to be that is representative of the area being studied. TR20 requires the following input data: precipitation, runoff curve number for each subbasin, time of concentration for each subbasin, stream channel cross sections, reservoir data, the distance between cross sections, and an initial antecedent moisture condition. Because the Severn Run does not have a streamflow gage it was not possible to calibrate the TR20 model. Therefore, historical rainfall amounts were used to produce the flood flows. Although for simplicity each flood will be referred to as a certain return-interval flood--say the 100-year flood--it is important to remember that this is in reality the simulated flood produced by the rainfall with that particular recurrence interval, and may be quite different from the actual flood with that return interval.

Precipitation

TR20 is a single event runoff model; in other words, it does not consider long-term (several years') rainfall records. This requires that selected rainfall events representative of the historic records be used. The following three sources were used to determine representative rainfall amounts: TP No. 40 and 25 published by the Weather Bureau and Hydro 35 by the National Weather Service. These references give the total amount of rainfall that would occur for a given return interval and storm duration. For example, the 100-year (i.e., the storm that would occur once in a hundred years), 6-hour duration storm has a total rainfall of 5.11 inches, while the 100-year, 24-hour storm has a total rainfall of 7.20 inches. The values used in the simulation are lower by a factor of 0.96 than the values reported in the above references to account for areal reductions as recommended by Table 21.1 of NEH-4.

Two storm durations were considered: a 24-hour duration and a 6-hour duration. These were used to see if a long-lasting storm or a storm slightly greater than the time of concentration of the watershed would produce the larger peak flows. The results varied from cross section to cross section, so the results of the larger of the two flows were used in the hydraulic analysis and are reported in this chapter.

The total amount of rainfall in inches should be realistically distributed over the time duration of the storm. The 24-hour storm was distributed in 10-minute increments according to the type II curve reported by the SCS in TP149. The total rainfall amounts in Table 5-1 were used. The 6-hour storm was distributed in such a manner as to preserve the 10-minute, 30-minute, 1-hour, 2-hour, 3-hour, and 6-hour rainfall totals. The peak rainfall intensity occurs at the beginning of the third hour. Table 5-2 gives the 10-minute rainfall accumulations for the 6-hour design storms used in the hydrology simulation.

Table 5-1
Total Rainfall in Inches Used
for the 24-Hour Storm

Recurrence Interval (years)	Total Rainfall (inches)
2	3.12
5	4.32
10	4.80
25	5.76
50	6.24
100	7.20

Table 5-2
Rainfall in Inches for
6-Hour Duration Design Storms

Time Since Beginning of Rainfall	Recurrence Interval (years)					
	2-year	5-year	10-year	25-year	50-year	100-year
0 min.	0.0	0.0	0.0	0.0	0.0	0.0
10	0.01	0.01	0.01	0.01	0.01	0.01
20	0.01	0.02	0.02	0.02	0.03	0.01
30	0.01	0.02	0.03	0.03	0.03	0.01
40	0.01	0.03	0.03	0.03	0.03	0.02
50	0.01	0.03	0.03	0.03	0.03	0.02
1 hr	0.01	0.03	0.03	0.03	0.03	0.02
10	0.01	0.04	0.04	0.04	0.04	0.02
20	0.02	0.04	0.04	0.04	0.04	0.03
30	0.03	0.04	0.02	0.02	0.03	0.03
40	0.03	0.02	0.02	0.02	0.04	0.05
50	0.04	0.02	0.05	0.03	0.08	0.05
2 hr	0.05	0.04	0.10	0.10	0.12	0.10
10	0.08	0.08	0.15	0.15	0.15	0.12
20	0.08	0.12	0.15	0.15	0.15	0.15
30	0.10	0.15	0.15	0.17	0.16	0.15
40	0.10	0.15	0.15	0.18	0.20	0.20
50	0.24	0.28	0.29	0.34	0.37	0.39
3 hr	0.62	0.79	0.92	1.08	1.21	1.35
10	0.30	0.38	0.44	0.52	0.59	0.65
20	0.11	0.15	0.19	0.25	0.30	0.40
30	0.10	0.11	0.15	0.20	0.25	0.40
40	0.10	0.11	0.15	0.18	0.20	0.30
50	0.08	0.10	0.10	0.10	0.20	0.18
4 hr	0.07	0.04	0.05	0.04	0.10	0.10
10	0.05	0.03	0.02	0.02	0.05	0.05
20	0.04	0.02	0.02	0.02	0.04	0.05
30	0.03	0.02	0.04	0.04	0.04	0.04
40	0.03	0.02	0.04	0.04	0.04	0.03
50	0.02	0.02	0.03	0.03	0.04	0.03
5 hr	0.01	0.02	0.03	0.03	0.04	0.03
10	0.01	0.02	0.03	0.03	0.04	0.03
20	0.01	0.02	0.03	0.03	0.04	0.02
30	0.01	0.02	0.02	0.03	0.04	0.02
40	0.01	0.02	0.02	0.03	0.04	0.02
50	0.01	0.02	0.02	0.03	0.04	0.02
6 hr	0.01	0.01	0.01	0.01	0.03	0.01
Total	2.46	3.04	3.62	4.10	4.87	5.11

A 10-minute time interval was chosen so that the effects of a short-duration, high-intensity rainstorm could be evaluated on a subbasin basis and the resultant flows could be used for local design purposes. A 6-hour total duration was used in order to evaluate the effects of channel routing, reservoir storage and the timing of tributary hydrographs on the peak flows.

Runoff Curve Numbers

TR20 uses the following relationship to compute the surface runoff for a rainfall event:

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

where: Q = surface runoff
P = rainfall
S = S' + Ia and S' = potential maximum retention and Ia = initial abstractions

$$= \frac{1000}{CN} - 10$$

or

$$CN = \frac{1000}{S+10}$$

where: CN = runoff curve number

The runoff curve number determines how much runoff results from a given amount of rain. The higher the CN, the larger the peak flow for a given rainfall event. Curve numbers are determined by the soil type and land use within a given subbasin. Soils with low infiltration rates and highly urbanized land uses result in high curve numbers. Curve numbers for each subbasin were determined using Table 5-3, the soils information (Table 4-2), slope data (Table 4-2), existing land use (Table 4-18), and ultimate land use (Table 4-19). Table 5-3 is nearly identical to Table 2-2 of the Soil Conservation Service's TR55 except

Table 5-3
Runoff Curve Numbers for Selected
Agricultural, Suburban, and Urban Land Use
(Antecedent Moisture Condition II, and $I_a = 0.2S$)
Adapted From TR 55

Land Use Description		Hydrologic Soil Group A	B	C	D
Cultivated land:	Without conservation treatment	72	81	88	91
	With conservation treatment	62	71	78	81
Pasture or range land:	poor condition	68	79	86	89
	good condition	39	61	74	80
Meadow:	good condition	30	58	71	78
Wood or forest land:	Thin stand, poor cover, no mulch	45	66	77	83
	Good cover	25	55	70	77
Open spaces, lawns, parks, golf courses, cemeteries, etc.					
Good condition:	grass cover on 75% or more of the area	39	61	74	80
Fair condition:	grass cover on 50% to 75% of the area	49	69	79	84
Commercial and business areas (75% impervious)		85	90	92	94
Industrial districts (72% impervious)		81	88	91	93
Residential:					
Density	Average % Impervious				
High	65	77	85	90	92
Medium	38	61	75	83	87
	30	57	72	81	86
Low	25	54	70	80	85
	20	51	68	79	84
Paved parking lots, roofs, driveways, etc.		98	98	98	98
Streets and roads:					
paved with curbs and storm sewers		98	98	98	98
gravel		76	85	89	91
dirt		72	82	87	89

that commercial and business areas have been changed to reflect a 75 percent imperviousness and the residential land uses have been grouped into high, medium, and low densities. Note that a range in CN from 57 to 61 exists for medium density residential developments on class A soils. This leaves some latitude in assigning the curve number. If a subbasin had a high percentage of steep slopes the higher curve number was used, while if the subbasin was completely flat (0-5 percent slope) the lower curve number was used. In this manner, the curve number assigned to each subbasin reflects land use, soil type and slope.

The curve numbers were determined by calculating a weighted average CN as shown in Table 5-4 for subbasin number 1. The table indicates that subbasin 1 has 2 percent of its land use in low density residential and that this is on soil type A, while 45 percent of the area is in medium density residential with 40 percent in soil type A, 2 percent in soil type B and 3 percent in soil type C. The percent of each land use in each soil type is multiplied by the curve number for that land use-soil type. The sum of all the land use-soil type products is determined, divided by 100, and results in the weighted average curve number.

The above methodology was used to obtain the existing and ultimate land use curve number values listed in Table 5-5. To help identify the location of subbasins, Severn Run is divided into three sections. Upper Severn Run consists of the area from Lake Marion to the Penn Central Railroad tracks; middle Severn Run goes from the railroad tracks to just past New Cut road, while lower Severn Run includes New Cut Road to Route 3.

Table 5-4
CN Determination
Hydrologic Soil Group
Basin #1

Existing Land Use	Hydrologic Soil Group											
	A			B			C			D		
	%	CN	Product	%	CN	Product	%	CN	Product	%	CN	Product
Residential												
Low Density	2	52	104									
Medium Density	40	58	2,320	2	73	146	3	82	246			
Agriculture	8	65	520				1	80	80			
Open Space	3	44	132				1	84	74			
Forest	35	25	875	2	55	110	3	70	210			
Total			3,951			256			610			

$$CN = \frac{3951 + 256 + 610}{100} = \frac{4817}{100} = 48.17 \cong 48$$

Table 5-5
Subbasin Curve Numbers and
Time of Concentration

Subbasins	Area (square miles)	Existing CN	Ultimate CN	Time of Concentration (hours)
Upper Severn Run				
1	0.41	48	53	0.45
2	0.18	70	78	0.26
3	0.32	46	61	0.46
4	0.50	49	49	0.42
5	0.35	48	58	0.90
6	0.47	58	67	0.54
7	0.17	64	65	0.80
8	0.46	71	79	0.79
Jackson Grove Road Branch				
9	0.22	53	72	0.60
10	0.62	44	72	0.82
11	0.31	47	70	0.49
Picture Frame Branch				
12	0.19	51	85	0.11
13	0.11	55	84	0.54
14	0.23	44	86	0.34
15	0.59	60	76	0.55
16	0.70	53	70	0.55
17	0.35	53	59	0.46
18	0.34	45	61	0.34
Middle Severn Run				
19	0.79	50	63	0.56
27	0.87	37	42	1.05
28	1.20	53	54	0.87
Beaver Creek				
20	0.21	51	60	0.35
21	0.16	30	50	0.46
22	0.22	53	53	0.30
23	0.61	43	64	0.46
24	1.10	51	58	1.02

Table 5-5 (Continued)

Subbasins	Area (square miles)	Existing CN	Ultimate CN	Time of Concentration (hours)
Delmont Road Branch				
25	0.57	34	43	0.52
26	0.25	40	43	0.49
Broad Branch				
29	0.69	39	48	0.81
30	0.85	51	57	1.01
31	0.99	51	53	1.05
Lower Severn Run				
32	0.55	49	54	0.78
33	0.56	66	72	0.55
34	0.44	56	68	0.63
35	0.52	59	60	0.62
38	0.38	49	49	0.27
46	0.11	51	73	0.24
Wells Branch				
36	0.92	55	61	0.58
37	0.45	61	63	0.51
Jabez Branch				
39	0.72	66	71	0.46
40	0.56	64	67	0.52
41	1.02	68	69	0.84
42	0.33	60	60	0.45
43	1.08	58	58	0.80
44	0.37	61	61	1.05
45	1.23	66	66	1.93

As a watershed develops, the soil type remains more or less constant but the land use changes. Urbanization does change the nature of the soil through compaction and grading but the changes cannot be predicted. Therefore the soil type was left unchanged in going from existing to ultimate land use. Those subbasins with CNs greater than 60 are shown in Figure 5-1. The area around Jabez Branch has high CN values due to the predominance of hydrologic group B soils (Figure 4-1) and steep slopes (Figure 4-2). The western portion of the watershed will have high CNs due to the development planned for that area. Figure 5-2 is repeated from Chapter 3 to aid in the identification of subbasins and cross sections.

Time of Concentration

Time of concentration is defined as the length of time required for runoff to travel from the hydraulically most distant point of a watershed to the watershed's outlet. The times listed in Table 5-5 were determined using Kirpich's formula given as:

$$t_c = .0078 \quad L^{0.77} \, S^{-0.385}$$

where: t_c = time of concentration in minutes
L = length of longest waterway in feet
S = slope of watershed in ft/ft

Other means of calculating t_c were tried, but Kirpich's formula gave reasonable results and was chosen for uniformity among subbasins.

Cross Sections and Reservoirs

Thirty-five cross sections were used for routing flows through the stream channels in the Severn Run Watershed.

The stage, discharge, and cross sectional areas of the cross sections were used as input data. This relationship was determined through a preliminary HEC-2 analysis using the 35-channel routing cross sections. One actual reservoir at Lake Marion and two roads that act as reservoirs were considered in the hydrology simulation. The roads considered were Route 32 on Jabez Branch and the Penn Central Railroad on Picture Frame Branch. The stage-discharge-storage volume relationship of the structures was input to TR20. These cross sections were taken from the larger number of cross sections (135) used in the hydraulic analysis (Chapter 6). Cross sections representative of the channel for the area being considered were used.

Antecedent Moisture Conditions

It is necessary to specify one of three possible antecedent moisture conditions, AMC, to run TR20. The antecedent moisture conditions are AMC I for dry soils, AMC II for normal soils, and AMC III for saturated soils. Specifying AMC I results in less runoff than normal by lowering the values of the curve numbers. AMC III raises the curve numbers and gives more surface runoff. The production runs of TR20 assumed normal soil conditions, AMC II.

SENSITIVITY ANALYSIS

A sensitivity analysis of the most important TR20 input parameters was performed to determine which parameters were the most critical.

Precipitation

The peak rainfall intensity was found to be more important than the total rainfall amount in determining

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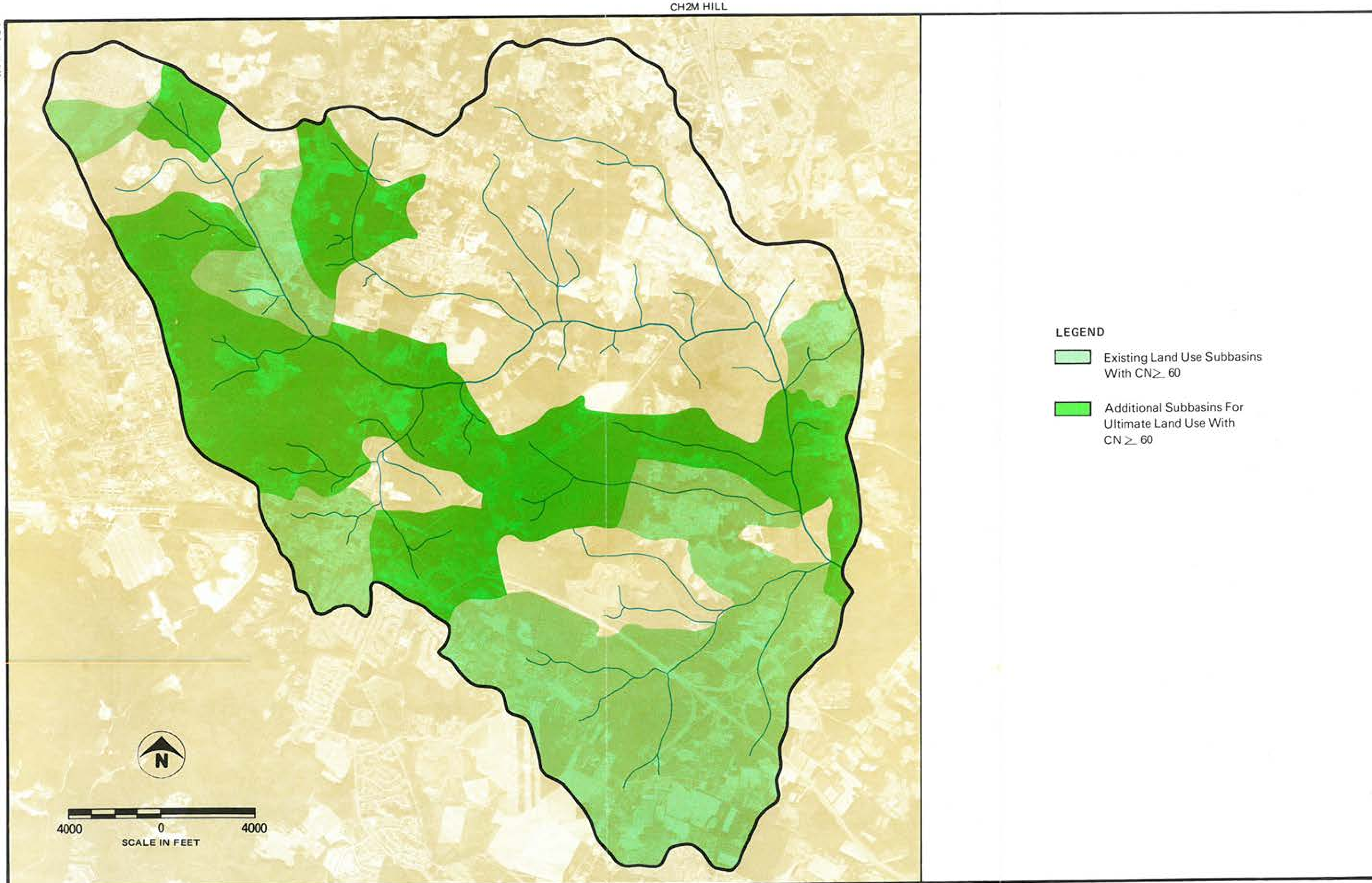

FIGURE 5-1: Subbasins With CN'S Greater Than 60

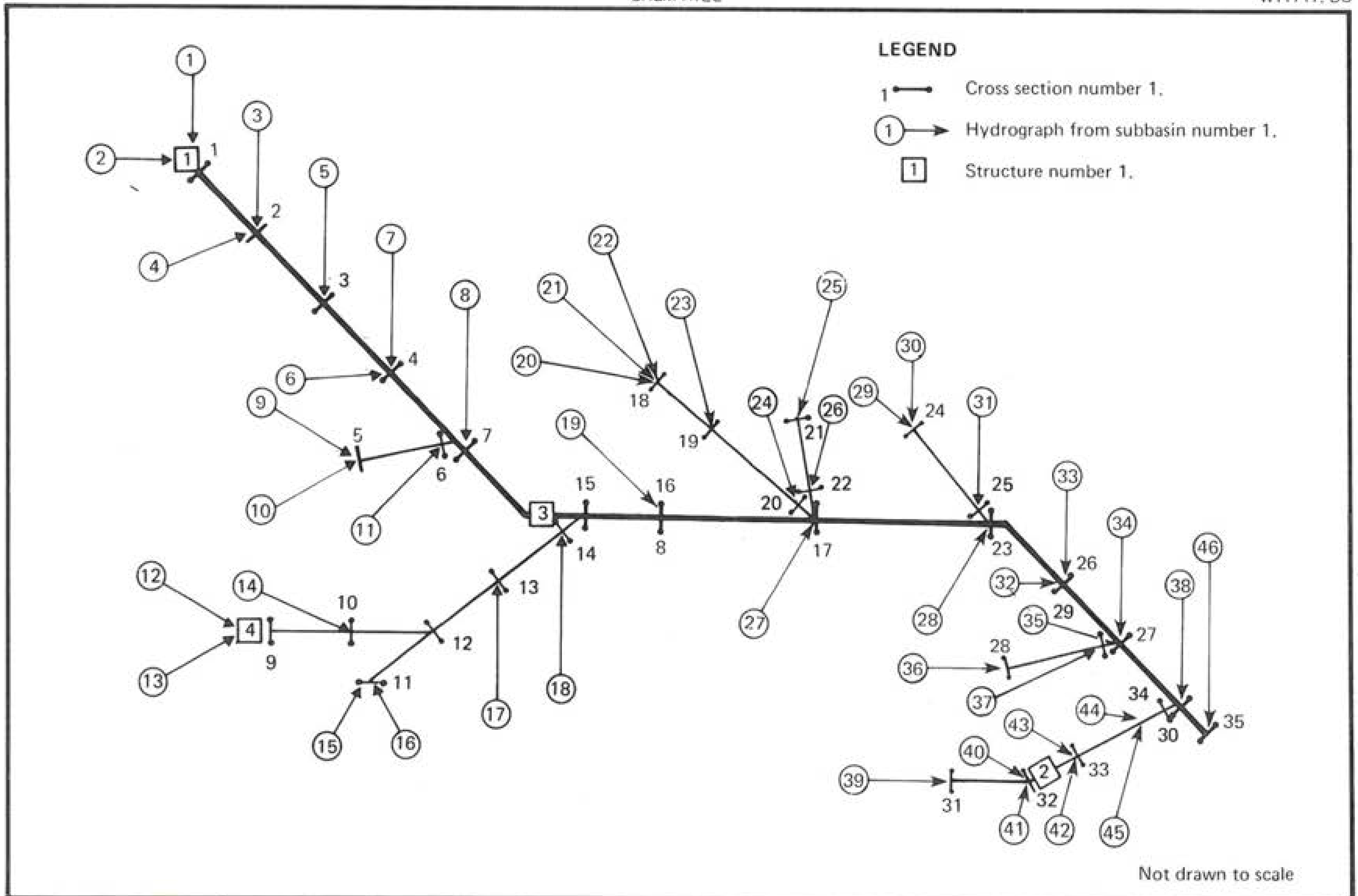

FIGURE 5-2: Hydrologic Model Schematic of Severn Run

the peak runoff rate. Two conditions for the same total rainfall as used in the 6-hour, 100-year storm (Table 5-2) and an evenly distributed rainfall over the 6-hour period were used. The resulting peak flows are shown by Figure 5-3. The evenly distributed rainfall produces only a fraction of the runoff that the design storm produces.

Antecedent Moisture Conditions

The choice of the antecedent moisture condition has a predominating effect on the peak runoff. Figure 5-4 is a flood peak frequency curve for all three AMC conditions. The overwhelming effect of the choice of AMC conditions can be seen by the fact that the 2-year flood for AMC III is larger than the 100-year flood for AMC I. Due to this large variation in results, AMC II was used since it is the more likely condition.

Time of Concentration

Changes in the times of concentrations used in the simulation had very little impact on the peak flows. For this reason, the same value for the time of concentration was used for ultimate land use as for existing land use. It is realized that as an area urbanizes, the time of concentration will be reduced; however, determining the new value of t_c could be subject to substantial error. The sensitivity analysis showed no perceptible changes in peak flows with changes in t_c of 20 percent.

Curve Number

The simulated peak flows are sensitive to the value of the curve number used. For example, a change in the curve number from 49 to 55 has a large impact on the value of the peak flow. Because of this sensitivity, care must be used in assigning curve numbers. This requires consideration of the existing land use and land use plans in detail since small changes in the degree to which an area will develop can have significant impacts on the predicted flood flows. Changes in land use plans will require updating of the curve numbers and subsequent runs of TR20 to determine the resulting flood flows.

Bridges and Culverts

The flow-restricting bridges and culverts mentioned earlier have large impacts on the peak flows. These restrictions were found as part of the backwater analysis and TR20 was then updated to include their reservoir routing effects. The differences in the peak flows for the cases of no restrictive bridges or culverts, and with the restrictions, are shown in Figure 5-5 for ultimate land use conditions.

RESULTS OF THE HYDROLOGY SIMULATION

The flows presented in this section are the ones used in the final HEC-2 backwater analysis. The simulations included the restrictive bridges and culverts; the greater of the two flows from the 6-hour and 24-hour duration storms was used. The local subbasin peak flows for existing and ultimate land use conditions are given in Table 5-6, while Table 5-7 has the peak flows at each channel routing cross section (these flows include the effects of adding the subbasin flows together and the dampening effects of channel and reservoir routing). Figures 5-6 and 5-7 show the differences between existing and

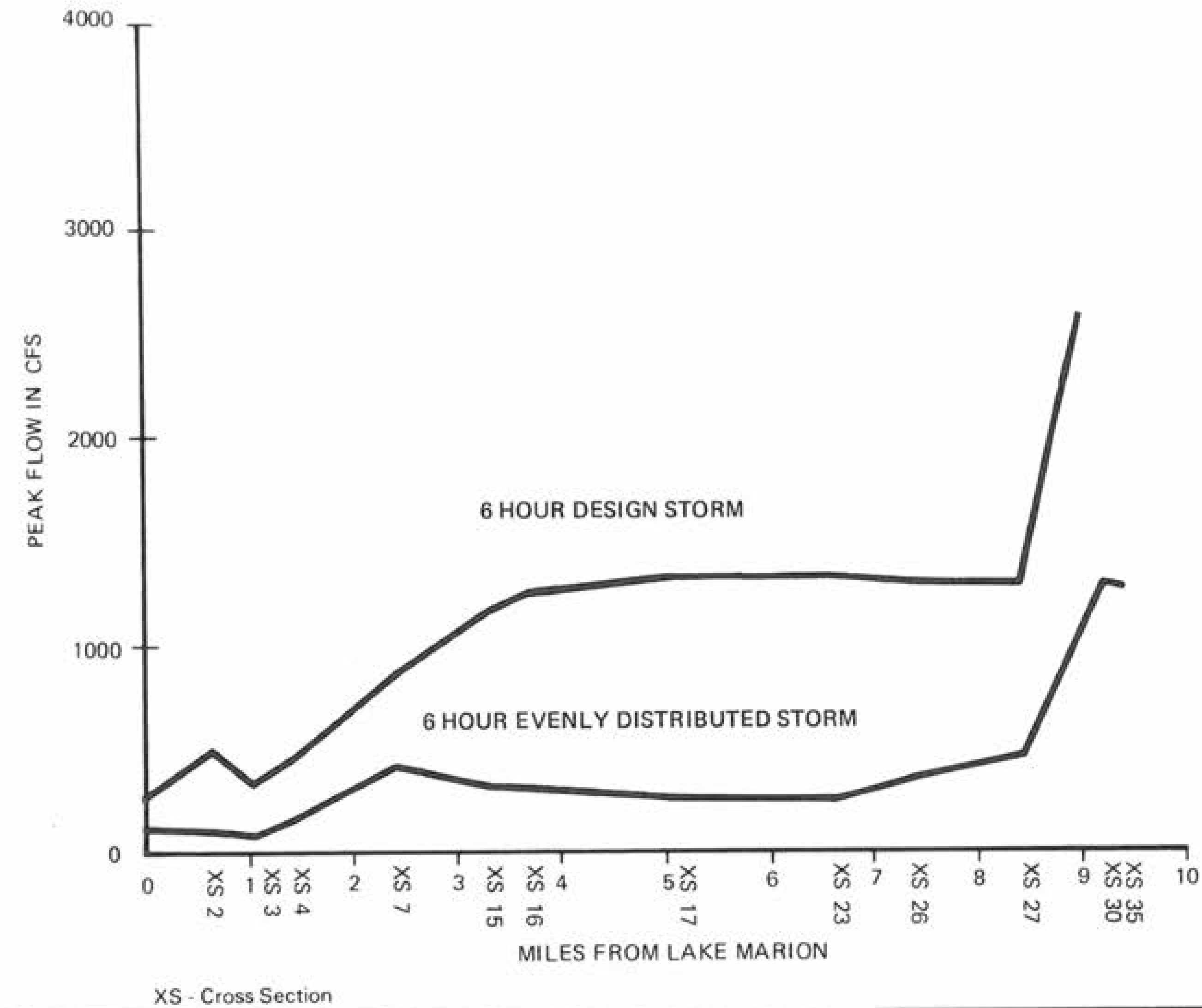

FIGURE 5-3: Results Of Rainfall Distribution Sensitivity Analysis

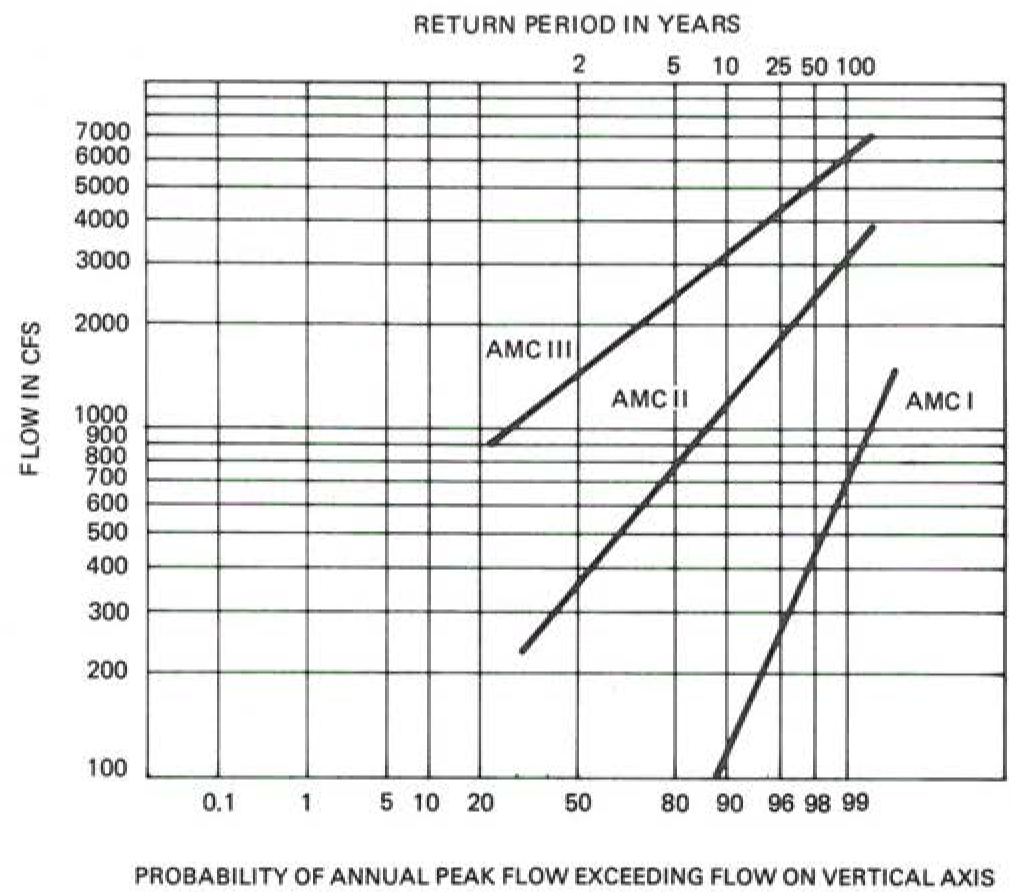

FIGURE 5-4: Results Of Antecedent Moisture Condition Sensitivity Analysis At Cross Section 7, Existing Land Use

Table 5-6
Existing and Ultimate Peak Flows for Each Subbasin

	Peak Flow In cfs											
	2-year		5-year		10-year		25-year		50-year		100-year	
Subbasins	Existing	Ultimate	Existing	Ultimate	Existing	Ultimate	Existing	Ultimate	Existing	Ultimate	Existing	Ultimate
Upper Severn Run												
1	1	9	12	28	31	59	58	104	97	155	144	204
2	53	107	111	181	161	242	209	300	262	361	285	393
3	0	22	5	68	17	113	35	167	60	227	95	251
4	3	3	18	18	44	44	83	83	133	133	194	194
5	1	15	8	39	22	69	41	107	70	151	99	194
6	23	70	65	164	114	248	179	339	251	438	304	481
7	15	17	36	39	57	61	82	87	109	115	132	139
8	87	168	174	283	250	375	331	477	420	580	491	654
Jackson Grove Road Branch												
9	4	52	14	103	29	147	51	191	76	240	103	271
10	0	126	3	243	17	349	41	460	82	580	123	678
11	1	68	7	144	20	206	38	275	64	348	99	385
Picture Frame Branch												
12	3	236	11	353	29	490	58	545	87	638	99	699
13	3	72	10	109	20	138	32	170	47	200	60	220
14	1	218	2	312	9	399	20	472	36	552	61	603
15	36	210	102	378	171	514	259	656	356	804	423	888
16	14	142	46	302	95	439	170	584	254	741	337	811
17	7	20	23	57	50	103	88	157	132	218	174	246
18	1	22	3	67	14	108	28	160	49	216	82	242
Middle Severn Run												
19	6	69	33	184	75	293	136	424	214	566	309	663
27	0	1	0	2	1	11	6	33	29	79	52	120
28	21	26	70	81	144	161	148	265	367	396	493	526
Beaver Creek												
20	3	13	11	45	24	73	48	111	75	151	96	170
21	0	1	0	7	0	16	0	29	0	46	1	65
22	5	5	17	17	37	37	65	65	97	97	113	113
23	0	65	2	177	17	276	42	392	83	518	135	580
24	11	45	43	116	98	206	170	315	272	449	370	575
Delmont Road Branch												
25	0	0	0	2	0	15	1	38	9	77	21	123
26	0	0	0	1	2	7	8	17	22	34	37	55
Broad Branch												
29	0	30	0	79	3	142	12	220	43	310	71	395
30	8	30	34	80	76	146	132	226	211	326	286	421
31	10	16	38	53	86	99	148	181	240	281	323	372
Lower Severn Run												
32	3	12	16	38	42	77	76	127	125	188	178	253
33	74	137	172	278	270	394	364	517	486	648	545	704
34	15	68	43	149	81	221	132	303	192	390	245	449
35	28	31	76	86	134	146	205	221	285	304	344	362
38	2	2	15	15	34	34	72	72	116	116	156	156
46	1	44	6	84	14	116	27	149	41	184	51	200
Wells Branch												
36	27	63	80	173	160	286	265	427	386	580	494	686
37	31	41	89	109	152	181	218	259	306	346	349	386
Jabez Branch												
39	99	181	250	368	378	520	525	689	682	866	758	954
40	59	84	147	198	240	299	339	408	450	528	502	577
41	138	154	293	316	438	467	604	636	781	818	929	969
42	21	21	63	63	108	108	162	162	222	222	245	245
43	47	48	124	124	223	223	346	346	488	488	624	624
44	22	22	52	52	87	87	128	128	178	178	222	222
45	97	97	180	180	277	277	379	379	520	520	623	623

Table 5-7
Existing and Ultimate Channel Peak Flows

Structure or Cross Section	Peak Flow In cfs											
	2-year		5-year		10-year		25-year		50-year		100-year	
	Existing	Ultimate	Existing	Ultimate	Existing	Ultimate	Existing	Ultimate	Existing	Ultimate	Existing	Ultimate
Upper Severn Run												
Lake Marion	15	45	37	106	51	165	102	254	131	335	203	400
1	15	45	37	102	51	160	100	248	127	332	199	398
2	14	65	49	152	74	258	158	399	201	563	313	747
3	12	63	49	131	74	216	142	298	185	436	281	525
4	24	89	79	200	113	306	202	434	255	575	373	719
7	56	374	165	711	231	970	386	1229	461	1526	620	1823
Jackson Grove Road Branch												
6	5	188	18	363	27	533	65	721	90	932	159	1129
Picture Frame Branch												
Penn Railroad	1	60	5	76	8	85	19	93	26	100	37	106
10	4	256	16	382	40	488	70	580	110	679	145	734
11	47	311	127	617	240	873	397	1153	572	1445	732	1639
14	50	472	130	854	256	1214	438	1620	707	2062	934	2467
Middle Severn Run												
15	97	508	201	962	343	1416	534	1893	901	2471	1171	2989
16	99	548	210	1030	365	1502	563	1991	964	2658	1250	3185
17	94	539	209	1013	384	1544	615	2063	1080	2872	1322	3435
23	101	503	311	942	432	1493	752	2031	957	2938	1434	3489
Beaver Creek												
19	7	73	26	191	69	317	131	452	217	616	314	770
20	12	70	45	136	99	232	171	353	272	599	371	779
Delmont Road Branch												
22	0	0	0	3	2	15	8	33	23	70	39	96
Broad Branch												
25	9	16	38	53	86	110	148	185	240	348	323	406
Lower Severn Run												
26	115	494	344	924	472	1466	810	1994	1023	2890	1525	3421
27	144	471	406	880	551	1396	922	1890	1154	2719	1686	3154
30	315	417	605	766	1006	1230	1420	1676	2078	2364	2492	2787
35	314	417	604	767	1004	1232	1418	1677	2078	2369	2491	2788
Wells Branch												
29	44	82	101	167	174	295	281	458	468	675	613	851
Jabez Branch												
32	257	341	522	686	837	1043	1213	1509	1629	1818	1990	2178
Route 32	220	286	443	561	708	840	948	1097	1244	1411	1497	1665
33	214	272	410	505	677	816	954	1100	1356	1535	1629	1816
34	273	327	509	604	867	1020	1263	1424	1897	2079	2300	2489

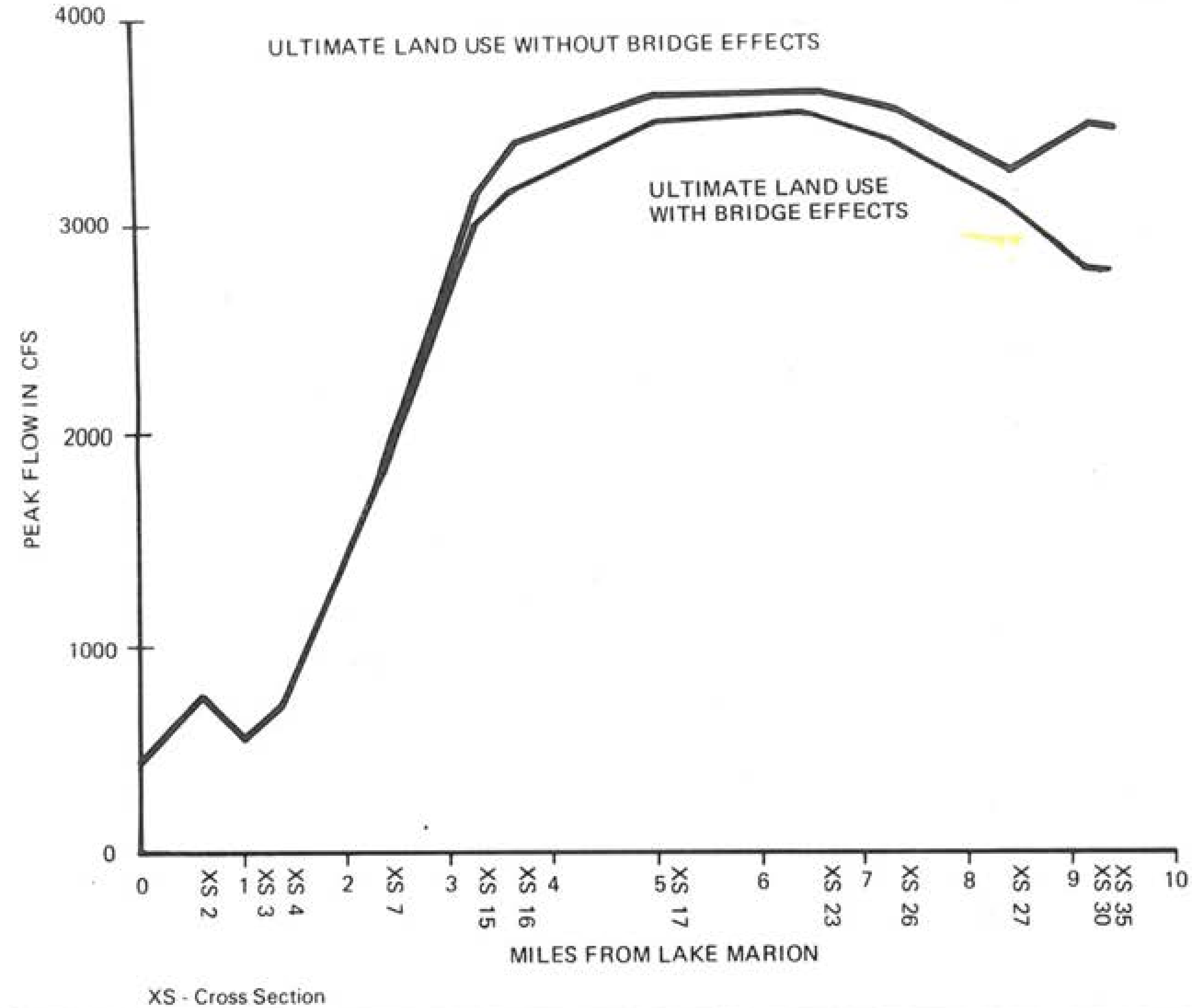

FIGURE 5-5: Influence of Restrictive Bridges and Culverts

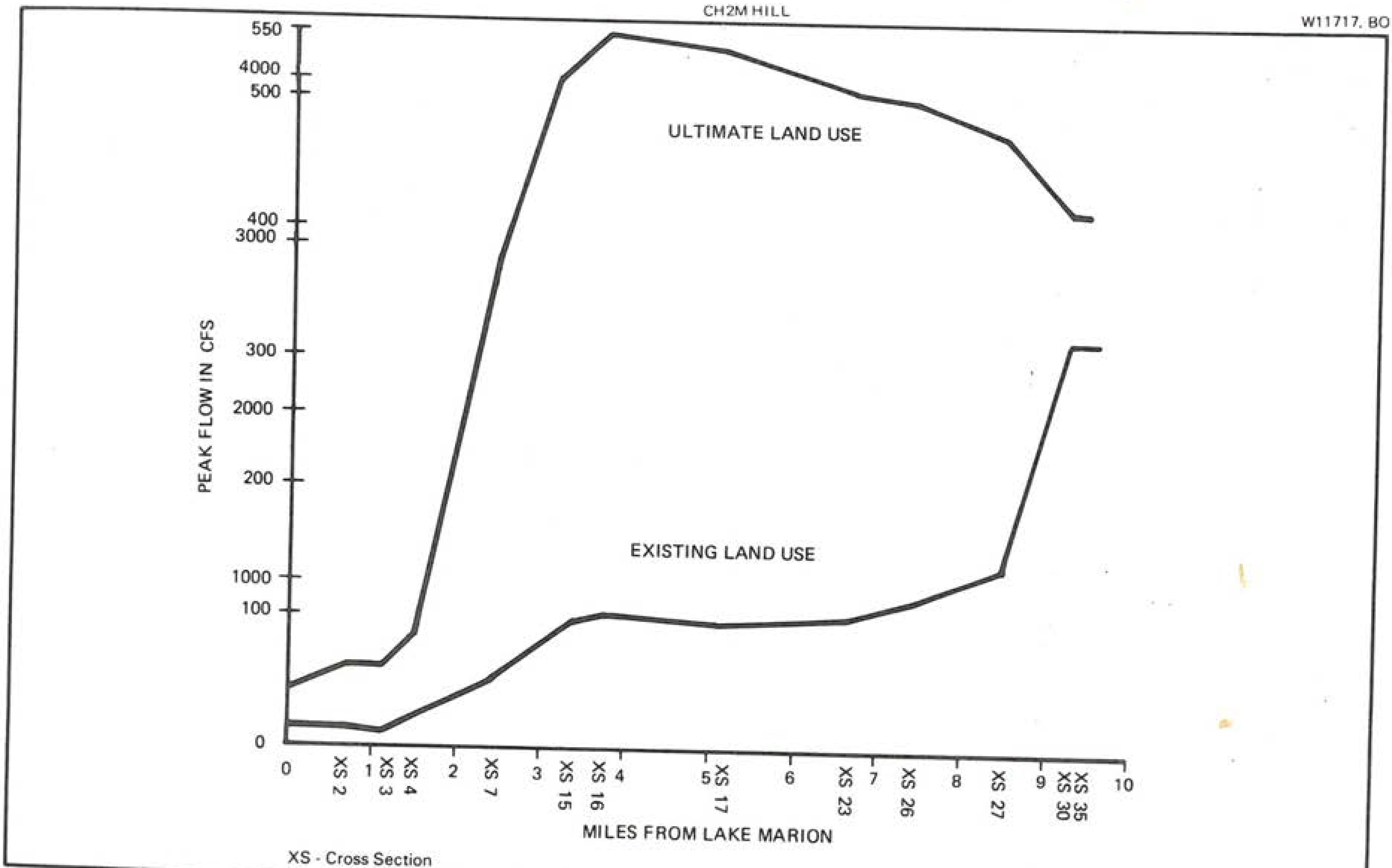

FIGURE 5-6: Severn Run 2 Year Flood Peak Flows

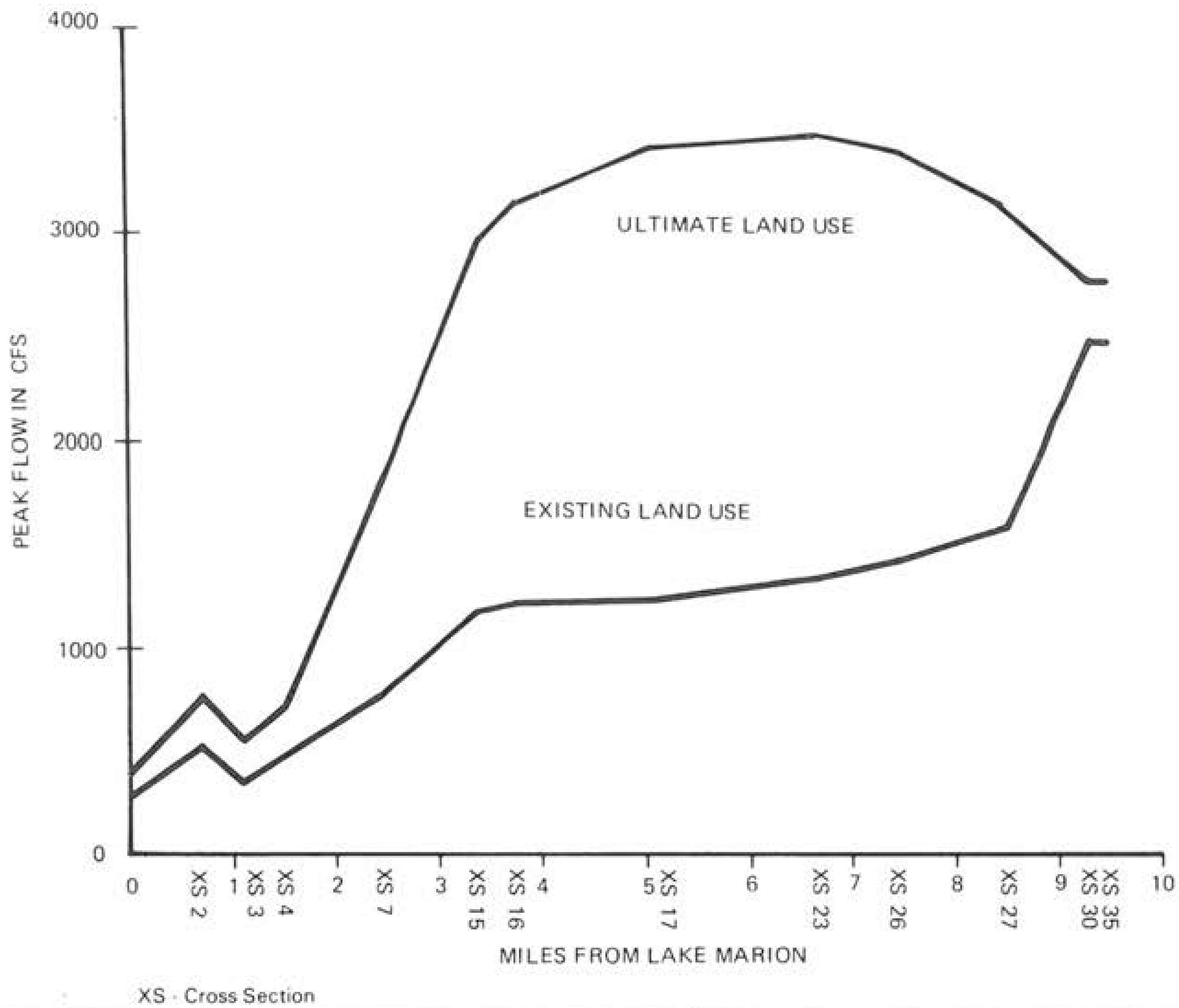

FIGURE 5-7: Severn Run 100 Year Flood Peak Flows

ultimate land use conditions for the 2-year and 100-year flood peaks on the Severn Run. Areas of significant flow increases are upper Severn Run near the Penn Central Railroad, Jackson Grove Road Branch, Picture Frame Branch, middle Severn Run, Beaver Creek, and lower Severn Run to Dicus Mill Road.

Note that although there are significant increases in flow for the lower Severn Run, the flow does not change significantly for cross section 35, Route 3. The peak flow at Route 3 is dominated by the flow from Jabez Branch, as Figure 5-8 demonstrates. The drainage area for Jabez Branch is predominantly composed of group B soils which have a higher runoff potential than the group A soils which make up the rest of the Severn Run watershed. This results in the large peak flow for Jabez Branch. The peak flow for Jabez Branch changes very litle for the ultimate land use condition because the area will experience minimal development. As a result, the peak flow at Route 3 remains nearly constant for the ultimate land use condition, even though Middle and Lower Severn Run experience significant increases in the peak flows.

Also note that the peak flows for the middle Severn Run are almost constant for a given land use condition; i.e., existing or ultimate. In this region, the incoming tributary flows are nearly balanced by the attentuation of the flood peak due to channel routing. Severn Run has wide flood plains with significant flow resistance because of the high density of brush and trees. The flood plains act to store water and hence reduce the flow, while the brush and trees slow the flow of water down and reduce its peak flow.

Frequency curves for existing and ultimate land use are shown in Figures 5-9, 5-10, and 5-11 for Picture Frame Branch, cross section 23 downstream from New Cut Road, and Route 3, respectively. Note that the curves converge for less frequent events and that there are large differences between existing and ultimate land use peak flows for Picture Frame Branch and New Cut Road.

Regional Analysis

Although the Severn Run is ungaged and the hydrology model could not be calibrated, confidence can be placed in the simulated flows based on the results of a regional analysis performed for nearby gaged streams. The flows for the streams listed in Table 5-8 were used to obtain flood frequency curves for each stream. The 2-, 5-, 10-, 25-, 50- and 100-year floods were divided by the area of the stream's watershed and are plotted in Figure 5-12. The maximum and minimum values form an envelope in which the results of the Severn Run should fall. Figure 5-13 indicates that the simulated results do fall within the envelope. The existing and ultimate flows at cross section 35 (Route 3) and cross section 23 (New Cut Road) are plotted.

Table 5-8
Regional Analysis Data

Gage Name	Gage No.	Drainage Area (square miles)	Years of Record
Saw Mill Creek	5895	5.1	14
North River	5900	8.5	42
Bacon Ridge Branch	5905	6.92	22
Little Patuxent River at Guilford	5935	38.0	45
Little Patuxent River at Savage	5940	98.4	29
Dorsey Run at Jessup	5944	11.6	18
St. Leonard Creek	5948	6.73	11
St. Mary's River at Great Mills	6615	24.0	31

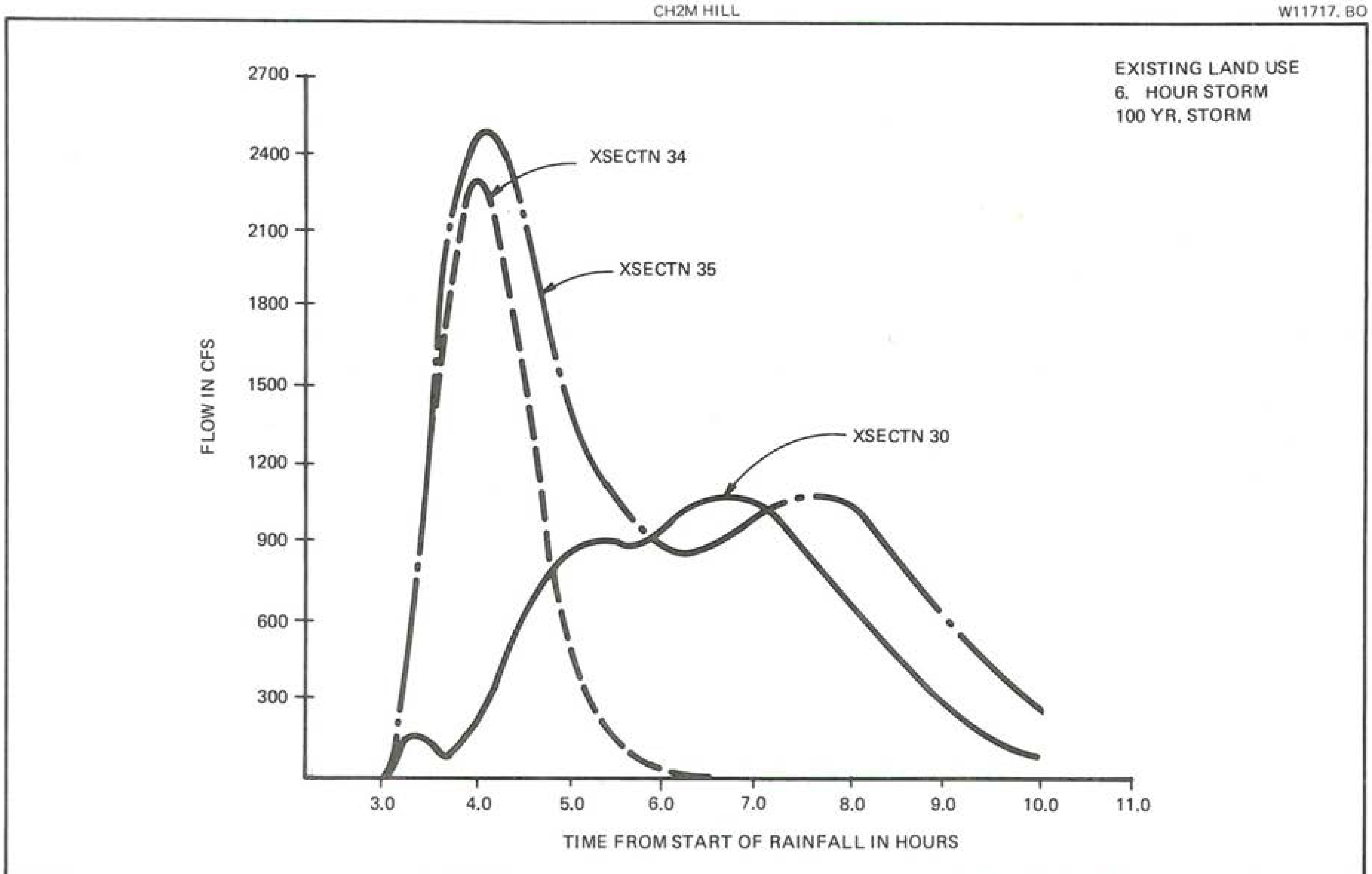

FIGURE 5-8: Components Of Hydrograph At Cross Section 35, Route 3

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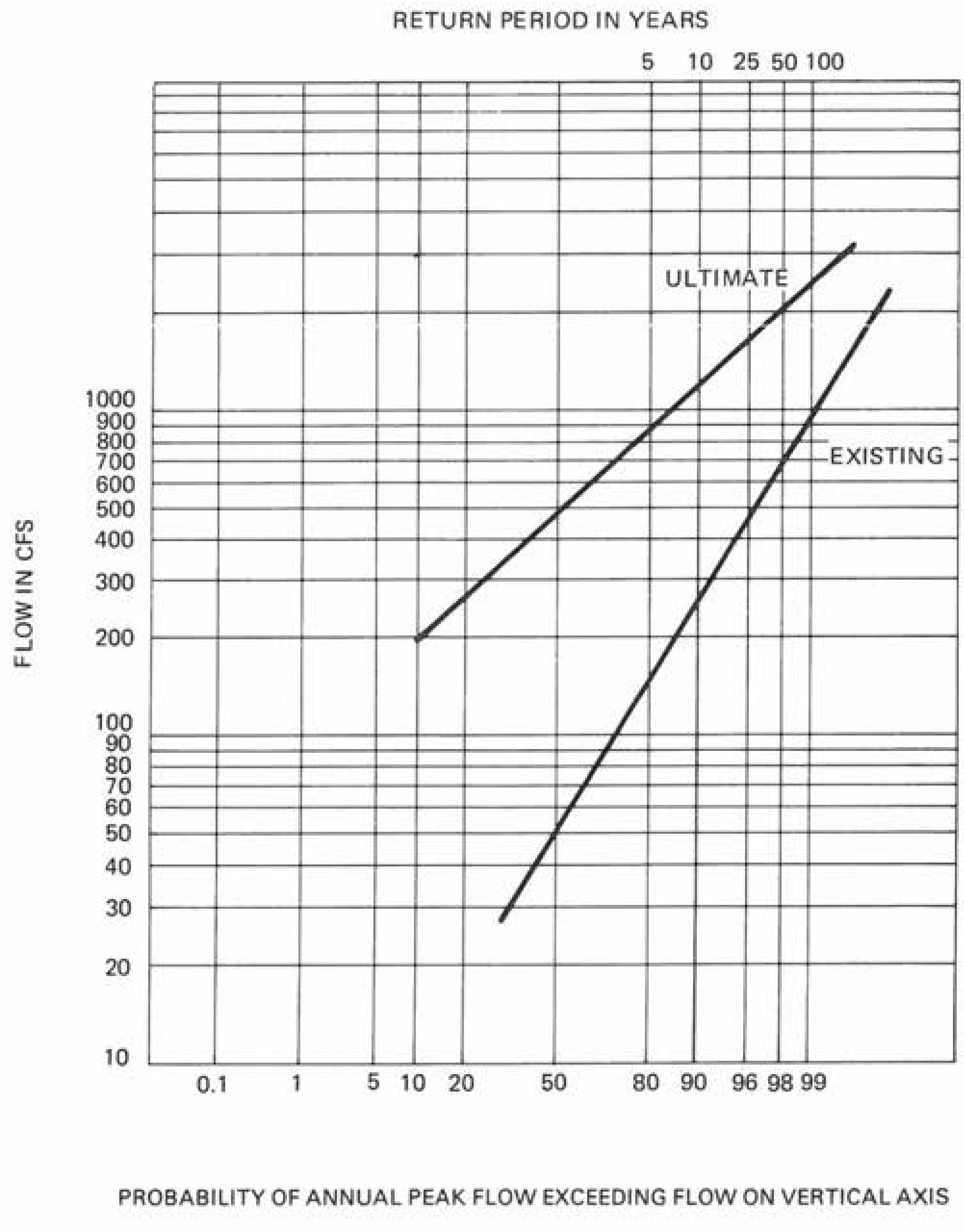

FIGURE 5-9: Cross Section 14, Picture Frame Branch,
Flood Frequency Curve

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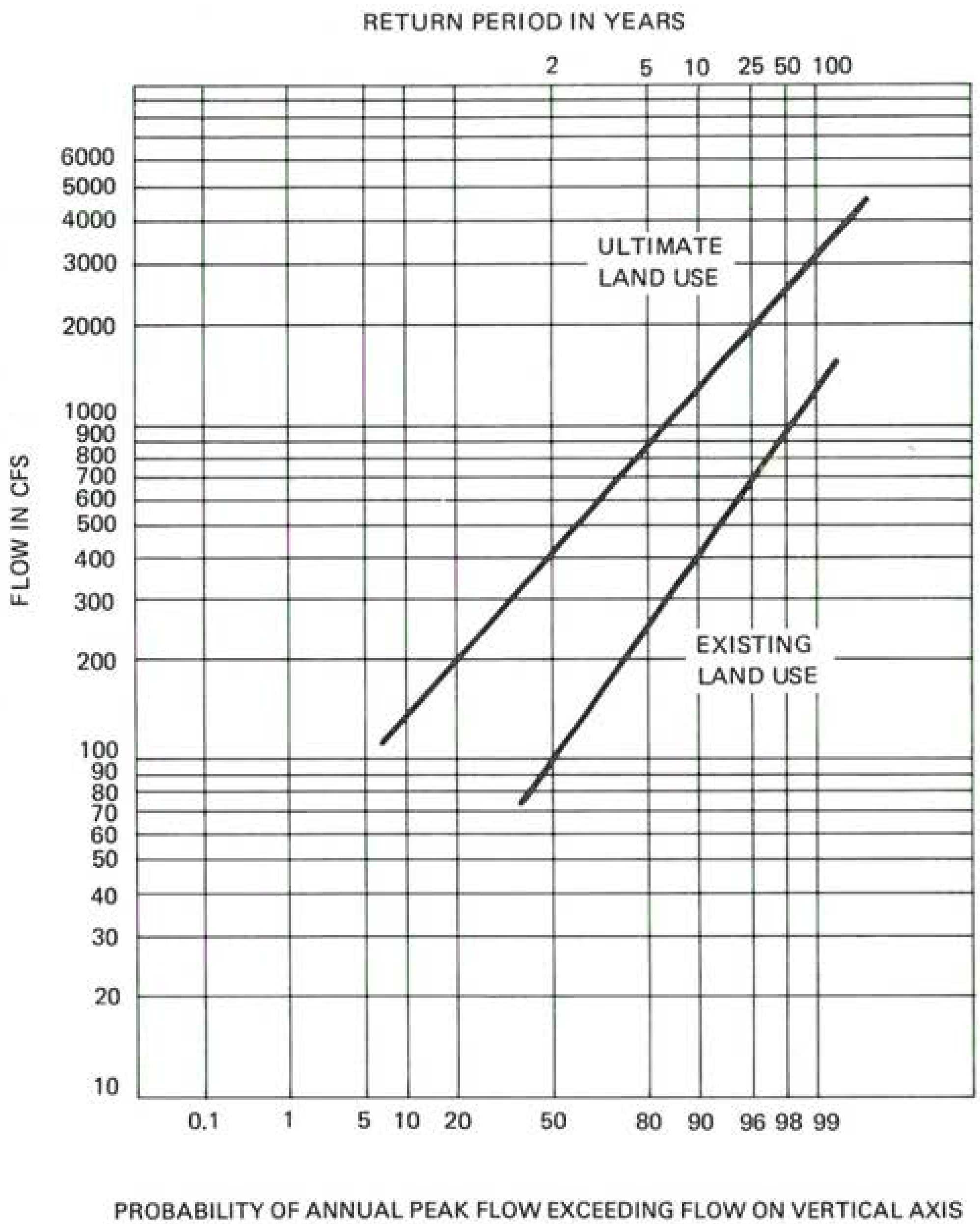

FIGURE 5-10: Cross Section 23, Downstream Of New Cut Road, Flood Frequency Curve

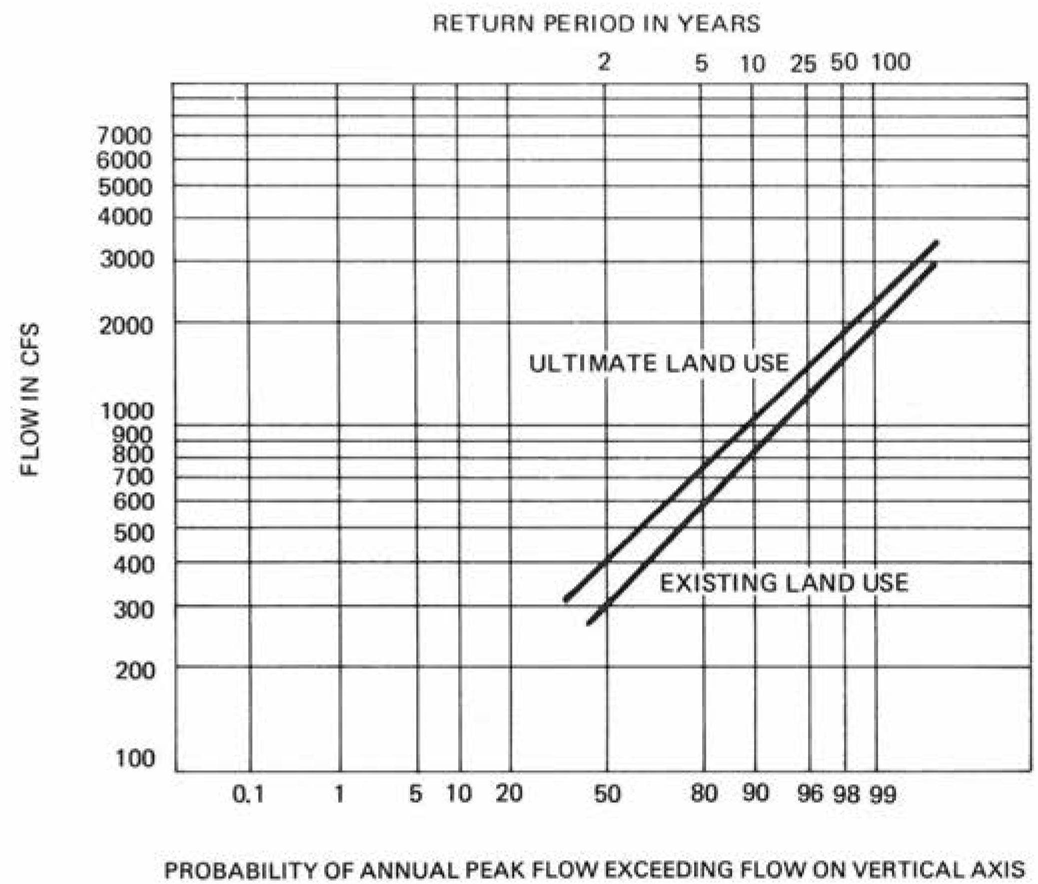

FIGURE 5-11: Cross Section 35, Route 3, Flood Frequency Analysis

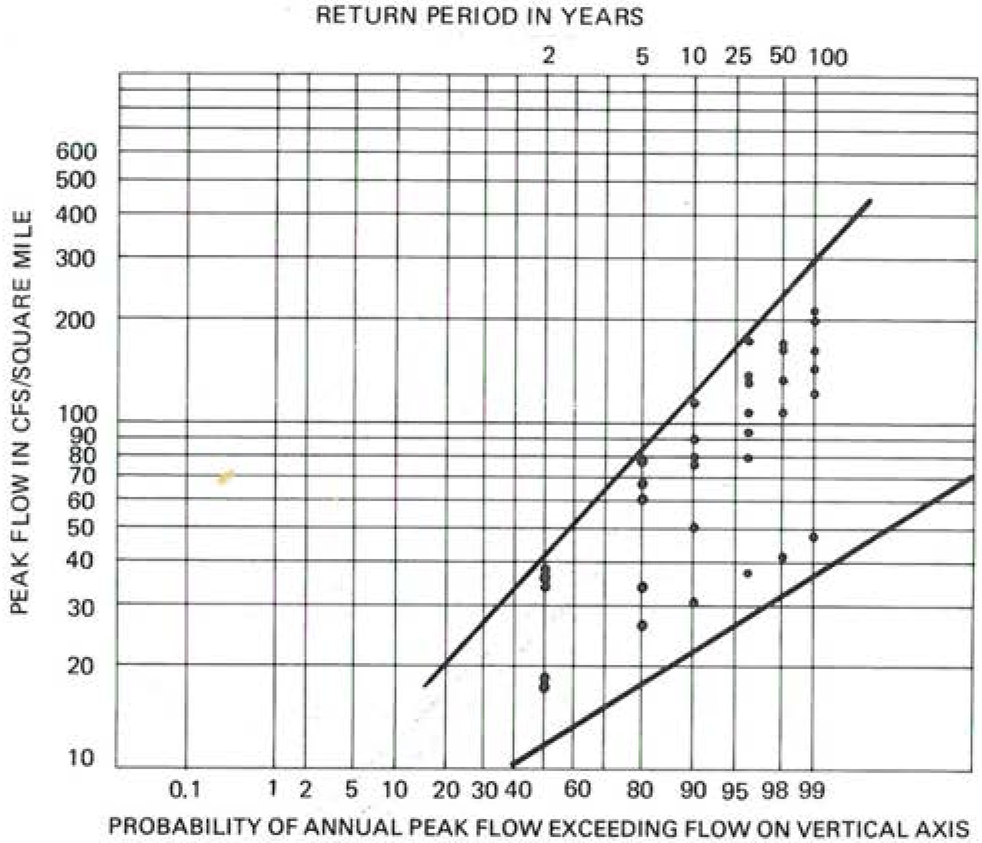

FIGURE 5-12: Regional Analysis – Observed Data

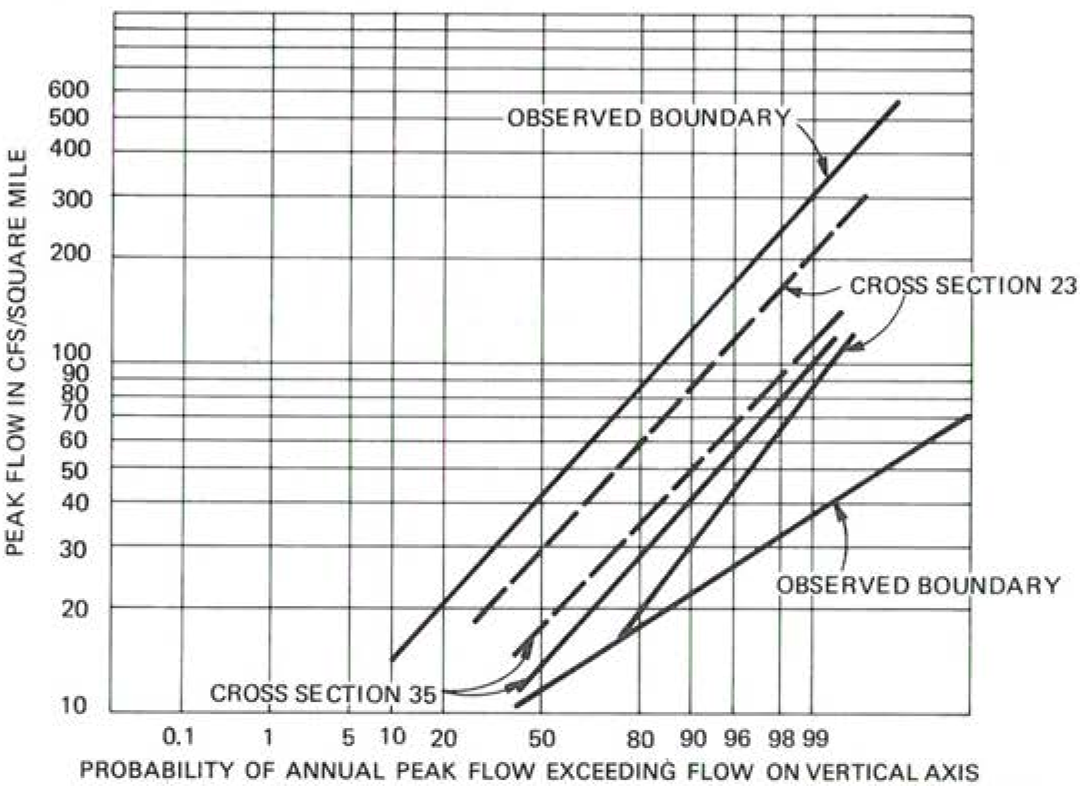

FIGURE 5-13: Regional Analysis – TR 20 Results

Chapter 6

CHAPTER 6
HYDRAULIC ANALYSIS

Hydraulics is the study of water in motion, and for this report, the hydraulic analysis consists of studying the flood waters in the Severn Run basin once they have reached the stream channel. The principal purpose of the hydraulic analysis is to establish flood elevations (flood profiles) along the streams for floods of various recurrence intervals.

INPUT REQUIREMENTS

The flooding in streams was analyzed at discrete locations along each stream where cross section information was collected. Cross section locations were chosen such that stream characteristics did not change significantly between sections. In the 22 miles studied, approximately 175 cross sections were required to adequately describe the hydraulic flow characteristics of the streams.

In computing a flow profile, the following information is necessary:

1. Channel geometry in the form of cross sections at various places along the longitudinal reach of the stream. The cross sections must include not only the channel proper, but also enough of the flood plain to accommodate the range of flows to be used in the analysis.

2. Channel and flood plain roughness estimations in the form of Manning's "n".

3. Information defining bridges and culverts.

4. The discharge (flow) throughout the longitudinal reach of the stream. The discharge can be adjusted to reflect diversions into or out of the stream, additional flow from a tributary or an accumulation of local inflow.

5. Energy loss coefficients for expansion and contraction of the stream channel.

A discussion of the sources of this information follows.

Channel Geometry

The necessary channel geometry at each cross section is a two-dimensional depiction of the channel, using grid points in a plane perpendicular to the flow. A set of ground elevations and stations (distance along the section from an arbitrary point) was obtained for each cross section. The information was developed by Maps, Incorporated of Baltimore, Maryland; by using photogrammetric analysis of aerial photographs.

Channel and Flood Plain Roughness

Hydraulic roughness is a measure of the resistance to flow over a particular surface. A smooth surface, such as a concrete channel, offers little resistance and carries floodwaters relatively easily. A rough surface, such as a stream channel clogged with debris or overgrown with bushes, impedes the progress of the water. Flows in a "rough" channel will be slower and deeper than corresponding flows in a "smooth" channel.

In the early days of open channel hydraulics, Manning derived a relationship for velocity as a function of several channel characteristics. One of these characteristics was a roughness value he called "n." Manning's "n" has come into wide use as a method of quantifying roughness.

Manning's "n" values for surfaces are a function of the depth of flow. For example, grass represents a very smooth surface to several feet depth of flood flow, but a rough surface to several inches of flood flow. Generally, maximum retardation of flow by roughness elements occurs when the depth of flow is about the same height as the elements. Roughness coefficients given in this analysis should be considered typical for water stages of at least 3 times the height of flow-flattened roughness elements other than tree trunks. A flood flow slightly overbank--say the average annual flood--may actually experience roughness coefficients somewhat greater than those used for this study. A larger flood, such as the 100-year return interval, may actually have roughness coefficients that are slightly less. Summer foliage can have considerably greater roughness than leafless shrubs and dead weeds. However, on small streams, such as those studied for this report, the larger floods occur in the summer and fall due to short-term, intense thunderstorms. For this reason, summer foliage was assumed in assigning "n" values.

Another factor to be considered is the effect of stream meander. A highly meandering stream possesses a high hydraulic roughness because of the dissipation of energy on banks from frequent changes in direction of flow. This effect would be most pronounced in the bank full condition--when the flow is at the top of the stream channel without being in the flood plain--and assumes less importance with increasing overbank flow. For large floods, the water flow will generally follow the direction of the stream valley and shortcut meanders. This will reduce both travel time and meander roughness factors.

The pattern of vegetation over the banks can be as important as average flood flow roughness. There may be floodways or open passages due to natural or manmade factors in the flood plain. Roads or utility rights-of-way alongside a stream can provide relatively easy passage to floodwaters. At the other extreme, vegetation elements might be arranged crosswise and provide barriers or dams to floodwaters even though the majority of the floodplain is grass or pasture. The damming effect of these strategically located clumps of brush or trees can serve to increase the hydraulic roughness of the floodplains to values characteristic of a complete cover of vegetation of the same type.

The analysis for this report required three roughness values at each cross section, a channel value and a value for each overbank. Tables 6-1 and 6-2 were used as guidelines in assigning "n" values in the Severn Run basin.

Bridge and Culvert Data Information

Bridges and culverts are important considerations in a backwater analysis. Constrictions in the stream where a roadway crosses can produce a backwater effect that could conceivably cause flooding upstream of the road. In addition, the increased velocity of the stream through a bridge opening and turbulence produced by overbank flow returning to the channel can produce scour that is sufficient to endanger the structure. These problems will occur rather frequently in locations where urbanization is causing a dramatic increase in the peak flow rates.

Table 6-1
Small Streams (Less Than 30-foot Bottom Width)

Vegetation	Manning's "n"
Fine gravel, straight, grass	.030
Coarse gravel, straight, clean banks	.035
Coarse gravel, straight, scattered tree fringe, weeds	.040
Fine gravel, slight winding, grass	.045
Fine gravel, slight winding, slight erosion, weeds	.048
Fine gravel, slight winding, high weeds, isolated trees	.052
Fine gravel, slight winding, moderate erosion, isolated trees, obstructions	.055
Fine gravel, slight winding, scattered trees and brush minor erosion	.065
Fine gravel, slight winding, tall weeds, nearly full fringe of brush, trees	.070
Fine gravel, tortuous, brush choked, weeds, trees	.080

Assumptions: 1. Bank full flow

2. Summer foliage

Note: If rocky bottom add .005

If channel bottom width less than 10 ft., add .01

Multiply by 1.2 if very winding

Table 6-2
Flood Plain Manning's "n"

Vegetation	Manning's "n"
Cropped pasture, fallow fields, lawns	.025
Low row crops, high grass	.03
High stiff weeds, corn	.035
Isolated brush and trees, grass	.04
Scattered brush, isolated trees, grass	.05
Light brush, isolated trees, grass	.06
Scattered trees, light brush, grass	.07
Scattered trees, high weeds, light brush	.08
Scattered trees, medium brush, grass patches	.10
Light woods, medium underbrush, grass	.12
Medium woods, shrubs, brush, high weeds	.16
Heavy woods, brush, vine tangles	.20

Assumptions:

1. Summer foliage
2. Slopes less than 5%
3. Depth of flow over 3 times height of elements (except trees)
4. Flattening of grass, weeds, crops by high flow

The following information is required for each bridge or culvert analyzed:

1. Top of roadway (elevation, station) across the flood plain.
2. Low chord elevations of the structure.
3. Invert elevations upstream and downstream.
4. Dimensions and shape of the structure opening.
5. Skew factor that defines the orientation of the structure to the direction of flow.

The necessary information at bridges and culverts was field surveyed by Maps, Incorporated.

Peak Flood Discharge

The peak flood discharges used in the hydraulic analysis were a direct output of the hydrologic analysis. Refer to Chapter 5 for a complete discussion of the hydrologic analysis.

Expansion and Contraction Loss Coefficients

A fairly abrupt change in the configuration of the flow area in the form of a constriction or an expansion will result in a loss of energy. The magnitude of the loss is a function of the velocity of flow and a specified loss coefficient. Energy losses resulting from expansions are usually much larger than losses resulting from constriction.

The loss coefficients used in the hydraulic analysis for this report varied between 0.5 and 0.8 for expansion and between 0.3 and 0.6 for contraction.

FLOOD PROFILE DETERMINATION

The calculations and data organization for hydraulic computations are well-suited for automation. Many good computer programs have been developed. The program called HEC-2, developed by the U.S. Army Corps of Engineers' Hydrologic Engineering Center, was used to compute the water surface profiles in the Severn Run basin. This program was selected because of its general acceptability and CH2M HILL's familiarity with it.

The basic principle of the HEC-2 computations is a determination of total energy at each cross section, using Bernoulli's Theorem. Friction head losses between cross sections are computed by using Manning's formula. Aside from this routine for natural valley cross sections, the HEC-2 program contains other computational sequences to deal with a variety of situations. It can handle pressure and weir flow at bridges or culverts, levees in the floodplain, encroachment in the floodplain, channel improvements, and minor energy losses between cross sections, such as expansion or contraction.

The HEC-2 computer program is flexible in the manner in which structures can be treated. Bridges with piers or special culverts can be specified with relative ease. Losses can be computed through a structure for low flow conditions, weir flow and pressure flow, or combinations of these. The publication, "Application of the HEC-2 Bridge Routines," contains a good description and several examples of setting up structures for analysis.

Two different options were used for starting the computations: a water surface elevation computed by using an estimated energy slope, and a known elevation at the confluence with a larger stream. Since peak flows do not occur simultaneously on all streams in a watershed, it is not always correct to use a known elevation at the mouth of a tributary. From the hydrologic analysis (Chapter 5), the time to peak of each stream was known. In cases where the peak flow on a tributary coincided with the peak flow on the main branch, the hydraulic computations proceeded up the tributary using the flood elevation of the larger stream. In all other cases, the starting water surface elevation was computed by using an estimated energy slope.

The principal results of the hydraulic analysis were flood elevations at each cross section. Using these discrete flood elevations, continuous flood profiles were drawn. These profiles are shown on the plan and profile sheets which accompany this report.

In addition to water surface elevations, other useful information can be derived from the HEC-2 output. Direct readouts of flow velocity, top width of flooded area, and numerous other variables describing the flow characteristics can be obtained. One important benefit of the HEC-2 analysis was that it identified bridges and culverts that caused considerable restrictions to the flow. In such places where significant damming effects were noted, flood routing was performed to compute the reduction in peak flow from the constriction.

MAPPING

Base plan and profile sheets were prepared by Maps, Incorporated, showing the stream profile on one half the page, and the plan view of the same reach on the other half. The topographic information was obtained by photogrammetric analysis of aerial photographs supplemented by field reconnaissance.

The "Profile" portion of the sheets shows the stream bed elevation, and bridge and culvert elevations at each point along the stream. The flood profiles were added, showing the elevation of each flood of interest. For clarity, only the 2- and 100-year floods have been shown on each sheet. Where roads or buildings are inundated by intermediate floods, these floods have been shown in the immediate vicinity. Chapter 7, "Problem Areas," contains further information concerning these areas. The flooding depth shown by the flood profiles, above the stream bed or above roads, gives a quick idea of the severity of each flood.

The "Plan" portion of the plan and profile sheets is a topographic map of the study area. Locations of the cross sections used in the hydraulic analysis are shown on these maps. Flood boundaries, which show the areas expected to be inundated by each flood were drawn on the "Plan" portion, using the previously plotted flood profiles according to contour lines at 5-foot intervals. Again, for clarity, only the 2- and 100-year floods have been shown on each sheet. Figure 6-1 shows a typical plan and profile sheet.

Plan and profile sheets were developed for both existing and ultimate land use conditions. These sheets provide a quick reference for existing or possible future flood problems. With these problems areas so identified, the task of reducing damage from floods can proceed in an informed, orderly manner.

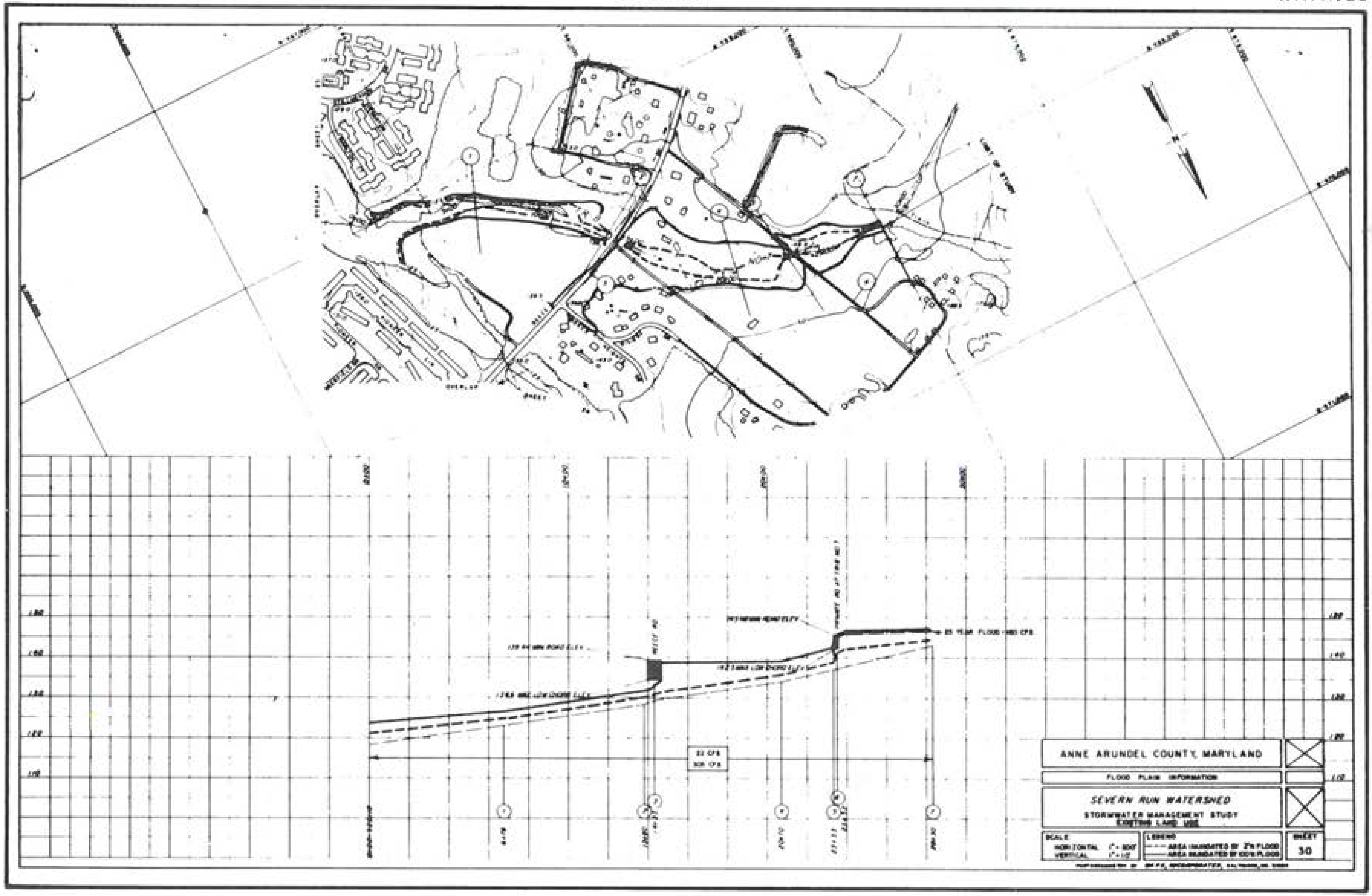

FIGURE 6-1: Sample Plan and Profile Sheet

CHAPTER 7
PROBLEM AREAS AND OPPORTUNITIES

In order to formulate workable alternatives to deal effectively with problems resulting from stormwater runoff in the undeveloped as well as the developed areas of the Severn Run watershed, the affected areas must first be identified. The areas of concern are flooding, construction site erosion, stream channel erosion and environmental and water quality problems or opportunities.

FLOODING

Three categories of flooding problems are considered--roads, developed areas, and planned developments. Criteria used to identify problem areas include the existing and ultimate 100-year flood plains, the hydraulic capacity of stream crossings, and planned changes in land use. The 100-year flood plain as delineated on the existing and ultimate land use plan and profile sheets was the basis used to identify problems relating to developed areas. The ability to adequately pass the 100-year flood for state roads and the 50-year flood peak for county roads was the basis to determine problems at stream crossings.

Roads

Roads impacted by flooding are listed in Table 7-1 and shown in Figure 7-1. Table 7-1 gives the depth of the

Table 7-1
Roadway Flooding

Problem Number and Name of Road	Stream	Depth of Flooding For 100-Year Flood (feet)		Chance of Being Flooded in Any Year (percent)	
		Existing	Ultimate	Existing	Ultimate
STATE ROADS					
1. Telegraph Road (170)	Beaver Creek	1.2	1.7	4-10*	10-20*
2. Reece Road (554)	Reece Road Br.	0.2	2.2	4-10*	20-50*
COUNTY ROADS					
3. Burns Crossing Road	Beaver Creek	1.4	2.0	4-10*	20-50*
4. Burns Crossing Road	Severn Run	1.8	3.5	4-10*	>50*
5. Old Mill Road	Severn Run	1.0	4.0	10-20*	>50*
6. New Cut Road	Broad Branch	0.5	0.6	2-4*	2-4*
7. Upton Road	Broad Branch	0.6	0.9	2-4*	10-20*
8. Lokus Road	Picture Frame Br.	-	0.3	<1	>50*
9. Gambrills Road	Jabez Branch	1.0	1.5	4-10*	4-10*
10. Hog Farm Road	Jabez Branch	1.1	1.2	20-50*	>50*
11. Dicus Mill Road	Severn Run	3.8	5.0	4-10*	10-20*
12. Jackson Grove Road	Jackson Grove Br.	0.6	1.9	4-10*	>50*
13. WB&A Road	Beaver Creek	-	0.7	<1	10-20*
14. Private Road	Reece Road Br.	0.8	0.9	4-10*	20-50*

* Indicates flooding by the 50-year storm

existing and ultimate 100-year flood peaks over the top of the road and the percent chance of the road's being flooded in any year. Those roads with an asterisk are not capable of passing the 50-year flood and are considered to be potential problems. The numbers on Table 7-1 and the following sections are keyed to Figure 7-1.

1 - Telegraph Road (Route 170). Although Telegraph Road over the Severn Run can pass the ultimate 100-year flood peak without flooding, Beaver Creek tops it with the existing 50-year flood peak and the ultimate 2-year flood. Telegraph Road is a state road and was originally designed to pass the 25-year flood. Due to projected urbanization of the Beaver Creek watershed upstream of Telegraph Road, the 25-year flood will top the road for ultimate land use conditions. Current state policy is to design roads to pass the 100-year flood. The flood control alternatives will need to identify means to allow Telegraph Road to remain unflooded for the ultimate 100-year flood if possible (plan and profile sheet 16).

2 - Reece Road (Route 554). Reece Road has an unusual problem in that the culvert for the road is adequately designed to prevent the road from flooding in the vicinity of the culvert, but it backs up the floodwaters which then flow over and along the road from a low spot north of the culvert. This happens for the existing 25-year flood and ultimate 5-year flood. The depths of flow over the low point are 4 feet and 6 feet for the existing and ultimate 100-year storms, respectively. Control alternatives will be needed to prevent the 100-year flood from topping the low point in the road. Also flooded are a private road, several houses

and Reece Heights Drive, as shown on plan and profile sheet 30. Reece Road and Telegraph Road are the top two priorities since they provide the major north-south access through the watershed.

<u>3 and 4 - Burns Crossing Road</u>. This is a county road that is flooded by both Severn Run and Beaver Creek. Severn Run is more likely to flood Burns Crossing Road than Beaver Creek for ultimate land use conditions. The county desires to keep Burns Crossing Road from flooding during a 50-year flood, making the road the third priority problem area since it currently floods for this event (plan and profile sheets 15 and 18).

<u>5 - Old Mill Road</u>. Old Mill Road currently is topped by the 10-year flood. The road connects Telegraph Road to Burns Crossing Road and the county does not consider it an important road to keep open. Further, the roadbed is so close to the stream that any control alternatives would be prohibitively costly. Therefore, Old Mill Road is not considered to be a solveable problem (plan and profile sheet 22).

<u>6 - New Cut Road</u>. Severn Run does not flood New Cut Road, whereas Broad Branch does. However, only the 50- and 100-year floods inundate the road, so it is not considered a priority problem (plan and profile sheet 9).

<u>7 - Upton Road</u>. Broad Branch also floods this road. Upton Road serves a low density residential/farming area and the Upton Road Recreational Area. The ultimate 10-year flood will top the road, but since it serves a small area that would be little impacted by its closing, Upton Road is not considered a priority problem (plan and profile sheet 9).

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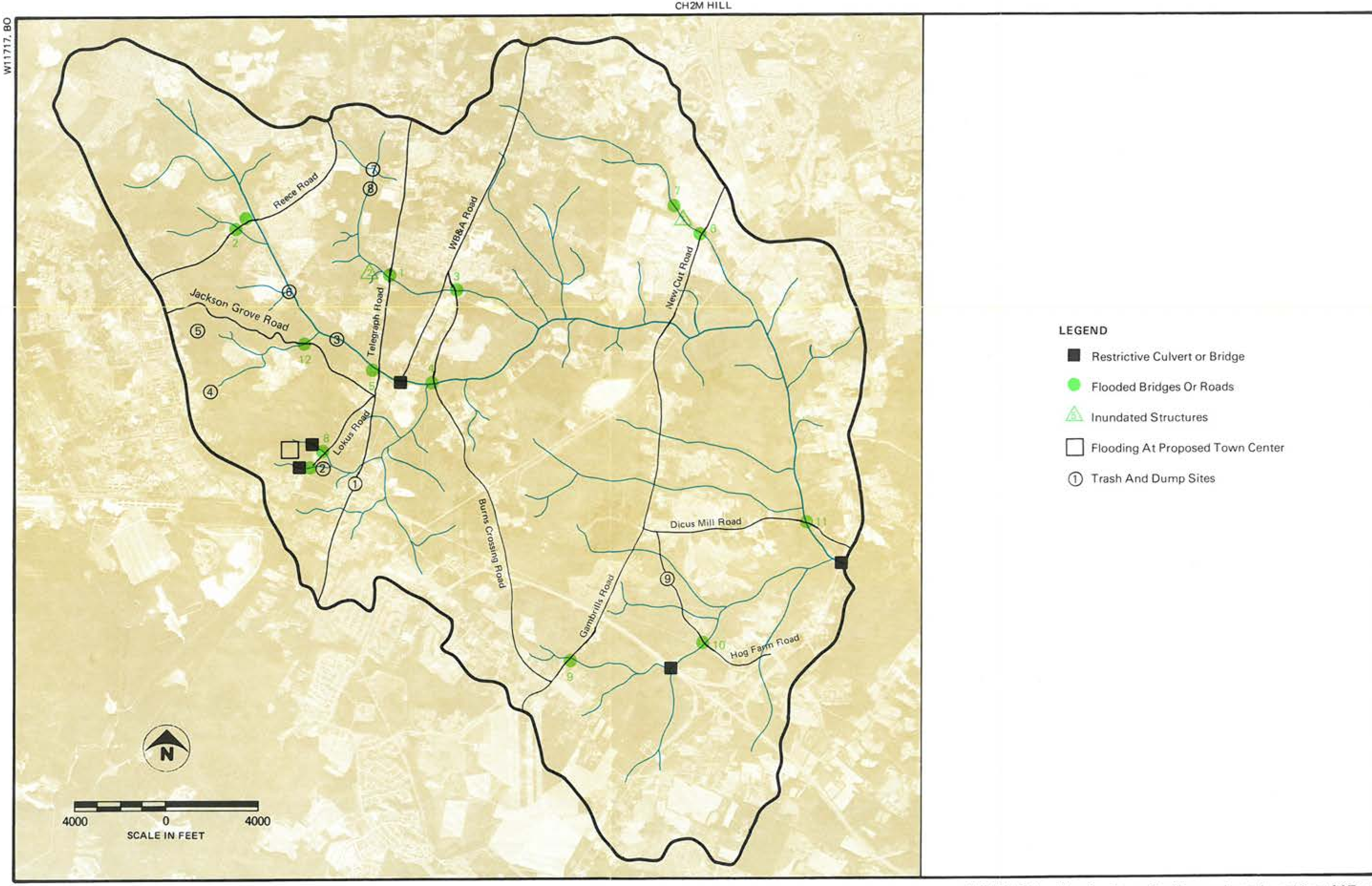

FIGURE 7-1: Flooding Areas And Approximate Loacations Of Trash And Dump Sites

8 - Lokus Road. The section of Lokus Road that floods serves a small industrial area that should be little affected by the 4-inch depth of water over the road. This area is zoned for further urbanization, and as this occurs the culverts under Upton Road could be easily improved. This is a low-priority problem area (plan and profile sheets 23 and 24).

9 - Gambrills Road. Jabez Branch floods Gambrills Road for the 25-year storm. This road was not included in the detailed analysis since it serves to connect Route 32 to Route 175. Alternative roads which are not flooded can serve the same purpose, making Gambrills Road a low-priority problem.

10 - Hog Farm Road. Hog Farm Road serves a rural area that is zoned to remain largely rural. The existing 5-year and ultimate 2-year floods of Jabez Branch top the road. However, because Hog Farm Road is lightly used and other roads can be safely used in times of flooding, it is considered a very low priority problem (plan and profile sheet 1).

11 - Dicus Mill Road. Dicus Mill Road is currently flooded by Severn Run up to depths of 4 feet over the roadway. A low spot in the road to the west of the bridge is an additional foot under water. The existing 25-year and ultimate 10-year floods top the bridge. Because the road is very low and serves rural areas that can use alternative highways, Dicus Mill Road is not considered as a solvable problem. This is shown on plan and profile sheet 3.

12 - Jackson Grove Road. Jackson Grove Road is a low-lying rural road serving a very small population. It is

currently flooded by the 25-year flood. The area upstream of Jackson Grove Road is planned for further urbanization which will increase the flood peaks so that the 2-year flood will top the road. Presently Jackson Grove Road is not a problem. However, as the area develops, either new roads or extensive improvements to Jackson Grove Road will be required. Plan and profile sheet 31 shows Jackson Grove Road.

13 - WB&A Road. Beaver Creek currently does not top WB&A Road. With the zoned urbanization upstream, the ultimate 10-year flood will inundate the road. Because several alternative transportation routes are available, WB&A road is not considered a problem (plan and profile sheet 16).

14 - Private Roads. Several private roads are flooded within the watershed. Anne Arundel County office of Planning and Zoning will notify those persons affected by the flooding of any private roads. These are on plan and profile sheets 14, 20, 30 and 32.

Route 32. Route 32 is not a problem; rather, it acts as an effective flood-control reservoir. Water backs up behind the Route 32 culvert in an area of very steep topography that restricts the lateral spreading of the impounded waters. The culvert reduces the ultimate 100-year peak flow by around 700 cfs and has no negative impacts, as this area is not suitable for urbanization (plan and profile sheet 1).

Route 3. Route 3 is not flooded but the older bridge does act to back up water due to its narrow channel width. The water that is backed up spreads out in the broad flood plains upstream from the bridge (plan and profile sheet 3).

Developed Areas

There are 6 houses, 2 trailers, and several shacks and sheds that are subject to some degree of flooding. The affected developed areas are shown in Figure 7-1.

1 - Upton Road Area. A barn and shed are flooded by both the existing and ultimate 100-year floods. They are located off Upton Road about 200 feet from New Cut Road. Plan and profile sheet 9 shows this area.

2 - Rogers Lane Area. Beaver Creek floods a house and shed located at 1402 Rogers Lane. There are also the ruins of a building and what appears to be an earth-dug pool within the 100-year flood plain. This is shown on plan and profile sheet 16.

3 - Area Near Diamond International Corporation. There are several shacks, sheds and trailers within the 100-year flood plain in the area near where the Diamond International Corporation used to be (plan and profile sheet 17). The two trailers are occupied and serve as residences. The sheds and shacks are either abandoned or serve as storage areas.

4 - Reece Road Area. Five homes, the burned ruins of a house, two swimming pools and a private road are in the 100-year flood plain of Reece Road Branch (plan and profile sheet 30). This is the area that backs up behind the Reece Road culvert and flows over a low point in Reece Road. Due to the number of homes involved, this area is a very high priority problem. This area is the same as flooding area number 2.

Pump Houses. There are two pump houses in the watershed that are about one foot above the ultimate 100-year flood plain. The Ridgeway pumping station on Burns Crossing Road (plan and profile sheet 15) is on the edge of the flood plain of Beaver Creek, while the Severn Run pumping station off Old Mill Road is on the edge of Severn Run's flood plain. Both of these pumping stations could be subject to flooding if more intensive urbanization occurs than is planned.

Planned Developments

Future developments should not be permitted within the 100-year flood plain. The plan and profile sheets can be used as a guide to restrict development for the areas considered in the hydraulic backwater analysis. An area not considered in the detailed hydraulic analysis that will influence future development plans is shown in Figure 7-2. The area is upstream of two restrictive railroad culverts on Picture Frame Branch and is zoned for a town center. As shown in Figure 7-2, a significant area--5.7 acres--is flooded due to the backwater from the culverts. This flooded area could easily be designed into the town center as a lake, the projected land use could be changed to reduce the flood peaks, or the culverts could be enlarged to pass the flows. This latter option is not recommended since it would result in flooding Telegraph Road. Creative planning could easily incorporate the needed storage volume in the site plans for the town center. The use of a fountain in a permanent wet lake would keep the water aerated and "fresh." A regular maintenance program would be needed to remove sediment from the pond, or it would fill up and not provide the needed 25 acre-feet of storage capacity.

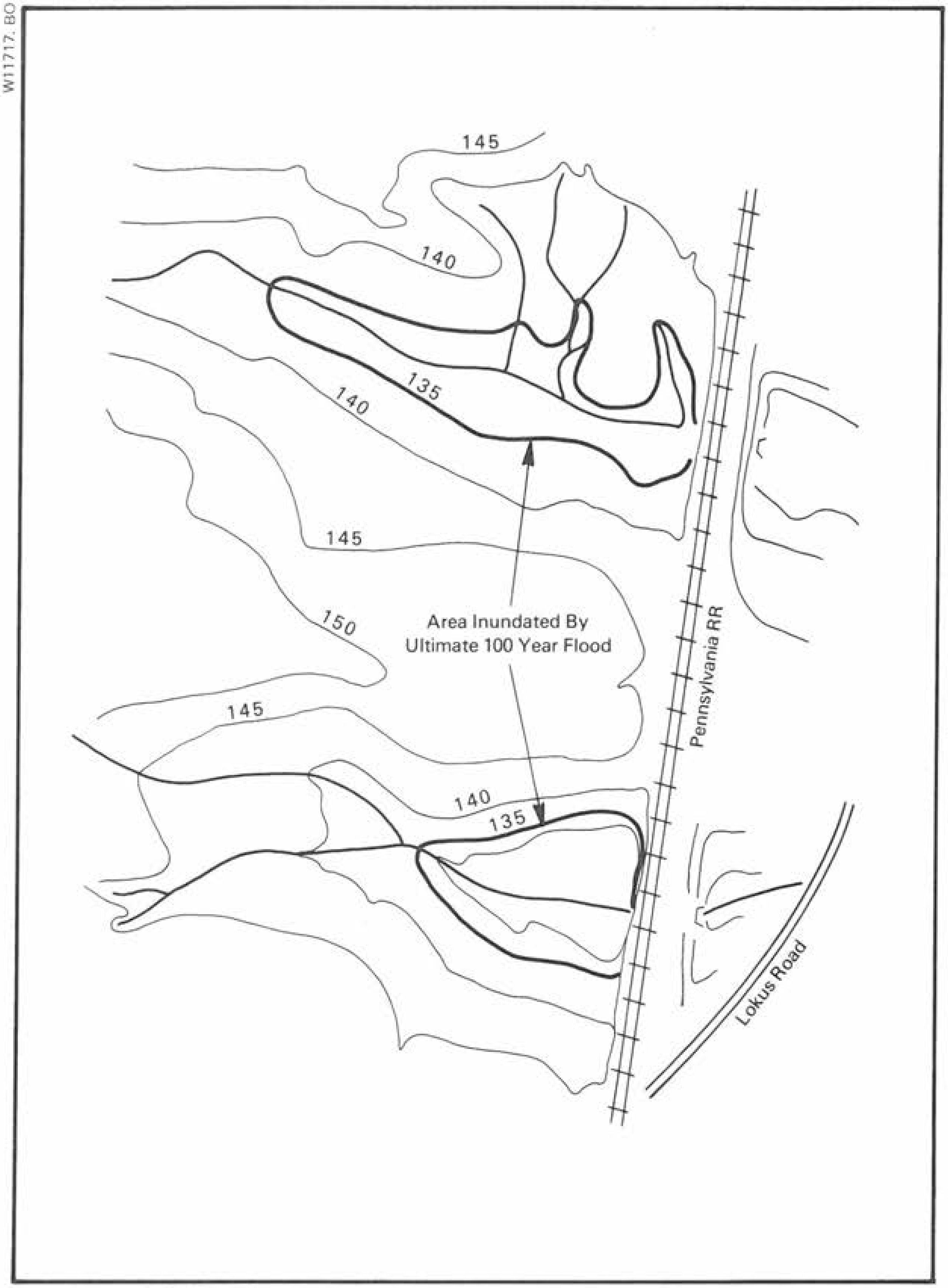

FIGURE 7-2: Flooding In Area Designated For Future Town Center In Picture Frame Branch Watershed

WATER QUALITY

Water quality concerns should be based on the intended use of the water. Severn Run has a Class IV Recreational Trout Water classification. Rainbow trout with some brook trout are stocked in Severn Run in the spring and largely fished out by early summer. No attempt is made to spawn trout in Severn Run; it is solely a put/take trout stream. However, as discussed in Chapter 4, there are several species of fish that are indigenous to the run and, along with the stocked trout, make Severn Run a popular game fishing stream.

Severn Run is also used as a limited source of irrigation water for farmers within the watershed. During summer dry periods, water is often pumped from the run to the fields.

Other than fishing and aesthetics, Severn Run has few other recreational uses, although limited swimming or wading does occur in a few deep pools.

Recorded Water Quality Data

Pertinent water quality data are given in Table 7-2. Those values enclosed in a solid box are in violation of Maryland water quality standards (Table 7-3).

The locations of the sampling sites are shown by Figure 7-3. Three potential problems are evident from the limited data; water temperature, pH, and fecal coliform. The water temperature problems were limited to Picture Frame Branch and Severn Run just downstream from Picture Frame Branch. There are several industries that discharge cooling water to Picture Frame Branch

Table 7-2
Recorded Water Quality Data For Severn Run

Site Identification	Date of Sample	Time of Sample	Flow (cfs)	DO (mg/1)	DO % Saturation	Water Temp C	Field pH	Fecal Coliforms (mpn/100 ml)	Turbidity (JTU)	Suspended Solids (mg/1)	BOD (mg/1)	T. Phosphorus (mg/1)	PO_4-P (mg/1)	Ammonia Nitrogen (mg/1)	NO_2 (mg/1)	NO_3 (mg/1)
JAB0000	10-16-73	1130	—	9.7	95.0	15.0	6.9	—	22	1	—	0.04	0.04	0.12	0.007	0.96
Jabe3	8-5-76	—	3.40	9.7	99.0	16.5	|6.3|	--	4	—	0.5	0.03	0.02	0.01	0.002	0.79
SER0011	4-14-65	1145	—	10.7	96.4	11.0	|6.2|	--	14	22	4.8	--	--	--	--	--
Dicus	6-23-76	—	15.78	6.9	78.4	21.8	|6.1|	--	3	—	1.0	0.09	0.04	0.02	0.003	1.04
Mill	8-5-76	—	11.90	8.2	83.7	16.5	6.6	—	3	—	0.5	0.11	0.10	0.01	0.002	1.08
Road	10-16-73	1150	—	8.2	81.2	15.5	6.7	—	8	1	—	0.08	0.06	0.02	0.003	1.19
	11-17-76	1535	18.96	9.9	81.1	6.5	|6.3|	--	4	1	3.0	0.07	0.02	0.01	0.003	0.96
	11-29-76	1500	28.59	10.0	84.0	8.1	|6.4|	—	16	26	0.4	0.07	0.04	0.02	0.011	1.00
	01-14-77	1310	21.80	11.1	88.8	5.9	--	—	7	2	1.4	0.08	0.02	0.07	0.002	0.71
	02-28-77	1245	16.76	10.4	85.2	7.4	|6.2|	--	11	14	0.7	0.07	0.03	0.03	0.005	0.97
	03-28-77	1230	19.94	11.6	102.7	10.0	|6.3|	|230|	4	8	0.5	0.07	0.03	0.01	0.002	1.00
	05-09-77	1340	15.99	8.7	80.6	12.2	|5.3|	--	7	7	1.8	0.05	0.02	0.01	0.003	0.76
	05-23-77	1000	9.30	8.3	87.4	18.0	|6.5|	--	7	4	5.0	0.11	0.05	0.03	0.003	1.06
	06-08-77	1230	12.21	8.2	80.2	14.5	|6.3|	--	6	6	2.0	0.09	0.04	0.09	0.001	1.07
	07-05-77	1145	9.71	8.0	85.1	19.2	—	--	3	7	1.1	0.06	0.03	0.02	0.002	1.32
	07-20-77	1305	15.06	7.4	85.1	22.9	—	--	9	18	1.8	0.16	0.08	0.03	0.008	1.00
	08-03-77	1030	9.25	8.2	89.1	20.0	6.5	—	6	11	1.0	0.03	0.01	0.04	0.025	0.30
	08-16-77	1243	11.53	8.1	90.0	21.2	7.0	—	6	4	1.6	0.03	0.01	0.03	0.001	0.14
	09-15-77	1300	9.92	8.0	82.5	17.2	|6.3|	--	11	15	1.0	0.11	0.07	0.01	0.003	0.94
	09-26-77	1120	9.62	8.1	85.3	18.2	—	--	4	6	1.3	0.07	0.05	0.01	0.001	1.08
	10-10-77	1450	—	8.5	83.3	14.5	—	--	9	10	2.6	0.07	0.05	0.06	0.010	0.81
WEL3	4-14-65	1215	—	10.7	105.0	15.0	|4.6|	--	20	2	0.7	—	--	—	--	--
Wells																
Branch																
SER0040	4-14-65	1222	—	9.8	90.7	12.0	|6.3|	--	11	16	2.0	—	--	—	--	--
New Cut	6-23-76	—	11.69	6.7	78.8	23.7	|6.4|	--	4	—	1.3	0.12	0.07	0.02	0.003	1.04
Road	8-5-76	—	10.55	8.2	86.3	18.0	6.8	—	2	—	0.5	0.17	0.17	0.01	0.002	0.96
	10-16-73	1320	—	7.7	79.4	17.0	6.9	--	57	36	—	0.26	0.14	0.04	0.015	1.04
SER0064	4-14-65	1315	—	7.1	73.2	16.8	6.6	--	40	32	4.6	—	--	—	--	--
Burns	10-16-73	1400	—	7.4	78.7	19.0	6.9	--	13	1	—	0.27	0.12	0.02	0.007	1.04
Crossing	6-23-76	—	10.04	6.8	80.0	24.3	6.7	|930|	4	—	1.2	0.21	0.07	0.02	0.005	0.91
Road	8-5-76	—	6.88	6.9	76.6	21.2	6.6	—	2	—	0.9	0.26	0.20	0.01	0.002	0.79
PIC0000	10-16-73	1410	—	6.6	73.3	21.0	6.9	--	10	8	—	0.43	0.21	0.02	0.007	0.77
Lower	6-23-76	—	8.03	6.5	80.2	26.9	7.1	|1500|	2	—	2.6	0.36	0.11	0.02	0.005	0.87
Picture	8-5-76	—	5.49	6.7	77.0	22.8	6.6	--	2	—	4.1	0.38	0.23	0.01	0.002	0.88
Frame																
Branch																
PIC0011	4-14-65	1415	—	|3.9|	49.4	|28.0|	|10.2|	--	|240|	298	29	—	--	--	—	--
Upper	6-23-76	—	0.81	4.3	57.3	|31.0|	7.0	|9300|	7	—	5.0	0.18	0.04	0.04	0.006	0.69
Picture	8-5-76	—	1.17	5.3	68.0	|28.6|	7.1	—	6	—	1.8	0.26	0.20	0.01	0.005	0.88
Frame																
Branch																
PIC0012	10-16-73	1510	—	6.2	72.9	24.0	6.7	—	12	4	—	0.34	0.14	0.10	0.007	0.92
SER0065	4-14-65	1337	—	10.5	101.0	13.7	|5.9|	--	10.5	2	0.7	--	—	--	--	--
Old Mill	6-23-76	—	2.79	7.8	89.7	22.8	7.0	--	6	—	0.5	0.06	0.02	0.02	0.005	0.87
Road	8-5-76	—	1.74	9.4	98.9	17.8	6.6	|1200|	3	—	0.7	0.03	0.03	0.01	0.002	0.88
SER0081	11-17-76	1510	1.29	10.6	85.5	6.5	|6.4|	—	5	6	1.4	0.04	0.01	0.01	0.004	1.19
Reece	11-29-76	1430	2.17	9.8	79.0	6.5	6.9	—	11	4	7.6	0.11	0.04	0.01	0.006	0.43
Road	12-27-76	1205	0.99	12.3	91.1	3.0	|6.3|	--	7	5	2.3	0.05	0.04	0.05	0.004	1.47
	02-14-77	1150	0.48	11.3	89.0	5.4	—	—	8	2	1.1	0.08	0.03	0.13	0.011	0.90
	02-28-77	1030	0.38	11.5	92.7	6.4	6.5	—	7	1	0.7	0.06	0.02	0.07	0.016	1.12
	03-28-77	1200	1.03	12.3	106.0	9.0	7.1	93	7	11	0.7	0.05	0.02	0.03	0.009	1.27
	05-09-77	1245	0.37	9.6	86.5	11.0	6.0	—	5	6	2.2	0.03	0.01	0.02	0.011	1.13
	05-23-77	1030	0.37	9.3	97.9	18.0	7.1	—	6	6	3.0	0.04	0.02	0.03	0.037	1.04
	06-08-77	1145	0.55	9.6	92.3	14.0	6.8	--	6	10	1.5	0.05	0.01	0.09	0.008	1.39
	07-05-77	1115	1.67	8.6	93.5	20.0	—	--	5	2	0.5	0.03	0.01	0.02	0.004	1.29
	07-20-77	1210	1.41	6.9	79.3	23.0	--	—	8	27	4.0	0.11	0.05	0.03	0.022	0.75
	08-03-77	0930	0.18	8.8	93.6	19.4	|5.7|	—	11	12	1.5	0.06	0.01	0.02	0.008	1.26
	08-16-77	0955	0.33	8.3	94.3	21.5	|5.5|	--	6	6	2.2	0.03	0.01	0.01	0.003	0.60
	09-15-77	1225	0.12	9.6	96.0	16.0	6.9	—	6	2	1.0	0.05	0.01	0.01	0.004	1.24
	09-26-77	1050	0.26	9.1	95.8	18.4	—	--	6	4	1.3	0.05	0.02	0.01	0.003	1.25
	10-10-77	1430	—	9.3	89.4	14.0	—	--	8	8	4.4	0.04	0.04	0.03	0.003	0.82

Table 7-3
Maryland State Class IV Water Quality Standards

REGULATION 08.05.04.03 - RECEIVING WATER QUALITY STANDARDS
This regulation is effective September 1, 1974

GENERAL

The following receiving water quality standards are established to protect the uses indicated. Where the waters of the State are, or may be, affected by discharges from point sources, these standards shall apply outside of a mixing zone designated by the Administration.

STANDARDS FOR CLASS IV WATERS

Recreational Trout Waters

(1) Bacteriological Standards

There shall be no sources of pollution which constitute a public health hazard. If the fecal coliform density exceeds a log mean of 200/100 ml, the bacterial water quality shall be considered acceptable only if a detailed sanitary survey and evaluation discloses no significant public health risk in the use of the waters.

(2) Dissolved Oxygen Standard

The dissolved oxygen concentration shall be not less than 4.0 mg/lites at any time, with a minimum daily average of not less than 5.0 mg/lites, except where, and to the extent that, lower values occur naturally.

(3) Temperature Standard

a. Thermal effects shall be limited and controlled so as to prevent:

   (1) Temperature changes that adversely affect aquatic life;

   (2) Temperature changes that adversely affect spawning success; and

   (3) Thermal Barriers to the passage of fish.

Table 7-3
Maryland State Class IV Water Quality Standards
(Continued)

b. Temperature may not exceed 75°F beyond the distance from any point of discharge specified by the Administration, except where, and to the extent that, higher temperature values occur naturally.

(4) pH Standard

Normal pH values must not be less than 6.5 nor greater than 8.5, except where--and to the extent that--pH values outside this range occur naturally.

(5) Turbidity Standard

a. Turbidity may not exceed levels detrimental to aquatic life; and

b. Within limits of Best Practicable Control Technology Currently Available, turbidity may not exceed for extended periods of time those levels normally prevailing during periods of base flow in the surface waters; and

c. Turbidity in the receiving water resulting from any discharge may not exceed 50 JTU (Jackson Turbidity Units) as a monthly average, not exceed 150 JTU at any time.

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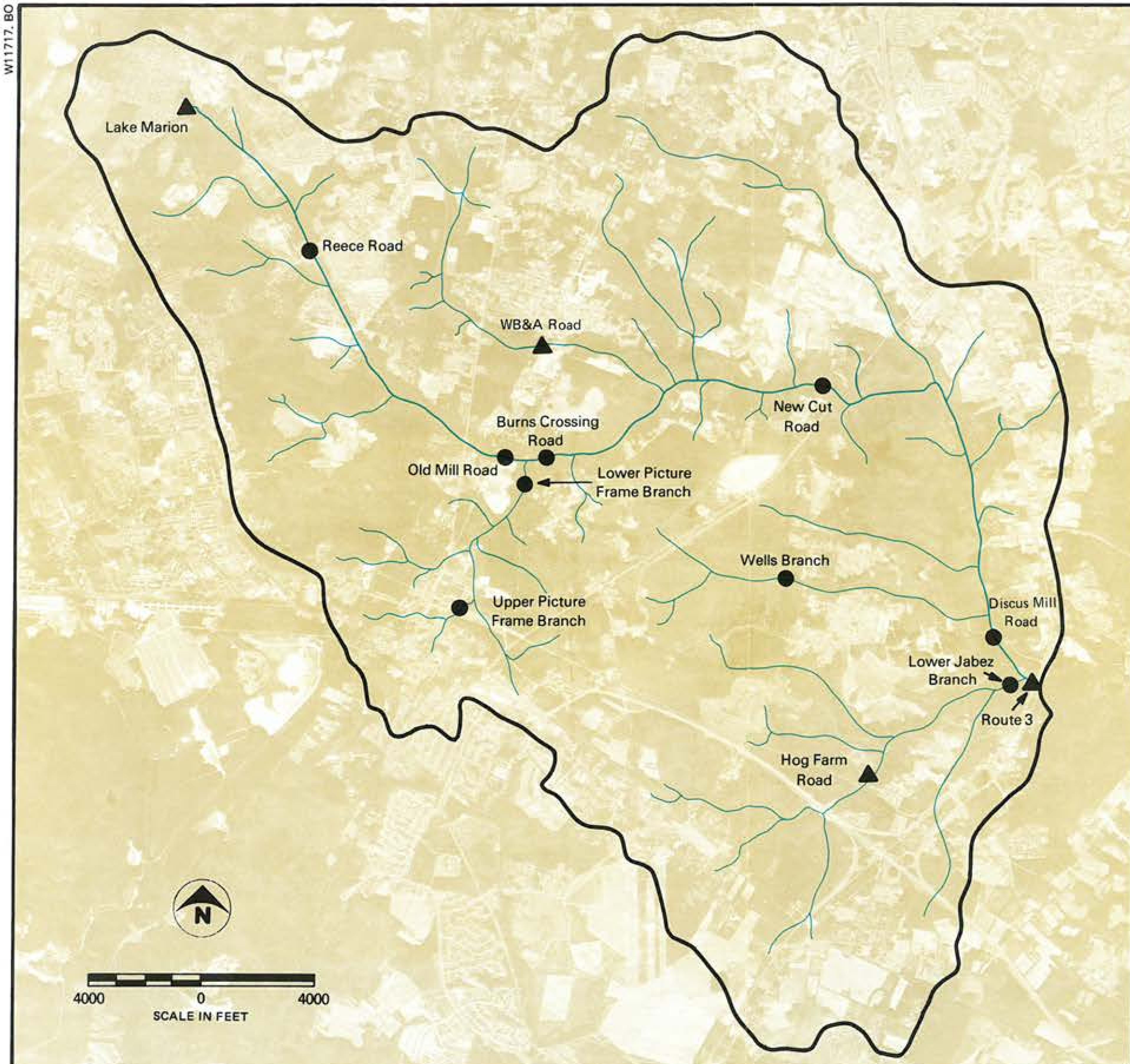

SAMPLING STATIONS

LEGEND

● Existing Stations

▲ Additional Recommeded Stations

FIGURE 7-3: Water Quality Sampling Stations and thereby raise the temperature. The industries now have holding ponds with the intention of allowing the effluent to cool below 75°F prior to discharging to Picture Frame Branch. The last sample of the area impacted by the industries was in 1976, so it is not known if thermal pollution from the industries is a current problem.

A frequently-occuring violation is low pH which, except for one case, is too acidic to be in the desired range of 6.5-8.5. Most of the values are only slightly below 6.5 and may well be natural values for Severn Run, since no known point sources or nonpoint sources should contribute to low pH values. The low values occur throughout Severn Run, further indicating a possible natural source.

Five out of six recorded fecal coliform values are well in excess of state standards. There is an insufficient number of samples to tell if this is a chronic problem. Possible sources of fecal coliform include: wild animals, pets, farm animals, failing septic systems, leaking sanitary sewers, or pumping station overflows. There is an abundance of animal life in the watershed that could be a source of the fecal contamination. Coincident measurements of fecal coliform and fecal streptococci can be used to determine if the source is most likely of human or nonhuman origin. Reported failures of septic systems have occurred in the Ridgeway, Elmhurst, Oakdale, Danza Village and Clark Heights subdivisions. A separate study of septic systems is required to determine how extensive failing systems are and whether they contribute to water quality problems.

There is one recorded high turbidity value. There would be many more if wet weather data were collected. Observation of Severn Run during and after a rainfall event shows that very turbid conditions exist. Future water quality studies should include sampling during wet weather conditions.

The BOD, dissolved oxygen, and nutrient levels show no problems, except for one dissolved oxygen value on Picture Frame Branch. The nutrient levels are fairly typical for a stream with no major point sources of effluent discharge. Again, wet weather data should be taken to see if the agricultural activities and urban runoff significantly contribute any nutrients.

Lake Marion has not been sampled for water quality purposes, but personal observations indicate that the lake has an algae problem. This is common for urban lakes and typically results in low dissolved oxygen levels near the lake bottom. The contributions of algae and water with low dissolved oxygen levels from the lake could create problems for Severn Run.

Future water quality studies should consider sites SER0011, SER0040, SER0064, SER0065, PIC0000, JAB0000, and additional sites at Lake Marion, Hog Farm Road, WB&A Road on Beaver Creek, and at/or below Route 3. These are shown in Figure 7-3 and will be further discussed in Chapter 14.

Nonpoint Sources

As the Severn Run watershed continues to urbanize, nonpoint sources of water pollution will increase in importance. Nonpoint sources include runoff from industrial, commercial and residential areas (urban runoff), construction activities, and agricultural activities. If the guidelines of the Soil Conservation Service and proper application of fertilizers and pesticides are followed, agricultural runoff should not constitute a major problem.

Urban runoff and construction activities may present problems. Construction activities can create erosion and sediment problems as well as litter, debris, oil and grease, solvents and other pollutants. As an area urbanizes, increased loadings of lead and other heavy metals, nutrients, debris, litter, suspended solids, chemical oxygen demand, and other pollutants may be expected. The Regional Planning Council 208 addresses nonpoint source pollutants and the discussion will not be repeated here. The key point is that as urbanization increases, nonpoint source pollutants will also increase.

A nonpoint source pollutant that is frequently encountered within the watershed is trash dumps and debris in and near the streams. Numerous trash dumps were sighted during field trips to the watershed and these are not only eyesores, but also a potential source of pollutants--especially oil and grease, metals, COD, solvents, and other potential toxins. The streams in the vicinity of most of the dumps were littered with debris washed off or carried from the dump.

Several abandonded cars were found in Severn Run, which is indicative of a general lack of concern for the stream. Industrial dumps without runoff controls were also sighted. Stricter enforcement of dumping and littering laws is needed, as well as a general public education program.

CONSTRUCTION SITE EROSION

Severn Run is a natural sandy-bottomed stream that is additionally subject to some fairly severe erosion and sedimentation problems. Two forms of erosion are considered--land surface erosion and, in the next section, stream channel erosion. Both are naturally occurring phenomena; problems arise when the processes are accelerated or adversely modified by man's activities.

Land surface erosion, particularly from construction sites, has received considerable attention recently. Although field inspections by the Department of Natural Resources in October 1978 did not include any construction sites within the Severn Run watershed, personal observations by the consultant generally concur with the DNR conclusions that erosion controls at that time were by and large not being adequately implemented.

Land surface erosion causes several potential problems. The removal of the top layers of soil constitutes a valuable resource loss that is very difficult and expensive to replace. The eroded soil must eventually settle somewhere, and it frequently does--in streams and estuaries or downstream land surfaces. Sedimentation in streams and estuaries can cover bottom organisms, resulting in their death or relocation, which has subsequent impacts on the remainder of the ecologic system. Auld and Schusel have reported that white perch hatching and yellow perch larvae survival are reduced by high sediment concentrations. Sediment is also frequently the carrier of numerous pollutants which can have adverse biologic effects. Deposited sediment can fill in the stream channel, reducing its ability to transmit floodwaters and thus increasing flooding problems.

Within the Severn Run watershed, land surface erosion results largely from construction and agricultural activities. Figure 7-4 is a soil erodibility map derived from the Anne Arundel Soil Survey. Approximately the northwestern two-thirds of the watershed consists of very highly erodible and highly erodible soils. Unfortunately, this same area is planned for the greatest degree of urbanization (refer to Figure 4-12, Ultimate Land Use), while the moderately and low erodible areas will remain rural. Obviously, the potential for severe land surface erosion problems due to construction are great. Without strict erosion controls, the Severn Run and its tributaries could experience serious sedimentation problems and the watershed will lose a valuable resource--its topsoil.

Observed problems were noticed just downstream of Route 3 where a sand bar extended two-thirds across the width of the stream. This area also has several inches of relatively loose sediment, partially accounting for the large number of aquatic plants and lack of aquatic invertebrates reported in Chapter 4. Similar conditions were observed at Dicus Mill Road, New Cut Road, Telegraph Road, and downstream from Jacobs Road.

An estimate, although very rough, can be made for the amount of soil that may be lost during the urbanization process from construction activities. Based on Figure 1 from "Sediment Problems in Urban Areas" by H.P. Guy, and assuming a typical construction site of 0.25 square miles with highly erodible soils, a sediment yield of 60,000 to 90,000 tons per square mile per year could be expected. A total area of around 8 square miles is expected to be changed from forest, open or agriculture to commercial, residential, or industrial land use. It is assumed that 90 percent of this area will be disturbed and expose soil for accelerated erosion, and that the average duration of potential accelerated erosion will be 1-1/2 years. This gives a total soil loss over the next 20 years of:

$$(8)(.9)(1.5)(6 \times 10^4) = 650{,}000 \text{ tons}$$
$$(8)(.9)(1.5)(9 \times 10^4) = 970{,}000 \text{ tons}$$

650,000 to 970,000 tons or from 7.8 million to 11.7 million cubic feet of soil, based on a specific gravity of 2.65 for the eroded soil.

CHANNEL EROSION

To understand the mechanics of stream channel erosion, it is necessary to realize that erosion is a balancing of various factors to eventually reach a stable channel. Following the discussion in Henderson, a stable channel can be said to exist if the ratio of channel flow to sediment transport remains constant throughout the stream. In other words, if

$$qs/q = \text{constant}$$

where qs = sediment discharge per unit width
q = discharge per unit width,
$= Q/W$ Q - discharge cfs, W - channel width

the channel is stable. If, on the other hand, the width of a channel increases in one section of a river, then q will decrease and so will qs/q. This will result in the deposition of sediment in the channel

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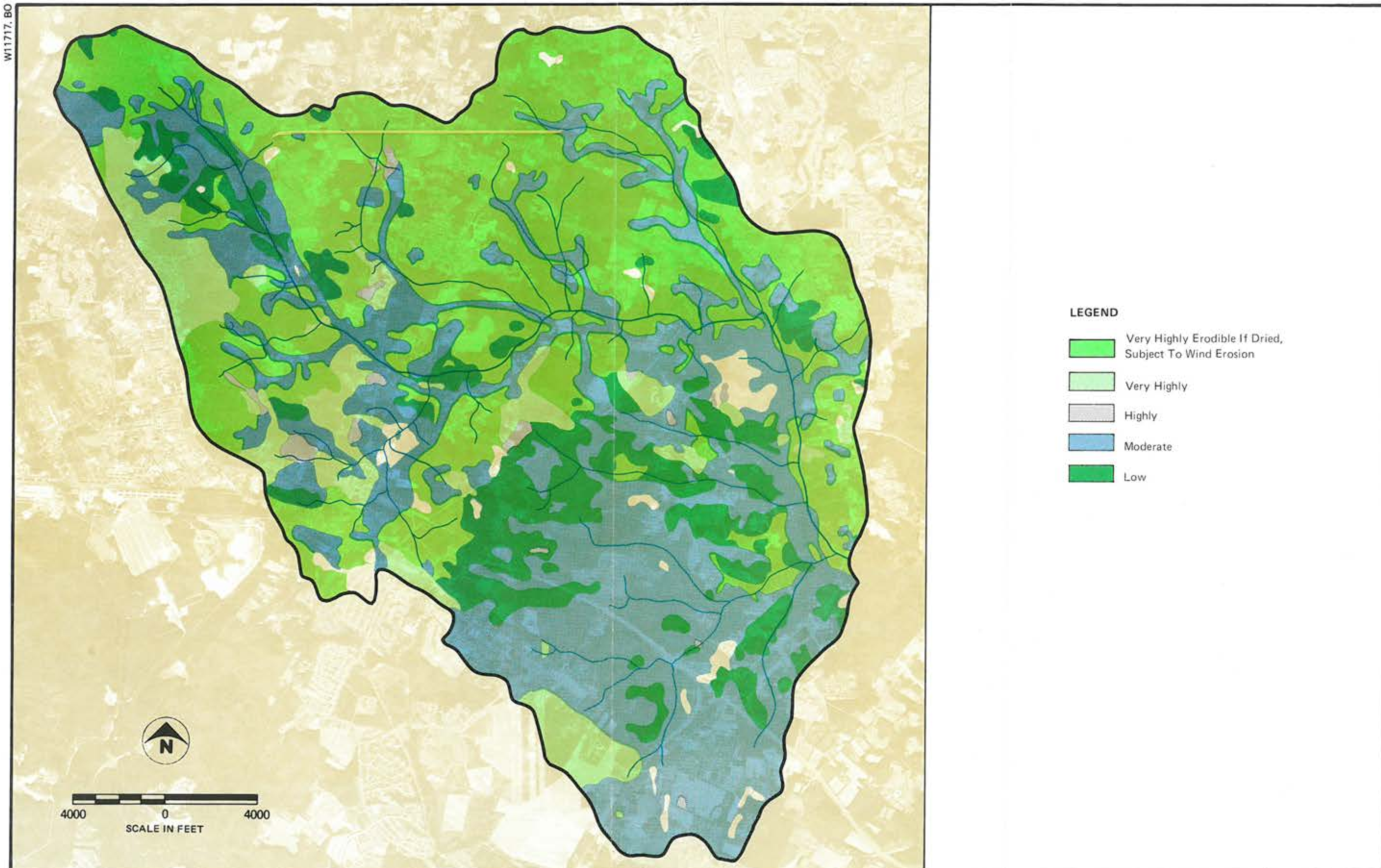


FIGURE 7-4: Soil Erodability Map

until the bottom slope is increased enough to return qs/q to its previous value. Similarly, if q increases (say due to urbanization or a flood), then qs must also increase. In fact, qs increases in proportion to q^2 so that a tenfold increase in flow will result in around a hundredfold increase in the sediment transport capacity. This is why large storms (100-year event) cause such severe stream channel erosion problems.

When urbanization or other factors increase the flows in a stream, the channel will adjust itself until the bank full discharge meets two conditions (Wolman and Leopold).

1. The discharge can maintain the channel shape without scour of the banks or bed, and without sediment deposition.
2. The banks are not topped frequently enough for berm buildup to be appreciable.

This discharge is close to the 2-year discharge. Therefore, the 2-year storm will largely control stream channel erosion.

Figure 5-6 and Table 5-7 show that significant increases in the 2-year peak flow are to be expected as the watershed urbanizes. Very large increases are expected on the Severn Run from Jacobs Road to Dicus Mill Road, on Jackson Grove Road Branch, Picture Frame Branch, and Beaver Creek. Unless the 2-year flood is controlled or stream bank protection measures are taken, considerable stream channel erosion and resultant sedimentation problems can be expected from these areas.

In order to obtain an estimate for the soil loss and stream widening due to channel erosion, the following relationship from Henderson for sandy-bottomed streams will be used:

$$P = 2.67\ Q^{.5}$$

where: P = wetted perimeter of the channel, feet
Q = flow in channel, cfs

This equation applies only to a limiting channel section of a minimum slope for channel stability. For our purposes we can ignore whether the proper conditions for the exact application have been met and use

$$P \alpha Q^{.5}$$

to evaluate the expected increase in channel width. Inherent in this methodology is the assumption that the existing channels are stable, the channel is wide, and that little or no bottom scour or deposition will occur. For a wide channel, the wetted perimeter can be assumed to be equal to the channel width. This allows us to compare the width to be expected after urbanization, W_2, to the existing width, W_1, measured during the hydraulics analysis as follows:

$$P_2 = k\ Q_1^{.5} = W_2$$

$$P_1 = k\ Q_1^{.5} = W_1$$

$$\frac{W_2}{W_1} = \frac{k\ Q_1^{.5}}{k\ Q_1^{.5}}$$

$$W_2 = \frac{Q_2^{.5}}{Q_1^{.5}} \quad W_1$$

where Q_2 and Q_1 are the ultimate and existing 2-year peak flows, respectively.

Table 7-4 summarizes the increase in stream channel width and the total soil loss for the areas experiencing significant urbanization. Jackson Grove Road Branch and Picture Frame Branch experience the largest increases in their channel widths. A total of 25 acres of land with a volume of 4.3 million cubic feet and 357,000 tons could be lost to stream channel erosion.

Summary

Land surface erosion from construction and channel erosion could result in a total soil loss in excess of 16 million cubic feet (1,330,000 tons) of soil over the next 20 years. This is a significant loss of a valuable natural resource and is a problem that should be addressed. Land surface erosion from agricultural areas was not included in this estimate because the Soil Conservation Service has ongoing programs in this area.

Table 7-4
Stream Channel Erosion

Cross Section	$Q_2^{.5}/Q_1^{.5}$	W_1 (ft)	W_2 (ft)	W_2-W_1 (ft)	Length (ft)	Area Lost (sq. ft)	Depth	Volume Lost (ft_3)	Tons Lost
Upper Severn Run									
2	2.2	7	15.4	8.4	3640	3.06×10^4	1.67	5.11×10^4	4.23×10^3
3	2.3	4	9.2	5.2	2220	1.15×10^4	2.84	5.27×10^4	2.72×10^3
4	1.9	10	19.0	9.0	2200	1.98×10^4	2.89	5.72×10^4	4.74×10^3
7	2.6	6	15.6	9.6	4700	4.51×10^4	2.08	9.39×10^4	7.77×10^3
Total						1.07×10^5		2.35×10^5	1.95×10^4
Jackson Grove Road Branch									
6	6.1	4	24.4	20.4	3440	7.02×10^4	1.96	1.38×10^5	1.14×10^4
Picture Frame Branch									
10	8.0	11	88.0	77.0	3240	2.49×10^5	2.59	6.46×10^5	5.35×10^4
11	2.6	4	10.4	6.4	1900	1.22×10^4	1.52	1.85×10^4	1.53×10^3
14	3.1	4	12.4	8.4	3600	3.02×10^4	2.71	8.20×10^4	6.79×10^3
Total						2.91×10^5		7.47×10^5	6.19×10^4
Middle Severn Run									
15	2.3	4	9.2	5.2	5120	2.66×10^4	1.34	3.57×10^4	2.95×10^3
16	2.4	4	9.6	5.6	1960	1.10×10^4	3.05	3.35×10^4	2.77×10^3
17	2.4	57	136.8	79.8	7040	5.62×10^5	2.22	1.25×10^6	1.04×10^5
23	2.2	49	107.8	58.8	8100	4.76×10^5	1.67	7.95×10^5	6.58×10^4
Total						1.08×10^6		2.11×10^6	1.76×10^5
Beaver Creek									
19	3.2	4	12.8	8.8	4240	3.73×10^4	0.99	3.69×10^4	3.06×10^3
20	2.4	8	19.2	11.2	8040	9.01×10^4	1.15	1.04×10^5	8.61×10^3
Total						1.27×10^5		1.41×10^5	1.17×10^4
Lower Severn Run									
26	2.1	76	159.6	83.6	4140	3.46×10^5	1.71	5.92×10^5	4.90×10^4
27	1.8	23	41.4	18.4	5700	1.05×10^5	3.10	3.25×10^5	2.69×10^4
Total						4.51×10^5		9.17×10^5	7.59×10^4
TOTAL						1.09×10^6 25 Acres		4.29×10^6	3.57×10^5

Chapter 8

CHAPTER 8
MANAGEMENT ALTERNATIVES

CONTROL OF RUNOFF

A comprehensive set of watershed management concepts that are known to be effective under a variety of conditions is presented in this chapter. The potential effects on the quantity of runoff and advantages and disadvantages of the control technique are described. The following concepts are considered: use of natural hydrology, onsite detention or retention, onsite infiltration, stream valley aquisition, downstream storage (large impoundments), flood insurance, flood proofing, roadway embankments, and existing Anne Arundel policies.

Natural Hydrology and Urban Land Management

These control methods are designed to use the existing hydrologic conditions to the maximum possible extent.

Natural Drainage. This concept involves designing developments so they maximize the use of the predevelopment drainage system. Natural drainage is considered a structural control because it usually involves some modification of the natural system. That is, natural drainageways can be lined with vegetation or slightly modified in other ways to increase infiltration and retention. Natural drainage can be most effective if supplemented by onsite detention, so that peak runoff can be reduced for subsequent bleedoff to the natural drainageway. This would provide the possibility for additional infiltration and protection of the natural drainageway. Figure 8-1 shows a typical example of how natural drainage can be utilized to control stormwater runoff.

The principal advantage of natural drainage is that by eliminating the need for catch basins and storm sewers, significant cost savings can be realized by the developer. The major problem with this control is the requirement for maintenance. Because of possible multiple ownership, coordination of maintenance may be difficult.

Contour Landscaping. Contour landscaping simply involves grading the surface so that infiltration is increased and runoff is reduced. This concept is the reverse of most traditional means of development where subdivisions are graded to promote the discharge of stormwater. In addition to careful grading, contour landscaping also involves the use of vegetation, so that runoff is discharged to vegetated areas for infiltration and storage, rather than to the streets and storm sewerage systems. This control is best applied in combination with one or more of the controls that are mentioned in this section.

Swale and Ditch Storage. Swales are small grass-lined depressions, either natural or manmade, which collect storm runoff. To be most efficient, they should be wide and shallow with a gradual slope. Infiltration and storage can be increased by maintenance of lush vegetation in the swale. Care must be taken to ensure that the use of swale drainage does not result in local flooding problems.

Urban Land Management. In the context of this report, the term urban land management refers to the methods by which the effects of impervious surfaces can be minimized. In principle, the object of urban land management is to encourage efficient use of land through open

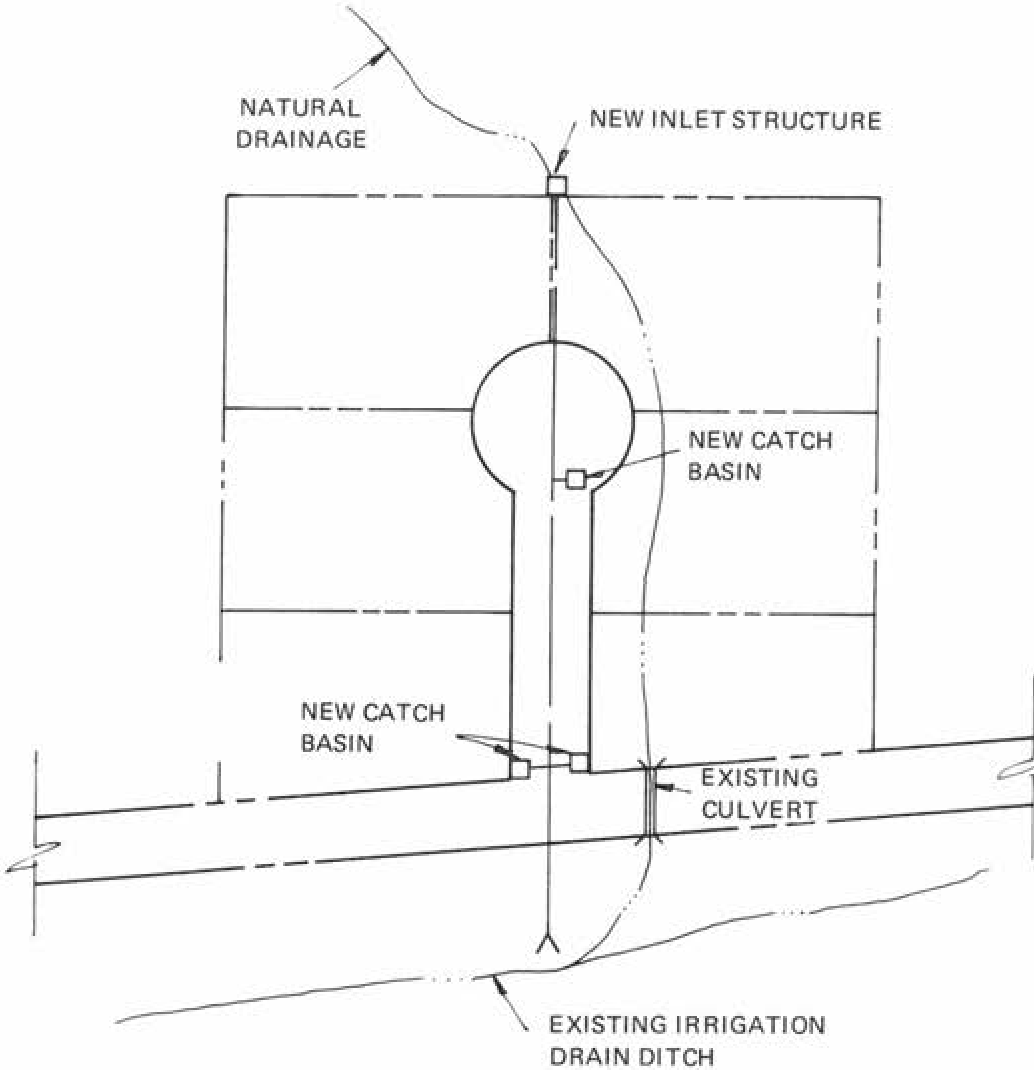


FIGURE 8-1: Natural Drainage Modified For Control Of Urban Runoff

space planning, cluster-type development, and density control.

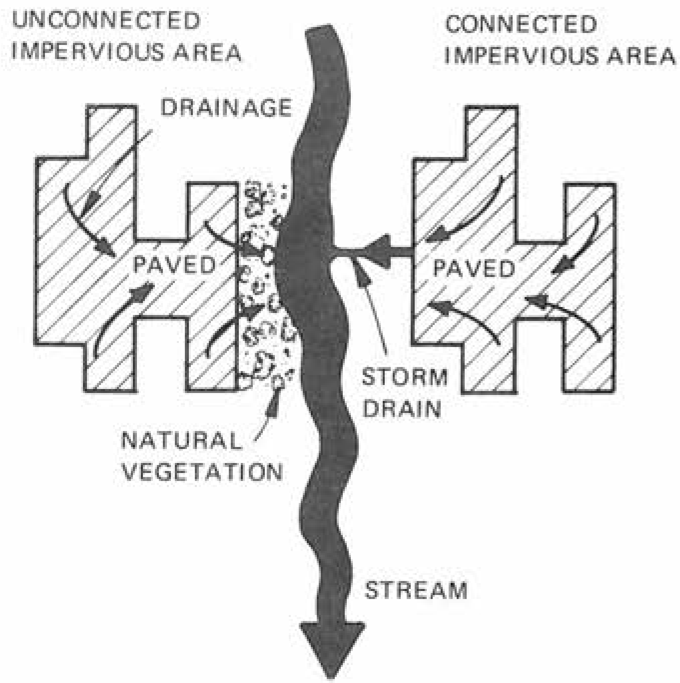
All impervious surfaces do not necessarily cause excessive and rapid stormwater runoff. Figure 8-2 shows two categories of imperviousness. One category is "connected" imperviousness; the other is "unconnected" imperviousness. The impervious area (i.e., rooftops, driveways, parking lots, plazas, etc.) separated from the stream by a buffer of natural vegetation or grass-lined drainage swales is defined as an unconnected impervious area. The area between the impervious surface and the stream usually slows the runoff and delays its entry into the stream. Any other impervious area connected to a stream by a storm sewer or lined drainage channel is defined as connected imperviousness. The difference between the two categories is the quantity and rate of runoff entering the stream channel during peak rainfall periods. A parcel of land with a given percentage of imperviousness could generate substantially different peak runoffs, depending on the degree to which the impervious areas are connected to the streams. The general relationship is that for a fixed percentage of imperviousness, the greater the degree of hydraulic connection between the impervious area and the streams, the greater the peak runoff.

Reduction of imperviousness and the degree to which impervious areas are connected to streams can be accomplished most easily in clustered developments and "new towns" employing open space planning and unit development techniques. Notable examples are the new towns of Columbia, Maryland, and Reston, Virginia. An example of a planned development is Montgomery Village near Gaithersburg. Current federal housing legislation includes provisions for new town and community development; and since the mid-1960s, land planning techniques have incorporated cluster-type subdivision design. These trends are expected to continue. Urban land management can best be achieved through regulatory controls, the most effective of which are zoning and subdivision regulations. The education of builders and developers to this concept can also be effective--particularly as a means to improve the quality and amenity value of new residential developments. Creative use of open space increases the aesthetic appeal of all types of land use. This appeal tends to add to stable values for residential neighborhoods and to long-term viability of commercial districts.

Debris Removal. Streams that are blocked or choked with debris do not effectively pass flood flows and can cause local flooding problems. Removing the debris can return the stream to its natural condition and allow it to safely pass the storm flows.

Advantages and Disadvantages. Some of the advantages of using natural hydrology and urban land management are:

- Open area concept is aesthetically pleasing.
- Requires low capital costs.
- Can reduce costs of storm sewer systems.
- Reduces hydrograph peak and total volume, thus decreasing erosion and pollutant load.
- Use of grass in systems can filter out some sediment.
- Infiltration recharges groundwater.



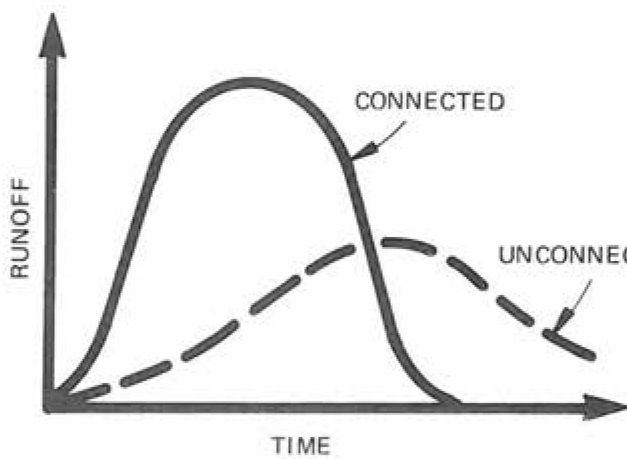


FIGURE 8-2: Categories of Imperviousness

The disadvantages of using natural hydrology are:

- o Possibility of flooding is increased due to less effective drainage.
- o Swales and ditches may erode significantly if high runoff flows occur.
- o Ponding can cause mosquito problems.
- o Open ditches and swales attract children who may play in poor quality water.
- o Vegetation requires maintenance.

Costs. These techniques should be applied in the planning process and should result in minimal or no additional costs. However, public maintenance costs may be higher for these techniques than for conventional curb and gutter systems if the property owner does not take responsibility for maintenance.

Onsite Detention or Retention

Onsite detention involves the temporary storage of water from its runoff source while onsite retention involves the indefinite storage of stormwater runoff. Onsite detention/retention may be accomplished by a number of approaches:

- o Storage in permanent ponds having provision for variable depth.
- o Temporary ponding on paved areas.
- o Temporary ponding on roofs of buildings.
- o Temporary ponding on recreational areas.
- o Underground storage.

These control measures can be effective, economical means of urban stormwater management. Besides controlling local flooding and water pollution, onsite detention may also provide aesthetic benefits, recreational opportunities, and reduced erosion and sedimentation hazards.

Onsite Detention/Retention (Storage) Ponds. Figure 8-3 illustrates the principle of onsite ponds. Major developments accelerate stormwater runoff because they increase the amount of impervious surface area and employ storm drain systems. With detention/retention ponds incorporated within the development, the peak runoff rate can be significantly reduced, as shown conceptually in the figure. If enough storage is available and with the proper design, the peak runoff can be reduced to its predevelopment level.

Ponds have the additional benefit of being aesthetic features in land developments. This can be a prime selling factor, as it serves to increase the amenities in living and/or working environments. New town developments, parks, golf courses, and open drainage systems employ onsite retention ponds for practical as well as aesthetic purposes.

The policies set forth in the requirements for the review and approval of sediment control plans by the Anne Arundel Soil Conservation District establish a basis for the design and development of onsite impoundments. These policies have been expanded to include the provision that stormwater storage capacity be made a feature of pond design. Onsite ponds are effective as a means to provide flood storage as well as to trap and control sediment and collect debris. They are

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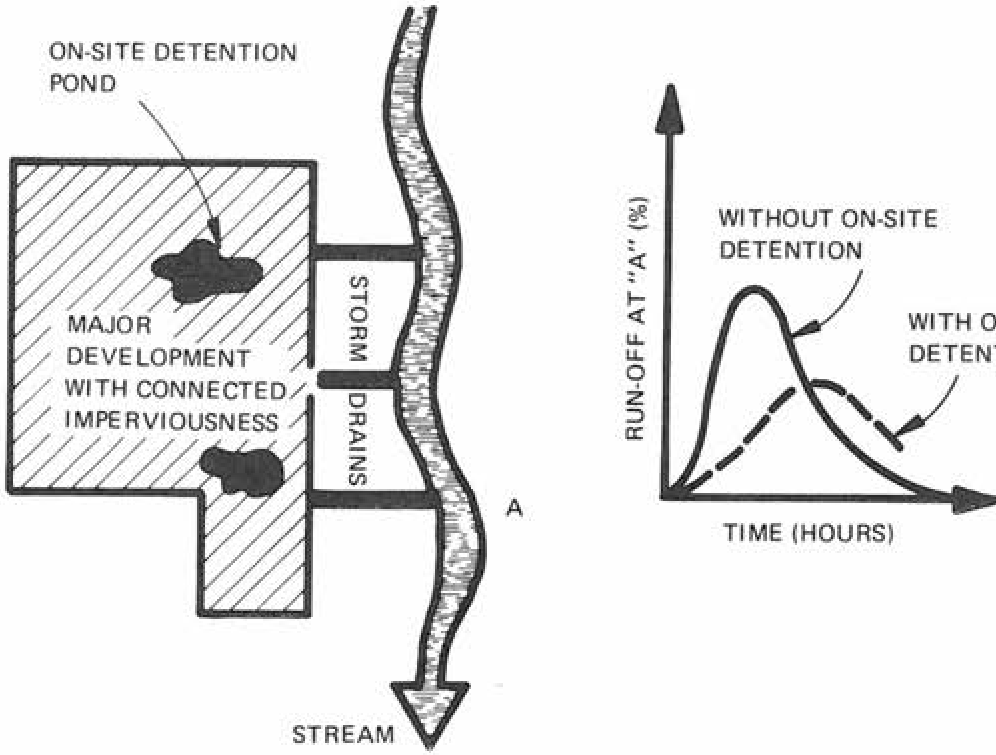

FIGURE 8-3: Effect of On-Site Detention On Runoff

simple to design and construct and are adaptable to the natural drainage pattern. One of the most desirable features of onsite ponds is that they can help to eliminate stormwater runoff problems before they occur. However, onsite impoundments will require periodic maintenance to remove sediment deposits and debris accumulation. Strict supervision of ponds is required to prevent accidents.

Among the advantages of onsite detention/retention ponds are:

- The ponds can act as sediment ponds and collect debris before it reaches the stream.
- Ponds are simple to design and construct.
- The effectiveness of a pond on reducing the peak flow rate is easy to determine.

Some of the disadvantages include:

- Ponds require significant maintenance to ensure their proper operation. Filling with sediment is the primary problem.
- The ponds require a significant land area that cannot be used for other purposes.
- Ponds can be a safety hazard for children.
- The effects of timing of pond releases on downstream peak discharges must be considered.

Generalized costs, adjusted to 1979 dollars, for detention basins based on DeTullio and Thomas are:

$$\text{Capital Costs } (\$/ft^3) = (\text{Land costs}/ft^3) + 116.88\ V_s^{-.517}$$

where V_s = storage volume in cubic feet

Operation and Maintenance Costs:

Pond Area (acres)	Cost
0-30	5% of construction costs
30-640	5% to 0.5% of construction costs

where construction costs = $93.5\ V_s^{-.517}$

Parking Lot Storage. Parking lots in commercial, industrial, and high density residential areas may be used to detain runoff. The runoff is stored in depressions constructed at drain locations. The stored water is slowly drained into the storm sewer system by reducing the size of the storm drain or increasing the spacing between the inlets at remote areas of the parking lot. If properly designed, the ponded areas could be located to cause as little inconvenience to the users as possible. Figure 8-4 shows how this could be arranged.

Certain advantages of parking lot storage are:

- o Storage could be easily designed in parking lot plans.
- o Large impervious areas are easily served.
- o There is no structural limit to the depth of water stored.
- o More easily maintained then rooftop storage.
- o Can be combined with porous pavement to reduce total volume of runoff.
- o Reduces runoff peak flow.

Some of the disadvantages of parking lot storage are:

- o Parking lot users may be inconvenienced by ponded water.

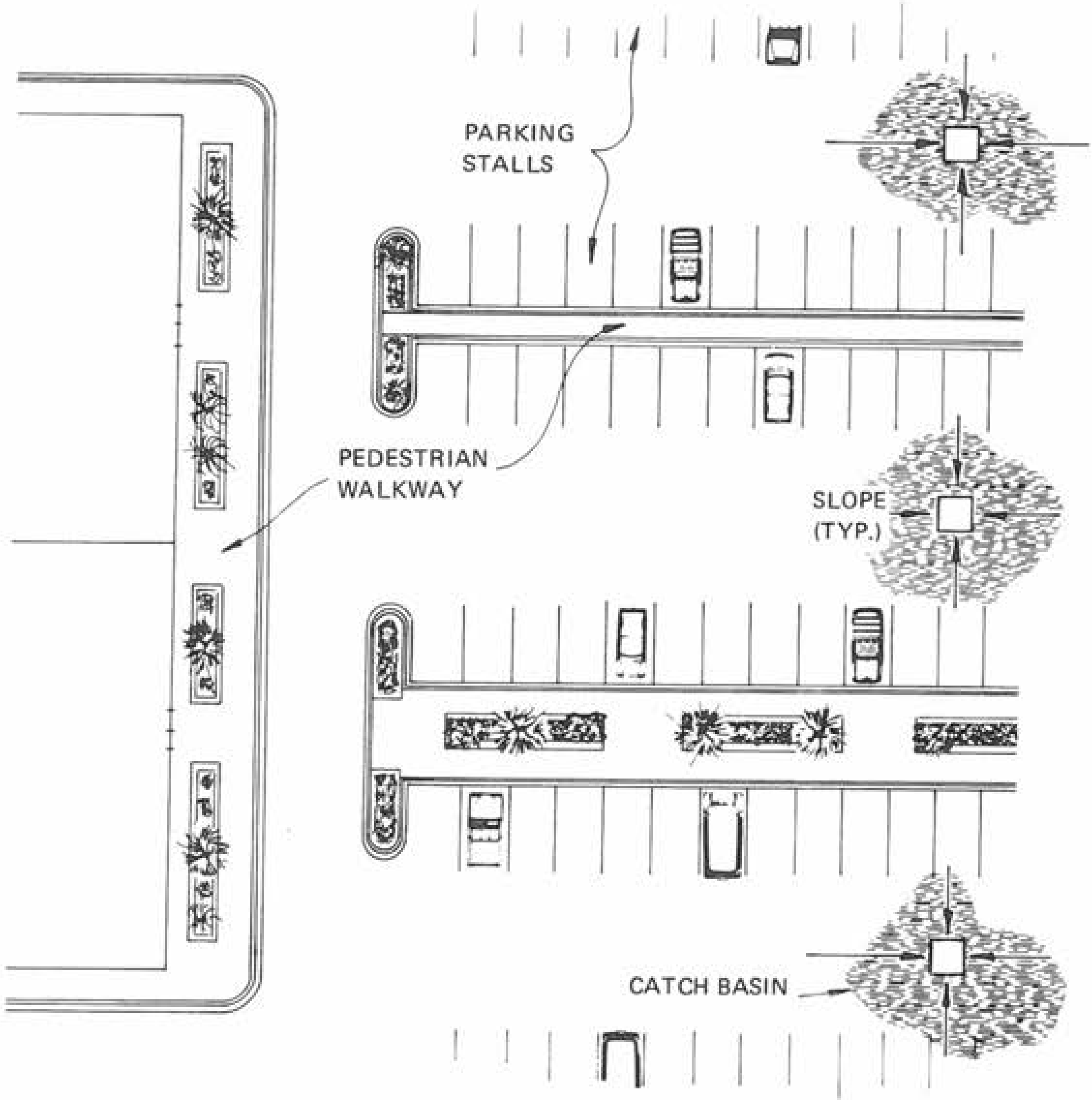

FIGURE 8-4: Example Of Parking Lot Storage For Control Of Urban Runoff

- Unevenness of lot can be unappealing.
- Ponded water can present a safety hazard, especially in winter.

Typically, there are few additional costs for parking lot storage. Some of the additional costs could include:

- Additional grading
- Maintenance
- Warning signs and markings in lot
- Extra curbing

Rooftop Storage. Stormwater may be temporarily stored on a flat or slightly sloping roof equipped with a controlled release drain, as shown in Figure 8-5. The drain is designed to allow a slow release of the stormwater so that if the rainfall rate exceeds this release rate, ponding occurs. The use of overflow scuppers prevents the water from ponding to an unacceptable leval and overflowing along the roof. Generally, 3 inches of water is stored.

Rooftop storage is advantageous because:

- The inconveniences of parking lot storage are avoided.
- There are no safety hazards for pedestrians and vehicles.
- Storage is not unsightly.
- Reduces runoff peak flow.

Rooftop storage is not without its drawbacks, including:

- If improperly designed, rainwater collected on the roof could cause the roof to collapse.

- o Tampering is easy and inspection difficult.
- o Rooftop waterproofing is required.
- o Drain and overflow scuppers can become easily clogged.
- o Maintenance is difficult.
- o Increased loads on rooftop will increase construction costs.
- o Primarily applicable to flat roofs only.

The major portion of the cost of rooftop storage is the increased structural requirements to support the extra load of the stored water. If the depth of water stored is limited to 3 inches, there should not be additional costs for structural requirements, because the extra load would be within the BOCA building code limits. Other cost factors include:

- o Increased waterproofing
- o Special roof drains
- o Parapet walls and scuppers
- o Slightly increased maintenance

Recreational Area Storage. Recreational areas such as tennis courts, parks, ballfields, and ponds may be used for stormwater storage, since these facilities are generally not in use during rain events. Pervious areas will allow for increased infiltration, further reducing the flow peak. The areas should be designed for quick and thorough drainage.

Advantages of recreational area storage are:

- o Little disruptive impact during rain event.
- o Some areas allow for increased infiltration, reducing the total volume of runoff.

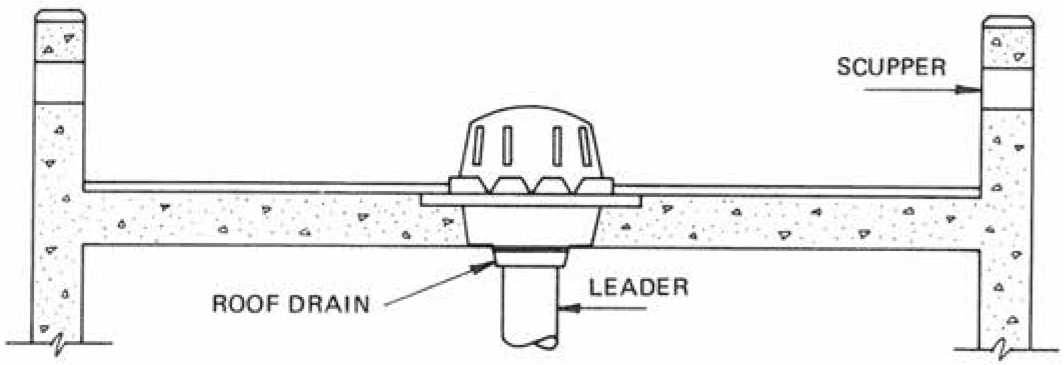

FIGURE 8-5: Typical Roof System With Controlled Released Roof Drain And Overflow Scupper

Disadvantages of recreational area storage can be:

- Proper drainage must be ensured.
- Facilities with grass must have grasses capable of surviving wetness, flooding, and sediment deposition.
- Increased erosion and channelization is possible.

Underground Storage. Underground storage in tanks and oversized drainage pipes is a viable alternative. A storage tank would function in much the same manner as a detention basin. Oversized drainage pipes with specially designed outlet devices can effectively store runoff. Underground structures should be equippped with overflow devices and designed so that overflows do not create public, environmental or aesthetic problems.

Advantages of underground storage include:

- Minimal land is required, making this a preferred option for rapidly urbanizing areas.
- Self-flushing design can minimize maintenance.
- Long useful lifetime can be expected.

Among the disadvantages are:

- More costly than other detention/retention measures unless land prices are very high.
- No capabilities for a multiple-purpose facility.
- Inspection is difficult after construction.

Costs for these controls vary considerably. Typical costs are in the range of 3 to 5 dollars per cubic foot of storage.

Legal and Political Problems of Onsite Detention. In order to implement onsite detention for new developments, some legal and political problems must be recognized.

The first problem concerns what type of legal basis can be used to require onsite detention. Some of the types of legislation used by local jurisdictions to control stormwater runoff from new land developments and urban renewal projects include: subdivision regulations, zoning ordinances, building codes, plumbing and sewer ordinances, water pollution control ordinances, flood control ordinances, and drainage fee assessment ordinances (some of which provide for reducing the assessment if stormwater detention facilities are installed). At least one national organization, the Building Officials and Code Administrators International, has developed standards for detention storage of rainfall on roofs.

Additional legal considerations or complications may include the following: 1) legal responsibility for maintenance of detention storage facilities, whether rooftop, parking lot, surface pond, or other facility; 2) legal responsibility for damages resulting from operation or physical failure of stormwater detention facilities; 3) legal responsibility for damages caused by excessive flows of stormwater when released from facilities located on public or private lands; 4) legal responsibility for providing safety facilities to minimize the hazards of onsite detention facilities, especially as an attraction to children; and 5) the legal right to use or consumption of the stored stormwater, thereby disturbing normal flows of water into areas downstream from detention facilities.

Potential political problems include that of modifying existing laws, building codes, zoning ordinances, subdivision regulations, etc., to include requirements for onsite detention of stormwater runoff that are practical and effective for solving water pollution and drainage problems, and are also acceptable to politicians and officials of the various public agencies involved. In order for these laws to be effective they will require approval of construction plans, provisions for inspections, and fines for noncompliance.

Advantages and Disadvantages of Onsite Detention/Retention. Some of the advantages of onsite detention/ retention are:

- Peak flow reductions.
- Can reduce the total volume of runoff.
- Can reduce costs of stormwater conveyance systems.
- Can be included in site plans for an aesthetically pleasing effect.
- Provides some erosion/sediment control or reductions.

Among the disadvantages of onsite detention/retention are:

- Storage ponds can require significant land areas.
- Can increase costs of developments.
- Can result in mosquito and algae problems as well as other user inconveniences.
- Retention storage can be a hazard to children.
- Improperly designed systems can result in structural damages, groundwater pollution, and downstream flooding problems.
- Most of these control options require routine maintenance.

Increased Onsite Infiltration

These control options are designed to increase infiltration on a site that has already been developed or to maintain the infiltration of a site undergoing development. The purpose of these techniques is as follows:

1. To maintain runoff volumes and peaks from areas undergoing urban development at or near natural conditions.
2. To maintain sufficient infiltration to shallow groundwater in order to to ensure that there is no appreciable decrease in the dry weather flow of streams.
3. To maintain recharge of major aquifers at a level equivalent to those under natural conditions.
4. To improve surface water quality.

It should be stressed that increased infiltration of severely polluted stormwater runoff may cause groundwater contamination. Therefore, the measures described here should not be used in areas with high seasonal groundwater tables. Figure 8-6 is a depth to seasonal high groundwater table map of the watershed. If the infiltration is increased over natural conditions, and a perched or seasonal high groundwater table exists, the groundwater level could be raised to the land surface, resulting in pollution of the groundwater, structural problems, and failures of onsite wastewater disposal systems. Increased infiltration measures should not be considered for areas with less than 1-1/2 to 2-1/2 feet to the seasonal high groundwater table. Most of the watershed has greater than 4 feet to the seasonal high groundwater table and is well suited for infiltration alternatives.

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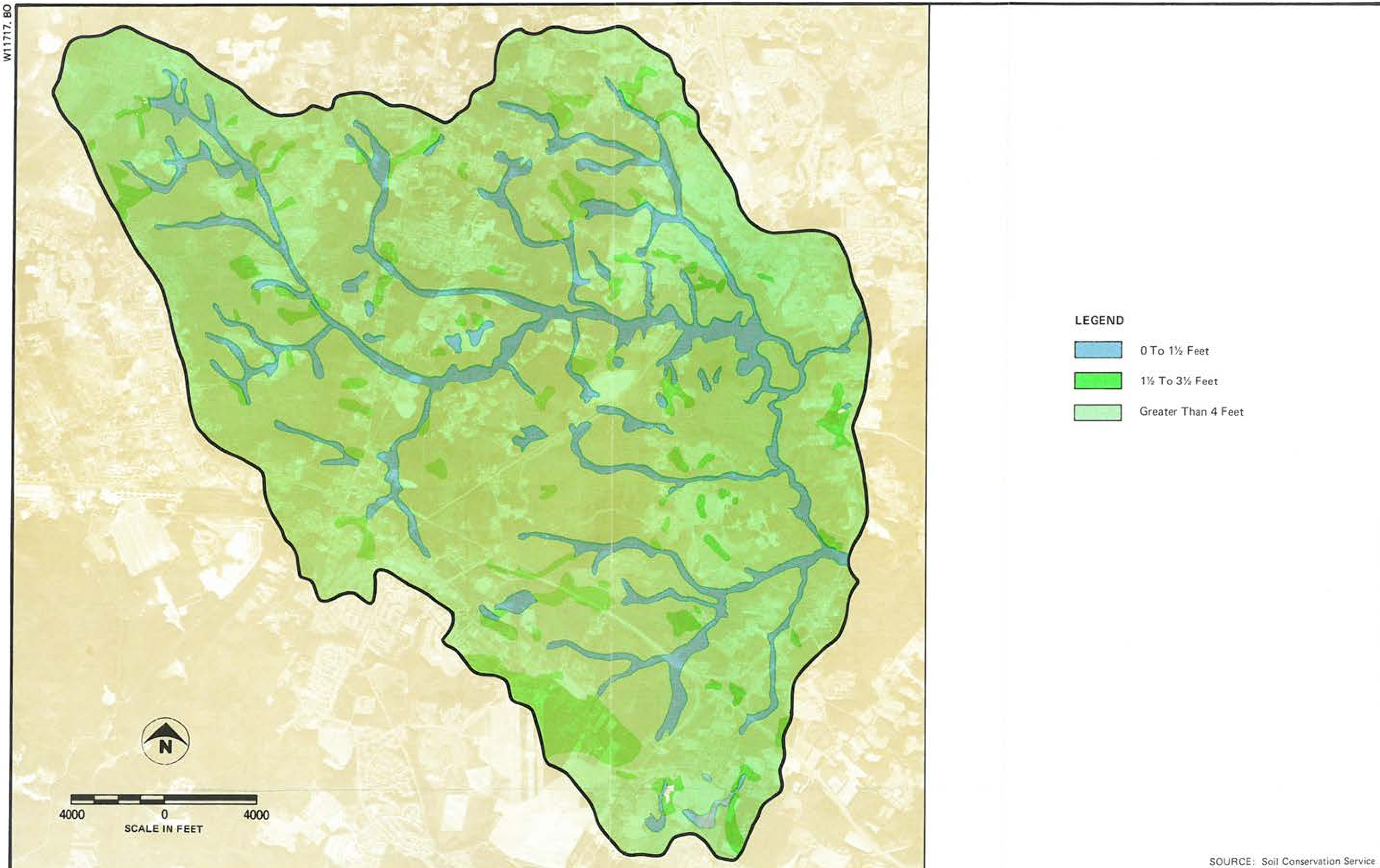

FIGURE 8-6: Depth To Seasonal High Groundwater

Dutch Drains. Dutch drains are gravel-filled ditches with an optional drainage pipe in the base. Dutch drains intercept the runoff prior to its getting to the stormwater conveyance system. The use of dutch drains will not alleviate the need for a stormwater conveyance system, but will reduce the size of the system. Dutch drains may be used to collect runoff from roofs without gutters, as dividing strips between impervious areas such as in a parking lot, and as a drain for small parking lots or driveways.

Porous Pavement. Porous pavement includes asphalt, asphalt-concrete mixtures and precast lattice blocks and bricks. Porous pavement is still largely in the developmental stage, although some successful pilot tests have been conducted. Porous pavement allows water to soak through the pavement and infiltrate. The use of porous pavement could reduce the required size of stormwater conveyance systems.

Some of the advantages of dutch drains and porous pavement include:

- Can improve highway safety.
- Reduce flow peak and runoff volume by increasing infiltration.
- Increase base flow of streams.
- Can act to recharge groundwater table.
- Can reduce size of stormwater conveyance systems.
- Not considerably more expensive than standard practices.
- Precast lattice blocks allow grass to grow in lattices, providing aesthetic value.

Certain disadvantages of dutch drains and porous pavement are:

- o Effectiveness depends on soil characteristics.
- o Not recommended for areas with seasonable high water tables.
- o Can result in goundwater pollution.
- o Local ordinances may not allow stormwater conveyance system to be sized based on increased infiltration.
- o Pores in pavement tend to clog and require maintenance.
- o Porous pavement costs more than conventional pavement.

Porous asphalt pavement generally costs from 8 to 10 dollars per square yard, while conventional asphalt costs about 5 dollars per square yard. However, it must be remembered that porous pavement reduces or eliminates the need for curbs and gutters. The use of porous pavement could then result in a net savings compared to conventional pavement and drainage.

Grass-lined Ditches. As the name implies, these are small grassed drainageways that can be used to replace storm sewers. The principal advantage of this method of drainage is that infiltration of runoff can be increased through ditch losses, and the roughness in the channel provided by the vegetation reduces water velocities and peak discharge. In addition, the grass in the ditch aids in filtering out many of the pollutants carried by the runoff. A drawing of a grass-lined ditch is shown in Figure 8-7.

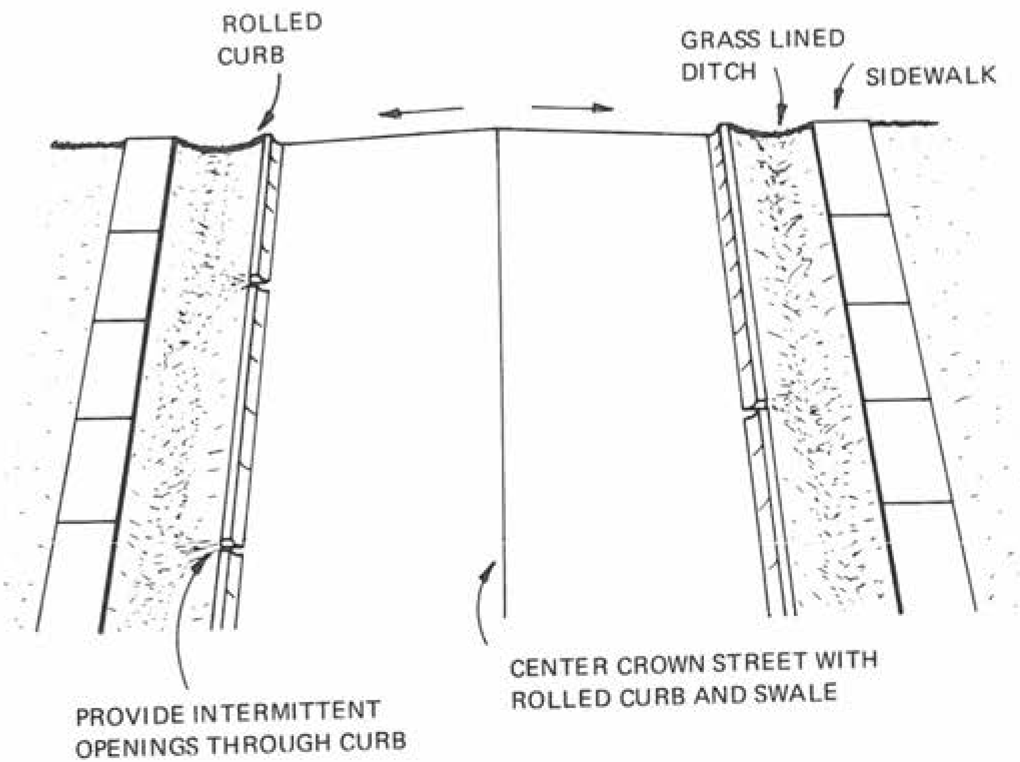

FIGURE 8-7: Typical Grass-Lined Ditch For Control Of Urban Runoff

One of the major advantages of grass-lined ditches is that they are typically cheaper than a traditional storm sewerage system. However, the drainage they provide is not as effective, they require maintenance, and if ponding results, they may become a breeding area for mosquitos. Ditches can pond water and result in mosquito and other pest problems. The stagnant water allows for the decomposition of organics so that the early phases of a subsequent runoff event could have a significant oxygen demand. Sediment trapped in ditches can be used as a source of topsoil.

Advantages of grass-lined ditches include:

- o Runoff peak flow and total volume may be reduced.
- o Grass acts as a filter, removing numerous pollutants.
- o Can reduce costs for stormwater sewer systems.

Disadvantages of grass-lined ditches are:

- o Possibility of flooding is increased due to less effective drainage.
- o Channel erosion is possible if high runoff velocities develop.
- o Ponded water is a health and safety hazard.

Grass-lined ditches should be less costly to construct than typical drainage systems. Maintenance costs, especially if passed to the public, would be higher.

Infiltration Beds and Seepage Basins. An infiltration bed or seepage basin is an excavated area of land that has been filled with rocks and gravel and overlies a soil with a high infiltration capacity. Stormwater runoff is directed to the bed or basin through an inlet screen or sediment trap which catches leaves, debris and heavier sediment particles. Infiltration beds are well suited to commercial centers, high density residential areas or industrial parks.

Among the advantages of infiltration beds are:

- Runoff peak flow and total volume are reduced.
- Groundwater recharge.
- The bed or basin may be located under paved areas.

Some of the disadvantages include:

- The bed or basin can tie up land desired for development.
- Requires maintenance which can result in tearing up the bed or basin.

Some of the costs of infiltration beds include:

- Excavation
- Backfill material and placement
- Drains
- Runoff filtration devices
- Maintenance

A net reduction in costs is possible due to savings on the size of drainage facilities.

Advantages and Disadvantages of Onsite Infiltration.

Among the advantages are:

- Can reduce peak flows, thereby reducing erosion and particulate transport.
- Can reduce total volume of runoff.
- Can reduce costs of stormwater conveyance systems.
- Can be included in site development plans.
- Recharges groundwater supply.

The disadvantages include:

- Effectiveness is difficult to determine and depends on soil properties.
- Most of the techniques require maintenance.
- Limited to areas without seasonal high groundwater tables; otherwise, groundwater pollution may occur.
- Can increase the cost of development.

Channel Improvements

An improved channel is a natural channel that has been modified in cross-section geometry, alignment, and slope to increase the flow capacity of the stream. For a specified flow, an improved channel will transmit water at a faster rate and lower depth than an unimproved channel, and will therefore reduce flooding risk. Frequently-used channel linings include grass, concrete, gabions and rip-rap. It may also be constructed as a levee.

Characteristic results of channel improvements are substantially increased velocities during flood periods and very little flow during dry periods. These characteristics have a significant impact on aquatic life and can aggravate flooding and erosion conditions downstream if the improvement is not carried to the mouth of the watershed or if it is not designed properly. Improved channels with grass linings may be subjected to erosion where soil conditions are not favorable. These conditions usually lead to reinforced concrete linings which are unappealing and usually costly.

Advantages and Disadvantages. The advantages of channel improvements include:

- Flood risks and damages are reduced.
- Severe channel erosion can be controlled.

Among the disadvantages are:

- Flooding problems may be increased downstream.
- Improved channel can have adverse ecologic impacts.
- Channel is often aesthetically unappealing.
- Can be very costly.

STREAM VALLEY ACQUISITION

The principal underlying concept of stream valley acquisition is to maintain in a natural condition land areas subject to flooding. Public ownership of stream valleys serves to avoid potential flood damages and concurrently provides significant conservation, wildlife habitat preservation, and recreation benefits. Recreational activities that are well suited to stream valleys include hiking, nature study, wading, biking, and horseback riding.

The Severn Run Environmental Area basically follows the stream valley, which has been acquired not only for its aesthetic value but also as a means of restricting development in sensitive areas. The process of maintaining lands subject to flooding and retaining them in a natural undeveloped state is best achieved through a direct purchase. Other methods of maintaining these land areas include restrictions to development by zoning, donation as open space in subdivision approval, and tradeoff agreements between developers and communities for development rights elsewhere.

Other areas can be gained by requiring developers to donate land or funds to the development of land areas for open space and recreational purposes, either "onsite" or in "land banks" for future acquisition and/or development.

Acquisition costs can be expected to increase with the passage of time. Early acquisition efforts should be made to accelerate the purchase of flood plain areas. Open space easements and use rights may require a smaller investment to maintain natural stream valley areas not available for purchase. Such arrangements also can be a financial (tax) benefit to the owner.

Advantages and Disadvantages. Some of the advantages of stream valley acquisition are:

- Flood-prone areas are unavailable for development.
- Multipurpose recreational areas are made available to the public.
- Environmentally sensitive areas are protected.

Certain disadvantages include:

- The flood peak and total runoff volume are not changed.
- Land prices may be high.
- A park system requires management and maintenance.

DOWNSTREAM STORAGE OR LARGE SCALE IMPOUNDMENTS

Large-scale impoundments in the context of this plan refer to bodies of water formed by damming the flow of water in rivers or streams. Impoundments have the potential for a wide variety of recreational activities including boating, swimming, and fishing. They also serve as a means of supplying water, controlling floods, trapping sediment, and augmenting low flows.

Figure 8-8 conceptualizes the effect of an impoundment on streamflows immediately downstream from the dam. Flood waters entering the reservoir are temporarily stored and thereby reduce flood peaks downstream from the impoundment. In addition to the flood peak reduction, the peak with the impoundment also is delayed--a factor that often abates downstream flooding, but can also create problems if not properly designed.

The efficient location of impoundments depends to a large degree on topography and adequate streamflow. Caution must be exercised in the location of the impounded waters to preclude destruction of historical and archeological sites and areas of environmental sensitivity. Intense recreational uses may cause local community impacts that require careful evaluation and treatment.

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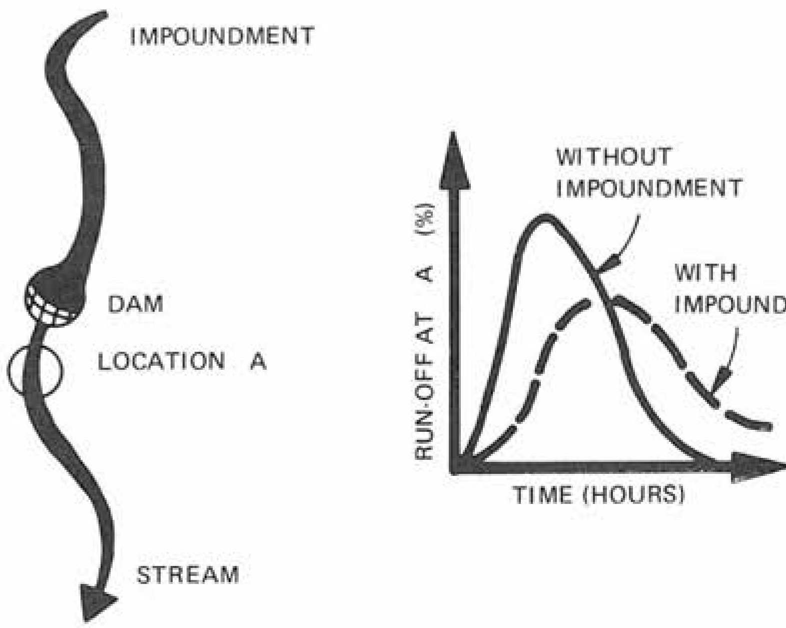


FIGURE 8-8: Effect Of Impoundment On Runoff

Off-Stream Storage. A modification to on-stream storage behind large-scale impoundments is the use of off-stream storage. This involves the use of a side channel behind an impoundment or off the main stream channel, which operates only when the channel flow exceeds a certain amount. Thus, the off-stream storage areas are used only during the peak of the hydrograph and are inundated only for a short time. Natural wetlands are ideally suited for this purpose.

Advantages and Disadvantages. Included among the advantages of downstream storage are:

- Peak flows are reduced and the reduction is easily calculated.
- Multiple uses are easily implemented.
- Sediment settles out in the impoundment and water quality may be improved.
- Wildlife can be supported by the reservoir.

Some of the disadvantages are:

- Large land areas may be required.
- The reservoir may create some water quality problems.
- If flood routing for the watershed as a whole is not considered, the delay in the peak flow caused by the impoundment may create more severe problems downstream.
- The reservoir changes the ecology of the area.
- Maintenance is required.

Road Embankment Ponding

The intentional or accidental use of roadway restrictions in culverts or bridge openings can serve a means of stormwater detention. Several roads in the watershed act in this manner. They are Route 3, Route 32 on Jabez Branch, and the Penn Central railroad track on Picture Frame Branch. Route 32 is an excellent example of beneficial road embankment ponding. However, Maryland policy is to not purposefully design roads as impoundments.

Advantages and disadvantages. The advantages of road embankment ponding include:

- Reduction in peak flow.
- Utilizes existing or planned structures.
- Impacts may be limited to the land used for right-of-ways.

Listed among the disadvantages are:

- The roadway should be designed to act as a dam to prevent failure.
- Additional land may be required for the area to be flooded.
- Should be used only where topography is ideal.

FLOOD INSURANCE

The National Flood Insurance Program is a federally subsidized program authorized by Congress in 1968 to protect property owners who, up to that time, were unable to get coverage through the private insurance industry. This program made flood insurance available to individuals at affordable rates, for the first time. In return for the federal subsidy, state and local governments are required to adopt certain minimum land use measures to reduce or avoid future damage within their flood-prone areas.

The flood insurance coverage extends to all types of buildings and their contents. Losses covered by the flood insurance include: 1) a general and temporary flooding condition of normally dry land areas; 2) erosion resulting from abnormally high water levels in conjunction with a severe storm; and 3) flood-related mud slides involving a mud flow.

This study will be incorporated into a flood insurance study being conducted by the Maryland Department of Natural Resources.

FLOOD PROOFING

Flood proofing is a combination of structural changes and adjustment to properties subject to flooding, primarily for the reduction or elimination of flood damages. Although it is more simply and economically applied to new construction, flood proofing is also applicable to existing facilities. It should be considered in the following situations:

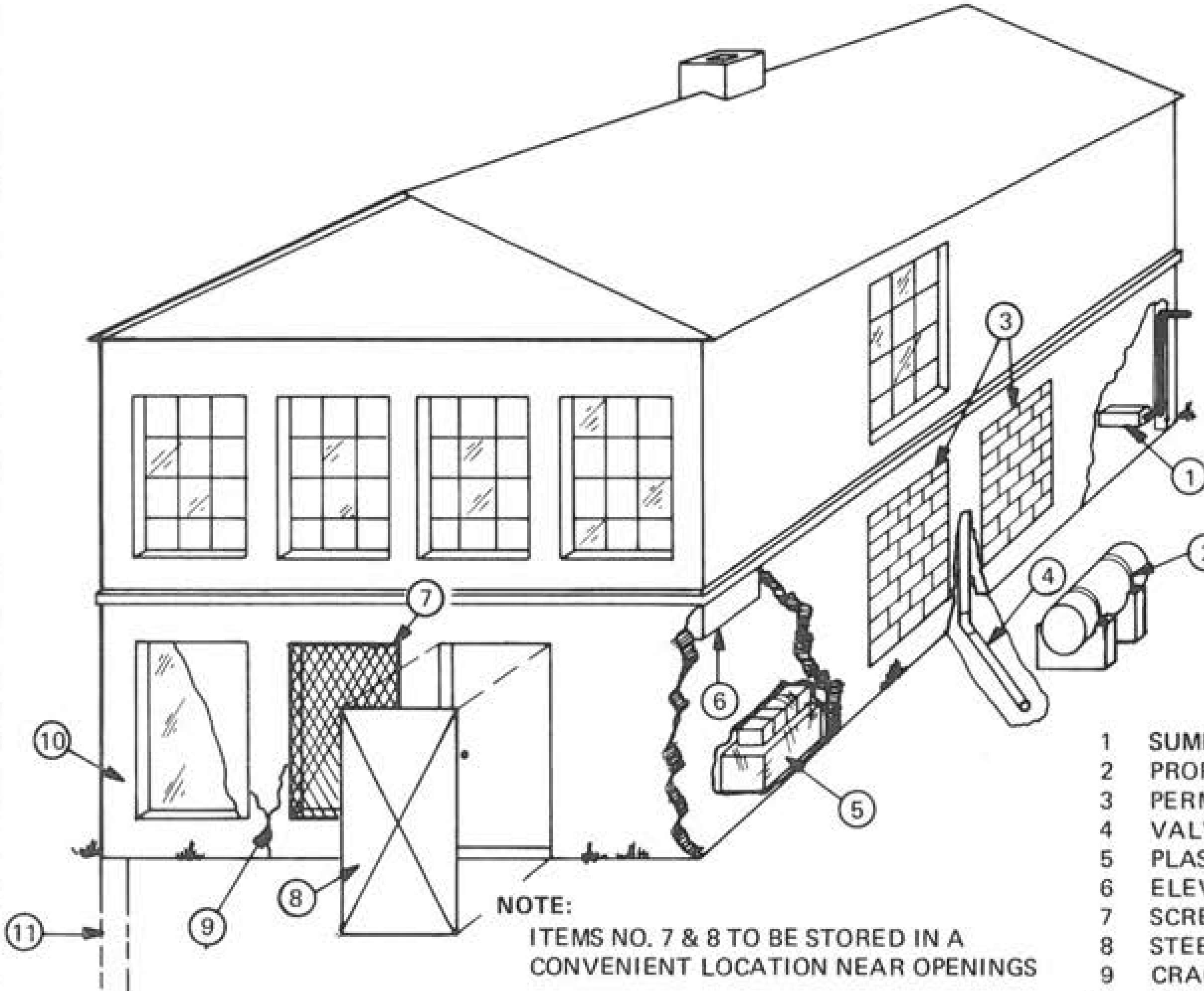
1. Where moderate flooding with low stage, low velocity, and short duration is experienced;
2. Where the traditional type of flood protection is not feasible; and
3. Where activities depend upon riverine locations and need or desire a higher degree of protection than that which is provided by an existing or proposed flood control project.

Figure 8-9 illustrates a flood-proofed structure. For the commercial building shown in the figure, several flood-proofing techniques are employed. It is evident from this example that only the first story of the two-story building is exposed to a flood hazard. Therefore, the flood-proofing techniques are limited to the first floor. The techniques shown include a sump pump, a properly anchored tank, permanent closure of openings with masonry, a valve on a sewer line, plastic covering of material inside the structure, elevated electrical control panels, screens to prevent breakage of glass from floating debris, steel bulkheads for entrances, sealing of cracks with hydraulic cement, sealing around openings to reduce seepage, and anchoring of the structure itself.

REGULATORY FLOODWAY

In preparing flood plain regulations, it is important to keep in mind that all parts of the flood plain are not alike. During a flood, the area near the channel is usually deep and fast-moving, carrying most of the flow. However, the flood waters in some overbank areas may be slowed by the damming effects of downstream obstructions. Consequently, these areas are ineffective in carrying the flood waters. A concept which addresses these two different conditions separately is the regulatory floodway. The basic idea of the floodway is illustrated in Figure 8-10.

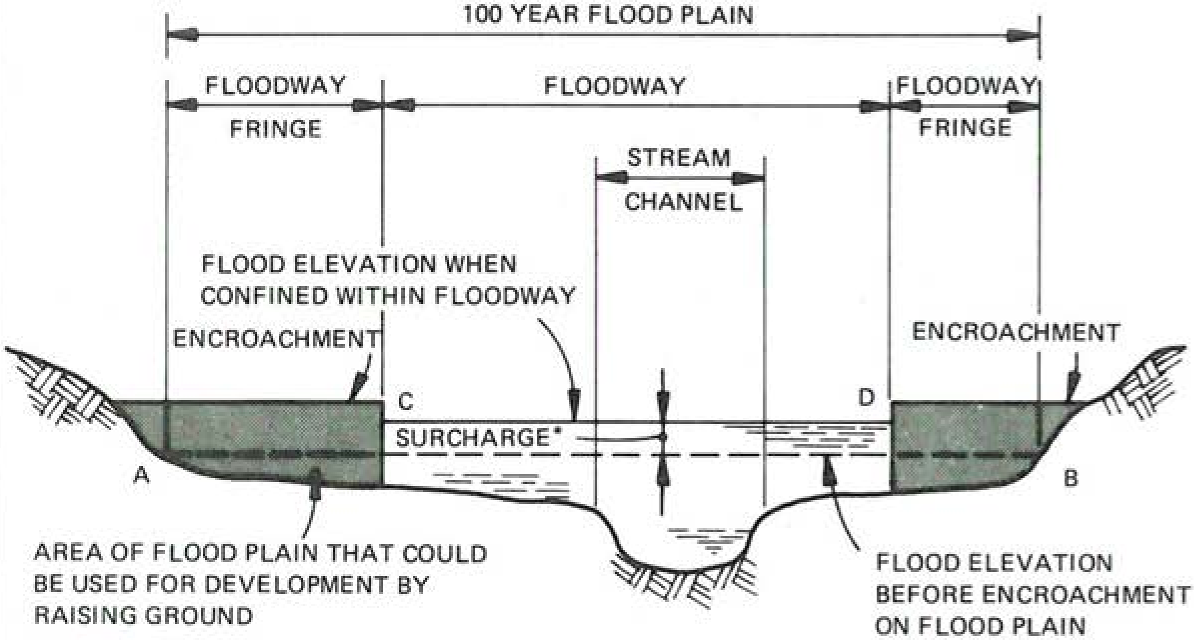
The idea of a regulatory floodway is to allow encroachment in the flood plain where this encroachment will not have a significant effect on flood elevations. A clear path, called the floodway, is kept in the natural condition to pass the floods. Under the regulatory floodway concept, the increases in flood elevations, called surcharges, are limited to a certain amount, usually 1.0 foot. In this way, development in a watershed is not overly restricted, yet increased flood problems from this development are kept to a minimum.



1 SUMP PUMP & DRAIN TO EJECT SEEPAGE
2 PROPERLY ANCHORED TANK
3 PERMANENT CLOSURE OF OPENINGS WITH MASONRY
4 VALVE ON SEWER LINE
5 PLASTIC COVERING
6 ELEVATED CONTROL PANEL
7 SCREENS TO PREVENT BREAKAGE OF GLASS
8 STEEL BULKHEAD FOR ENTRANCE
9 CRACKS SEALED WITH HYDRAULIC CEMENT
10 THOROSEAL COATING TO REDUCE SEEPAGE
11 ANCHORAGE

SOURCE: Flood Plan Regulations; TVA-U.S. Army Corps Of Engineers, 1967

FIGURE 8-9: Flood Proofed Structure



LINE A - B IS THE FLOOD ELEVATION BEFORE ENCROACHMENT
LINE C - D IS THE FLOOD ELEVATION AFTER ENCROACHMENT

*SURCHARGE NOT TO EXCEED SPECIFIED AMOUNT

FIGURE 8-10: Floodway Schematic

Defining the boundary between the floodway, where development is totally restricted, and the floodway fringe, where encroachment is allowed, is not a straight-forward process. The first step is to use the hydraulic model, HEC-2, to determine how much of the flood plain can be completely obstructed without raising water surface elevations more than the specified amount. Generally, the 100-year flood is used in the analysis; the surcharge from filling in the floodway fringe is limited to 1.0 foot. The computational sequence of the HEC-2 computer model removes flow area from each side of the flood plain until the revised flow area carries the same discharge at an elevation 1.0 foot higher than the natural cross section. Preliminary floodway boundaries are computed for each cross section in this manner. If there were no political considerations, the final floodway boundaries could be established quite easily from the initial results. Conditions may require coordination with local interests to identify areas to receive special treatment in floodway delineation. These areas could include:

1. Private lands where the flood plain on both sides of stream is under common ownership and the owner has a preferred location for the floodway;

2. Areas where legal and moral land-use commitments of local officials preempt floodway options;

3. Public parks, greenways and preservation areas where development will not be considered for the flood plains;

4. Partially developed areas where zoning or other regulation programs demand special placement of floodways for overall consistency in their programs; and

5. High-valued flood plain complexes where floodway surcharges could result in significant damages.

After all special cases are treated, a revised floodway is developed which may be quite different from the original computer estimate. This revised floodway must be tested to ensure that the surcharge limit has not been exceeded.

There are two other factors to consider in designing a floodway. The first is velocity of the flood water. Flood plain encroachment will not only raise flood elevations, but will also raise flood velocities. These higher velocities could cause excessive scouring and erosion, and possible damage to structures already in the designated floodway. Encroachment should not be allowed in areas where excessive velocities will result. Table 8-1 can be used as a guide in determining maximum allowable velocities in straight, uniform channels.

Maximum permissible velocities in bends of a stream should be lower than those shown in the table, since erosion is more likely on a stream meander. If velocities in the natural flood plain are already excessive, floodways which would increase these velocities should not be considered. In these cases, the only areas which should be designated "floodway fringe" are localized storage areas where velocities are low.

The remaining factor to consider in designing a floodway is implementation. The floodway boundaries must be such that there is no question as to whether or not a particular parcel of land is in the floodway or the floodway fringe. This can be accomplished by having straight boundaries and uniform widths over short reaches. Another way to avoid enforcement problems is

Table 8-1
Suggested Maximum Permissible Mean Channel Velocities In Straight, Uniform Channels

Channel Material	Mean Channel Velocity, fps
Fine sand	2.0
Coarse sand	4.0
Fine gravel (less than 3/4")	6.0
Earth	
Sandy silt	2.0
Silt clay	3.5
Clay	6.0
Grass-lined earth	
Bermuda Grass - sandy silt	6.0
- silt clay	8.0
Kentucky Blue Grass - sandy silt	5.0
- silt clay	7.0
Poor rock (usually sedimentary)	10.0
Soft sandstone	8.0
Soft shale	3.5
Good rock (usually igneous or hard metamorphic)	20.0

Source: Army Corps of Engineers, "Hydraulic Design of Flood Control Structures."

to keep all interested parties informed of any proposed floodways before the laws are passed.

A regulatory floodway can be a good way to preserve streams without restricting development in the watershed. If care is taken in designing the floodway, it can be a solution to flood problems acceptable to developers, environmentalists, local governments, and any other concerned parties.

The State of Maryland Department of Natural Resources has guidelines for designing floodways that are generally more restrictive than the ones given here. If a regulatory floodway is to be considered, the Maryland guidelines should be followed.

STATUS QUO

Maintaining the "status quo" in many instances is a valid management technique. Where ongoing programs are successful, they should be continued. Also, in certain circumstances, improvements may eventually be desirable, but due to site conditions and long-range programs, immediate action may not be warranted. In other circumstances, the cure can become another problem of greater magnitude. Sometimes the cost involved to provide a solution is far beyond the scale of the problem, making such solutions impractical; therefore, a do-nothing alternative can be effective and often acceptable.

One of the alternatives that will be evaluated in Chapter 11 is the County's current (as of February 1979) stormwater management policy. Discussion of the existing policy will be covered in Chapters 9 and 11.

EROSION AND SEDIMENTATION

Erosion and the resulting sedimentation is probably the most severe water quality problem in the Severn Run watershed. Two types of erosion will be addressed: overland flow surface erosion and stream channel erosion. A brief description of the erosion process will provide a further understanding of the control measures considered.

Overland flow erosion, which includes sheet, rill and gully erosion, occurs during rainfall events. The impact of raindrops hitting the soil dislodges and breaks up the soil particles. The soil can be moved several feet by the rainfall, and larger soil particles are broken into smaller particles which are easier to remove by overland flow. The small particles can also fill voids between the larger soil grains and decrease the infiltration capacity of the soil. As the rainfall event continues, overland flow begins and transports soil from the land surface. The transported soil comes from soil particles loosened by rainfall impact, soil that is loose as a result of a soil-disturbing activity (plowing, digging, scraping, etc.), and soil that has been loosened by the hydraulic lift of the overland flow. The amount of soil that can be transported depends on the depth and velocity of the flow and the size, density, and shape of the soil particles. Small, light particles are more easily transported than large heavy particles. Therefore, the smaller particles are the first particles to be picked up by the overland flow and the last to be deposited.

Stream channel erosion is the widening or deepening of a stream's banks or bottom. It is determined in part by the nature of the bottom and side material, the stream gradient and alignment, and the flow in the stream. There are three major processes in stream channel erosion: hydraulic action, solution, and corrasion. Hydraulic action results from the force of the water striking the stream channel. It is a function of the streamflow and channel materials. The water flowing in a stream dissolves some of the channel material while corrasion is the hitting of transported soil particles against the channel, causing removal of some channel material.

It must be recognized that stream channel erosion is a natural process of a stream reaching an equilibrium with its flow and channel materials. Accelerated stream channel erosion can become a problem when increased flows due to urbanization, forest clear cutting, and other land changes cause the stream to seek a new equilibrium. It is generally thought that a stream channel reaches an equilibrium with the 1.4- to 2-year flood peak and that large floods have only a temporary effect on the channel width and depth.

Control measures will be briefly discussed for construction sites and urban areas, agricultural areas, and stream channel erosion. A point to keep in mind is that before any man-induced changes occur in the watershed, biological factors are typically the primary erosion control. For this reason, emphasis is given to maintaining or reestablishing vegetation.

Construction Sites

Construction sites are prime candidates for significant erosion. Clearing of vegetation, slope modifications, digging and scraping of the soil, and other elements of the construction process allow rainfall and the resulting overland flow to remove considerably more soil than under natural conditions. The control measures considered are planning, land surface protection, runoff diversion, grade control, sediment traps, detention basins, and energy dissipators. Table 8-2, adapted from EPA's Sediment and Erosion Control Handbook, summarizes possible controls. Details of the control measures and their costs can be found in the references for this chapter. Further explanation and cost information would be of limited value due to the site-specific nature of the control measures.

Planning. Proper planning of developments and construction can have a large impact on reducing the amount of erosion. The potential for erosion-causing rainfall events is greatest from May through October. If most grading and earth moving operations were scheduled for other than this period the potential for erosion would be reduced. Planning the site to avoid steep slopes and highly erodible soils would be beneficial. Phased construction rather than large-scale denuding of vegetation could be coordinated with low erosion potential periods to greatly limit erosion.

Advantages of planning construction are:

- Reduces potential for erosion.
- Reduces area subject to erosion.
- Maintains the natural conditions as long as possible.

Disadvantages include:

- Requires more thoughtful site plans.
- Once erosion does occur there are no other controls.

Table 8-2
Construction Site Erosion Control Measures

Erosion Control Measure	Characteristics of Measure
PLANNING	
Timing of Land Disturbance	A majority of the erosion producing rainfall events occur from May to October. If land disturbing activities are minimized during this period, erosion could be significantly reduced.
Timing of Control Implementation	An excellent erosion control measure is of no value until it is implemented. Therefore erosion control measures should be implemented at the proper time and place to be of maximum benefit.
Surface Area Exposure	The smaller the area exposed to the elements at a time with no protection, the less will be the erosion from that particular site. Good management will ensure the cleared areas have erosion control measures installed before additional areas are bared.
Compaction	Proper compaction of fill embankments will reduce the erosion rate, especially at lower water velocities. It should be done in proper increments at the optimum soil moisture content.
LAND SURFACE PROTECTION	
Vegetative Stabilization Forbs Grasses Legumes Shrubbery Trees	Vegetative stabilization is accomplished by planting imported or native vegetation on cut and fill slopes and other areas needing erosion protection.

Table 8-2
(Continued)

Seeding Aerial (Chopper or fixed wing) Broadcasting Drilling Hydroseeding with mulch and/or matting	Seeding is done to establish vegetative erosion control. Stage seeding, both temporary and permanent, is generally very effective in controlling erosion on construction sites.
Sprigging	Sprigging consists of planting shoots or sprouts as opposed to seeds. It is done to achieve more rapid growth of larger vegetation.
Sodding	Used for surface and channel protection. Sod may be hand laid over the entire surface or in narrow strips along the contours of a slope. On steep slopes it may need to be staked to prevent slippage. Another effective use of sod in areas of high rainfall is a 15" wide strip laid along the edges of the pavement of highways, to prevent the shoulders from eroding.
Topsoiling	Stockpiling and subsequent spreading of topsoil on cut and fill slopes aid greatly in the establishment of vegetation. Fertilizer may not be required if topsoiling is done. Topsoil may also be brought from an outside area, depending on cost.
Tubelings	A dry land planting technique which eliminates the need for irrigation during plant establishment and is conducive to mechanization. Plants are grown in 2-1/2-inch by 24-inch paper tubes reinforced by plastic mesh sleeves. The "tubelings" are planted in holes drilled into the ground with a power auger.

Table 8-2
(Continued)

Fertilization	Applied according to soil vegetation needs as determined by testing. Stimulates growth which increases erosion resistance.
Irrigation	For the purpose of establishing and maintaining vegetation. The water is generally most efficiently applied by sprinklers or drip irrigation.
Mulch Cellulose Dairy Waste Gravel Hay Hydromulch Rice Hulls Sawdust Shredded Paper Straw Vegetative Fodders Wood Chips Wood Fibers Other	Used to increase infiltration, decrease runoff, protect soil surface from erosive action of raindrops and to enhance seedbed for vegetative growth. Mulch is applied with machinery or by hand using either water or air as the carrying agent. Proper application rates are important.
Mulch Anchoring Asphalt Tacking Matting Netting Punching	Anchoring increases the effectiveness of mulch against surface erosion by water and wind. It is accomplished by spraying (asphaltic materials), covering and stapling (paper, plastic, nylon, jute, wire netting, etc.) and discing (incorporating mulch materials into the soil surface).
Matting Excelsior Jute Plastic	Matting is used as a surface and channel protector. In most cases it requires staking to the ground. It is usually used in conjunction with seeding and protects the surface until vegetation becomes established.

Table 8-2
(Continued)

Plastic Film	Used as a temporary protection for bare soil surfaces including channels, chutes, downdrains, etc.
Aggregate Cover	Stabilizes soil surface. Used on seeps. Permits construction traffic in adverse weather. May be used as part of permanent base construction. Made by placing gravel on soil surface.
Cellular Concrete Block Revetment (Gobi Blocks)	Excellent for surface protection on slopes and especially against wave action. These blocks are constructed of dense concrete and are installed on top of a plastic filter cloth. After installation topsoil is spread loosely over the revetment to partially fill the cell openings, and the revetment is then fertilized and seeded.
Chemical Stabilization Aerospray 52 Aerospray 70 Aquatain Arzan Asphalt Emulsion Coherex Conwed Fiber Curasol Dust Binder Ecology Control Erode-X Fiber Glass Roving, Tacked Glenkote Petroset PVA Soil Bond Soil-Lok Soil Master Soil Seal Surfaseal Terra-Krete Verdyol (Super) Wood Fiber Slurry (Others)	Used to reduce the movement of soil and other soil protectors. Applied by spraying the liquid chemical onto the soil surface or over other protectors.

PROTECTION FROM RUNOFF

Diversion Ditch, Cut Slope	Constructed at the upper edges of cut slopes to collect water from adjacent properties and divert it around the cut. Materials used to construct these ditches are determined by the slope of the ditch but include sod, gravel, stone, asphalt, and concrete. Ditches may be temporary or permanent.
Berms Berms and Ditch Burlap Sand Sausage Diversion Slope	To control or divert the flow of surface runoff. Made by piling a soil window or other obstruction along the shoulders of the roadbed or top of cut to prevent surface runoff from eroding slopes. Requires adequate downdrains to dispose of water. The burlap sand sausage is made by filling a burlap tube with sand or piling sand on a long piece of burlap and sewing the burlap into a tube.
Channels Asphalt Bare Burlap Concrete Concrete Block Excelsior Fiber Glass Roving Grass Jute Plastic (Nylon) Mat Plastic Sheeting Rock or Riprap Sod	Used to convey runoff from points of concentration across, through, along, and around highway rights-of-way, or other areas to be protected. Channels steeper than approximately three precent need proteciton to prevent erosion. Allowable slope of bare channels depends on the type of soil.
Interceptor Dike	Directs overland flow to a desired collection or runoff point. Constructed with any material that will withstand the anticipated flows.
Toe Drain Ditch	A toe drain ditch is used to collect seepage and runoff from a slope and transort it to a channel. It should be lined with rock rip-rap or other protective material as needs dictate.

Land Surface Protection. If the land surface can be kept covered as much as possible, erosion can be reduced by decreasing the disruptive force of rainfall, slowing down and decreasing overland flow, and requiring higher flow velocities to transport the soil. Land surface protection can consist of vegetation, mulches, plastic linings, and other covers. A protective covering should be used as soon as possible after an area has been stripped of its vegetation. This is the primary preventive control for surface erosion.

Advantages of land surface protection include:

- o Prevents increased erosion from occurring.
- o Can be aesthetically pleasing.
- o Can reduce stormwater runoff.
- o Permanent vegetation can be used.

Some of the disadvantages are:

- o May require frequent maintenance.
- o Soils may require fertilization or irrigation.
- o Does not remove sediment once it has eroded.

Runoff Diversion. Diversion structures such as diversion berms and ditches can be used to direct runoff from highly erodible sites or environmentally sensitive areas. This measure can also be used to direct runoff to areas that have a high infiltration capacity.

Certain advantages are:

- o Erosion from highly susceptible soils can be diminished.
- o Runoff flows can be reduced.

- Vegetation on steep slopes can be allowed to grow.

Included among the disadvantages are:

- Does not reduce erosion from nondiverted areas.
- Does not remove sediment once it has eroded.

Grade Control. Avoidance of long lengths of steep grades will significantly reduce erosion, as will limiting the angle of grades. The angle should not be so great that vegetation or other surface protection measures can not be employed.

Some of the advantages include:

- Reduction in erosion (steep slopes are highly erodible).
- Allows use of land surface protection.
- May allow removal of eroded sediment on deposition planes.

A few of the disadvantages are:

- May require extensive earth moving.
- Requires careful site planning.

Energy Dissipators. If the velocity of overland flow can be reduced, the capacity of the flow to transport sediment will be reduced and less erosion will occur. This is an effective control measure for both surface erosion and stream channel erosion.

The advantages include:

- Reduces surface and stream channel erosion.

- o Protects downstream culverts and manmade channels.
- o Reduces high velocity flows which could be hazardous to children.

Among the disadvantages are:

- o Does not effectively remove eroded sediment.
- o Acts as a partial cure, not a prevention.
- o Can be unsightly.
- o May require maintenance.

Sediment Traps and Filters. Eroded soil can be kept onsite and out of the receiving waters through the use of filters and sediment traps. This helps reduce sedimentation problems by settling the larger sized soil particles. This method is one of the most widely misused erosion control alternatives, particularly the use of straw bales. Improper placement of straw bales can channel the flow and result in higher erosion rates than if the bales were not present. Straw bales should not be used where the flow is concentrated and the velocity is high. They must be maintained to be of practical use.

Some of the advantages are:

- o Removes eroded sediment.
- o Can decrease peak flows.
- o Easily installed.

A few of the disadvantages include:

- o Does not stop or significantly reduce erosion, i.e., a cure rather than prevention.

- Requires frequent maintenance.
- Generally ineffective for small sized particles.
- If improperly used, may worsen the problem.

Detention and Settling Basins. Detention or settling basins may be used onsite or offsite. They are larger than sediment traps, and with the use of flocculants and coagulants, can remove the smaller particles. The effect on the timing of runoff and stream hydrographs should be considered for impoundments, as discussed previously.

Included in the advantages are:

- Removes eroded sediment.
- Can decrease storm flows and channel erosion.
- Can improve water quality.
- Can be designed into detention/retention structures or flood control impoundments.
- Estimates of removal efficiencies can be made easily.

The disadvantages include:

- Does not stop or reduce upstream land surface erosion.
- May increase downstream peak flows and channel erosion.
- Requires land areas.
- Requires periodic maintenance.
- May create water quality problems.

Fine Grained Sediment and Water Quality. Fine grained sediment is the most easily eroded, the hardest to control, and generally contains most of the water quality pollutants. The best control measures for fine grained sediment are proper planning of construction, maximum use of surface protection measures, silt fences, and adding flocculants and coagulants to settling basins. Whenever possible, it is better to avoid erosion than to require the extensive use of expensive chemical additions. The following references address the control of fine grained sediment: "Methods to Control Fine-Grained Sediments Resulting from Construction Activity, EPA 440/9-76-026"; "Methods for Separation of Sediment from Storm Water at Construction Sites, EPA 600-77-003"; and "Erosion and Sediment Control Handbook, EPA 440-3-78-003."

Generally, the more sediment removed, the better the downstream quality. Problems may result from fertilizer and pesticide applications to vegetated areas, chemical soil stabilizers, washout of sediment traps and filters, scouring of sediment deposits, and overflow of settling basins. Although usually beneficial, settling basins can also create water quality problems by prolonging the discharge of highly turbid water. Without the basin the turbid water would flow through the stream system in a short time period. However, the prolonged discharge from a major basin or several small basins can result in high turbidity values for an extensive period of time. Sediment basins can also support concentrated algae growths which could reach the stream and cause aesthetic, dissolved oxygen, and nutrient problems. Depending on the detention time, the organic loading and other factors, it is possible for the effluent from a basin to have a very low dissolved oxygen level and high BOD concentrations. These problems would generally be worse for in-stream basins than for onsite basins.

The point to be remembered is that the whole stream system--hydrology, hydraulics, sedimentation, water quality and ecology--must be considered, not just one aspect of the system.

AGRICULTURE CONTROL PRACTICES

There are two basic strategies for controlling agricultural erosion and nonpoint pollution. The first is to manage the application of wastes and chemicals to the cropland while the second involves the management of soil and water movement. The amount of water pollution caused by agriculture is more dependent on production and waste management practices than on the volume of wastes involved.

While the management of waste and chemical applications may appear to be an inherently efficient strategy, this is not necessarily true. It requires a high level of farm management skills and generally consumes substantial labor and machine time which is in short supply during the planting and growing seasons. As a result, these practices are often not economically advantageous to the farmer. Also, they are very difficult to monitor.

Because of its nutrient value, manure should be considered a resource rather than a waste, and when possible, use of all waste as fertilizer or soil conditioner should be evaluated and incorporated into an owner's management plan. The land provides a natural treatment system for animal wastes when managed properly.

Management of soil and water movement from agricultural land can be greatly influenced by differences in watershed characteristics such as slope, soil permeability, surface culture, drainage pattern, degree of erosion, and other hydrogeologic factors. This requires individually tailored control systems for different watersheds.

Soil and Water Movement Control

Soil and water movement control practices have several advantages. They serve to maintain or improve agricultural productivity, and certain practices can be cost-shared with the federal government. In addition, monitoring of the practices can be relatively straightforward. The practices are not without drawbacks, however. Many farmers have been reluctant to implement soil and water conservation programs, since the benefits to agricultural productivity are generally realized in the long run. The immediate benefits are seldom obvious. The practices may also aggravate certain water quality problems. The retention of runoff water on the field may result in increased movement of water and soluble pesticides and nitrate to groundwater aquifers. Minimum tillage, which is an effective means of erosion control, generally requires increased use of pesticides for weed control and insect control.
Table 8-3 describes techniques to control nonpoint pollution from agricultural activities. The most important of these techniques are following standard soil and water conservation practices, and limiting livestock access to streams.

STREAM CHANNEL EROSION

Because stream channel erosion is largely determined by the composition of the stream's channel, the channel alignment, the 2-year peak flow and the amount of sediment in the flow, the control measures considered address channel and flow modifications.

Table 8-3
Techniques To Control Nonpoint Pollution From Agricultural Activities

1. Nonstructural Control of Agricultural Runoff and Erosion

    No-till planting in prior crop residues
    Minimum tillage techniques
    Sod based rotations
    Meadowless rotations
    Winter cover crops
    Improved field operations timing
    Plow-plant systems
    Contouring
    Contour strip cropping
    Narrow row cropping
    Ridge planting
    Change in land use

2. Structural Methods to Control Agriculture Runoff and Erosion

    Construction of ponds
    Terracing
    Diversions
    Grassed outlets
    Subsurface drainage systems
    Reforming land surface

3. Practices to Control Nutrient Loss From Crop Raising Activities

    Eliminating excessive application of nutrients
    Timing fertilizer application
    Crop rotations
    Plowing under green legume crops
    Slow release fertilizers
    Control of nutrient effectiveness

4. Practices to Control Pollution From Confined and Pasture Animal Feeding

    Prevent direct discharge of manure to streams.
    Provide runoff collection systems for livestock holding areas having bare soil.
    Apply livestock wastes to cropland.
    Apply wastes uniformly.
    Govern rate, time, and frequency of application for maximum nutrient utilization by plants.
    Select disposal areas with low erosion potentials.
    Do not apply waste on grassed waterways or other drainage paths.
    Do not apply manure to frozen or water-saturated soils.

Table 8-3
(Continued)

Plow waste under on barren fields.
Locate livestock holding areas away from unvegetated or sparsely vegetated slopes leading directly to streams.
Provide at least 100 feet of vegetated area between confinement areas and resting areas from streams or drainage paths.
Pasture animals away from streams and drainage paths.
Fence them out unless stream banks prevent direct access to water.

5. Practices to Control Pesticide Loss From Agriculture Activities

Controlled application methods
Using alternative pesticides
Optimizing pesticide formulation
Eliminating excessive treatment
Optimizing time of day for pesticide
Optimizing date of pesticide application
Controlling pesticide application rates
Managing aerial applications
Biological control
Crop rotation
Growing resistant plant varieties
Mechanical control methods
Optimizing crop planting time

6. Practices to Maintain or Create Proper Water Temperatures for Fish

Minimum tillage
Grassed waterways
Streambank protection from livestock
Maintain buffer vegetation along streams

Channel Modifications

One way to stop stream channel erosion is to modify the channel by straightening it, changing its dimensions, or altering its composition. Straightening and paving a stream is a desperate measure usually taken when the problem is nearly unsolvable. Channel composition modifications can be effectively used as permanent or temporary controls without severe adverse aesthetic effects. The use of gabions, vegetation, lattice blocks and the like can effectively reduce the bank erosion and maintain a natural appearance. This control, in conjunction with streamflow modifications, can be quite effective.

Streamflow Modifications

When an area urbanizes, extremely large increases in the 2-year flood peak can result, which could create significant stream channel erosion. If the 2-year flood peak is reduced, or better yet, kept unchanged from existing conditions, excessive unnatural stream channel erosion should be greatly reduced or stopped. The onsite runoff controls discussed previously in this chapter could be used to control the 2-year flood. These are recommended over instream control measures since instream controls do not improve conditions upstream of the impoundment and may create worse problems further downstream.

Chapter 9

CHAPTER 9
POLICIES

Policies relating to the protection, conservation, and control of flood plains and to the development of watershed management policies are established by a number of agencies. These policies include Federal level interests in minimizing flood-incurred losses, state requirements limiting developments within established flood plains, and the policies of local governments in specifying development controls through zoning and other ordinances. A general review of these policies follows.

FEDERAL LEVEL

Federal agencies most actively involved in flood-related programs include the Department of Housing and Urban Development; Department of Agriculture, Soil Conservation Service; Department of the Army, Corps of Engineers; and Department of the Interior, Geological Survey.

The Federal Insurance Administration (FIA), under the Department of Housing and Urban Development, administers the Federal Disaster Protection Act of 1973, which establishes a policy of protection against flood damages and losses, provided that local jurisdictions adopt land use control measures in accordance with federal standards. The flood-prone areas are to be displayed eventually by FIA on detailed maps of the 100-year flood plain.

Federal policies relating to flood control, flood prevention, flood plain management, and watershed protection are carried out mainly through programs of the Corps of Engineers and the Soil Conservation Service. Technical and financial assistance is made available by these programs.

Executive Order 11988 concerns federal policy regarding flood plain management, while Executive Order 11990 concerns the protection of wetlands. These executive orders establish federal policy to minimize damage and destruction of flood plains and wetlands. This policy will also minimize the impacts of floods involving federal property, activities or programs, and federally financed or supported construction. These orders may have importance for Anne Arundel County due to the presence of Ft. George Meade and plans to upgrade some state highways to interstate status. The regulations of EPA and the Federal Highway Administration that will result from these Executive Orders should be followed.

The major federal regulations concerning water quality are PL92-500 (The Federal Water Pollution Control Act) and the Clean Water Act of 1977, which amended PL92-500. These acts set deadlines and required the establishment and funding of numerous activities including grants for construction of treatment works (201 studies), areawide waste treatment management (208 studies), basinwide planning (303e studies) and effluent discharge limits. Water quality concerns and other environmental issues are primarily the concern of the Environmental Protection Agency which administers the requirements of the Clean Water Act.

Water and sewage master plans done as part of 201 studies can greatly influence the character and nature of development within a watershed. The location and discharge requirements of treatment plants can significantly impact receiving water quality. The 208 planning program is very active in Anne Arundel County and is the focal point of water quality concerns and information. The nationwide program has recently undertaken studies to determine the nature, extent and impact of nonpoint source pollutants as well as an evaluation of control measures. The results of this nationwide effort should assist local 208 agencies in more definitive control programs for nonpoint sources.

STATE LEVEL

A principal policy establishing the basis for flood plain management in the state is the Department of Natural Resources' Rules and Regulations Governing Construction on Non-Tidal Waters and Flood Plains, August 1978, that restricts development in, obstructions to, and encroachment on the 100-year flood plain. Any changes made to the course, current, or cross section of a stream or body of water in the state requires a permit from the Department. The waters of the state are defined to include the 100-year flood flow line. This is interpreted to mean that for any kind of obstruction or invasion of the flood plain, a permit from the Department is required.

The Maryland Sediment Control Act of 1970 (Art. 96A, Section 105) requires the approval, by the local soil conservation district, of sediment control plans in connection with land clearing and proposed earth changes prior to clearing and grading for development. In carrying out the provisions of this act, Anne Arundel County has passed Bill No. 141-70, the Grading and Sediment Control Ordinance.

The Maryland Environmental Policy Act of 1973 declares that it is the policy of the State to give highest public priority to the protection, preservation and enhancement of the State's diverse environment. To this end, the Act requires that an environmental effects report be prepared for proposed park and recreation areas, proposed planning actions, and proposed legislative actions affecting the natural and socioeconomic environment. This affects Severn Run since the state has funds to expand the Severn Run Environmental Area.

The November 1977 Maryland Interim Watershed Management Policy (Storm Water Management, Flood Plain Management, Flood Control and Agricultural Drainage) outlines the policies for state construction projects and encourages the adoption of the policies by local governments. The purpose of the policy is to minimize the negative impacts of man's activities on the runoff process, specifically:

1. To minimize loss of life and property by floods,
2. To assist in development and construction of flood control structures,
3. To implement a stormwater management program that will prevent an increase in flood frequency and/or magnitude,
4. To prevent stream channel erosion, and
5. To try to reduce the transport of pollutants to receiving waters.

The policy encourages a preventive, rather than curative, approach to watershed problems. Land use controls and decisions are seen as the cornerstone to this approach. Vegetative and porous stormwater management controls are preferable to nonvegetative or impervious systems and in general, small structures are preferable to large structures.

Stormwater management, according to the state, is intended to maintain or reduce the frequency and magnitude of floods, reduce or prevent stream channel erosion from upstream development, and reduce nonpoint source pollution loads. Storm drainage designs should minimize the velocity of runoff and provide a chance for filtration or settling of pollutants prior to its arrival at the receiving waters.

Stormwater management structures are to be designed using the SCS hydrograph method, and peak discharges will be released at the predevelopment rates. The design storm is the 100-year storm. The following performance criteria have been adopted:

1. The existing 2-year flood peak will be maintained at all points on a stream system.
2. Less frequent events may be increased to a maximum of 10% for the 100-year storm.
3. Structures must be designed so that downstream flood peaks are not increased.

An alternative approach to onsite stormwater management is recommended. This is the systems, or watershed, approach which consists of mathematical modeling of the watershed to define potential problems and their solutions. This leads to the development and implementation of management plans.

Flood plain management is designed to minimize future flood damages by prohibiting development within the 100-year flood plain. Flood control deals with existing problems and outlines several guidelines that allow for considerations other than economic ones in flood control projects.

The Scenic and Wild Rivers Act states that it is Maryland state policy to protect the water quality and fulfill conservation purposes by wise use of resources within certain scenic and wild rivers. Severn River has been declared as a scenic river. As such, a scenic river study to be done by the Department of Natural Resources has been undertaken. The study is intended to develop a management plan for the protection and preservation of the water quality and scenic values of the Severn River.

The Water Resources Administration and the State Soil Conservation Committee have been working on the development of a Statewide Agriculture Water Quality Management Program for the Control of Sediment and Animal Wastes. The program will involve establishment by the State Soil Conservation Committee of statewide critical areas for sediment and/or animal waste problems from farms. Also, each Soil Conservation District will designate local critical areas for which Soil Conservation and Water Quality plans will be developed. Guidelines and best management practices will be developed as part of this program for the Soil Conservation and Water Quality Plans.

ANNE ARUNDEL COUNTY

Stormwaters

Anne Arundel County Bill No. 16-77, as amended by Bills No. 153-77 and 6-78, establishes stormwater management for certain developments within the county. The purpose of the bill is twofold--to protect life and property and to minimize potential damage to receiving channels. Only the highlights of the bill will be discussed.

The ordinance permits the adoption by the Department of Public Works (DPW) of stormwater management design standards. This was done on 20 June 1977 by DPW's Storm Water Management Order No. 1. This order will be discussed later.

Preliminary and final stormwater management plans are required prior to approval by the Office of Planning and Zoning of all subdivision plats. The stormwater management plans must be approved by the Department of Public Works, which will base its decision on the requirements and recommendations of the Anne Arundel Soil Conservation District.

Two types of structures are allowed; both are intended to protect the receiving channel from accelerated runoff. A Class I structure is located onsite at the end of a drainage system. It is designed to maintain the runoff from a development at the same level as the existing runoff from a 10-year storm.

A Class II structure may be located onsite or offsite and is an in-stream structure, designed to control the 100-year storm runoff at predevelopment levels. The performance criteria for both types of structures is given in Table 9-1. These structures must be designed by a registered professional engineer.

Table 9-1
Performance Criteria of Stormwater Management Structures

Return Interval (years)	Minimum Percent of Increased Runoff to be Managed
2	70
5	85
10	100
100	50 Class I only 100 Class II only

There are numerous exemptions to the ordinance. The ones applicable to the Severn Run are:

"1. Single family dwellings to be situated on recorded lots not subject to the "Subdivisions" subtitle to Title 13 of this Code.

2. Any parcel, within one watershed of five acres or less, to be developed at a maximum density of 2.5 dwelling units per acre.

3. All parcels of five acres or greater to be improved by only one single family dwelling.

4. Land parcels, within one watershed of five acres or less, zoned R-5 or of less dense residential development, served by a properly functioning storm drainage system which has been designed and constructed according to the latest County Design Manual.

5. Exemptions 2, 3, and 4 above must be certified as a non-contiguous development to be eligible for the exemption.

6. All parcels of two acres or less, served by an adequate storm drainage system having outlets that are stable and free from erosion as approved by the Department of Public Works.

7. All property not otherwise exempted for which it can be demonstrated to the Department of Public Works and Anne Arundel Soil Conservation District that an increase in peak rate of runoff will not occur after development."

Several bonds, fees, and agreements are required by the ordinance. An applicant for a subdivision plat is required to post a construction bond or pay a construction guarantee fee to the County Controller equal to the estimated construction cost of the stormwater management facility. If the facility is to be accepted by the county, the applicant and/or landowner must also post a maintenance bond to cover the cost of maintaining the facilities for 5 years from the date of acceptance of the facilities by the county. The amount of the bond is the same as the construction cost. Further, the applicant and/or landowner must pay a stormwater management fee for the area that the facility is designed to serve. The fee is $100 per lot per single family lot residential development or 1-1/2 cents (0.015) per square foot per acre for multi-unit development projects, commercial or industrial development and is intended to cover maintenance costs of the facilities for the first 5 years of operation and must be paid when the facility is accepted by the county. Both the maintenance bond and the stormwater management fee are required; the fee is for operating purposes and the bond acts as a backup source of funds.

For those facilities that will not be accepted by the county, the applicant and/or landowner must execute an operation and maintenance agreement with the county prior to construction. The agreement requires establishing a stormwater management account equal to the cost, as determined by DPW, of maintaining the facilities for the first 2 years of operation. This account is the continuing responsibility of the property owner and must be maintained to provide sufficient funds for 2 years' operation and maintenance costs.

The county has the right of entry and the right to operate and maintain any privately-owned facility that has not met the requirements of the operation and maintenance agreement. Costs incurred by the county may be paid by the fund or may be held as a lien against the property.

The Department of Inspection and Permits is charged with inspecting stormwater management facilities during construction and periodically after construction.

<u>Public Works</u>. Public Works Storm Water Management Order No. 1 details the design considerations to be used for stormwater management structures. Small ponds must be

designed in accordance with SCS guidelines, and other structures or control alternatives must get prior approval from SCS and DPW.

The design of stormwater management structures requires use of the SCS curve number methodology to compute peak flows, employing the tabular method of TR55 to determine runoff rate and volume. SCS or Bureau of Public Works documents are specified for hydraulic design, while routing through structures is based on TR55, the SCS Field Manual for single-stage releases, or the SCS Storm Water Management Pond Design Manual for multiple-stage releases.

Sediment and Erosion Control

Anne Arundel County Bill No. 141-70, with amendments, establishes grading and sediment control. The major emphasis will be on the sediment control section of the ordinance, which provides for control of soil erosion and sediment. The ordinance requires a grading permit from the Department of Inspections and Permits prior to any grading, stripping, excavating or filling of land, or the creation of borrow pits, quarries or spoil areas, subject to several exceptions. An application for a grading permit requires a general information sheet, a performance bond, plans and specifications, approval of DNR when required, fees, and a right of entry to the county for restoration of the site upon default of the applicant.

Erosion and sediment control is required throughout all phases of the development. The control plan must be approved by the Anne Arundel County Soil Conservation District, and by DNR if applicable. DPW must review the plans and verify the estimated costs.

A performance bond or other security is required for disturbance of more than 15,000 square feet (1/3 acre) of aggregate soil bared or affected. The purpose of the bond is to ensure that in case of default, the site can be restored to a satisfactory condition (stabilize disturbed areas). If the bond is insufficient to properly restore the site, a lien on the property may be imposed.

Grading within the 100-year flood plain is prohibited unless authorized by DNR.

The erosion and sediment control plan must include or provide for the following:

"1. Development shall be fitted to the topography and soils so as to create the least erosion potential.

2. Natural vegetation shall be retained and protected wherever possible.

3. Only the smallest practical area shall be exposed, and only for the shortest practical period of time.

4. Erosion control practices (such as interceptor ditches, berms, terraces, contour ripping, soil erosion checks and sediment basins) shall be installed to minimize soil and water losses.

5. Temporary vegetation and/or mulching shall be used to protect critical areas exposed during the time of development.

6. During and after development, provisions shall be made to effectively accommodate increased runoff caused by CHANGES IN soil and surface conditions, and to avoid siltation of receiving streams.

7. Permanent vegetation and structures shall be installed in the development as soon as the weather permits."

Any protective measures that are used must be maintained by the applicant in accordance with the approved plan until permanent measures are accepted by the Department of Inspections and Permits. Further, no debris is allowed in the flood plain or watercourse.

Inspections of the erosion control measures is called for by the ordinance. The applicant must submit a proposed inspection program prior to starting work on the site. The program requires the applicant to notify the Department of Inspections and Permits when a new phase of the project is about to begin. The phases are given in the ordinance.

The Department of Inspections and Permits may inspect a site at any time.

If the work being done on a site does not comply with the permit or the plans and specifications, a Notice of Noncompliance is sent and 10 days are given to correct the noted problems. If the problems are not corrected, a Stop Work Notice can be posted on the site and the permit holder can be held in default of his obligations. Violations of the ordinance can be considered a misdemeanor and are punishable by fine or imprisonment.

Subdivision Regulations

The intent of the subdivision regulations, from a watershed management viewpoint, encompasses the following goals: promoting development in areas free from the dangers of flooding, erosion and stream siltation; preserving wetlands; and protecting estuaries and streams. Development is restricted within the existing 100-year flood plain as well as within tidal marshes or swamps. Flood plains must be kept in or returned to their natural condition, and given to the county with an easement for access to the flood plain.

The regulations require the dedication of land for community facilities, which limits the amount of impervious area and helps reduce storm runoff peak flows. Preservation of natural cover to the maximum extent possible is required, as well as compliance with the sediment control program.

The section on storm drainage requires that closed drainage systems be based on the 10-year flood, and that flood plains and culverts be based on the 100-year flood. Onsite drainage must be constructed by the developer to an acceptable outlet, the developer can commit property owned by him for a future benefit tax assessment, or pay a fixed amount to the county for its use in providing offsite drainage facilities.

Violations of the subdivision regulations are misdemeanors punishable by fine or imprisonment.

Zoning Ordinance

By requiring green areas and limiting the percent of a lot that can be covered by a building or parking areas, the zoning ordinance helps reduce the percent of impervious area, thereby lowering storm runoff peaks. Open space districts are intended to preserve open areas for recreation, flood protection, and environmental purposes. They include lands within the 50-year flood plain plus one additional foot in elevation and natural drainage systems; i.e., upland areas with slopes greater than 15 percent, swamps, bogs, marshes, streams, ponds and lakes. Structures in open space districts cannot obstruct the free flow of water and must be properly anchored to prevent their floating away.

Water Quality

The Anne Arundel and Regional Planning Council 208 Agencies are involved in deciding a course of action to be taken, and outlining recommendations for water quality concerns.

No specific county ordinances exist that address water quality. However, the Baltimore Regional 208 Water Quality Management Program and local 208 staff are involved in research into the water quality impacts of sewage facilities, urban land use and construction activity technical and management practices, agricultural land cultivation practices, and other practices which are potential sources of water pollution. Their aim is to develop a data base for integrating water quality considerations into existing programs and encourage greater attention to water quality in planning and management. Through this program the County, with the Office of Planning and Zoning as lead agency, has assumed responsibility for water quality management.

Chapter 10

CHAPTER 10
EVALUATION CRITERIA

The criteria selected for the evaluation of alternative plans are those that can be measured by a particular set of performances. Three categories of criteria are used in this study. These relate to economics, community, and the environment.

Table 10-1 outlines a specific set of criteria for each of the three categories that should be used to assess the alternative plans. These specific criteria relate to costs, benefits, desirability, daily activity, environmental impact, and aesthetics.

ECONOMIC CRITERIA

Economic criteria are divided into costs and benefits.

Five additional criteria are used to characterize each alternative plan in terms of cost. These are capital costs; land acquisition costs; relocation costs; operation, maintenance and replacement costs; and average annual costs. Capital cost is expressed in dollars for the initial construction cost of the facilities proposed in the plan. Land acquisition and relocation costs are a part of total capital costs but are included as separate criteria to detail these aspects of the cost picture. Operation, maintenance, and replacement costs are estimated in terms of average outlay pertinent to the alternative plan being evaluated. The final cost criteria is the average annual cost, which includes annual debt service on the capital costs, amortized over a specified time frame, plus annual operation and maintenance costs.

TABLE 10-1
EVALUATION CRITERIA

Category	Criteria
ECONOMICS	COSTS
	a. Capital Cost
	b. Land Acquisition Costs
	c. Relocation Costs
	d. Operation, Maintenance, and Replacement Costs
	e. Average Annual Cost
	BENEFITS
	a. Reduction in Repair, Debris Cleanup
	b. Reduction of Flood Damage to Improved Property
	c. Opportunities - Recreation, Multiple Use
	d. Average Annual Benefits
COMMUNITY	DESIRABILITY
	a. Social Acceptability
	b. Political Acceptability
	c. Responsiveness to Policies and Plans
	DAILY ACTIVITY
	a. Communications, Utilities
	b. Transportation (Traffic)
	c. Delays Due to Construction
ENVIRONMENT	ENVIRONMENTAL IMPACT
	a. Aquatic Habitat
	b. Wildlife Habitat
	c. Sensitive Areas; Historical, Archeological Sites
	d. Sedimentation
	AESTHETICS
	a. Change in Stream Alignment
	b. Effect on Stream Valley Vegetation
	c. Stream Channel Erosion

Project benefits are expressed in terms of reduced costs for repair and debris cleanup, reduction of flood damage costs, opportunities for recreational uses and other multiple uses resulting as part of the alternative plan, and average annual benefits. It should be realized that many of the benefits are qualitative in nature and cannot be assigned a dollar value. Average annual benefits are determined in dollars per year as the sum of benefits obtained from damage reduction, reduced repair and debris cleanup costs, and related opportunities.

COMMUNITY CRITERIA

To evaluate the effect of alternative plans on the "community," two groups of criteria should be used. One is to assess the plan's desirability, and the second concerns the plan's impact on daily activity.

Under desirability, social and political acceptability are criteria which require a degree of value judgement as to the needs and desires of the area being protected. Aspects of an alternative plan may contain adverse impacts or impose restrictions which can affect local attitudes toward acceptance. Also, positive results of multiple use concepts could receive favorable response. Similarly, political reaction can relate to the degree of difficulty in gaining needed financing or legislative authority to accomplish the plan's objectives. Ease of implementation and degree of social acceptance also can effect a positive reaction and a higher degree of political acceptability. These criteria would be measured upon the positive and/or negative characteristics of the alternative. Each characteristic rated would be stated for others to interpret, if so desired.

Responsiveness to policies and plans of the "community" can be measured in terms of positive, negative or neutral values. Where alternative stormwater management plans support area master plans and/or the policies stated in the General Development Plan and plans of the region or county, a positive value can be made and elaborated upon in supporting statements.

Under daily activity, criteria included refer to communication and circulation. Any interruption or rerouting of utility systems or vehicular traffic will impact the community in a positive or negative way. Delays caused by constructing improvements recommended in an alternative plan can be scaled as a negative value.

ENVIRONMENTAL CRITERIA

The environmental criteria include eight criteria defined under two major groups--environmental impact and aesthetics.

Environmental Impact

The most probable areas of the environment impacted by nature of an alternative plan recommendation include aquatic and wildlife habitat; areas of sensitive quality including unique vegetation, wetlands and land forms; historical and archeological sites; land, air, and noise pollution; and sedimentation.

The effect of an alternative plan on the aquatic environment is expressed in terms of positive or negative values. Any change in width or depth of a stream, or any change in its flow or temperature will have a corresponding effect on the aquatic habitat present. A stormwater management plan which will cause any change in stream characteristics will require a more detailed survey of aquatic life along the length of stream affected by the plan.

Wildlife habitat relates to areas adjacent to streams and to the nature of vegetation on the underdeveloped portions of the watershed. The effect of an alternative plan on a particular wildlife area can be expressed as short-term or long-term disruption which can influence the positive, negative or neutral value judgements made. Short-term disruption refers to a temporary inundation caused by a flood. Long-term disruption relates to long term flooding or a major change in the existing natural habitat, such as clearing of brush or forested land or creating a permanent impoundment.

Sensitive areas, historical and archeological sites located within the 100-year flood plain may be affected by a particular alternative plan. Should any specific area or site be adversely affected by the plan, additional recommendations to preserve the affected area will be described.

Sedimentation control measures are general requirements for developments occurring in the county. Each alternative plan will estimate an approximate measure of benefit in terms of positive or negative values of streams protected by sedimentation control measures such as impoundments and detention ponds.

Aesthetics

Changes in stream alignment, stream valley vegetation, and bank erosion are three criteria relating to the aesthetic aspects of the environment. Each alternative plan will be scaled in terms of positive, negative and neutral values regarding length of stream changed, number of acres of vegetation affected, and probable impact of stream channel erosion within the stream valley.

Chapter 11

CHAPTER 11
MANAGEMENT ALTERNATIVE ANALYSIS, RECOMMENDATIONS AND IMPLEMENTATION

The management alternatives to be analyzed will be considered from the viewpoint of the problems addressed in Chapter 7--namely, flooding, land surface erosion, stream channel erosion, and water quality and environmental concerns. The alternatives are: highway improvements, large scale impoundments, existing ordinances and policies, and recommended changes to existing ordinances and policies. Following the discussion of each alternative, recommendations are given. A case study is presented to describe how the recommendations could be applied. The appropriate agencies and costs to implement the recommendations are discussed.

HIGHWAY IMPROVEMENTS

This section addresses flooding problems that may be solved or greatly reduced by improvements to roadway bridges or culverts. The problems to be solved are impassable roads, inundated structures, and extensive flood plains due to impounded flows.

Guidance was provided by the Department of Public Works as to which roads to consider. In general, those roads not considered in detail can solve their flooding problems by providing a culvert or bridge opening of 100 square feet.

Method of Analysis

In most of the flooding problem areas encountered in the Severn Run watershed, the problem is caused by inadequate capacity of the culverts under roads. When a culvert is too small to pass the floodwaters, the water backs up behind the embankment and eventually flows over the road. This problem can usually be corrected by enlarging the bridge or culvert opening under the road.

In the hydraulic analysis, the two most important factors in determining the flood capacity of a bridge or culvert are the total area under the bridge and a "critical elevation." The critical elevation is the maximum flood elevation allowed before a problem situation arises. Logically, when proposing alternatives, the two most effective improvements are increasing the flow area under the road, and/or increasing the critical elevation (raising the road).

Using the HEC2 computer program, the culvert capacity can be computed without knowing the fine points of the structural design. In proposing alternatives, only the required area of opening and the critical elevation will be given. It is left up to the bridge or roadway designer to apply these guidelines to specific situations.

In problem areas where the roadway was high enough above the stream, a required culvert area was computed, using the existing elevation of the roadway. In cases where the roadway was too low to provide the necessary flow area under the bridge, a combination of a larger opening and a higher "critical elevation" was used to solve the problem.

Table 11-1 shows the roads where structural alternatives were analyzed to solve the flood problems. Also shown are the existing characteristics of each structure and the existing and desired flood capacities. The flood

Table 11-1
Flow Capacity of Existing Stream Crossings

Name of Road	Stream	Existing Culvert Opening (Sq ft)	Existing Critical Elevation (ft)	Existing Capacity (cfs)	Desired Capacity (cfs)
State Roads					
Telegraph Road	Beaver Creek	9.6	102.2	110	780
Reece Road	Reece Road Branch	21	135	125	480
County Roads					
Burns Crossing Road	Beaver Creek	13	83.5	130	600
Burns Crossing Road	Severn Run	37	75.5	350	2,470
New Cut Road	Broad Branch	18	84.5	230	350
WB & A Road	Beaver Creek	35	91.5	500	600

capacity of a stream crossing is the largest flow that can be passed before the flood height exceeds the "critical elevation." For this study, the desired capacity for state roads is taken to be the 100-year flood under ultimate land use conditions. For county roads, the desired capacity is the 50-year flood. These return intervals are the current design criteria.

Alternatives

Telegraph Road. The existing road surface for Telegraph Road over Beaver Creek is less than six feet above the stream bed. Computations show an unreasonably wide culvert would be required to pass the desired flow under the existing roadway elevation. It appears necessary to raise the roadway elevation about one foot to pass the 100-year flood. With the higher roadway, a larger culvert opening can be attained. To make the lowest part of the roadway high enough, about 200 feet of roadway must be raised. Raising the roadway will reduce the width of the 100-year flood plain, but the house at 1402 Rogers Lane may still be in the flood plain, as previously discussed.

Reece Road. The bridge over Reece Road Branch at Reece Road is safe from all but the most extreme floods, but the backwater produced by the constriction creates other problems with more frequent events. The roadway in the left overbank is up to 4 feet lower than it is at the stream channel. In a large flooding event, water will "escape" over the left flood plain and flow down Reece Road to Severn Run. Not only will ponded water inundate several structures, but the sheet flow along Reece Road will damage some yards and create a hazard to traffic.

A larger culvert area, about 4 times the existing size, is needed to pass the desired flood without allowing water to cross Reece Road. The lower ponding elevation will keep the road and most structures from being flooded.

Burns Crossing Road at Beaver Creek. Burns Crossing Road at Beaver Creek is another example of a circular culvert of inadequate size creating flood problems. A larger box culvert or a bridge with about 100 square feet of opening would be required to keep the roadway from being flooded. This enlargement can be accomplished without raising the existing elevation of the road.

Burns Crossing Road at Severn Run. In contrast to the crossing at Beaver Creek, Burns Crossing Road over Severn Run cannot be helped without raising the existing roadway elevation. One complication of raising Burns Crossing Road is the intersection with Old Mill Road. To avoid interfering with this intersection, the increased elevation of Burns Crossing Road must be limited to about 2 feet. With this limitation, a culvert area of about 330 square feet is required to achieve the desired flow capacity.

New Cut Road. The flood problems at New Cut Road over Broad Branch can be solved by replacing the relatively small culvert with a culvert about 4 times the existing size. The existing roadway elevation is sufficient if the required opening can be created below this level.

WB & A Road. WB & A Road over Beaver Creek is similar to Reece Road over Reece Road Branch, in that water flows over the roadway in the left flood plain, while the bridge over the channel is dry. However, the flood waters of

Beaver Creek return immediately to the main flow after crossing the road.

There are two possible solutions to the flooding situation at WB & A Road. If water is prevented from crossing the road in the overbank area, the existing structure would be capable of carrying the 50-year flood under ultimate land use conditions without flooding the bridge. This could be accomplished by raising the minimum elevation of the road by about 2 feet, or constructing an obstacle to keep the water from reaching the road. This obstacle could be an earthen mound or any type of wall, and would need to be no taller than 3 feet. Approximately 500 linear feet of mound would be required to protect WB & A Road. Alternatively, a larger opening could be created to convey the flow through the culvert at a lower elevation.

Recommendations

In general, the flooding problems at road crossings in the Severn Run watershed are caused by inadequate culvert capacity. In some situations, such as Dicus Mill Road and Burns Crossing Road on Severn Run, the crossings were built too low to be free of flooding, no matter what the culvert size. The alternatives presented here can be used as guidelines in estimating the magnitude of the effort required to avoid flood problems in cases where a larger culvert would be beneficial.

Table 11-2 shows the characteristics of possible solutions to each problem addressed. These are by no means design parameters, but they do give an idea of the type of solution required.

Table 11-2
Capacity of Structural Alternatives

Name of Road	Stream	Alternative Culvert Opening (Sq ft)	Existing Critical Elevation (ft)	Alternative Critical Elevation (if different)	Capacity of Alternative (cfs)	Desired Capacity (cfs)
State Roads						
Telegraph Road	Beaver Creek	84	102.2	103.4	800	780
Reece Road	Reece Road Branch	100	135	-	600	480
County Roads						
Burns Crossing Road	Beaver Creek	100	83.5	-	580	600
Burns Crossing Road	Severn Run	330	75.5	77.7	2,500	2,470
New Cut Road	Broad Branch	80	84.5	-	390	350
WB & A Road	Beaver Creek	35	91.5	94.7	600	600
WB & A Road	Beaver Creek	70	91.5	-	700	600

Due to the large number of roads that are flooded by the 50-year storm, only selected roads should be improved. Those recommended for improvements are, in order of priority: Reece Road (Rt. 554), Telegraph Road (Rt. 170), Burns Crossing Road, New Cut Road and WB&A Road. Telegraph Road and Burns Crossing Road (Severn Run) should be raised in order to prevent flooding. The recommended improvements are summarized in Table 11-3. The most critical roads to improve are Reece Road, Telegraph Road and Burns Crossing Road because they provide the major north-south transportation in the watershed. Reece Road is most important because of the homes that are flooded behind it.

Even with the roadway improvements, some flooding damages are still possible. The problem of what to do with the house on Reece Road Branch which remains within the 100-year flood plain should be addressed. Recommended alternatives are: buying the house and removing it, requiring flood insurance, and/or requiring extensive flood proofing. The house at 1402 Rogers Lane may be within the 100-year flood plain. An accurate survey of the elevation of the back corners of the house is recommended to see if it is within the flood plain. Consideration should also be given to requiring flood insurance and minor flood proofing. The trailers along Beaver Creek should be moved to higher ground, while the barn on Broad Branch may require minor flood proofing, flood insurance, or consideration of the possiblity of flooding in its storage configuration.

Great care should be exercised during the repair and upgrading of these roads to prevent problems in the Severn Run. The potential for locally severe erosion and sedimentation problems is very high. Strict enforcement and

Table 11-3
Summary of Roadway Improvements

Road	Stream	Necessary Increase in Culvert Opening (sq ft)	Necessary Increase in Top of Roadway Elevation (ft)	Resultant Increase in Flow Capacity (cfs)
STATE ROADS				
Reece Road	Reece Road Branch	79	-	475
Telegraph Road	Beaver Creek	74	1.2	690
COUNTY ROADS				
Burns Crossing Road	Severn Run	255	2.2	2150
Burns Crossing Road	Beaver Creek	87	-	450
New Cut Road	Broad Branch	62	-	160
WB&A Road	Beaver Creek	35	-	200

inspection of the sediment control plans will be required in order to prevent serious degradation of Severn Run and its tributaries.

There are other potential problems that can be caused by the repair of the roads. These include oil and grease pollution, debris and litter accumulation, solvents or other potential toxics pollution, and destruction of habitat. The agency responsible for the repairs needs to make sure that the construction crews and supervisors are aware of the possible negative impacts and that they take every conceivable precaution to minimize damage to the streams. Spot checks by the Department of Inspections and Permits, the Office of Planning and Zoning, and interested citizens should help assure that these precautions are being vigorously followed.

LARGE SCALE IMPOUNDMENTS

Large scale impoundments are in-stream structures priarily designed for flood control purposes. Smaller in-stream structures may also be used for controlling stream channel erosion, but they do not prevent erosion from the channel upstream of the structure.

An in-stream impoundment should be located where the natural topography contains the water impounded behind the structure. This avoids costly excavation or construction of berms. The structure should also be placed so that the area inundated will have as small a disruptive impact as possible. Areas meeting these requirements are found at the mouth of Jabez Branch and Picture Frame Branch.

An impoundment was tested using TR20 on Picture Frame Branch as a possible alternative to the flooding of Burns

Crossing Road. The analysis showed that although the ultimate 100-year peak flow from Picture Frame Branch was reduced by nearly 900 cfs. This very small reduction occurred because the time of the peak flow from Picture Frame Branch was delayed enough to coincide with the peak on the Severn Run. The delay caused nearly the same combined Severn Run and Picture Frame Branch peak as existed before the impoundment was tested. The ineffectiveness of the structure dramatically shows that flood hydrograph timing considerations are extremely important in the planning and design of impoundments; this is particularly applicable to Jabez Branch. Figure 5-9 shows that the hydrograph peak at Route 3 is largely determined by the flow from Jabez Branch. A 3-hour delay in the peak from Jabez Branch would combine its peak with the peak from Severn Run and result in a much larger peak flow at Route 3.

Recommendations

Due to unsuitable topographic conditions, the absence of major flooding problems, and the failure of the structure on Picture Frame Branch to produce the desired results, no large-scale in-stream impoundments are recommended for Severn Run. However, large scale impoundments may be suitable for other watersheds. Any impoundment considered must be designed with downstream impacts in mind. Testing the effects of structures with TR20 or other flood and reservoir routing models is strongly encouraged to ensure that the beneficial results desired are obtained throughout the watershed.

ORDINANCES AND POLICIES

Chapter 9 summarized existing ordinances and policies. Their review will be on a problem basis. Table 11-4 summarizes the problems that each ordinance or policy addresses. Recommended modifications will also be discussed.

Table 11-4
Problems Addressed by Existing Ordinances and Policies

Ordinance or Policy	Problems Addressed			
	Flooding	Land Surface Erosion	Stream Channel Erosion	Water Quality and Environment
COUNTY				
General Development Plan	X	X	X	X
Storm Waters 16-77	X		X	
Grading and Sediment Control		X	X	
Subdivision Regulations	X			X
Zoning Ordinance	X		X	X
Storm Water Management Order No. 1	X			
STATE				
Sediment Control Act		X	X	
Watershed Management Policy	X	X	X	X
Construction on Flood Plains	X		X	X

X indicates that ordinance addresses problem.

FlOODING ORDINANCES AND POLICIES

Present Policy

Existing Structures. Flooding of existing structures within the 100-year flood plain is covered to some degree by the subdivision regulations and building permits. These regulations can be used to restrict further additions to structures within the flood plain. If a structure is illegally built within the flood plain, legal action can be taken.

The county has begun a program of buying homes within a flood plain, and has established a program for the Patapsco River watershed. If the recommended highway improvements are implemented, there will still be two homes, several sheds, 2 trailers, a swimming pool, and a barn within the ultimate 100-year flood plain of Severn Run. One of the homes and the pool are in the Reece Road Branch subbasin and are in the 2-year flood plain. The other house, located on Rogers Lane, is on the fringe of the 100-year flood plain and may possibly be flooded by the 100-year storm.

The county has several options regarding these structures, including: do nothing, warn present and future owners, buy the property, require flood proofing, require flood insurance, or require removal of the trailers. Removing the trailers from the flood plain is recommended, since trailers are by nature temporary structures. The house off Reece Road (plan and profile sheet 30) is within the ultimate 2-year flood plain if the structural improvements to Reece Road are not made. With the improvements, the house is still completely within the 100-year flood plain. Flood proofing, flood insurance, or buying the property should be seriously considered. The house on Rogers Lane is barely within the 100-year flood plain. The precise elevation of the house should be determined to see if it is within the flood plain. If it is, moderate flood proofing and flood insurance seem appropriate.

Highways. The Department of Public Works' policy is to correct highway flooding problems for the most important streets first. This is an appropriate policy, because many of the older roads in the watershed were built before the development of county highway standards and are too close to the streams they cross.

Future Structures. Prevention of future structures from flooding is accomplished by the subdivision regulations, zoning ordinance, and the Maryland Interim Watershed Management Policy. The zoning ordinance calls for the 50-year flood plain to be zoned as open space, while the subdivision regulations and Maryland policies do not, in general, allow development within the existing 100-year flood plains. These ordinances and policies are very effective; however, only the area around the Severn Run proper is zoned as open space. The tributaries are not zoned as such, but are protected by the subdivision regulations.

Recommendations

In general, the existing ordinances and policies regarding flooding are good, particularly for preventing future flooding problems. There are cases in which existing zoning maps do not show areas that should be zoned as open space. This occurs on the tributaries to Severn Run and is not considered a major problem because the Subdivision Regulations protect the 100-year flood plain. It should be noted that the zoning ordinance defines open space zoning in terms of the 50-year flood plain, while the subdivision regulations consider the 100-year flood plain. It is recommended that open space zoning be changed to include the 100-year flood plain.

A system of parks or environmental areas consisting of the ultimate 100-year flood plain should be considered as an extension of the Severn Run Environmenal Area and as a general county policy. Tributaries should be included as well as the main streams. For the Severn Run watershed, Jabez Branch, Wells Branch, and Broad Branch should be given consideration because they have received minimal prior disruption of the 100-year flood plain and adjoin the Severn Run Environmental Area.

Modifying the Subdivision Regulations should be considered to forbid construction within the projected 100-year flood on those watershed areas that have had a detailed hydrologic and hydraulic study. If this is done and the 100-year flood for the projected ultimate land use does not cause any more damage than the existing 100-year flood, the state may want to modify its Interim Watershed Management Policy. The modification should allow less stringent controls than currently desired of the 100-year event and other less frequent events. Detailed hydrologic and hydraulic watershed studies are required to accurately determine the location of the 100-year flood plain.

Although the Stormwater Ordinance states that its purpose is control of stream channel erosion and flooding, the description of the Class II structure makes it appear that it is intended for stream channel erosion only.

Controlling the increase in the 100-year flood due to urbanization for stream channel erosion purposes appears to be misguided. Very little protection would be given to streams and the one chance in a hundred likelihood in any given year of the 100-year event is too low to warrant control of the storm for purposes of controlling stream channel erosion. The ordinance should be modified to allow onsite or offsite structures for the prevention of flooding problems. Controlling 100 percent of the increase in the 100-year peak is not always necessary. If a watershed study and computer model are available, the required degree of control to prevent flooding damages can be determined. Administratively, it is easier and less costly to require a fixed control program, rather than specific solutions, to solve potential problems. However, this approach results in higher costs for control measures since they are often overdesigned. In either case, control of the increase in the 100-year flood peak should be effected for control of flooding problems, not stream channel erosion.

LAND SURFACE EROSION ORDINANCES AND POLICIES

Present Conditions

Land surface erosion from construction sites is covered by the Grading and Sediment Control Ordinance and by the state's Sediment Control Act of 1970. Recent reviews by the Department of Natural Resources (DNR), conducted in December 1978 and April 1979, found the county's sediment control program unacceptable. Rather than review the state's findings and the county's response in detail, a brief summary of the state's requirements for the County to update its sediment control program is given.

1. Onsite preconstruction conferences with the contractor are to be conducted.

2. Sediment control plans as approved by the Soil Conservation District are to be implemented and enforced.

3. The adopted procedures and guidelines for inspection and enforcement routine must be submitted to the state.

4. Appropriate Sediment Control Inspection Report forms must be submitted to the state.

5. The county and Soil Conservation District must resolve who has field revision authority and the District must define major/minor field revisions.

6. The District must develop a sediment control plan checklist.

7. The District will evaluate the feasibility of an initial phase sediment control plan.

8. Vegetative notes for the District should be revised and recommendations made to the Deprtment of Public Works.

9. District review procedures will be slightly modified.

The county has taken exception to some of the findings and requirements of the State's inspection. It is strongly recommended that the county cooperate and work with the Department of Natural Resources as much as possible. Inspections are made to find areas that need improvement. The recommendations of an inspection or a report such as this give an outsider's view of the county's operation. By working with DNR and the Soil Conservation District, the county can continue to make improvements in its sediment control program. Another inspection was made in October, 1979 and the county's program was found to be acceptable.

Personal observations on field trips support some of the findings of DNR. Some construction sites had no apparent sediment controls, and controls on others were ineffective due to no maintenance and poor infield design. At some sites, control measures were generally in place and properly functioning, but occasionally they were found to be ineffective due to lack of maintenance. These observations are based on field trips conducted throughout the study, not on a single isolated visit to construction areas. However, most of the trips were conducted prior to the October 1978 implementation of the new sediment control program inspection procedures.

Estimating the effectiveness of the current sediment control program is a very difficult task. This difficulty is compounded by the change of inspection responsibilities solely to the Department of Inspection and Permits in October of 1978. The effects of this change cannot be seen overnight, so an estimate of the sediment control program's effectiveness will not be given. Based on the first inspection the Department of Natural Resources estimated that 75 percent of the construction sites they visited--none of which were within the Severn Run Watershed--had inadequate sediment control programs. The construction sites visited in February showed significantly fewer problems, but still had some unacceptable sites.

Personal observations by the consultant were made prior to the new inspection procedures and were not intended to provide detailed followup such as checking the sediment control plan, reviewing inspection reports, and meeting with the county's inspectors. It is recommended that future watershed studies include a task for detailed evaluation of a limited number of construction sites to act as an independent review of the county's sediment control program.

Due to the rapid changes in the county's sediment control program and any pending changes resulting from the state's inspection, an estimation of the current effectiveness of the sediment control program will not be made, except to say that with the consolidation of inspection responsibilities under the Department of Inspections and Permits, the number of sites with inadequate sediment control should continue to decrease significantly. With thorough and frequent inspections and enforcement, the number of properly applied sediment control plans should improve to around 95 percent.

Recommendations

Numerous parties are considering recommendations to the county's erosion and sediment control program. Among those considering changes are the Department of Natural Resources, Soil Conservation District, Department of Public Works, Department of Inspections and Permits, the Office of Planning and Zoning, the County 208 program, and this study. Recommendations should be carefully evaluated by the agencies previously listed. In particular, requesting DNR review would show a willingness on the county's part to cooperate with the state to improve the sediment control program.

A committee consisting of members from the Office of Planning and Zoning, the County 208 program, the Department of Inspections and Permits, the Department of Public Works, and the Soil Conservation District has been formed to help the county fulfill the goals of effective sediment control and the county's 208 program. The committee is reviewing the enforcement of plans, the adequacy of sediment control plans, the location of areas of the county sensitive to erosion or sedimentation, and inspection procedures as called for in the Grading and Sediment Control Ordinance.

The recommendations of the Department of Natural Resources regarding field inspections and reports should be given strong consideration. The need for a more formalized and documented training program for inspectors, especially for new inspectors or those who have had little experience with erosion problems, should be investigated. The training should include instruction concerning correction of in-field problems not addressed by the sediment control plan.

The number of nonscheduled inspections should be increased, especially following large rainfall events that could damage or reduce the efficiency of erosion control devices. To do this, more inspectors will be required. The planned growth in the number of inspectors appears to be adequate; a reduction in this growth could adversely impact inspection planning.

The Grading and Sediment Control Ordinance should be revised to require the same inspection and enforcement procedures of sediment control plans for Anne Arundel County Capital Improvements and Public Works Projects as are required for all other sediment control plans. County projects should be subject to the same or more stringent requirements as private projects. The county should set the example, not the exception.

An index like the one to the Subdivision Regulations is needed for the Ordinance. Finding a section of interest can be a frustrating and time-consuming task. Consideration should be given to writing a separate sediment and erosion control ordinance.

The section on steep slope and sediment control measures allows development on slopes greater than 15 percent, provided that 30 percent of the lot has slopes less than 15 percent and access to the lot via an approved county road. This should be revised to include review by the Office of Planning and Zoning so that development on steep slopes near unique ecological or critical areas can be controlled.

The current practice of holding meetings between the Department of Inspections and Permits and contractors prior to the start of land disturbing activities is a good one, and should be included as a requirement in the ordinance. Also, the Department of Inspections and Permits should be authorized to require additional plans or modifications to plans if an inspector determines that the original sediment control plan is inadequate or inappropriate for the field conditions. This is more than a minor modification presently covered in the ordinance, and should be included in the ordinance, rather than done as a matter of practice. Further, the section that states that additional (unscheduled) field inspections "may be conducted" should be changed to "will be conducted," thus requiring unscheduled inspections by law rather than by practice, as is currently done.

Two major problems became evident as a result of field trips to construction sites. One was the general lack of maintenance or inconsistent maintenance of erosion control measures. It is expected that more frequent nonscheduled inspections and enforcement of maintenance requirements would greatly reduce this problem. Consideration should be given to requiring a maintenance bond similar to the one required for the stormwater management ordinance.

The other problem noted was that most sites did not meet the general intention of Section 12-2019 of the Grading and Sediment Control Ordinance, which follows:

> "Section 12-2019 EROSION AND SEDIMENT CONTROL
>
> All grading plans and specifications shall provide for the following:
>
> (1) Development shall be fitted to the topography and soils so as to create the least erosion potential.
>
> (2) Natural vegetation shall be retained and protected wherever posssible.
>
> (3) Only the smallest practical area shall be exposed, and only for the shortest practical period of time.
>
> (4) Erosion control practices (such as interceptor ditches, berms, terraces, contour ripping, soil erosion checks and sediment basins) shall be installed to minimize soil and water losses.
>
> (5) Temporary vegetation and/or mulching shall be used to protect critical areas exposed during the time of development.
>
> (6) During and after development, provision shall be made to effectively accommodate increased runoff caused by soil and surface conditions, and to avoid siltation of receiving streams.
>
> (7) Permanent vegetation and structures shall be installed in the development as soon as the weather permits."

More specifically, it was observed that:

1. natural vegetation was not maintained and protected,

2. large areas of soil were needlessly exposed for long durations (in excess of 8 months),

3. very little temporary vegetation or mulching was used, and

4. topography controls were not used to reduce the potential for erosion.

It is important to realize the fine but distinct difference between erosion and sediment control. Erosion controls are designed to prevent or reduce soil erosion, while sediment controls are designed to prevent or reduce eroded soil from leaving the construction site. Sediment controls can be considered curative in nature; i.e., the problem (erosion) has already occurred and the intent is to prevent offsite damage. Erosion controls are preventive in nature. By preventing or reducing erosion, the need for sediment controls diminishes.

Figure 11-1 can help to explain this difference and illustrate how various controls interact with the erosion process. Preventive (erosion) controls such as vegetation, mulch, diversion dikes, and grading practices act to reduce the detachment or transport of soil. Once the soil has been detached and transported it can be removed by sediment ponds, filtering in straw bales or vegetation, or it could be deposited by slope controls designed to reduce the transport capacity of the runoff.

The control measures observed in the Severn Run watershed were primarily sediment ponds, berms, and straw bales--all curative controls. A greater emphasis should be placed on planning construction sites using land surface protection measures to minimize the potential for erosion. These controls are described in Chapter 8, and are preventive measures rather than curative measures. Inclusion of these concepts, which are called for in the Grading and Sediment Control Ordinance, in Sediment Control Plans should significantly reduce the period of potential erosion. Curative controls will still be required, and their proper placement and maintenance is essential. With the inclusion of preventive controls, better maintenance and more thorough inspections and enforcement of sediment control plans, it is estimated that 80 to 90 percent of the mass of potentially eroded soil can be kept onsite.

It is further recommended that sediment ponds and dry stormwater management ponds be provided with positive drainage to prevent ponding and subsequent mosquito problems or safety hazards. Also, very strong consideration should be given to providing stabilized entrances to construction areas or a means to remove mud and dirt from truck and car tires. This should be implemented especially for construction sites near environmentally sensitive or critical areas.

In order to accomplish high reduction efficiency, the intent and spirit of erosion and sediment control will have to be willingly accepted and practiced by construction contractors. An inspection program, no matter how diligently applied, cannot force an 80-90 percent sediment removal efficiency throughout the county. It will take the resolve of the citizens of Anne Arundel County to let contractors know that they demand sediment control. Violations or suspected violations need to be reported to the Department of Inspections and Permits which must receive these reports in a positive manner and act upon

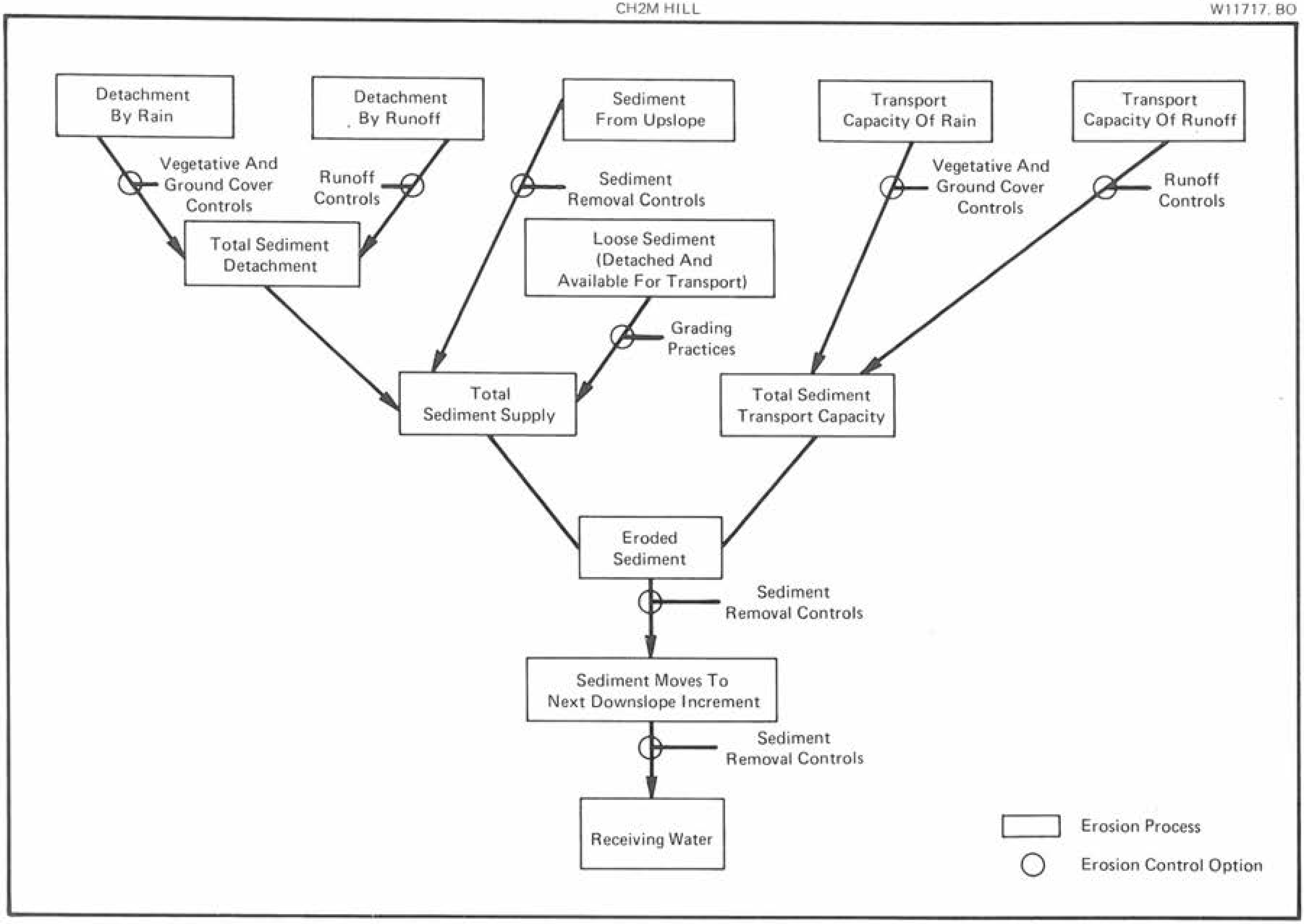


FIGURE 11-1: Erosion Process and Control Schematic

them immediately. With close cooperation of the county government, its citizens, the state, and contractors, effective sediment control can be accomplished.

STREAM CHANNEL EROSION ORDINANCES AND POLICIES

Current Practice

The regulations applicable to stream channel erosion are the Storm Water Management Ordinance, Bill No. 16-77 with amendments, DPW's Storm Water Management Order No. 1, and the Maryland Interim Watershed Management Policy. The stormwater ordinance calls for controlling increased flows as a result of urbanization with onsite 10-year structures, Class I, or onsite or offsite 100-year structures, Class II. Both structures control 70 percent of the increased runoff for the 2-year event. The effect of this is to reduce but not prevent increased stream channel erosion since the 1.4 to 2-year event (dominant discharge) controls the eventual width and depth at which a stream channel will stabilize. Table 11-5 gives the erosion factor for each subbasin for two conditions--one without any controls, and the other with the controls called for by the existing ordinance. The erosion factor is based on the discussion in Chapter 7 and is the square root of the ratio of the ultimate 2-year peak flow to the existing 2-year peak flow. Further, it gives an idea of the degree of possible stream channel widening caused by the increased flows. An erosion factor greater than 2.0--a potential doubling of the channel width--is considered a serious problem. There are 19 subbasins that have serious problems if no controls are used. If controls are used in accordance with the existing bill, the number of subbasins with serious stream channel erosion problems will be reduced to 12.

Table 11-5
Subbasin Erosion Factors for No Controls
and Existing Controls

Subbasin	Erosion Factor: No Controls	Erosion Factor: Existing Controls
Upper Severn Run		
1	3.0	1.8
2	1.4	1.1
3	4.7	2.7
4	1.0	1.0
5	3.9	2.3
6	1.7	1.3
7	1.1	1.0
8	1.4	1.1
Jackson Grove Road		
9	3.6	2.1
10	11.2	6.2
11	8.2	4.6
Picture Frame Branch		
12	8.9	4.9
13	4.9	2.8
14	14.8	8.1
15	2.4	1.6
16	3.2	1.9
17	1.7	1.2
18	4.7	2.7
Middle Severn Run		
19	3.4	2.0
27	1.0	1.0
28	1.1	1.0
Beaver Creek		
20	2.1	1.4
21	1.0	1.0
22	1.0	1.0
23	8.1	4.5
24	2.0	1.4
Delmont Road Branch		
25	1.0	1.0
26	1.0	1.0

Table 11-5
(Continued)
Subbasin Erosion Factors for No Controls
and Existing Controls

Subbasin	Erosion Factor	
	No Controls	Existing Controls
Broad Branch		
29	5.5	3.1
30	1.9	1.3
31	1.3	1.1
Lower Severn Run		
32	2.0	1.4
33	1.4	1.1
34	2.1	1.4
35	1.0	1.0
38	1.0	1.0
46	6.6	3.7
Wells Branch		
36	1.5	1.2
37	1.1	1.0
Jabez Branch		
39	1.3	1.1
40	1.2	1.1
41	1.1	1.0
42	1.0	1.0
43	1.0	1.0
44	1.0	1.0
45	1.0	1.0

The effect of the ordinance on the estimated soil loss from stream channel erosion can be determined from Table 11-6, which gives the soil loss for those cross sections that will undergo stream channel erosion. A comparison of this table with Table 7-4 shows a reduction in the volume of soil loss of nearly 60 percent. However, significant losses of soil still occur. The volume lost is 1.8 million cubic feet or 150 thousand tons. This is a considerable amount of soil to lose from the watershed, and could have adverse impacts not only on Severn Run, but on the Severn River upper tidal areas as well.

Recommendations

As mentioned previously, the stormwater management ordinance does not fully control the 2-year flood. Research indicates that stable stream channels are a function of the 1.4- to 2-year flood peaks. Therefore, to prevent stream channel erosion from increasing beyond its natural amount, the post-development 2-year peak flow should be maintained at a level equal to the predevelopment 2-year flow. Changes in the ordinance are recommended to accomplish this. Control of the 10-year storm can still be included, and would be wise since present Maryland policy is to maintain the frequency and magnitude of flood peaks the same for post-development and predevelopment cases.

Particular strengths of the Stormwater Management Ordinance are its application to projects undertaken by the county, the requirement for a construction bond, and either a maintenance bond and fee or a stormwater management account. In addition to requiring 100 percent control of the 2-year flood, the ordinance should be modified to change the nature of the controls required. The county should have

Table 11-6
Stream Channel Erosion with Existing Controls

Cross Section	Erosion Factor	Increase in Width Feet	Area Lost Square Feet Thousands	Volume Lost Cubic Feet Thousands	Tons Lost Thousands
Upper Severn Run					
2	1.45	3.1	11.5	19.1	1.5
3	1.51	2.0	4.5	12.9	1.0
4	1.35	3.5	7.7	22.3	1.8
7	1.64	3.8	18.0	37.5	3.1
Jackson Grove Road					
6	3.46	9.8	33.8	66.3	5.4
Picture Frame Branch					
10	4.46	38.1	123.0	320.0	26.5
11	1.64	2.6	4.9	7.5	0.6
14	1.88	3.5	12.6	34.1	2.8
Middle Severn Run					
15	1.51	2.0	10.2	13.7	1.1
16	1.54	2.2	4.3	13.2	1.1
17	1.56	31.9	225.0	499.0	41.3
23	1.48	23.5	190.0	318.0	26.3
Beaver Creek					
19	1.96	3.8	16.1	16.0	1.3
20	1.57	4.6	37.0	37.0	3.5
Lower Severn Run					
26	1.41	31.2	129.0	221.0	18.3
27	1.30	6.9	39.3	122.0	10.0
Total			867,000 20 acres	1.76 million	146,000

the option of requiring onsite or offsite controls for the purpose of reducing stream damage. Currently, any offsite controls have to be Class II structures and must be built in-stream. The act of constructing a structure on the stream could result in more damage than the increased flows it is intended to control.

The City of Rockville, Maryland has taken an innovative and flexible approach to reducing stream channel erosion. Developers, subject to city approval, have the option of onsite management, offsite management, or contributions to an offsite management program. The onsite management option would be similar to the existing ordinance, except that it should control the 2-year flood. To best understand the other options, the appropriate sections from the Rockville ordinance will be quoted with necessary changes to reflect conditions for Anne Arundel County.

"Offsite Storm Water Management

In lieu of on-site storm water management measures, the permittee may construct stormwater management facilities on County owned parkland or on land to be dedicated to the County as parkland, provided that the Department, the District and, where applicable, the Water Resources Administration, approve such facility, and that the facility and the land on which it is placed, if not already owned by the County, be dedicated to the County, and that the County Executive and Council accept all dedications on behalf of the County."

Contributions to Offsite Storm Water Management

"When it is deemed to be in the County's interest, the Department may, in lieu of the requirement for on-site storm water management, require or accept a monetary contribution to the construction, expansion, and/or maintenance of off-site County owned storm water management facilities, provided that the amount of any contribution that may be required shall not exceed the cost of the otherwise required on-site storm water management facility, and further provided that no contribution may be required if a waiver of the on-site requirement is not granted by the District. Either the County or the applicant may request such a waiver."

"The County Executive and Council shall by resolution establish a contribution schedule based on the average storm water runoff generated by the maximum allowable development in various zones or development categories."

"Contributions to an off-site County owned storm water management facility, whether required or accepted, shall not relieve the permittee of the responsibility of providing storm water drainage deemed necessary by the Department to avoid or minimize damage to other properties and waterways."

"Funds collected pursuant to this section shall be used for the construction of off-site stormwater management detention/retention facilities contained in an approved Capital Improvements Program, and not for construction of conventional storm drain systems or stop gap repair measures to damaged stream channels."

The intent of offsite storage is not the same as that in the existing Anne Arundel County ordinance for Class II structures. The offsite storage is not in-stream, nor is it primarily geared toward control of the 100-year flood. It is intended to allow flexible and effective options to be pursued for reducing stream channel erosion and removing nonpoint source pollutants.

The option of not directly providing for onsite or offsite control measures, but rather contributing funds towards a management program, is highly recommended. This would allow centralization of controls and lower operation and maintenance costs. It would also be very useful in the case of a development that drains directly to a tributary just upstream of its confluence with the major stream, or a development near the mouth of a stream. For this case, onsite or offsite storage would have little beneficial impact since the affected stream length is short. Contributions by the developer could, however, be used for controls elsewhere in the watershed. If these controls were located in the headwater areas or upstream of particularly sensitive areas, they would provide protection for the entire tributary length or for the sensitive area.

The choice of a contribution instead of onsite or offsite control would have to be the joint decision of the developer, Office of Planning and Zoning, Public Works, the Soil Conservation District, and where appropriate, the Department of Natural Resources. The design of these facilities could be modified so that they would not be self cleansing. This would allow some settling of sediment and other nonpoint source pollutants. If desired, special designs or chemical additions could be included to protect sensitive areas from urban pollution.

Going to a more regional concept of management will require changes in the Department of Public Works' Storm Water Management Order No. 1. As currently written, the order does not provide for the ability to develop runoff hydrographs. It should allow for methods developed by the SCS or other methods acceptable to the Soil Conservation District to be used. (These are described in Chapter 12.) Runoff hydrographs are required so that the effects of multiple developments adding their flows together can be analyzed, as well as the effects of reservoir routing on the timing of hydrographs. The routing techniques called for in the ordinance cannot properly evaluate hydrograph lags due to reservoir routing. This can be very important in some cases, since it is possible for a structure to not decrease downstream peak flows and to make them even larger. An example of this is discussed in the section on large-scale impoundments.

The Department of Public Works, therefore, needs to enlarge the capabilities considered in its stormwater management order to allow for hydrograph generation, addition, and routing. TR20 is a good tool for this purpose, but it is not the only possible one. Sufficient latitude should be given to allow the use of other accepted models or techniques.

If the present state policy is either required by the county or enacted by the state, storage as either detention or retention will be required for the 2-, 10-, and 100-year events. The means of providing this storage are varied and are given in Chapter 8. Some of the control measures cannot be highly recommended. In Montgomery County, infiltration devices do not perform adequately because of clogging problems. They should be used for roof drainage only to reduce clogging problems from oil, grease and sediment. Rooftop storage has worked well in some locations, but in others tampering with the drains has negated their usefulness. Inspection of rooftop facilities is difficult and time consuming. Heavy penalties are needed to prevent or reduce tampering. County projects and large developments would be best suited for rooftop storage. Small commercial or industrial sites using rooftop storage could easily place too heavy an inspection burden on the county. Parking lot storage must be very carefully designed to avoid potential hazards, especially in the winter. The actual storage area must be located where few customers would park, or their complaints could tempt commercial owners to tamper with the storage device. A limit of 6 inches of storage is generally recommended.

Porous pavement has shown some very promising results, especially when underlain with sufficient gravel to provide the required storage in the gravel void spaces. Rockville has several test sites but the results are still preliminary. The county may wish to wait several years before encouraging the use of porous pavement, until Rockville has finished its tests.

The purposeful overdesign of stormwater drains upstream of a constriction can provide the required storage. This overdesign, and underground storage, are particularly well adapted to commercial and industrial areas, and can be economically feasible, while recreation area storage or multipurpose lakes and ponds are best suited for residential developments.

The storage volumes,as determined by the methodology presented in TR55, required to keep the ultimate 2-, 10-, and 100-year peak flows the same as existing peak flows are given for each subbasin in Table 11-7. Figure 11-2 shows those subbasins for which delay of the runoff hydrographs could have either no benefits or adverse impacts. The time to peak of the subbasins and cross sections is given in Tables 11-8 and 11-9, respectively. For example, delaying the runoff from subbasin 8 by a half-hour or so would allow its peak to coincide with the local peak flow in the Severn Run. This would result in increasing the peak flow in Severn Run and creating a more severe stream channel erosion problem than previously existed. This can be avoided by designing the control facilities to allow a very low rate of runoff from subbasin 8, which would require a larger storage volume than a normal design.

The Road Design Division of the Department of Public Works has designated an engineer to learn the use and application of TR20. Training is being accomplished by attendance at a TR20 short course and assistance from DNR. In-house expertise on TR20 and HEC-2 is vital for watershed-wide planning and the use of offsite and regional stormwater management facilities. The effectiveness of proposed facilities can be tested using TR20, with special emphasis on the downstream impacts of delaying the runoff. This type of analysis could show areas where delaying the runoff might only worsen the erosion problems so that onsite or offsite controls would be undesirable. In this case, the contribution to the stormwater management program could be used elsewhere.

HEC-2 can be used in conjunction with TR20 to analyze how stormwater management facilities, flood control facilities, or alterations in restrictive highway culverts or bridges could change the flood plain and depth of water behind a constriction. The need for this application is shown in the case study.

Table 11-7
Required Storage Volume To Keep
Ultimate Peak Flows The Same As Existing

Subbasins	2-Year (acre-ft)	10-Year (acre-ft)	100-Year (acre-ft)
Upper Severn			
1	0.63	2.72	4.81
2	2.04	3.37	4.38
3	3.07	8.80	15.56
4	0.00	0.00	0.00
5	2.02	6.27	11.23
6	3.50	6.81	10.51
7	0.10	0.55	0.98
8	5.37	8.04	11.04
Jackson Grove Road Branch			
9	5.49	10.28	16.05
10	17.06	36.90	61.11
11	7.34	15.28	25.60
Picture Frame Branch			
12	11.43	18.97	25.78
13	5.85	9.65	13.73
14	14.87	26.05	38.57
15	11.80	17.95	25.82
16	9.86	19.40	30.80
17	1.05	2.36	4.21
18	2.69	8.07	14.33
Middle Severn Run			
19	17.70	20.73	35.39
27	0.00	2.23	8.35
28	3.07	7.53	34.56
Beaver Creek			
20	0.82	2.22	3.96
21	0.10	1.95	6.25
22	0.00	0.00	0.00
23	8.59	22.65	41.39
24	3.17	9.51	16.75

Table 11-7
(Continued)
Required Storage Volume To Keep
Ultimate Peak Flows The Same As Existing

Subbasins	2-Year (acre-ft)	10-Year (acre-ft)	100-Year (acre-ft)
Delmont Road Branch			
25	0.00	2.19	9.48
26	0.00	0.64	1.60
Broad Branch			
29	4.42	18.11	37.54
30	2.14	6.05	11.04
31	0.58	3.50	5.83
Lower Severn Run			
32	0.77	2.31	4.61
33	3.96	8.39	1.63
34	3.99	7.97	8.25
35	0.34	0.99	2.00
38	0.00	0.00	0.00
46			
Wells Branch			
36	2.83	7.08	11.70
37	1.05	1.84	3.16
Jabez Branch			
39	4.51	7.63	11.45
40	3.05	6.61	9.66
41	1.30	2.61	3.91
42	0.00	0.00	0.00
43	0.00	0.00	0.00
44	0.00	0.00	0.00
45	0.00	0.00	0.00
46	1.48	2.82	4.47

Table 11-8
Subbasin Time of Peak Runoff

Subbasin	Time in Hours from Beginning of Storm					
	2-Year		10-Year		100-Year	
	Exist.	Ult.	Exist.	Ult.	Exist.	Ult.
Upper Severn Run						
1	4.83	4.20	3.82	3.53	3.73	3.66
2	3.23	3.19	3.18	3.16	3.21	3.19
*3	6.03	3.85	3.87	3.38	3.77	3.49
4	4.62	4.62	3.78	3.78	3.70	3.70
*5	5.12	4.31	4.08	3.84	4.02	3.90
*6	4.06	3.51	3.49	3.39	3.62	3.50
7	3.91	3.87	3.65	3.63	3.76	3.75
*8	3.69	3.58	3.57	3.53	3.69	3.63
Jackson Grove Road Branch						
*9	4.32	3.50	3.70	3.41	3.76	3.52
*10	0.00	3.70	4.16	3.58	4.03	3.70
*11	4.98	3.41	3.86	3.34	3.77	3.40
Picture Frame Branch						
*12	4.03	3.42	3.22	3.69	3.89	3.04
*13	4.18	3.36	3.55	3.33	3.68	3.38
*14	0.00	3.20	3.85	3.19	3.71	3.21
*15	3.97	3.41	3.47	3.36	3.60	3.42
*16	4.29	3.48	3.63	3.38	3.72	3.71
*17	4.21	3.96	3.54	3.39	3.66	3.54
*18	6.15	3.41	3.83	3.26	3.70	3.36
Middle Severn Run						
*19	4.56	3.69	3.81	3.43	3.78	3.56
27	0.00	0.00	6.16	4.42	4.35	4.22
28	4.54	4.48	3.93	3.42	3.89	3.70
Beaver Creek						
*20	4.24	3.84	3.47	3.29	3.63	3.38
21	0.00	4.45	0.00	3.76	5.31	3.71
22	4.08	4.08	3.36	3.36	3.52	3.52
*23	0.00	3.50	3.97	3.36	3.81	3.42
*24	4.84	4.39	4.06	3.92	4.05	3.98

Table 11-8
(Continued)
Subbasin Time of Peak Runoff

	Time in Hours from Beginning of Storm					
	2-Year		10-Year		100-Year	
Subbasin	Exist.	Ult.	Exist.	Ult.	Exist.	Ult.
Delmont Road Branch						
25	0.00	0.00	0.00	4.00	4.07	3.85
26	0.00	0.00	5.42	3.98	3.88	3.83
Broad Branch						
*29	0.00	4.25	5.66	3.74	4.12	3.84
*30	4.83	4.43	4.06	3.94	4.05	3.99
31	4.86	4.69	4.10	4.05	4.08	4.06
Lower Severn Run						
32	4.90	4.40	3.98	3.83	3.93	3.87
*33	3.54	3.50	3.40	3.37	3.53	3.46
*34	4.20	3.57	3.61	3.45	3.73	3.57
35	4.07	4.03	3.54	3.53	3.68	3.66
38	4.41	4.41	3.66	3.66	3.61	3.61
*46	4.15	3.20	3.36	3.16	3.53	3.19
Wells Branch						
36	4.20	3.95	3.58	3.49	3.71	3.61
37	3.88	3.57	3.41	3.40	3.55	3.52
Jabez Branch						
*39	3.43	3.38	3.34	3.32	3.40	3.38
40	3.56	3.50	3.40	3.38	3.52	3.46
41	3.79	3.75	3.63	3.62	3.75	3.74
42	3.91	3.91	3.37	3.37	3.49	3.49
43	4.24	4.24	3.74	3.74	3.83	3.83
44	4.29	4.29	3.90	3.90	3.98	3.98
45	4.74	4.74	4.42	4.42	4.54	4.54

* Subbasins with substantial potential to cause stream channel erosion.

Table 11-9
Cross Section Time of Peak Runoff

Cross Section	Time in Hours from Beginning of Storm					
	2-Year		10-Year		100-Year	
	Exist.	Ult.	Exist.	Ult.	Exist.	Ult.
Upper Severn Run						
*1	3.23	3.81	3.77	3.60	3.82	3.74
*2	4.42	4.14	3.92	3.81	3.87	3.79
*3	5.35	4.93	4.74	4.47	4.70	4.59
*4	4.14	4.35	3.56	3.48	3.85	3.86
*7	4.15	4.05	3.93	3.86	4.11	3.86
Jackson Grove Road Branch						
*6	4.86	4.13	4.20	3.86	4.19	3.87
Picture Frame Branch						
Penn Railroad						
*10	0.00	3.20	3.85	3.19	3.71	3.21
*11	4.32	3.67	3.79	3.53	3.82	3.58
*14	4.99	4.23	4.53	3.89	4.19	3.86
Middle Severn Run						
*15	4.56	4.39	4.95	4.08	4.40	4.07
*16	5.83	4.49	5.15	4.20	4.49	4.21
*17	7.36	6.16	6.62	5.73	5.94	5.37
*23	8.81	7.72	8.17	7.47	7.61	6.74
Beaver Creek						
*19	4.50	3.58	3.95	3.42	3.89	3.70
*20	5.15	5.39	4.07	5.48	4.05	4.68
Delmont Road Branch						
22	0.00	0.00	5.42	4.40	3.92	4.57
Broad Branch						
25	4.86	4.69	4.10	4.05	4.08	6.27

Table 11-9
(Continued)
Cross Section Time of Peak Runoff

Cross Section	Time in Hours from Beginning of Storm					
	2-Year		10-Year		100-Year	
	Exist.	Ult.	Exist.	Ult.	Exist.	Ult.
Lower Severn Run						
*26	9.44	8.37	8.81	3.83	8.22	7.25
*27	4.55	9.62	4.16	9.45	4.05	8.60
*30	5.83	5.94	5.37	5.64	4.90	4.95
35	5.93	6.03	5.47	5.75	4.96	5.01
Wells Branch						
29	4.42	4.41	4.08	4.18	4.04	3.99
Jabez Branch						
32	3.98	4.05	3.73	3.87	3.78	3.75
Route 32						
33	5.21	5.19	4.86	4.95	4.59	4.55
34	5.63	5.67	5.17	5.38	4.70	4.70

In order for a regional concept of stormwater management to be effectively implemented, the engineer assigned the responsibility of using TR20 will need to have as his primary responsibility the analysis of stormwater management alternatives. If this engineer is burdened with other responsiblities that overly detract from the time he can spend on stormwater and watershed problem analysis, the recommended regional concept may well create downstream problems or inadequately accomplish its goal. At first there may not be a very large demand for the use of TR20. However, as additional watersheds are studied and the usefulness of hydrologic computer simulation is recognized, using TR20 could develop into a full time job. In order to meet this eventual demand, two new engineers above current staffing should be added to the Roads Design Division. Hiring may be staged to allow the demand for the use of TR20 to develop. One engineer should be hired soon to allow for the completion of training on TR20 as well as some "hands on" experience.

TR20 can also be used for land use planning and as an aid in sector plans. Chapter 12 will discuss this use in more detail.

WATER QUALITY AND ENVIRONMENTAL CONCERNS

Present Conditions

By restricting development in the flood plain, the Zoning Ordinance, Subdivision Regulations, Maryland Interim Watershed Management Policy, the statewide Agriculture Water Quality Management Program for the Control of Sediment and Animal Wastes, and the state's Rules and Regulations Governing Construction on Non-Tidal Waters and Flood Plains help prevent the degradation of water quality and preserve the ecological systems within the flood plains. The Public

Health Department is responsible for septic systems and water wells, while the Department of Natural Resources responds to major water quality problems.

The Office of Planning and Zoning has recently started a countywide program of collecting and analyzing water quality data. They will recommend areas that should undergo further study, including water quality sampling. This program is needed and should be continued. It is imperative that sufficient data be collected to fully identify water quality problems and sources before extensive corrective programs are undertaken.

The Regional Planning Council (RPC) and Anne Arundel County 208 Program have identified regional as well as county problems and will be suggesting possible control alternatives. Close cooperation of the 208 program with other programs of the Office of Planning and Zoning, other county agencies, and the state should eventually produce a viable water quality improvement program.

Controlling nonpoint pollution sources--the major sources within the Severn Run--is a difficult task, and the most effective control techniques have yet to be determined. The Environmental Protection Agency has undertaken a program to determine the effectiveness of various urban nonpoint source control measures. One of the demonstration projects will be conducted by RPC and should provide useful information for the county's 208 program.

Because many pollutants are associated with sediments, reducing construction site and agricultural erosion, as well as reducing the increase in the 2-year peak flows, should lessen the nonpoint source loads. Figure 11-3 and Table 11-10, with Chapter 8 and the RPC 208 report, describe many of the possible nonpoint source control options.

Table 11-10
Summary of Best Management
Practices For Urban Runoff

Source Controls

- Litter
- Fertilizer and Pesticide Application
- Commercial and Industrial Stockpiles
- Road Maintenance
- Vegetative Debris
- Illegal Storm Sewer Discharges
- Refuse Pickup
- Industrial Spills
- Animal Control
- Road Salting

Air Pollution Control

Accumulated Pollutant Removal

- Street Sweeping
- Private Parking Lot Sweeping
- Animal Control

*Runoff Control

- Natural Drainage
- Contour Landscaping
- Swale Drains
- Parking Lot Storage
- Rooftop Storage
- Recreational Area Storage
- Dutch Drains
- Porous Pavement
- Grass-lined Ditches

Conveyance System Cleaning

- Catch Basin Cleaning
- Ditch Cleaning
- Sediment Basin Cleaning

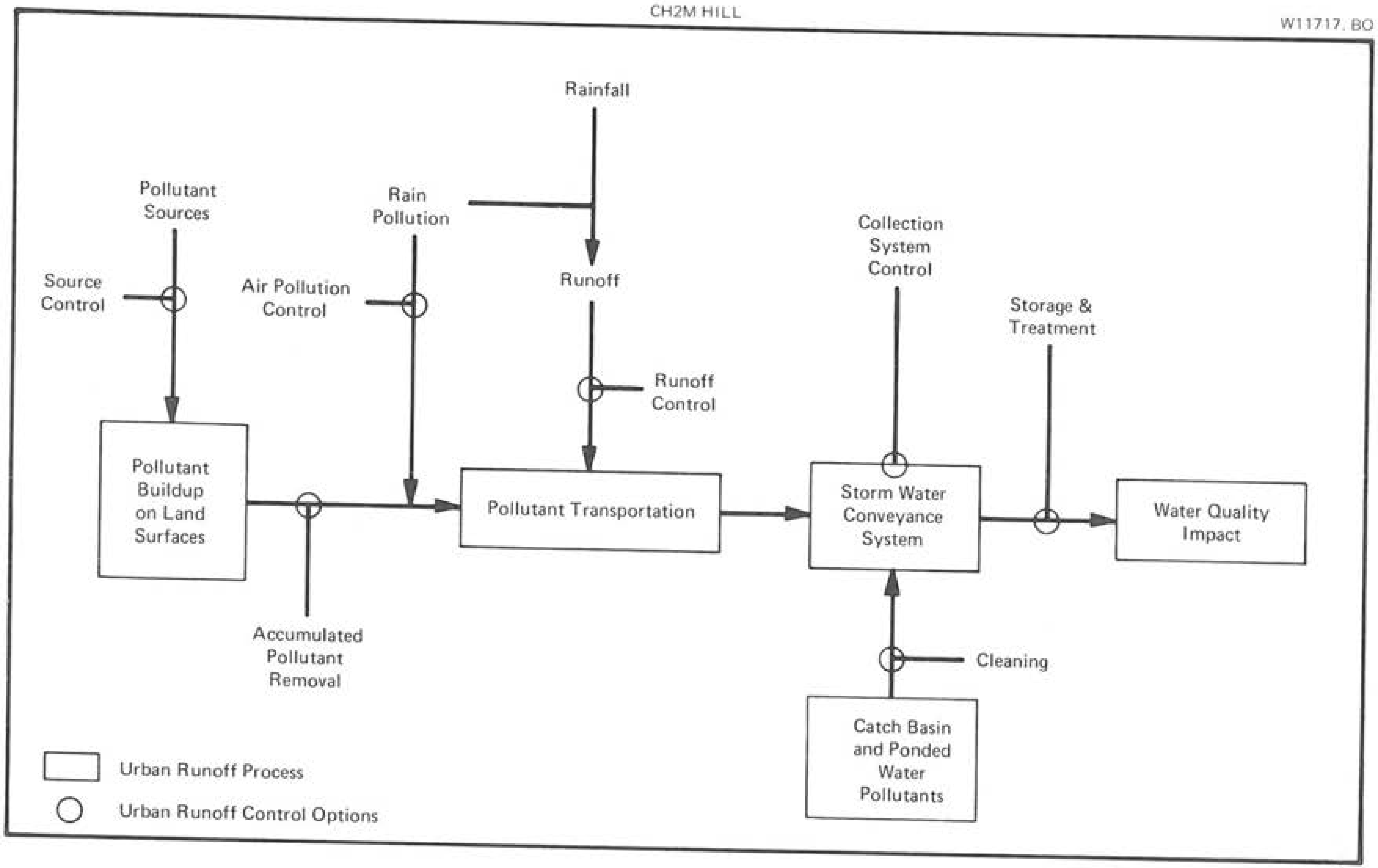


FIGURE 11-3: Urban Runoff Process & Control Schematic

Recommendations

The stormwater ordinance does not mention that water quality concerns can be addressed by onsite or offsite facilities. The Maryland Interim Watershed Management Policy, however, recognizes water quality concerns and encourages the design and implementation of stormwater management systems that minimize the entrainment and transport of pollutants from the land surface and allow pollutants to be removed from the runoff prior to reaching the stream. Control options that reduce the flow onsite before it travels over extensive impervious surfaces will also reduce the potential for pollutant transport. Alternatives such as rooftop storage, parking lot storage, natural drainage, porous pavement, and increased onsite infiltration are effective. General good housekeeping practices can also reduce the availability of pollutants. Findings of the 208 program should be enacted within the fiscal resources of the county, and the current program by Planning and Zoning of watershed management studies and plans should continue. The Office of Planning and Zoning is devoting special efforts to locate all existing water quality data and determine cooperative means of obtaining additional data. A prototype watershed water quality study should be considered to determine the feasibility and utility of such studies.

Throughout the Severn Run Watershed, illegal dumping is a major aesthetic problem. Dumps abound in all headwater areas. Most tributaries and some sections of the Severn Run itself are littered with tires, appliances, cars, furniture, bottles and other refuse. The slow degradation of these items adds metals, phenols, rubber, petroleum products, and other pollutants to the stream system. Areas along the railroad tracks often have railroad ties in and alongside of the stream. These ties could be leaching creosote, a potentially toxic pollutant. Evidence of oil and grease dumping and overflowing septic systems was seen in several locations. Domestic animals, particularly horses, have direct access to the streams which can result in bacteriological and organic pollutants. A general disregard for the stream and its environment was evident throughout the watershed.

To help alleviate these problems, the county, through the 208 program and citizens organizations such as the Boy and Girl Scouts, Save our Streams, Trout Unlimited and others should conduct a public awareness program and encourage cleaning up the streams. Other options include applying for a 208 demonstration grant, using high school or college students during the summer, and investigating the use of Scenic River funds. (The Severn River has been designated as a Scenic River.) Strict enforcement and publication of dumping laws should be undertaken, with news releases issued that large fines will be issued to all violators. Debris in the streams is not only a pollutant, but can also create flooding hazards by blocking culverts, restrictive channels, or bridges.

Measures to prevent direct access to streams by domestic animals should be considered. This can be included as part of the Statewide Agricultural Water Quality Management Program. Attention also should be given to the identification of failing septic systems and means to improve them. This task is beyond the scope of the present study but could be included in a watershed water quality study.

The upland swamps, shrub and wooded swamps in the watershed are located in areas that are due to urbanize.

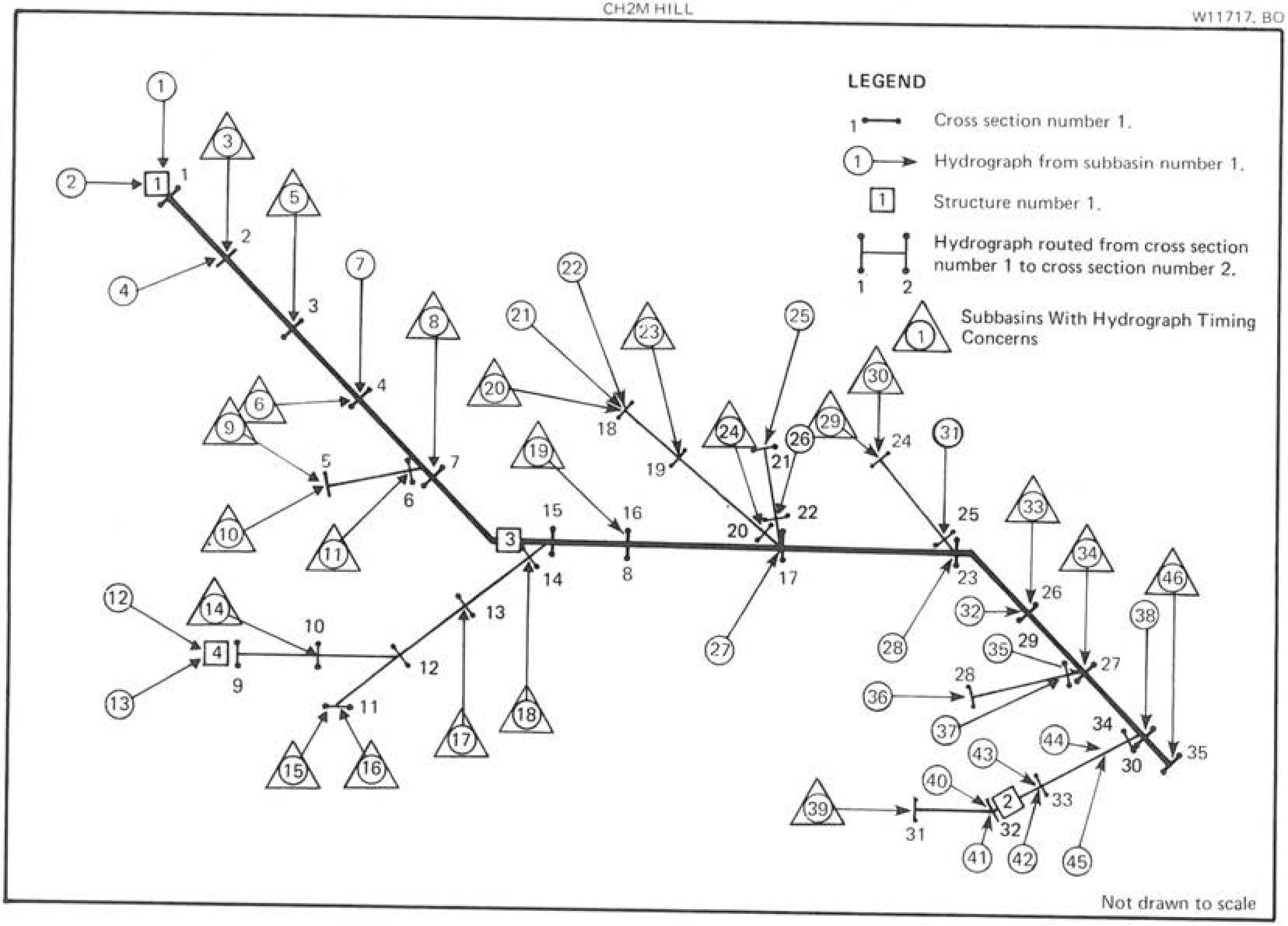


FIGURE 11-2: Subbasins With Hydrgraph Timing Concerns

These swamps, which are not included in the state's upland natural areas, have unique ecological features which may warrant preservation. In addition, these areas are very effective at holding stormwater runoff and act to reduce flooding and erosion problems. Rather than protecting all swamps, which would require extensive rezoning, a select few located in low density residential zoning areas could be considered. This would include the swamps near Gambrills Road, at the upper end of Beaver Creek, and east of Route 3 (Figure 4.7). Due to the low density of planned urbanization in these areas, the hydrologic nature of the swamps should not be seriously impacted.

The state has funds for acquiring more land for the Severn Run Environmental Area. Close cooperation between the county and DNR is encouraged to obtain the best possible areas. Consideration should be given to early acquisition of those areas that are most immediately threatened with possible urban expansion, such as the areas downstream from Picture Frame Branch, Beaver Creek, and the Route 32 corridor.

SUMMARY OF RECOMMENDATIONS

A very brief summary of the major recommendations of this chapter follows.

Flooding

1. Improve the culverts to Reece Road (Rt. 554), Telegraph Road (Rt. 170), and Burns Crossing Road.
2. Take action for the protection of the house off Reece Road, the barn on Broad Branch, and the house on Rogers Lane. Remove the trailers from the flood plain of Beaver Creek.

3. Modify the subdivision regulations to ban construction within the ultimate 100-year flood plain. Apply a uniform criteria to zoning and subdivision regulations.

4. Modify the Stormwter Ordinance to provide for onsite, offsite, in-stream or off-stream flood control alternatives.

5. The town center planned in the Picture Frame Branch watershed should include provisions for storing water impounded by the restrictive railroad culverts. If the culverts are enlarged, additional hydrologic and hydraulic simulations will be required to determine the impact on the areas downstream from the culverts.

Land Surface Erosion

1. Increased emphasis should be placed on erosion controls (preventive) such as proper planning and maintenance of natural vegetation rather than on sediment controls (curative). The intent and spirit of sediment control should be met.

2. County government agencies, the Soil Conservation District, and the Department of Natural Resources should continue to work together to create a cooperative climate to further improve the county's sediment control program.

3. Capital Improvement and Public Works Projects should be subject to the same requirements and inspections as all other projects. The Department of Inspections and Permits should have sole inspection responsibilities.

4. Inspector training should be more formalized and documented.

5. Construction on steep sloped areas should be approved by the Office of Planning and Zoning to protect critical areas.

Stream Channel Erosion

1. Modify the Stormwater Ordinance to consider:

   a) keeping the pre- and post-development 2-year peak flows the same;
   b) onsite, offsite, or regional controls including a regional offsite management program; and
   c) deleting Class I and II structure.

2. Require the downstream impacts of control alternatives to be investigated using hydrologic and hydraulic computer simulation models when needed.

Water Quality and Environmental Concerns

1. Insufficient data currently exists to assess the water quality of Severn Run. A data collection program and separate water quality study are required.

2. The location and severity of septic tank failures needs to be determined.

3. Industrial discharges require periodic monitoring.

4. Erosion and sedimentation should be reduced.

5. Upland swamps contain unique biota and should be preserved.

6. The Severn Run Environmental Area should be expanded.

7. The county should consider a park system along stream valleys especially in areas such as Jabez Branch, Wells Branch, and Broad Branch that have not yet been severely impacted by man's activities.

CASE STUDY

To illustrate the principles discussed in the report, a case study of a section of the Picture Frame Branch area is presented. The area of concern is shown in Figure 11-4.

The existing TR20 subbasins are shown as well as possible further subdivisions for a detailed study. For illustrative purposes, the existing subbasins and land uses were used, except that within subbasin 14 development was allowed in new subbasins 19, 20, and 21. Subbasins 19 and 20 will be assumed to be planned shopping centers, while subbasin 21 is assumed to be a large single commercial establishment. The effects of this development will be investigated.

TR20 was used to simulate this development, and the increase in flow peaks and required storage to prevent the increase in runoff are given in Table 11-11. Figure 11-5 shows the existing and ultimate hydrographs at cross section 10 for the 10-year storm. The shaded area is the storage volume required to reduce the ultimate peak to the same value as the existing peak.

The erosion factors (square root of the ratio of the ultimate 2-year peak flow to the existing 2-year peak flow) for the cross sections considered are:

Cross Section	Erosion Factor
10	5.2
12	1.7
13	1.3
14	1.2

The major problem area for stream channel erosion is downstream from the development on the tributary to Picture Frame Branch. The existing stormwater management ordinance would reduce the erosion factors to:

Cross Section	Erosion Factor
10	3.0
12	1.2
13	1.1
14	1.1

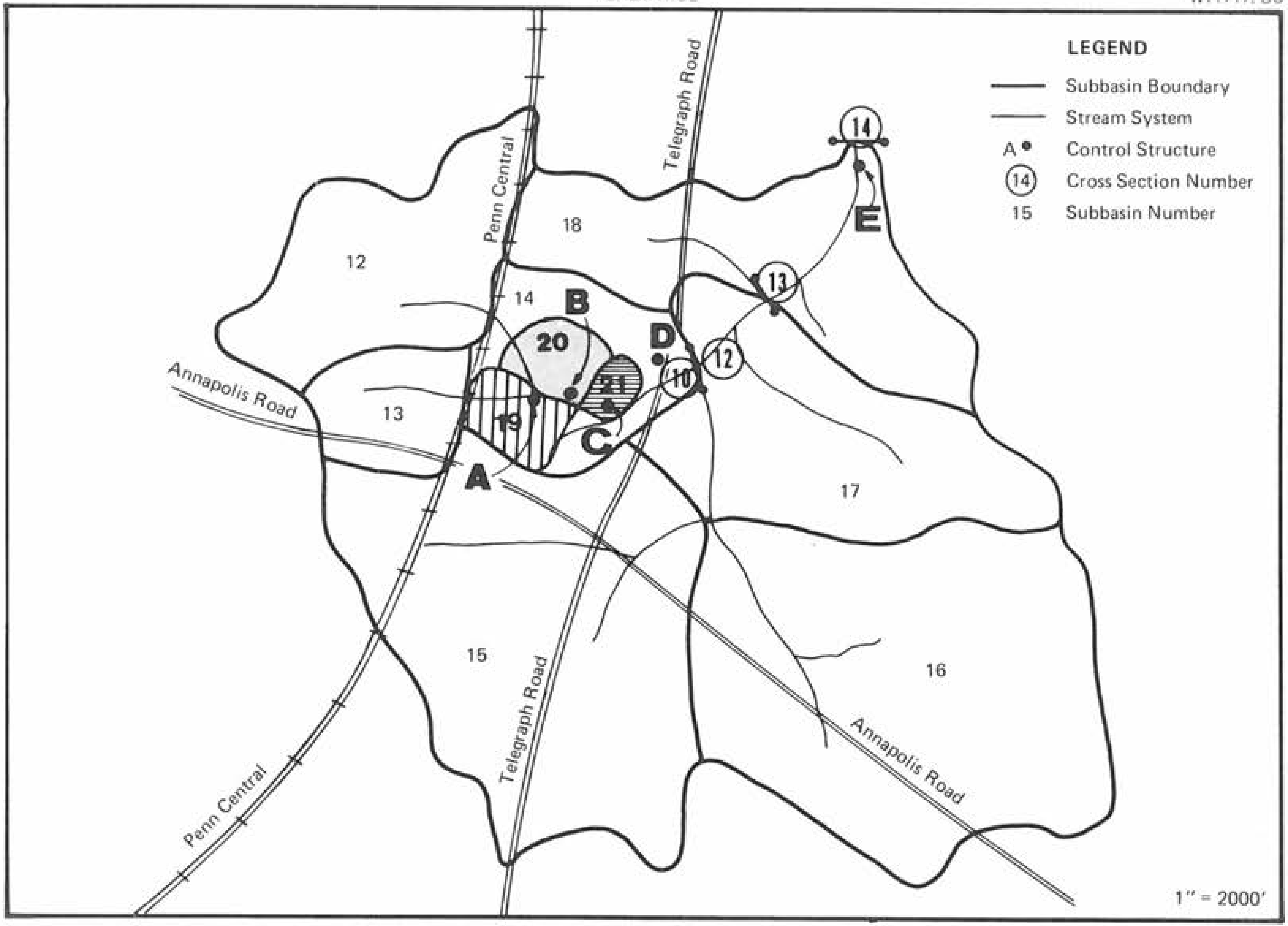


FIGURE 11-4: Picture Frame Branch Case Study

Table 11-11
Flows and Storage Volumes
For Case Study

Subbasin	Flows (cfs)						Storage (acre/ft)		
	2-Year		10-Year		100-Year				
	Existing	Ultimate	Existing	Ultimate	Existing	Ultimate	2-Year	10-Year	100-Year
19	0.0	68.3	2.4	140.6	15.2	199.3	3.33	5.38	8.00
20	0.0	54.7	1.9	112.5	12.1	159.4	2.66	4.30	6.40
21	0.0	27.3	0.9	56.2	6.1	79.7	1.33	2.15	3.20
Cross Section									
10	5.5	150.3	47.4	310.2	185.4	446.6	7.35	11.88	17.53
12	52.7	150.4	287.7	335.3	910.8	983.4	6.99	11.65	17.47
13	54.6	87.4	289.0	338.2	990.8	1,075.5	8.33	12.50	18.05
14	51.4	71.0	263.6	316.9	971.1	1,058.8	6.27	12.54	17.25

The existing stormwater management ordinance would allow a possible tripling in the width of the tributary. To prevent this, the 2-year peak flow needs to be maintained at or near its predevelopment level.

Numerous control alternatives can be used to reduce the peak runoff rate. These alternatives will not be analyzed in detail; instead, an approach to the problem will be discussed. As recommended earlier, DPW should use TR20 to analyze proposed solutions. Possible alternatives include onsite storage ponds (A, B, and C), a regional storage pond (D), a large scale in-stream impoundment (E), rooftop storage, parking lot storage, porous pavement, and underground storage. The effects of onsite storage could be easily simulated with TR20 if a stage-discharge-storage volume relationship were determined for the structures. The effects of timing delays on the peak flows should be investigated.

This area lends itself to a regional in-stream or off-stream storage facility, possibly located at site D in Figure 11-4. An in-stream facility would not reduce the stream channel erosion on the tributary upstream from the structure where the greatest potential for erosion exists. In fact, depending on hydrograph timing relationships, the structure could aggravate erosion problems for the rest of Picture Frame Branch.

An off-stream regional facility could solve the increased runoff problems but may require extensive stormwater conveyance systems to carry the runoff to the facility. Also, overflow precautions need to be taken in the design of the facility in case the volume of runoff exceeds the available storage volume. Delay of runoff from this structure could act to increase downstream peak

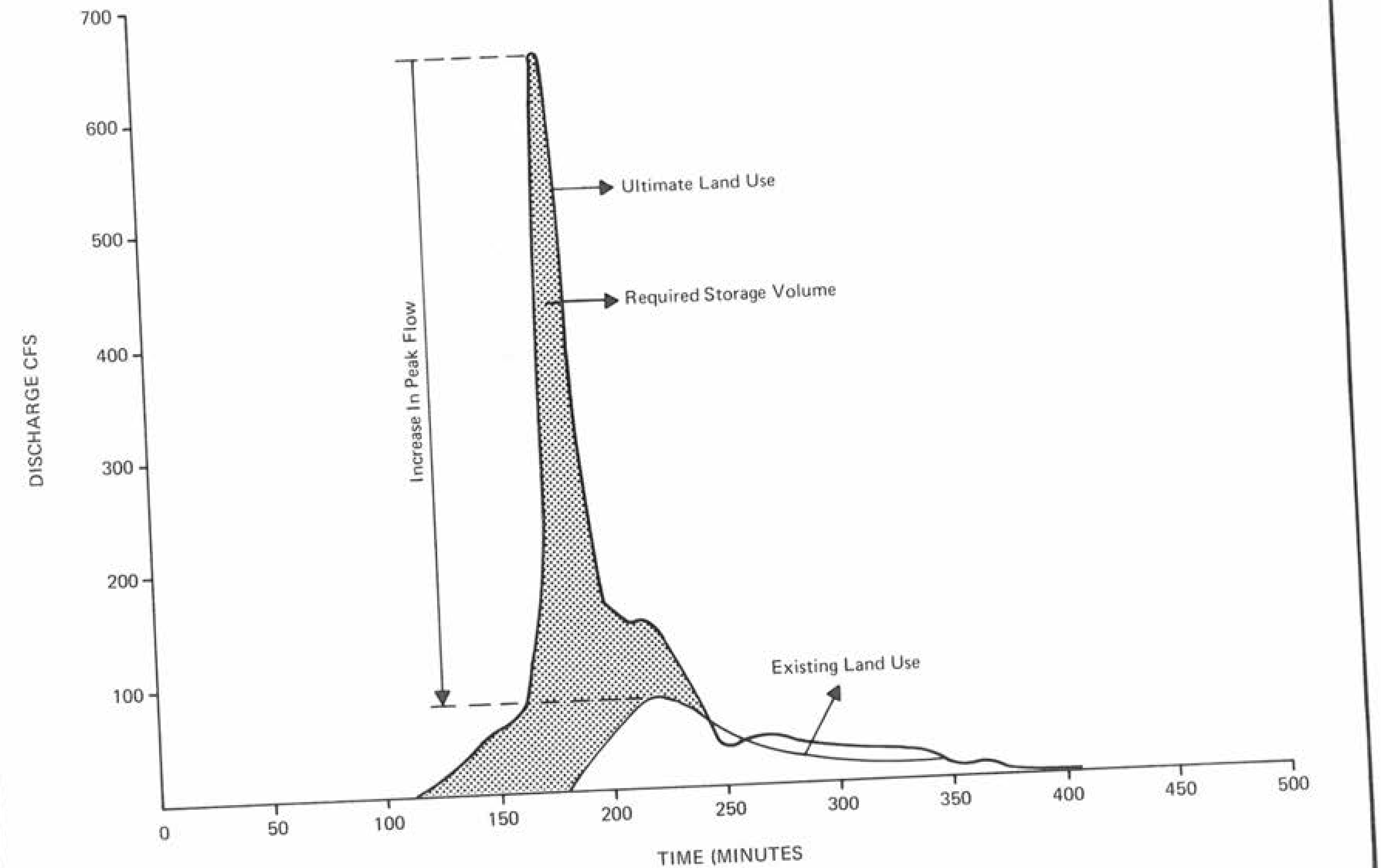


FIGURE 11-5: Existing And Ultimate Hydrographs, Cross Section 10, Case Study

flows. If such a site were considered, DPW should apply TR20 to the area and determine what impacts the structure would have. Consideration should be given not only to existing conditions in the watershed, but also to planned growth in determining the suitability of possible control alternatives. A regional facility at D could be designed for additional future urbanization and incorporated as a multi-use facility in other potential developments.

Rooftop and parking lot storage can effectively be used for onsite controls. The areas of the subbasins are 0.05 square miles for subbasin 19, 0.04 square miles for subbasin 20, and 0.02 square miles for subbasin 21. Considering subbasin 19 only, the Zoning Ordinance allows 80 percent of the area to be covered with buildings or parking areas. This gives 0.04 square miles or 25.6 acres of impervious area. Fifty percent of the impervious area or 12.8 acres will be assumed to consist of buildings. If these buildings have flat roofs and are designed to store 1.5 inches of rainfall, nearly half the storage required for the 2-year storm could be obtained.

If parking lot storage of 6 inches is used on one-eighth of the parking lot, 0.8 acre-feet of storage can be obtained. Combined with rooftop storage, 2.40 acre-feet or 72 percent of the required 2-year storage volume is possible. This significantly reduces the size of additional storage facilities. Up to 3 inches can be stored on rooftops, which would provide nearly all the storage needed for the 2-year storm.

If control of stream channel erosion on Picture Frame Branch were not desired, but control for Severn Run were desired, a structure could be located at site E. The effects of a structure at this location were previously investigated and found to have essentially no beneficial results due to coincident peaks from Severn Run and the outflow of the structure.

This case study raises several other interesting points. What should be done with the tributary running through the planned commercial development? During the summer the stream experiences periods of no flow, yet a definite channel and flood plain exist. The Zoning Ordinance calls for the 50-year flood plain to be zoned as open space, and the subdivision regulations, forbid development within the 100-year flood plain. To what extent are these ordinances meant to apply to small tributaries? The county must answer this question to prevent possible future conflicts.

This area is one that was considered in the HEC-2 hydraulic analysis and is downstream of the restrictive culverts under the Penn Central Railroad. If the culverts were enlarged to avoid ponding in the proposed town center on the western side of the railroad, the 50- and 100-year flood plains would significantly increase, since the flow from subbasins 12 and 13 would no longer be reduced by the restrictive culverts and could impact the proposed shopping center. The increased flow could be large enough to create flooding problems at Telegraph Road. The hydraulic analysis of this study used the reduced flows from the culverts. If the culverts were enlarged, HEC-2 would have to be rerun to determine whether Telegraph Road would be flooded or back water up and inundate a large portion of the land planned for development. This case demonstrates the need for the county to have in-house expertise in both TR20 and HEC-2. It also shows that regional or watershed considerations may be required even if onsite storage is initially planned.

This area is one that has severe debris problems in the stream channels. If the channels are to be protected and maintained, the developer or the county should be made responsible for cleaning up the stream. Otherwise, control devices could be impaired or rendered ineffective by blockage with debris.

Because the stream is intermittent, local water quality concerns are difficult to address. However, changing a wooded area to a large shopping center will increase nonpoint source pollutant loads and could adversely impact Picture Frame Branch and Severn Run. Therefore, the area should be considered for the control options that the 208 agency will be formulating.

The proposed development is located in generally highly erodible soils, and without a sound sediment control plan, could produce significant amounts of eroded soil. This eroded soil would probably settle in Picture Frame Branch and could degrade the existing water quality and adversely effect the ecology of the area. Phased construction designed to minimize exposed soil and provide ongoing runoff controls would greatly reduce the erosion potential.

In summary, the case study shows the multitude of concerns that are involved in watershed management. It demonstrates the need for DPW to expand its hydrologic and hydraulic modeling capabilities so that regional concerns can be addressed. Obviously many agencies and departments are involved in watershed planning, and mutual cooperation and communication are necessities for proper watershed management.

IMPLEMENTATION AND COSTS

Numerous government agencies and citizens' groups should become involved in implementing the proposed suggestions. The recommendations and those agencies that have primary or secondary interests or responsibilities in implementing them as well as their costs are summarized in Table 11-12, which was provided by the County.

The Office of Inspections and Permits should continue its active role in improving the county's sediment control program and should give this area its highest priority.

The Office of Planning and Zoning and the Department of Public Works should take prompt action to initiate the improvements to Reece Road, Telegraph Road, and Burns Crossing Road. Reece Road deserves immediate priority since it could cause considerable property damage to the homes upstream of the road.

The Office of Planning and Zoning, Department of Inspections and Permits, Department of Public Works, and the Soil Conservation District need to begin a critical review of the Stormwater Ordinance in light of the recommendations of this report. It is not possible to assign a cost to changing the ordinance, but without some of the recommended changes, the ordinance will not achieve its stated purpose of reducing or preventing flood damages and stream channel degradation.

Table 11-12
SUMMARY OF SEVERN RUN WATERSHED STUDY RECOMMENDATIONS, RESPONSIBILITIES AND COST

	Recommendations	Agency Responsible	Cost	Status
STATE	Expansion of Severn Run Environmental Area	DNR	Purchase of approximately 440 ac.	On-going project
	Increase culvert opening of Reece Road crossing	SHA	$144,000	Future capital project
	Raise elevation of Telegraph Road 1 Foot	SHA	$160,000	Future capital project
	Periodic monitoring of Industrial Discharges	WRA		Current work element
		SUBTOTAL	$304,000	
CAPITAL IMPROVEMENTS	Increase culvert opening of New Cut Road at Broad Branch	DPW		DPW recommends that this project not be considered for a future capital program.
	Raise elevation of Burns Crossing Road at Severn Run - 2 ft. and increase culvert size	DPW	$432,000	Future capital project
	Increase opening under Burns Crossing Road at Beaver Creek to 100 sq. ft.	DPW	$147,000	Future capital project
	Increase culvert opening under WB&A Road by 35 square feet	DPW		DPW recommends that this project not be considered for a future capital project.
		SUBTOTAL	$579,000	

Table 11-12 (Cont'd)

SUMMARY OF SEVERN RUN WATERSHED STUDY RECOMMENDATIONS, RESPONSIBILITIES AND COST

Recommendations	Agency Responsible	Cost	Status
Two trailers remaining in flood plain move to higher ground - notification of owners	P & Z, Zoning Enforcement, Law Office		*Future Project
Survey of house and flood plain at Rodger's Lane - notification of owners	DPW		*Future Project
Correct flooding problem at Reece Road Branch through county acquisition/flood proofing/ flood insurance	DPW Relocation Section Right of Way Div.	Appraisal needed	*Future appraisal to determine acquisition costs.
Correct flooding problem at barn at Broad Branch	P & Z		*Future Project
Assure awareness of construction crews and supervisors of negative impacts to streams associated with roadway repair.	DPW	Possible training program	Future Work Element
County should consider a park system along stream valleys in Severn Run	Rec. & Park	Acquisition or easement	For Future Consideration
IN-HOUSE Establish watershed management program	P & Z		On-going project
- P & Z staff should include a - permanent water resources planner	P & Z	$24,000/yr (includes overhead)	*Contract
- permanent water shed/sector planner	P & Z	$26,730/yr (includes overhead)	Permanent Staff
- addition of 2 engineers to Roads Design Division	DPW	$41,800 - $52,900 per year includes overhead	*For future consideration
- staff training program in theory and use of appropriate computer modeling programs	P & Z - DPW	$2300	*1 week training session be given by consultant
- watershed should be gauged	P & Z		Initial steps have been taken to determine what direction to take in watershed management for future consideration

Table 11-12 (Cont'd)

SUMMARY OF SEVERN RUN WATERSHED STUDY RECOMMENDATIONS, RESPONSIBILITIES AND COST

IN-HOUSE

Recommendations	Agency Responsible	Cost	Status
- methodology should stress needs of DPW & SCD	P & Z, SCD, DPW		*For Future Consideration
- use of continuous model should be considered	"		*For Future Consideration
- studies should include task for detailed evaluation of limited number of construction sites	P & Z & I & P		*For Future Consideration
- DPW should enlarge capabilities for use of hydrograph generation, addition and routing in stormwater management orders	DPW, SCD, WRA		*Future working agreement for sharing facilities
Preventive erosion controls should be emphasized rather than curative sediment controls	I & P & SCD		Erosion control is a part of an inspection program.
Sediment ponds and dry stormwater management ponds should be provided with positive drainage and entrances to construction sites should be stabilized.	I & P, DPW, SCD		Positive drainage is provided for in DPW stormwater management order #1. Stabilized entrances to construction site are incorporated on all sediment and erosion control plans.
The following revisions should be made to the Grading and Sediment Control Ordinance	I & P, DPW, P & Z, Law Office, SCD	6 man/months for all revisions	Future Work Element
- Capital Improvement and Public Works projects should be required to follow same procedures for inspection and enforcement of sediment controls plans as other projects.	"		Capital improvement project plans currently approved by SCD and major grading operations approved by I & P.
- Add an index similar to that in subdivision regulations	I&P, DPW, P&Z Law Office, SCD		Future Work Element
- A separate sediment and erosion control ordinance should be considered.	"		DPW recommends revision to existing ordinance and stricter enforcement of existing laws.

Table 11-12 (Cont'd)

SUMMARY OF SEVERN RUN WATERSHED STUDY RECOMMENDATIONS, RESPONSIBILITIES AND COST

IN-HOUSE

Recommendations	Agency Responsible	Cost	Status
- Approval by P & Z should be required for sediment control measures on steep slopes	I&P, DPW, P&Z Law Office, SCD		Future work element
- Predevelopment meetings between inspectors and contractors should be required and I & P should be authorized to require additional plans or modifications.	"		Predevelopment meetings are required now. I&P can make minor changes in field per SCD - I&P Policy
- A maintenance bond requirement should be considered.	"		Future work element
- All sediment control plans should undergo the same review, inspection and enforcement, and I&P should assume complete inspection responsibility	"	Additional staff needed for SCD & I & P	"
- Provisions for construction site entrance mud and dirt removal should be added.	"		"
The following revisions should be made to the Subdivision Regulations and Zoning Ordinance	P & Z	7½ man/months	Subdivision regulations are currently under consideration for revision by P & Z.
- Prohibit construction within the projected 100 yr. flood plain for areas which have been studied in detail.	P & Z SCD	$12,000 salary (cost figures are for entire revision of subdivision regulations not just those listed here.)	
- Prohibit construction of steep slopes without retaining a ground cover buffer	P & Z SCD		
- Prevent clearing of trees adjacent to streams	P & Z		
- Open Space zoning should include the 100 yr. flood plain	P & Z		
Countywide program of collection water quality data should be continued	P & Z AACC?	1 man/month per year	Recently begun by P & Z. Could be considered in work program of AACC proposal.

Table 11-12 (Cont'd)

SUMMARY OF SEVERN RUN WATERSHED STUDY RECOMMENDATIONS, RESPONSIBILITIES AND COST

Recommendations	Agency Responsible	Cost	Status
Modify stormwater management ordinance to consider - keep pre & post development peak flow the same - onsite, offsite or regional controls - deleting Class I and Class II Structures	P & Z lead DPW, I & P SDC, Law Office, WRA	6 man/months	*To be incorporated into work program
Initiate an active public education program regarding water quality, ecology, and impacts of illegal dumping	P & Z	1 man/month	Currently implemented under 208 program, needs more emphasis
Increase the number of non-scheduled inspections of erosion control projects	I & P	$95,700 - $115,300	*4 additional inspectors needed
County should cooperate and work with DNR in terms of sediment and erosion control.	I & P		Coordination ongoing
County should consider DNR's recommendations regarding field inspections and reports and investigate the need for a more formalized and documented training programs.	I & P with DPW?		Currently training program being carried out with inspectors attending 4 field training sessions
Land protection measures should be emphasized in planning construction sites.	P & Z and		Accomplished now. Enforcement needs administrative support.
County should continue study of groundwater resources	P & Z MGS	$17,500 FY 80	County share of Aquia Auifer study, 4th study done in County
County should participate in a regional comprehensive groundwater supply study	P & Z RPC, MGS DNR	$5,354	County share of 4th year 208/RPC groundwater study
County should preserve the unique biota of some upland swamps.	P & Z DNR, SCD	6 man/months	*Future Work Element

IN-HOUSE

Table 11-12 (Cont'd)

SUMMARY OF SEVERN RUN WATERSHED STUDY RECOMMENDATIONS, RESPONSIBILITIES AND COST

Recommendations	Agency Responsible	Cost	Status
County should perform a comprehensive study of septic systems and contribution to water quality problems	P & Z Health Department	a. $4718 b. $5354	*County Health Department has on-going survey of septic systems. This currently does not include Severn Run. 208 4th year progam a. septic system data management b. WQ monitoring program assessment.
County should develop a program of placing high water marks in county	DPW	about 1-2 man/months	DPW determined marks for tropical storms Agnes and Eloise and will continue to maintain records for storms of significant magnitudes.
County should consider a system of parks along ultimate 100 year flood plains in Severn Run and as a County Policy	Rec. & Parks P & Z	3 man/months	*Include in future County open space study
	SUBTOTAL	$288,356	

IN-HOUSE

Table 11-12 (Cont'd)

SUMMARY OF SEVERN RUN WATERSHED STUDY RECOMMENDATIONS, RESPONSIBILITIES AND COST

IN-HOUSE AND/OR CONSULTANT

Recommendations	Responsible	Consultant Costs	In-House Costs	In-House Requirements and Status
Design of stormwater management control alternatives should be tested with hydrologic and hydraulic computer simulation models	DPW P&Z DNR SCD	Approximately $1000 per review	2 man/days engineer 1 man/day technician $100 computer costs per review	*Existing staff would require training. *Future work element for new engineers; hiring trained engineers would eliminate training costs.
Design of town center in Picture Frame Branch should include hydrologic and hydraulic simulations of stormwater control provisions.	P&Z DPW DNR	See Above	See Above	*See Above
Watershed management studies should be followed up by water quality studies, first one to be done is Severn Run. (example costs are for a 4 day synoptic study with 10 sampling sites on Severn Run)	P&Z DPW	I. STUDY DESIGN		*In-house costs assume trained staff members in data collection and analysis. Full scale program would require availability of sampling crews and lab technicians. A test study might be done with CETA or college student workers and adjustment of existing staff work programs. WQ sampling program might be included in work program of AACC proposal for environmental center.
		$800 - 1,000	$650	
		II. SAMPLE COLLECTION		
		$15,480 Labor + Transportation (varies with location of consultant + lab	$8,640 Labor + $293 Transportation (county veh.) + $275 training	
		III. LAB COSTS		
		$15,860	$7,150	
		IV. DATA REVIEW		
		$3,000	$1,950	

Table 11-12 (Cont'd)

SUMMARY OF SEVERN RUN WATERSHED STUDY RECOMMENDATIONS, RESPONSIBILITIES AND COST

Recommendations	Responsible	Consultant Costs	In-House Costs	In-House Requirements and Status
		TOTAL FOR 4 DAY STUDY		
		$35,340	$18,683	
		+		
		Transportation		
APPROXIMATE SUBTOTAL		$35,340	$18,683	
GRAND TOTAL (everything Done In-House) =			1,190,039	
GRAND TOTAL (Consultant Hired for Water Quality Studies) =			1,206,696	

*Recommendations that are new initiatives and will require additional staffing and funding. All others can likely be integrated into existing work programs and staffing.

Chapter 12

CHAPTER 12
ADDITIONAL CONSIDERATIONS

This chapter addresses concerns that do not conveniently fit into previous chapters and presents the consultant's opinion on various subjects. Topics considered are suggestions for future watershed studies, additional studies for the Severn Run, water quality studies, and a watershed management program.

FUTURE WATERSHED STUDIES

Additional watershed management studies should be undertaken by the county. Not only do these studies determine problems within a watershed; they also serve as a focal point for gathering data on the study area. This can be most helpful for a multitude of planning purposes.

Watershed management requires that a watershed and its possible problems as a whole be studied, not just one limited aspect of the watershed. Because of its diverse interests and responsibilities, the Anne Arundel Office of Planning and Zoning should continue to be the lead agency in watershed studies. Further, the Office of Planning and Zoning has administered the county 208 program, and has undertaken its own programs to obtain a data base for future studies, including water quality and watershed management projects. Leadership in future watershed studies by the Office of Planning and Zoning would be another important way of fulfilling its 208 responsibilities.

Gaged Watersheds

It is strongly urged that the next watershed studied have a stream gage that has been in operation at least 10 years. Table 12-1 lists such streams. Based on streamflow data, it appears that the tributaries to the South River, North River and Bacon Ridge Branch would be best suited for the next study. The Little Patuxent River could be studied jointly with Howard County. Gage 5940 listed in Table 12-1 is located in Howard County, and land use changes in Howard County will largely determine the response of the Little Patuxent River.

A gaged stream with long-term flow records is desired so that the hydrologic computer simulation model can be calibrated. Calibration consists of adjusting the input parameters of the model to achieve simulated flows that closely match observed flows. A greater degree of confidence can be placed on a calibrated model than on an uncalibrated model.

Careful consideration should be given to the location of stream gages. Using Severn Run as an example, a stream gage at the Route 3 bridge would show little change in peak flow caused by urbanization, since Jabez Branch, which determines the peak flow, will remain largely undeveloped. A completely different picture would be obtained from a gage at Dicus Mill Road, which is above the Jabez Branch confluence because at this location large increases in peak flows would be observed.

The county should give serious thought to the benefits of using a continuous hydrologic model rather than a single event model. The continuous model would have to be used in such a manner as to allow ease of interfacing with TR20. This procedure is necessary because the Soil Conservation District and the Department of Public Works use TR20 methodologies for onsite and offsite stormwater

Table 12-1
Gaged Streams for Future Studies

Stream Name	Gage Number	Watershed Area (square miles)	Period of Record
Sawmill Creek	5895	5.1	1944-1952 1964-1967
North River	5900	8.5	1931-1974
Bacon Ridge Branch	5905	6.92	1942-1952 1965-1978
Dorsey Run	5944	11.6	1948-1967
Little Patuxent River*	5940	98.4	1939-1958 1975-1978

* Gage located in Howard County

management controls. The next watershed study could be used to develop the required methodology to integrate a continuous hydrologic model with TR20 or other models approved by the Soil Conservation District and DPW. Reasons for this recommendation follow.

A brief discussion of differences between continuous and single-event hydrologic models will be given to emphasize the desirability of using a continuous model for future studies. TR20 and other similar single-event models consider individual rainfall events independant of other rainfall events. The amount of runoff from a precipitation event is largely determined by one parameter, the curve number (CN), which remains fixed for any size, duration, or distribution of rainfall. Soil moisture is partially considered by the use of an antecedant moisture condition (AMC), which is an estimated input parameter necessary to run the model. A basic assumption of single-event models is that the runoff flow frequency is the same as the rainfall frequency, e.g. the 10-year runoff event is produced by the 10-year design rainfall event. Noted hydrologists have indicated that this is not a valid assumption (Jackson and Karplus, 1976; Linsley, 1977; Larson, 1969; and Linsley, Kohler and Paulhus, (1975). It is further assumed that a given return period flood at one point in the watershed, corresponds to the same frequency event at all other points. In other words, the assumption is that there is one design storm that results in the same frequency of runoff at all points in the watershed. This is rarely observed.

TR20 does not account for changes in soil moisture during and between events, and further has no groundwater or water quality capabilities. The inability to simulate soil moisture requires the user to estimate the initial conditions for the design rainfall event. In reality, a given rainfall event on the same watershed can produce widely varying runoff flows as the soil moisture conditions vary. TR20 can only consider three possible soil moisture conditions while a multitude of variations are possible. In fact, Jackson and Karplus, and Hawkins raise questions concerning the basic methodology used in TR20. Calibration of TR20 to numerous events under varying soil moisture conditions within the existing AMC guidelines given by the SCS can be very difficult. Despite these drawbacks, TR20 has received extensive use because it is easy to understand. TR20 is often applied to ungaged streams, which requires no calibration of the model.

A continuous model considers a series of rainfall events in chronological time. Soil moisture accounting is performed during and between events, so that the model determines the antecedant soil moisture conditions for each runoff event. Continuous simulation does not assume that runoff frequency and rainfall frequency are related. Instead, by simulating the runoff produced by many years of observed rainfall, a frequency analysis can be performed on the runoff flows. This has advantages over using observed streamflows to produce frequency curves, especially for urbanizing watersheds. The observed records may not reflect conditions as they currently exist, and hence observed frequency curves may produce flows lower than present (more urbanized) conditions would. Continuous simulation is an excellent means for analyzing the impact of land use changes on peak runoff rates, runoff frequency, and volumes of runoff. In addition, structural and/or nonstructural stormwater management alternatives can be analyzed on a continuous basis. An example of this advantage can be seen in the importance of knowing antecedent water levels in flood prevention reservoirs and the effect this can have on reservoir design.

Continuous simulation models, such as the Stanford Watershed Model, can be used for low flow analysis, groundwater recharge studies, and water quality concerns. Numerous parameters interact in a dynamic manner to allow calibration to long periods of flow records under varying soil, weather, and land use conditions.

The single-event models are sometimes mistakenly considered more desirable than continuous models for ungaged streams. The simplicity of a single-event model means there are fewer parameters to estimate than for a continuous model, but the results of the single-event simulation are just as questionable as the results of the continuous simulation. In fact, the continuous model would be more reliable because water balances between surface runoff, evapotranspiration, and groundwater storage can be changed to match conditions representative of the area being studied. Also, a continuous model can be calibrated on a nearby gaged watershed. Appropriate calibrated parameters can then be used for the ungaged watershed with a high degree of confidence. A comparison of continuous and single-event hydrologic models is given in Table 12-2.

By applying a continuous hydrology model to a gaged watershed, reliable stream flow, groundwater recharge, and soil moisture estimates can be made for several years' worth of rainfall records. The results could be used not only for a watershed management study such as this one, but also for water quality, groundwater, drought, and other concerns.

Table 12-2
Comparison of Single Event and Continuous Hydrology Models

Single-Event	Continuous
Simple to understand and use	Complex models, harder to understand or use
Inexpensive to run	Higher computer costs
Can be further simplified for hand calculations	More intensive data requirements
Rainfall frequency and runoff frequency relationship is questionable	Allows determination of flow frequencies, not based on rainfall frequencies
Unit hydrograph and rainfall excess procedures subject to doubt	Considers components of physical hydrologic cycle
Standard intensity-duration-frequency curve is an inadequate way of describing rainfall	Uses historical rainfall records
Simulated flow frequency is the same at all points in the watershed	Permits development of flow frequencies at several points in watershed
No antecedent soil moisture accounting	Has soil moisture accounting
No groundwater considerations	Can simulate groundwater recharge
No water quality capabilities	Can be used for water quality studies
Can be difficult to calibrate for various soil moisture and meteorologic conditions	Can calibrate to a wide variety of situations
No low flow capabilities	Can consider low flow situations and develop low flow statistics

Soil Erosion Models

Future watershed studies could concentrate more effort on studying control of land surface erosion. Two new computer simulation models will be released in the fall of 1979. Both models are significantly more advanced than the universal soil loss equation in that they can consider sediment deposition and control alternatives that cannot be simulated with the universal soil loss equation. One of the models is being developed at Colorado State University for the U.S. Forest Service, while the other is being developed by the Agricultural Research Service of the Department of Agriculture and has national Soil Conservation Service approval.

These models, which consider particle sizes of sediment, should allow investigation of slope controls, buffer strips, mulching, runoff reduction and other preventive controls. A study utilizing these models with soil, slope, rainfall, and climatic conditions found within Anne Arundel County could improve evaluation of sediment control alternatives and sediment control plans. Used in conjunction with a model such as DEPOSITS (University of Kentucky) that considers particle sizes, inflow hydrographs, and outflow structures in determining the effectiveness of sedimentation basins, the models could shed new light on various approaches to erosion control in Anne Arundel County.

Stream Channel Erosion Models

If stream channel erosion is a major concern for a future study, three approaches are possible. One is the simple, yet theoretically sound, approach taken in this report.

Another method is the regime approach, which analyzes stream channel width, depth, slope and meander based on empirical equations that relate these parameters to the dominant stream discharge. The regime methodology does not implicitly consider the sediment load in the stream and is best used for a general--rather than detailed--analysis of stream morphology changes.

The third approach involves the use of complex computer simulation models that can analyze changes in stream channels in detail. Dr. Howard Chang of San Diego State University has developed several models that could be used, if considerable field data were collected. Details of the models are beyond the scope of this study, although appropriate references are included in the bibliography.

High Water Marks

A program of placing high water marks on major roads that cross the main channels of streams within the county would prove to be quite useful in backwater analysis, as it would provide calibration points. Only significant floods should be marked and the marks dated. Also, a map showing the locations of high water marks throughout the county should be maintained.

Training

If the county is to truly undertake watershed management planning, a training budget should be included in future studies to provide "hands on" experience with the computer models used for the study. This experience is necessary to familiarize county personnel with the particular details of the model application for the watershed under study.

Model application requires some personal judgement that must be transferred from the consultant to the county.

WATER QUALITY STUDIES

Water quality is an integral part of any comprehensive watershed management study. However, only in recent years has attention been given to water quality considerations. As a result, the availability of water quality data is lagging behind that of climatological and runoff data by many years. Further, it has only recently been recognized that in many watersheds the major problems derive from nonpoint source pollutants. Such is the case in Severn Run. Nonpoint pollutant sources are intermittent in nature and can be difficult to quantify, making water quality investigations more laborious than hydrologic or hydraulic investigations.

The Office of Planning and Zoning has recently initiated a program designed to centralize all water quality information for the streams within the county. The program will also identify problem areas and study needs, and will estabish study priorities. Present planning calls for detailed water quality studies to be conducted following watershed management studies such as the Severn Run study. This procedure will allow the information gathered during the watershed study to be used as a guide to the water quality study.

Future water quality studies should consider the nature, extent, source and frequency of occurrence of problems and the potential for future problems based on land use planning. These studies should also formulate alternatives for the alleviation and prevention of problems. Water quality considerations that should be investigated are point source discharges, septic systems, urban nonpoint pollutants, agricultural runoff, groundwater quality, erosion and sedimentation, location of fish spawning areas, landfill and dumping sites, and any unique problem or attribute of the watershed.

Often the best approach to water quality planning is the adoption of an appropriate water quality model. The nature of the problems and objectives of the study dictate the type of model to be used. For example, if nonpoint pollutants and in-stream water quality for fish production were to be investigated then a continuous model should be considered. This type of model would be able to simulate the buildup and washoff of pollutants from the nonpoint source areas and also model the in-stream quality during the wet and dry weather periods. One aspect to be considered in the modeling studies is the linkage between the hydrologic modeling and the water quality modeling. Using the appropriate model, runoff files based on land use can be used to analyze stormwater related as well as water quality related problems.

As previously mentioned, very little water quality data exists for Severn Run. In order to analyze the water quality condition of Severn Run and most of the other streams within the county, water quality sampling and monitoring programs will be required. The type of monitoring program to be used, the parameters to be sampled, and the location of monitoring sites are a function of the objectives of the data collection program. In general, there are three types of monitoring programs: trend monitoring, synoptic monitoring, and pollution source identification monitoring.

Trend monitoring programs are used to provide general baseline water quality data. By conducting the program for a number of years, basic changes or trends in water quality conditions can be identified. Samples are normally taken every other week at a few key locations. This type of sampling program does not usually identify exact sources of pollution; rather, it determines whether a problem exists and/or if a problem is developing. Trend monitoring does not produce the type of data required for the more complex water quality models. However, sufficient data is generally measured for the more simplistic water quality models. Typically, trend monitoring programs do not define wet weather problems, diurnal changes in parameters, or pollution sources.

Routine grab-sampling at a multitude of sampling stations is of little value for meaningful analysis of water quality conditions. In order to provide adequate data for both model calibration and a meaningful analysis of water quality, a synoptic type of water quality monitoring program is required. A synoptic monitoring program is one that is designed to collect data on the river system as a whole in a coordinated intensive sampling program conducted over a relatively short time frame (several days to two weeks). Diurnal variations, the effect of point and nonpoint sources, and the effect of river hydraulics can be identified with this type of sampling program. Seasonal variations may be discerned by conducting a similar program at various times of the year. Trends in water quality may be identified with subsequent routine monitoring or, preferably, by subsequent synoptic monitoring during similar hydrologic conditions.

For most water quality parameters (or processes), a synoptic study is the only means by which enough concurrent data can be collected to obtain a reflection of the water body as an integral, continuous system. Even with a well-designed study, this reflection can be seen for only a brief period. However, subsequent studies made during diverse conditions allow meaningful comparisons to be made.

Unlike routine monitoring, synoptic studies can easily be tailored to fit the needs of each particular area. This allows a concentration of effort on paramaters and problems of interest, rather than the expenditure of effort on arbitrarily selected parameters at arbitrary locations.

The selection of sampling locations and the frequency of sample collection are problems that each study must assess for itself based on the objectives of the study, budgetary and time constraints, knowledge of water quality problem areas in the river, hydraulics of the river, and access to potential sampling sites. A thorough study of existing data can help determine water quality problem areas and the more essential parameters to be measured. Ideally, each type of hydraulic regime should be sampled; i.e., lakes, rapids, pools, etc. Temperature and dissolved oxygen measurements should be taken every few feet of depth in a lake in a consistent manner to determine its degree of stratification or mixing, and the effect of sediment oxygen demand.

Stormwater runoff may be measured by separate monitoring programs or by in-stream measurements. In-stream measurements should be located below a largely uniform land use, with samples taken during the storm event to determine the pollutant loading. Samples should also be taken further downstream after the event, in order to determine the in-stream water quality impacts of the nonpoint source pollutants.

Parameters that should generally be considered are:

Flow
Temperature
Dissolved oxygen
pH
Turbidity
Total coliform, fecal coliform, and fecal streptocci bacteria
Suspended solids
Biochemical oxygen demand
Chemical oxygen demand
Sediment oxygen demand
Total Kjedhal nitrogen
Ammonia nitrogen
Nitrite and nitrate nitrogen
Ortho Phosphate phosphorus
Chlorophyll a (phytoplankton)
Oil and grease
Heavy metals
Pesticides
Other toxins

In addition to these physical-chemical parameters, concurrent biologic studies should be conducted, especially of algae and macroinvertebrates. These should be checked for pollution resistant and pollution indicator species to obtain a balanced physical-chemical and biologic picture of the water quality conditions within the streams.

The third type of sampling program is problem-specific, and often consists of specialized techniques to identify specific sources of pollution. This program should be conducted after problems have been identified, possible pollution sources determined, and a comprehensive plan to identify the sources worked out. It may include urban runoff sampling, landfill monitoring, agricultural runoff sampling, septic system analysis and more. This type of program would lead to control alternative recommendations.

The decision to model or not model the water quality of a stream, lake, or estuary should be made after an initial analysis of water quality data to determine if problems currently exist or may exist in the future. Certain water quality models are very good at considering point source problems and the degree of effluent control required to improve in-stream quality. Some models can also be used to predict future water quality conditions as development increases the urban nonpoint sources of pollution. However, quantifying the degree of effectiveness of nonpoint source control measures is presently beyond the state of the art of current models, although by assuming differing degrees of effectiveness, assessments on the general importance of nonpoint source controls can be made. Models allow "what if" alternatives to be analyzed, and can be an invaluable aid in water quality studies.

Water quality studies can be expensive and time-consuming unless clear objectives and priorities are determined at the outset. A series of synoptic monitoring programs would be preferable to biweekly samples for both trend analysis and detailed studies. The synoptic programs should include wet and dry weather conditions and various seasons. A synoptic program can be designed that would cost about the same as a biweekly trend monitoring program.

GROUNDWATER STUDIES

Although several groundwater studies have been done for Anne Arundel County by the Maryland Geologic Survey, a comprehensive study of the use and management of groundwater and other potential water sources as a potable water supply has not been completed. Since the county relies heavily on groundwater and has a large supply, this natural resource should be properly managed. Stressing a particular aquifer by increased pumping could create some serious problems. There is a possibility that withdrawing excessive quantities of water from the Patapsco aquifer could result in saltwater intrusion in the Magothy aquifer, which would make it unsuitable as a water supply. This may occur in areas below Round Bay on the Severn River and the Broadneck peninsula below Dividing Creek in the Magothy River watershed.

Another potential problem is the urbanization of aquifer recharge areas both within and outside the county. Urbanization decreases the amount of water that goes to groundwater storage, and with increasing water supply demands, could result in localized water shortages from a given aquifer.

Depending on the "leakiness" of the impermeable layer separating aquifers, it is possible to draw water from a polluted shallow aquifer into a deeper, heavily pumped aquifer. This could result in rendering the deeper aquifer unsuitable for potable water supply purposes.

The Maryland Geologic Survey has conducted four groundwater studies for the Anne Arundel County Office of Planning and Zoning. Two are complete and the other two are still in progress. This interest in increasing the knowledge about one of Anne Arundel County's vital natural resources is to be commended. Without the information and details on the area's aquifer system provided by these studies, a comprehensive planning project could not be undertaken.

It is suggested that the county, in cooperation with the Maryland Geologic Survey, the Department of Natural Resources, and surrounding jurisdictions, consider undertaking a comprehensive groundwater supply study. Other counties need to be included because they are potential withdrawers from the aquifers and they contain substantial recharge areas. The Maryland Geologic Survey is conducting a computer modeling study, the results of which would aid a comprehensive groundwater management study.

There is some concern regarding the possibility of polluting the shallow aquifers. Possible pollution sources are saltwater intrusion, failing septic systems, illegal dumping of wastes into springs, and groundwater injection of wastes or polluted water. Anne Arundel County has large reserves of groundwater, but must be careful not to mismanage this invaluable resource.

ADDTIONAL CONCERNS FOR THE SEVERN RUN WATERSHED

Hydrology and Hydraulics

This study based the ultimate hydrologic simulations on land use as determined from county zoning maps current in June 1978. If zoning variances, special exceptions, or rezoning occurs the flows for individual subbasins and to a lesser extent, for Severn Run, will change. In order to reflect future land use changes not anticipated when the study was completed, the hydrologic model will require periodic rerunning to obtain updated flows. These flows can be used with the HEC-2 hydraulic backwater results to update the boundaries of the 100-year flood plain.

Twenty-two miles of stream were considered in the backwater analysis of this study. Several tributaries were not considered due to budgetary constraints. If land development plans change, new areas may have to be considered for backwater analysis. Upper Delmont Road Branch and Broad Branch, due to their proximity to Glen Burnie, are areas that could experience more intensive urbanization than planned. These areas may be considered for future backwater analysis.

Stream Gages

If it were decided to gage Severn Run for future studies (water quality, etc.) or to verify the hydrologic simulation of this study, great care must be taken in the location of the gage. As discussed earlier, if only one gage were used downstream from Route 3, an inaccurate picture of the results of urbanization would be obtained.

Several options are available for gaging Severn Run: (a) Route 3 only; (b) Route 3 and Dicus Mill Road; (c) Route 3, Dicus Mill Road and Jabez Branch; or (d) Dicus Mill Road and Jabez Branch. Gages at Route 3 and Dicus Mill Road would adequately determine peak flows and hydrographs that would allow analysis of the impacts of urbanization on the watershed. Any plans to gage other tributaries should be carefully reviewed to make certain the gage is located correctly.

Water Quality

Existing data is insufficient to accurately determine the water quality conditions of Severn Run and its tributaries. In order to determine the sources of pollution and the nature of water quality in Severn Run, a water quality study should be undertaken. The study should collect and analyze data prior to making any decisions on water quality modeling.

It is recommended that a water quality study for Severn Run consist of an initial 2- to 5-day synoptic study using the water quality sampling sites given in Figure 7-3. The study should be designed to determine the impacts of sedimentation, particularly on macroinvertebrates, fish spawning areas, and the upper reaches of the Severn River. Picture Frame Branch should be closely studied for any adverse thermal impacts caused by the industrial dischargers. Other areas of concern are Lake Marion, urban runoff, failing septic systems, in-stream algae, dump sites, groundwater quality, and leaking sanitary sewer systems.

The value of any monitoring program depends upon the proper selection of monitoring locations. For example, the sanitary sewage pump house on Burns Crossing Road is located downstream from an area that allows horses direct access to the stream. Fecal coliform or total coliform samples below the pump house could well have high values that are caused by the horses, rather than the pump house. Without detailed knowledge of the area being studied, the high bacterial levels could be wrongly blamed on the pump house.

Portions of the study could be done by college students as part of their academic program. Close supervision would be required to ensure that proper sampling procedures, sample preservation, and analytical techniques are used. The potential for DNR and other state or federal agencies to assist is currently being investigated by the office of Planning and Zoning. Biological surveys should be done concurrently with the water quality sampling.

WATERSHED MANAGEMENT PROGRAM

Some initial suggestions regarding the establishment of a watershed management program follow. These suggestions should be considered preliminary and as food for thought rather than as inflexible dictates. An effective, enthusiastically supported watershed management program will have to evolve with time to adequately reflect the county's needs and concerns. Unless the program is genuinely desired by the county it will fail. As stated by Mr. Colby B. Rucker, a member of the Severn Scenic River Advisory Board, "Any plan (program) is only as good as the resolve of the people and their government to make it work."

It is hoped that the recommendations and considerations of this study will lead to the formation of an active, full-time multiagency watershed management program. The agencies involved should include: the office of Planning and Zoning, Department of Inspections and Permits, Department of Public Works, Public Health Department, Soil Conservation District, Anne Arundel County and Regional Planning Council 208 staff personnel, and state agencies as the need arises. Representative citizens' groups should be involved in the program.

The purpose of the program would be to ensure that decisions and problems regarding flooding, land surface erosion, stream channel erosion, water quality, environmentally endangered areas, recreation and park areas, land use planning, traffic planning, groundwater, water and sewer services, and other items are considered from a watershed viewpoint as well as a local viewpoint. The program would also serve as a means to increase communication and cooperation between agencies so that watershed management and protection becomes a viable day-to-day concern and is actively considered in the decision making process.

The initial steps for a watershed management program have already been taken. By establishing the Environmental Resources Section, the Office of Planning and Zoning has taken the lead role in watershed management. Included on the staff of the Environmental Resources Section (ERS) are 208 program staff members and water resources, coastal zone, solid waste, and environmental planners, some of whom are contract rather than permanent staff.

It is suggested that the ERS staff include a permanent water resources planner and a permanent watershed/sector planner. Permanent positions are desirable to allow a continuous, long-term commitment to watershed concerns, rather than facing the annual uncertainties of staff position and program continuation.

One of the tasks presently in progress by the ERS is designed to evaluate criteria and collect data to establish the next watershed for a detailed study. Several options are available for this study. One is to have a consultant perform the complete study as was done for

Severn Run. Another option is to have a consultant do part of the study and direct the efforts of the Environmental Resources Section for the remaining elements of the study. Or, the county can do the study completely in-house.

Currently, sufficient staff and expertise does not exist within the county to complete a watershed study in a timely fashion. Staff members with training and experience in the following fields would be required: hydrology, hydraulics, computer simulation, groundwater hydrology, statistics, biology, water quality, geology, soils, channel morphology, graphics, sediment transport, and project management. This would normally require as a minimum a hydrologist/hydraulics engineer, a water resources engineer, a biologist (all with graduate degrees and two years' experience), and a graphics technician.

If the county desires to eventually do in-house watershed management studies, it should consider hiring most of the required staff and working with a consultant on an as-needed basis to provide project management and technical assistance until the county staff becomes familiar with the methodology and approach to watershed studies.

Increasing the capabilities of the Environmental Resource Section by learning to use hydrologic models is recommended and could be quite valuable in land use planning. By running a model that has previously been applied to a watershed, the hydrologic and hydraulic impacts of land use changes can be evaluated. Sector plans could include testing various land use scenarios to determine which causes the least amount of flood damage and stream channel erosion. Detailed knowledge of how to completely apply a model would not be required. The stream channel routing configuration would remain the same with the various land uses applied. For TR20 this implies changing the curve numbers for the subbasins and leaving the rest of the input stream intact. The ability to conduct these tests could result in more meaningful and useful land use planning.

Integrating sector plans and watershed management planning would be an essential element of the watershed management program. Also required is the inclusion of stormwater management into sector/watershed plans to ensure that land use plans will provide the desired results. This will require close cooperation between the Office of Planning and Zoning and the Department of Public Works as well as a commitment from DPW to provide staff time to analyze stormwater mangement alternatives and assist the Department of Planning and Zoning. The primary duty of this staff engineer should be stormwater and watershed management.

Land use plans may be formulated to protect certain unique ecological areas or require very strict erosion controls during and after construction. To provide this protection, adequate sediment control plans must be prepared and strictly followed. Any such areas should be noted by Planning and Zoning and given extra attention by the Department of Inspections and Permits and the Soil Conservation District. Spot checks by other agencies to help the Department of Inspections and Permits monitor the construction sites could be considered.

Establishing a successful watershed management program will require a strong commitment from the people of Anne Arundel County and their government. The program will require close interagency cooperation and maintenance of sufficient staff to allow those charged with the responsibilities of watershed management to work on the program, rather than other projects. With a strong and dedicated watershed management program, the waters and land of Anne Arundel County will continue to be a valuable resource for generations to come.

Glossary

APPENDIX A
GLOSSARY OF TERMS

Accretion: Outward growth of banks or shore by sedimentation.

Aggradation: Upgrading of a stream bed by sedimentation.

Annual flood: The maximum rate of flow occurring in a stream during any period of 12 consecutive months.

Antecedent moisture condition: A respresentation of the amount of moisture in the soil prior to a rainfall event.

Aquifer: An underground layer of porous rock, sand, etc., containing water.

Average flow: The arithmetic average of the discharge at a given point or station on the line of flow for some specified period of time.

Backwater: Ponding of a stream above an unnatural constriction; the incremental depth caused thereby.

Backwater curve: Sometimes, in a generic sense, all computed water-surface profiles, usually in cases where the water is flowing at depths greater than the critical. In uniform channels, curve is concave upward.

Bank: The continuous margin along a river or stream where all upland vegetation ceases.

Bank full flow: Flow in a channel that is just up to the top of the bank, usually around the 2-year flow.

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

Basin: A natural or artificially created space or structure, surface or underground, that has a shape and character of confining material that enables it to hold water, or the surface of the area tributary to a stream or lake.

Bernoulli's Theorem: An equation describing the available energy of a body of water.

Biochemical oxygen demand (BOD): The quantity of oxygen used in the biochemical oxidation of matter in a specified time, at a specified temperature, and under specified conditions.

Channel: A waterway that periodically or continuously contains moving water. It has a definite bed and banks that confine the water.

Channelization: The straightening and dredging of a stream and the clearing of overbank areas to permit the rapid passage of flood flows.

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

Channel routing: Tracing the movement of a stream flow down a channel using mathematical approximations to synthesize such movement.

Confluence: The convergence of two streams of comparable size into a single channel.

Constriction: An obstruction narrowing a waterway.

Contour: A line of equal elevation above a specified datum, usually mean sea level.

Corrasion: Erosion or scour by abrasion in flowing water.

Critical: A condition of flow (and corresponding depth, slope and velocity) for which the specific energy is a minimum.

Cross section: Measurement of a stream's channel and flood plain at a right angle to its direction of flow.

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

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

Curve number (CN): A number representative of hydrologic conditions that determines the amount of rainfall that becomes overland flow.

Dam: A barrier constructed across a watercourse for the purpose of (a) creating a reservoir, and (b) diverting water therefrom into a conduit or channel.

Degradation: Downgrading of a stream bed by scour.

Deposition: The act or process or settling solid material from a fluid suspension.

Depression storage: The volume of water, expressed as depth on the entire water surface of the area, that is required to fill natural depressions.

Depth: Vertical distance, (1) from surface to bed of a body of water (2) from crest or crown to invert of a conduit.

Design flood: The largest flow that a reservoir, channel, or other works can accommodate without damage or with limited damage.

Detention: Temporary storage of storm water runoff and the subsequent slow release of the water to drainage-ways.

Detention dam: A small dam constructed to impound or retard surface runoff temporarily. Also used to bring about deposition of soil being carried away by runoff of surface water.

Dike: An embankment constructed to prevent overflow of water from a stream or other body of water.

Discharge: As applied to a stream or conduit, the rate of flow, or volume of water flowing in the stream or conduit at a given place and within a given period of time. Usually expressed in cubic feet per second (cfs).

Dissolved oxygen (DO): The oxygen dissolved in water. Usually expressed in milligrams per liter.

Diversion channel: An aritificial channel constructed around a point of high potential flood damages to divert floodwater from the main channel.

Drainage area: The area of a drainage basin or watershed. Usually expressed in acres or square miles. Also called catchment area, watershed, and river basin.

Dominant discharge: That streamflow that tends to determine the dimensions of a stable stream channel, usually between the 1.4- to 2-year flood.

Ecosystem: A complex of ecological community and environment forming a functioning whole in nature.

Encroachment: The use of the flood plain for anything that would alter the natural flooding process.

Erosion: The wearing away of soil by running water.

Erosion factor: An approximate measure of the ratio of the possible increase in a stream's width due to increases in the dominant discharge.

Evaporation: The process by which water becomes a vapor at a temperature.

Evapotranspiration: The total water loss from the land and water surfaces including that by direct evaporation and that by transpiration from the surfaces of plants.

Fecal coliform: An indicator bacteria that lives in the intestines of warm blooded animals. Its pressure suggests the possibility of bacterial contamination.

Flood: A relatively high flow as measured by either gage height or discharge quantity.

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 that will, over a long period of time, be equaled or exceeded on the average once every "n" years.

Flood frequency curve: A curve that shows the relation of discharge, in ratio to the recurrence interval in years.

Flood plain: For a given flood event, that area of land adjoining a watercourse which has been covered temporarily by water.

Flood plain managment: Utilizing various land use controls so as to restrict the use and development of flood plains and other flood-prone areas. Flood plain legislation is currently one of the many tools being used to protect environmentally sensitive areas.

Flow, steady: Flow at constant discharge.

Flow, unsteady: Flow on rising or falling stages.

Flow, varied: Flow in a channel with variable section.

Friction: Energy-dissipating conflict among turbulent water particles disturbed by irregularities of channel surface.

Gabion: A basket or cage filled with earth or stone and placed as, or as part of, a bank-protection structure.

Gaging 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. The station usually has a recording gage or some other gage for measuring the elevation of the water surface in the channel or conduit.

Grade: 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.

Groundwater: Subsurface water occupying the saturation zone, from which wells and springs are fed. Provides the base flow of streams.

Head: Energy expressed as potential, usually in feet. A measure of static or dynamic activity of water, especially in its conversion to kinetic form.

Hydraulics: The branch of science that deals with practical applications of the mechanics of water movement.

Hydrograph: A graph showing, for a given point on a stream, the discharge or stage 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 processes such as precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transpiration.

Hydrologic soil group: A classification of soils by the Soil Conservation Service into four runoff potential groups.

Hydrology: The science dealing with the processes governing the depletion and replenishment of the water resources of the land areas of the earth.

Impervious surface: That portion of the land surface through which water cannot infiltrate.

Impoundment: A pond, lake, basin, or some other space, either natural or created in whole or in part by the building of engineering structures, that is used for the storage, regulation, and control of water.

Infiltration: The entering of water through the interstices or pores of a soil.

Jump: Sudden transition from supercritical flow to the complementary subcritical flow, conserving the momentum and dissipating energy; the hydraulic jump.

Mean depth: For a stream at any stage, the wetted normal section divided by the surface width; hydraulic mean depth.

Meander: Indirect or devious alignment of channels in erodible, alluvial valleys of a mature stream.

Mean velocity: For a stream at any stage, the discharge divided by area of the wetted normal section.

Manning's equation: An equation that describes flow in open channels.

Manning's "n": A term in Manning's equation that represents flow resistance or channel and flood plain roughness.

Natural drainage system: A drainage network consisting of both surface and underground watercourses and underground watercourses such as streams, rivers, and underground aquifers, all of which were created by natural agencies and conditions. These watercourses work together to drain a particular drainage basin.

NEH-4: SCS publication, National Engineering Handbook 4, Hydrology.

Onsite detention/retention ponds: Ponds that act as a control on erosion while at the same time reduce the discharge of peak runoff flows to the natural drainage area.

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

Overland flow: The flow of water over the land surface before it enters a defined channel.

Oxygen demand: The quantity of oxygen utilized in the biochemical oxidation of organic matter in a specified time, at a specified temperature, and under specified conditions.

Peak flow: Maximum instantaneous quantity or rate of flow of water at a given location.

Permeability: The property of a material that permits movement of water through it when it is saturated and the movement is actuated by hydrostatic pressure of the magnitude normally encountered in natural subsurface water.

Permeable: Having a texture that permits water to move through it.

Pollution: A condition created by the presence of harmful or objectionable material in water.

Precipitation: The total measurable supply of water received directly from clouds of rain, snow, hail, or sleet. Usually expressed as depth in an hour, day, month, or year, and designated as hourly, daily, monthly, or annual precipitation.

Probability: The chance of occurrence or recurrence of a specified event within a unit of time, commonly expressed in 3 ways. Thus a 10-year flood has a chance of 0.1 per year and is also called a 10 percent chance flood.

Rainfall duration: The length of time that rainfall occurs for a given storm event.

Rainfall intensity: Rate of rainfall.

Rainfall, type II: A distribution of rainfall over time used by the Soil Conservation Service.

Reach: A length of a stream suitable for description or analysis as a unit.

Recharge: The addition of water to the zone of saturation from precipitation, infiltration from surface streams, and other sources.

Recurrence interval: The average interval of time within which a given event will be equaled or exceeded once.

Regimen: The characteristic behavior of a stream during ordinary cycles of flow.

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

Retention: Storage of stormwater runoff in a facility that has a relatively permanent minimum water level.

Rip rap: 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 large stream of water that serves as the natural drainage channel for a drainage basin of considerable area.

River basin: The area drained by a river and its tributaries.

Rooftop ponding: A type of surface storage whereby existing rooftops, along with a downspout and overflow designed to drain the roof at a slow rate, store and retain storm water. This results in an increase in time of concentration of storm runoff.

Runoff: Diffused water derived from precipitation which reaches a stream, drain, sewer, ect.

Runoff curve number: See curve number.

Runoff potential: The possibility of precipitation becoming a part of surface runoff. This potential is dependent on the existing ground cover makeup; that is, surfacing or stripping of the land resulting in an impervious layer will increase the amount of surface water runoff. Conversely, decreasing the amount of impervious cover will reduce the runoff potential because more water infiltrates into the ground.

Scour: The action of a flowing liquid as it lifts and carries away the material on the sides or bottom of a stream channel.

Sediment: Soil matter transported or deposited by water.

Sedimentation: The process of subsidence and deposition of suspended matter carried by water and by gravity. This process is usually accomplished by reducing the velocity of the water below the point at which it can transport the suspended material.

Sedimentation basin: A basin or tank in which water or wastewater containing settleable solids is retained to remove by gravity a part of the suspended matter.

Slope: The inclination of gradient from the horizontal of a surface, stream bed, energy line, etc. Usually measured in feet/feet.

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

Storage: The impounding of water, either in surface, rooftops, instream, or underground reservoirs, or in mines or tunnels for future use. The term differs from pondage and regulation in that the latter refer to more or less temporary retention of the water, whereas storage involves retention for much longer periods.

Storm drain: A closed conduit conveying storm water.

Storm runoff: That portion of the total runoff that reaches the point of measurement within a relatively short period of time after the occurrence of precipitation.

Streamflow record: A report that usually consists of description of a gaging station, a skeleton rating table, and a table showing the daily discharge and monthly and yearly discharge of the stream.

Surface storage: Impounding water in various surface structures such as in-stream reservoirs, rooftops, ponds, quarries, and swales.

Suspended sediment: The very fine soil particles that remain in suspension in water for a considerable period of time without contact with the bottom.

Swale: a slight depression or a wide, shallow ditch, usually grassed or paved.

Terracing: A method for retarding erosion by constructing terraces on sloping grounds.

Time of concentration: Time required for surface runoff from the most remote part of a drainage basin to reach the basin's outlet.

Topographic map: A map showing the various topographic features of a given area, such as hills, valleys, mountains, slope of the land surfaces, usually by means of contours or lines connecting points of equal elevation

Transpiration: The process by which water vapor is lost to the atmosphere from living plants.

Transport: To carry solid material in a stream--in solution, suspension, saltation, or entrainment.

Watercourse: A natural or artificial channel for passage of water.

Water quality: The chemical, physical, and biological characteristics of water with respect to its suitability for a particular purpose.

Watershed: The area contained within a divide above a specified point on a stream.

Water surface profile: The longitudinal profile asumed by the surface of a stream of water flowing in an open channel.

Water table: The upper surface of the zone of soil saturation.

Waterway: Any natural or artificial channel that provides a course for water flowing either continuously or intermittently.

Weir: A stream obstruction built to divert streamflow through an opening prepared such that discharge can be readily measured.

TR20: Soil Conservation Service's hydrologic computer simulation model.

TR55: Technical Release No. 55 by the Soil Conservation Service, Urban Hydrology for Small Watersheds.

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APPENDIX B
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