MANAGEMENT PLAN

FOR THE

WEEMS CREEK WATERSHED

Prepared for the

ANNE ARUNDEL COUNTY

DEPARTMENT OF PUBLIC WORKS

Prepared by

GREENHORNE & O'MARA, INC.

August 1985

MANAGEMENT PLAN FOR THE
WEEMS CREEK WATERSHED

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1. INTRODUCTION

Within the last two years, Anne Arundel County has undertaken a comprehensive program of stormwater management. Under the direction of the Department of Public Works and the Office of Planning and Zoning, watershed plans and policies are being formulated and implemented. The major goal of the stormwater management program is to protect the County's riverine and tidal water resources as land in Anne Arundel County is converted into urban uses.

One of the initial components of the County program is the development of a Management Plan for the Weems Creek Watershed. The essential elements of this plan are presented in subsequent sections of this report.

1.1 GOALS AND OBJECTIVES

The management plan for the Weems Creek Watershed is intended to provide a series of recommendations which, when implemented, will:

- o Reduce existing and future erosion and sedimentation problems;
- o Reduce the potential for water quality degradation;
- o Minimize or eliminate flooding impacts;
- o Preserve the natural and environmentally sensitive areas in the watershed, particularly the wetland areas; and
- o Maintain and/or enhance the scenic and recreational values within the watershed.

To develop the most effective recommendations, a number of quantitative and qualitative water resources analyses were made as part of this study.

It is also the intent of the plan to address the concerns expressed by citizens residing in the watershed and to be compatible with existing policies, regulations and planning of the County and the State.

1.2 PLAN DEVELOPMENT

A comprehensive watershed management plan must deal with a broad range of technical information, issues, policies, and regulations. Guidance for the development of the Weems Creek Plan was obtained from the following sources:

- o Anne Arundel County Stormwater Management Ordinance (1984)
- o Anne Arundel County General Development Plan (1978)
- o Current zoning for Anne Arundel County
- o Critical Area Legislation and the proposed criteria for development
- o Maryland Wetlands Act (1970)
- o Weems Creek - Tidal Areas, Technical Study by Engineering Technologies Associates (1985)
- o Weems Creek - Non-Tidal Areas, Technical Study by Greenhorne & O'Mara (1985)
- o State Highway Administration Highway studies
- o A Greenway Strategy for Weems Creek, Weems Creek Conservancy
- o Anne Arundel County Soil Survey (1982)
- o Modification of Existing Pond at Annapolis Mall and J.R. Annapolis, Report by Engineering Technologies Associates (1985)
- o Various other data, plans, and information provided by the Office of Planning and Zoning and the Department of Public Works

2. EXECUTIVE SUMMARY - STUDY RESULTS AND MANAGEMENT PLAN RECOMMENDATIONS

This chapter presents a summary of the findings of the Weems Creek Watershed Study. The purposes of the study were to identify existing and potential future water resources problems and to recommend a plan of action to remedy these problems.

For cases in which insufficient data or information exist to conclusively define whether or not a problem exists (such as the situation with nutrient loads to the tidal reach and their contribution to algae growth), on-going monitoring and further investigations are recommended.

A summary of the specific results of the watershed analysis is presented below, followed by a summary of the elements of the recommended watershed management plan. Results of technical analyses and management alternative evaluations are presented in Chapters 5 and 7. The recommended Weems Creek Watershed Management Plan is presented in detail in Chapter 8.

2.1 STUDY RESULTS

The study findings were derived objectively by means of field reconnaissance, stream surveys, hydrologic and hydraulic analyses, and nonpoint source pollutant loading studies. In general, the study findings are:

Flooding and Stormwater Management

- There are no residential structures or commercial properties experiencing flooding problems;
- Admiral Drive is flooded by storm flows having a 5 to 10 year recurrence period;
- The existing stormwater management ponds at Restaurant Park and J.R. Annapolis are effective in controlling runoff rates up to the 100-year storm event to pre-development levels.

Water Quality

- o Turbid waters in the tidal portions of Weems Creek upstream of Rowe Boulevard have been observed for extended periods following storm events;
- o Existing water quality data is insufficient to provide quantitative, or even reasonable qualitative, assessments of the level of water pollution in both the riverine and tidal reaches of the Creek;
- o Preliminary estimates indicate that uncontrolled runoff associated with ultimate land use will increase annual pollutant loadings to the Creek by 25 to 110 percent above existing loads;
- o Approximately 75 percent of the Anne Arundel County tidal portion of the watershed is within the designated Chesapeake Bay critical area (Figure 10);
- o The J.R. Annapolis pond will provide some water quality benefits by removing pollutants from the mall runoff.

Erosion and Sedimentation

- o Uncontrolled peak discharges associated with ultimate land use will have the potential to accelerate stream channel erosion in some reaches of the Creek;
- o The Weems Creek channel, starting at the culvert under the ramp from Rt. 50 (leading to West Street) to a point approximately 480' downstream, exhibits results of severe stream channel erosion;
- o There are several significant sources of erosion in the watershed, including certain storm sewer outlets, bridge abutments, areas of steep slopes, and land surfaces under stress from recreational and development activities;
- o Junk and debris have accumulated at various locations in the non-tidal stream channels and floodplains, exacerbating channel erosion and severely impacting aesthetics of the streams.

2.2 MANAGEMENT PLAN RECOMMENDATIONS

The Management Plan provides a plan of action for alleviating existing problems and proposes recommendations for mitigating potential future problems related to flooding, erosion and sediment control, and water quality protection. Many alternatives were evaluated in order to determine the most effective and economical methods of minimizing the impacts of man's activities within the Weems Creek Watershed.

Recommended alternatives are categorized into three priority levels:

- o High Priority
- o Intermediate, and
- o Low Priority

Recommended alternatives were assigned priorities based on their relative effectiveness, the magnitude of the impact and/or problem, the estimated cost, and the effectiveness of the plan element in preventing future problems.

The plan consists of non-structural recommendations, relying on existing programs, agencies, and private organizations, as well as structural elements, directed at mitigating specific existing problems. As much as possible, structural solutions should be coordinated with planned capital projects (i.e., Anne Arundel County and State Highway Administration Highway projects) to achieve potentially cost savings.

As summarized in Table 13, high priority, structural recommendations, which must be coordinated with highway projects, include:

1. Channel improvements downstream of Route 50/301-West Street Ramp
2. Erosion control measures at the Route 50/301 bridge abutment near Admiral Drive, and
3. 100-year flood control measures at Admiral Drive

The locations of these proposed improvements are shown in Figure 7, as numbered above.

Additional high and intermediate priority structural elements include:

- o The stabilization and protection of steep slopes in both tidal and nontidal areas;
- o The establishment of a solid waste and sewerage collection station convenient to boats in the tidal portion of Weems Creek;
- o The implementation of multi-objective regional stormwater management facilities, and
- o The investigation in more detail of the feasibility of retrofitting appropriate existing stormwater management facilities to improve their performance in controlling water quality, sediment, and storm flows.

Recommendations of a non-structural nature include the continuation of existing programs in the areas of stormwater management, erosion and sediment control at new construction sites, floodplain management, and wetland preservation.

Two additional high priority plan recommendations are 1.) to restrict development on steep slopes greater than 15%, and 2.) to provide shoreline protection and aquatic vegetation at the base of steep slopes in tidal reaches to prevent further serious shoreline erosion.

It was also recommended that a water quality monitoring program be established to quantify and allow evaluation of the levels of pollution in the stream and tidal portions of Weems Creek. This program would provide baseline data necessary to monitor future changes in Weems Creek in order to determine if more intensive management alternatives are required to protect water quality. If monitoring results indicate that water quality degradation is occurring, two intermediate priority plan elements should be considered:

- o Parking lot cleaning in the Annapolis Mall area, and
- o Implementation of an information/education program to inform residents in the Watershed about what they can do to improve the situation.

The proposed management plan, as outlined above, is intended to provide a workable plan of action to:

1) maintain current stream conditions through coordinated, comprehensive water resources planning, and

2) using stream monitoring results, provide alternatives to improve water quality conditions and ensure the achievement of designated uses of Weems Creek into the future.

The implementation of this comprehensive watershed management plan calls for the cooperation of many individuals, agencies, and programs to ensure the long term viability of Weems Creek. With the cooperation and coordination provided by the Anne Arundel County Department of Public Works, the Department of Planning and Zoning, and the City of Annapolis, the water resources of Weems Creek can be successfully managed.

3. WATERSHED DESCRIPTION/CHARACTERISTICS

3.1 LOCATION

The Weems Creek Watershed covers a 1.90 square mile area and drains the east-central portion of Anne Arundel County and the northern portion of the City of Annapolis (See Figure 1), the centerline of the tidal portion of the creek being the border between the two jurisdictions. The study area is located approximately a mile and one-half north of downtown Annapolis.

The watershed is served by a number of major roads. U.S. Route 50/301 links Annapolis with Washington, D.C., to the west and the Maryland Eastern Shore to the east. The watershed is also served by a number of State highways including Maryland Routes 2 (Solomons Island Road), 70 (Rowe Boulevard), 178 (Generals Highway), 436 (Ridgely Avenue), and 450 (Defense Highway and West Street). The major County roads include Bestgate Road, Ridgley Avenue, Admiral Drive, and Jennifer Road. These roads influence the hydrologic characteristics of the watershed to a great degree in that highway embankments often impinge on natural floodways, cause ponding of floodwaters, and impact erosion and sedimentation processes. They also greatly affect the visual aesthetics of the stream reaches.

3.2 CLIMATE

The Weems Creek watershed is subject to a general atmospheric flow of air from west to east, as is characteristic of the middle latitudes of the North American continent. As a result, the watershed experiences a continental type of climate with well-defined seasons. These general characteristics of the climate are modified by the presence of the Chesapeake Bay to the east.

The warmest part of the year is the last half of July when maximum afternoon temperatures average 89^{o}F. The maximum temperature reaches 90^{o}F approximately 20 days each year. The coldest part of the year is the end of January and the beginning of February when minimum temperatures

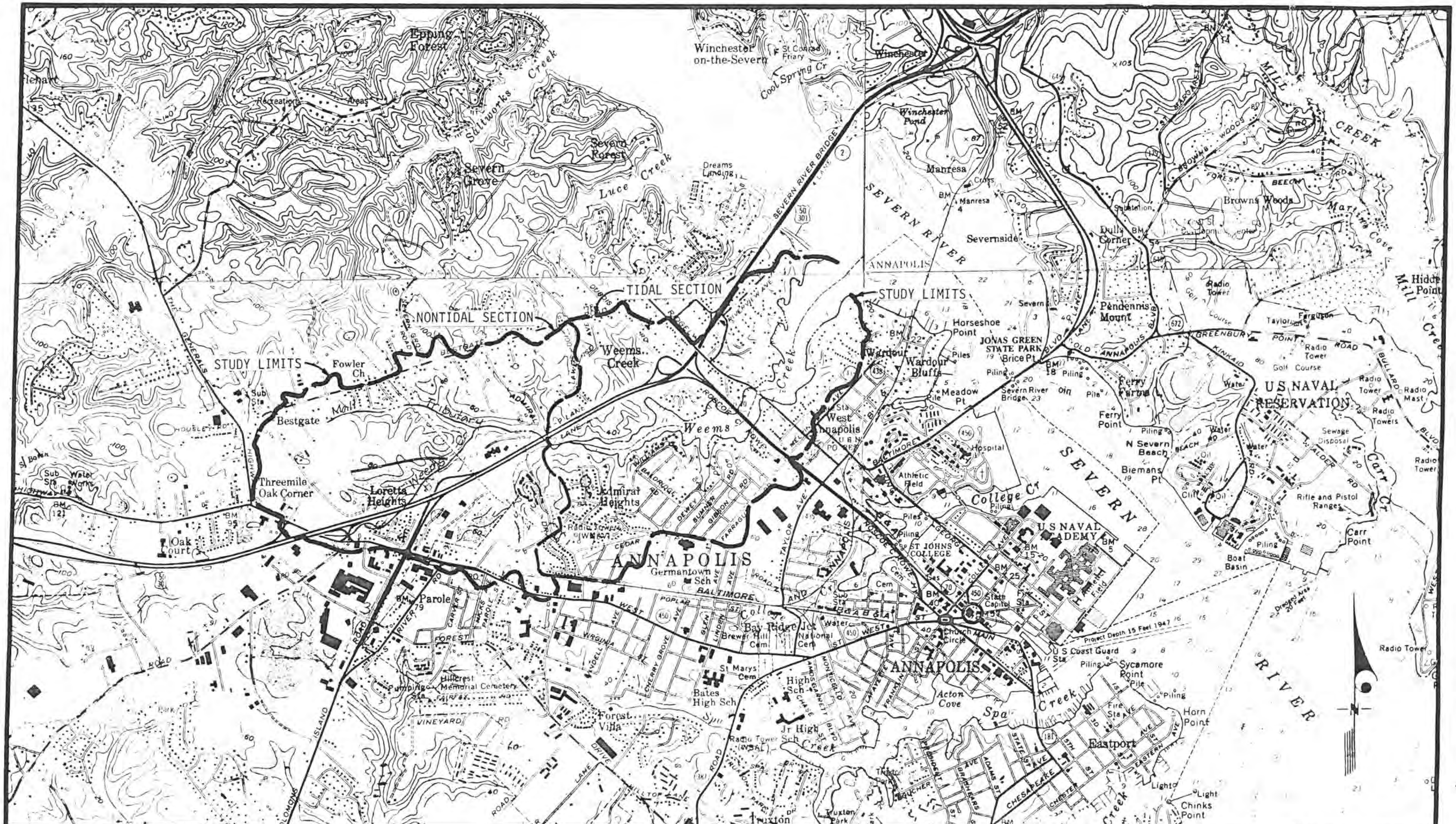

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FIGURE 1
MANAGEMENT PLAN FOR
WEEMS CREEK WATERSHED
VICINITY MAP
ANNE ARUNDEL COUNTY, MARYLAND

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average about 24°F. The temperature falls below 32°F approximately 80 days each year.

The average annual precipitation is 44 inches. Generally, this rainfall is uniformly distributed throughout the year. The precipitation during the colder half of the year is usually the result of low pressure systems moving northeastward along the coast. Approximately 2.0 inches of the averge annual precipitation falling each year is in the form of snow. The average annual snowfall depth is approximately 20 inches. In the summer, significant precipitation is often due to short duration thunderstorms.

3.3 GEOLOGY

The Weems Creek watershed is underlain by the Aquia Formation. This geologic formation is a thick, wedge shaped sedimentary deposit extending to a thickness of 180 feet in some places and comprised of large amounts of glauconite. The Aquia Formation is very firm and largely unweathered. The formation outcrops in a number of locations. This accounts for the 40 to 50 foot bluffs visible near the mouth on the city side of the creek and for the abundance of steep slopes throughout the watershed.

The Aquia Formation is used as a source groundwater in Anne Arundel County.

3.4 SOILS

The soils in the Weems Creek watershed belong to the Monmouth-Collington Association. A soil association is a distinctive pattern of soils including one or more major soils and at least one minor soil. In this association, the major soils belong to the Monmouth and Collington soil series and the minor soils belong to the Adelphia, Beltsville, Bibb, Butlertown, Donlonton, and Evesboro soils series. All of the soils in a soil series have similar profiles. The major horizons are similar in thickness, arrangements, and other important characteristics. According to the "Soil Survey of Anne Arundel County, Maryland" (4), the soils in this association are "nearly level to moderately steep, well-drained, sandy and loamy soils that developed in sediments containing glauconite."

Soils belonging to the Monmouth series cover approximately 60 percent of the watershed. These soils are primarily located on higher ground in the non-tidal portion of the watershed and in the tidal portion south of the creek. Monmouth soils are deep, well-drained soils that have an olive-brown surface layer, and a thick, olive-brown, moderately fine textured and fine textured, sticky subsoil. The soils range from loamy sand to clay loam. Monmouth soils have moderately low permeability and as such fall into the Soil Conservation Service's (SCS's) hydrologic soil group C. Areas underlain by Monmouth soils are characterized by steep slopes, high erosion potential, and gully erosion.

Approximately 25 percent of the Weems Creek watershed is covered by soils belonging to the Collington series. These soils can be found north of the creek, primarily in the tidal portion of the watershed. Soils belonging to the Collington series are deep, well-drained, predominantly brown soils of the uplands. The soils range from sandy loams to silt loams. Collington soils have moderately high permeability and fall into SCS's hydrologic soils group B.

Most of the remaining 15% of the watershed is covered by the minor soils of the Monmouth-Collington association. These minor soils fall into three of the four SCS hydrologic soils groups. Soils belonging to Evesboro series exhibit rapid permeability and are thus clarified as soil type A. The Adelphia, Beltsville, Butlertown, and Donlonton soils series are characterized by moderately low permeability and are classified as type C. The soils included in the Bibb series exhibit low permeability and are classified as soil type D.

Soils found near streams where the water table is very high and little water infiltrates where assigned to soil group D. Urban (disturbed) land and land used for gravel and borrow pits were assumed to fall into soil group C.

Maps showing the distribution of hydrologic soils groups were prepared for both the tidal and non-tidal portions of the watershed. The map for the non-tidal portion is given in Figure 2. The map for the tidal portion can be found in Reference 8. The distribution of the hydrologic soils groups on each of these maps is summarized in Table 1.

TABLE 1

DISTRIBUTION OF SOILS GROUPS

Soil Group	Non-Tidal Portion Area (Acres)	Non-Tidal Portion Percent	Tidal Portion Area (Acres)	Tidal Portion Percent	Entire Watershed Area (Acres)	Entire Watershed Percent
A	2.2	0.3	0	0	2.2	0.2
B	43.3	6.3	271.2	43.8	314.5	24.0
C	598.7	86.3	334.5	54.1	933.2	71.1
D	49.6	7.1	13.3	2.1	62.9	4.7
TOTALS	693.8	100.0	619.0	100.0	1312.8	100.0

3.5 SLOPES

Because the watershed is underlain by the firm, largely unweathered Aquia formation, many of the slopes along the creek's shoreline are steep to very steep (greater than 15 percent). Near the mouth, these steep slopes give way to 40 to 50 feet high bluffs. The steep slopes form a continuous band along the north (county) side of the creek and a less continuous, but distinctive, band along the south (city) side of the creek.

The soils of the Monmouth-Collington association account for most of the soils in the steeply sloping areas. These soils are highly erodable. A majority of the steep slopes in the tidal portion show some signs of erosion. A slope stabilization project involving revegetation near the cul-de-sac at the end of Tucker Street has been undertaken by the Anne Arundel Soil Conservation District and the local citizens to prevent further slope erosion.

Ref: U.S.D.A. Soil Conservatior
Soil Survey of Anne Arunde

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FIGURE 2
MANAGEMENT PLAN FOR
WEEMS CREEK WATERSHED
SOILS MAP
ANNE ARUNDEL COUNTY, MARYLAND

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Steep slopes, defined as those in excess of 15 percent, are also found near the stream in the non-tidal section. While these slopes are seldom as steep as those encountered in the tidal section, the potential for erosion exists. Most of the steep slopes in the non-tidal section are located in wooded areas and are therefore protected from the damaging effects of wind and rain. The root systems of trees growing on the embankments also provide stability. Another benefit of forested areas is produced by the mat of fallen leaves and other debris that shelters slopes from rainfall impacts.

Figure 3 contains a map showing the areas of the watershed with slopes exceeding 15 percent. The map is based on the information contained on the map "Geologic Factors Affecting Land Modification" developed by John D. Glaser and published by the Maryland Geologic Survey in 1976.

3.6 DEMOGRAPHICS

According to the report entitled "A Greenway Strategy for Weems Creek," the 1980 population of the watershed was estimated to be 3,388. Of these people, 3,065 were found to live in the City of Annapolis and 323 to live in Anne Arundel County. These populations compare to a 1980 population of 31,740 and 330,775 respectfully.

A majority of the homeowners in the watershed have lived there for over 15 years. These homeowners are generally white-collar workers, professionals, and retirees. Those employed work in one of the three nearby cities: Annapolis, Baltimore, or Washington.

3.7 STREAM SYSTEM

Weems Creek, which extends 2.8 miles from its confluence with the Severn River to Annapolis Mall, drains an area of approximately 1.9 square mile (1216 Ac).

The Weems Creek stream system consists of a tidal portion, which drains a number of small watersheds, and a non-tidal portion with one large tributary and a number of small tributaries (See Figure 4). The

LEGEND

SLOPES EXCEEDING 15 PERCENT

NOTE:

Based on Map of Geologic Factors Affecting Land Modification by John D. Glaser of The Maryland Department of Natural Resources

NOTE: Aerial Photography provided by Anne Arundel County Office of Planning and Zonning.

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FIGURE 3
MANAGEMENT PLAN FOR
WEEMS CREEK WATERSHED
STEEP SLOPES MAP
ANNE ARUNDEL COUNTY, MARYLAND

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NOTE: Aerial Photography provided by Anne Arundel County Office of Planning and Zonning.

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FIGURE 4
MANAGEMENT PLAN FOR
WEEMS CREEK WATERSHED
DRAINAGE AREA MAP
ANNE ARUNDEL COUNTY, MARYLAND

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tidal portion extends from the mouth at the Severn River westward approximately 1.5 miles to the U.S. Route 50/301 Bridge.

The tidal portion of the watershed consists of a series of coves along both sides of the creek. These coves cause the width of the tidal portion to vary from as little as 300 feet to as much as 1,200 feet. There are numerous very small tributaries that discharge into these coves. Only three of these unnamed tributaries drain areas larger than 50 acres. Depths in the tidal portion range from about 1 foot near the tidal interface to 14 feet near the center of the channel east of the Ridgely Avenue bridge.

The non-tidal portion of Weems Creek extends 1.3 miles from the U.S. 50/301 Bridge to the SWM pond in Restaurant Park. In this reach, the stream channel varies from about 3 to 5 feet in width and is about 1 foot deep on the average. One major tributary to Weems Creek in the non-tidal portion, called Mall Tributary in this study, is about 0.7 miles long extending from the confluence with Weems Creek to the Annapolis Mall. A number of smaller unnamed tributaries discharge into Weems Creek and Mall Tributary. Two of these tributaries drain more than 50 acres.

3.8 PUBLIC FACILITIES

3.8.1 Transportation

As was pointed out in Section 3.1, the Weems Creek Watershed is linked to the surrounding areas by a number of roads including U.S. Route 50/301 and Maryland Routes 2, 70, 178, 436, and 450. There is no airport in the immediate vicinity and no commercial water transportation enterprises operate on the creek. The tidal portion of the Creek does, however, provide adequate depths for recreational craft, thus allowing navigation to the Severn River and subsequently to the Chesapeake Bay.

At the time of this study, the Maryland State Highway Administration (SHA) is in the process of planning and designing improvements along the U.S. Route 50/301 Corridor. These improvements will upgrade U.S. Route

50/301 to bring it up to the standards of the Federal Interstate Highway system. The road will be renamed Interstate 68.

Proposed interchange modifications involve the interchanges at Maryland Route 450, Maryland Route 2 and Rowe Blvd. (Maryland Route 70). Under the existing plan, the interchange at Route 450 would be downgraded by eliminating the ramps connecting Route 450 and Riva Road with eastbound Route 50/301. The interchange at Route 2 would be upgraded to allow connections to Jennifer Road and to allow access from northbound Route 2 to westbound Route 50/301 and from eastbound Route 50/301 to southbound Route 2. This proposal also includes the replacement of the at grade intersection of Route 450 and Route 2 with a grade separation. A preliminary plan of the proposed interchange is presented as Figure 5.

Maryland Route 70 (Rowe Boulevard) would be extended north of Route 50/301 where it would tie into the existing Bestgate Road. A preliminary plan of the proposed interchange is presented in Figure 6.

The preliminary interchange plans presented in this report were provided by SHA. Final design has not been completed and, therefore, the plans shown are subject to change. Coordination of SHA plans with the Weems Creek Watershed Management Plan will be required.

3.8.2 Water and Sewer

The Weems Creek Watershed has areas with public water and sanitary sewer and areas with wells and septic tanks. The areas serviced with public water and sewer include: the majority of the areas within the City of Annapolis; the businesses and residences along the West Street corridor; the Annapolis Mall and Restaurant Park areas; and the Anne Arundel County Detention Center. The tidal portion below U.S. Route 50/301 receives public water but not public sewer. The residences throughout the remainder of the watershed rely on well water and septic tanks.

According to the "General Development Plan for Anne Arundel County," all of the area south of U.S. Route 50/301, and a majority of the area

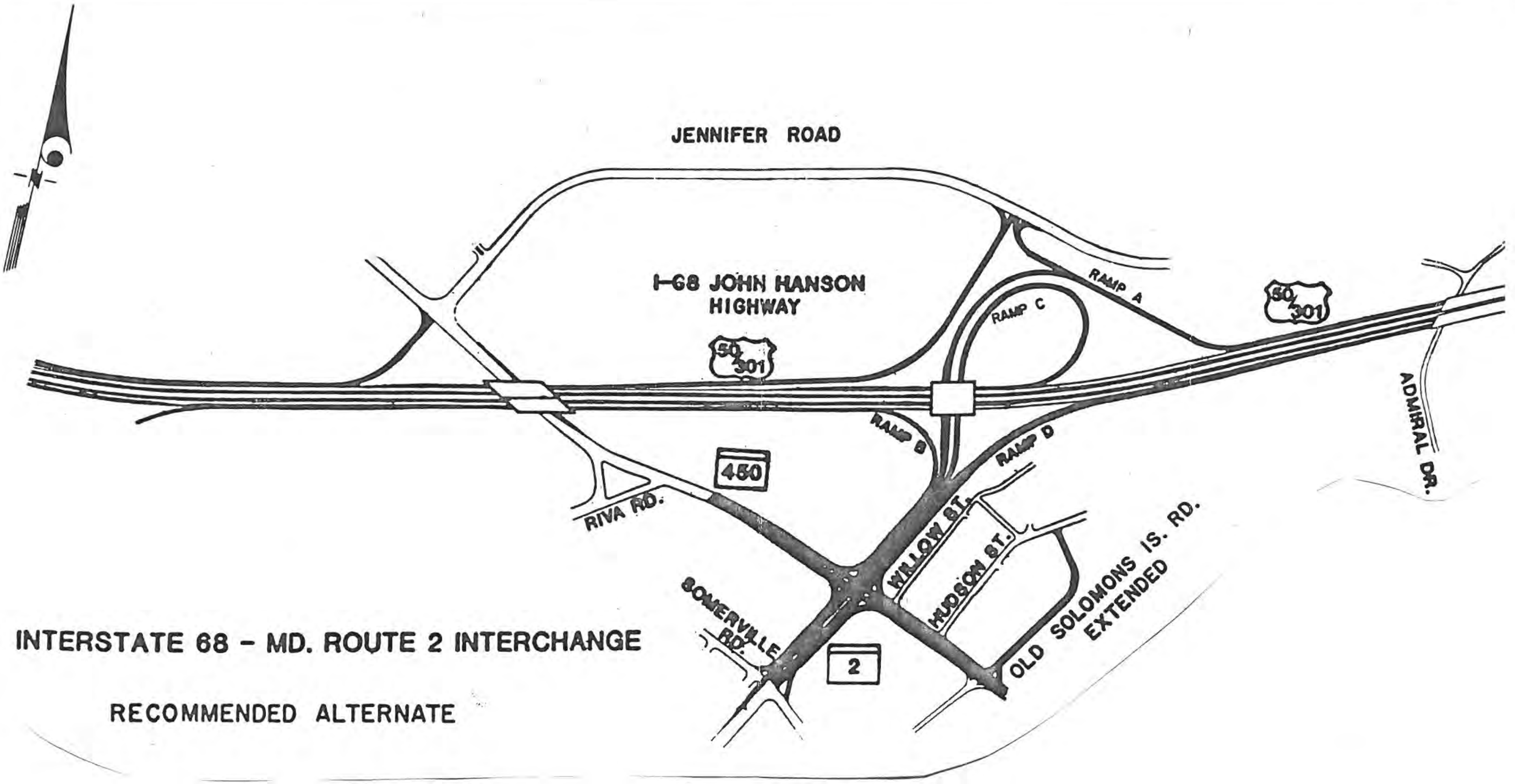

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FIGURE 5
MANAGEMENT PLAN FOR
WEEMS CREEK WATERSHED
PROPOSED INTERCHANGE AT MARYLAND RT/2
ANNE ARUNDEL COUNTY, MARYLAND

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FIGURE 6
MANAGEMENT PLAN FOR
WEEMS CREEK WATERSHED
PROPOSED INTERCHANGE AT MARYLAND RT/70
ANNE ARUNDEL COUNTY, MARYLAND

north of the highway falls within the 6-10 year water and sewer plans. The construction of these utilities will enable an orderly development in accordance with existing zoning and the County's critical area management plan (to be developed).

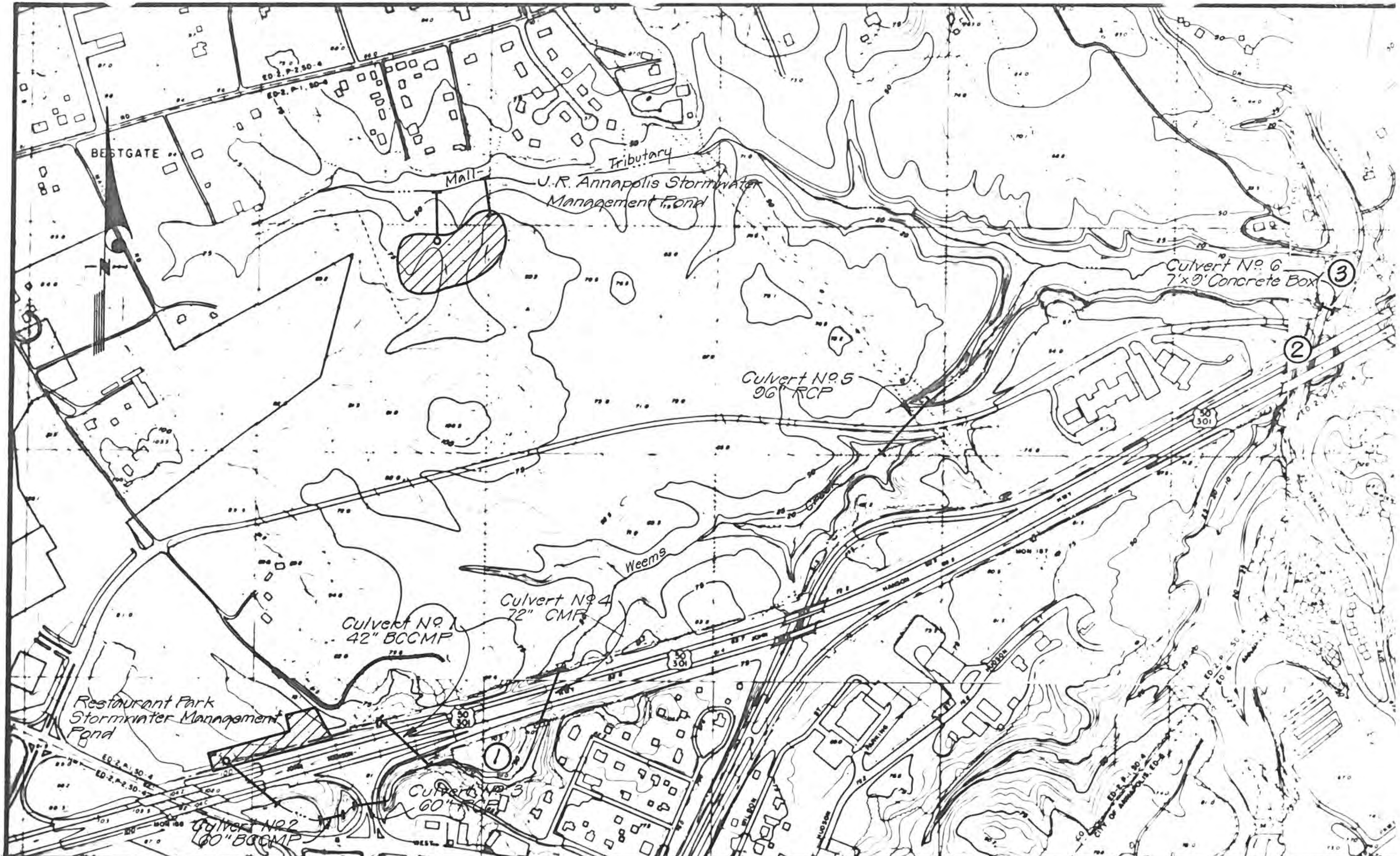
3.8.3 Drainage

Storm drains have been provided for low frequency events at a number of locations in the Weems Creek Watershed. These locations include most of the area within the City of Annapolis; the areas along the West Street corridor; the areas along Defense Highway (Rte 450); the Annapolis Mall and Restaurant Park areas; the Anne Arundel Detention Center; and the areas along the roadways especially along U.S. Route 50/301. The impact of these storm drain systems on storm runoff characteristics has been considered in the hydrologic analysis.

The Annapolis Mall and parking area has three outfalls: 1) to Salt Works Creek, 2) to Mall Tributary via the JR Annapolis pond, and 3) to Weems Creek via the Restaurant Park pond. Approximately 15% of the mall drains into Weems Creek. About 5% of the mall area is in the Salt Works Creek Watershed. The remaining 80% drains into the Mall Tributary. The Mall area draining to the Mall Tributary is hydraulicly connected to the Salt Works Creek drainage area by a 12 in. diameter connecting pipe. Therefore, all flows less than approximately 8 cfs will drain to Salt Works Creek. Mall runoff greater than 8 cfs at the connecting pipe flows to Mall Tributary.

3.8.4 Stormwater Management

Presently, there are two stormwater management ponds in the Weems Creek Watershed. These ponds were designed to reduce future peak discharges to predevelopment levels and are designed to be dry soon after storm events. Both facilities are located near the western side of the watershed (see Figure 7). The smaller of the two ponds, called the Restaurant Park pond, is located just north of U.S. Route 50/301 about 150 feet east of



(1), (2), (3) Locations of Major Proposed State Highway Improvements which affect plan recommendations

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FIGURE 7
MANAGEMENT PLAN FOR
WEEMS CREEK WATERSHED
LOCATIONS OF EXISTING CULVERTS
AND SWM PONDS
ANNE ARUNDEL COUNTY, MARYLAND

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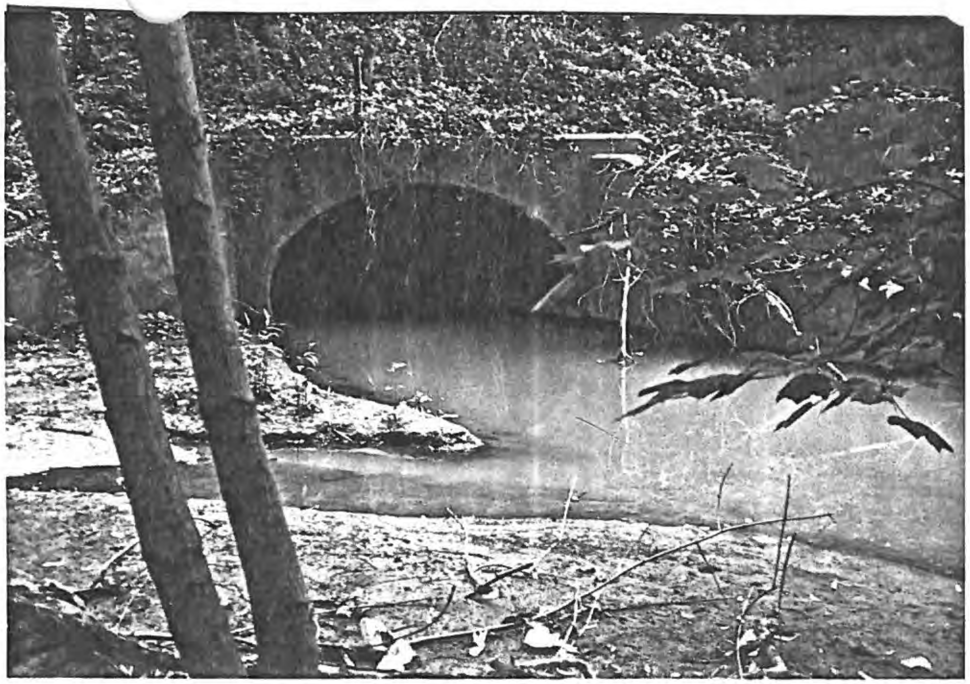

Photo 1 Weems Creek at Outfall of 60" RCP under U.S. Rte. 50 (Pt. A)

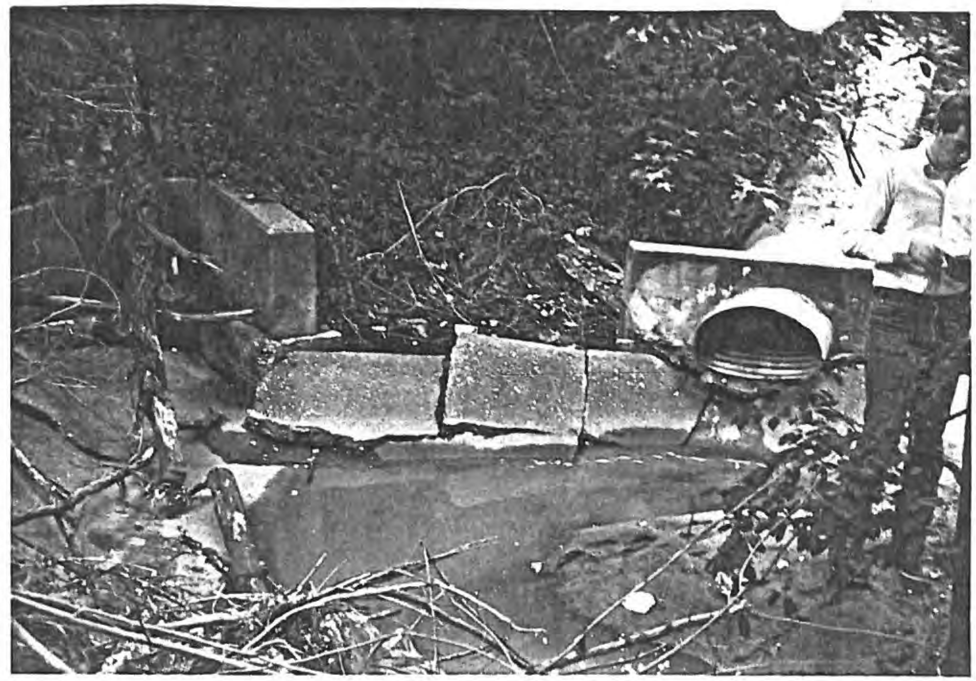

Photo 2 Weems Creek at Outfall of 60" RCP at U.S. Rte. 50 and MD. Rte. 450 Ramps (Pt. B)

Photo 3 Weems Creek at Outfall of 60" RCP at U.S. Rte. 50 and MD. Rte 450 Ramps (Pt. C)

Photo 4 Undercutting of Steep Banks on Weems Creek at U.S. Rte. 50 and MD. Rte. 450 Ramps (Pt. D)

Maryland Route 450. This pond provides 2-, 10-, and 100-year SWM for the Restaurant Park site and a portion of Annapolis Mall.

The second pond, located adjacent to the new J.R. Annapolis site, replaced an older pond which provided stormwater management for the Annapolis Mall. The new pond provides 2-, 10-, and 100-year control for both the Mall and the J.R. Annapolis shopping center.

In addition to discharge control benefits, the J.R. Annapolis pond provides some water quality benefits to the Mall Tributary and points downstream reaches by trapping a fraction of the sediment, nutrients and other pollutants carried by Mall runoff.

3.9 LAND USE

3.9.1 Existing Land Use

Land use conditions for early 1985 were derived from two technical reports (5, 6). Existing land use was delineated using 1980 aerial photographs and updated by field reconnaissance to reflect changes between 1980 and 1985. For existing conditions, thirty seven (37) percent of the land area was residential, twenty (20) percent was commercial, ten (10) percent was open space, and thirty three (33) percent was woodlands.

Figure 8 illustrates the existing land use for the non-tidal portion of the watershed. The symbols used in the legend for this map are explained in Table 2. These abbreviations are based on the symbols used on the Anne Arundel County zoning maps. The existing land use for the tidal portion can be found in Reference 8.

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FIGURE 8
MANAGEMENT PLAN FOR
WEEMS CREEK WATERSHED
EXISTING LAND USE NON-TIDAL PORTION
ANNE ARUNDEL COUNTY, MARYLAND

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TABLE 2

PLANNING AND ZONING LAND USE CLASSIFICATIONS

Symbol	Land Use
C1A	Neighborhood Commercial
C4	Highway Commercial
CLR	Cleared Land for Roads
CLT	Cultivated
OS	Open Space
R15	Low Density Multi-family
R2	1/2 Acre Residential
R22	Medium Density Multi-family
R5	1/5 Acre Residential
TC	Town Center
W1B	Industrial Development District
W2	Light Industrial
W3	Heavy Industrial
WDS	Woodlands

3.9.2 Ultimate Land Use

The ultimate land use scenario developed for the Weems Creek Watershed is the anticipated future land use patterns assuming full development as specified by zoning ordinances. For this study, the ultimate land use map was based on currently approved zoning maps for Anne Arundel County and the City of Annapolis. Ultimate land uses were delineated based on existing land uses for some small areas of the drainage basin in the City of Annapolis for which zoning maps were not available. This was done by assuming the undeveloped sections to be developed in the same manner as surrounding developed sections. Because there is little room for further development in these areas of the city, the hydrologic characteristics of the areas should not change drastically. Conversely, the potential changes in land use in the County portion of the watershed should result in significant changes to hydrologic characteristics which could lead to considerable negative impacts if not managed properly.

The ultimate land use map for the non-tidal portion of the watershed is presented in Figure 9. The ultimate land use map for the tidal portion can be found in Reference 8.

3.9.3 General Development Plan

A map showing the land use plan for the County is included in the "General Development Plan for Anne Arundel County" published in 1978. The zoning maps used to determine the ultimate land use are in agreement with the County's Development Plan.

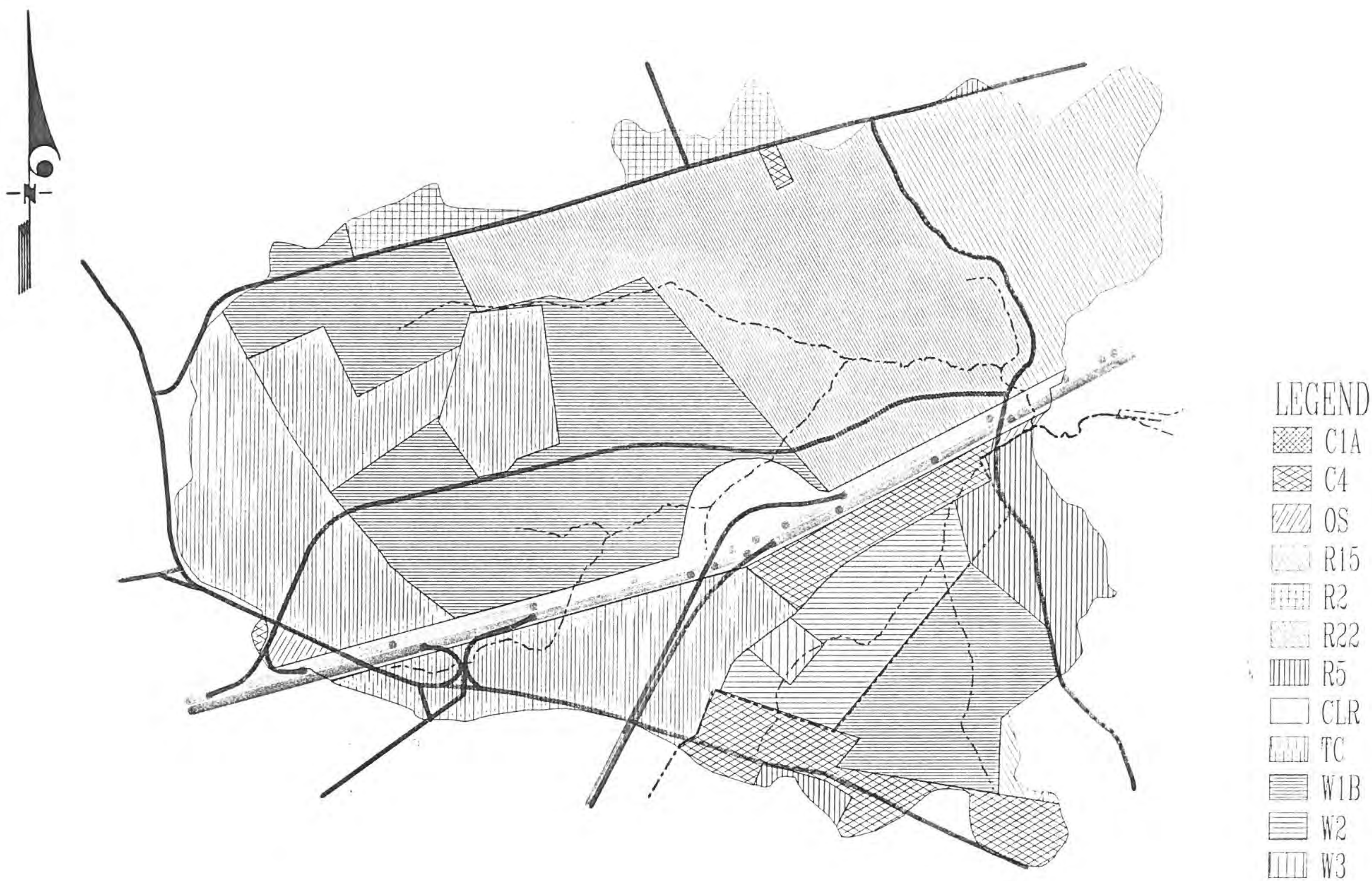

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FIGURE 9
MANAGEMENT PLAN FOR
WEEMS CREEK WATERSHED
ULTIMATE LAND USE NON-TIDAL PORTION
ANNE ARUNDEL COUNTY, MARYLAND

4. ENVIRONMENTAL FEATURES

4.1 WETLANDS

Throughout the Chesapeake Bay the importance of the beneficial characteristics of wetlands is being realized. Critical to the ecology of the Weems Creek watershed, wetlands provide habitats for many forms of vegetation and wildlife while also providing recreational opportunities. Wetlands also serve to buffer both the physical and chemical impacts of man. Specifically, beneficial aspects of wetlands regarding water resources may include:

- the removal of nonpoint source pollutants such as sediment and nutrients
- temporary storage of flood waters
- groundwater recharge
- reduction of shoreline erosion in tidal areas

The State of Maryland defines those areas that support aquatic vegetation as wetlands. The wetlands above the mean high water line are subject to private ownership while those below the mean high water line are owned by the state. Most of the wetlands within the Weems Creek Watershed are privately owned.

The Wetlands Division of the Department of Natural Resources has identified and classified the seven wetland areas along Weems Creek. These wetlands support seven different types of wetland vegetation: red mapleash, meadow cordgrass/spikegrass, marshelder/groundselbush, cattail, rosemallow, smooth cordgrass, and submerged aquatic plants. These plants flourish in the brackish water found in marsh areas of the Chesapeake Bay. The tidal wetland areas in Weems Creek are depicted in Figure 10. The primary species of aquatic vegetation are also indicated.

The State of Maryland passed a law in 1970 aimed at protecting Maryland's wetlands. Property owners wishing to alter state wetlands must obtain a license from the State Board of Public Works. Projects to dredge, fill, or

NOTE: Aerial Photography provided by Anne Arundel County Office of Planning and Zonning

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FIGURE 10
MANAGEMENT PLAN FOR
WEEMS CREEK WATERSHED
WETLANDS AND CRITICAL AREA BOUNDARY MAP
ANNE ARUNDEL COUNTY, MARYLAND

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otherwise modify private wetlands require a permit or notification of approval from the Department of Natural Resources. In addition to these requirements, the U.S. Army Corps of Engineers, in order to perseve wetland areas, requires a federal permit to dredge or fill in all navigable waters.

4.2 CHESAPEAKE BAY CRITICAL AREA

It is recognized that land use activities in areas adjacent to the Bay and its tidal streams have a definite impact on the aquatic ecosystems. In order to minimize adverse impact, the State of Maryland passed the Chesapeake Bay Critical Areas Law in 1984.

For regulatory purposes, critical areas have been defined as all land lying within 1000 feet of tidal waters and their associated wetlands. Approximately 75 percent of the tidal portion and 10 percent of the non-tidal portion of the Weems Creek watershed lie within these critical areas. Figure 10 shows the critical areas as delineated by the Wetlands Division of the Department of Natural Resources.

At the time of this study, the restrictions to be applied to the critical areas have not been finalized. The Chesapeake Bay Critical Area Commission is developing guidelines which local governments will use to develop critical area management plans that will minimize the impacts of development on water quality and protect fish, wildlife, and vegetation, while accommodating some growth. The land use restrictions are being considered under three types of criteria: development, agriculture, and natural resources. The resulting program is to be in place prior to June 1, 1988. In the interim period, local planning and zoning authorities are required to consider the impacts of proposed projects in the critical areas on water quality and on fish, wildlife, and vegetation.

4.3 VEGETATION AND WILDLIFE

Vegetation in the Weems Creek watershed is characteristic of the Chesapeake Bay region. As was discussed in the section on wetlands, Weems Creek supports a variety of wetlands vegetation such as salt water grass, salt meadow grass, cattails, and groundsel. As is common in drier areas near brackish marshes, marsh elders can also be found. Upland wooded areas include tulip poplar and varieties of oaks and hickories. Dogwood and American Holly are common canopy species in the upland areas of the watershed.

The wetlands and the upland natural areas support a wide variety of wildlife. As reported in the "Greenway Strategy for Weems Creek," the following wildlife can be found in the area: mammals including, river otter, opposum, gray squirrel, muskrat, raccoon, and white-tailed deer; birds including green heron, mallard, bobwhite, quail, mourning dove, woodpecker, crested flycatcher, great blue heron, canvasback, gull, brown creeper, slate-colored jimco, bittern, bald-eagle, and ruby throated hummingbird; reptiles and amphibians including a variety of snakes, the common snapping turtle, easter box turtle, and american eel; and fish including white perch, pumpkinseed, bluegill, sunfish, and minnows.

4.4 WATER QUALITY

The tidal portion of Weems Creek was given a Class II rating under the State of Maryland Water Quality Standards in August 1980. Class II waters should meet the standards required for shellfish harvesting. This standard is met by waters where shellfish are "propogated, stored, or gathered for marketing purposes, including actual or potential areas for the harvesting of oysters, softshell clams, hardshell clams, and brackish water clams."

The concentration or amount of pollutants in either the tidal or non-tidal portions of Weems Creek is undocumented at this time. Therefore, would be very difficult to estimate, either qualitatively or quantitatively, the existing or projected future quality of waters in Weems Creek. Even with the documentation of pollutant concentrations, predictions of stream and tidal water quality would be difficult to determine due to the complex influences of storms and tides which vary with time and may either concentrate or dilute pollutant measurements. In addition to temporal variations, there will also be significant spatial variations in water quality data measurements in the tidal reach.

Water quality problems common in streams draining developing suburban and urban areas include:

- o high turbidity from upland erosion, non-point source washoff, and stream channel erosion.
- o high nutrient NPS washoff contributing to algae growth and attendant dissolved oxygen deficits.
- o high fecal coliform counts from purging waste tanks and failed septic systems - possibly contaminating fish & shellfish and prohibiting swimming.
- o sediment deposition in reaches erosion in upstream locations - creating the need for dredging of channels and inlets.
- o oil, grease, or toxic material from cars and boats.
- o Again, whether or not, and to what degree, such problems are present in Weems Creek has not been definitely determined to date.

In summary, water quality problems will affect the recreational uses, the type and health of wildlife, and the aesthetics of Weems Creek. The one thing known with some degree of certainty is that NPS pollutant loads are greater today than they were under natural conditions, and will be even greater under future land use conditions unless an effective watershed management program is directed toward water quality control. Consequently, although existing problems are undocumented at present, water quality management alternatives have been recommended for the Weems Creek Watershed. These alternatives are presented in Chapter 7.

4.5 PARKS AND HISTORIC SITES

There are no parks which lie within the Weems Creek watershed. Bestgate Park lies just north of Bestgate Road at Admiral Drive and is just outside of the watershed. This park consists of one baseball field, one softball field, and two tennis courts.

The Weems Creek watershed contains the site of Howard's Inheritance. This site is listed on the Maryland Historic Sites Inventory. Howard's Inheritance is the home of the Howard family who owned most of the land north of the creek from the early 18th century until 1772. The major attraction of the site is the Howard family house. This house is a rare 1-1/2 story brick dwelling with a gambrel roof. Howard's Inheritance is located south of Bestgate Road near Lawrence Road.

4.6 RECREATIONAL ACTIVITIES

The primary recreational activities available in the Weems Creek watershed are created by the availability of the estuary. These recreational activities are both passive and active. Passive recreational activities stem from the attractiveness of the aquatic environment. The activities include walking and sightseeing.

Weems Creek also provides more active recreational opportunities including swimming, fishing, crabbing, boating, and ice skating. Because of the lack of waves, the absence of extensive boating, the depth of the water, and the natural setting, Weems Creek is an excellent site for swimming. The level of water quality and the rural character of the watershed also provide excellent opportunities for fishing and crabbing.

Boating on Weems Creek includes all types of boats. The depth of the water provides sufficient depth for medium sized boats. High-masted sailboats are found only to the east of Rowe Boulevard because of the fixed height of the Rowe Boulevard bridge. Motor boats and canoes are also common on the creek. No commercial marinas exist on the creek, however, there are three small community piers on Weems Creek: one on the north side at Riverview Manor and two on the south side at Admiral Heights. In addition to the small community piers, there are a number of smaller private piers. Boating access is also provided by a ramp at the end of Tucker Street.

4.7 ENVIRONMENTAL SENSITIVE AREAS

The Weems Creek watershed has a number of environmentally sensitive areas. The importance of the creek and its associated wetlands has been discussed in previous sections. There are two other areas in the watershed of particular environmental interest (Figure 10). The first of these is the Hock Property which is located between the creek and U.S. Route 50/301, approximately 0.5 miles upstream of Rowe Boulevard. The other environmentally sensitive area is Priest Point, located at the north side of the creek at its confluence with the Severn River.

The Hock Property is the single most distinctive site in the tidal portion of the watershed. This 30 acres of woodlands is responsible for much of the rural nature of the watershed. The Hock Property has been designated as an uplands natural area by the Maryland Department of Natural Resources. This designation highlights the environmental importance of this site. The Hock Property supports a wide variety of vegetation and wildlife. An excellent listing of these environmental attributes is contained in the report "A Greenway Strategy for Weems Creek."

The Hock Property has been owned by the Maryland State Highway Administration (SHA) for many years. SHA has identified the site as a scenic land project and deemed the site a right-of-way for scenic purposes. SHA has indicated it would like to retain the property in its present state. Currently, Anne Arundel County has the Hock Property zoned as open space.

The proximity of the Hock Property to the highway results in two of the major external disturbances on that property: noise and windthrow. Of course, these disturbances are of greatest concern near the highway, being for the most part dissipated in areas near the creek. The other external disturbance on the creek side of the property results from wave action, which can be harmful to wetlands and to the creek banks. This wave action comes from both natural and man-made sources. Natural wave action in this area is not thought to be significant. Man-made sources of wave action appear to be more detrimental and are primarily due to motor boats that violate the 6 mile per hour speed limit for the creek.

Priest Point, located along the north side of Weems Creek at the mouth, is a retreat for priests in the Redemptorist Order. The retreat is a natural preserve area and, as such, is primarily undisturbed. A few cabins and a swimming pool are the only developed areas. In recognition of the environmental importance of this area, the site has been zoned open space to restrict future development. A discussion of the vegetation and wildlife can be found in the report "A Greenway Strategy for Weems Creek".

Both the Hock and Priest Point properties are totally within the defined Chesapeake Bay critical area.

5. TECHNICAL ANALYSES

5.1 HYDROLOGY

5.1.1 Methodology

The hydrology used for this management plan was performed as part of two earlier studies. Engineering Technologies Associates, Inc. (ETA) performed hydrology for the tidal portion of the watershed using the Soil Conservation Service's (SCS's) Method TR-55. The results of the application of TR-55 were included in ETA's report "Weems Creek Watershed Study: Phase II." Greenhorne & O'Mara, Inc. (G&O) performed the hydrology for the non-tidal portion of the watershed using SCS's computer program TR-20. These results were included in G&O's report "Weems Creek Watershed Study," dated June 1985.

The TR-20 and TR-55 models use the methodology outlined below:

1) The total drainage area is delineated.
2) Drainage areas are divided into a number of smaller "subareas".
3) Runoff Curve Numbers (RCNs) are determined by the two major factors affecting runoff potential - land use and soil type.

Figures 2, 4, 8, and 9 present the hydrologic soils, drainage area, existing land use, and ultimate land use maps, respectively.

A second parameter is required to describe the routing potential within the subarea. This hydrologic parameter is the time of concentration which is the longest time required for any rainfall landing on the subarea to reach the outlet of the subarea. Flow paths, slopes, and distances were estimated from topographic mapping to calculate flow velocities and the times of concentration.

Hydrographs were generated for rainfalls of a known return period at each subarea. In the tidal portion, only the hydrographs for the individual subareas were computed. The small discharges from these subareas have no significant influence on the water surface elevations in the tidal areas. In the non-tidal section of the watershed, the hydrographs from the smaller subareas accumulate and have a major impact on the water surface elevations downstream. In the TR-20 model, the summation and routing of hydrographs through stream reaches and impoundments to a point of interest can be performed. In this manner, peak discharges for known return periods were computed at various locations throughout the non-tidal portion of Weems Creek watershed. Discharges in both the tidal and non-tidal portions of the watershed were computed for both existing and utlimate land use conditions.

5.1.2 Subareas

As was mentioned in Section 5.1.1, the Weems Creek watershed was divided into a number of smaller, hydrologically similar subareas. The tidal portion of the watershed was broken into 17 subareas while the non-tidal subarea was broken into 13 subareas (see Figure 4). The 17 subareas in the tidal portion were given three digit identification numbers that were multiples of ten. The second digit was even for those subareas on the southern or City side of the creek and odd for those on the northern or County side. The 13 subareas in the non-tidal portion were numbered 1 through 13.

The subareas in the tidal portion were delineated by ETA based on 1" = 200' scale topographic mapping and field reconnaissance. Since there are numerous discharge points along both sides of the estuary, ETA decided to group some of the smaller drainage areas together to obtain a reasonable size drainage area with a significant point of discharge. Delineation of the 17 subareas also considered the effects of the existing storm drain systems on the drainage patterns.

The delineation of the subareas in the non-tidal portion of the creek was primarily based on 1" = 400' topographic mapping and field reconnaissance. Design reports for the two SWM ponds, survey data for the drainage along U.S. Route 50/301, and existing storm drain plans (especially in the Annapolis Mall area) were also taken into account.

5.1.3 Storage Considerations

As was noted in Section 5.1.1, flood routing was only performed for the non-tidal portion of the Weems Creek Watershed. Flood routing is the attenuation of flood hydrographs that results from the temporary storage of flood waters in impoundments and floodplains. The TR-20 model for the non-tidal portion utilized 14 storage segments, 7 impoundments, and 7 floodplains reaches. The two existing SWM ponds accounted for two of the seven impoundments and road embankments; culvert numbers 1 through 5 accounted for the other five (See Figure 7). The seven floodplain reaches were a total of 1.45 miles long and included all reaches for which routing was not accomplished within the subarea or through impoundments.

5.1.4 Discharges

Table 3 contains a summary of the discharges computed for the subareas located in Anne Arundel County and Table 4 contains discharges for the subareas located in the City of Annapolis. Table 5 contains the discharges at key locations in the non-tidal portion. Tables 3, 4, and 5 indicate significant peak flow increases between existing land use conditions and ultimate land use conditions with no stormwater management. The greatest increases in peak discharge rates occur within the non-tidal areas within Anne Arundel County. Also note that the most significant percent increases in peak flow occurs for the two-year storm event and the smallest increases are observed for the 100-year storm event. The 2-year and 10-year discharges from Table 5, along with selected discharges from Tables 3 and 4, have been shown graphically on Figures 11 and 12 respectively.

5.2 HYDRAULICS

5.2.1 Methodology

The U.S. Army Corps of Engineers (COE) computer program HEC-2 was used to estimate flood elevations and velocities on the major fluvial stream reaches within the Weems Creek Watershed. Two reaches were modeled including

TABLE 3

SUMMARY OF DISCHARGES FOR SUBAREAS
IN THE TIDAL PORTION IN THE COUNTY

Subarea	D.A. (Acres)	Discharge (cfs) Existing Land Use 2-Year	10-Year	100-Year	Ultimate Land Use* 2-Year	10-Year	100-Year	Percent Difference 2-Year	10-Year	100-Year
110	26.8	24	63	117	48	107	183	100	70	56
130	106.9	54	168	336	222	461	761	311	174	126
150	52.7	54	134	245	67	150	259	24	12	6
170	21.2	17	50	98	61	118	187	259	136	91
190	34.9	44	105	188	109	200	308	148	90	64
210	11.0	18	41	71	34	64	100	89	56	41
230	14.7	18	45	82	43	80	125	139	78	52
250	12.7	15	39	72	24	53	91	60	36	26

*without SWM controls

TABLE 4

SUMMARY OF DISCHARGES FOR SUBAREAS
IN THE TIDAL PORTION OF THE CITY

Subarea	D.A. (Acres)	Discharge (cfs) Existing Land Use 2-Year	Existing Land Use 10-Year	Existing Land Use 100-Year	Ultimate Land Use* 2-Year	Ultimate Land Use* 10-Year	Ultimate Land Use* 100-Year	Percent Difference 2-Year	Percent Difference 10-Year	Percent Difference 100-Year
120	16.7	42	85	138	59	106	161	40	25	17
140	111.4	206	408	658	275	496	756	33	22	15
160	16.7	40	82	134	59	106	161	48	29	20
180	69.8	178	338	534	209	377	575	17	12	8
200	48.0	112	218	348	142	256	391	27	17	12
220	21.4	47	97	161	72	129	197	53	33	22
240	10.3	19	42	72	30	57	90	58	36	25
260	29.7	33	84	155	77	148	235	133	76	52
280	14.3	12	35	67	24	53	91	100	51	36

*without SWM controls

TABLE 5

SUMMARY OF DISCHARGES AT KEY LOCATIONS
IN THE NON-TIDAL PORTION

Location	D.A. (Acres)	Discharge (cfs) Existing Land Use 2-Year	Existing Land Use 10-Year	Existing Land Use 100-Year	Ultimate Land Use 2-Year	Ultimate Land Use 10-Year	Ultimate Land Use 100-Year	Percent Difference 2-Year	Percent Difference 10-Year	Percent Difference 100-Year
<u>Weems Creek</u>										
Entering SWM Pond in Restaurant Park	36.5	118	198	290	121	201	292	2.5	1.5	0.7
Leaving SWM Pond in Restaurant Park	36.5	56	73	90	57	74	91	1.8	1.4	1.1
Just Downstream of of Rt. 450-U.S. Rt. 50/301 Ramp Embankment	46.1	77	110	140	80	113	142	3.9	2.7	1.4
Just Downstream of U.S. Route 50/301 Culvert	81.1	136	212	288	175	261	322	28.7	23.1	11.8
Just Downstream of Jennifer Road	186.5	189	323	441	261	397	496	38.1	22.9	12.5
Just Upstream of Confluence with Mall Tributary	204.7	196	337	461	267	408	511	36.2	21.1	10.8
Just Downstream of Confluence with Mall Tributary	424.7	338	702	1188	536	972	1489	58.6	38.5	25.3

TABLE 5 (continued)

SUMMARY OF DISCHARGES AT KEY LOCATIONS
IN THE NON-TIDAL PORTION

Location	D.A. (Acres)	Discharge (cfs) Existing Land Use 2-Year	Existing Land Use 10-Year	Existing Land Use 100-Year	Ultimate Land Use 2-Year	Ultimate Land Use 10-Year	Ultimate Land Use 100-Year	Percent Difference 2-Year	Percent Difference 10-Year	Percent Difference 100-Year
Just Upstream of Admiral Drive	539.1	324*	742	1316	621	1192	1867	91.7	60.6	41.9
Just Downstream of U.S. Route 50/301 Bridge	546.8	319*	728*	1298*	567*	1120*	1799*	77.7	53.8	38.6
At Tidal Interface	693.8	458	1048	1836	865	1654	2601	88.9	57.8	41.7
<u>Mall Tributary</u>										
Entering SWM Pond in J.R. Annapolis Area	65.0	124	249	410	124	249	410	0.0	0.0	0.0
Leaving SWM Pond in J.R. Annapolis Area	65.0	11	80	181	11	80	181	0.0	0.0	0.0
Just Downstream of SWM Pond Outfall	113.0	95	198	423	141	247	458	48.4	24.7	8.3
Just Upstream of Confluence with Weems Creek	220.0	142	369	729	319	600	996	124.6	62.6	36.6

*Decrease in discharge from previous location is due to floodplain storage

NOTE: Aerial Photography provided by Anne Arundel County Office of Planning and Zonning.

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FIGURE 11
MANAGEMENT PLAN FOR
WEEMS CREEK WATERSHED
2-Yr DISCHARGES AT KEY LOCATIONS
ANNE ARUNDEL COUNTY, MARYLAND

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FIGURE 12
MANAGEMENT PLAN FOR
WEEMS CREEK WATERSHED
10-YEAR DISCHARGES AT KEY LOCATIONS
ANNE ARUNDEL COUNTY, MARYLAND

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Weems Creek from the tidal interface to just downstream of the existing West Street exit ramps, and Mall tributary from the confluence with Weems Creek to the outfall from the J.R. Annapolis SWM pond.

The subcritical HEC-2 water surface profile begins at the downstream end of a reach and computes the water surface elevation at each succeeding section along the stream for discharges of a given return period. The shape of the stream channel is input at each cross section to describe the flow geometry. Manning's roughness coefficients are input to reflect the resistance to flow across the section. The flow lengths for the channel and the left and right overbanks are also input. Finally, a description of the road crossings that may affect the flow depth are included as model input.

5.2.2 Cross Sections

Cross sections are used to describe the geometry of streamflow. Cross sections are placed at locations along the stream where flow characteristics change significantly. For example, a change in channel slope, or an increase or decrease in floodplain flow area. The cross section locations as modeled by the HEC-2 program are shown on Figure 13. The plots of these cross sections can be found in Greenhorne & O'Mara's technical study for the non-tidal portion of the watershed. Cross section plots were developed from information from a number of sources including a field survey, topographic mapping, and the study "Restaurant Park Drainage Outfall Study."(2)

5.2.3 Bridge and Culverts

There are four road crossings on the stream reaches modeled for this study. All of these crossings are on Weems Creek. The bridge opening at U.S. Route 50/301 was found to be large enough so that significant backwater impacts were not projected by the HEC-2 model. Bridge routines were not required to model this crossing. The 7' X 9' culvert under Admiral Drive was modeled using the special bridge method in HEC-2 program. The 96" culvert under Jennifer Road and the 72" culvert under U.S. Route 50/301

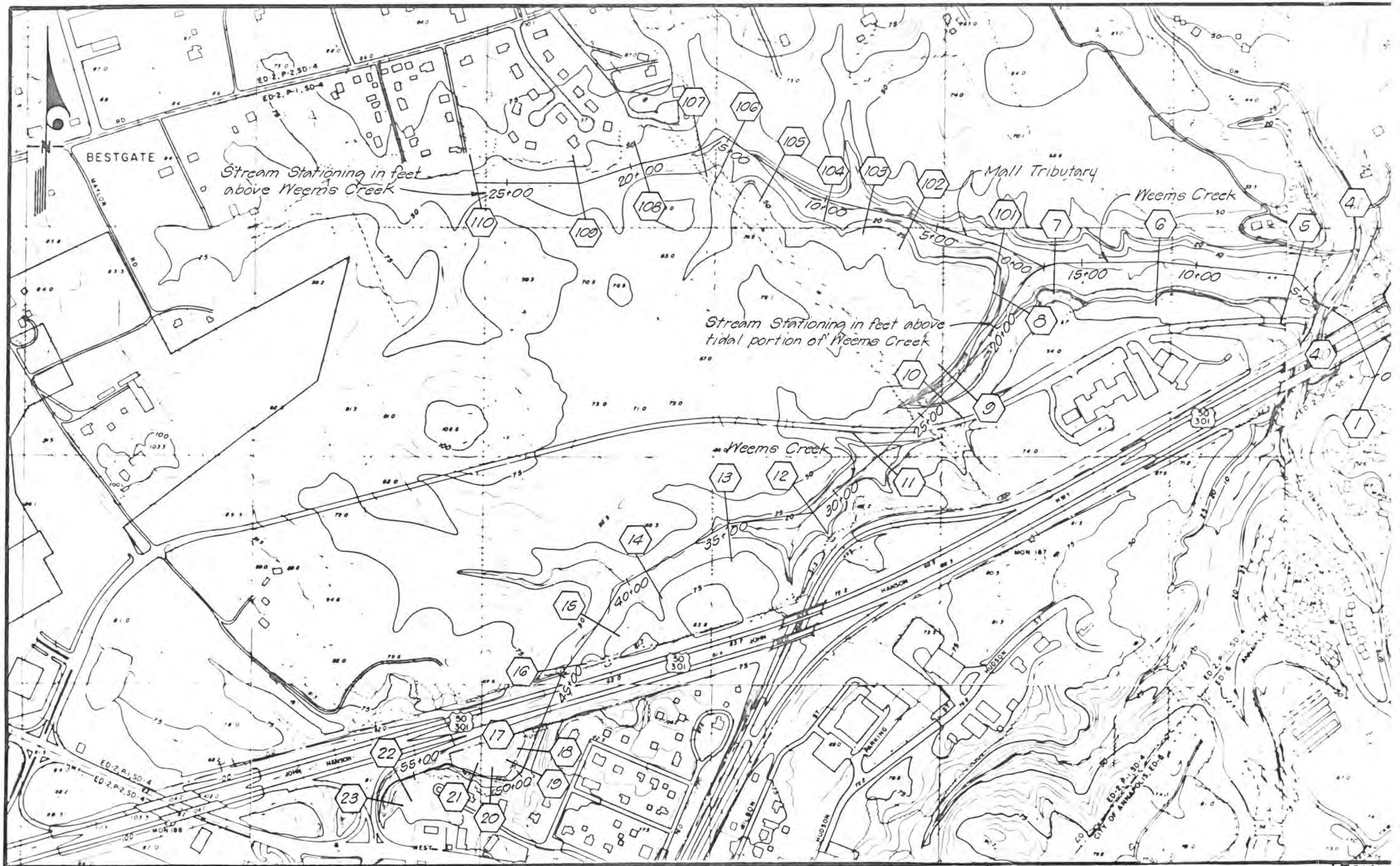

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FIGURE 13
MANAGEMENT PLAN FOR
WEEMS CREEK WATERSHED
CROSS SECTION LOCATIONS
ANNE ARUNDEL COUNTY, MARYLAND

TCM
PAR
TCM
5-2085

were previously modeled using TR-20. Flood elevations were evaluated using HEC-2 working upstream to the outlet of these culverts. The water surface elevations at the upstream end of the culverts were then taken from the TR-20 results and input directly into the HEC-2. The location of these road crossings is shown on Figure 7.

5.2.4 Computed Water Surface Elevations

Water surface elevations are computed by the HEC-2 program. By knowing the location of a cross section and the computed water surface elevation for a given storm event, a determination can be made as to whether or not a specific structure is flooded. The computed water surface elevations for the stream reaches studied are summarized in Table 6. This table includes the water surface elevations for the 2-, 10-, and 100-year storms for both ultimate and existing land use conditions. A second way of summarizing computed water surface elevations is graphically with a profile. A profile is a plot which connects the water surface elevation at various cross sections to visually show the flood depths and elevations. The channel bottom is also plotted as a point of reference. The profiles for these reaches is included in the technical study of the non-tidal portion of Weems Creek.

5.3 NONPOINT SOURCE POLLUTION

5.3.1 Methodology

Based on data generated through 8 years of monitoring stormwater runoff, the Washington Metropolitan Council of Government (COG) published "A Guidebook for Screening Urban Nonpoint Pollution Management Strategies."(10) This report presents estimates of uncontrolled nonpoint pollution loading rates for a number of land use/soil type combinations for six pollutants for watersheds in the metro-Washington Area. Due to the lack of site-specific monitoring data for Weems Creek, these rates, given in pounds/acre/year, were used to estimate the uncontrolled pollutant loadings to the stream for the subareas of the Weems Creek Waterhsed.

TABLE 6
COMPUTED WATER SURFACE ELEVATIONS

Location	ELEVATION (ft.) Existing Land Use 2-Year	10-Year	100-Year	Ultimate Land Use 2-Year	10-Year	100-Year
Weems Creek						
Just Downstream of Rt. 450-U.S. Rt 50/301 Ramp Embankment	56.4	57.0	57.4	56.5 (+0.1)**	57.0	57.4
Just Upstream of U.S. Route 50/301	45.2	46.8	48.6	46.0 (+0.8)	48.0	49.7
Just Downstream of U.S. Route 50/301	38.8	39.2	39.5	39.0 (+0.2)	39.4	39.6
Just Upstream of Jennifer Road	19.0	21.1	23.5	20.0 (+1.0)	22.6	24.7
Just Downstream of Jennifer Road	15.3	16.1	16.6	15.7 (+0.4)	16.5	16.6
At Confluence with Mall Tributary	8.8	11.2	12.6	10.8 (+2.0)	12.2	13.5
Just Upstream of Admiral Drive	5.9	10.1	11.1	7.1 (+1.2)	10.9	11.2
Just Downstream of Admiral Drive	5.8	6.8	8.8	6.5 (+0.7)	7.8	10.3
At Tidal Interface	3.4	4.6	7.2*	4.3 (+0.9)	5.4	7.2*
Mall Tributary						
At Outfall from SWM Pond in J.R. Annapolis Area	38.7	39.6	40.7	39.1 (+0.4)	40.0	40.8

* Tidal Elevations (From Flood Insurance Study)
**Increase in 2-year flood elevations in feet.

Wet weather pollution loads carried by a stream such as Weems Creek may be reduced as a result of on-stream flood retention/detention facilities which decrease flow velocity, causing settling of sediment, nutrients and some other pollutants. The removal efficiencies (or the percentage of pollutants trapped by such a facility) were also estimated for the two existing stormwater management facilities in the Weems Creek watershed using published data (10). This was accomplished by selecting a reasonable removal efficiency from a range of efficiencies reported for similar stormwater management facilities. The selected values for various pollutants were:

Pollutant	Reported Range of Removal Efficiencies (%)	Estimated Efficiency (%)
Biochemical Oxygen Demand (BOD)	40-55	50
Total Phosphorus (TP)	10-30	20
Total Nitrogen (N)	15-30	28
Lead (Pb)	30-50	45
Zinc (Zn)	45-60	51
Suspended Sediment	65-80	70

5.3.2 Pollutant Loadings

Using the estimated annual loadings and removal efficiencies discussed above, the annual loads of the six pollutants reaching the stream within the Weems system were computed. Tables 7 and 8 contain the annual loads in the tidal portion for existing and ultimate land use conditions, respectively. The subtotals show the total nonpoint pollutant loads from the County and the City. The total reflects the total loads for the entire tidal portion. Tables 9 and 10 give the pollutant loads in the non-tidal portion for existing and ultimate land use conditions, respectively. The values for Subareas 1 and 7 have been adjusted for the removal of pollutants by the two existing stormwater management ponds.

5.3.3 Results of Non-Point Source Pollution Loads

From the results presented in Tables 7-10, it can be generally stated that non-point source pollution originates in relatively equal proportions

TABLE 7

NONPOINT POLLUTANT LOADINGS
FOR EXISTING LAND USE
TIDAL

Subarea	Area (Acres)	BOD	POLLUTANT LOADS (lbs/year) P	N	Pb	Zn	Sediment (Tons/YR)
			City of Annapolis Subareas				
120	16.7	446	9	138	5	4	2
140	111.4	3553	120	978	60	42	21
160	16.7	424	16	131	6	5	3
180	69.8	2432	77	632	40	30	13
200	48.0	2785	59	505	61	35	8
220	21.4	1819	33	285	43	23	4
240	10.3	327	10	84	5	3	2
260	29.7	601	22	192	6	6	3
280	14.3	237	7	76	2	2	1
SUBTOTAL FROM CITY SUBAREAS	338.3	12624	353	3021	228	150	57
			Anne Arundel County Subareas				
110	26.8	630	9	119	12	6	2
130	106.9	1936	41	494	24	15	13
150	52.7	2136	41	402	14	10	5
170	21.2	430	12	118	3	3	2
190	34.9	1379	26	249	28	16	4
210	11.0	280	10	83	4	3	2
230	14.7	294	10	88	3	3	2
250	12.7	297	7	72	3	2	2
SUBTOTAL FROM COUNTY SUBAREAS	280.9	7382	156	1625	91	58	32
TOTAL FROM TIDAL SUBAREAS	619.2	20006	509	4646	319	208	89

TABLE 8

NONPOINT POLLUTANT LOADINGS
FOR ULTIMATE LAND USE
TIDAL

Subarea	Area (Acres)	POLLUTANT LOADS (lbs/year) BOD	P	N	Pb	Zn	Sediment (Tons/YR)
		City of Annapolis Subareas					
120	16.7	534	22	174	9	7	4
140	111.4	3564	145	1158	60	48	26
160	16.7	535	22	174	9	7	4
180	69.8	2234	91	726	38	30	16
200	48.0	2101	68	556	43	29	11
220	21.4	741	26	224	33	18	3
240	10.3	308	13	108	5	4	2
260	29.7	887	38	309	15	12	6
280	14.3	338	16	126	6	5	2
SUBTOTAL FROM CITY SUBAREAS	338.3	11242	441	3555	218	160	74
		Anne Arundel County Subareas					
110	26.8	1455	29	268	35	18	4
130	106.9	5063	160	1330	126	69	27
150	52.7	2296	60	526	51	29	10
170	21.2	636	28	223	11	9	5
190	34.9	1802	79	596	58	37	12
210	11.0	364	14	117	6	5	2
230	14.7	454	19	154	8	6	3
250	12.7	259	10	91	4	3	2
SUBTOTAL FROM COUNTY SUBAREAS	280.9	12329	399	3305	299	176	65
TOTAL FROM TIDAL SUBAREAS	619.2	23571	840	6860	517	336	139

TABLE 9

NONPOINT POLLUTANT LOADINGS
FOR EXISTING LAND USE
NON-TIDAL

Subarea	Area (Acres)	BOD	POLLUTANT LOADS (lbs/year) P	N	Pb	Zn	Sediment (Tons/YR)
1*	36.5	2896	48	363	55	36	3
2	13.3	660	9	88	12	8	2
3	31.3	3849	54	477	85	50	7
4	38.8	2325	27	274	41	28	5
5	66.6	5880	70	650	114	73	10
6	18.2	545	7	84	10	6	2
7*	65.2	5002	80	593	87	62	5
8	48.1	1932	84	497	20	19	28
9	106.9	1526	42	461	16	14	10
10	24.1	1382	16	157	22	16	3
11	90.3	1378	55	470	11	11	14
12	7.7	760	9	87	17	10	1
13	147.0	12081	144	1293	200	142	24
TOTALS	694.0	40216	645	5494	690	475	114

*Pollutant loadings reduced due to existing stormwater management facilities.

TABLE 10

UNCONTROLLED NONPOINT POLLUTANT LOADINGS
FOR ULTIMATE LAND USE
NON-TIDAL

Subarea	Area (Acres)	BOD	POLLUTANT LOADS (lbs/year) P	N	Pb	Zn	Sediment (Tons/YR)
1*	36.5	2815	46	343	51	35	2
2	13.3	2007	21	176	34	25	3
3	31.3	5348	56	479	97	68	8
4	38.8	5901	62	513	100	75	9
5	66.6	11296	125	1080	221	144	16
6	18.2	2364	25	204	34	23	4
7*	65.2	5258	82	614	91	65	5
8	48.1	5717	65	530	86	65	10
9	106.9	12121	134	1115	166	104	24
10	24.1	2745	29	248	36	18	6
11	90.3	10084	108	911	127	64	22
12	7.7	1190	15	130	25	13	4
13	147.0	19055	221	1828	311	240	33
TOTALS	694.0	85,901	915	8171	1379	939	146

*Pollutant loadings reduced due to existing stormwater management facilities.

from the tidal and non-tidal drainage areas of the watershed. Exceptions are obvious in the cases of BOD, lead and zinc. These exceptions are due primarily to the fact that pollutant washoff is a function of land use and non-tidal subareas, such as 7, 5 and 13, sustain land uses (including suburban shopping centers and high density urban residential uses) which contribute proportionally higher loads of these pollutants than tidal subareas of similar sizes.

This result leads to the important conclusion that non-point source pollution controls would be, unit for unit, more effectively employed in the non-tidal subareas than in tidal subareas. This conclusion is further promoted by the fact that commonly used structural controls are generally feasible where most of the flow is concentrated in stream channels, as is the case in the non-tidal drainage areas. For the most part, drainage in tidal subareas is not tributary to defined channels and would be, therefore, more difficult to control with structural methods. Of course, non-structural controls (such as street sweeping, revegetation, and fertilizer controls) could be considered in either situation.

With respect to sediment loads estimated in Tables 7-10, the total load for the combined tidal and non-tidal subareas for ultimate land use conditions is equivalent to approximately 20 dump trucks of sediment.* Although this may seem like a substantial amount, if spread uniformly over the bottom of the Weems Creek tidal reach, it would raise bottom elevations less than one-tenth of an inch. Of course, some of this sediment is eventually flushed from the tidal reach and actual accumulations could be even less than that estimated. Also, it is recognized that collodial (non-settling) sediment is of more concern than deposited material in this reach.

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*Assuming a dump truck with a 10 cubic yard capacity.

It must be noted that, for other pollutants, actual pollutant loads to Weems Creek, actual removal efficiencies of each stormwater management facility, and resultant water quality of the Creek and its receiving water can be predicted accurately only with results of a comprehensive field monitoring program, combined with relatively sophisticated computer modeling of the complex physical and biological processes governing water quality. In addition, effects of the tides and meteorologic conditions in the tidal reach of the Creek add more variables to an already complex system.

For these reasons and in light of essentially no available water quality sampling data for the Creek, it would be untenable, if not misleading, to make definitive or conclusive statements regarding the current and projected water quality of the Creek. The loading estimates in Tables 7-10 are a valid preliminary estimate of existing and future conditions and will be useful when adjusted as monitoring data and more detailed water quality analyses are available.

Nevertheless, comparing estimates for ultimate conditions to existing conditions does show the consequences of increased urban land uses on pollutant loads. Considerable increases in loading over time, particularly from non-tidal subareas, warn of potential future water quality problems if controls are not implemented. For this reason, this Management Plan includes recommendations for monitoring of water quality, additional studies to determine needs more precisely, and a program for control of pollutant loads, primarily to protect the tidal reach where pollutant accumulation will ultimately occur.

6. PROBLEM AREA IDENTIFICATION

Chapter 5 presented the results of a comprehensive hydrologic and hydraulic evaluation of the Weems Creek Watershed. In addition, a preliminary assessment of nonpoint source pollutants has been performed for both existing and ultimate development conditions. Stormwater management facilities other than existing facilities were not considered in these analyses. It is clear from the results of Chapter 5 that there will be significant increases in flood flows, flow depths, and pollutant loads as a result of urbanization of the watershed. In this chapter, the results of hydraulic and of hydrologic modeling, field reconnaissance, literature reviews, and other studies are integrated to define the nature and extent of existing problems and to predict, for planning purposes, future concerns related to the Weems Creek Watershed. Identified problems are presented by the following three categories:

- Erosion and Sedimentation
- Water Quality
- Flooding

6.1 EROSION AND SEDIMENTATION

6.1.1 General

Erosion and sedimentation are continually occuring processes in all watersheds and are, in fact, responsible for many of the major natural physical features of a river system and its landscape. Sediment is delivered to a river system through a number of natural mechanisms including surface erosion, stream bank erosion, channel degradation and mass wasting (landslides or slope failure). Man's activities such as construction, agriculture, and recreation can result in increased supplies of sediment to a stream. Such activities also may increase streamflows which, in turn, lead to increased channel, and stream bank erosion. A streams ability to transport and deposit sediment is based on a variety of factors including the flow, depth, channel slope, hydraulic radius, sediment particle size and other variables.

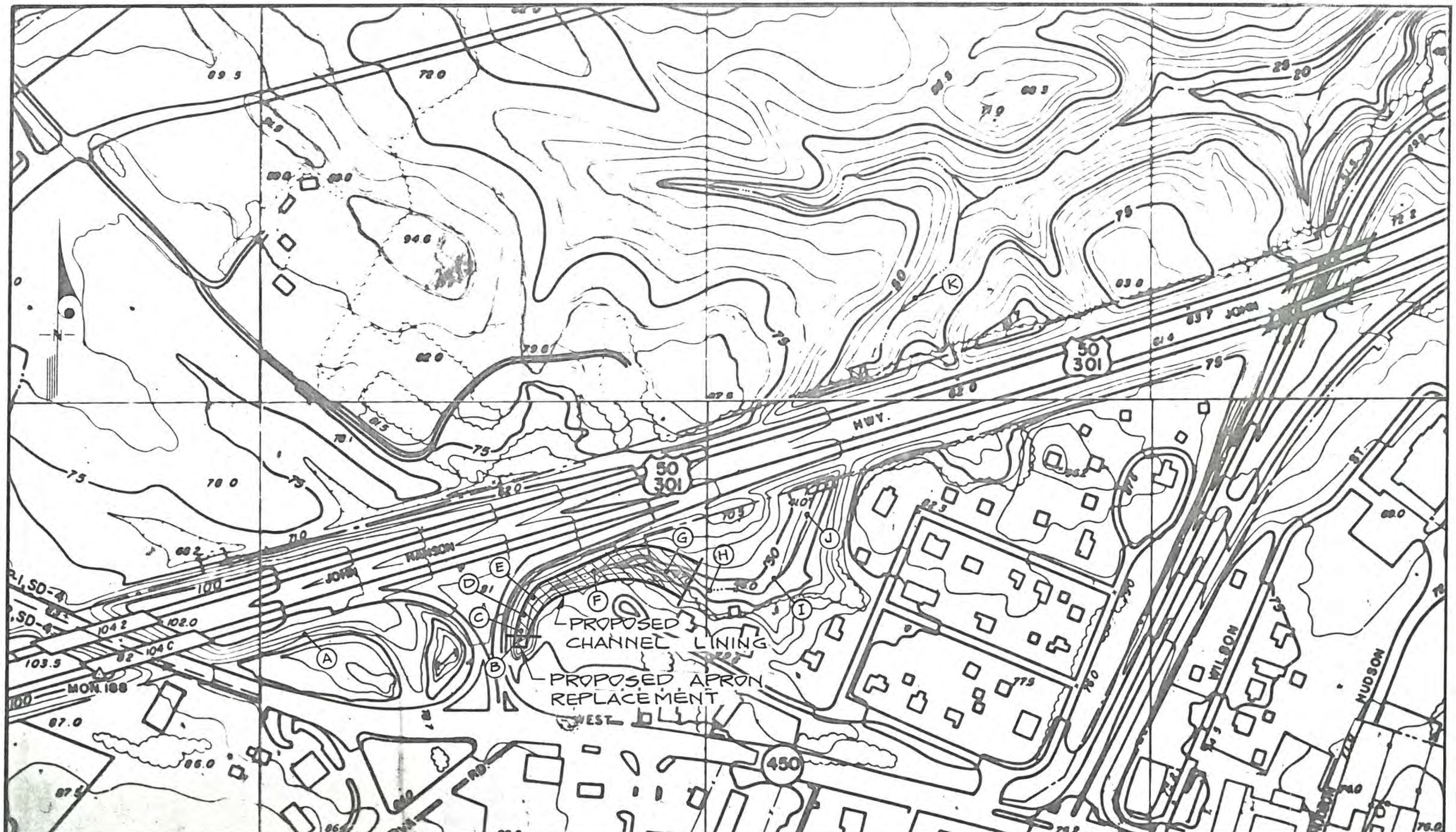
Over the last several decades, urbanization of the Weems Creek Watershed has resulted in increased sources of sediment and, simultaneously, has altered the hydrologic characteristics of the watershed further affecting erosion and sedimentation processes.

6.1.2 Sources of Sediment in the Watershed

Field reconnaissance, aerial photo interpretation and analysis of data indicate that natural processes in the Weems Creek Watershed are responsible for part of the total sediment delivered to the streams and estuary area.

Selected frames of aerial photography over portions of the Weems Creek Watershed were interpreted stereoscopically to locate and identify potential areas that contribute sediment pollution, or pose a significant potential to contribute sediment to any waterways within the drainage basin. All interpretations were delineated on mylar overlays registered to the individual photo frames. Primary emphasis was placed on mapping the aerial extent and distribution of all identifiable areas characterized by sparse or thin vegetative cover, terrain scars and steep soil - covered slopes exhibiting a dense pattern of rills and gullies, since these are areas most prone to erosion.

As discussed in Section 3.5, steep slopes adjacent to the tidal portion of the creek have experienced considerable erosion, often in the form of mass-wasting as shown in the photos. Figure 14 indicates the locations where photos were taken to examine the mass wasting near the stream channel. Such a condition is often the result of the increased weight of soil that results from saturation through bare surfaces by direct precipitation and overland flow from upland runoff. Although failure of steep slopes may not result in soil sloughing directly into the creek, bare unconsolidated surfaces are left open to increased erosion, promoting direct impact of raindrops and subsequent runoff. In addition to loss of useable land, visual asthetics of the creek shore often suffer from such problems. An example of this problem is the steep east-facing slope adjacent to an unamed northerly flowing tributary to Weems Creek (Area A on Figure 15) in



(B) Points of Reference

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FIGURE 14
MANAGEMENT PLAN FOR
WEEMS CREEK WATERSHED
PROPOSED CHANNEL IMPROVEMENTS
ANNE ARUNDEL COUNTY, MARYLAND

MFD	SCALE 1" = 200'
mdv DRAWN	OF
MFD CHECKED	SHEET
8/85 DATE	JOB N.

LEGEND

SOURCES OF EROSION

→ EROSION PATHLINES

EROSION PROBLEM AREAS:

1. POWER LINE CROSSING
2. U.S. ROUTE 50/301 BRIDGE
3. RESTAURANT PARK SWM POND

NOTE:
This map indicates the sources of erosion for those areas for which stereoscopic aerial photographics were available.

NOTE: Aerial Photography provided by Anne Arundel County Office of Planning and Zonning.

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FIGURE 15
MANAGEMENT PLAN FOR
WEEMS CREEK WATERSHED
SOURCES OF EROSION MAP
ANNE ARUNDEL COUNTY, MARYLAND

ADB (DESIGN)	SCALE 1"=1000'	
PAR (DRAWN)	OF	
TCM (CHECKED)	SHEET	
8/85 (DATE)	JOB No.	FILE No.

the Admiral Heights area. This slope is characterized by sparse vegetation cover and rills and gullies which indicate high erosion potential and potential for saturation of soils with resultant slope failure.

In the non-tidal portions steep slopes adjacent to the floodplains of Weems Creek and its tributaries result in only minor sediment loading directly to the stream. Most of these slopes are heavily wooded, have thick covers of topsoil, leaves and brush, and are some distance (often 50 to 100 feet) from the main stream channel and resulting in only minor sediment loss. An exception to this is the area where the power transmission lines cross the tributary from Annapolis Mall. Here the power line right of way has very steep unprotected slopes subject to gullying and erosion from rainfall.

Man-induced erosion is presently the most significant source of sediment in the watershed. An example is the large open land area bounded on the south by US 50/301, on the west by Annapolis Mall, and on the north by an easterly flowing tributary to Weems Creek. This moderately sloping surface, characterized principally by brush and scrub vegetation, contains a complex pattern of bike trails, which criss-cross most of the area. These bike trails, in addition to the transmission line right-of-way which extends across the area in a northeast-southwest direction, are "avenues" of exposed soil which can be considered potential contributors of sediment to the adjacent waterways. The arrows on Figure 15 indicate the principal direction of sediment transport into the drainage channels.

Another area of concern is the "filled" land area and the baresoil areas immediately to the southwest of the intersection of US 50/301 and Admiral Drive. This fill is a prime sources of sediment into a north-northeasterly flowing tributary of Weems Creek.

Four steep sloped areas in the non-tidal section were found to be experiencing erosion as the result of man's activities. The stormwater management (SWM) pond in Restaurant Park has a small slough along the U.S. Route 50/301 embankment just east of the outlet works. Another potential problem area is the power line crossing over Mall Tributary. At this location, a man-made hill has been created to support a utility pole. This hill and the natural slopes all show some signs erosion.

Two additional areas with erosion problems in the non-tidal portion of the watershed are described in the report "A Greenway Strategy for Weems Creek". The less severe of these two sites was the Environmental Protection Agency field office located just south of Bestgate Road where bank erosion is evident. The second site is located in the Boston Heights area where erosion had created deep gullies and exposed tree roots. During heavy rains, 6 inches to 8 inches of silt laden flow have been observed (by residents) flowing towards the creek near Admiral Drive.

Other potential sources of sediment include the embankment south of Jennifer Drive just west of Admiral Drive, denuded areas at various locations shown on Figure 15, and the Weems Creek channel south of Route 50 downstream of the Route 50/450 ramps. This latter case is discussed in more detail below.

It should be noted that a detailed quantitative analysis of sediment delivery, transport and deposition was not possible due to the lack of appropriate data and was beyond the scope of this study. As a consequence, the actual impacts of erosion in the study area in terms of deposition in the tidal estuary (i.e. increased bottom elevations) cannot be definitively concluded. Such conclusions could be reached only with results of hydrographic surveys, bottom soil samples and more detailed analysis and photo interpretation of the tidal receiving areas. However, field reconnaissance during this study involving inspection of the entire length of Weems Creek and its major tributaries indicated the following:

1. Except for the reach downstream of the US 50/450 ramps (discussed below) no significant channel erosion was observed in the non-tidal reaches. Bank erosion, channel widening or scour (degradation) of the channel beds are generally not problems upstream of Admiral Drive.

2. Only minor accumulations of sediment exist in the non-tidal channels. These tend to be at the inlet and/or outlet ends of culverts or at places where trash and debris have blocked the channel causing pools or significant changes in velocity. These accumulations are primarily of sand, fine sand and silt. Very little, if any, course material is present. This is consistent with surface soil profiles of the study area. Fine silt and clay fractions of the sediment load are carried to the tidal reach and are not encountered in non-tidal channel bottoms in significant amounts.

3. Aerial photos confirm that sediment is conveyed to the tidal reach particularly during storm events. Discoloration of water at the head of the tidal reach (downstream of Rt. 50 and Admiral Drive) is due to suspended fine sediment. Some of these sediments are colloidal clays and are dissipated through dispersion rather than settling. Based on a preliminary estimate of sediment loads as discussed in Section 5.3.3, it would appear that no significant increase in bottom elevations would be expected in the tidal reach as a result of sediment deposition. Very little change in the configuration of the channel in plan view was noticeable when comparing aerial photos of 1984 with those of 1971.

6.1.3 Weems Creek Downstream of West Street Exit Ramp

Considerable attention has been focused on the problems and protection of the Weems Creek channel between the Route 50/450 ramps and the Route 50 culvert. Field reconnaissance performed during this study resulted in the following findings:

1. The reach between the Restaurant Park SWM Facility and the last ramp culvert is in good condition except for moderate debris accumulation and minor sediment deposits.

2. Accummulations of debris in the channel downstream of the Route 50/450 ramps have increased the resistance to flow, created

irregular velocity distributions, and caused additional stress against the banks and bed of the channel, resulting in substantial bank failure, erosion and scour between sections 23 and 19 on Figure 13. (See Photos 3, 5, 9, 10)

3. Field reconnaissance and review of the stream profile indicate that scouring has lowered the channel bed at sections 22 and 19. In these reaches, undercutting of banks and erosion at and below tree roots has led to stream bank failure and the uprooting of vegetation.

4. Curvature of the stream channel in this reach is relatively sharp causing increased shear stress and erosion on outside banks of the channel. (Photos 4, 5)

5. Steep side slopes from the highway embankment are subject to failure due to undercutting and soil saturation from local runoff.

Previous comments regarding the Restaurant Park facility suggest that the facility would increase erosion downstream by sustaining peak discharges over a longer period of time. (3) To address this possibility, 2 and 10 year storm hydrographs were routed through the pond and downstream culverts for conditions with and without the new Stormwater Management Facility for existing and earlier land uses, respectively. The resultant hydrographs are shown on Figures 16 and 17. Comparing the hydrograph for the old pond/earlier land use to the hydrograph for the new pond/existing land use (the hydrograph for ultimate land use would be about the same as this one) shows that no lengthening of the duration of peak flows has occured. In fact, current high flows are of a few minutes shorter duration than previously. The pond has resulted in extending the hydrograph but only for flows below about two-thirds of the peak and for times that would not generally alter stream channel erosion potential.

In summary, this reach downstream of the Rt. 50/450 ramps is under relatively severe stress due to a combination of debris accumulation and physical characteristics of the channel. Hydrologic analysis indicates

Photo 5 Debris and Vegetation in Weems Creek at U.S. Rte. 50 and MD. Rte. 450 Ramps (Pt. E)

Photo 6 Channel Degradation and Bank Failure on Weems Creek (Pt. F)

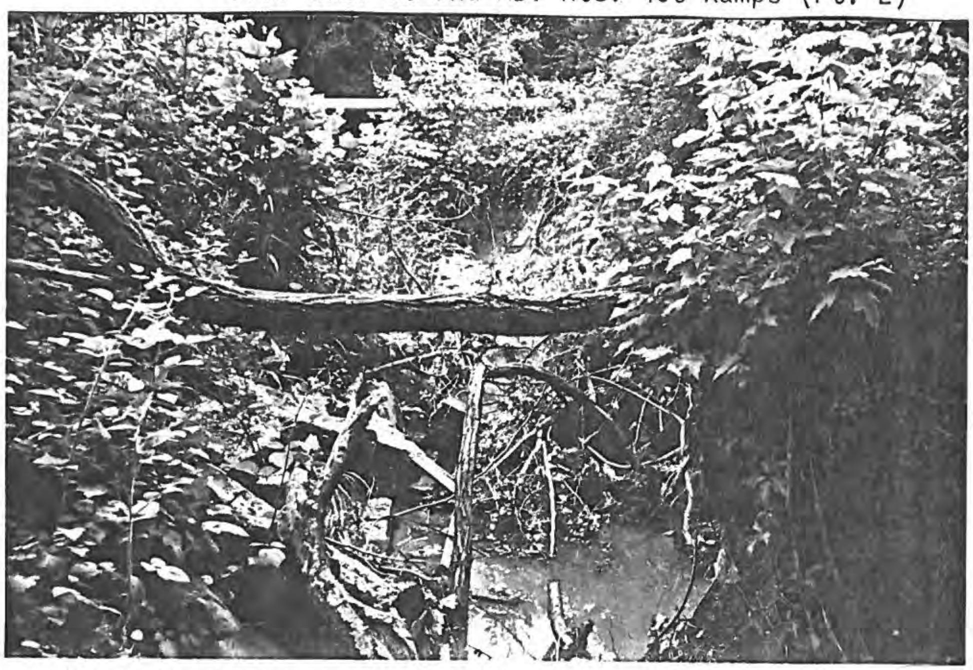


Photo 7 Bank Erosion Undercutting Trees on Weems Creek (Pt. G)

Photo 8 Bank Sloughing and Erosion on Weems Creek (Pt. H)

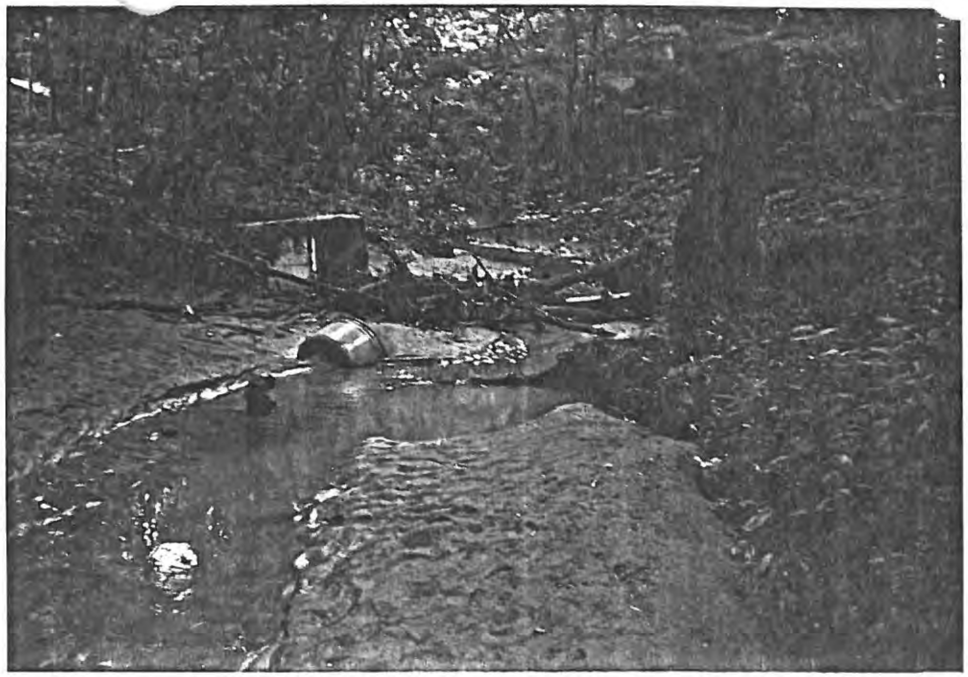


Photo 9 Channel Aggradation and Debris on Weems Creek (Pt. I)

Photo 10 Bank Erosion and Debris on Weems Creek at U.S. Rte. 50 (Pt. J)

Photo 11 Debris and Aggradation in Weems Creek Downstream of U.S. Rte. (Pt. K)

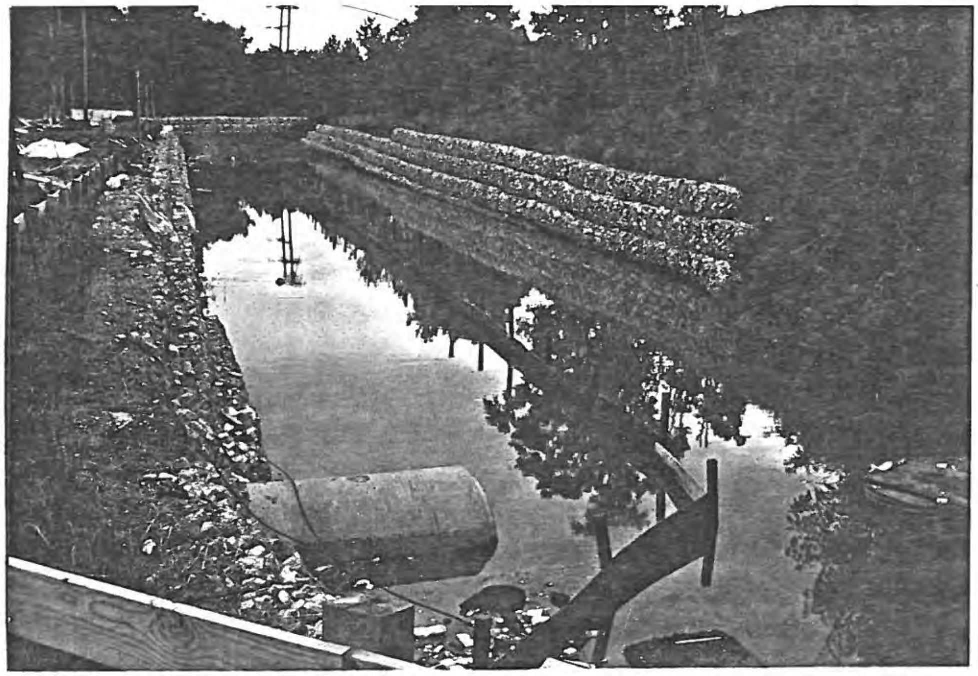


Photo 12 Stormwater Management Facility Southeast of Annapolis Mall

Photo 13 Stormwater Management Facility near J R Annapolis

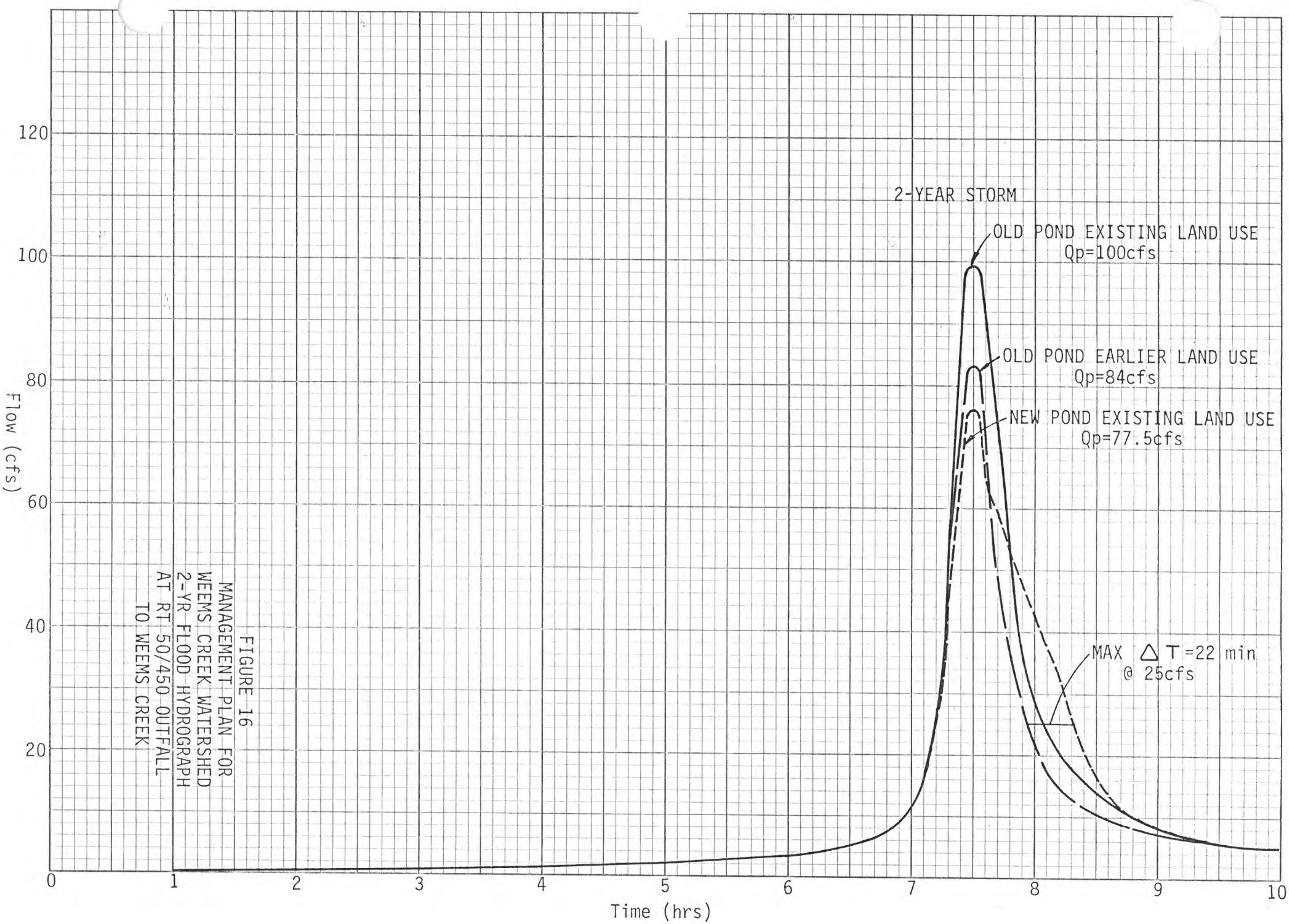


FIGURE 16
MANAGEMENT PLAN FOR
WEEMS CREEK WATERSHED
2-YR FLOOD HYDROGRAPH
AT RT 50/450 OUTFALL
TO WEEMS CREEK

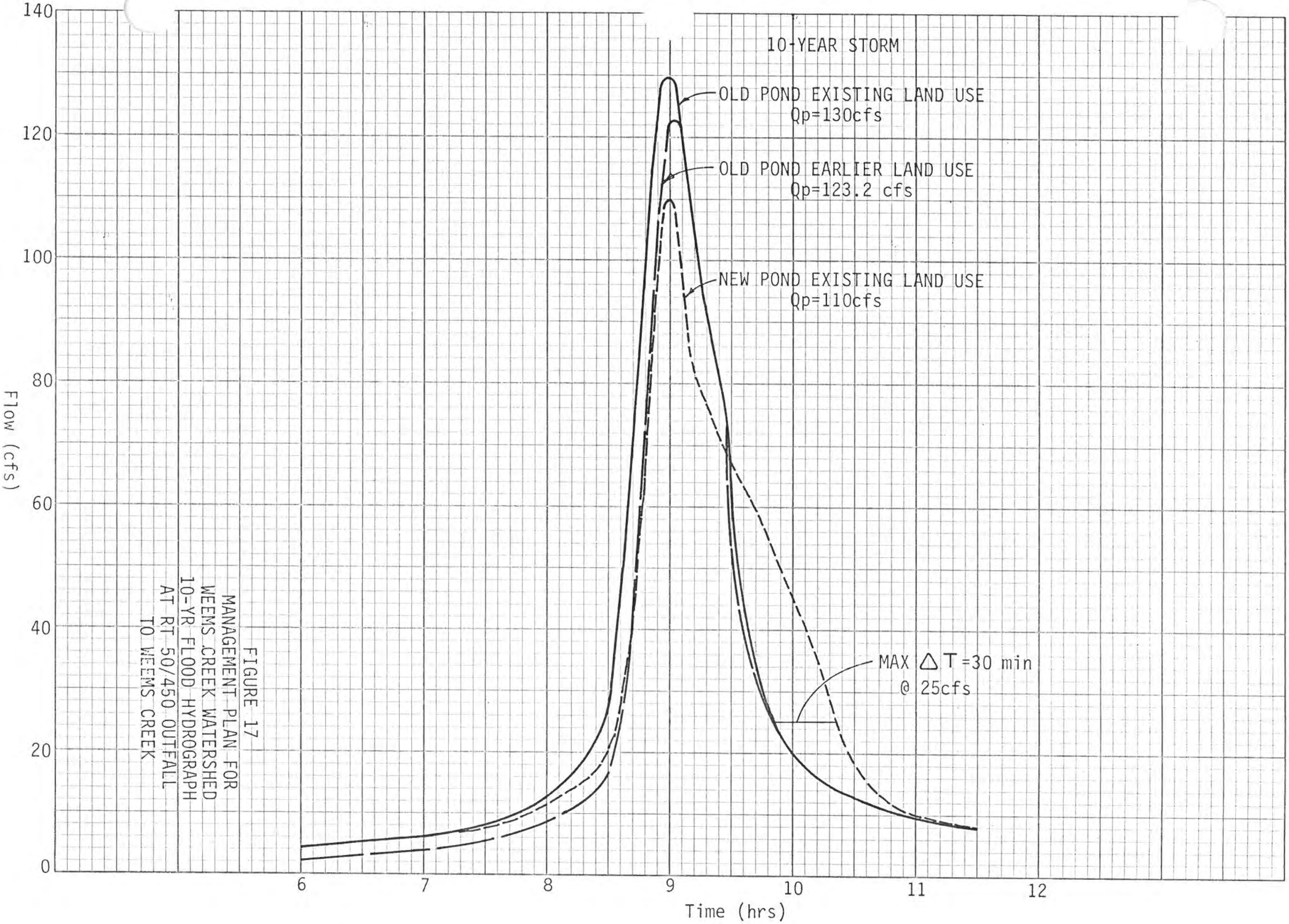


FIGURE 17
MANAGEMENT PLAN FOR
WEEMS CREEK WATERSHED
10-YR FLOOD HYDROGRAPH
AT RT 50/450 OUTFALL
TO WEEMS CREEK

that the Restaurant Park Stormwater Mangement Facility achieves the required flow control and does not extend duration of bankfull stream flows.

6.2 WATER QUALITY

Besides the sources of sedimentation addressed in the previous section the other typical sources of pollution are:

- Runoff from urban (developed) areas;
- Runoff from the major highway systems;
- Sewage and garbage dumped by boaters; and
- Failing septic systems.

Is is a difficult analysis to quantify the impacts of these sources of pollutants on either the existing or the long term viability of Weems Creek. In the absence of extensive detailed water quality data that would indicate either a healthy creek or a creek under stress, it would seem prudent to take practical measures to control pollutant discharges to the creek.

If the assumption is made that an increase in annual pollutant loadings to the Weems Creek system is an indicator of a potential problem, then the pollutant loadings as reported in technical studies [10, 11] are worthy of note. Table 11 shows total pollutant loadings for existing conditions and ultimate land use conditions, without future stormwater management controls. Note that both existing and ultimate conditions consider the reduction effects of the stormwater management ponds at Restaurant Park and J.R. Annapolis. Without stormwater controls, the amount of pollutants that will be introduced into Weems Creek under ultimate development condition will increase greatly. It is expected that properly constructed and maintained on-site SWM controls would maintain ultimate pollutant loadings at close to the existing levels.

TABLE 11

TOTAL POLLUTANT LOADS GENERATED IN THE WATERSHED

(lbs/Year)

Pollutant	Existing Land Use	Ultimate Land Use	% Increase
BOD	60,222	109,472	82
Phosphorus	1,154	1,755	52
Nitrogen	10,140	15,031	48
Lead	1,009	1,896	88
Zinc	683	1,275	87
Sediment (Tons/Year)	203	285	40

6.3 FLOODING

The flooding of structures in both the tidal and non-tidal portions of the watershed is negligible. The tidal portion is subject to tide and storm elevations from the Severn River. High bluffs and a relatively narrow channel, which acts to reduce the fetch length, minimizes wave action that would cause flooding.

In the non-tidal portion of the watershed, the only flooding problem identified occurs at Admiral Drive [5]. Under existing conditions the 100-year flood inundates the roadway to a maximum depth of 1.0 feet. Approximately 200 feet of road is flooded. Proposed ultimate development, with no control, increases the flooding depth by only 0.1 of a foot.

7. MANAGEMENT ALTERNATIVES

The following section presents alternatives that were formulated to mitigate the problems identified and discussed in Chapter 6. In summary, the management alternatives will address problems associated with the natural rainfall/runoff processes, as well as with man's activities within the watershed, including erosion and sedimentation, water quality degradation, and flooding.

7.1 Alternative Criteria and Objectives

7.1.1 Criteria

The criteria listed below serves as the basis for the development and formulation of management alternatives and will also serve as the basis for the evaluation process:

- Technical feasibility
- Cost effectiveness
- Aesthetic impacts
- Environmental impacts
- Recreational opportunities

7.1.2 Objectives

Management alternatives are formulated to achieve the following objectives within the watershed:

- Reduce the sediment load delivered to Weems Creek
- Minimize flooding impacts
- Prevent accelerated stream channel erosion
- Maintain and/or improve water quality
- Preserve wetlands and natural features

7.2 Alternative Formulation

Alternatives were developed for a number of impacts as discussed in detail in Chapter 6. Some of these impacts are man-induced and others are naturally occurring phenomena. The stormwater impacts delineated in Chapter 6 can be summarized as follows:

1. Soil erosion of steeply sloped terrain.
2. Slope failure and soil sloughing of "cliffs" bordering the tidal reaches.
3. Fine sediments and collodial materials discoloring the upstream portions of the Weems Creek tidal reach.
4. Stream channel erosion and accumulation of debris downstream of the Route 50/450 ramp.
5. A projected increase on the order of 60% in uncontrolled non-point source pollutant loads under ultimate land use conditions.
6. The overtopping of Admiral Drive by one foot of water during the 100-year storm event.

In addition to stormwater impacts there are potential impacts related to the uses of the Weems Creek tidal portion due to man's activities. These impacts may include:

7. Engine waste by-products from motor boats, specifically oil, grease, and heavy metals.
8. Re-suspension of sediments due to boat traffic.
9. Purging of waste products by boaters.

Management alternatives were developed in a comprehensive framework to address both the tidal and non-tidal areas of Weems Creek. Additionally, alternatives were formulated utilizing existing programs and agencies wherever possible. The selection process considered both non-structural and structural management alternatives. Essentially, structural alternatives were formulated at specific problem areas within the watershed, where non-structural solutions would have little benefit. In summary, the management alternatives address all nine flooding, erosion, and water quality impacts as described above.

7.3 Alternative Evaluation

7.3.1 Qualitative Screening of Alternatives

To evaluate the merits of management alternatives, a qualitative evaluation was performed as a preliminary screening mechanism. Table 12 presents the results of the qualitative screening evaluation. This preliminary screening procedure, although based primarily on engineering judgement, is a useful planning procedure which involves a qualitative evaluation of a wide range of alternatives to ensure that potentially feasible alternatives are not overlooked. Some of the alternatives listed in Table 12 may be disqualified because they are technically infeasible or have potential adverse impacts on the Weems Creek environment.

7.3.2 Detailed Alternative Analysis

A detailed analysis of selective alternatives was performed to evaluate the overall effectiveness and costs of each alternative. "Policy and Program Alternatives", numbered 1-12, are projected to have significant benefits, however, it would be difficult to estimate the program costs associated with the Weems Creek Watershed. Further, these program costs would be realized by many groups (property owners, the State of Maryland, Anne Arundel County, the City of Annaplis, land developers, and others). Therefore, detailed alternative analyses have been completed for "Engineering Solution Alternatives" where a specific quantification of the alternative will provide meaningfull information regarding the implementation of the Weems Creek Watershed Management Plan. The detailed evaluation of structural management alternatives was performed for alternatives 13, 14, 15, 16, 17, and 18 as described below.

TABLE 12. QUALITATIVE ALTERNATIVE EVALUATION

Alternative	Qualitative Alternative Evaluation	Impacts Addressed
A. Policy and Program Alternatives (Non-structural solutions)		
Non-tidal		
1. Ongoing enforcement of the City and County Erosion and Sediment Control Programs. Restrict development on slopes greater than 15%.	The enforcement of these existing programs will serve to minimize construction site erosion.	1. Soil erosion. 2. Slope failure. 3. Fine sediments in tidal areas.
2. Delineate and enforce the 100-year floodplain boundaries. Consider dedicating this land as open space.	The development and enforcement of 100-year floodplain regulations will eliminate the possibility of future flooding. Additionally, if this land is dedicated as parkland, a maintenance program will keep waterways clear of debris.	4. Stream channel erosion.
3. Ongoing enforcement of County/City Stormwater Management Ordinances.	The enforcement of existing SWM programs on new development which encourages onsite infiltration practices on suitable soils, will minimize flooding, stream erosion, and water quality benefits.	5. Nonpoint source pollution.
4. Implement and enforce a regular parking lot cleaning program at the Annapolis Mall and other large parking lot areas.	A major contributor of NPS pollutant loads in Weems Creek is the large parking lots at and near the Mall. Regular removal (i.e., 2-4 times per week) of the pollutants at the source by vacuum sweepers can be a very effective control.	5. Nonpoint source pollution.

TABLE 12. QUALITATIVE ALTERNATIVE EVALUATION (Continued)

Alternative	Qualitative Alternative Evaluation	Impacts Addressed
Tidal		
5. A.A. Co. SCD technical assistance directed toward embankment stabilization. First priority should be given to steep slopes along the Weems Creek shoreline. Refer to Figure 3.	Stabilization of steep slopes can reduce sediment loads that are directly deposited in the tidal area of Weems Creek.	1. Soil erosion. 2. Slope failure. 3. Fine sediments in tidal areas.
6. Shoreline Protection, Habitat Enhancement, Aquatic Re-vegetation.	By protecting the tidal shoreline at the bottom of steep sloped areas, the undercutting of embankments can be reduced, minimizing further slope failures. A program to enhance habitat and encourage aquatic vegetation can serve to improve water quality, dampen the impacts of wave action and support wildlife.	2. Slope failure. 3. Fine sediments in tidal areas.
7. Enforcement of boat speed limits.	By limiting the speed of motor boats, the re-suspension of sediments in the estuary due to boat movement and the erosion potential due to wakes will be minimized.	8. Re-suspension of sediments.
8. Limit size of motors on Weems Creek.	This alternative will limit the contribution of oil, grease, and heavy metals from motors.	7. Engine waste by-products. 8. Re-suspension of sediments.

TABLE 12. QUALITATIVE ALTERNATIVE EVALUATION (Continued)

Alternative	Qualitative Alternative Evaluation	Impacts Addressed
9. Set up Program/Facilities for nearby solid waste and sewerage collection for boaters.	By providing convenient waste disposal facilities and having stiff fines for non-compliance, the dumping of waste products in Weems Creek can be minimized.	9. Purging of wastes by boats.
10. Information Program, coordinated through Weems Creek Conservancy to inform homeowners and boaters within the watershed about the condition of Weems Creek and what homeowners can do about it.	By directing the Program toward what the individual homeowner can do to minimize collective impacts, a reduction of NPS pollutants can be achieved. An example would be the safe application and disposal of weed killers (herbicides) so that they don't directly wash into the Creek and possibly kill important aquatic vegetation.	5. Nonpoint source pollution. 7. Engine waste by-product. 8. Re-suspension of sediments. 9. Purging of wastes by boats.
11. Water Quality Monitoring and Evaluation Program (tidal & non-tidal) including estuary sediment samples for metals and toxic compounds. Primary purpose to develop preliminary indications of pollution impacts. Analysis of shellfish pollution contamination levels.	To assess the exisiting conditions and monitor future conditions, a water and sediment quality sampling and analysis program will provide indications of the "State of Weems Creek." If severe problems are developing, this program will potentially provide an early warning so that more intense management measures can be taken.	All Water Quality Impacts
12. The preservation of wetland areas to serve as natural filters of stormwater runoff (tidal & non-tidal).	Wetland areas will remove NPS pollutants by biological and physical processes.	3. Fine sediments in tidal areas. 5. Nonpoint source pollution.

TABLE 12. QUALITATIVE ALTERNATIVE EVALUATION (Continued)

Alternative	Qualitative Alternative Evaluation	Impacts Addressed
Engineering Solution Alternatives (Structural solutions)		
Non-Tidal		
13. Channel improvement near the Route 50/301 West Street ramp.	This improvement will minimize further stream erosion in this channel reach.	4. Stream channel erosion.
14. Mitigate the erosion problem at the west bridge abutments at Route 50 and Admiral Drive.	Erosion protection at this downstream location will potentially minimize the deposition of sediment in the Tidal portions of Weems Creek.	1. Soil erosion. 2. Slope failure. 3. Fine sediments in Tidal areas.
15. Retrofit existing SWM facilities.	Water quality and stream erosion benefits can be derived from retrofitting existing structures.	3. Fine sediments in Tidal areas. 5. Nonpoint source pollution.
16. Construct regional stormwater management facilities.	Regional facility(ies) can be designed to reduce flooding at Admiral Drive, as well as stream erosion and water quality impacts.	4. Stream channel pollution. 5. Nonpoint source pollution. 6. Flooding of Admiral Drive.
17. Enlargement of the stream crossing at Admiral Drive.	By enlarging this stream crossing, flooding can be eliminated although downstream areas may be adversely impacted. Actions should be coordinated through State Highway Authority.	6. Flooding of Admiral Drive.
18. Construct gabion check dams in series for stream reaches with channel erosion problems.	This alternative will potentially stabilize eroding channel reaches.	3. Fine sediments in Tidal areas. 4. Stream channel pollution.

Alternative 13

Channel Improvement near the Route 50/301 West Street ramp

Downstream of the Route 50/450 ramps, Weems Creek must be stabilized to prevent further severe erosion that could lead to larger problems of slope failure of the highway embankments and increased sediment loads to the tidal reach. Stabilization should be achieved by:

1. An initial program to clear trash, vegetative debris, loose rubble and other obstructions from the channel between sections 23 and 17. Living trees and shrubs which have been undercut and are in danger of uprooting should also be removed.

2. Channel banks should be regraded to provide a continous flow path of constant geometry (probably trapazoidal) in the reach shown on Figure 14.

3. Channel banks between Section 23 and 21 (about 480 feet) should be protected with a flexible channel lining. Initial analysis indicates that rock riprap would be preferred over gabions or revet mattresses. Aesthetic considerations are minimal for this reach. Riprap should be designed to provide two foot freeboard for the 50 year flow. Special consideration must be given to increased flow depths and shear stress on outer banks of channel bends. Flow depths should be checked using roughness values for riprap based on the mean stone size determined during design. Special consideration must be made for steep side slopes. A plastic filter cloth should be use as an underlaying filter material. The width of riprap channel should be increased before discharge into the natural waterway to decrease flow velocity.

4. The channel bed should be stabilized either by extending riprap to protect the channel bottom or by constructing groins as grade controls to prevent bed degradation. Groins could be made of concrete or gabions and should be adequately anchored. Spacing

should be determined during design based on final channel slope and flow velocity criteria.

5. The existing concrete aprons at the outfalls of the three pipes downstream of the Route 50 on-ramp (Point B, Photo 2) should be removed and replaced with gabion or concrete aprons and splash surfaces to prevent further bank erosion.

6. A regular maintenance program should be implemented to keep the channel free of debris, repair riprap as required, and monitor conditions in the natural waterway downstream.

7. Side channels, outfalls and tributaries should be cleared of debris and adequately protected to prevent erosion.

It is estimated that construction costs for the above improvements, including the riprap lining, groins and apron replacment, would be about $43,000.

It is very important that decisions to implement the above recommendations are made with consideration of the nature and schedule of the most recent State Highway Administration plans for widening of Rt. 50 and reconstruction of the access ramps.

Alternative 14
Erosion at bridge abutment near Route 50/301 and Admiral Drive

Drainage from the highway has caused significant erosion at the western abutments of the U.S. Route 50/301 spans over Weems Creek. This erosion has resulted in the formation of two gullies: one along the north side of the westbound lane and the other along the south side of the eastbound lane. The gullies are an immediate concern since the erosion occurs within 50 feet of Weems Creek. The erosion in these areas can be reduced by providing riprap drainage ditches to carry the drainage from the highway to the stream. Riprap toe walls should be provided at the upstream and downstream ends of the ditches. Providing two of these ditches constructed with 18 inches of riprap would cost approximately $1400.

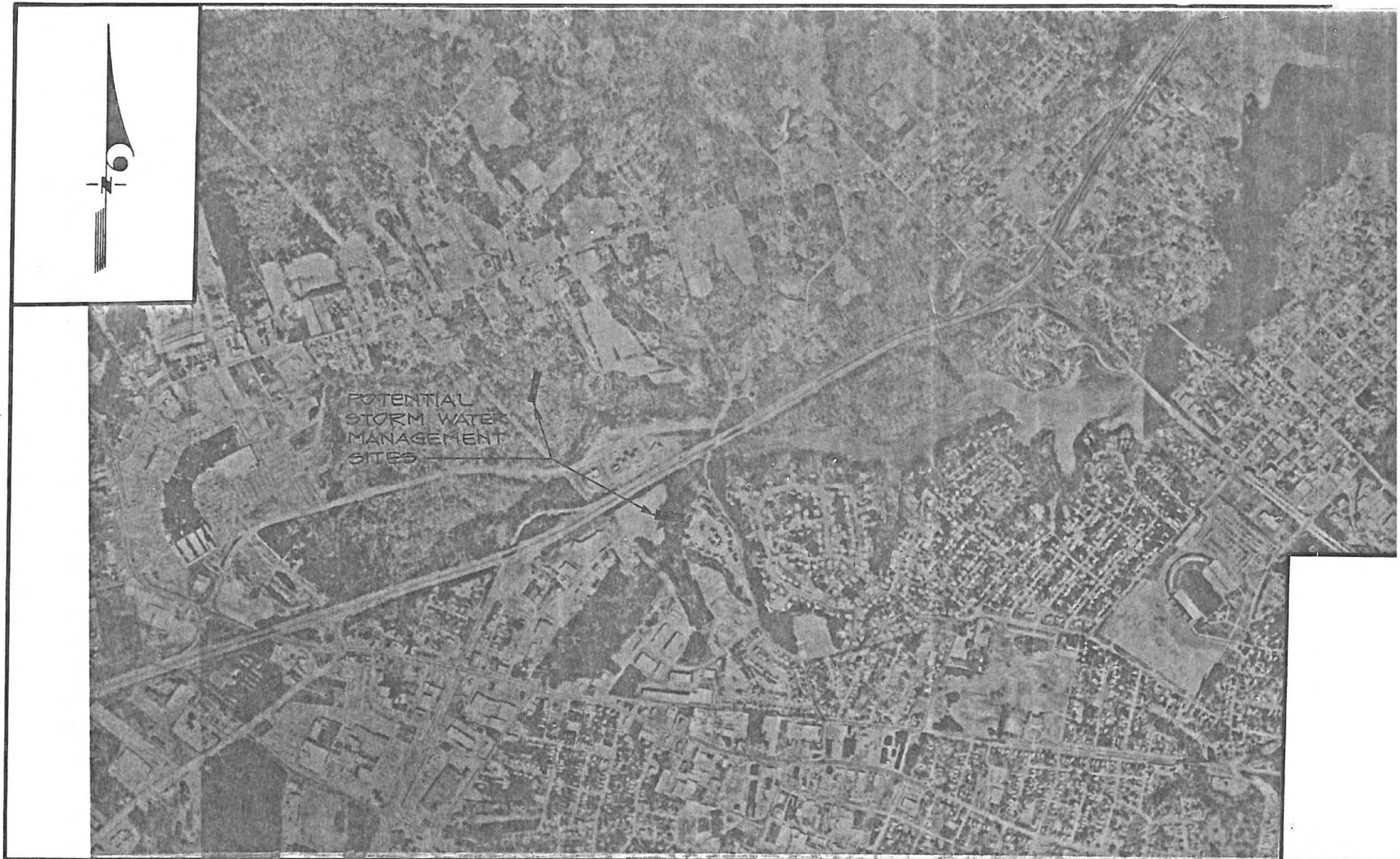
In general, field inspections of road and highway drainage channels should be conducted regularly to identify locations of gullying and erosion. Alternatives 13 and 14 should be coordinated with plans for state and local highway projects.

Alternative 15
Retrofit existing SWM facilities

There are presently two major stormwater management facilities within the Weem Creek watershed where retrofitting was considered. The first facility, as shown in Photo 12 is located in subarea number 1 southeast of the Annapolis Mall and north of Route 50/301. This facility drains a 36.5-acre area around Restaurant Park and was designed to control the 2-, 10-, and 100-year storm flows. Retrofitting this facility for water quality control is not recommended because of storage limitations.

The second SWM facility is a dry pond located in the J.R. Annapolis area at the outlet to subarea number 7. Shown in Photo 13 after a storm event, the 17.4-acre-feet pond provides 2-, 10-, and 100-year peak flow control for the 65.2-acre drainage basin. According to a report about recent modifications to the facility (8), the pond has been designed to enhance infiltration by establishing the bottom of the pond on a suitable soil. A possible "retrofit" consideration for this facility would be to establish wetland vegetation in the pond and to ensure a good vegetative cover along the sides of the pond.

Additional retrofitting alternatives, not specifically evaluated in this study, should be considered as part of the long range objectives of the Weems Creek Watershed Plan. Management consideration should be given to the control of runoff from urban areas that drain directly into the tidal portions of Weems Creek, specifically, the area within the City of Annapolis on the south side of Weems Creek.



NOTE: Aerial Photography provided by Anne Arundel County Office of Planning and Zonning.

No.	REVISION	DATE	BY

ENGINEERS • ARCHITECTS • PLANNERS • SCIENTISTS • SURVEYORS • PHOTOGRAMMETRISTS

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FIGURE 18
MANAGEMENT PLAN FOR
WEEMS CREEK WATRESHED
PROPOSED SWM PONDS LOCATIONS
ANNE ARUNDEL COUNTY, MARYLAND

SN DESIGN
mdv DRAWN
SN CHECKED
8/85 DATE

Alternative 16

Regional Stormwater Facilities

The possible use of regional stormwater management facilities in the Weems Creek watershed could be implemented as a coordinated effort between the County and the future developers of areas in the watershed. Typically, a Regional Stormwater Program involves the County or municipality assuming a major role to oversee planning, design, construction, and maintenance of the facility. The developers involvement, in lieu of 2-, and 10-year, onsite control structures/facilities, would be to contribute to the cost to the regional facility. A detailed economic and environmental evaluation of the benefits of regional stormwater management was performed in the Washington, DC area (9). The watershed study concluded that the regional stormwater management facility construction and maintenance costs were on the order of one third of the cost of comparable onsite structures/facilities. Additional potential benefits of a regional versus an onsite stormwater management plan include:

- Increased recreational opportunities
- Net reduction in land area committed to SWM
- Easier to inspect and regulate one larger versus many smaller facilities
- Wider public visibilty to promote the objectives of SWM

As part of this project a preliminary design of two regional stormwater facilities was developed. The location of these facilities is shown in Figure 18. The stormwater management facility benefits were evaluated using the TR-20 watershed model. Stormwater management benefits of these ponds include a reduction in flood flows, a reduction in pollutant loads to the tidal areas, and a reduction of stream channel erosion. Both regional facilities were designed to store approximately 0.5 inches of runoff at the normal pool elevation which results in a pond depth of 7 to 9 feet. Because of the steep topography, the normal pool areas are approximately 1.5 acres. A two-foot freeboard over the 100-year flood elevation was included in both designs. The first wet pond, Regional Pond Site Number 9, would be located about 2500 feet upstream of the intersection of Admiral

Drive and Jennifer Road within Subarea 9. The second pond, referred to as Regional Pond Site Number 13, would be located approximatley 1000 feet upstream of Admiral Drive in Subarea 13.

Regional Pond 9 was designed to be 23.5 feet in height, has an embankment length of 220 feet, and a drainage area of 218 acres. The maximum storage volume is approximately 40 acre feet at an elevation of 32.0 feet National Geodetic Vertical Datum (NGVD). The cost of constructing this facility is estimated between $150,000 and $200,000 based on information from recent cost estimates of similar stuctures and reference 10. The facility would remove approximately 50% of incoming nonpoint source pollutants, and would control 2-, 10-, and 100-year flood peak flows to existing levels.

Regional Pond 13 would be 16.5 foot high, with an embankment length of 280 feet and a drainage area of 108 acres. Pond 13 would be designed to have a maximum storage volume of 36.5 acre-feet at an elevation of approximatley 30.0 feet NGVD. The estimated construction cost is between $160,000 and $220,000. This facility would be designed to remove approximately 50% of incoming nonpoint source pollutants which would control upstream pollutants runoff to condition existing levels. Additionally, 2-, 10-, and 100-year flood flows under ultimate land use conditions would be reduced to predevelopment levels.

Alternative 17

Enlargement of Weems Creek crossing at Admiral Drive

It is recommended that this alternative be evaluated using the watershed model developed for this study when the currently-planned Anne Arundel County capital improvement project for Admiral Drive is designed. Any proposed modifications to the existing culvert should be carefully evaluated so that detrimental downstream impacts do not occur.

If it is decided to enlarge the culvert, a triple 7-foot by 10-foot box culvert would be required to safely pass the 100-year flood under ultimate land use conditions. The estimated cost of this structure is $100,000.

Alternative 18

Construct gabion check dams in stream channels with severe erosion problems

This alternative would only be necessary if severe problems from natural or man-made sources should develop. The use of small gabion structures to reduce channel velocities and control stream erosion is an aesthetically pleasing technique which can be a cost efficient control. For planning purposes, these structures are estimated to cost approximately $40.00 dollars per square foot.

8. WATERSHED MANAGEMENT PLAN

In this chapter, the Weems Creek management plan is presented and the plan implementation aspects of the plan are discussed. The nature of the watershed, the problems that were identified, and the feasible solutions do not lend themselves to the traditional alternative evaluation procedures. In a traditional evaluation procedure, there are several alternatives for each problem. Ordinarily, these alternatives can be compared and evaluated against each other, and using specific criteria, the most desirable alternative is selected. In the Weems Creek Watershed, however, erosion and water quality are the primary concerns. In order to properly address these concerns, several actions need to be undertaken. These actions, or alternatives, are not tradeoffs, but must be undertaken in combination or in some sequence in order to address the identified problems. Therefore, this Management Plan is presented as a plan to be implemented with priorities associated with each plan element.

8.1 GOALS AND OBJECTIVES

In summary, the goal of this Management Plan is to provide the County with a set of recommendations which, when implemented, provide for orderly growth within the watershed while protecting and improving water resources and the existing quality of life in the Weems Creek Watershed.

These goals will be accomplished in large measure if the objectives of minimizing erosion and sedimentation and preventing water quality degradation are achieved.

8.2 RECOMMENDED MANAGEMENT PLAN

Table 13 presents a prioritized list of recommendations for management of the Weems Creek Watershed. This plan is the product of many activities including:

- Field reconnaissance.
- Research on past studies and information.

- o Technical analyses.
- o Discussions with DPW and P&Z staff.
- o Determination of citizens opinions and concerns.

Each element of the plan is referenced to the associated alternative as discussed in Chapter 7.

8.3 IMPLEMENTATION

The most critical part of any watershed plan is the implementation of management elements to accomplish the immediate and long-term goals of he program. This Management Plan was formulated to utilize effectively the resources of as many existing programs and agencies as possible in the plan implementation stages. Additionally, by utilizing existing resources, the financial burden to the County may be controlled.

The Watershed Management Program, administered through the Department of Public Works, will be responsible for the overall coordination and implementation of the Weems Creek Watershed Management Plan. Watershed Management Program staff will work in close coordination with the Department of Planning and Zoning, which will provide valuable assistance with land use and zoning regulations, and other non-structural management alternatives. Additionally, the coordination with the City of Annapolis, the State of Maryland, and other County agencies and departments will be important. Table 14 is a matrix of various agencies whose participation is necessary to successfully implement the Weems Creek Watershed Management Plan.

TABLE 13. WATERSHED MANAGEMENT PLAN

Plan Element	Alt. No.	Comments	Cost (1985 dollars)
HIGH PRIORITY			
Channel improvement downstream of Rt 50/301 West Street ramp	13	Requires SHA coordination and integration into I-68 design.	$45,000
Erosion mitigation at Rt 50/301 bridge abutment near Admiral Drive	14	Requires SHA coordination/action.	$1,700
Slope/embankment protection	5	Coordination with City of Annapolis, Soil Conservation District, citizen groups	site specific
Ongoing enforcement of County/City SWM ordinances	3	Will require well trained inspection personnel.	no capital cost
Ongoing enforcement of erosion and sediment control programs	1	Directed toward controlling construction site erosion.	no capital cost
Enforce 100-year floodplain boundaries	2	Adopt floodplain maps for the purpose of regulating development within the floodplains.	no capital cost
Set up program/facilities for providing convenient solid waste and sewage collection for boaters	9	Requires joint County/City program. Should impose fines for violators after facilities are made available.	undetermined
Wetland preservation	12	Incorporate as part of critical area plan.	no capital cost
Water quality monitoring and evaluation program	11	Needed for assessment and baseline data.	dependent on program design
Restrict development on slopes greater than 15%	1	County and city regulation required.	no capital cost
Shoreline protection, habitat enhancement by aquatic re-vegetation	6	Primarily directed at the base of steep slopes in the tidal areas. This alternative includes the use of shoreline protection in combination with aquatic revegetation.	undetermined

TABLE 13. WATERSHED MANAGEMENT PLAN (Continued)

Plan Element	Alt. No.	Comments	Cost (1985 dollars)
INTERMEDIATE PRIORITY			
Mall parking lot cleaning program	4	Controls pollutants at the source.	$39,000/yr
Regional stormwater management facilities	16	Requires cost sharing or the adoption of a fee in lieu of program.	site specific
Retrofit existing stormwater management facilities	15	Requires cooperation with facility owners.	undetermined
Reduce flooding at Admiral Drive by channel and culvert enlargement	17	Requires coordination with County Capital Project upgrading Admiral Drive.	$100,000
Information/education program	10	Coordination through Weems Creek Conservancy.	no capital cost
LONG RANGE PLAN ELEMENTS			
Enforcement of boat speed limit	7	Concerted county/city effort required.	undetermined
Limitation on size of boat motors	8	Difficult to implement.	no cost
Gabion check dams for channel erosion prevention	18	If stream channel erosion occurs as future development takes place.	Approximately $8,000 per gabion check dam

TABLE 14. WATERSHED MANAGEMENT PLAN - LEAD AGENCY MATRIX

Plan Element	Department of Public Works	Planning & Zoning	Department of Inspection & Permits	City of Annapolis	State Highway Administration	Soil Conservation District	Department of Health	State WRA
Channel improvement downstream of Rt 50/301 West Street ramp	P				P	S		
Erosion mitigation of Rt 50/301 bridge abutment near Admiral Drive	S				P	S		
Slope/embankment protection	S	S		P	S	P		
Ongoing enforcement of County and City SWM ordinances	S	P	P	P				S
Ongoing enforcement of erosion and sediment control programs	S		P	~~P~~ S*		P		~~S~~ P*
Enforce 100-year floodplain boundaries	S	S	P	P*				
Program/facilities for solid waste and sewerage collection for boaters	S	S		S*			P	
Wetland preservation	S	P	S					S
Water quality monitoring and evaluation program	P	P		P			P	S
Restriction of development on steep slopes		P	S	P		S		
Mall parking lot cleaning program	P	P	P				S	
Regional SWM facility program	P	S	S					S
Retrofit existing SWM facilities	P		S	P*		S		S

P = Primary Responsibility
S = Secondary Responsibility

* CHANGES RECOMMENDED BY CITY OF ANNAPOLIS

TABLE 14. WATERSHED MANAGEMENT PLAN - LEAD AGENCY MATRIX (Continued)

Plan Element	Department of Public Works	Planning & Zoning	Department of Inspection & Permits	City of Annapolis	State Highway Administration	Soil Conservation District	Department of Health	State WRA
Reduce flooding at Admiral Drive by culvert enlargement	P							
Information/education program for citizens	P	S		P		S	P	
Enforcement of boat speed limit		~~S~~ *		~~P~~ *				(DNR)*
Limitation on size of boat motors		S	P	P				
Gabion check dams for channel protection	P					P		
Shoreline protection, habitat enhancement, and aquatic re-vegetation	S	P		P*		P		S

P = Primary Responsibility
S = Secondary Responsibility

* CHANGES RECOMMENDED BY CITY OF ANNAPOLIS

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