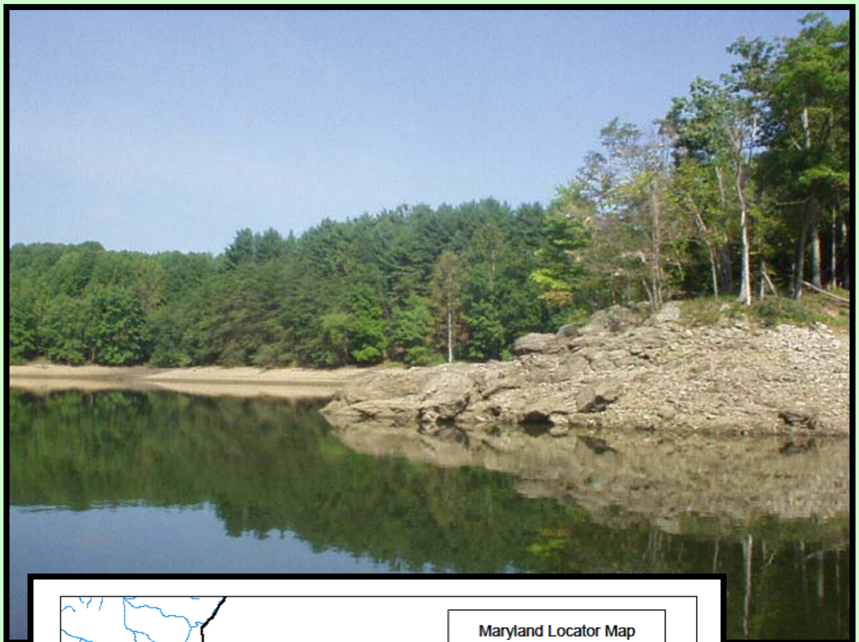

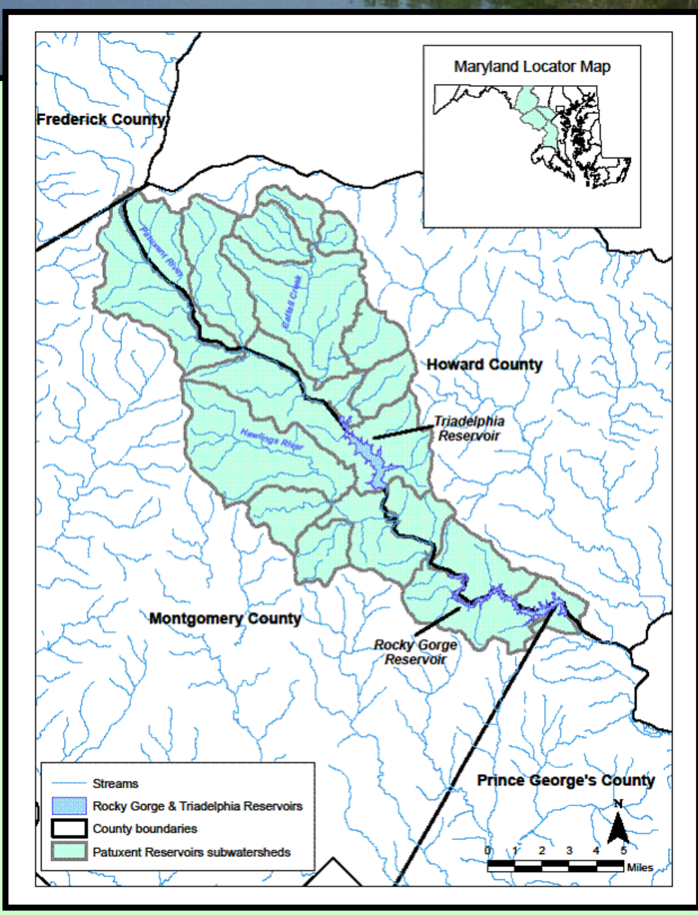

PATUXENT RESERVOIRS INTERIM WATERSHED MANAGEMENT REPORT

Submitted to

Patuxent Reservoirs Watershed Protection Group
Technical Advisory Committee

Submitted by

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EXECUTIVE SUMMARY

The Patuxent Reservoirs

The Triadelphia Reservoir, created by construction of the Brighton Dam in 1943 and the Rocky Gorge Reservoir, created by construction of the T. Howard Duckett Dam in 1952, and the watershed which feeds them, provide an 11-billion gallon source of drinking water for approximately 650,000 inhabitants in the supply area of Prince George's and Montgomery counties, Maryland. Water withdrawn from the Rocky Gorge Reservoir is treated at the Washington Suburban Sanitary Commission's (WSSC) Patuxent Water Filtration Plant. A very small population within Howard County also receives water from the Patuxent Plant. The reservoirs are located in the upper, non-tidal reaches of the 100-mile long Patuxent River. The two reservoirs and approximately 5,500 acres of the 85,000-acre watershed are under the direct management of the WSSC. The Triadelphia Reservoir drains 79 square miles and Rocky Gorge lies 13 miles downstream and drains 132 square miles (EA Engineering 1991).

The 132-square-mile drainage area for the two reservoirs is distributed among four counties, but 99% of the drainage area lies in Montgomery County and Howard County, with 39,600 acres or 46% of the total watershed in Montgomery County, and 44,800 acres or 53% of the total watershed in Howard County. Less than 1% lies within Prince George's and Frederick counties (Montgomery County DEP 1995).

Source Water Quality

There is a long history of research detailing concerns about nutrient, sediment, and other pollutant contributions to the Patuxent Reservoirs, and Total Maximum Daily Loads (TMDLs) have been established for phosphorus in both reservoirs and for sediment in Triadelphia Reservoir. The TMDL document, prepared by Maryland Department of the Environment (MDE) and approved by EPA in November 2008, calls for a 58% reduction in phosphorus to Triadelphia Reservoir, a 48% reduction in phosphorus to the Rocky Gorge Reservoir, and a 29% reduction in sediment to Triadelphia Reservoir. The TMDLs were supported by a modeling effort by the Interstate Commission on the Potomac River Basin (ICPRB 2007). An estimated 50% of total phosphorus loads to the Triadelphia Reservoir are derived from crops and 28% from stream channel scour (Table 8-2). An estimated 34% of total phosphorus to the Rocky Gorge Reservoir originates in the Triadelphia watershed, 24% is from crops and 18% is from developed land uses (Table 8-4). Also, 54% of sediment to the Triadelphia Reservoir originates from crops and 38% from stream channel scour (Figure 8-4).

ICPRB notes that, "Like many lakes and reservoirs, Triadelphia Reservoir and Rocky Gorge Reservoir are stratified by temperature-induced density differences from the spring through later summer and sometimes early fall, and this stratification can induce low DO concentrations in the hypolimnion or bottom layer of the reservoirs. The hypoxia is caused by the fact that decaying organic material in the sediments and water column consumes oxygen, while stratification dampens the mixing of DO from surface reaeration."

Project Context

This Interim Watershed Management Report, commissioned by WSSC for the Patuxent Reservoirs Watershed Protection Group's Technical Advisory Committee (TAC), is a compilation of 33 reports on the Patuxent Reservoirs watershed over a 30-year period, in combination with new GIS analysis using the latest data layers to characterize current land use and other stressors. Evaluation of this body of literature is not only critical for characterization of the watershed historically, but it also demonstrates a consensus of recommendations generated over three decades by numerous public agencies, non-governmental organizations, and consultants. This report is intended to inform long-term management of the contributing watersheds, including both WSSC-owned land and those areas outside of the direct control of WSSC.

The report is not intended to serve as a TMDL Implementation Plan. It is deemed "interim" because some of its findings and recommendations may be modified or superseded by watershed implementation plans that are to be developed specifically for meeting the 2008 TMDLs for phosphorus and sediment. However, this report does review and provide the status of meeting the nine minimum elements required in a watershed plan in order to be considered for future EPA Clean Water Act Section 319 funding for nonpoint source programs.

This report takes into consideration resource management priorities and goals which have been developed by the TAC, the need to address the sediment and phosphorus TMDLs, historic findings, and ongoing efforts by counties and other partners to provide a series of broad management recommendations and focus areas for the TAC. Recent GIS data have been analyzed here to calculate and map land use, imperviousness, forest cover, extent of vegetated riparian buffers, land ownership, Indices of Biotic Integrity, septic system locations, and green schools locations, among other parameters.

Key Findings

Land Use

Draft 2007 Maryland Department of Planning land use data (Figure 5-2), show that 33% of the Patuxent Reservoirs Watershed is residential, primarily in its lower half, 32% is agriculture, primarily upstream of the Triadelphia Reservoir and 30.5% is forest cover, concentrated along the mainstem of the Patuxent River. Residential land is predominantly low to very low density.

Although a direct, quantitative comparison between 2007 and prior years' land-use data is not possible due to data incompatibility, a pattern of increasing urban use and decrease in agricultural acreage is apparent. Other data show a 64% increase in the number of septic systems within the watershed from 1997 to 2008 (Section 10.2), indicative of new rural residential construction.

Imperviousness

Impervious cover based on 2007 data, on average across the entire watershed, is only 6%, below the level at which stream degradation is often observed (10% for moderate degradation; 25% for severe). James Creek subwatershed in Montgomery County has by far the highest impervious surface at 18%, while Reddy Branch and Lower Rocky Gorge are at the 10% imperviousness threshold (Table 5-1, Figures 5-3 and 5-4). Note that although exceeding the 10% imperviousness threshold is commonly associated with stream channel instability and degraded water quality conditions, it is not a direct indicator of reservoir water quality for water supply purposes.

Forest Cover

Forest lands immediately around the reservoirs are owned and controlled by WSSC and make up 12% of total forest cover in the Patuxent Reservoirs watershed. In addition, 36% of the forest land is owned by Maryland Department of Natural Resources (DNR), 10% is in county-owned parks, primarily in the Hawlings River subwatershed, and the remaining 42% is privately-owned (Figure 6-1). Three subwatersheds in Howard County, the Cattail Creek Headwaters West, Cattail Creek Headwaters Central and the Upper Dorsey Branch, show particularly low levels of forest cover at 9.8%, 12.3%, and 6.1%, respectively.

Riparian Buffers

The majority of the Patuxent Reservoirs watershed has a significant percentage of unbuffered riparian zones (Table 7-1 and Figure 7-1). The subwatersheds of greatest concern, due to high percentages of unbuffered riparian area, are the Cattail Creek Headwaters West (72%), Cattail Creek Headwaters Central (65%), and Upper Dorsey Branch (66%).

Land Ownership

Public entities own nearly half of the watershed land area: DNR (26.3%), counties (11.7%), WSSC (6.6%), M-NCPPC (1.4%) and federal (0.3%). The remainder is privately owned.

Agriculture

Agriculture is a critical and unavoidable topic in reservoir management. The predominant agricultural input originates specifically from row crops, with additional contributions from pasture and animal waste (Figures 8-2 and 8-3). County nutrient discharges to the Patuxent River roughly correspond to the amount of acreage a county has in the watershed. Lowtill farming with manure application, specifically, is by far the greatest source of nutrients from Montgomery and Howard counties into the greater Patuxent River (NOAA 2007).

Stream Biological Integrity

Maryland DNR, Howard County and Montgomery County conduct stream biological and physical monitoring in the watershed. According to Maryland Biological Stream Survey results, benthic invertebrate assemblages in the Patuxent Reservoirs Watershed were categorized as in good condition in 40% of locations sampled, while 50% were rated as fair, 10% were rated poor, and none was rated very poor (Figure 9-1). With respect to the fish IBI (Figure 9-2), 41% were rated as good, 33% were fair, 21% poor, and 5% were rated as very poor. These results indicate that overall, the streams of the Patuxent Reservoirs are in far better biological condition than the statewide average.

Septic Systems

Septic systems contribute 9 pounds per person per year of nitrogen compared to only 2 pounds per person per year of nitrogen for centralized wastewater treatment facilities. Within the Patuxent Reservoirs watershed, the last estimate of numbers of septic systems made in 1997 for WSSC found that roughly 6,619 septic systems were present in the watershed. The latest data provided by MDE show an increase to 10,887 systems, 5,079 in Howard County and 5,808 in Montgomery County (Table 10-1 and Figure 10-2).

Key Recommendations

The recommendations generated for this report focused on addressing the sources of impairment to the reservoirs, phosphorus and sediment, as identified in the approved 2008 TMDLs. They include:

Riparian Buffers

- Planting of riparian buffers to address phosphorus and sediment sources from agriculture, in particular, but also for reduction in stream scour/channel erosion, the second largest source of impairment to the reservoirs.

- Planting of 50-meter (on each stream bank) unbuffered riparian zones on lands set aside for protection through easements, or planting of stream buffers within Green Infrastructure gaps, can help resolve additional natural resources management challenges while enhancing water quality. An even better response would be targeting planting where all three parameters coincide: easements, Green Infrastructure gaps, and unbuffered riparian zones.

Agricultural Initiatives

- Refocusing the TAC priorities towards implementation of agricultural initiatives, without which the TMDL will not be achieved. This includes greater emphasis on Soil Conservation District (SCD) initiatives as well as emphasis on agricultural best management practices (BMPs), water quality cost-share opportunities and compliance issues.

Headwaters Protection

- Increased emphasis on headwater streams, which account for 55% of the total stream miles in the Reservoirs Watershed.

- It is also recommended that the counties evaluate current stream network maps and assess whether improvements are warranted. If necessary, they should work to more accurately locate and map headwater streams to allow for more precise targeting of protection efforts.

Zoning and Development Regulation

- It is recommended that zoning and other development regulations, codes and ordinances be added to the TAC's Priority Resources Chart and explored as tools with which to create and protect stream buffers, contiguous forests tracts, and other key natural resources. Existing zoning is useful as a tool to maintain the rural and agricultural character of the watersheds. Updates to local development regulations, codes and ordinances may provide an opportunity to increase protection for water resources such as wetlands, streams, and floodplains, and for increased forest conservation via the Forest Conservation Act.

Stream Channel Restoration & Quantity Control BMPs

- Opportunities for stream restoration should be assessed by the TAC and coordinated with ongoing restoration efforts of TAC member agencies to help limit stream scour/channel erosion. TAC member agencies should coordinate with the US Fish and Wildlife Service (FWS) Chesapeake Bay Field Office. The Chesapeake Bay Field Office is a leader in the restoration field, a good source of information and technical assistance and situated nearby in Annapolis MD.

- Stream scour, the second most important source of phosphorus and sediment to the reservoirs after crop-based sources, is an urban and suburban stormwater control challenge which could be addressed through strategic retrofit of new volume control BMPs or enhancement of existing flood control ponds to better protect from channel erosion and scour, particularly in small tributaries and headwater streams.

Invasives and Deer Population Management

- The TAC needs to coordinate with DNR, the largest public lands holder (56.8% of public lands) and Howard and Montgomery counties (together holding 25.3% of public lands in the watershed) to coordinate and develop strategies for invasive plants and insects and for deer management, in light of the new TMDL and the known deleterious impact of invasives and deer on forest regenerative capacity and stream buffer/floodplain stability.

- Seek support of a technical advisory committee versed in forest management and techniques for source water protection through forests and forestry practices.

Urban Stormwater Management

- It is recommended that the TAC pays special attention to lessons learned and advances by Montgomery County in this third round of municipal NPDES stormwater permit in anticipation of applying those lessons and tools to Howard and Prince George's counties' portions of the watershed. This might include a briefing to the TAC by Montgomery County on applicability of lessons learned from the efforts surrounding expanded requirements of the third round NPDES MS4 permit to reservoirs watershed management.

Cross-County Standardization of Watershed Policy Metrics

- County record-keeping that allows consistent comparisons of how much county spending and man-power are allocated to enforce environmental laws compared to other jurisdictions and to allow for meaningful review of and justification of policy changes.

Representation of SHA on TAC

- It is recommended that the Maryland Department of Transportation/State Highway Administration and other government entities charged with maintenance of roadways become active members in the TAC, given the potential contribution of highway and local road surfaces to both water quantity and water quality impairment.

Education and Outreach

- The TAC, and the WSSC in particular, is making a reasonable and creditable effort at outreach and education. It is recommended that education and outreach be targeted strategically in subwatersheds with strong potential for improving water quality conditions, such as the Cattail Creek and Hawlings River watersheds.

Fulfillment of EPA's Nine Elements

The EPA requires that nine elements be included in a watershed plan for projects funded using incremental Section 319 funds. Although there is no formal requirement for EPA to approve watershed plans, the plans must address the nine elements if they are developed in support of a Section 319-funded project (EPA Watershed Planning Handbook 2008).

In the case of the Patuxent Reservoirs Watershed, as in many cross-jurisdictional watersheds, no single entity has responsibility for management of the entire watershed. As such, creation of a coordinated management strategy is complex. MDE's recent development of TMDLs for the reservoirs has brought focus to the issues of phosphorus and sediment loading. However, progress to date in planning for non-point source (NPS) management measures by the TAC does not yet provide the level of detail stipulated by the EPA in the nine elements framework of a watershed management plan.

Historic management efforts and the new TMDLs have addressed two of the nine EPA watershed management plan elements (Causes of Impairment and Estimate Load Reductions), and the TAC and WSSC have a head start on some of the other elements, as summarized in Table 15-1, Chapter 15, and Table ES-1 below.

This interim management report includes the first comprehensive compilation of 30 years of historic studies, their observations and recommendations. The new desktop analysis of land uses, characterization of imperviousness and other watershed features, and identification of opportunities for simple but effective watershed-wide BMPs represent a necessary step forward to fully addressing the nine elements required for 319 funding. The TAC's current progress in addressing the EPA's 9 elements is summarized in the following table.

Table ES-1. For Patuxent Reservoirs watershed, summary of status of addressing nine required elements for watershed plans for EPA Incremental 319 funding. See particular sections of this report for details.

Nine Elements (EPA 2008)	Complete	In Progress	Future
a. Identify causes of impairment	• TMDL development and modeling (Section 11)		
b. Estimate load reductions needed	• TMDL development and modeling (Section 11)		
c. Description and location of NPS management measures		• Riparian buffer enhancement programs in Howard and Montgomery County (Section 12.2, 14.6) • Stream channel restoration projects (Section 12.1, 14.5) • Equine operations/community assistance (Section 8.3.2) • Cost share program to establish stream-side BMPs (Section 8.3.2) • Additional recommendations to reduce phosphorus and/or sediment loads (Section 14)	• Horse manure management (Section 8.3.2)
d. Estimate of the amounts of technical and financial assistance		• The TAC has begun to estimate costs of various BMPs addressing both sediment and phosphorus loading.	
e. Information and education component of plan and NPS measures		• The education component specific to management plan addressing TMDLs not yet been developed but TAC members have a good history of outreach activities and dedicated staff (e.g., WSSC).	
f. Schedule for implementing the NPS management measures		• A timeline for implementation items is included in Priority Resource Chart (Appendix B Table 1)	• Once a suite of BMPs is identified to meet TMDLs, update schedule in Priority Resource Chart
g. Interim measurable milestones for NPS management measures		• Measures and goals are included in Priority Resource Chart (Appendix B, Table 1)	• Once a suite of BMPs is identified to meet TMDLs, update measures and goals in Priority Resource Chart
h. Monitoring criteria		• WSSC has 18 year history of monitoring key parameters in reservoirs.	
i. Monitoring plan		• WSSC has 18 year history of monitoring key parameters in the reservoirs (Section 14.13), including phosphorus and turbidity. • Stream flow monitoring in major tributaries (Section 12) • State and County stream biological indicators monitoring (Section 9) • Water quality monitoring and pollutant load estimation to the reservoirs (Section 14.13)	• Water quality monitoring and pollutant load estimation to the major tributaries (Section 12, 14.13)*

*Water quality monitoring and pollutant load estimation was conducted in major tributaries from October 1996 through June 2003, but not since June 2003.

TABLE OF CONTENTS

Page

EXECUTIVE SUMMARY III

LIST OF ACRONYMS XIX

1.0 INTRODUCTION...1-1
- 1.1 The Patuxent Reservoirs Watershed 1-1
- 1.2 The Challenge 1-1
- 1.3 The Interim Watershed Management report 1-4

2.0 GOALS AND TECHNICAL ADVISORY COMMITTEE EXPECTATIONS.......2-1
- 2.1 The Patuxent Reservoirs Watershed Protection Group Technical Advisory Committee..2-1
- 2.2 Goals of this Watershed Management Report 2-1
  - 2.2.1 Incorporate Existing Reports and Studies..2-2
- 2.3 TAC Priority resources 2-44

3.0 REGULATORY, LEGAL AND POLICY CONTEXT 3-1
- 3.1 Federal and Regional 3-1
  - 3.1.1 Federal..3-1
  - 3.1.2 Regional 3-1
- 3.2 Maryland Specific Regulations..3-1
  - 3.2.1 Maryland General Water Quality Criteria 3-2
  - 3.2.2 Patuxent Reservoirs Regulations 3-5

4.0 BACKGROUND: THE PATUXENT RESERVOIRS WATERSHEDS 4-1
- 4.1 WSSC and the Reservoirs..4-1
- 4.2 Land Ownership..4-3
- 4.3 Geology and Soils 4-4

5.0 CURRENT LAND USE...5-1
- 5.1 Land use 5-1
- 5.2 Imperviousness 5-5

6.0 FOREST COVER IN THE WATERSHED 6-1

7.0 STREAM BUFFERS 7-1

8.0 AGRICULTURE...8-1
- 8.1 Agriculture in the Literature 8-1
- 8.2 Agriculture Derived Sediment and Phosphorus..8-2

TABLE OF CONTENTS (Cont'd)

Page

8.3 Agriculture BMP Programs 8-7
8.3.1 State-Wide Initiatives 8-7
8.3.2 TAC Agriculture Initiatives 8-10

9.0 BIOLOGICAL ASSESSMENTS OF STREAM CONDITION 9-1
9.1 Index of Biotic Integrity 9-1
9.2 Maryland Biological Stream Survey 9-1
9.3 Montgomery County Biological Monitoring 9-4
9.4 Howard County Biological Monitoring 9-4
9.5 High Quality (Tier II) Surface Waters in Howard and Montgomery County 9-9

10.0 THE ROLE OF SEPTIC SYSTEMS 10-1
10.1 State-wide Perspective 10-1
10.2 Septic Systems in the Patuxent Reservoirs Watershed 10-1
10.3 Bay Restoration Fund Onsite Disposal Systems (OSDS) Implementation 10-4

11.0 THE TMDLS 11-1
11.1 Phosphorus and Sediment, Before the TMDLs 11-3
11.2 Beyond TMDLs 11-6

12.0 HAWLINGS AND CATTAIL CREEK: SUBWATERSHEDS OF SPECIAL INTEREST 12-1
12.1 Hawlings River Watershed Specific Studies 12-3
12.2 Cattail Creek Watershed Specific Studies 12-4

13.0 OUTREACH AND EDUCATION 13-1
13.1 Green Schools 13-1
13.2 H20 Fest 13-1

14.0 RECOMMENDATIONS 14-1
14.1 Recommendations for Addressing Agriculture-derived Impairments 14-1
14.2 Riparian Buffers 14-4
14.2.1 Riparian Buffers in the Literature 14-4
14.2.2 Land Acquisition for Buffer Creation 14-6
14.2.3 Recommendations 14-7
14.3 Headwater streams 14-11
14.3.1 The Literature 14-11
14.3.2 Recommendations 14-13

TABLE OF CONTENTS (Cont'd)

Page

14.4 Zoning and Land Use 14-15
14.5 Stream Channel Restoration 14-16
14.6 Invasives Plant Control and Deer Management 14-18
14.7 Urban Stormwater Management 14-20
14.7.1 The Literature 14-20
14.7.2 Urban Stormwater Loads 14-22
14.7.3 Stream Scour 14-23
14.7.4 Dry Pond Modification 14-24
14.8 On-Site Septic Waste Water Treatment 14-27
14.9 Programmatic Recommendations 14-27
14.9.1 Prior Programmatic Recommendations 14-27
14.9.2 New Programmatic Recommendations 14-29
14.10 Education and Outreach 14-29
14.11 Inspection and Enforcement 14-31
14.11.1 Erosion and Sediment Control 14-31
14.11.2 Point-Source Discharge Enforcement 14-32
14.11.3 Agricultural Programs Enforcement 14-33
14.12 Spill and Contamination Control 14-33
14.13 Monitoring 14-34
14.14 Estimating Pollutant Load Reductions 14-36

15.0 NINE MINIMUM ELEMENTS FOR EPA INCREMENTAL 319 FUNDING 15-1
15.1 Background 13-1
15.2 Addressing the Nine Elements for Patuxent Reservoirs Watershed 13-12

16.0 REFERENCES 16-1

APPENDICES

A LITERATURE REVIEW A-1

B PERFORMANCE MEASURES AND GOALS FOR PRIORITY RESOURCES CHART and PATUXENT RESERVOIRS WATERSHED WORK PROGRAM FOR FY09 AND FY10 ..... B-1

C TAC 2008 ANNUAL REPORT C-1

D FOREST YOUR POND BROCHURE D-1

LIST OF TABLES

Table **Page**

ES-1 For Patuxent Reservoirs watershed, summary of status of addressing nine required elements for watershed plans for EPA Incremental 319 funding 4-1

4-1 Area in acres and percentage of the Triadelphia and Rock Gorge Reservoir watersheds within Howard County and Montgomery County 4-1
4-2 Physical characteristics of the Patuxent Reservoirs Maryland 4-3
4-3 Public lands ownership in Patuxent Reservoirs watershed, Maryland 4-3

5-1 2007 land use in acres and percentage of total subwatershed acres, in the Patuxent Reservoirs watershed, Maryland, by subwatershed and reservoir watershed............... 5-4
5-2 Impervious acreage and percent imperviousness by subwatershed, Patuxent Reservoirs watershed, Maryland.. 5-8

7-1 Characterization of stream miles, acres of 100 meter riparian area, acres of forested 100 meter stream buffer, acres of unforested 100 meter stream buffer and percent of stream buffer that is unforested in the Patuxent River watershed, by subwatershed and county in Maryland 2007 7-5

8-1 Nutrient management plan compliance within the entire Patuxent River watershed, Maryland. 8-8
8-2 Environmental Quality Incentives Program dollars obligated by counties in the Patuxent River Watershed for 2005. 8-9
8-3 Patuxent Reservoirs Watershed Agricultural BMPs Progress during 2008............... 8-13

9-1 Summary of Howard County benthic and habitat scores and ratings by subwatershed, for areas sampled within Patuxent Reservoirs watershed 9-6

10-1 Location of on-site septic systems by watershed and county in the Patuxent Reservoirs watershed, Maryland in 1997 and in 2008... 10-4

11-1 The Elements of the nutrient and sediment TMDLs for the Triadelphia and Rocky Gorge Reservoirs, Maryland... 11-1
11-2 Nonpoint source phosphorus loads attributed to significant land uses for the Triadelphia Reservoir, Maryland, Nutrient TMDL 11-2
11-3 Nonpoint source phosphorus loads attributed to significant land uses for the Rocky Gorge Reservoir, Maryland, Nutrient TMDL.. 11-2
11-4 Nonpoint source sediment loads attributed to significant land uses for the Triadelphia Reservoir, Maryland, Sediment TMDL... 11-2

LIST OF TABLES (Cont'd)

Table **Page**

14-1 Total phosphorus and sediment loads attributed to MS4 point sources in the Triadelphia Reservoir total phosphorus and sediment TMDLs 14-23
14-2 Total phosphorus loads attributed to MS4 point sources and the US FEMA Waste Water Treatment Plant in the Rocky Gorge Reservoir total phosphorus TMDL 14-23
14-3 Total number of on-site septic systems by subwatershed in the Patuxent Reservoirs watershed and the number of on-site septic systems within 500 and 1000 feet of a tributary to the Patuxent Reservoirs, Maryland, in 2008 14-28

15-1 For Patuxent Reservoirs watershed, summary of status of addressing nine required elements for watershed plans for EPA Incremental 319 funding 15-3

LIST OF FIGURES

Figure		Page
1-1	Watershed, subwatershed boundaries and tributaries draining the Patuxent River upstream of the Triadelphia and Rocky Gorge Reservoirs	1-2
4-1	Location of Patuxent Reservoirs watershed	4-2
4-2	Public lands in the Patuxent Reservoirs watershed	4-5
4-3	Easements in Patuxent Reservoirs watershed, Maryland	4-6
5-1	Land use for the Patuxent Reservoirs watershed, Maryland, based on 1997 Maryland Department of Planning land use/land cover data	5-2
5-2	Draft 2007 Maryland Department of Planning land-use data for Patuxent Reservoirs watershed.	5-3
5-3	Impervious cover in Patuxent Reservoirs watershed, Maryland	5-6
5-4	Average percent imperviousness by subwatershed in Patuxent Reservoirs watershed, Maryland in 2007	5-7
6-1	Forest cover by ownership in Patuxent Reservoirs watershed, Maryland	6-3
7-1	Locations of 100 meter unforested riparian area in the Patuxent Reservoirs watershed, Maryland	7-3
7-2	Average percentage of unforested stream riparian areas by subwatershed, Patuxent Reservoirs watershed, Maryland	7-4
8-1	Agricultural land-use types in the Patuxent Reservoirs watershed, Maryland	8-3
8-2	Modeled percent contribution of sources to Total Phosphorus loads to the Triadelphia Reservoir, Maryland.	8-4
8-3	Modeled percent contribution of sources to Total Phosphorus loads to Rocky Gorge Reservoir, Maryland.	8-4
8-4	Modeled percent contribution of sources to sediment loads to the Triadelphia Reservoir, Maryland	8-5
8-5	Percentage of nitrogen equivalents of discharge into the greater Patuxent River, Maryland, by county in 2006	8-6
8-6	Total nutrient discharges (in pounds) to the greater Patuxent River, Maryland, by sector in 2006	8-6
8-7	Row crop nutrient discharges into the greater Patuxent River from Montgomery County and Howard County, Maryland in 2006	8-7
8-8	Location and summary of reservoir cost-share projects in the Patuxent Reservoirs watershed as of 2007	8-11
9-1	Benthic Index of Invertebrate Biotic Integrity scores in Patuxent Reservoirs watershed, Maryland	9-2

LIST OF FIGURES (Cont'd)

Figure		Page
9-2	Fish Index of Biotic Integrity scores in Patuxent Reservoirs watershed, Maryland. 1995-2008 MBSS sampling.	9-3
9-3	Montgomery County, Maryland, Benthic Index of Biotic Integrity scores by sampling location for sampling years 1995-2007.	9-5
9-4	Benthic IBI scores for sites sampled within Patuxent Reservoirs watershed by the Howard County Biomonitoring Program, 2001-2008	9-7
9-5	Tier II stream segments in the Patuxent Reservoirs watershed, Maryland	9-10
10-1	Planned sanitary sewer systems in and around the Patuxent Reservoirs watershed, Maryland	10-2
10-2	Locations of on-site septic systems in 2008 and planned sewer systems in and around the Patuxent Reservoirs watershed, Maryland	10-3
10-3	Chesapeake Bay Restoration Fund OSDS Implementation grant awards, 2006-2007, by county in Maryland	10-5
12-1	Cattail Creek and Hawlings River subwatersheds within the Patuxent Reservoirs watershed, Maryland, with water quality monitoring station locations	12-2
12-2	Twelve candidate stream bank stabilization and buffer enhancement projects in the Hawlings River watershed, Maryland. Top 3 ranked projects are highlighted in orange	12-5
13-1	All schools, both Maryland Green Schools and non-participating schools, in and around the Patuxent Reservoirs watershed, Maryland	13-3
13-2	All schools, both Maryland Green Schools and non-participating schools, within Patuxent Reservoirs watershed, Maryland	13-4
14-1	Phosphorus delivery as influenced by stream buffer width	14-5
14-2	Areas where easements overlap unforested 100 meter riparian zone in the Patuxent Reservoirs watershed, Maryland	14-9
14-3	Areas where Green Infrastructure gaps overlap unforested 100 meter riparian zone in the Patuxent Reservoirs watershed, Maryland	14-10
14-4	Areas where Green Infrastructure gaps overlap unforested 100 meter riparian zone and existing easements in the Patuxent Reservoirs watershed, Maryland	14-12
14-5	First-order streams in the Patuxent Reservoirs watershed, Maryland	14-14
14-6	Photographs of typical detention ponds with low flow channel	14-25
14-7	Conceptual drawing of modified dry pond by Matt Arnn of the USDA Forest Service	14-26

LIST OF ACRONYMS

BMPs	Best Management Practices
CBT	Chesapeake Bay Trust
CDM	Camp Dresser and McKee
Chl*a*	Chlorophyll-a
COMAR	Code of Maryland Regulations
CSPS	Countywide Stream Protection Strategy
CWA	Clean Water Act
CWAP	Clean Water Action Plan
DEP	Department of Environmental Protection
DNR	Department of Natural Resources
DO	Dissolved Oxygen
DPW	Department of Public Works
ECHO	Enforcement Compliance History Online
EPA	Environmental Protection Agency
EQIP	Environmental Quality Improvement Program
ESC	Erosion and sediment control
FEMA	Federal Emergency Management Agency
FY	Fiscal Year
GIS	Geographic Information System
IBI	Index of Biological Integrity
ICPRB	Interstate Commission of the Potomac River Basin
MACS	Maryland Agricultural Cost Share
MBSS	Maryland Biological Stream Survey
MDA	Maryland Department of Agriculture
MDE	Maryland Department of the Environment
MDP	Maryland Department of Planning
M-NCPPC	Maryland-National Capital Park and Planning Commission

NMP	Nutrient Management Plan
NOAA	National Oceanic and Atmospheric Administration
NPS	Nonpoint Source
NRCS	Natural Resources Conservation Service
ONRW	Outstanding National Resource Water
OSDS	Onsite Disposal System
PMAs	Primary Management Areas
SCD	Soil Conservation District
SMD	Stormwater Management Division
SOD	Sediment Oxygen Demand
SOS	Save Our Streams
SWA	Source Water Assessment
TAC	Technical Advisory Committee
TMDLs	Total Maximum Daily Loads
TOC	Total Organic Carbon
TSS	Total Suspended Solids
UMCES	University of Maryland's Center for Environmental Science
USACE	Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WMR	Watershed Management Report
WQLS	Water Quality Limited Segment
WQS	Water Quality Standards
WRAP	Watershed Restoration Action Plan
WSSC	Washington Suburban Sanitary Commission
WWTPs	Wastewater Treatment Plants

1.0 INTRODUCTION

1.1 THE PATUXENT RESERVOIRS WATERSHED

The Triadelphia Reservoir (basin code 02-13-11-08), created by construction of the Brighton Dam in 1943 and the Rocky Gorge Reservoir (basin code 02-13-11-07), created by construction of the T. Howard Duckett Dam in 1952, and the watershed which feeds them, provide source drinking water for the approximately 650,000 inhabitants (11 billion gallons annually) in the supply area of Prince George's and Montgomery County Maryland. Only a very small population within Howard County receives water from the reservoirs. The reservoirs are located in the upper, non-tidal reaches of the 100-mile long Patuxent River. The two reservoirs and approximately 5,500 acres of the 85,000 acre watershed are under management of the Washington Suburban Sanitary Commission (WSSC). The Triadelphia Reservoir drains 79 square miles and Rocky Gorge lies 13 miles downstream and drains 132 square miles (EA Engineering 1991). The watershed, subwatershed boundaries and tributaries draining the Patuxent River upstream of the two dams are detailed in Figure 1-1.

1.2 THE CHALLENGE

A 1981 report prepared for WSSC by Ecological Analysts Inc. found that the biggest challenge to watershed protection is that only 5% of the total watershed lies within WSSC controlled properties. That same report concluded that modeled estimates of phosphorus loading based upon 1981 land-use characteristics placed the reservoirs in the eutrophic range (box below) and projections of land use 20 years into the future showed an increase in phosphorus inputs to the reservoirs.

***Eutrophication** is defined as "a process whereby water bodies, such as lakes, estuaries, or slow-moving streams receive excess nutrients that stimulate excessive plant growth (algae, periphyton attached algae, and nuisance plants weeds). This enhanced plant growth, often called an algal bloom, reduces dissolved oxygen in the water when dead plant material decomposes and can cause other organisms to die. Nutrients can come from many sources, such as fertilizers applied to agricultural fields, golf courses, and suburban lawns; deposition of nitrogen from the atmosphere; erosion of soil containing nutrients; and sewage treatment plant discharges. Water with a low concentration of dissolved oxygen is called hypoxic." (Source: US Geological Survey)*

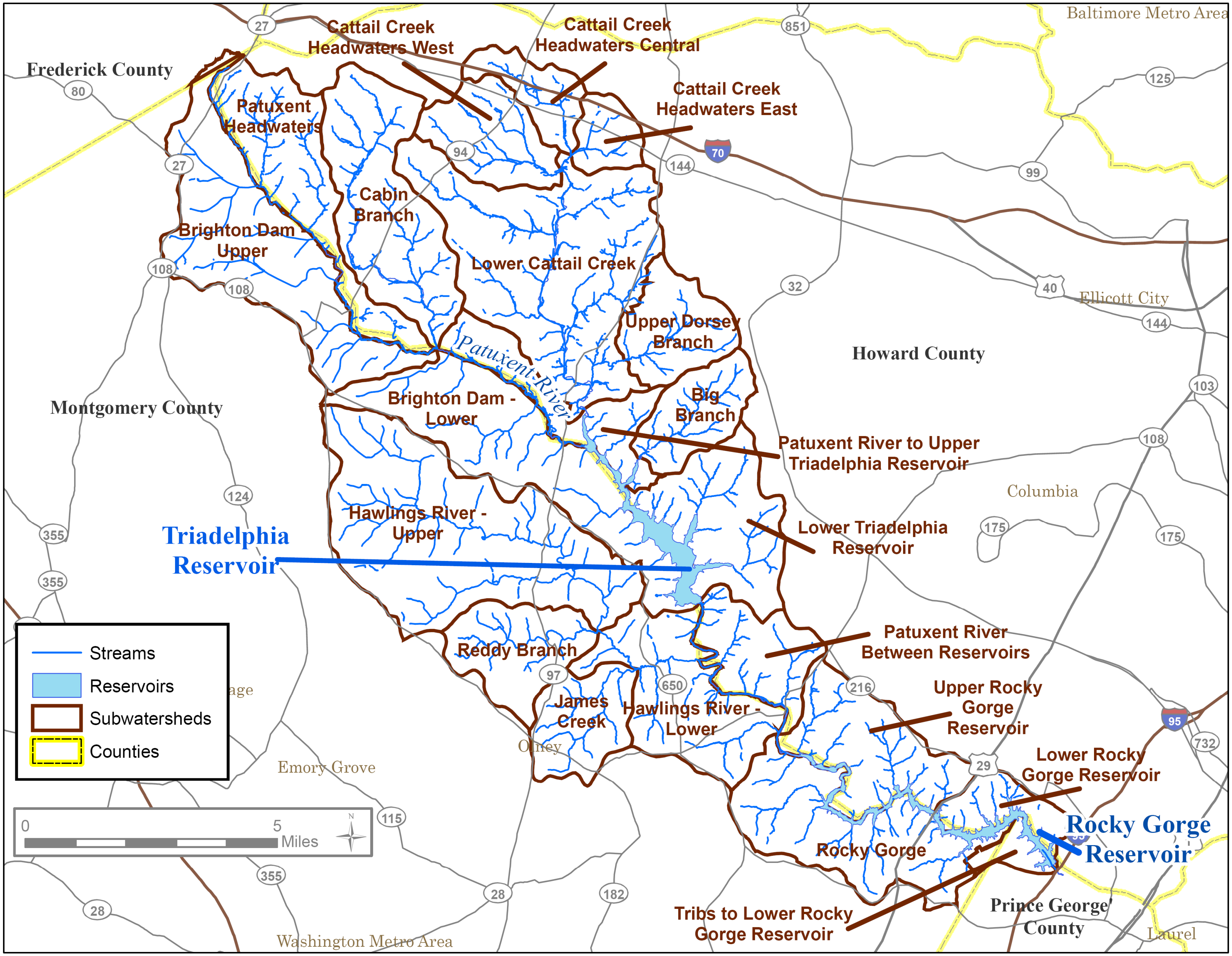


Figure 1-1. Watershed, subwatershed boundaries and tributaries draining the Patuxent River upstream of the Triadelphia and Rocky Gorge Reservoirs

A 1984 report (Patuxent River Reservoirs Water Quality Assessment: Final Report, JTC Environmental Consultants) commissioned by WSSC raised concerns about possible impairment of the reservoirs. That report concluded the following: 1. The drainage area to reservoir drainage ratio was significantly higher than normal and detention times were significantly lower, indicating the potential for high nutrient loading from runoff, 2. in-lake nitrogen concentrations were very high indicating that phosphorus was the limiting nutrient, and 3. both reservoirs exhibited oxygen depletion in summer months in the hypolimnetic region (non-circulating layer below the thermocline of a thermally stratified lake).

A 1991 report commissioned by WSSC (Water Quality Monitoring and Nutrient Loading Analysis of the Patuxent River Reservoirs Watershed, EA Engineering) reinforced these findings saying that multiple studies from as early as 1981 indicated that the reservoirs were subject to siltation and eutrophication which could affect water quality.

According to the Pan-American Health Organization (http://www.cepis.ops-oms.org/sde/ops-sde/ingles/bv-agua.shtml), eutrophication can cause taste and odor problems in drinking water, corrosion of hydroelectric equipment and upset water treatment processes due to the reduction of the dissolved oxygen (DO) content, accumulation of ammonia in the water column and re-suspension of certain metals (iron, manganese) from the sediments under anaerobic conditions. In eutrophied reservoirs, the high level of organic substances (total organic carbon, or TOC) combined with the application of chlorine for drinking water supplies can generate substances potentially harmful to human health. According to the U.S. Geological Survey (USGS), "In addition to taste and odor concerns associated with excess algae production, elevated levels of total organic carbon are an increasing concern because of the harmful and stringently regulated disinfection by-products that result from chlorinating waters high in TOC." As noted by Tetra Tech in the 1997 Comprehensive Management Planning Study for the Patuxent Reservoir watershed, nutrient compounds can also combine with chlorine during treatment to produce trihalomethanes, which are toxic to humans.

Transport of suspended solids in streams and into a reservoir decreases holding capacity and has a deleterious effect on stream and reservoir ecology by inhibiting sunlight penetration and smothering benthic organisms in stream bottoms and the reservoir floor. Increases in suspended solids in the upper Patuxent river watershed streams and reservoirs can be the result of construction within the watershed, scour and resuspension of bottom and floodplain sediment, and bank erosion brought on by higher peak stream flows due to the increase in impervious surfaces from road and building construction. Cropland and animal pasture are also significant sources of suspended solids in major streams of the Patuxent Reservoirs watershed (Versar 2004).

The 2004 Patuxent Reservoirs (Triadelphia and Rocky Gorge) Source Water Assessment (SWA) for WSSC Patuxent Water Filtration Plant report prepared by the Maryland Department of the Environment (MDE) identified current contamination threats to these two reservoirs as including point and non-point sources from transportation infrastructure, railroads, a petroleum products pipeline, agriculture, septic systems, and urban/suburban areas. The analysis indicated phosphorus as the primary contaminant of concern. Secondarily, turbidity, sediment, disinfection byproducts, iron, manganese and protozoa (pathogens) were indicated as contaminants of concern.

According to the 2007 Maryland Tributary Strategy Patuxent River Basin Summary Report for 1985-2005 Data, “Total nitrogen and total phosphorus in the upper Patuxent have some significant increasing non-linear trends (for the period 1985-2005). Overall, concentrations are down since 1985, but recent trends are increasing. Special attention is needed to halt this increase in nutrients and reverse improvements made to date. Upper Patuxent algal abundance is generally relatively good and improving. Water clarity, however, is degrading at almost all stations and is relatively poor. Summer bottom DO concentrations are also degrading in the upper Patuxent.”

The National Water Quality Inventory Report to Congress in 1996 (USEPA 1996) cites nutrients (nitrogen and phosphorus) as one of the leading causes of water quality impairment in our Nation's streams, rivers, lakes, reservoirs and estuaries. Forty percent of the impacted rivers were impaired due to nutrient enrichment; 51% of the lakes and reservoirs and 57% of the surveyed estuaries were similarly adversely impacted. The subsequent 1998 and 2002 reports have demonstrated similar impairments.

In addition, a report summarizing a modeling effort for the Patuxent Reservoirs written by the Interstate Commission of the Potomac River Basin (ICPRB) in 2007 states that, “Like many lakes and reservoirs, Triadelphia Reservoir and Rocky Gorge Reservoir are stratified by temperature-induced density differences from the spring through later summer and sometimes early fall, and this stratification can induce low DO concentrations in the hypolimnion or bottom layer of the reservoirs. The hypoxia is caused by the fact that decaying organic material in the sediments and water column consumes oxygen, while stratification dampens the mixing of DO from surface reaeration.”

1.3 THE INTERIM WATERSHED MANAGEMENT REPORT

These reservoirs have been the subject of more than 30 studies, policy and management documents, as well as education and outreach documents since the early 1980s. Of this significant body of knowledge, the majority have been discrete documents, where no document has considered the total volume of historic information generated, summarized it, and made use of it to develop a management report.

This interim Watershed Management Report (WMR), commissioned by WSSC and the Patuxent Reservoirs watershed Technical Advisory Committee (TAC), is the first such comprehensive assessment. This report includes review of previous studies as well as new analyses of current conditions based on geographic information system (GIS) data. This report is intended to inform long-term management of the contributing watersheds, including both WSSC-owned land and those areas outside of the direct control of WSSC. The report is deemed an interim one because some of its findings and recommendations may be modified by Implementation Reports that are to be developed for meeting the USEPA-approved Total Maximum Daily Loads (TMDLs) for phosphorus and sediment. The WMR is not intended to serve as a TMDL Implementation Report.

This report takes into consideration resource management priorities and goals which have been developed by the TAC. Finally, this report considers ongoing efforts and provides a series of management recommendations to the WSSC and TAC for a holistic management of the two reservoirs.

Note that much of the narrative/description and background information included in this effort has been taken directly from the myriad previous works focusing on the Patuxent River watershed and/or the Patuxent Reservoirs watershed specifically. Most of these documents are summarized in Appendix A - Literature Review.

2.0 GOALS AND TECHNICAL ADVISORY COMMITTEE EXPECTATIONS

2.1 THE PATUXENT RESERVOIRS WATERSHED PROTECTION GROUP TECHNICAL ADVISORY COMMITTEE

On October 29, 1996, the Patuxent Reservoirs Watershed Protection Agreement was signed by Howard, Montgomery, and Prince George's Counties, Howard and Montgomery Soil Conservation Districts (SCDs), Maryland-National Capital Park and Planning Commission (M-NCPPC), and WSSC in order to establish an interjurisdictional partnership to develop and implement reservoir watershed protection strategies. Through interagency cooperation, this unique cooperative partnership, referred to as the Patuxent Reservoirs Watershed Protection Group, has developed a strategic goal to protect the Patuxent Reservoirs as partners in implementation and acceleration of source water protection and Chesapeake Bay restoration. The Agreement also created a Policy Board and TAC charged to work together to protect watershed resources. These signatories, along with seven other state and local resource management agencies, have developed a cooperative work program for data collection and analysis, project implementation, and public outreach. In 2003, the U.S. Environmental Protection Agency (EPA) recognized the Patuxent Reservoirs Watershed Protection Group as a Clean Water Partner, among 79 groups from across the country who are working cooperatively to protect their water resources.

2.2 GOALS OF THIS WATERSHED MANAGEMENT REPORT

The two primary goals of this interim WMR, as defined by the TAC, are as follows:

1. Provide information to support reservoir source water protection and watershed land-use management; and
2. Bolster multi-jurisdictional cooperation.

In consultation with the TAC, we have incorporated the following into this effort:

- A review of existing reports and studies;
- Watershed assessment using recent GIS data;
- A review of requirements for EPA 319 funding; and
- Reference of the Total Maximum Daily Loads (TMDLs) for sediment and phosphorus.

2.2.1 Incorporate Existing Reports and Studies

The reservoirs, which hold source drinking water for the 650,000 inhabitants in the supply area, and the watersheds which feed them, have been the subject of numerous studies, policy and management documents, as well as education and outreach documents, since the early 1980s. Those documents have been summarized in this effort and a summary can be found in Appendix A. They include, in chronological order:

1. **Patuxent River Watershed Protection Program.** 1981. Prepared for WSSC by Ecological Analysts Inc.
2. **Patuxent River Reservoirs Water Quality Assessment: Final Report.** 1984. Prepared for WSSC by JTC Environmental Consultants, Inc.
3. **Patuxent River Policy Plan: A Land Management Strategy.** 1984. Written by the Maryland State Department of State Planning.
4. **Water Quality Assessment for Patuxent Watershed (Task 1-G Report).** 1987. Prepared by Camp Dresser and McKee (CDM) for Greenhorne and O'Mara was generated as part of M-NCPPC Patuxent Watershed Management Program
5. **Patuxent River Watershed Montgomery County Maryland: Technical Report February.** 1990. Prepared by Greenhorne and O'Mara Inc., as a continuation of the watershed technical analysis program undertaken by the M-NCPPC in the 1970s.
6. **Water Quality Monitoring and Nutrient Loading Analysis of the Patuxent River Reservoirs Watershed.** 1991. Prepared by EA Engineering and commissioned by WSSC.
7. **Montgomery County Functional Master Plan for the Patuxent River Watershed.** November 1993. This master plan was prepared by M-NCPPC.
8. **Developing a Patuxent Reservoir Protection Strategy; Interim Report of the Patuxent Reservoir Protection Group.** March 1995. Developed at the request of the Montgomery County Council and prepared by the Montgomery County Department of Environmental Protection (DEP).
9. **Public Awareness and Education Marketing Plan for Triadelphia and Rocky Gorge Reservoir Watersheds.** March 1995. Commissioned by the Montgomery County DEP and prepared by Save Our Streams.
10. **Tributary Strategy for Nutrient Reduction in Maryland's Patuxent Watershed.** May 1995. Prepared by MDE, Department of Natural Resources (DNR), MD Department of Agriculture (MDA), MD Office of State Planning and the University of MD as required by Chesapeake Bay Agreement of 1987.
11. **The Upper Patuxent Curriculum: Our Water, Our Land, Our Community.** 1996. This curriculum was developed by Save Our Streams in partnership with WSSC and the Chesapeake Bay Trust.

12. **Patuxent River Water Resources Reconnaissance Study.** July 1996. Prepared by the Army Corps of Engineers (USACE), Baltimore District. This study was authorized by the House Committee on Public Works and Transportation.
13. **Comprehensive Management Planning Study for the Patuxent Reservoir watershed.** July 1997. Prepared by Tetra Tech Inc. for the Patuxent Reservoir Watershed TAC.
14. **On-Site Wastewater Management Practices in the Upper Patuxent Watershed.** 1997. Prepared for WSSC by GMB Architects and Engineers.
15. **Patuxent River: Water Quality and Habitat Summary Report. Tributary Team, 1998**. Prepared by MD DNR.
16. **Hawlings River Watershed Assessment.** March 1999. Prepared by the Watershed Management Division, Montgomery County, Department of Environmental Protection.
17. **Olney Family Neighborhood Park Water Quality Monitoring: Final Report.** March 2000. Submitted to the Department of Parks and Planning, M-NCPPC by Chris Athanas, Ph.D and Associates.
18. **Upper Patuxent Watershed Study.** 2001. Prepared by Montgomery County MD, **Department of Environmental Protection, Watershed Management Division.**
19. **Biological Assessment of the Little Patuxent River, Cattail Creek, and Brighton Dam Watersheds, Howard County MD.** Final Report October 2001. This assessment was prepared by Tetra Tech Inc. for Howard County Department of Public Works (DPW).
20. **Washington Suburban Sanitary Commission Patuxent Reservoirs Watershed Tributary Monitoring and Sediment Nutrient Flux Testing Program Third Annual Report.** 2002. This was completed by Versar for WSSC, as part of a larger Patuxent Reservoirs watershed protection effort.
21. **Triadelphia Sediment-Water Exchange Study.** 2002. Prepared by **J. Cornwell and M. Owens of** the University of MD Center for Environmental Science (as an appendix to the 2002 report above).
22. **Hawlings River Watershed Restoration Study. Final Report.** February 2003. Prepared for the Montgomery County DEP by Charles P. Johnson and Associates and Environmental Quality Resources, LLC.
23. **Olney and Vicinity Environmental Resources Inventory.** April 2003. Prepared by M-NCPPC and Montgomery County Department of Park and Planning.
24. **Hawlings River Watershed Restoration Action Plan.** December 2003. Prepared for the Montgomery County DEP by Charles P. Johnson and Associates and Environmental Quality Resources, LLC.

25. Water Chemistry Monitoring in the Patuxent River at USGS' Gaging Station near Unity, Maryland. **January 2004. Monitoring and reporting by Versar, for WSSC.**
26. **Biological Assessment of Rocky Gorge, Hammond Branch, and Dorsey Run Watersheds, Howard County, Maryland.** January 2004. This document as prepared by Tetra Tech Inc. for the Howard County Stormwater Management Division (SMD).
27. **Patuxent Reservoirs (Triadelphia and Rocky Gorge) Source Water Assessment for WSSC Patuxent Water Filtration Plant** June 2004. Prepared by the Maryland Department of the Environment Water Management Administration Water Supply Program as required by the 1996 Safe Drinking Water Act.
28. **Sediment Mapping and Sediment Oxygen Demand of Triadelphia and Rocky Gorge Reservoirs.** 2007. Conducted and written by the **Maryland DNR Resource Assessment Service, and the Maryland Geological Survey, Coastal and Estuarine Geology Program for WSSC.**
29. **Forest Conservation Plan for Washington Suburban Sanitary Commission Reservoir Properties.** 2007. Prepared for WSSC by Maryland DNR Forest Service by Anne Hairston-Strang, Ph.D.
30. **Modeling Framework for Simulating Hydrodynamics and Water Quality in the Triadelphia and Rocky Gorge Reservoirs, Patuxent River Basin, Maryland. Final.** September 2007. Prepared by Interstate Commission on the Potomac River Basin for MDE.
31. **Managing Patuxent River Water Quality: Looking Beyond Science and Politics to the Economics of Decision-making.** 2007. Prepared for National Oceanic and Atmospheric Administration (NOAA) by University of Maryland, Center for Environmental Science.
32. **Patuxent River 20/20: The Need for Effective Action and Effective Solutions.** Patuxent Riverkeeper 2007. Prepared by Patuxent Riverkeeper, post 2006 State of the River Summit.
33. **Total Maximum Daily Loads of Phosphorus and Sediments for Triadelphia Reservoir (Brighton Dam) and Total Maximum Daily Loads of Phosphorus for Rocky Gorge Reservoir, Howard, Montgomery, and Prince George's Counties, Maryland. Final Report. June 2008.** Submitted to EPA Region III by MDE.

Full citations are included in the Reference section (Section 16).

2.3 TAC PRIORITY RESOURCES

The Patuxent Reservoirs Watershed Protection Group TAC has identified the following six priorities or "priority resources" and their respective goals/targets as the following:

1. Reservoirs and drinking water supply
   a. Chlorophyll-a (Chl*a*)
   b. DO
   c. TMDLs for phosphorus and sediment submitted to EPA
   d. TOC
   e. Sediment: accumulation rate not to exceed previous years.
2. Terrestrial habitat
   a. Forest cover
   b. Forest connectivity
   c. Forest size
   d. Forest diversity
   e. Forest sustainability
3. Stream systems
   a. Buffer corridor width and continuity
   b. Stream bank and stream channel stability
4. Aquatic biota
   a. Index of Biological Integrity (IBI)
5. Rural character and landscape
   a. Agricultural preservation enrollment
   b. Agricultural demographics
   c. Open space and parkland acquisition and easement programs
   d. Participation in agricultural conservation programs
6. Public awareness and stewardship
   a. Residents participating in stewardship activities
   b. Schools participating in mentoring
   c. Active support by elected officials
   d. Routine coverage by media

The TAC Goal-Setting Workgroup has developed a chart (Table 1 in Appendix B) entitled the *Performance Measures and Goals for Priority Resources Chart*, which lists each priority resource and describes the associated issue, measures, goals, implementation items, time line, and responsible partners.

Each year the TAC establishes a work program summarized in a table entitled *Patuxent Reservoirs Watershed Work Program*, to facilitate progress towards addressing the partnership's priorities. A recent example for FY09 and FY10 is included as Table 2 in Appendix B.

Each year, since 1997, the TAC has completed an annual report to summarize accomplishments and identify funding needs to address watershed priority resource issues. The latest Annual Report (2008) can be found in Appendix C and is accompanied by a separate Technical Supplement to provide detailed background information and additional documentation for items summarized in the report. These reports can also be found on the WSSC web site.

3.0 REGULATORY, LEGAL AND POLICY CONTEXT

3.1 FEDERAL AND REGIONAL

Various regulatory imperatives drive this and previous efforts to protect the reservoirs. State and federal laws set standards annually, or seasonally, to protect water bodies depending on their particular designated uses. These standards are set by first defining a water body's designated use and then requiring quantifiable criteria to measure potential threats to its designated use.

3.1.1 FEDERAL

The Federal Clean Water Act of 1972 is intended to reduce direct pollutant discharges into waterways, finance municipal wastewater treatment facilities, and manage polluted runoff. The CWA regulations (40 CFR §131.20) require that States review their WQS every three years ("Triennial Review") and revise the standards as necessary.

The CWA requires three components to WQS that set goals for and protect each State's waters:

1. Designated uses that set goals for each water body (e.g., recreational use);
2. Criteria that set the minimum conditions to support the use (e.g., bacterial concentrations below certain concentrations); and
3. An antidegradation policy that maintains high quality waters so they are not allowed to degrade to meet only the minimum standards.

3.1.2 REGIONAL

Nationwide, starting in the late 1980s, increasing emphasis has been placed on polluted stormwater runoff. Maryland began requiring stormwater management in 1984. Also significant is the Patuxent River-specific 1981 "Patuxent Charette", a binding agreement between the seven counties along the Patuxent River that committed these jurisdictions to reduce the flow of nitrogen and phosphorus from sewage treatment plants into the river to specified levels.

3.2 MARYLAND SPECIFIC REGULATIONS

MDE uses water quality standards to assure that state waterways are useable for drinking water, swimming, fishing, industry and agriculture. These standards are used by permit writers to regulate what individuals, businesses or farms may discharge into waterways (http://www.mde.state.md.us/Programs/WaterPrograms/TMDL/wqstandards/faqs.asp).

In 1985 Maryland adopted an antidegradation policy as part of its WQS, the intent being to protect existing uses attained on or after November 28, 1975 and the level of water quality necessary to protect existing uses. The WQS also provide a means for assessing activities that may lower water quality in high quality waters.

3.2.1 Maryland General Water Quality Criteria

The purpose of Maryland State water quality criteria is to protect, maintain and improve the quality of Maryland surface waters. The following are the three components of water quality standards in Maryland, taken from http://www.mde.state.md.us/Programs/WaterPrograms/-TMDL/wqstandards/index.asp/:

1. Designated Uses
   a. Each major stream segment in Maryland is assigned a Use. The Use is a goal for water quality and may or may not be served now, but should be attainable. (See Use designations below)

Designated uses define an intended human and aquatic life objective, use, or goal for a water body. An area's designated use refers to a water body's function, such as fishing or swimming. This takes into account the attainable use of the water body for public water supply, the protection of fish, shellfish, and wildlife on a consumer level, as well for its recreational, agricultural, industrial and navigational purposes. (http://www.mde.state.md.us/Programs/-WaterPrograms/TMDL/wqstandards/faqs.asp). The Triadelphia Reservoir and Rocky Gorge Reservoir have been designated as Use IV-P and Use I-P. Use IV-P is defined as "Recreational Trout Waters and Public Water Supply." Use I-P is defined as "Water Contact Recreation, Protection of Aquatic Life, and Public Water Supply" waterbodies, respectively, in the Code of Maryland Regulations (COMAR 26.08.02.08M(6) and COMAR 26.08.02.08M(1)) See: http://www.mde.state.md.us/ResearchCenter/Data/waterQualityStandards/index.asp].

2. Water quality criteria to protect the designated uses:
   a. Numeric criteria set the minimum water quality to meet the designated uses.
   b. Maryland has numerous numeric criteria for the protection of aquatic life and human health (e.g., 5 mg/l for DO; 82 mcg/l for lead (acute, freshwater))
   c. Criteria are published for toxics, DO, turbidity, bacteria, and temperature.
   d. Where specific numeric criteria are not available (e.g., oil, grease, odor, nuisance), narrative criteria apply.

In other words, MDE states that "Water quality criteria, as part of a water quality standard, express water pollutant (*e.g.,* nutrients) or water quality parameter (*e.g.*, DO) or a "free from" condition, to protect given designated uses. Quality Criteria may be expressed in numbers or narrative, to measure frequency (how often), magnitude (size of offense), and duration (length of time). Meeting these criteria strives for a quality of water that supports and protects each designated use." (Taken from: http://www.mde.state.md.us/Programs/WaterPrograms/TMDL/-wqstandards/faqs.asp)

3. Antidegradation policy; Maryland's antidegradation policy assures that water quality continues to support designated uses. EPA regulations provide for three tiers of protection:
    a. Tier I specifies the minimum standard that must be met—support of balanced indigenous populations and support of contact recreation—this is often referred to as "fishable-swimmable." In other words it maintains and protects existing uses and water quality conditions necessary to support such uses.
    b. Tier II protects water that is better than the minimum specified for that designated use. In other words, it maintains and protects "high quality" waters -- waterbodies where existing conditions are better than necessary to support CWA § 101(a)(2) "fishable/swimmable" uses. In 2004, MDE adopted Tier II implementation policy and promulgated 87 stream segments based on biological integrity. (Tier II waterbodies in the Patuxent Reservoirs watershed are mapped in Figure 9-5). The language of Tier II regulations can be read in the text box below.
    c. Maryland adopted the third tier of protection, called an Outstanding National Resource Water (ONRW) or Tier III, in 2001. Tier III maintains and protects water quality in ONRWs. Except for certain temporary changes, water quality cannot be lowered in such waters.

Maryland's antidegradation policy has been promulgated in three regulations:

1. COMAR 26.08.02.04 sets out the policy itself;
2. COMAR 26.08.02.04-1 provides for implementation of Tier II (high quality waters) of the antidegradation policy; and
3. COMAR 26.08.02.04-2 which describes Tier III. No Tier III waters have been designated at this time.

(From:
http://www.mde.state.md.us/ResearchCenter/Data/waterQualityStandards/Antidegradation/index.asp and http://www.mde.state.md.us/assets/document/TARSA%20-%20WMA%20Primer%202(1).pdf)

Maryland Tier II High Quality Water Regulations (from COMAR)

1. 26.08.02.04 – 1(B)
"**General:** An applicant for proposed amendments to **county plans** or **discharge permits** for discharge to Tier II waters that will result in a new, or an increased, permitted annual discharge of pollutants and a potential impact to water quality, shall evaluate alternatives to eliminate or reduce discharges or impacts. **If impacts are unavoidable, an applicant shall prepare and document a social and economic justification.** The Department shall determine, through a public process, whether these discharges can be justified."

2. 26.08.02.04 – 1(F)(1) – (3)
"(1) Permits. Before submitting an application for a new discharge permit or major modification of an existing discharge permit (for example, expansion), the discharger or applicant shall determine whether the receiving water body is Tier II or, a Tier II determination is pending, by consulting the list of Tier II waters."

"(2) Water and Sewer Plans (County Plans). As part of its continuing planning process, the Department shall review proposed amendments to county plans for any new or major modifications to discharges to Tier II bodies of water. If a proposed amendment to a County Plan results in a new discharge or a major modification of an existing discharge to a Tier II water body, the applicant shall perform a Tier II antidegradation review."

"(3) Exemptions. The requirement to perform a Tier II antidegradation review does not apply to individual discharges of treated sanitary wastewater of less than 5,000 gallons per day, if all of the existing and current uses continue to be met."

3. 26.08.02.04 – 1(G)
(1) If a Tier II antidegradation review is required, the applicant shall provide an analysis of reasonable alternatives that do not require direct discharge to a Tier II water body (no-discharge alternative). The analysis shall include cost data and estimates to determine the cost effectiveness of the alternatives.

(2) If a cost effective alternative to direct discharge is reasonable, the alternative is required as a condition of the discharge permit or amendment to the county plan.

(3) If the Department determines that the alternatives that do not require direct discharge to a Tier II water body are not cost effective, the applicant shall:

(a) Provide the Department with plans to configure or structure the discharge to minimize the use of the assimilative capacity of the water body, which is the difference between the water quality at the time the water body was designated as Tier II (baseline) and the water quality criterion; and

(b) If an impact cannot be avoided, or no assimilative capacity remains as described in §G(3)(a) of this regulation, provide the Department with a social and economic justification for permitting limited degradation of the water quality.

(4) An applicant shall update an antidegradation review when applying for a new permit or major modification to an existing permit.

4. 26.08.02.04 – 1 – L
(1) Components of the Social and Economic Justification (SEJ) may vary depending on factors including, but not limited to, the extent and duration of the impact from the proposed discharge and the existing uses of the water body.

(2) The economic analyses shall include impacts that result from treatment beyond the costs to meet technology-based or water quality-based requirements.

(3) The economic analysis shall address the cost of maintaining high water quality in Tier II waters and the economic benefit of maintaining Tier II waters.

(4) The economic analysis shall determine whether the costs of the pollution controls needed to maintain the Tier II water would limit growth or development in the watershed including the Tier II water.

3.2.2 Patuxent Reservoirs Regulations

The 2007 ICPRB Modeling Framework report details regulations specific to the Patuxent River Reservoirs:

- Maryland's General Water Quality Criteria prohibit pollution of waters of the State by any material in amounts sufficient to create a nuisance or interfere directly or indirectly with designated uses (COMAR 26.08.02.03B(2)).
- In the case of excess eutrophication, this is interpreted to mean that (1) a 90^{th}-percentile instantaneous Chl*a* concentration is not to exceed 30 µg/l and (2) a 30-day moving average Chl*a* concentration is not to exceed 10 µg/l. A concentration of 10 µg/l corresponds to a score of approximately 53 on the Carlson Trophic State Index. This is the approximate boundary between mesotrophic and eutrophic conditions, which is an appropriate trophic state at which to manage these reservoirs. Mean Chl*a* concentrations exceeding 10 µg/l are associated with peaks exceeding 30 µg/l, which in turn are associated with a shift to blue-green assemblages, which present taste, odor and treatment problems (Walker 1984) (ICPRB 2007).
- The water quality standards applicable to Triadelphia and Rocky Gorge Reservoirs require DO concentrations of not less than 5.0 mg/l at any time (COMAR 26.08.02.03-3E(2)) unless natural conditions result in lower levels of DO (COMAR 26.08.02.03A(2)). New standards for tidal waters of the Chesapeake Bay and its tributaries take into account stratification and its impact on deeper waters. MDE recognizes that stratified reservoirs and impoundments present circumstances similar to stratified tidal waters, and is applying an interim interpretation of the existing standard to allow for the impact of stratification on DO concentrations (ICPRB 2007).

4.0 BACKGROUND: THE PATUXENT RESERVOIRS WATERSHEDS

The 132-square-mile (85,000 acres) drainage area for the two reservoirs is distributed among four counties, but 99% of the drainage area lies in Montgomery County and Howard County, with 39,600 acres or 46% of the total watershed in Montgomery County, and 44,800 acres or 53% of the total watershed in Howard County. Less than 1% lies within Prince George's and Frederick Counties (Montgomery County DEP, 1995). Figure 4-1 below shows the Patuxent Reservoir watershed relative to the four counties within which it lies. Table 4-1 shows area and % of each reservoir watershed in Howard and Montgomery County.

The tributaries to the reservoir located in Montgomery County are classified as Use III-P (Nontidal Cold Water and Public Water Supply) upstream of the Triadelphia Reservoir, Use IV-P (Recreational Trout Waters and Public Water Supply) in the Hawlings River subwatershed and Use I-P (Water Contact Recreation, Protection of Aquatic Life, and Public Water Supply) in downstream drainage areas.

Table 4-1. Area in acres and percentage of the Triadelphia and Rock Gorge Reservoir watersheds within Howard County and Montgomery County. For simplicity, small portions of land in Howard and Frederick Counties were excluded from this survey. (Data provided by M-NCPPC, Montgomery County and Howard County, 2008)

Reservoir Watershed	Total Area (acres)	Portion of Reservoir Watershed in:	
		Howard County	Montgomery County
Triadelphia	50,577	36,919 (73%)	13,675 (27%)
Rocky Gorge	33,484	7,885 (23.5%)	25599 (76.5%)

The tributaries upstream of the Triadelphia Reservoir, located in Howard County, are classified as Use III-P, tributaries to the Triadelphia Reservoir and between the Triadelphia and Rocky Gorge Reservoirs as Use IV-P (Recreational Trout Waters and Public Water Supply), and those tributaries to Rocky Gorge Reservoir are classified as Use I-P.

4.1 WSSC AND THE RESERVOIRS

Hairston-Strang (DNR 2007) nicely summarizes the development of WSSC and the reservoirs:

> The WSSC was formed in 1918. By the mid 1930s, population growth and increased water demand led to the construction of Brighton Dam for the Triadelphia Reservoir, completed in 1943. Expanded water storage was added in

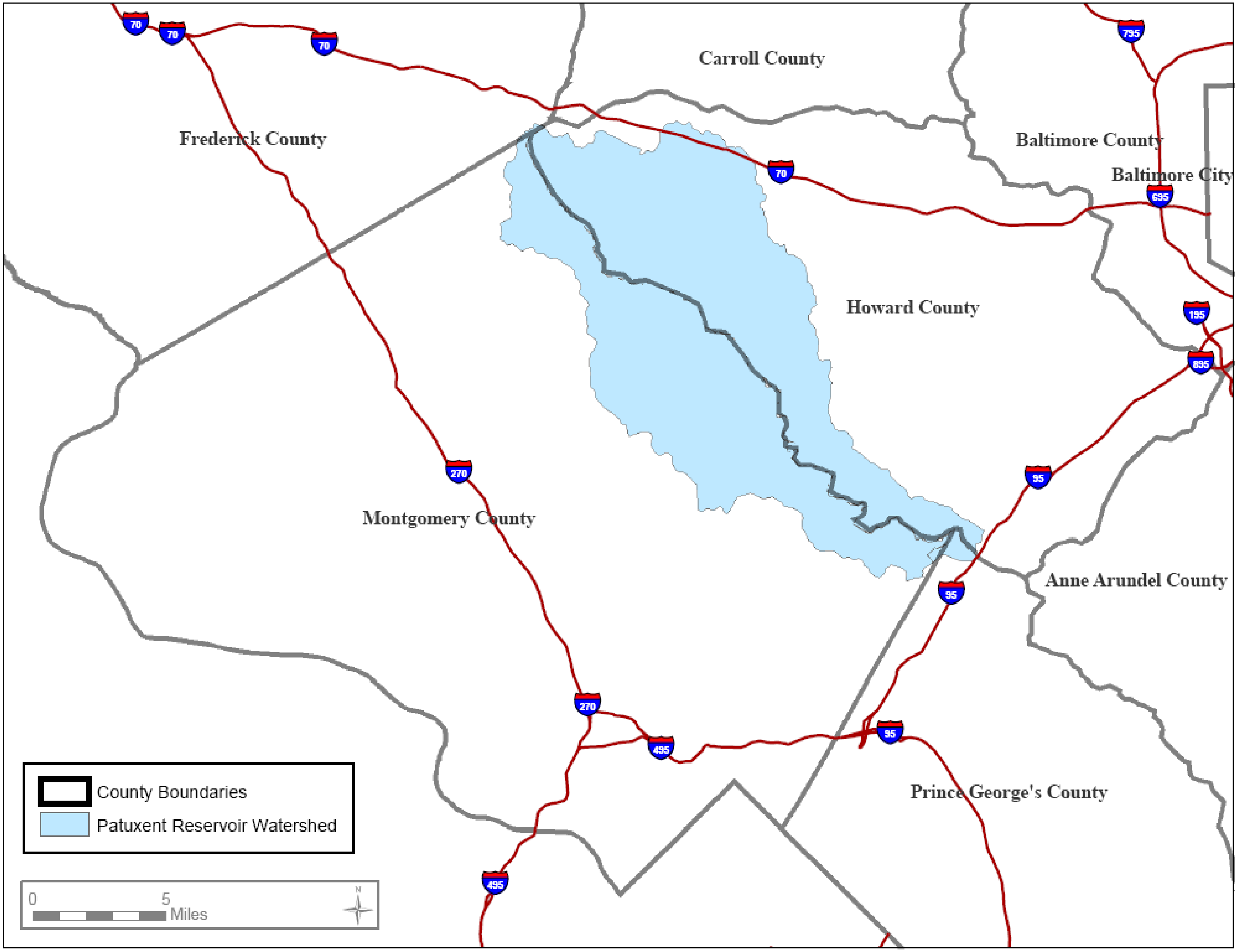


Figure 4-1. Location of Patuxent Reservoirs watershed

1952 with the completion of the T. Howard Duckett Dam and Reservoir (Rocky Gorge), downstream of the Triadelphia Reservoir. The WSSC acquired about 6,000 acres of land surrounding the reservoirs between 1930 and 1955 to insure control of critical areas immediately adjacent to the reservoirs. The watersheds that drain water into the reservoirs are located in Howard, Montgomery, and Prince George's Counties. The WSSC lands are less than 6% of the approximately 85,000 acres draining into the reservoirs.

Table 4-2 summarizes some basic characteristics of the two reservoirs.

Table 4-2. Physical characteristics of the Patuxent Reservoirs Maryland

Characteristic	**Triadelphia**	**Rocky Gorge**
Location:	Howard County, MD Montgomery County, MD Lat. 39° 11' 36" N Long. 77° 00' 18" W	Howard County, MD Montgomery County, MD Prince George's County MD Lat. 39° 07' 00" N Long. 76° 52' 36" W
Surface Area:	800 acres (34,848,000 ft^2)	773 acres (33,672,000 ft^2)
Normal Reservoir Depth:	52.0 feet	74.0 feet
Purpose:	Water Supply Recreation	Water Supply Recreation
Basin Code:	02-13-11-08	02-13-11-07
Volume:	19,000 acre-feet	17,000 acre-feet
Drainage Area to Reservoir:	77.3 mi^2 (49,500 acres)	132 mi^2 (84,480 acres)
Average Discharge[1]:	82.4 $ft^3 s^{-1}$	85.9 $ft^3 s^{-1}$

Source: Inventory of Maryland Dams and Hydropower Resources (Weisberg et al. 1985).
[1] Water Resources Data Maryland and Delaware Water Year 2000 (USGS 2000).

4.2 LAND OWNERSHIP

Table 4-3 shows the number of acres and percentage of property within the Patuxent Reservoir watershed owned by public agencies as of 2008. The WSSC owns and controls 6.9 square miles (5590 acres) of land contiguous to the reservoirs with the primary purpose of creating a buffer zone to control sediment and pollutant runoff.

Table 4-3. Public lands ownership in Patuxent Reservoirs watershed, Maryland (based on 2008 data provided by WSSC, M-NCPPC, DNR, Montgomery and Howard County).

Land owner	**Total Acres**	**Watershed Area (%)**
County	9,922	11.7
DNR	22,281	26.3
Federal	265	0.3
MNCPPC	1,159	1.4
WSSC	5,590	6.6

Figure 4-2 shows the latest (2007) public land ownership by land owner.

Figure 4-3 shows locations of various easement types throughout the watershed.

- **Montgomery County Forest Conservation Easements:** Forest conservation easements.
- **Montgomery County Protected Lands:** Definition unknown.
- **Howard County Environmental Easements:** Environmental preservation parcels created through the rural cluster subdivision or density exchange requirement.
- **Howard County Forest Conservation Easements:** Forest conservation easements.
- **Howard County Agricultural Easements:** Agricultural easements held by the Howard County Agricultural Land Preservation Program.
- **Howard County Historic Easements:** Historic easements held by the Maryland Historic Trust.
- **Howard County MALPF Easements:** Agricultural easements held by the Maryland Agricultural Land Preservation Foundation.
- **Howard County MET Easements:** Easements held by the Maryland Environmental Trust.
- **Howard County MIF Preservation Easements:** Definition unknown.

4.3 GEOLOGY AND SOILS

According to the 2007 Maryland Geological Survey report (2007):

The Triadelphia Reservoir is located within the Hampstead and Glenwood Uplands geomorphic districts, which collectively cover an extensive portion of the Piedmont and are characterized by a dominance of gneiss and schist bedrock.

The Rocky Gorge Reservoir is located downstream from the Triadelphia Reservoir in the Fall Zone Region. The Fall Zone is a unique geomorphic transition zone from the Piedmont to the Coastal Plain physiographic province. This zone is characterized by a mix of metamorphic rocks with some overlying unconsolidated gravels, sands, silts, and clays. Bedrock outcrops are distinctly visible in well defined narrow gorges that can be observed in the waterways that traverse them. This characteristic morphology is apparent in the confined width of Rocky Gorge Reservoir.

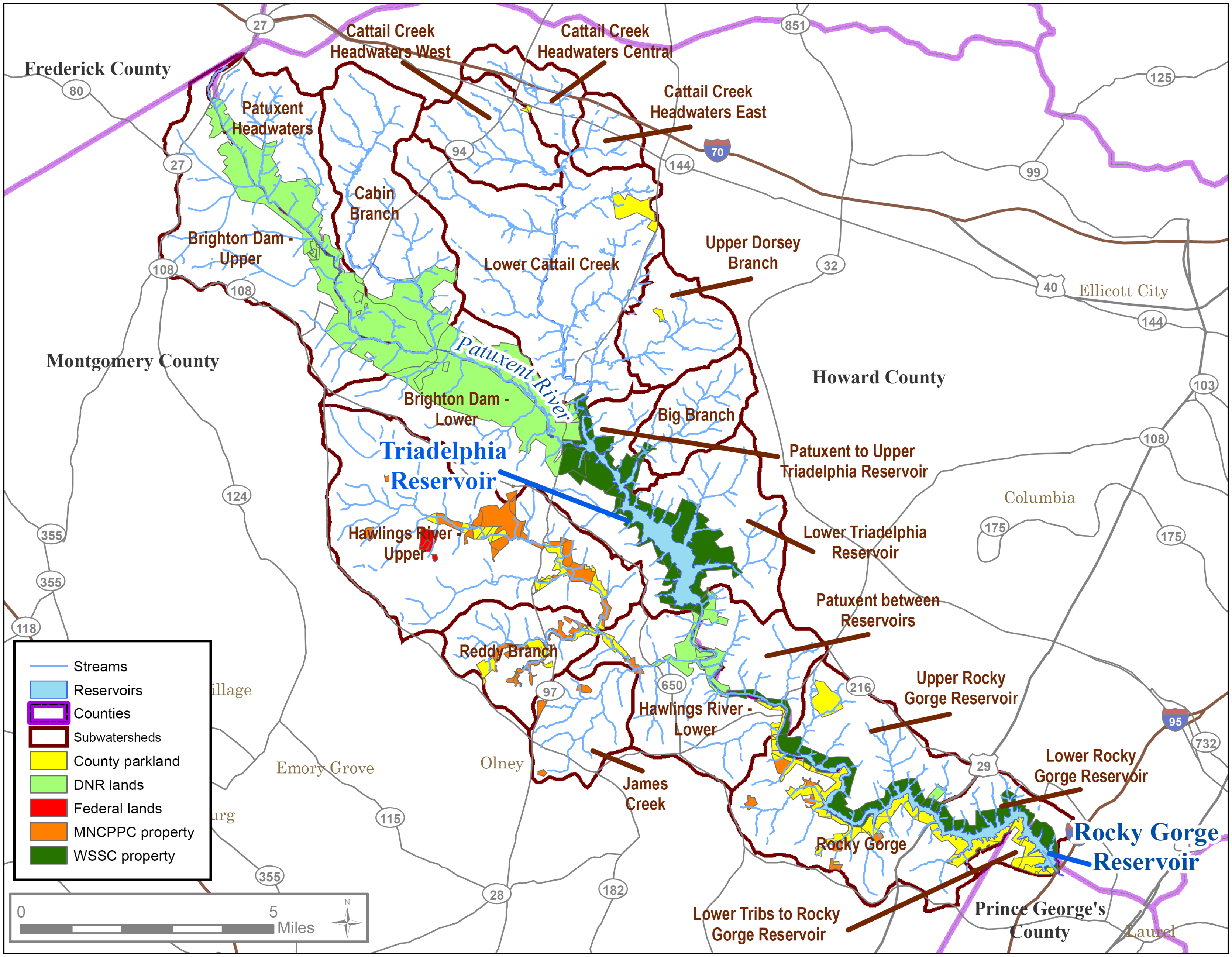


Figure 4-2. Public lands in the Patuxent Reservoirs watershed (2008 data provided by WSSC, M-NCPPC, DNR, Montgomery and Howard County).

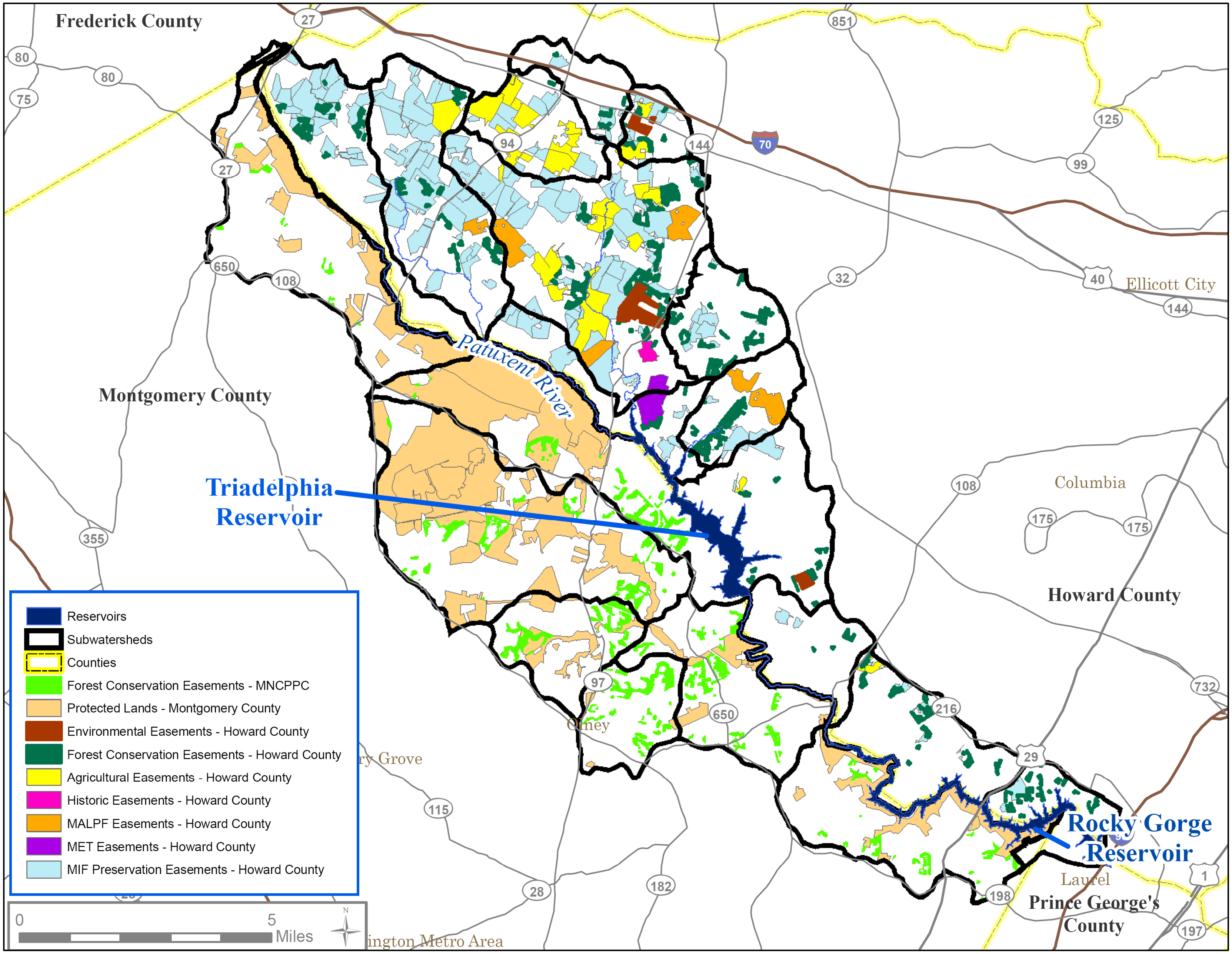


Figure 4-3. Easements in Patuxent Reservoirs watershed, Maryland (data provided by M-NCPPC, Montgomery and Howard County 2008).

> Triadelphia, broader and shallower than Rocky Gorge Reservoir, covers the lower, narrow portions of the Patuxent River at the Fall Zone. The original Triadelphia Reservoir bottom and upper reaches of Rocky Gorge Reservoir bottom were largely composed of Quaternary alluvial deposits that formed the Patuxent River valley floodplain. Portions of both reservoir bottoms are now covered with sediments that have accumulated since dam construction and backwatering.

The MDE TMDL report (MDE 2008) also summarizes some basic geologic parameters of the two reservoirs.

> The watersheds of Triadelphia and Rocky Gorge Reservoirs lie in the Piedmont physiographic province. The surficial geology is characterized by metamorphic rock of Late Precambrian age. The headwaters of the Patuxent River lie in the schists and metasedimentary rock of the Marburg Formation. Almost all of the rest of the watershed lies in the Wissahickon Formation of gneisses and schists. Upper Pelitic schist is the dominant bedrock of the headwaters of Cattail Creek and Hawlings River. Gneiss of the Sykesville Formation underlies the Patuxent River and Cattail Creek drainage to Triadelphia Reservoir, as well as Hawlings River. Lower Pelitic schist is the primary underlying bedrock of the direct drainage to Rocky Gorge and Triadelphia Reservoirs. The soils found in the reservoir watersheds are primarily deep and well-drained to excessively drained (Mathews and Hershberger 1968; Brown and Dyer 1995). The dominant soil associations in the Rocky Gorge Reservoir watershed are the Glenelg-Manor-Chester and the Glenelg-Gaila-Occoquan associations. The Glenelg-Chester-Manor association forms the dominant soils of Cattail Creek and areas northwest of Triadelphia Reservoir, while the Mt. Airy-Glenelg-Chester association is dominant in the Patuxent River watershed draining into Triadelphia Reservoir. Mt. Airy soils belong to hydrologic group “A,” while the rest of the dominant soils belong to group “B” (MDE 2008).

5.0 CURRENT LAND USE

5.1 LAND USE

In 1987, 40% of Patuxent Reservoirs watershed was forested, 10% of the watershed was urbanized (70% of which was large lot single-family residential or low-medium density residential) and 30% of the watershed was cropland (CDM 1987).

A report by MDE (2008) on nutrient and sediment TMDLs for the reservoirs watershed summarized land use based on 1997 Maryland Department of Planning (MDP) land use/land cover data. In 1997, about half of the Triadelphia Reservoir watershed was in crops or pasture, 32% in forest, and 15% in residential, commercial, or industrial land uses (Figure 5-1). The 1997 MDP data showed that the Rocky Gorge Reservoir watershed was approximately 28% developed and 39% forest, with the remainder (~ 33%) in crops or pasture.

The most recent data, from 2007 acquired from MDP (Figure 5-2), show that approximately 33% of the Patuxent Reservoirs watershed is residential, primarily in its lower half, 32% is agriculture, primarily upstream of the Triadelphia Reservoir and 30.5% is forest cover, concentrated along the mainstem of the Patuxent River. Residential land is predominantly low to very low density. Table 5-1 shows current land use (2007) by subwatershed and divided up by the Rocky Gorge Reservoir watershed and the Triadelphia Reservoir watershed.

Over the past 20 years, the watershed has experienced an increase in residential land use. Unfortunately the most recent MDP data on land use (2007) are not directly comparable with the previous MDP data (e.g., 1997 or 2002) primarily for two reasons (pers. comm. Melissa Appler, Planner, Maryland State Department of Planning): new, better leaf-on imagery used to generate 2007 data and new land-use categories added in 2007 (very low density residential and transportation). Therefore, we cannot easily make comments on land-use change over time. Although a direct, quantitative comparison between 2007 and prior years' land-use data is not possible, a pattern of increasing urban use and decrease in agricultural acreage is apparent. Other data show a 64% increase in the number of septic systems within the watershed from 1997 to 2008 (Section 10.2), indicative of new residential construction.

The ultimate build-out in both Howard and Montgomery Counties will be controlled to some degree by zoning. In portions of the watershed in both counties, the zoning already established is intended to protect agriculture and rural residential land uses. Note that only a small portion of the watershed is within current or planned sewer service areas.

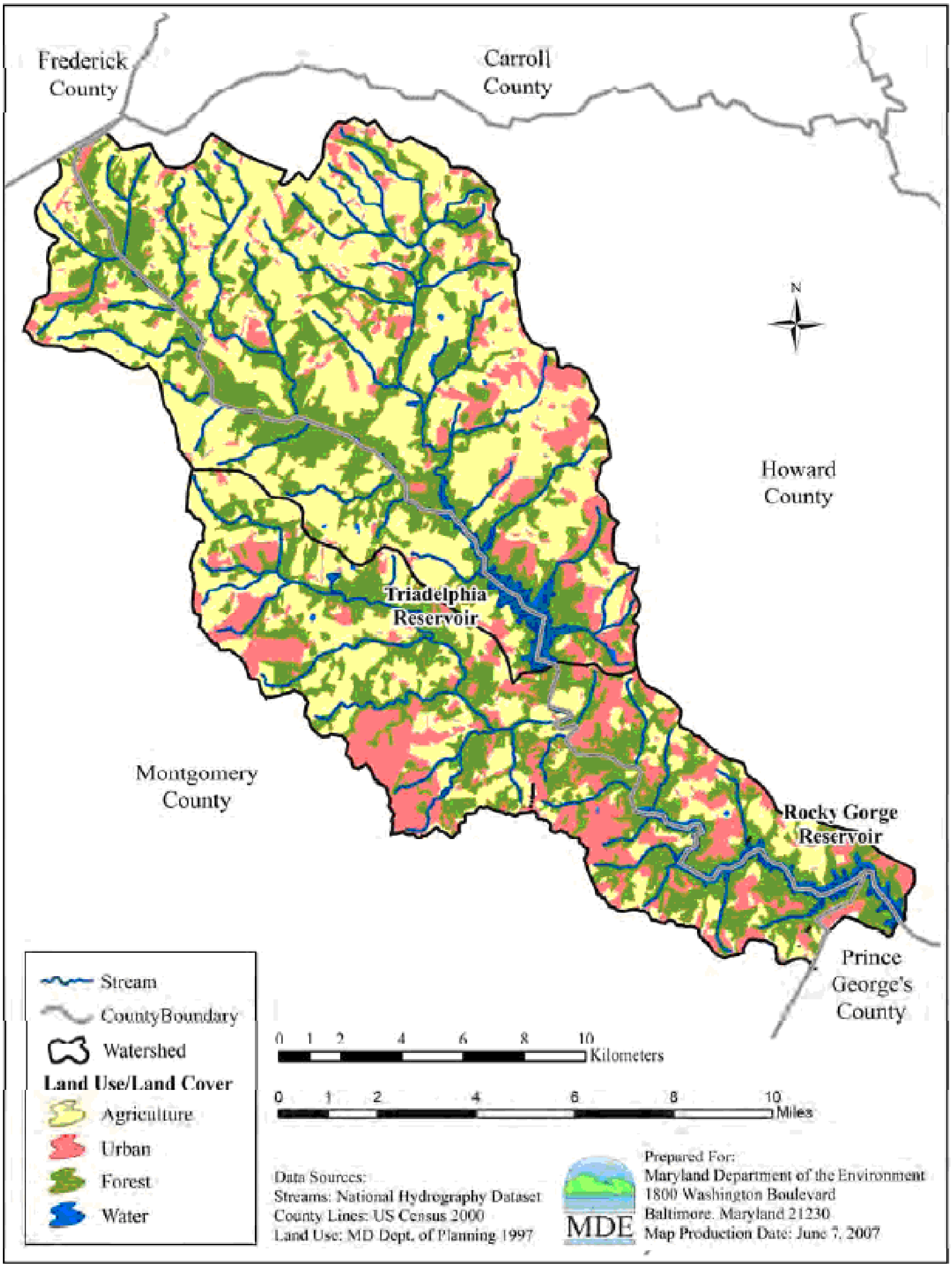


Figure 5-1. Land use for the Patuxent Reservoirs watershed, Maryland, based on 1997 Maryland Department of Planning land use/land cover data (map from MDE 2008).

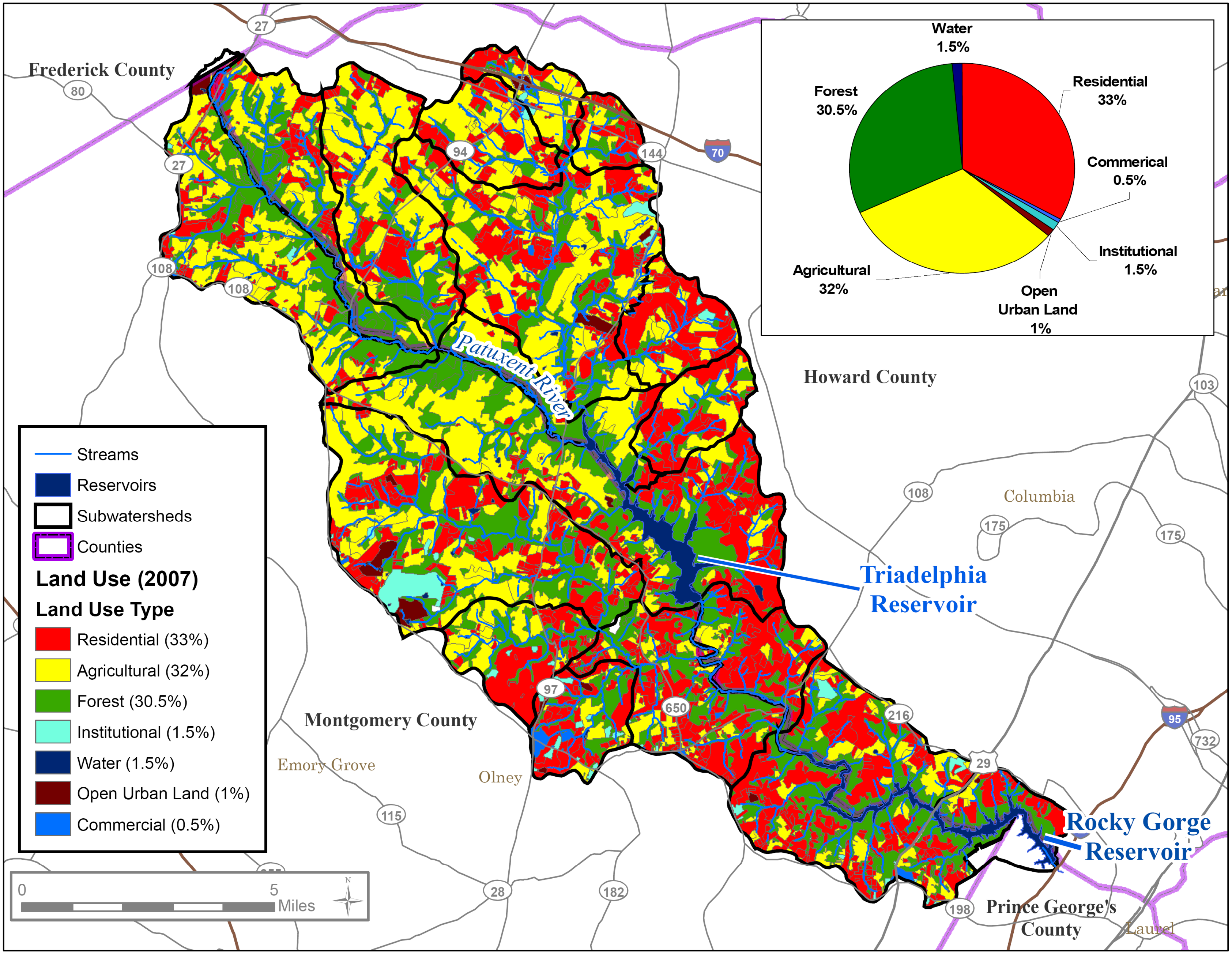


Figure 5-2. Draft 2007 Maryland Department of Planning land-use data for Patuxent Reservoirs watershed.

Table 5-1. 2007 land use in acres and percentage of total subwatershed acres, in the Patuxent Reservoirs watershed, Maryland, by subwatershed and reservoir watershed (MDP 2007 data).

Location	Agri-cul-tural (acres)	Agri-cul-tural %	Com-mer-cial (acres)	Com-mer-cial %	Forest (acres)	Forest %	Insti-tu-tional (acres)	Insti-tu-tional %	Open Urban Land (acres)	Open Urban Land %	Resi-dential (acres)	Resi-dential %	Trans-por-tation (acres)	Trans-por-tation %	Water (acres)	Water %	Bar-ren Land (acres)	Bar-ren Land %	Indus-trial (acres)	Indus-trial %	Total Acres
Triadelphia Reservoir Watershed: Land use by Subwatershed																					
Cattail Creek Headwaters Central (HC)	718	47.4	25	1.7	186	12.3	29	1.9	51	3.4	445	29.4	59	3.9							1514
Patuxent Headwaters (HC)	1316	30.7	18	0.4	2205	51.5	3	0.1	0	0.0	739	17.3									4281
Cabin Branch (HC)	2707	47.0			1641	28.5	3	0.1			1379	24.0			24	0.4					5753
Cattail Creek Headwaters West (HC)	1390	52.5	13	0.5	258	9.8	21	0.8			967	36.5									2648
Cattail Creek Headwaters East (HC)	327	29.4	8	0.7	235	21.2					520	46.8	21	1.9							1111
Big Branch (HC)	712	32.5	2	0.1	417	19.1	2	0.1			1056	48.3									2188
Lower Cattail Creek (HC)	4458	44.5	22	0.2	2387	23.9	111	1.1	134	1.3	2872	28.7			25	0.2					10009
Upper Dorsey Branch (HC)	710	28.5			153	6.1	55	2.2			1570	63.0			2	0.1					2491
Lower Triadelphia Reservoir (HC)	450	10.4	8	0.2	1151	26.5	1	0.0			2342	54.0			383	8.8					4334
Pax to Upper Triadelphia Res (HC)	971	37.5			1224	47.2					299	11.5			97	3.8					2591
Brighton Dam - Upper (MC)	2949	42.8	42	0.6	2537	36.8	59	0.9	72	1.0	1224	17.8			10	0.1					6894
Brighton Dam - Lower (MC)	2880	42.6	1	0.0	2620	38.7	4	0.1	16	0.2	907	13.4			333	4.9			1	0.0	6763
TOTAL	19588	38.7	138	0.3	15015	29.7	287	0.6	274	0.5	14319	28.3	80	0.2	874	1.7	0	0.0	1	0.0	50577
Rocky Gorge Reservoir Watershed: Land use by Subwatershed																					
Patuxent between Reservoirs (HC)	307.6	12.0	2	0.1	760	29.7	3	0.1			1483	58.0			0	0.0					2555
Lower Rocky Gorge Reservoir (HC)	108.9	7.4	11	0.8	595	40.4			7	0.5	561	38.1	18	1.2	173	11.7					1474
Upper Rocky Gorge Reservoir (HC)	724.1	18.8	9	0.2	1402	36.4	121	3.1			1447	37.5	24	0.6	118	3.1	11	0.3			3856
Hawlings River – Upper (MC)	3572.5	34.1	21	0.2	3021	28.8	500	4.8	313	3.0	2969	28.3			56	0.5			22	0.2	10475
Hawlings River - Lower (MC)	659.8	14.4	32	0.7	1520	33.1	27	0.6			2320	50.5			6	0.1			26	0.6	4590
Reddy Branch (MC)	829.1	28.8	3	0.1	746	25.9	39	1.4			1256	43.6	1	0.0	6	0.2					2880
Rocky Gorge (MC)	595.7	11.4	63	1.2	2020	38.6	74	1.4	27	0.5	2241	42.8	19	0.4	198	3.8					5238
James Creek (MC)	285.5	11.8	122	5.0	595	24.6	148	6.1	49	2.0	1194	49.4	6	0.2	16	0.7					2415
TOTAL	7083.2	21.2	262	0.8	10660	31.8	913	2.7	396	1.2	13471	40.2	68	0.2	572	1.7	11	0.0	48	0.1	33484

Empty cells indicate zero acreage in a category.
(HC) Howard County
(MC) Montgomery County
Note the Prince George's County portion of Rocky Gorge Reservoir watershed is not included in these calculations.

5.2 IMPERVIOUSNESS

As discussed by Schueler (1994) the amount of impervious surface in a watershed is a landscape indicator which integrates a number of concurrent interactions that influence a watershed's hydrology.

Impervious surfaces include roadways, rooftops, sidewalks, and parking lots are a consequence of and therefore good indicators of the intensity of urbanization (Arnold and Gibbons 1996). Many researchers have characterized the environmental impacts of urbanization. Increased volume and time of concentration from stormwater conveyance systems have been addressed by Leopold (1968) and Tourbier and Westmacott (1981). Impacts on stream temperatures have been identified by Klein (1979) and Galli (1991). The impact of impervious surfaces on hydraulic change and stream stability has been discussed in Hammer (1972), Leopold (1973), Dunne and Leopold (1978), Booth (1990), and Henshaw and Booth (2000). Anderson (1968), Hollis (1975), Harbor (1994) as well as Rose and Peters (2001) discussed the impacts of urbanization and impervious surfaces on streamflow.

Figure 5-3 shows impervious cover based on 2007 data, which on average across the entire watershed is only 6%. However, those areas in and around Olney and in the Lower Rocky Gorge subwatershed show areas of more concentrated, contiguous imperviousness.

In order to make conceptualizing imperviousness by subwatershed easier, we averaged imperviousness across subwatersheds. Figure 5-4 shows average imperviousness by subwatershed in four categories: 1-5%, 6-10%, 11-15% and 16-20% impervious. Note that stream degradation is typically found at approximately 10% impervious cover (Schueler and Holland 2000). Table 5-2 details exact acres of impervious cover and percent imperviousness by subwatershed, as well as a breakdown by county and overall. Note that James Creek subwatershed in Montgomery County has by far the highest percent impervious surface at 18% while Reddy Branch and Lower Rocky Gorge are at the 10% imperviousness threshold.

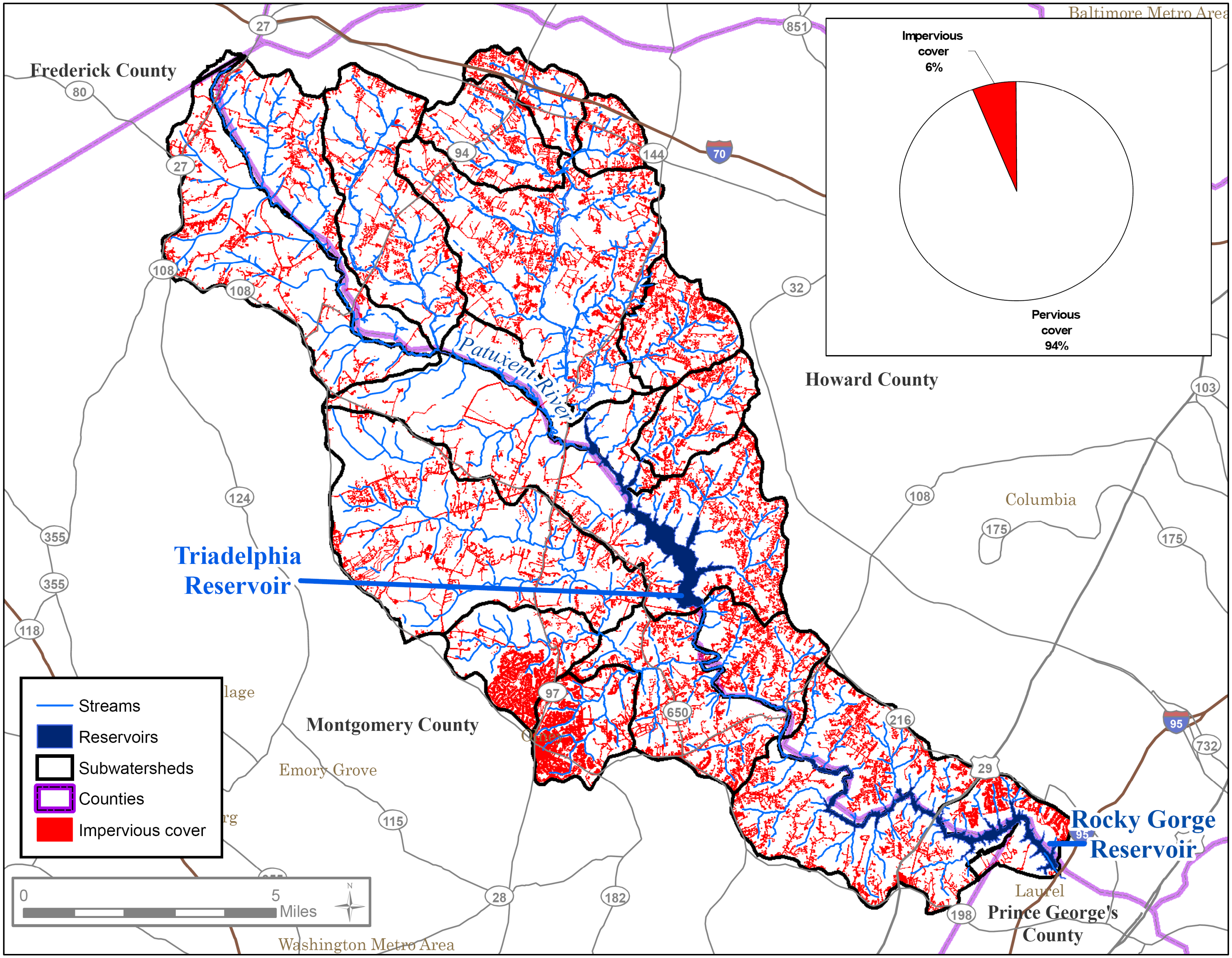


Figure 5-3. Impervious cover in Patuxent Reservoirs watershed, Maryland (Howard, Montgomery, and Prince George's Counties data 2007).

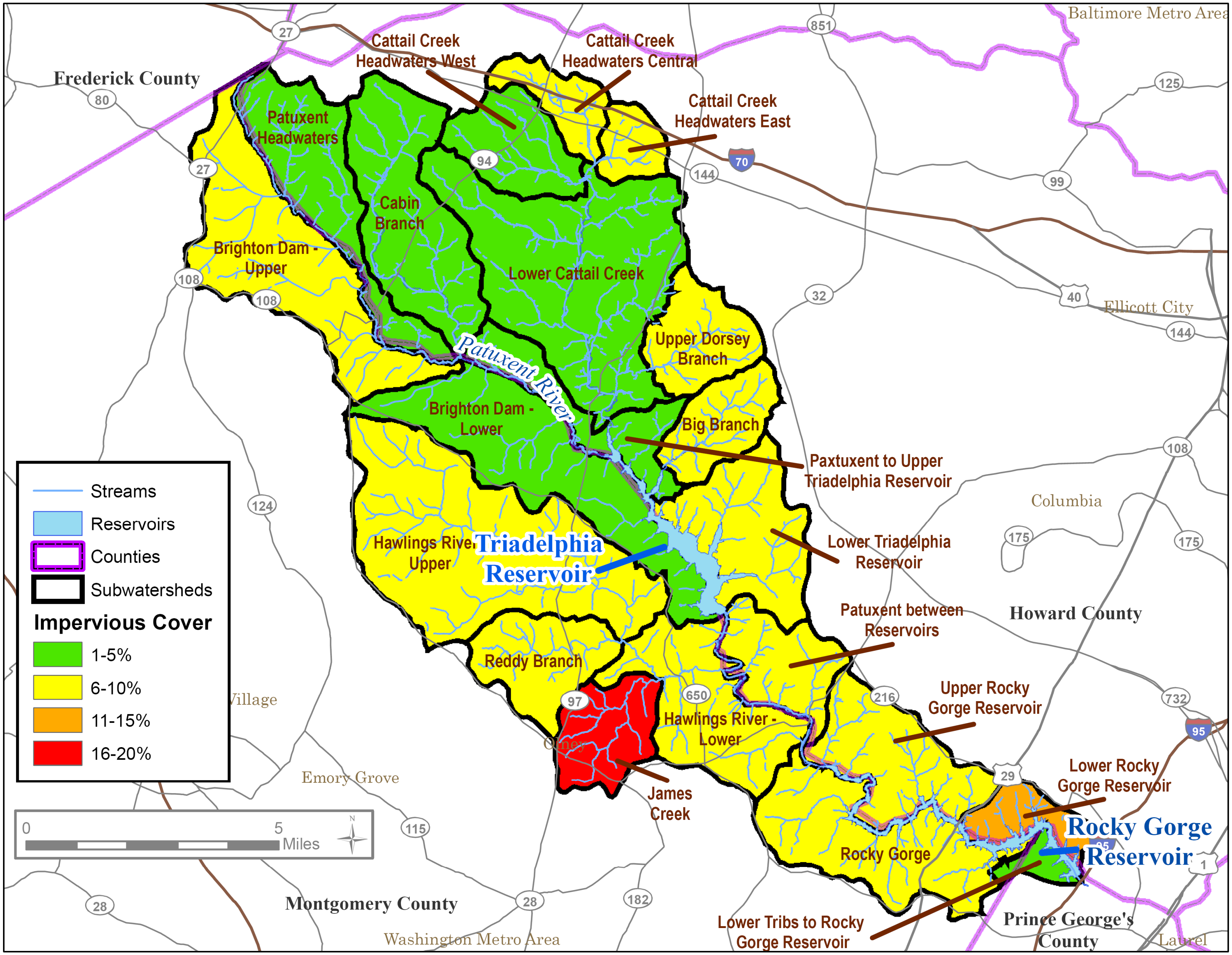


Figure 5-4. Average percent imperviousness by subwatershed in Patuxent Reservoirs watershed, Maryland in 2007 (Howard, Montgomery, and Prince George's Counties 2008 data).

Table 5-2. Impervious acreage and percent imperviousness by subwatershed, Patuxent Reservoirs watershed, Maryland (based on Howard, Montgomery, and Prince George's Counties 2008 data)

.

Subwatershed	County	Acres of Impervious Cover	% Impervious Cover
Pax to Upper Triadelphia Res	Howard	56	2%
Patuxent Headwaters	Howard	132	3%
Cabin Branch	Howard	178	3%
Brighton Dam - Lower	Montgomery	265	4%
PG County Portion	Prince George's	23	4%
Cattail Creek Headwaters West	Howard	123	5%
Big Branch	Howard	116	5%
Lower Cattail Creek	Howard	461	5%
Brighton Dam - Upper	Montgomery	359	5%
Hawlings River - Upper	Montgomery	543	5%
Lower Triadelphia Reservoir	Howard	248	6%
Upper Rocky Gorge Reservoir	Howard	235	6%
Rocky Gorge	Montgomery	320	6%
Cattail Creek Headwaters Central	Howard	122	8%
Cattail Creek Headwaters East	Howard	85	8%
Patuxent between Reservoirs	Howard	199	8%
Upper Dorsey Branch	Howard	187	8%
Hawlings River - Lower	Montgomery	386	8%
Lower Rocky Gorge Reservoir	Howard	148	10%
Reddy Branch	Montgomery	277	10%
James Creek	Montgomery	440	18%
	Total Impervious Area in Howard County section of Patuxent Reservoirs watershed	**2297**	5%
	Total Impervious Area in Montgomery County section of Patuxent Reservoirs watershed	**2593**	7%
	Total Impervious Area, Patuxent Reservoirs watershed	**4913**	6%

6.0 FOREST COVER IN THE WATERSHED

In their 2002 report, the organization American Forests estimated that tree cover in the Washington DC metro area had declined by about 30% over the last 30 years (American Forests 2002). Dwyer and Nowak (2000) estimate that tree canopy cover in urban and metropolitan areas across the U.S. averages 27% and 33%, respectively.

East of the Mississippi and in the Pacific Northwest, American Forests recommends an average of 40% tree canopy overall, 50% tree canopy in suburban residential, 25% tree canopy in urban residential and 15% tree canopy in the central business districts. 2007 land-use data from MDP show 30.5% forest cover over the entire Patuxent Reservoirs watershed, which is within the range cited by American Forests given the mix of land uses found in the Patuxent Reservoirs watershed.

Figure 6-1 shows forest cover in the watershed by ownership. As illustrated, forest immediately around the reservoirs is owned and controlled by WSSC and make up 12% of total forest cover in the Patuxent Reservoirs watershed. Overall, 36% of the forests are owned by DNR (mainly upstream of the Tridelphia Reservoir along the Patuxent River), 10% are county-owned parks primarily in the Hawlings River subwatershed and the remaining 42% are privately-owned forests. Table 5-1 shows the acreage and percentage of forest by subwatershed and by reservoir watershed. Three subwatersheds in Howard County, the Cattail Creek Headwaters West, Cattail Creek Headwaters Central and the Upper Dorsey Branch show particularly low levels of forest cover at 9.8%, 12.3% and 6.1%, respectively.

In 2007, a "Forest Conservation Plan for Washington Suburban Sanitary Commission Reservoir Properties" [only] was prepared by Anne Hairston-Strang, Ph.D of the Maryland Department of Natural Resources Forest Service. The purpose of this plan is to guide conservation and sustainable management of the forests surrounding the reservoirs. The plan presents data and management recommendations for the 3,858 acres of forested land surrounding Triadelphia and Rocky Gorge Reservoirs owned by WSSC. Key findings of that report, relative to this effort, include:

1. Reservoir forests are significant contributors to forests in the watersheds;
2. Lack of a diversity of trees of various ages and sizes;
3. Only 26% of the WSSC forest is likely to provide interior forest conditions, based on the linear nature of the reservoir forests, roads, and the openings provided by the reservoir itself
4. Neither reservoir forest had seedling densities near or above the 2,000+ trees/acre desired for dependable regeneration;
5. Several areas of excessively dense stands, primarily pine, where risks of pests and fire are increased and habitat value can be diminished;

6. Low levels of shrubs and ground cover, particularly in Rocky Gorge plots;
7. Invasive species were well-distributed throughout Rocky Gorge and parts of Triadelphia forests;
8. The total accumulation of woody debris habitat is high for the forest's age and size.

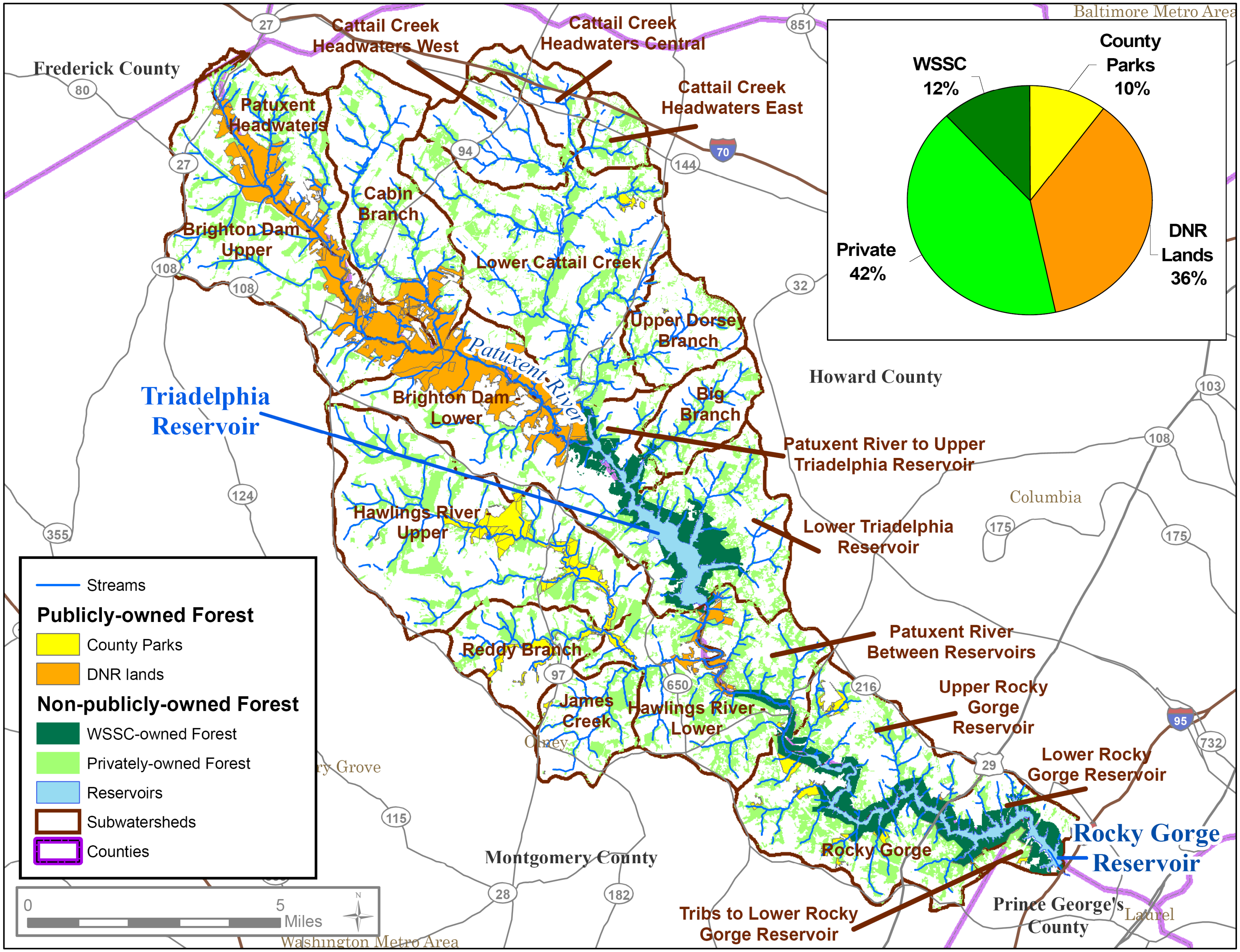


Figure 6-1. Forest cover by ownership in Patuxent Reservoirs watershed, Maryland (Howard County 2007, Montgomery and Prince George's Counties 2008 data).

7.0 STREAM BUFFERS

Riparian areas are defined as ecosystems adjacent to or near flowing waters such as streams, lakes, shorelines, and wetlands. Riparian buffers are linear bands of permanent vegetation, preferably consisting of native and locally adapted species, located between aquatic resources and adjacent areas subject to human alteration (Castelle et al. 1994; Fischer and Fischenich 2000; Kennedy et al. 2003). As per Wenger 1999 and Fischer & Fischenich 2000, riparian buffer widths are measured from the top of the bank or level of bankfull discharge of one side of a water body. Therefore, a 50 meter buffer on each side of a 10 meter stream would create a zone 110 meters wide.

More than 80% of riparian vegetative buffer in North America and Europe has disappeared in the last 200 years (Naiman et al. 1993). To ameliorate the negative impacts of adjacent land uses, a common regulatory and management practice is to establish protected areas, or buffers, around aquatic resources like rivers, streams, lakes and wetlands (Environmental Law Institute 2003).

As the Environmental Law Institute states in its literature review of 2003:

> Buffers can help regulate riparian microclimate and provide necessary shading for the in-stream growth and reproduction of aquatic life; stabilize stream banks and prevent channel erosion; provide organic litter (e.g., leaf litter) and woody debris, which are important sources of food and energy for fish and aquatic invertebrate communities; remove or regulate sediment, nutrients, or other contaminants (e.g., pesticides, herbicides) from runoff; provide flood attenuation and storage to decrease damage to property; and provide wildlife habitat (Castelle et al. 1994; O'Laughlin and Belt 1995; Wenger 1999; Fischer and Fischenich 2000; National Research Council 2002).

The Environmental Law Institute summarized most pre-1992 literature on recommended-minimum riparian (and wetland) buffer widths necessary to maintain water quality and wildlife functions within the United States, sorted by control parameters of interest. Their survey found recommended buffer widths ranging from one meter up to 1600 meters, with 75% of the values extending up to 100 meters. Again buffer widths are measured from the top of the bank or level of bankfull discharge of one side of a water body. They also concluded that based on the majority of literature, a minimum width of 25 meters is required to provide nutrient and pollutant removal; a minimum of 30 meters to provide temperature and microclimate regulation and sediment removal; a minimum of 50 meters to provide detrital input and bank stabilization; and over 100 meters to provide for wildlife habitat functions. To provide water quality and wildlife protection, buffers of at least 100 meters are recommended for the Patuxent Reservoirs watershed as measured from the top of the bank or level of bankfull discharge of one side of a water body.

To meet the goals of nutrient and pollutant removal as well as detrital input and bank stabilization, 50 meter areas on one side of the stream centerline are evaluated below. Figure 7-1 shows the approximate locations of unforested riparian zones within a 100 meter area, 50 meters on each side, perpendicular to the centerline of the stream. Note that the red polygons are exaggerated in size in order to be visible at the scale of this map. Although it is not easy to distinguish overall buffer coverage by subwatershed in this map, it does however allow one to locate specific riparian segments in need of planting in the riparian buffer zone.

In order to better gage and visualize overall buffer completeness, across the reservoirs watershed, a map of average percent unforested riparian area by subwatershed was created. Figure 7-2 breaks the subwatersheds into 3 categories using the same 100 meter stream buffer threshold, 50 meter on each bank from the centerline of the stream. Those watersheds marked in blue have 1-33% unforested area in the 0-100 meter riparian zone, those in yellow are 34-66% unforested and those in red are 67-100% unforested. Those subwatersheds of greatest concern due to the high percentage of unforested buffer are noted in red.

The majority of the Patuxent Reservoirs watershed has a significant percentage of unbuffered riparian zone as indicated by those subwatersheds in yellow. Table 7-1 details, by subwatershed, the total stream miles, the total acres of riparian area (100 meters total, 50 meters perpendicular to the centerline of the stream on each side), a breakdown of that area as forested or non-forest land, and the percentage that is non-forest As can be seen in the table, the subwatersheds of greatest concern, due to high percentages of unbuffered riparian area, are the Cattail Creek Headwaters West (72%), Cattail Creek Headwaters Central (65%), and Upper Dorsey Branch (66%).

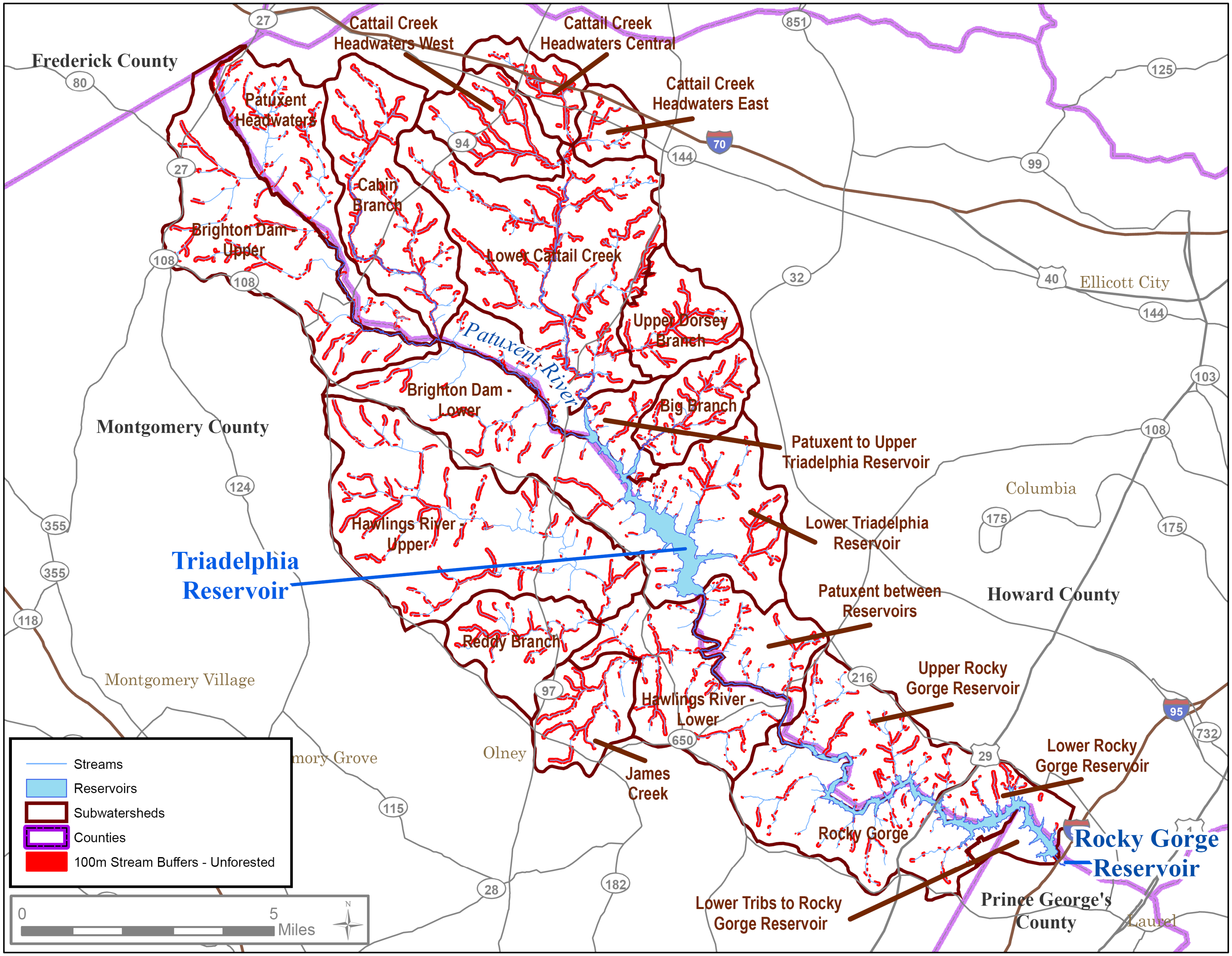


Figure 7-1. Locations (not to scale) of 100 meter (50 meters each side from center of stream) unforested riparian area in the Patuxent Reservoirs watershed, Maryland (Howard County 2008 data and Montgomery County 2008 data). Prince George's County data not shown.

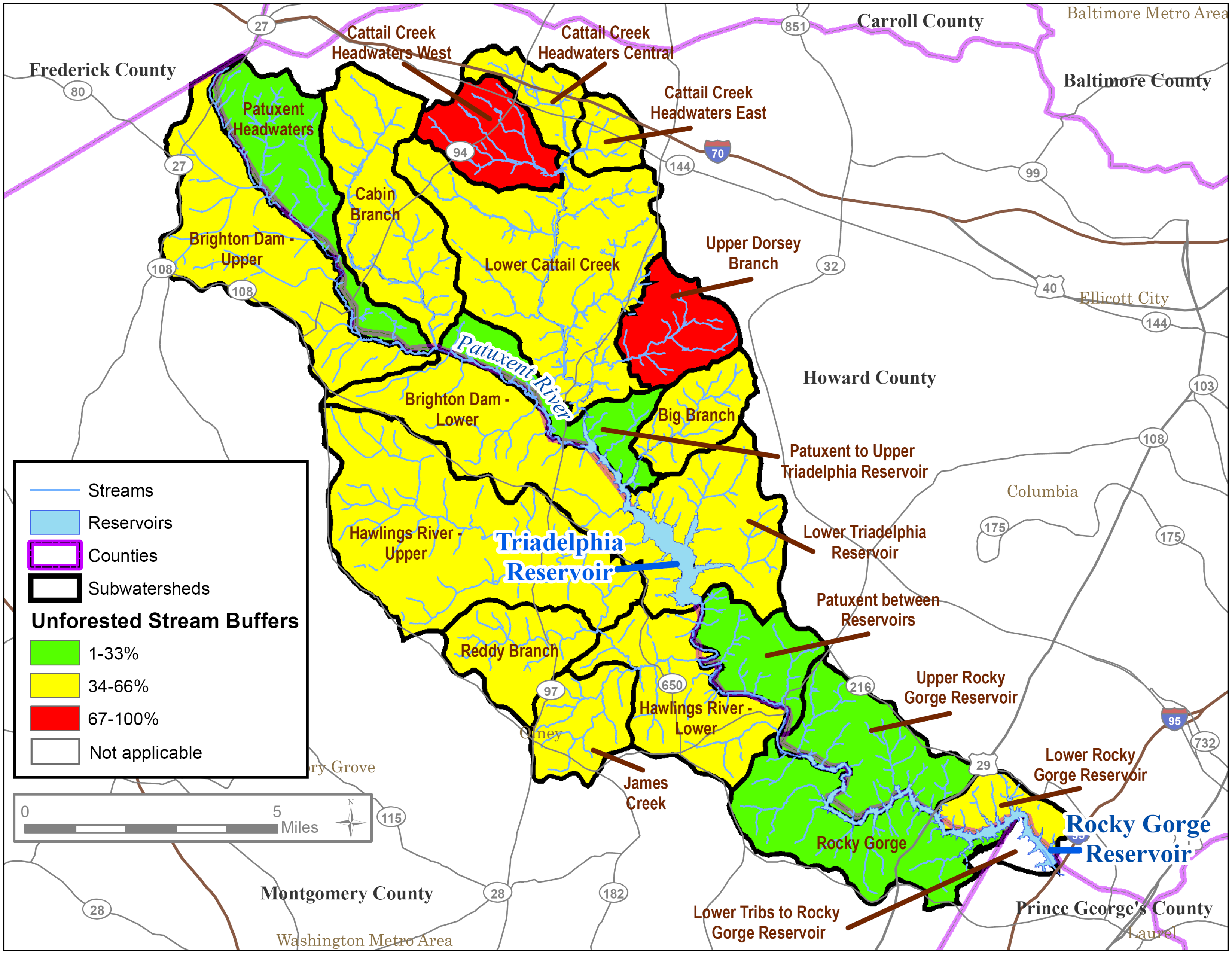


Figure 7-2. Average percentage of unforested stream riparian areas (100 meters total; 50 meters on each side from stream center) by subwatershed, Patuxent Reservoirs watershed, Maryland (Howard County 2007 data and Montgomery and Prince George's Counties 2008 data).

Table 7-1. Characterization of stream miles, acres of 100 meter riparian area, acres of forested 100 meter stream buffer, acres of unforested 100 meter stream buffer and percent of stream buffer that is unforested in the Patuxent River watershed, by subwatershed and county in Maryland 2007 (MDP 2007).

Subwatershed	County	Stream Miles	Total 100m Riparian Area (acres)	Forested 100m Stream Buffer Area (acres)	Unforested 100m Stream Buffer Area (acres)	% of Stream Buffers that are Unforested
Rocky Gorge	Montgomery	15.7	642.8	550.2	92.6	14%
Patuxent Headwaters	Howard	25.9	877.9	741.8	136.1	15%
Patuxent between Reservoirs	Howard	13.8	481.2	345.1	136.0	28%
Pax to Upper Triadelphia Res	Howard	12.6	425.7	289.3	136.4	32%
Upper Rocky Gorge Reservoir	Howard	14.6	582.4	398.1	184.2	32%
Brighton Dam - Upper	Montgomery	22.4	863.6	576.0	287.6	33%
Hawlings River - Lower	Montgomery	18.2	690.6	457.2	233.4	34%
Brighton Dam - Lower	Montgomery	15.6	624.2	393.9	230.2	37%
Hawlings River - Upper	Montgomery	35.3	1387.3	850.9	536.4	39%
Big Branch	Howard	10.8	406.5	238.9	167.6	41%
Reddy Branch	Montgomery	9.4	362.8	214.1	148.7	41%
Cabin Branch	Howard	25.4	900.0	525.8	374.2	42%
Lower Rocky Gorge Reservoir	Howard	4.4	175.0	102.1	73.0	42%
Lower Triadelphia Reservoir	Howard	12.5	489.5	276.6	213.0	44%
Cattail Creek Headwaters East	Howard	3.9	146.9	80.6	66.3	45%
Lower Cattail Creek	Howard	48.8	1717.6	881.7	835.9	49%
James Creek	Montgomery	10.2	391.6	201.5	190.1	49%
Cattail Creek Headwaters Central	Howard	7.0	255.9	90.1	165.8	65%
Upper Dorsey Branch	Howard	9.7	363.5	123.6	239.9	66%
Cattail Creek Headwaters West	Howard	12.7	438.2	122.7	315.5	72%
PG County Portion*	Prince George's	0	0	0	0	0%

* Zero stream miles mapped by Prince George's County. In other words, data show no stream in the Patuxent Reservoirs watershed portion of Prince George's County.

8.0 AGRICULTURE

8.1 AGRICULTURE IN THE LITERATURE

Past authors have recognized the importance of agriculture, and the need to address polluted agricultural runoff, on numerous occasions. The 1981 "Patuxent River Watershed Protection Program" study for WSSC by Ecological Analysts Inc. called for the counties to be encouraged, through cooperation with the USDA Soil Conservation Service (NRCS as of 1994), to implement BMPs for all agricultural areas. According to that report, BMPs should include riparian buffer strips, no-till farming, denial of future packaged WWTPs, denial of future feedlots, as well as institution and enforcement of stormwater volume controls.

Montgomery County has issued included statements calling for BMP implementation in several documents. Expansion of agricultural stream buffer programs to control NPS pollution and stronger incentives for the use of agricultural BMPs was cited by the 1993 Montgomery County Functional Master Plan for the Patuxent River Watershed prepared by M-NCPPC. The use of financial incentives to promote agricultural BMPs for cropland and animal waste management were cited as part of a "multi-barrier" approach in the 1995 "Developing a Patuxent Reservoir Protection Strategy: Interim Report of the Patuxent Reservoir Protection Group" prepared by the Montgomery County Department of Environmental Protection.

Although no reports reviewed for this report explicitly documented Howard County's position on agricultural stream buffers, given the county's other efforts to increase riparian buffers, it can be assumed that Howard County had similar intentions to expand agricultural stream buffers.

The 1996 Patuxent River Water Resources Reconnaissance Study prepared by USACE identified failing small-lot horse farm practices as a primary threat to reservoirs due to excessive nutrient loading. The 2003 Hawlings River WRAP cites agricultural BMPs as necessary for water quality improvement in the Hawlings River subwatershed.

The 2004 Patuxent Reservoirs SWA for WSSC Patuxent Water Filtration Plant report recommended implementation and monitoring of agricultural BMPs to gauge efficacy on the control of sediment, temperature, pathogens and nutrients (total and dissolved phosphorus). The Patuxent Riverkeeper's 2007 report (Patuxent River 20/20: The Need for Effective Action and Effective Solutions) suggested that State and local governments should provide adequate funding, technical assistance, and enforcement to ensure that farmers can and are implementing nutrient management plans (NMPs) on their farms to minimize polluted runoff.

One of the most recent documents dealing with agriculture and water quality also offers the most comprehensive reviews of agricultural resource protection programs and enforcement activities in the Patuxent River watershed. This 2007 NOAA report entitled "Managing Patuxent River Water Quality: Looking Beyond Science and Politics to the Economics of Decision-making" devotes a chapter to farm subsidies and green payment programs, cost-share and nutrient management programs, NMP enforcement and cost-share compliance. This document is discussed in greater detail below.

8.2 AGRICULTURE DERIVED SEDIMENT AND PHOSPHORUS

According to MDP 2007 land-use data, agriculture makes up approximately 32% of the acreage of the reservoirs watershed (Figure 5-2). Of that 32%, 80% is cropland and 18% is pasture, as can be seen in Figure 8-1. Montgomery County has the most land in agricultural use of any county in the Patuxent Reservoirs watershed with 79,000 acres, or approximately 25% of its land (NOAA 2007). Of this amount, 14,000 agricultural acres are in the Patuxent Reservoirs watershed portion of the county (NOAA 2007). Howard County has the highest percentage of land in agriculture, with its 49,000 acres comprising 31% of its total acreage (NOAA 2007). Prince George's County has the lowest percentage in agriculture, with only 13% of its total acreage in agriculture (NOAA 2007). Some recent documents have generated interesting analysis on the impact of agriculture in the greater Patuxent River watershed and the Patuxent Reservoirs watershed.

Analysis by the University of Maryland Center for Environmental Science (UMCES) for NOAA (NOAA 2007) demonstrated that while agriculture accounts for less than 0.5% of the economic output from the Patuxent River watershed as a whole, it accounts for over 30% of nutrient discharges into the Patuxent River. Chesapeake Bay-wide, agriculture accounts for 39% of nitrogen discharge and 46% of phosphorus discharge (NOAA 2007). Point sources, which include wastewater treatment plants (WWTPs), account for another 20% of discharges to the entire Patuxent River watershed, according to the Chesapeake Bay Program (NOAA 2007).

According to MDE estimates, agricultural runoff from crops and pasture is the primary source of phosphorus and sediment impairing the reservoirs, contributing 56% of total phosphorus and 57% of sediment to the Triadelphia Reservoir and 30% of phosphorus to the Rocky Gorge Reservoir, plus another 34% of phosphorus which originates from the Triadelphia Reservoir, of which half is also presumably of agricultural origins (MDE 2008). Agriculture is thus a critical and unavoidable topic in reservoir management. In both cases, the predominant agricultural input originates specifically from row crops, with additional contributions from pasture and animal waste, as can be seen in Figures 8-2 and 8-3.

The sediment TMDL developed for the Triadelphia Reservoir points to agriculture as a major contributor (MDE 2008). Figure 8-4 shows that row crops are responsible for 54% of the sediment load to the Triadelphia Reservoir and pasture is responsible for an additional 3%. In general, river basins in the Chesapeake Bay watershed with the highest percentage of agricultural land yield the highest overall amount of sediment each year (http://www.chesapeakebay.net/landuse_agriculture.aspx?menuitem=19551).

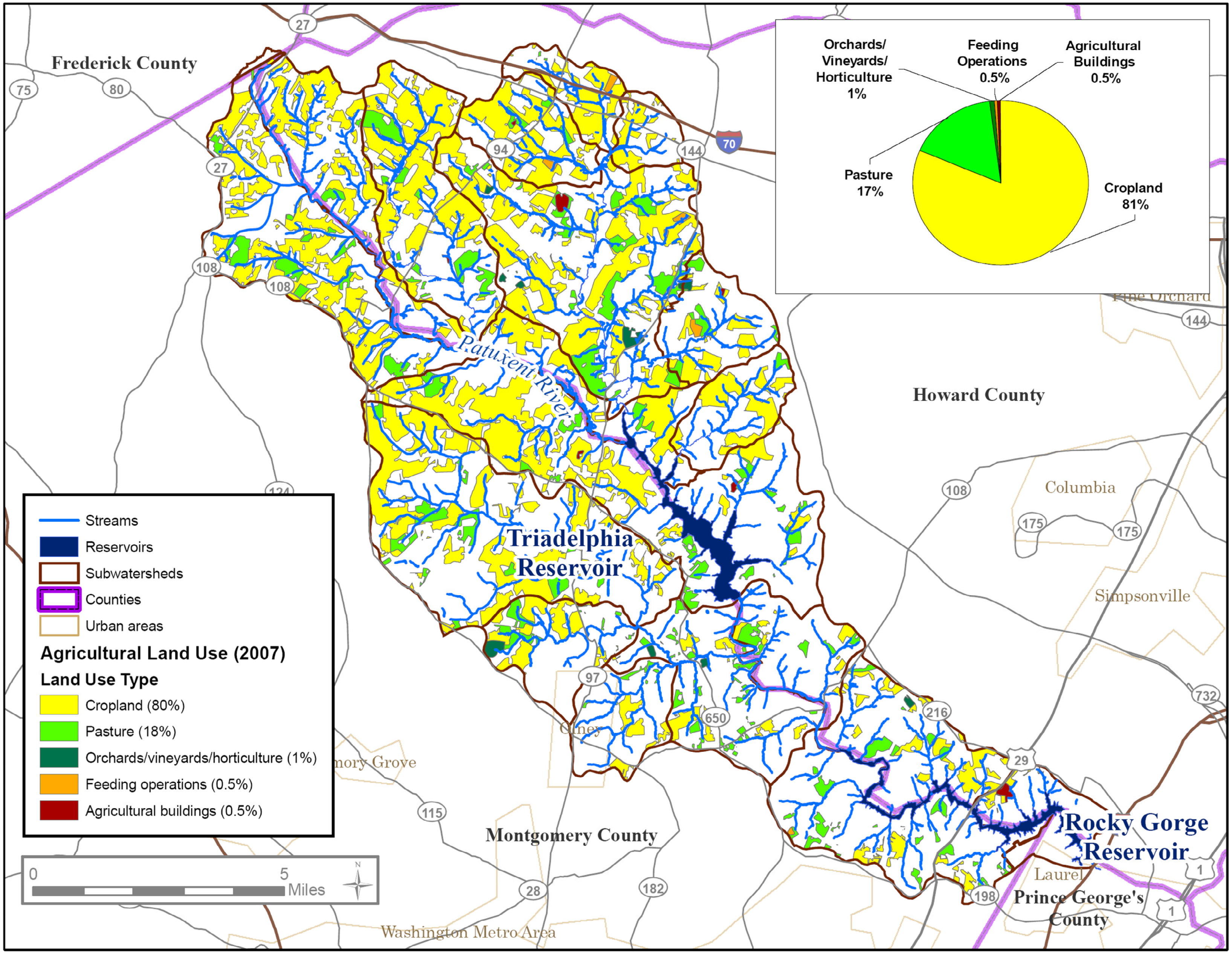


Figure 8-1. Agricultural land-use types in the Patuxent Reservoirs watershed, Maryland (Draft 2007 MDP land-use data).

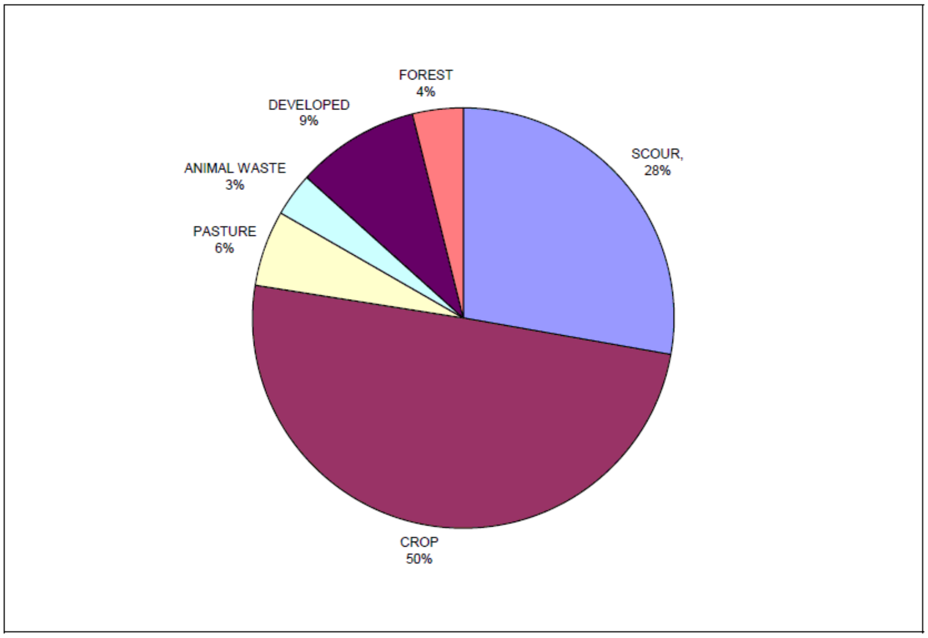


Figure 8-2. Modeled percent contribution of sources to Total Phosphorus loads to the Triadelphia Reservoir, Maryland (MDE 2008).

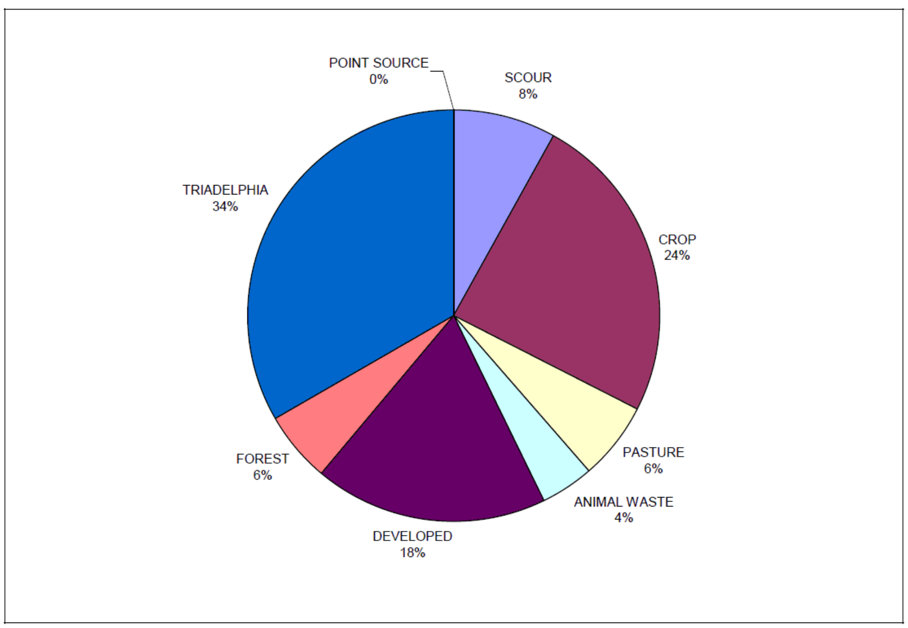


Figure 8-3. Modeled percent contribution of sources to Total Phosphorus loads to Rocky Gorge Reservoir, Maryland (MDE 2008).

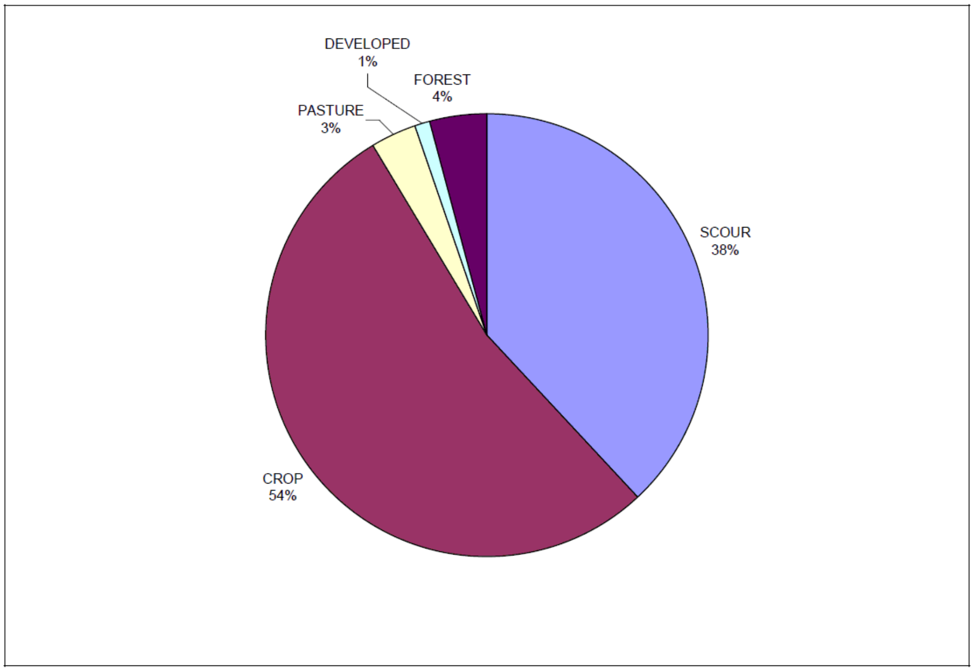
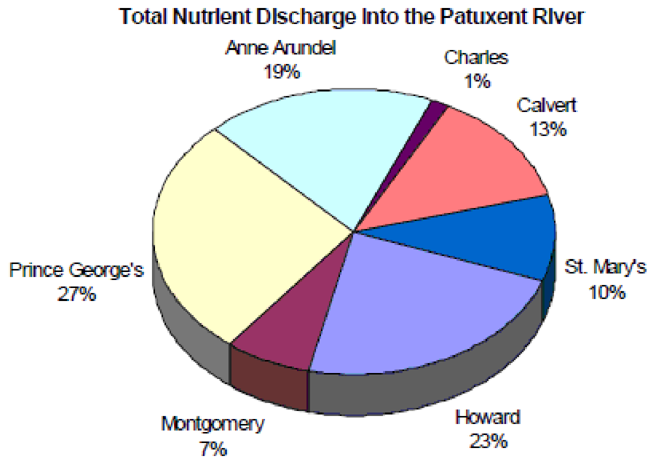


Figure 8-4. Modeled percent contribution of sources to sediment loads to the Triadelphia Reservoir, Maryland (MDE 2008).

Figures 8-5 and 8-6 show the geographic sources of "edge of stream" nutrient discharges to the greater Patuxent River as detailed in NOAA (2007) using data from the Chesapeake Bay Program from 2006. They provide a broader context for examining nutrient inputs to the entire Patuxent River.

According to NOAA (2007), "County discharges roughly correspond to the amount of acreage a county has in the watershed..." Figure 8-5 illustrates the total nutrient discharge by county as a percentage of total inputs. In terms of total pounds of N-equivalents (one pound of phosphorus = 5 nitrogen equivalents), if county discharges into the entire Patuxent River watershed roughly correspond to the amount of acreage a county has in the watershed, then we might assume that Montgomery (with approximately 39,300 acres in the Patuxent Reservoirs watershed) and Howard County (with approximately 44,800 acres in the watershed) are contributing roughly similar amounts of N-equivalents to the Patuxent Reservoirs.

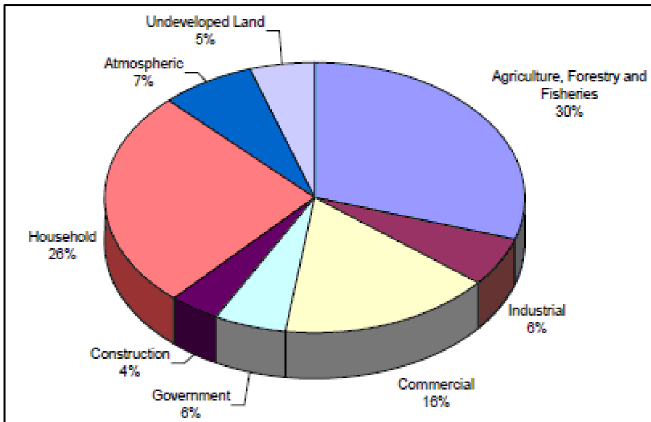
As relates to agriculture specifically, NOAA (2007) estimated that 30% of nutrient discharges to the entire Patuxent River watershed originate from agriculture, forestry and fisheries, as illustrated in Figure 8-6.



Total N-Equivalent Discharge into the Patuxent River (lbs.)	
Howard	1,952,457
Montgomery	598,372
Prince George's	2,304,495
Anne Arundel	1,582,774
Charles	126,693
Calvert	1,113,035
St. Mary's	815,408
TOTAL	**8,493,234**

Source: Chesapeake Bay Program Office, 2006

Figure 8-5. Percentage of nitrogen equivalents of discharge into the greater Patuxent River, Maryland, by county in 2006. (Original data source is Chesapeake Bay Program, figure taken from NOAA 2007)



Total Nutrient Discharge to Patuxent River by Sector (lbs.)	
Agriculture	2,536,842
Industrial	517,332
Commercial	1,373,655
Government	475,643
Construction	344,443
Household (sewer/septic)	2,215,836
Atmospheric	602,601
Undeveloped Land	426,883
TOTAL	**8,493,235**

Source: Chesapeake Bay Program Office, 2006

Figure 8-6. Total nutrient discharges (in pounds) to the greater Patuxent River, Maryland, by sector in 2006. (Original data source is Chesapeake Bay Program, figure taken from NOAA 2007)

The same report summarized data from the Chesapeake Bay Program which found that lowtill farming with manure application, specifically, was by far the greatest source of nutrients from Montgomery and Howard counties into the greater Patuxent River (Figure 8-7). Low till refers to an agricultural planting practice using a "planter" or "seed drill" - in which disturbance of the soil is kept to a minimum.

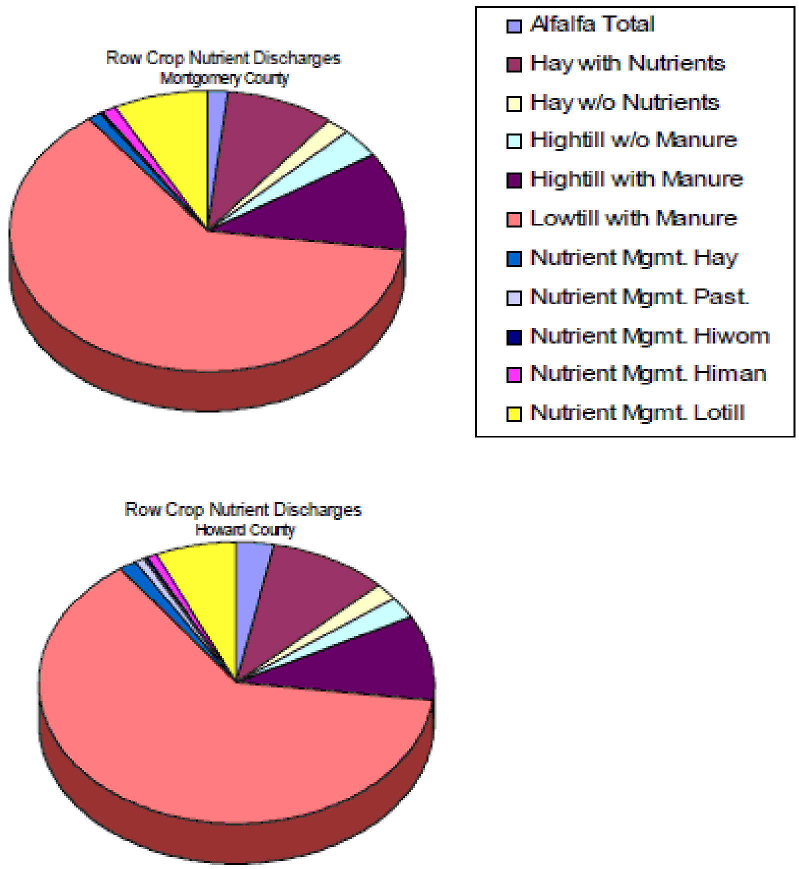


Figure 8-7. Row crop nutrient discharges into the greater Patuxent River from Montgomery County and Howard County, Maryland in 2006. Figures represent percentage of nutrient discharge from row crops in each county that is derived from land using the specified management practice. (Original data source is Chesapeake Bay Program, figure taken from NOAA 2007)

8.3 AGRICULTURE BMP PROGRAMS

The Patuxent Reservoirs watershed has several overlapping agricultural BMP implementation programs.

8.3.1 State-Wide Initiatives

According to the 1990 Patuxent River Watershed Technical Report for Montgomery County, at the time, 92% of farms were using BMP and conservation practices recommended by Montgomery County Soil and Water Conservation District.

8.3.1.1 Nutrient Management Plans

As of the end of 2002, the Maryland 1998 Water Quality Improvement Act required agricultural nutrient management plans (NMP) for nearly any agricultural operation with more than $2,500 gross annual income or eight animal units (8,000 pounds or more of live animal weight). The Act required that anyone operating a farm and using chemical fertilizer, sludge or animal manure must have had a nitrogen- and phosphorus-based plan by December 31, 2001, which needed to be implemented by December 31, 2002. Furthermore, in 2004, Maryland approved regulatory changes to the Act that require farmers to file specific information with MDA, starting in 2005.

> By March 1, 2005 farmers were required to file an Annual Implementation Report to describe how their NMP was implemented during the previous year. By March 1, 2005, farmers who had not submitted NMP information were required to submit a Nutrient Management Reporting Form and supporting documentation. By July 1, 2005, farmers who apply organic nutrient sources such as manure and biosolids were required to begin implementing a nitrogen and phosphorus NMP (NOAA 2007).

As of December 2005, MDA reported that 80% of Maryland's farmland was covered by NMPs. Compliance with NMP reporting requirements by SCDs, shown as the total of non-responsive operators in the county/district that filed NMPs is detailed in Table 8-1.

Table 8-1. Nutrient management plan compliance within the entire Patuxent River watershed, Maryland. Table taken from NOAA 2007.

	Non-responsive or justified delay as of 7/1/05	First NOV	Personal visits or telephone contact	Still not in compliance as of 6/30/06
Anne Arundel	48	48	47	21
Calvert	50	39	32	25
Charles	49	36	30	23
Howard	59	33	34	23
Montgomery	121	40	47	70
Prince George's	100	60	47	68
St. Mary's	104	32	17	87

NOV: Notice of Violation

Source: Maryland Department of Agriculture (2006)

According to NOAA (2007), "Data collected from MDA indicate that most of the enforcement activity in the Patuxent watershed during the first year of the new nutrient management plan reporting requirements has focused on the first stages of the enforcement process. First notices of violations have been sent to operators, but this varies considerably from [soil conservation] district to [soil conservation] district in the watershed."

8.3.1.2 Federal Farm Subsidy and Green Payment Programs

Agricultural resource protection programs analyzed in the NOAA (2007) report include the Federal Farm Subsidy Program and the Green Payment Program, that provide cost-sharing assistance or other economic incentives to farmers to encourage them to adopt management strategies that improve the environment.

According to NOAA (2007) "Montgomery County, by far, leads the watershed in the amount of fixed Federal agricultural subsidies provided to farmers in its district, with 76 eligible recipients receiving a total of $551,317 in the 2005 planting year. St. Mary's County received the second highest amount, with 197 eligible recipients receiving a total of $305,604. Calvert (40 recipients; $92,899) and Prince George's (41 recipients; $95,433) received the least amount of fixed Federal farm subsidies (source: Environmental Working Group)."

Specific programs include the federal Environmental Quality Improvement Program (**EQIP**), which provides cost-share grants to protect natural resources on cropland, forested lands, and grazing lands, to construct animal waste facilities and to obtain nutrient management services. EQIP-obligated dollars are indicated below in Table 8-2 by county.

Table 8-2 Environmental Quality Incentives Program (EQIP) dollars obligated by counties in the Patuxent River Watershed for 2005. Table taken from NOAA 2007.

County	Number of Contracts	Cost Share Obligated
Anne Arundel	33	$ 493,986
Calvert	13	144,664
Charles	26	200,100
Howard	9	173,047
Montgomery	37	143,358
Prince Georges	17	34,963
St. Mary's	8	122,041

Source: U.S. Department of Agriculture (See Post, 2006)

The Maryland Agricultural Cost Share (**MACS**) Program which provides assistance for implementation of a range of BMPs including cover crops, streamside buffers, animal waste systems, manure transport programs, NMPs, and participation in the Federal/State Conservation Reserve Enhancement Program (**CREP**) to remove environmentally sensitive cropland from production.

NOAA (2007) examined 2005 MACS data to provide examples of farm participation levels by County. "For MACS capital programs, Montgomery County leads Patuxent River counties with a total of $122,566 in cost-share for 8 participating farms, about twice the level of cost-share as Charles County, which is second at $64,492; although Charles County has a greater number of participating farms (13). Anne Arundel had just one project with a $692 cost share. Montgomery also leads the Patuxent River watershed in cost share funds for cover crops, with $60,939 for 2,031 cover crop acres on 14 farms. Howard had the least amount of cover crop cost share, with $3,123 for 104 acres on two farms." (NOAA 2007)

Note that the Maryland Agricultural Water Quality Cost-Share Program MACS 2006 Annual Report and 2007 Annual Report indicate more cover crop cost-share projects completed from 2005-2007. Howard County completed 166 acres of cover crops on 4 farms with a total payment of $6,355 in the winter of 2005/2006, and 853 acres on 10 farms with a total payment of $19,716 (MDA 2006). However, the MACS Annual Reports do not distinguish between the Patapsco and Patuxent watersheds. In addition, some farmers voluntarily use cover crops and other BMPs, which are not accounted for in these Annual Reports (K. McCormick, Howard County Soil Conservation District, pers. comm. 2009).

According NOAA (2007) there have been no CREP retired environmentally-sensitive lands in Montgomery County or Prince George's County and a very small amount of land has been set aside in Howard County.

In the case of MACS, "soil conservation managers play an important role in helping famers participate in this program, although MDA is responsible for MACS compliance inspections" (NOAA 2007). MDA is responsible for compliance enforcement for MACS. In 2005, 100% of scheduled spot checks (10% of all participating farms) by MDA for compliance with MACS were performed. The question raised by NOAA (2007) is whether this 10% is enough to guarantee the success of MACS.

8.3.2 TAC Agriculture Initiatives

The TAC member agencies administer a reservoir cost-share program, more formally known as the Agricultural Management Local Cost Share Initiative. The reservoir cost-share program pools funding from WSSC, the Howard Soil Conservation District (HSCD), and the Montgomery County Soil Conservation District (MSCD) to provide cost-share funds for agricultural landowners to implement streamside best management practices (2006 TAC Annual Report). According to the 2006 TAC Annual Report, the cost-share program supports protection of all priority resources by improving habitat and water quality, and by supporting the economic health of the farming community (Figure 8-8).

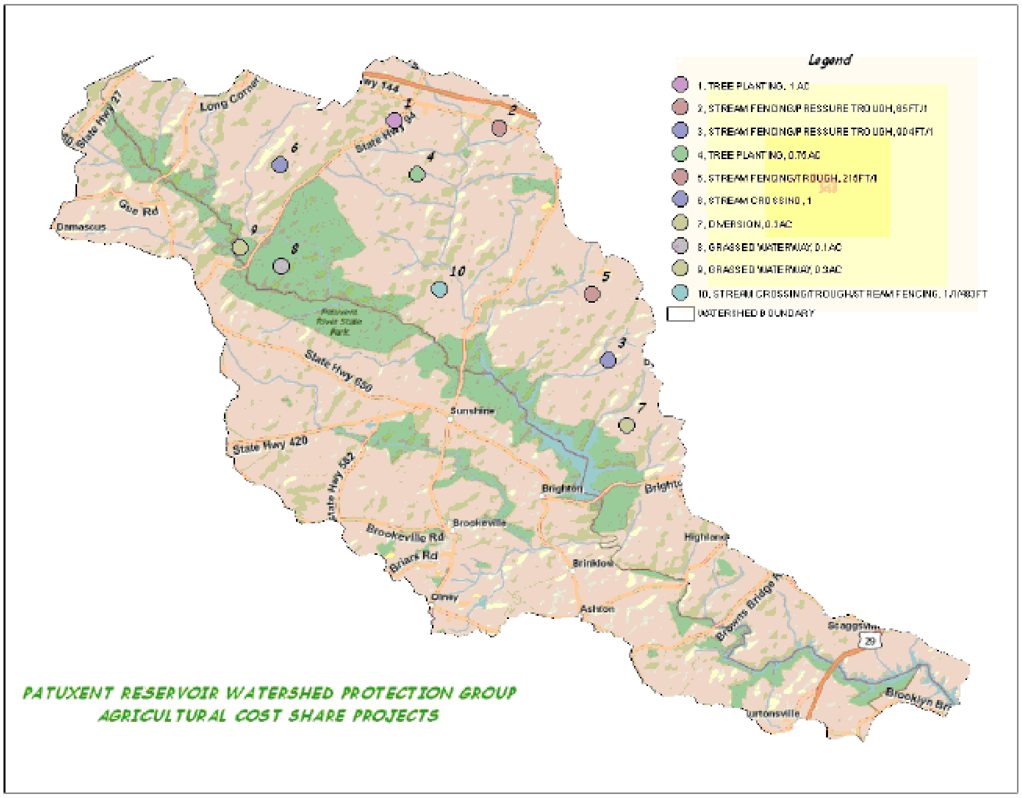


Figure 8-8. Location and summary of reservoir cost-share projects in the Patuxent Reservoirs watershed as of 2007. From TAC 2007 Supplement to 2007 Annual Report.

According to the 2008 TAC Annual Report, both the Montgomery County Soil Conservation District (SCD) and the Howard County SCD have determined that horse farming operations seem to be the best potential fit for the reservoir cost-share program. The cost-share program has good applicability to horse farms and other smaller operations since it has fewer administrative requirements than do other programs (TAC Annual Report 2005).

Along with a contractor, both SCDs have been working to expand the cost-share program to equine operations. Through a grant from the Chesapeake Bay Trust (CBT), the two SCDs collaborated on a joint survey to 2,047 landowners in the Patuxent Reservoirs watershed, targeting owners of small horse farms. The threshold was 7 or fewer horses per landowner in Montgomery County and 3 acres or smaller in Howard County (K. McCormick, Howard County SCD, pers. comm. 2009). According to the TAC (2008), the contacts and data compiled from this survey "will be used to create future funding opportunities and develop strategies for delivering technical and cost-share assistance to this underserved group". The CBT also funded the development of a newsletter to be sent to equine owners in the Triadelphia Reservoir watershed from the Howard County SCD. Montgomery County SCD already has such a newsletter and MDA has also provided an Equine Specialist to serve Howard, Frederick and Carroll counties.

For the purposes of the Chesapeake Bay Stewardship Fund Innovative Nutrient and Sediment Reduction Project pre-proposal, the TAC had estimated that in the Howard County portions of the watershed, implementation of BMPs for horse farms of 7 horses or less could remove 11,573 pounds of nitrogen per year (5.8 tons/yr) and achieve phosphorus removal of 2,250 pounds per year (1.13 tons/yr). In the Montgomery County portions of the watershed, the estimates were that implementation of the same manure management BMPs could remove 7,122 pounds of nitrogen per year and achieve phosphorus removal of 1,305 pounds per year (TAC Supplement to 2008 Annual Report).

Each year, in its Annual Report, the TAC summarizes progress made in agricultural BMPs within the Reservoirs watershed by the Howard County and Montgomery County Soil Conservation Districts. The latest version is shown here (Table 8-3)

In addition, according to the 2008 TAC Annual Report, MDA has given each county $10,000 to use toward cost sharing with operations that fall outside of the traditional MACS and EQIP programs. According to Howard County SCD, MDA received a grant from the National Fish and Wildlife Foundation for this $10,000 and then allotted it to counties for small equine operations and limited BMPs. This same grant helped fund the Equine Specialists positions.

Table 8-3. Patuxent Reservoirs Watershed Agricultural BMPs Progress during 2008 (Technical Advisory Committee Annual Report 2008).

Practice	Howard SCD*	Montgomery SCD
Conservation Plans developed	8 (705.2)	6 (250.7 ac)
Conservation Plans Revised	8 (738.7)	3 (313.2 ac)
Landowners Contacted or Requesting information	34	0
Landowners Applying BMPs	14	10
BMPs Installed	47	140
Cover Crop	13 (824.1 ac)	1361 ac.
Conservation Tillage	1 (10.3 ac)	350.9
Grassed Waterways	2 (3.8 ac)	0
Diversion	2 (600 ft)	0
Fencing	3 (6000 ft)	1 (2600 ft.)
Filter Strip	0	2
Grade Stabilization Structure	2 (4 ea)	0
Heavy Use Area (HUA)	0	1165 ac
Nutrient Management	2 (20.5 ac)	377.5 ac
Pest Management	4 (797 ac)	0
Roof Runoff	2 (2 ea)	0
Stream Crossing	0	0
Trough	2 (4 ea)	0
Waste Storage Structure	1 (1 ea)	2
New Cost Share Agreements	1	0
Cost Share Agreements Completed	1	1
Pipeline	2 (482 ft)	0
Ag Chemical Facility	0	0
Subsurface Drainage	0	0
Educational/Outreach Events	2	4
Lined Waterway	0	0
Spring Development	1 (1 ea)	1
Wildlife Upland Habitat Management	0	77.5 ac
Pasture / Hayland Planting	1 (14 ac)	0
Pond	1 (1 ea)	0

* Numbers provided are only projects within the Patuxent Reservoirs Watershed portion of Howard

9.0 BIOLOGICAL ASSESSMENTS OF STREAM CONDITION

9.1 INDEX OF BIOTIC INTEGRITY

The Index of Biotic Integrity (IBI) is a stream assessment tool that evaluates biological integrity based on characteristics of the fish or benthic macroinvertebrate assemblage at a site. Biological integrity is defined as the ability to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region (Karr and Dudley 1981 as cited in Karr 1991, Versar 1999). To develop an IBI, reference sites are selected to represent regional natural habitats, also referred to as "minimally impacted" conditions. Reference conditions should not be viewed as completely natural or pristine. They are, however, a representative sample of the best streams that currently exist. Benthic macroinvertebrate and fish communities, as assessed by the IBI, can serve as useful indicators of stream degradation associated with urbanization, poor water quality, habitat degradation, streamflow variability, and other stressors.

In Maryland, a good framework for interpretation of biological data is provided by the Maryland Biological Stream Survey (MBSS), a program of the state's DNR. MBSS has established reference sites and IBIs for assessing biological condition of the state's freshwater, non-tidal streams using fish and benthic macroinvertebrate data. Reference sites were used to establish appropriate expectations within a region, based on minimally impacted sites. The IBIs can be used to assess conditions and set appropriate management goals.

9.2 MARYLAND BIOLOGICAL STREAM SURVEY

Begun in the mid-1990s, the MBSS is a statewide stream sampling program based on a probability-based or random sampling design intended to provide unbiased estimates of stream conditions with known precision at various spatial scales. Fish and benthic IBIs were developed for the MBSS by Versar (for detailed methods, see Southerland et al. 2005a). IBI scores for the MBSS are determined by comparing the fish or benthic assemblages at each site to those found at minimally impacted reference sites. Site-specific IBI results are used to estimate the extent of non-tidal streams in good, fair, poor, and very poor condition with respect to the biotic integrity of the fish or benthic community. The IBI rating scale is as follows:

- Good: 4.0 - 5.0
- Fair: 3.0 - 3.9
- Poor: 2.0 - 2.9
- Very Poor: 1.0 - 1.9

Figures 9-1 and 9-2 show MBSS IBI scores for sites in the Patuxent Reservoirs watershed, sampled from 1995-2008, with scores computed for both benthic macroinvertebrate

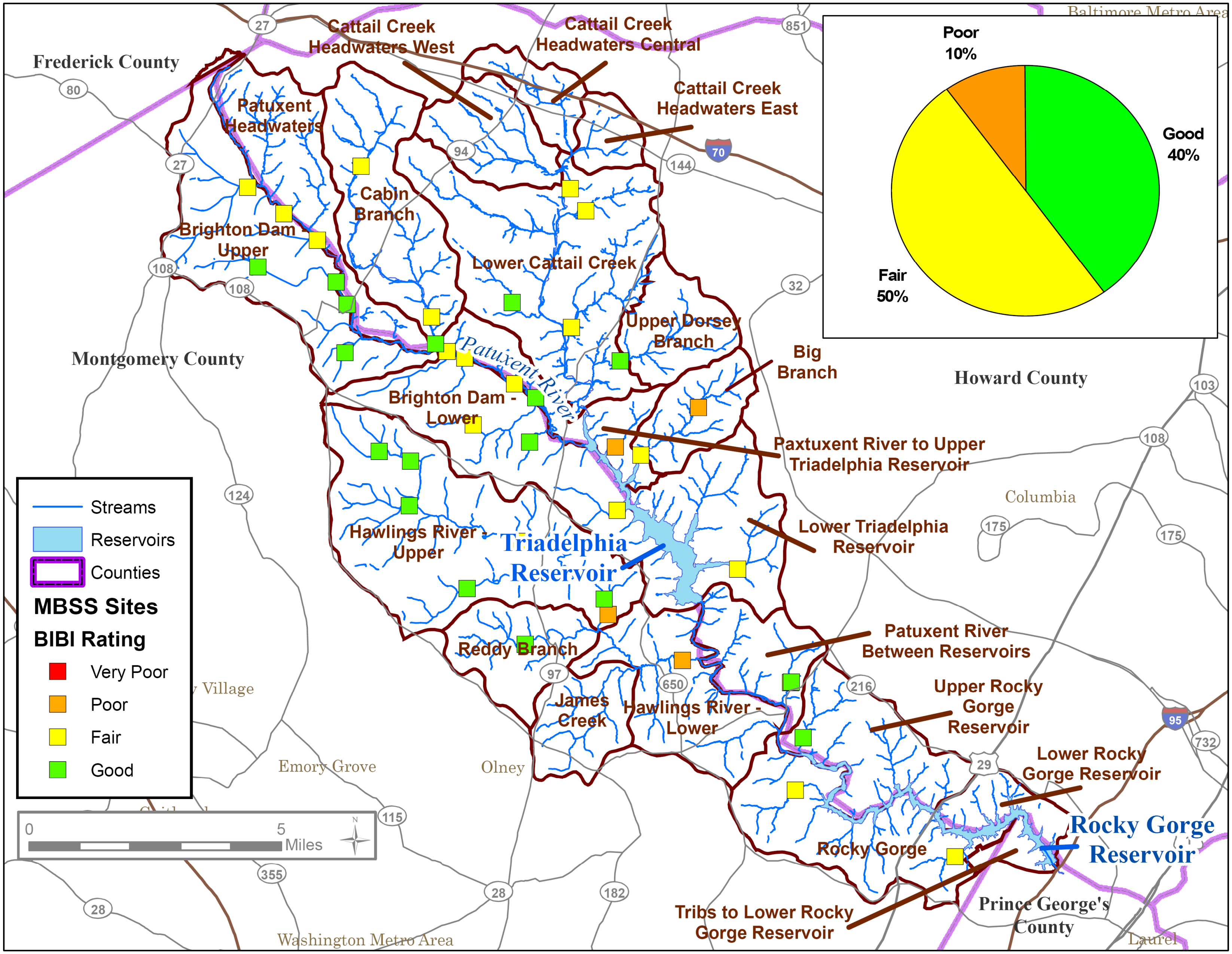


Figure 9-1. Benthic Index of Invertebrate Biotic Integrity (BIBI) scores in Patuxent Reservoirs watershed, Maryland. 1995-2008 MBSS sampling.

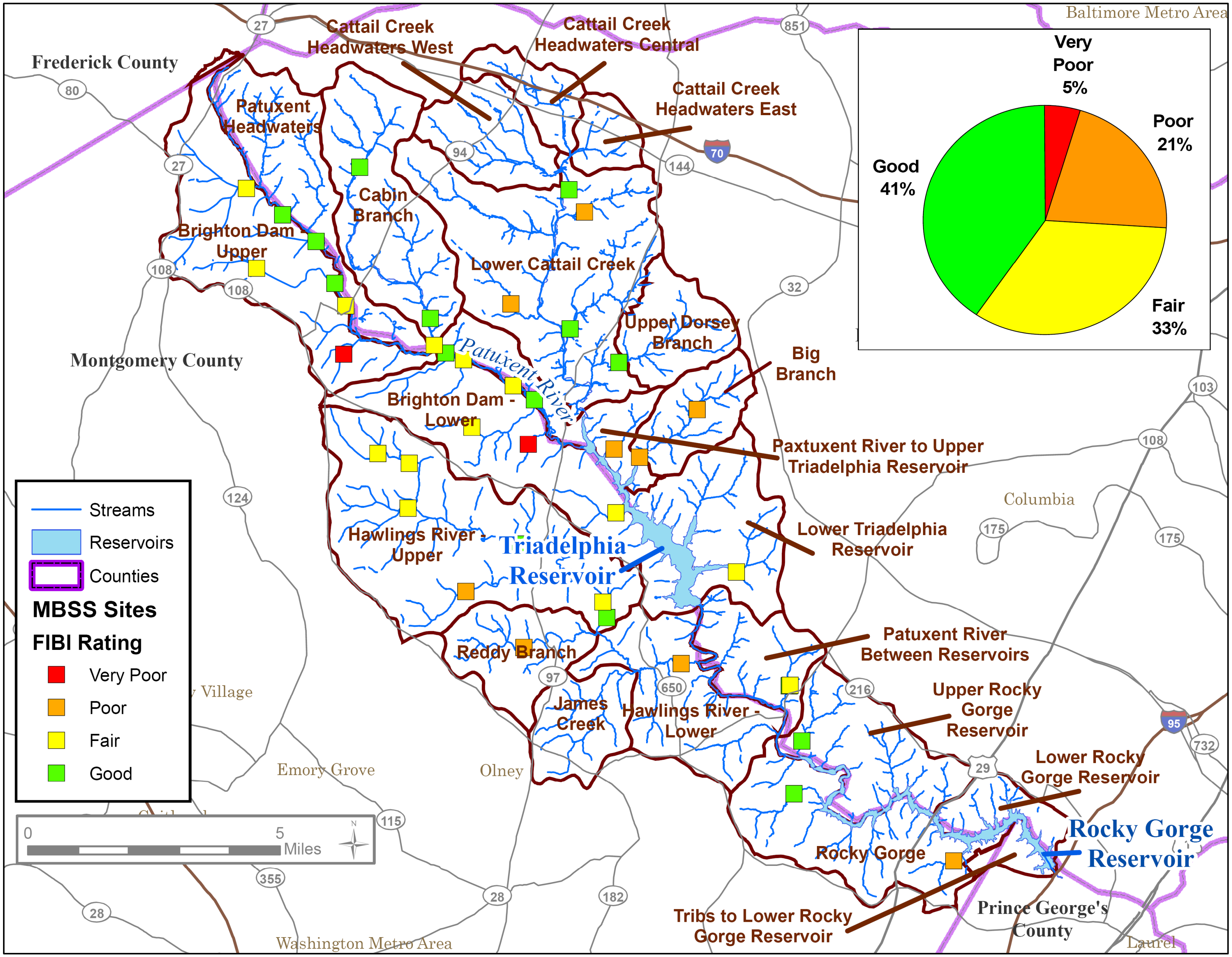


Figure 9-2. Fish Index of Biotic Integrity (FIBI) scores in Patuxent Reservoirs watershed, Maryland. 1995-2008 MBSS sampling.

and fish assemblages. Figure 9-1 shows that stream benthic invertebrate assemblages in the Patuxent Reservoirs watershed were categorized as in "good" condition in 40% of locations sampled, while 50% were rated as "fair", 10% were rated "poor", and none were rated "very poor."

With respect to the fish IBI (Figure 9-2), 41% were rated as good in the sampling period, 33% were fair, 21% poor and 5% were rated as very poor (one tributary in Brighton Dam Lower subwatershed and another in Brighton Dam Upper subwatershed).

These results indicate that overall, the streams of the Patuxent Reservoirs are in far better biological condition than the statewide average. For example, 2000-2004 MBSS results (Southerland et al. 2005b) yielded statewide estimates of 51% of stream miles rated as good to fair for fish IBI and 54% of stream miles in good to fair benthic condition.

9.3 MONTGOMERY COUNTY BIOLOGICAL MONITORING

Montgomery County conducts its own biological monitoring program to gauge stream ecosystem health, using sampling methods and an IBI rating scale consistent with the MBSS. Figure 9-3 shows the location and scores generated for benthic invertebrate assemblages in Montgomery County from 1995-2007. The majority of locations show the streams to be rated as "fair" (15%), "good" (48%) or "excellent" (31%), with only 6% rated as "poor."

9.4 HOWARD COUNTY BIOLOGICAL MONITORING

Howard County also conducts a biological monitoring program that is consistent and comparable with MBSS, employing the same sampling methods and benthic IBI. Sampling has included areas of Howard County within the Patuxent Reservoirs watershed (Note: subwatershed names used by the biological monitoring program, as reported in this section, are slightly different from those used elsewhere in this report). During the first round, Cattail Creek and the Upper and Lower Brighton Dam subwatersheds were sampled in 2001, and Rocky Gorge watershed was sampled in 2003. In 2005, Howard County began its second round of biomonitoring, conducting sampling again in Cattail Creek and the Upper and Lower Brighton Dam watersheds.

Benthic IBI results are scored with the same scale as MBSS. Habitat assessment results are scored using the following scale, with total habitat scores expressed as a percentage of the maximum possible score:

- Comparable: Capable of maintaining biological conditions similar to reference streams, > 90.0%

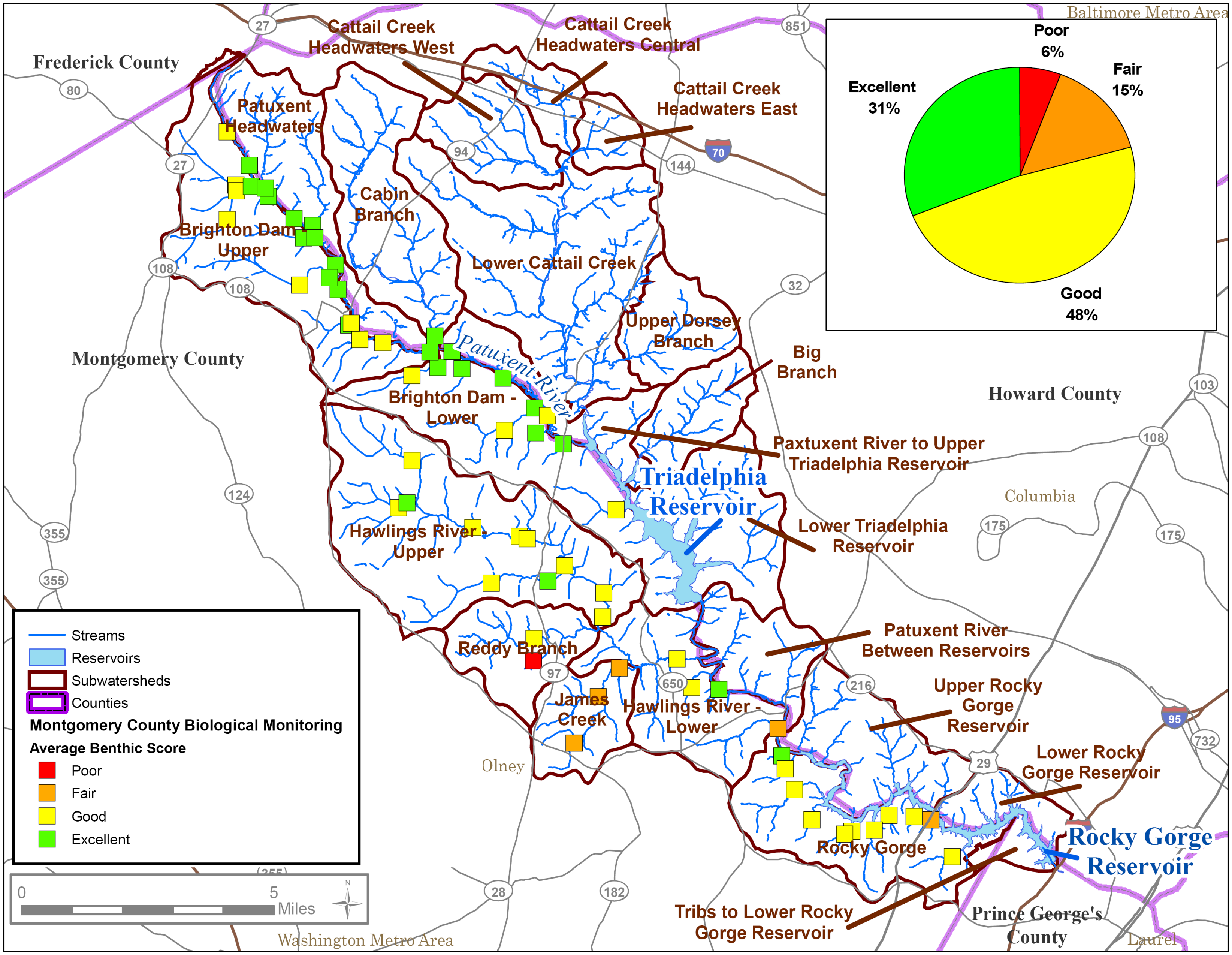


Figure 9-3. Montgomery County, Maryland, Benthic Index of Biotic Integrity scores by sampling location for sampling years 1995-2007.

- Supporting: Habitat of somewhat reduced condition, but often can support reference quality biology, 75.1 - 89.9%
- Partially Supporting: Capable of supporting biological conditions of lower quality than reference conditions, 60.1 - 75.0%
- Non-Supporting: Not able to maintain healthy biological conditions, < 60.0%

Key benthic and habitat assessment results for the Patuxent Reservoirs subwatersheds are summarized in Table 9-1. For individual sites sampled within the Patuxent Reservoirs watershed during 2001 to 2008, benthic IBI scores ranged from good to poor (Figure 9-4).

Round One results comparing all 15 Howard County subwatersheds were summarized by Pavlik and Stribling (2005). Of the 15 subwatersheds, the highest mean benthic IBI scores were observed in Upper Brighton Dam (3.82) and Cattail Creek (3.60). Lower Brighton Dam and Rocky Gorge also had mean benthic scores higher than the Howard County average.

Within the Patuxent Reservoirs subwatersheds, mean habitat scores have fallen above or near the countywide Round One average, with ratings in the "Partially Supporting" and "Non-Supporting" categories (Table 9-1). Across all Howard County watersheds, habitat results have generally indicated higher quality habitat in the western part of the County, and more degraded habitat in the eastern portion. Sites have spanned a range of land cover types across the County, from rural agriculture uses in the western portion, to quickly growing suburban/commercial uses in the east.

Table 9-1. Summary of Howard County benthic and habitat scores and ratings by subwatershed, for areas sampled within Patuxent Reservoirs watershed

Subwatershed	Year	Mean BIBI Score	Mean BIBI Rating	Mean Habitat Score	% of Maximum	Mean Habitat Rating
Round One[a]						
Cattail Creek	2001	3.6	Fair	107.2	53.6	Non-Supporting
Lower Brighton Dam	2001	3.49	Fair	109.8	54.9	Non-Supporting
Upper Brighton Dam	2001	3.82	Fair	121.3	60.7	Partially Supporting
Rocky Gorge	2003	3.29	Fair	114.3	57.2	Non-Supporting
Howard County Mean	2001-2003	2.99	Poor	111.9	55.9	Non-Supporting
Round Two[b]						
Cattail Creek	2005	4.0	Good	115.8	57.9	Non-Supporting
Lower Brighton Dam	2005	4.41	Good	132.0	66.0	Partially Supporting
Upper Brighton Dam	2005	4.04	Good	133.5	66.8	Partially Supporting

[a]Data from Round One summary in Pavlik and Stribling 2005
[b]Data from Gallardo et al. 2006

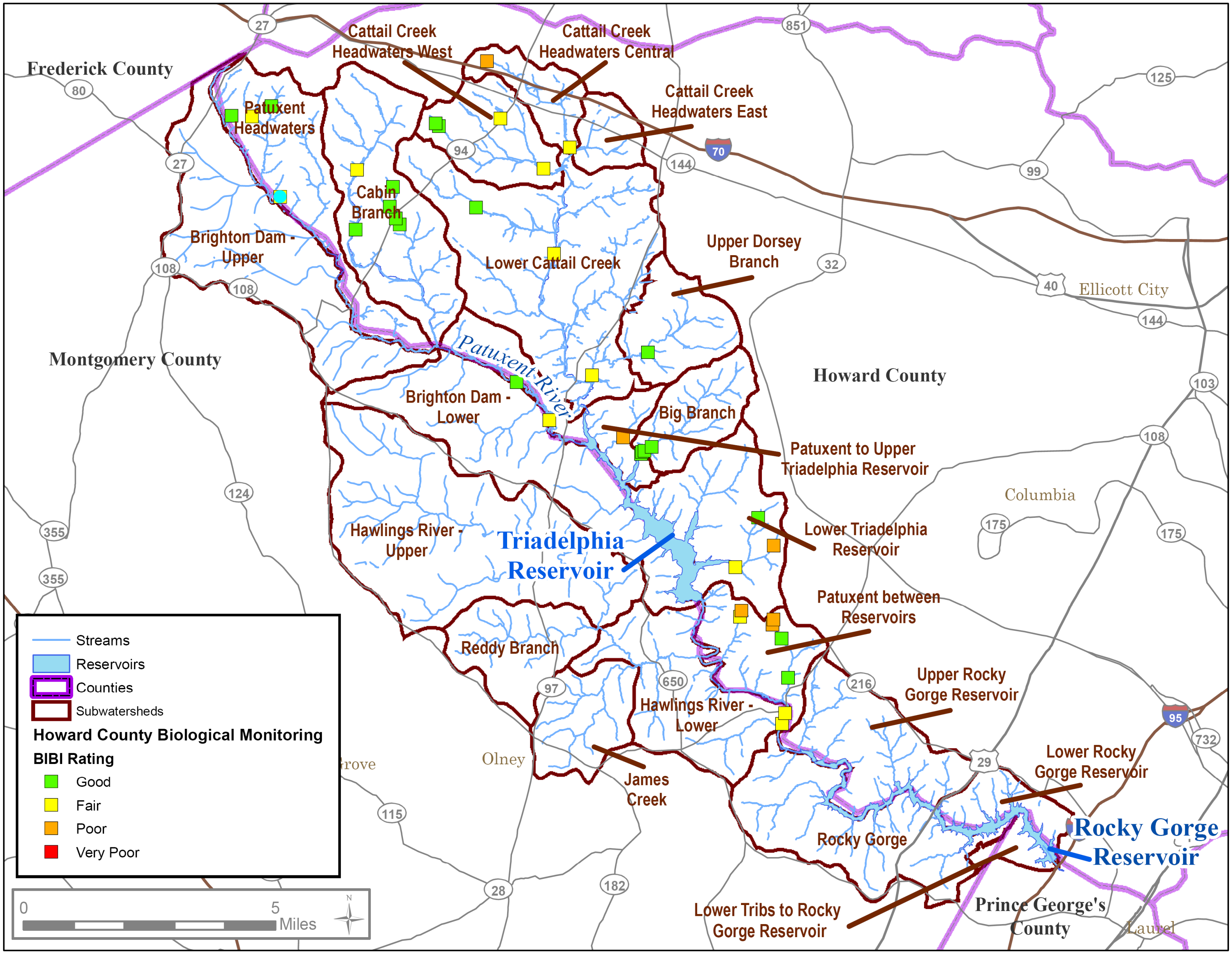


Figure 9-4. Benthic IBI scores for sites sampled within Patuxent Reservoirs watershed by the Howard County Biomonitoring Program, 2001-2008. (Data provided by Howard County Stormwater Management Division)

Individual site results from Howard County biomonitoring (from Pavlik and Stribling 2001, 2003, and Gallardo et al. 2006) include the following:

- *Cattail Creek, Upper and Lower Brighton Dam Subwatersheds - 2001*

  - Cattail Creek: Of the ten sites sampled, seven were rated as "non-supporting" for physical habitat quality, and the other three sites received a "partially supporting" rating. Three sites received "good" biological condition ratings, six rated as "fair" and one received a "poor" rating.

  - Lower Brighton Dam: Seven of the ten sites were rated as "non-supporting." The other three received "partially supporting" physical habitat ratings. Overall biological condition was rated as "fair". Two sites were rated as "good", five sites rated as "fair" and the remaining three sites received "poor" ratings.

  - Upper Brighton Dam: Six individual sites were rated "partially supporting." The remaining four rated as "non-supporting". For benthic indicators, three of the ten sites received "good" ratings, six rated as "fair" and one received a "poor" rating.

- *Rocky Gorge Subwatershed - 2003*

  - Two sites rated "good", four sites rated "fair", and four sites rated in "poor" biological condition. Of the 10 sites sampled, 50% were "partially supporting" and the other 50% were rated as "non-supporting". Correlation between physical habitat quality and biological condition had a very low r-value (r = 0.12), suggesting that stressors other than habitat are having a substantial effect on overall biological condition in this subwatershed.

- *Cattail Creek, Upper and Lower Brighton Dam Subwatersheds – 2005*

  - Cattail Creek: Seven of ten sites were rated as "non-supporting" for physical habitat quality, two "partially supporting", and one "supporting". Four sites received a "good" biological condition rating, five rated as "fair", and one received a "poor" rating.

  - Lower Brighton Dam: Of the ten sites sampled, four were rated as "non-supporting" for physical habitat quality, four "partially supporting", and two "supporting". Eight sites received a "good" biological condition rating and two were rated as "fair".

  - Upper Brighton Dam: Of the ten sites sampled, three were rated as "non-supporting" for physical habitat quality, six sites as "partially supporting", and the remaining site was rated as "supporting". Seven sites received a "good" biological condition rating and three received a "fair" rating.

9.5 HIGH QUALITY (TIER II) SURFACE WATERS IN HOWARD AND MONTGOMERY COUNTY

The Patuxent Reservoirs watershed includes four Tier II designated waters. Three Tier II streams in Howard County and one in Montgomery County can be seen in Figure 9-5. Tier II waters are selected by MDE and represent high quality streams (Section 3.2.1). These areas would be high priority locations for protection. All of Maryland’s current Tier II waters were designated on the basis of indices of biological integrity (MDE 2006).

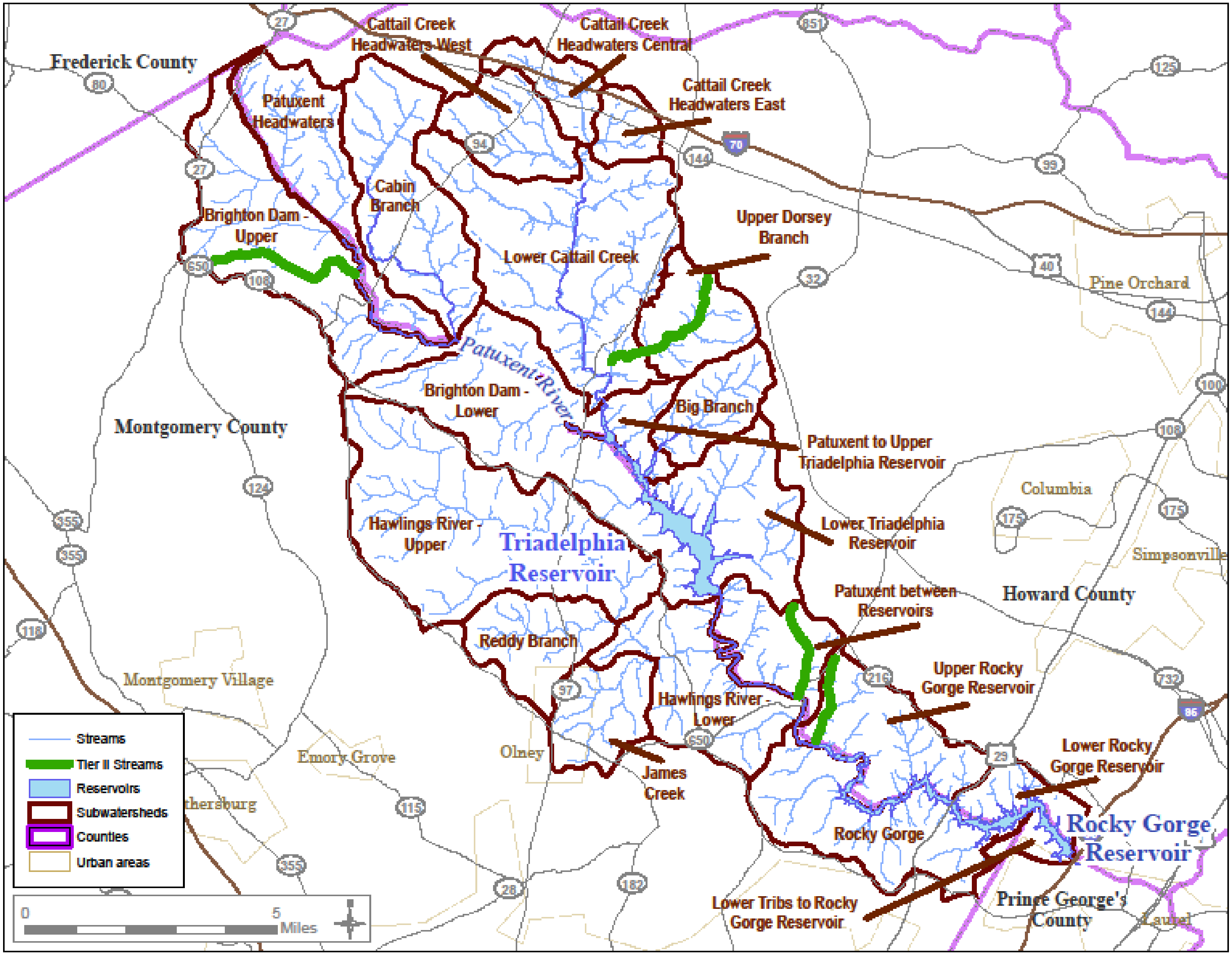


Figure 9-5. Tier II stream segments in the Patuxent Reservoirs watershed, Maryland (MDE 2008 data).

10.0 THE ROLE OF SEPTIC SYSTEMS

10.1 STATE-WIDE PERSPECTIVE

Roughly 420,000 septic systems exist in the State of Maryland, serving a population roughly two times the size of the population of Baltimore City and processing 100 million gallons of sewage and wastewater daily. These septic systems are the largest source of wastewater into the ground in the state. (MDE DVD "Onsite Sewage Disposal Systems," 2005)

Fifty percent of the Chesapeake Bay's water comes from groundwater and 75% of nitrogen entering the Chesapeake Bay comes from groundwater contaminated with nitrogen from septic systems and agricultural fields. Septic systems contribute 9 pounds per person per year of nitrogen compared to only 2 pounds per person per year of nitrogen for centralized wastewater treatment facilities. (MDE DVD "Onsite Sewage Disposal Systems").

10.2 SEPTIC SYSTEMS IN THE PATUXENT RESERVOIRS WATERSHED

There are no "major" WWTPs (greater than 0.5 million gallons per day, MGD, design flow) in the reservoirs' watersheds. (DNR 2007) There are no WWTPs of any size contributing phosphorus or sediment loads in the Triadelphia Reservoir watershed. The Federal Emergency Management Agency (FEMA) WWTP is the only WWTP contributing phosphorus (182 pounds per year of total phosphorus) and is located in the Rocky Gorge Reservoir watershed. (MDE Point Source Tech Memo 2008) The majority of land in the low-density, agricultural Patuxent Reservoirs watershed is not served by sewers nor is service planned, as noted in Figure 10-1, with the exception of areas in Reddy Branch and James Creek in Montgomery County.

Within the Patuxent Reservoirs watershed, the last estimate of septic systems made in 1997 for WSSC concluded that roughly 6619 septic systems were present in the watershed (GMB Architects and Engineers, Inc. 1997). That same report predicted an almost doubling of septic systems by 2010 to 12,000. The latest data provided by MDE shows an increase to 10,887 systems, 5079 in Howard County and 5808 in Montgomery County. Table 10-1 breaks down locations of septic systems by county and subwatershed using 1997 and 2008 data. Figure 10-2 below shows the location of 10,877 on-site septic systems in addition to planned sewer service areas, as defined by Montgomery and Howard Counties.

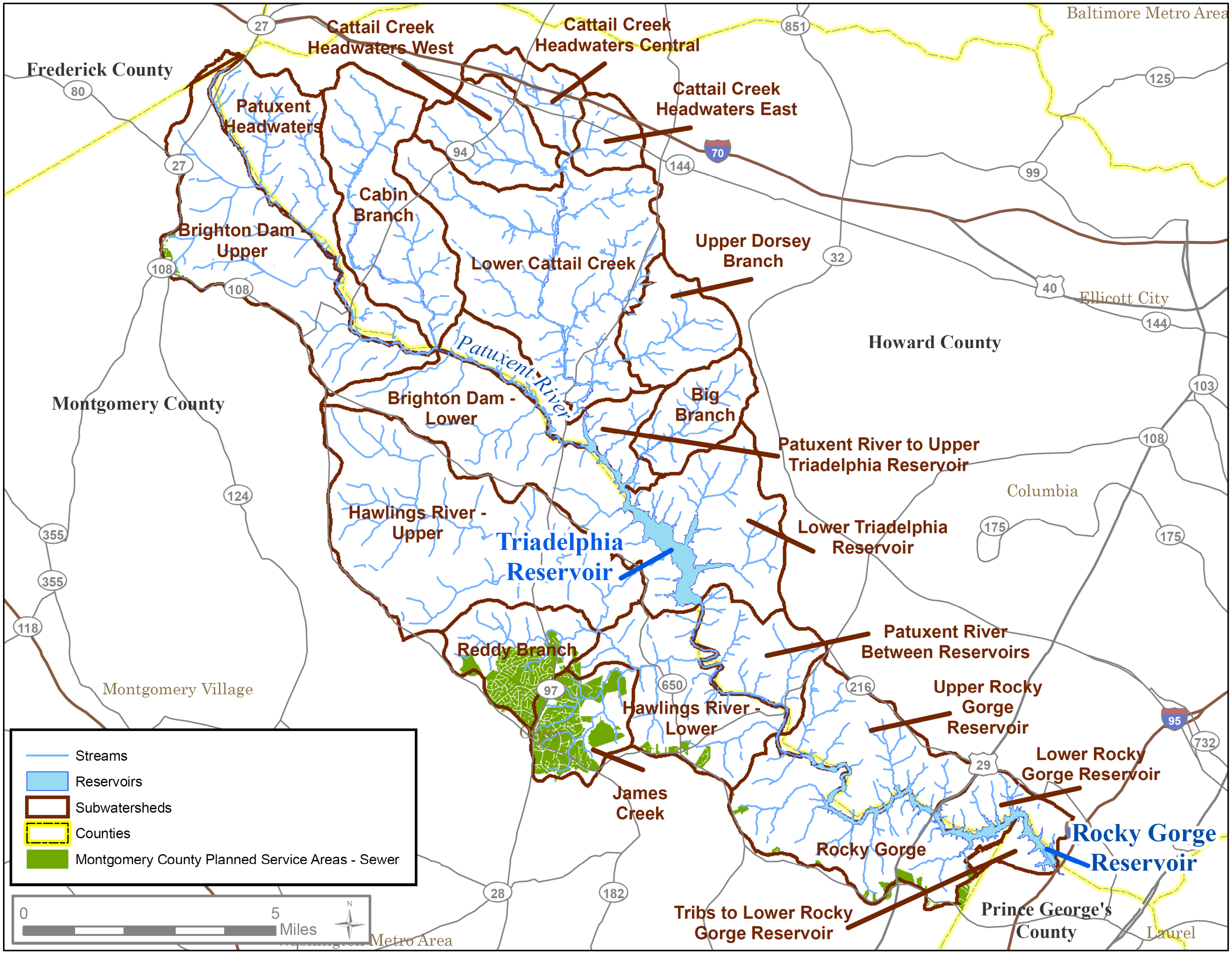


Figure 10-1. Planned sanitary sewer systems in and around the Patuxent Reservoirs watershed, Maryland (Howard and Montgomery Counties 2008 data). Note that there is no sewer service currently planned for the Howard County portion of Patuxent Reservoir watershed, according to the Resource Conservation Division of the Howard County Department of Planning and Zoning.

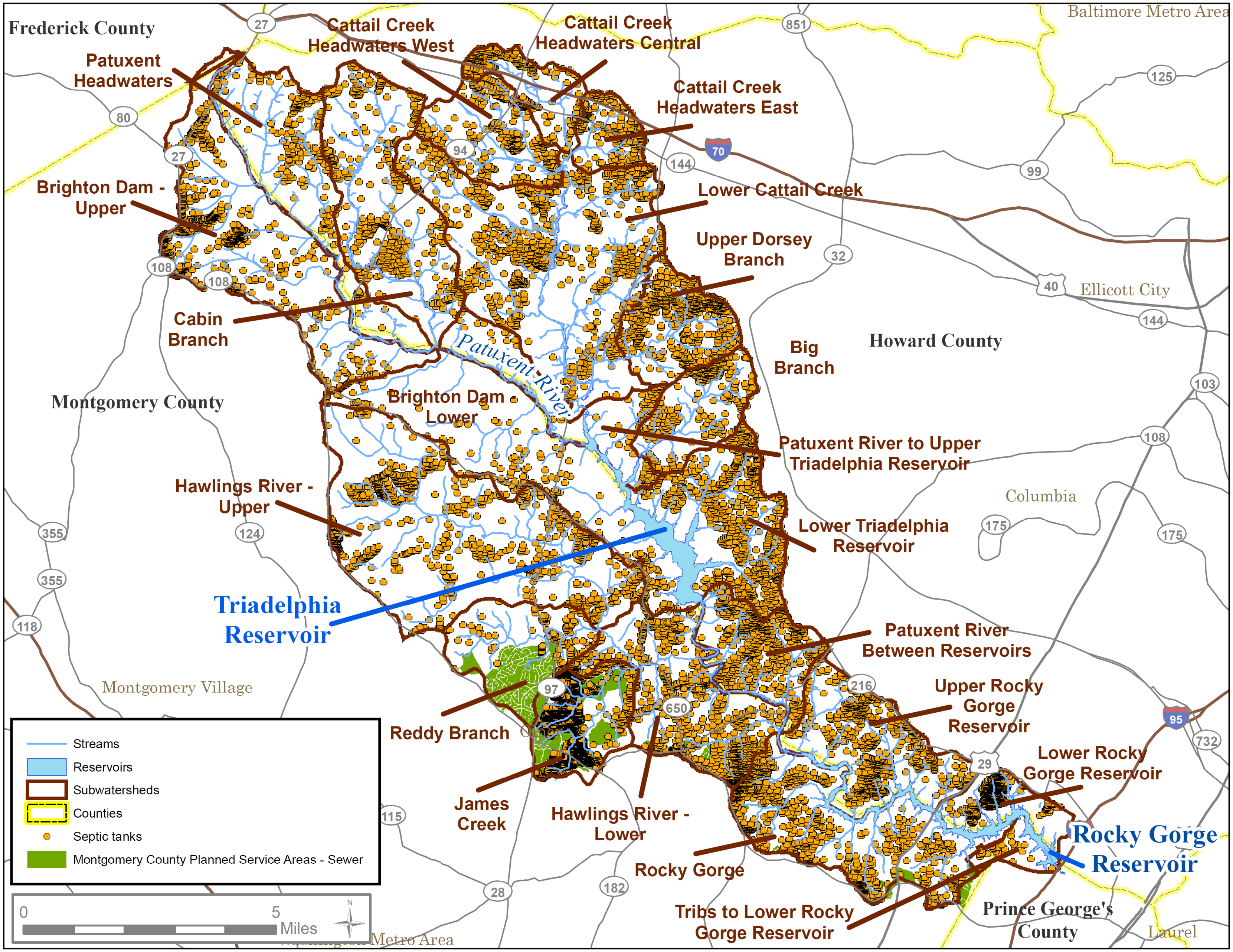


Figure 10-2. Locations of on-site septic systems in 2008 and planned sewer systems in and around the Patuxent Reservoirs watershed, Maryland (MDE 2008 data).

Table 10-1. Location of on-site septic systems by watershed and county in the Patuxent Reservoirs watershed, Maryland in 1997 (GMB Architects and Engineers, Inc. 1997) and in 2008 (data provided by MDE in 2009)

County	Subwatershed	Sum of On-Site Septic Systems 1997	Sum of On-Site Septic Systems 2008
Montgomery	Triadelphia	629	882
Montgomery	Rocky Gorge	2,161	4897
Howard	Triadelphia	2,921	3608
Howard	Rocky Gorge	908	1471
Total		**6,619**	**10,887**

In 1996 the USACE Reconnaissance Study (USACE 1996) defined one of the primary threats to the reservoirs as excessive nutrients from failing septic systems. The 1997 report by GMB Architects and Engineers, Inc., a document focused on septic systems, noted that phosphorus from septic systems was the nutrient of greatest concern in the reservoirs and recommended continued location of the soil adsorption component of the septic system in the shallowest zone that will provide adequate hydraulic disposal in order to provide better treatment of nutrients. Shallow adsorption systems provide more adsorption sites in fine upper layer soils, have better aeration and subsequently more biological activity. Low cost improvements of septic design and installation as well as low cost improvements to effluent distribution to soil adsorption systems are detailed in the report (GMB Architects and Engineers, Inc.1997).

Saprolite conditions in the Patuxent Reservoirs watershed result in low hydraulic conductivity and favor movement of soluble nitrogen (primarily nitrate, NO_3^-) because of low cation exchange capacity and low soil pH. Saprolite is also a poor barrier to phosphorus movement because it does not adsorb phosphorus (GMB 1997).

MDE's 2004 Patuxent Reservoirs SWA for WSSC Patuxent Water Filtration Plant noted that current contamination threats to these two reservoirs include point and non-point sources, including septic systems.

10.3 BAY RESTORATION FUND ONSITE DISPOSAL SYSTEMS (OSDS) IMPLEMENTATION

Since 2006 the State of Maryland has awarded approximately $19 million for upgrading septic systems to Best Available Technology for the removal of nitrogen. None of those awards has been to Montgomery, Howard or Prince George's counties as demonstrated in Figure 10-3 from MDE, although an unknown number of grants may have been given directly to applicants within these counties.

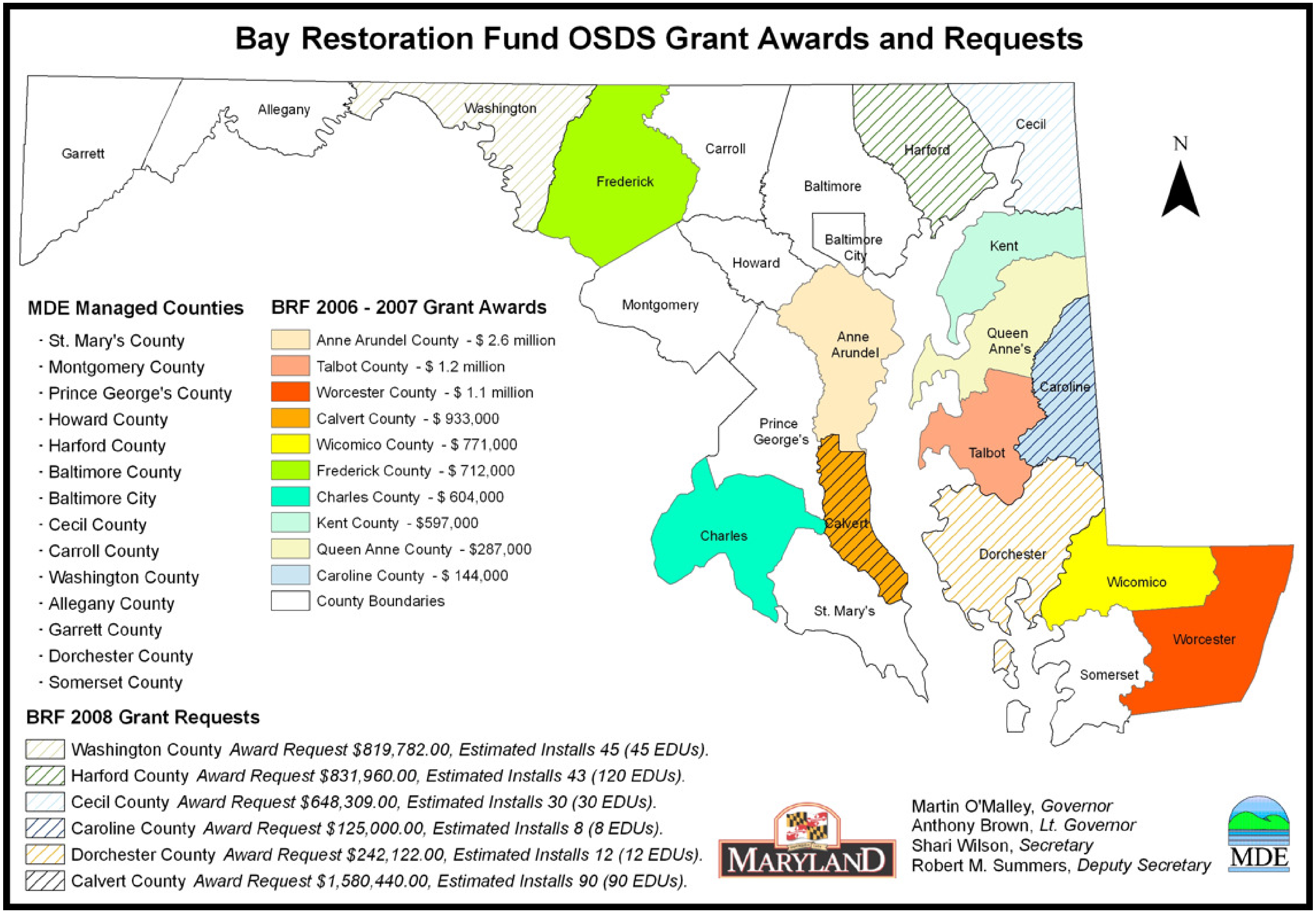


Figure 10-3. Chesapeake Bay Restoration Fund OSDS Implementation grant awards, 2006-2007, by county in Maryland (http://www.mde.maryland.gov/Water/CBWRF/pop_up/brf_osds_map.asp). EDU = Equivalent Dwelling Unit. Equivalent Dwelling Unit (EDU) is a measure where one unit is equivalent to wastewater effluent from one home, which is 250 gallons per day per home (1 EDU = 250 gallons per day). This amount is based on most wastewater pollution textbooks estimating an average of 100 gallons of wastewater per person, and based on the national average home occupancy of 2.5 persons per home.

11.0 THE TMDLs

The 2008 TMDL document (MDE 2008), submitted by MDE in 2007 and approved by EPA in November 2008, establishes TMDLs for the nutrient and sediment impairments in the Patuxent Reservoirs. Biological impairments within these watersheds will be addressed at a future date. "In summary, the TMDLs for phosphorus and sediment are intended to: 1) resolve violations of narrative criteria associated with phosphorus enrichment of Triadelphia and Rocky Gorge Reservoirs, leading to excessive algal growth; 2) resolve violations of narrative criteria associated with excess sedimentation of Triadelphia Reservoir; and 3) ensure that both Triadelphia and Rocky Gorge Reservoirs meet the interim interpretation of the non-tidal DO criteria, as applied to reservoirs." (MDE 2008)

The TMDL calls for the following pollutant reductions as seen in Table 11-1.

Table 11-1. The Elements of the nutrient and sediment TMDLs for the Triadelphia and Rocky Gorge Reservoirs, Maryland. (MDE 2008)

Waterbody	Triadelphia Reservoir	Rocky Gorge Reservoir	Triadelphia Reservoir
Constituent	TP (lbs/yr)	TP (lbs/yr)	Sediment (tons/yr)
Baseline Load	65,953	46,935	32,141
Percent Reduction	58%	48%	29%
TMDL	27,700	24,406	22,820
WLA	5,288	7,429	400
LA	21,027	15,757	22,420
MOS	1,385	1,220	Implicit

WLA = waste load allocation
LA = load allocation
MOS = margin of safety

The TMDLs were developed by MDE via a modeling effort by the Interstate Commission for the Potomac River Basin. This modeling effort (ICPRB 2007) is detailed in MDE's 2008 TMDL report entitled "Total Maximum Daily Loads of Phosphorus and Sediments for Triadelphia Reservoir (Brighton Dam) and Total Maximum Daily Loads of Phosphorus for Rocky Gorge Reservoir, Howard, Montgomery, and Prince George's Counties, Maryland."

Tables 11-2, 11-3, and 11-4 show the modeled percent contribution of sources to total phosphorus loads to both reservoir and sediment loads to the Triadelphia. The following three tables detail non point sources from significant land uses. As pointed out in the tables and in Section 8 (Figures 8-2, 8-3 and 8-4), with respect to agriculture-derived sources of phosphorus and sediment, agriculture is by far the largest source of impairment to the reservoirs, followed by streambank erosion (referred to as scour in Figures 8-2, 8-3 and 8-4), particularly in the case of

Table 11-2. Nonpoint source phosphorus loads attributed to significant land uses for the Triadelphia Reservoir, Maryland, Nutrient TMDL. (Table taken from MDE 2008 NPS Technical Memorandum)

Land Use Category	Percent of Nonpoint Source Load	TP Nonpoint Source Load (lbs/year)
Mixed Agricultural	60%	12,612
Forest and Other Herbaceous	12%	2,514
Streambank Erosion	28%	5,900
Total	100%	21,027

Table 11-3. Nonpoint source phosphorus loads attributed to significant land uses for the Rocky Gorge Reservoir, Maryland, Nutrient TMDL. (Table taken from MDE 2008 NPS Technical Memorandum)

Land Use Category	Percent of Nonpoint Source Load	TP Nonpoint Source Load (lbs/year)
Mixed Agricultural	34%	5,311
Forest and Other Herbaceous	17%	2,644
Streambank Erosion	8%	1,239
Upstream	42%	6,563
Total	100%	15,757

Table 11-4. Nonpoint source sediment loads attributed to significant land uses for the Triadelphia Reservoir, Maryland, Sediment TMDL. (Table taken from MDE 2008 NPS Technical Memorandum)

Land Use Category	Percent of Nonpoint Source Load	Sediment Nonpoint Source Load (tons/year)
Mixed Agricultural	56%	12,625
Forest and Other Herbaceous	6%	1,296
Streambank Erosion	38%	8,499
Total	100%	22,420

sediment. Sediment from point sources is only 400 tons per year compared to 22,420 tons per year for non point sources.

Modeled point sources of sediment and phosphorus from the permitted municipal separate stormwater dischargers and one waste water treatment plant are shown in Tables 14-1 and 14-2.

One might consider the TMDLs as the primary regulatory mechanism and certainly a catalyst for addressing at least two important sources of impairment to the reservoirs: sediment and phosphorus.

As explained in the 2008 TMDL report submitted by MDE to the EPA:

- Section 303(d) of the federal CWA and EPA's implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS, the State is required to either establish a TMDL of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate that water quality standards are being met.

- Both reservoirs were identified on the 303(d) list submitted to EPA by MDE as impaired by the following (years listed in parentheses): nutrients (1998) – due to signs of eutrophication, expressed as high Chl*a* levels – and impacts to biological communities (2002 and 2004). In addition, Triadelphia Reservoir was listed as impaired by sediment in 1998.

- The water quality goal of the nutrient TMDLs is to reduce high Chl*a* concentrations that reflect excessive algal blooms, and to maintain DO at a level supportive of the designated uses for Triadelphia and Rocky Gorge Reservoirs. The water quality goal of the sediment TMDL for Triadelphia Reservoir is to increase the useful life of the reservoir for water supply by preserving storage capacity (MDE 2008).

11.1 PHOSPHORUS AND SEDIMENT, BEFORE THE TMDLS

The TMDL report submitted to EPA by MDE is the most recent, or perhaps even the culmination of numerous efforts pinpointing nutrients and sediment as major sources of impairment to the reservoirs. The following paragraphs demonstrate the primacy of these two sources of impairment over the past three decades.

A 1981 report prepared for WSSC by Ecological Analysts Inc. focusing on Montgomery and Howard counties reviewed water quality and nutrient loading to the Patuxent Reservoirs using 1980 and year-2000-predicted land-use scenarios and population densities. That early study concluded that both reservoirs appeared to be eutrophic due to excess phosphorus, but only

Rocky Gorge had supporting data. Modeled estimates of phosphorus loading based upon land-use characteristics of the time placed the reservoirs in the eutrophic range. Projections of land use 20 years (*i.e.,* year 2000) into the future showed an increase in phosphorus inputs to the reservoirs. Note that stormwater loadings had not been estimated in this effort.

A 1984 study by JTC Environmental Consultants, Inc. was commissioned by WSSC to determine reservoir water quality via monthly sampling and analysis during a one-year period and "to determine how watershed protection can be accomplished". The authors reported that drainage-area-to-reservoir-area-drainage-ratios were significantly higher than normal and detention times were significantly lower, indicating the potential for high nutrient loading from runoff. In addition, in-lake nitrogen concentrations were very high, indicating that phosphorus was the limiting nutrient. Iron, manganese, silica and carbon were all present in sufficient quantities to indicate that they were not limiting nutrients. This early study concluded that reservoir water quality and nutrient loading characteristics needed to be determined and variability and trends established in order to implement BMPs.

Modeling done as early as 1987 by CDM for Greenhorne and O'Mara as part of the M-NCPPC Patuxent Watershed Management Program, among other goals, assessed the water quality of both reservoirs using a desktop eutrophication model for existing and ultimate land use. Based on average annual phosphorus loading, the Triadelphia Reservoir was predicted to be slightly eutrophic under existing land-use conditions and the Rocky Gorge Reservoir was rated as upper mesotrophic (intermediate level of productivity). The Triadelphia Reservoir was predicted to be receiving 9 tons of phosphorus per year and the Rocky Gorge Reservoir was predicted to be receiving 11 tons of phosphorus per year. In terms of sediment, the model showed 10,000 tons per year entering into the Rocky Gorge reservoir and twice as much, 20,000 tons per year, entering into the Triadelphia Reservoir, due to a higher percentage of tillage in the upper watershed and sediment trapping in the Triadelphia Reservoir.

This same 1987 report predicted that sediment loads would decline significantly in the build-out scenario: an 80% and 70% reduction in the Triadelphia Reservoir and Rocky Gorge Reservoir, respectively, due to conversion of cropland to low density residential. Phosphorus was predicted to increase by 36% and 60% for Rocky Gorge and Triadelphia Reservoirs respectively. Nitrogen was predicted to increase by 33% and 40% for Rocky Gorge and Triadelphia Reservoirs respectively. Heavy metals were expected to increase by a factor of 2 for the Rocky Gorge Reservoir and a factor of 3 for the Triadelphia Reservoir. In all cases no mitigation measures were assumed. Increased nonpoint pollution loadings from future urban development without structural nonpoint pollution control would result in water quality deterioration in both reservoirs. Under the ultimate land-use scenario, the loadings and eutrophication model predicted that both reservoirs would become eutrophic.

In 1990, water quality/watershed process modeling was done for the Hawlings River basin (located within Montgomery County only) and extrapolated to the entire watershed using a desktop spreadsheet model called NPS Screen as reported in the 1990 Patuxent River Watershed Montgomery County Maryland: Technical Report (Greenhorne and O'Mara Inc. 1990). Results of modeling showed that under 1990 conditions, on an annual average basis, both reservoirs were under significant stress from nutrient enrichment. In addition, two subareas within the upper reaches of Hawlings watershed were found to be contributing 15-20% more pollutant load than the average and it was recommended they be targeted for management activities. In contrast to the 1987 report by CDM for Greenhorne and O'Mara, ultimate (build-out) land-use projections indicated significantly higher sediment loads but lower total nutrient loads due to an increase in expected rural residential housing and conversion of high intensity cropland into pasture and forest. Both 1990 land use and projected land use in the Patuxent River watershed showed that nutrient and sediment loadings were "significant".

This 1990 report recommended that existing land-use conditions should be the focus of efforts to reduce nutrient and sediment loadings due to slow transition between existing and ultimate land-use conditions and lack of immediate response by hydrologic systems to decreased nutrient inputs, particularly in reservoirs where nutrients are stored. The authors pointed out that the magnitude of loadings would vary depending upon many variables such as time and intensity of fertilization, amount and type of forest, actual land use, and use of agricultural BMPs, which are hard to predict with absolute confidence given the amount of data collected.

A 1991 report by EA Engineering (Water Quality Monitoring and Nutrient Loading Analysis of the Patuxent River Reservoirs Watershed) stated that multiple studies over the last 10 years indicate that the reservoirs were subject to siltation and eutrophication, which could affect water quality. The authors also stated that loading estimates from the 1990 stormwater monitoring program and earlier NPS models were in relative agreement. Data gathered for the 1991 effort over a one-year period drew the following conclusions:

- 95-97% of suspended sediment loadings into the reservoirs came from stormwater;
- 85-88% of phosphorus loadings into the reservoirs were from stormwater;
- Nitrogen loadings were derived equally from baseflow and stormwater.
- Cattail Creek watershed is 15% smaller than the Hawlings River watershed but yielded phosphorus and total suspended solids (TSS) equal to the Hawlings and 40% more nitrogen. This is attributed to higher concentration of all three parameters in stormwater runoff from Cattail Creek.

The 1996 USACE Patuxent River Water Resources Reconnaissance Study, commissioned by Congressman Steny Hoyer, defined primary threats to the reservoirs as excessive nutrients from failing septic systems, small-lot horse farm practices and excessive sediment loading/siltation of the reservoirs from poor stormwater quantity management and resultant streambank erosion, which was estimated to lead to a 50% reduction in storage capacity of the Triadelphia Reservoir by 2100. The authors also concluded that additional raw water supplies would be required, due to increases in demand, by only 2015. The 1997 report by GMB Architects and Engineers Inc, commissioned by WSSC, noted that phosphorus from septic systems, agriculture, urban runoff and point sources was the nutrient of greatest concern in the reservoirs.

The 2004 Patuxent Reservoirs SWA, authored by MDE, concurred that the primary contaminant of concern, according to their analysis, was phosphorus.

11.2 BEYOND TMDLS

Note that although TMDLs for nutrients and sediment have been identified for the two reservoirs, MDE's 2004 report also notes that:

> *The current contamination threats to these two reservoirs include point and non-point sources from transportation infrastructure, railroads, a petroleum products pipeline, agriculture, septic systems, urban/suburban areas. The analysis indicates phosphorus as the primary contaminant of concern. Secondarily, turbidity/sediment, disinfection byproducts, iron, manganese and protozoan (pathogens) are indicated as contaminants of concern.*

These additional contaminants and contaminant sources are discussed in the Recommendations Section (Section 14).

12.0 HAWLINGS AND CATTAIL CREEK: SUBWATERSHEDS OF SPECIAL INTEREST

Cattail Creek and the Hawlings River are the two major tributaries feeding the reservoirs (MDE 2004). These particular waterways have been the focus of various monitoring and modeling efforts and could be considered subwatersheds of special interest. As noted in the Hawlings River Watershed Restoration Action Plan (WRAP) of December 2003 (Charles P. Johnson and Associates and Environmental Quality Resources, LLC 2003), the Hawlings River watershed in Montgomery County and the Cattail Creek watershed in Howard County, represent rapidly expanding rural-suburban/urban fringe development (Figure 12-1). As major tributaries, they were specifically recommended for large-scale chemical monitoring in the Comprehensive Management Planning Study for the Patuxent Reservoir watershed done by Tetra Tech in 1997.

The Hawlings River subwatershed is located in Montgomery County and drains 27.7 square miles (13% of total watershed area) (MDP 1997) before joining the Patuxent River between the Triadelphia and Rocky Gorge Reservoirs. The Hawlings subwatershed had the highest concentration of low and medium density residential land use as reported by MDE (2004).

Cattail Creek is a major subwatershed located in Howard County and drains into the Patuxent River upstream of Triadelphia Reservoir. The Cattail Creek subwatershed drains a land area of 27.6 square miles (13% of total) and had the greatest agricultural land use in the Patuxent Reservoirs watershed, 57%, as reported by MDE (2004). The 2007 land-use data provided by MDP confirm that agriculture is still a major land use within Cattail Creek watershed (Table 5-1), although different delineations of subwatersheds make analysis of changes in agricultural land use in the Cattail Creek subwatershed difficult.

Historical monitoring had been conducted by USGS from 1986 to 2000 at a flow gauging station nearby (referred to by USGS as Patuxent River near Unity, MD, number 01591000), attached to the overpass of MD 97 over the Patuxent River, 0.8 miles upstream of Triadelphia Reservoir (Versar 2004). Both watersheds were also monitored from 1989-1990 as reported by EA Engineering in “Water Quality Monitoring and Nutrient Loading Analysis of the Patuxent River Reservoirs Watershed” (1991). The goal of this study by EA Engineering was to supplement and continue stream water quality monitoring to better describe and predict sediment and nutrient loading rates (as recommended by the WSSC commissioned study of 1984) as well as to evaluate predictions of previous desktop eutrophication models previously prepared for WSSC. The EA Engineering monitoring project included five sampling sites: Cattail Creek, Hawlings River, the Patuxent River at the USGS Unity gauge station, Rocky Gorge Reservoir, and Triadelphia Reservoir. Hawlings River and Cattail Creek were sampled during storm events to determine stormflow pollutant loadings, and between storms to obtain baseflow loadings. EA Engineering conducted three baseflow samplings during the study. Eleven storms were monitored in each tributary during the course of about a year and were used for data analysis (EA Engineering 1991).

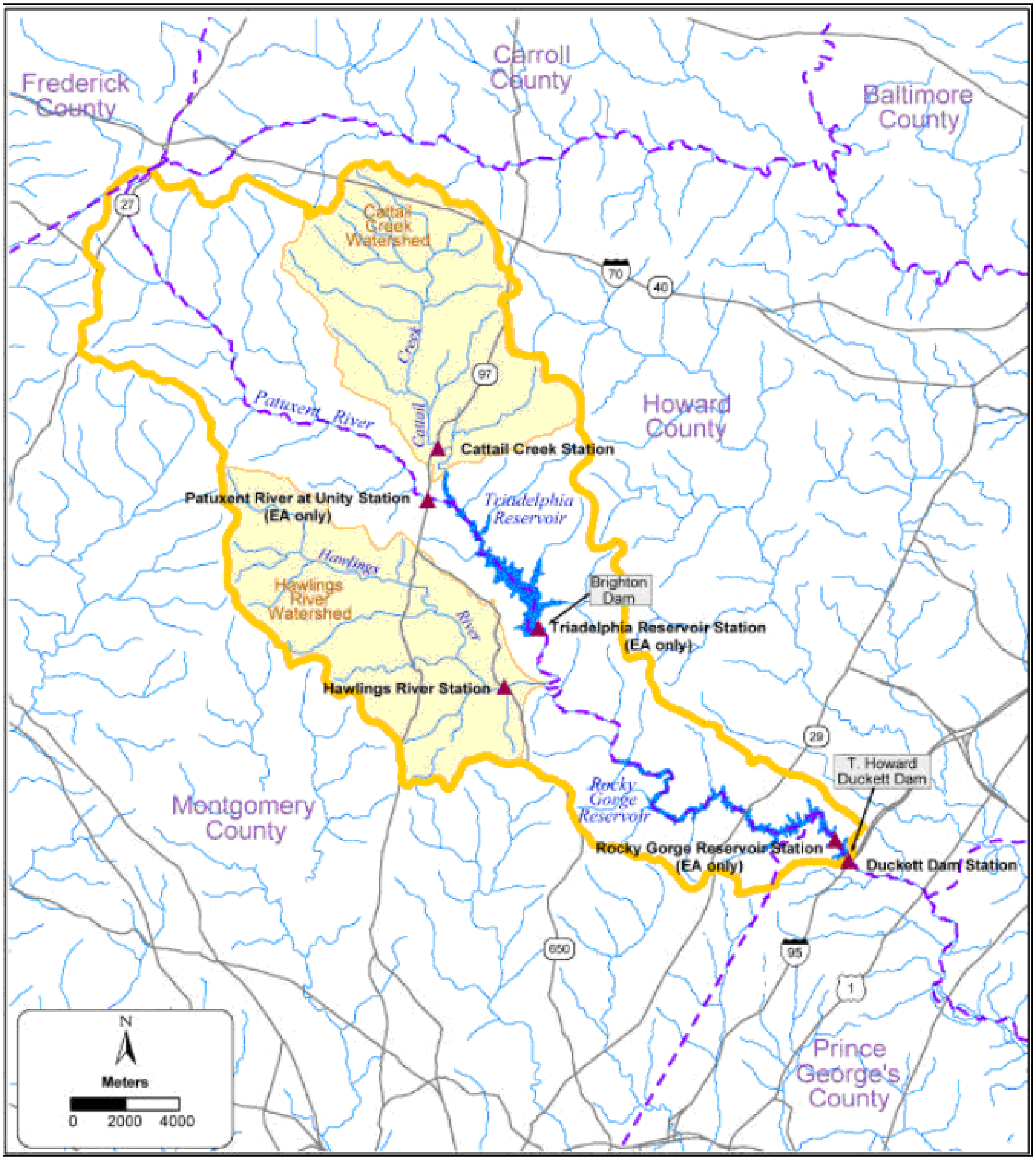


Figure 12-1. Cattail Creek and Hawlings River subwatersheds within the Patuxent Reservoirs watershed, Maryland, with water quality monitoring station locations (Map source, Versar 2002).

Both subwatersheds were also monitored for WSSC from 1998-2001, as reported by Versar (2002), in "Washington Suburban Sanitary Commission Patuxent Reservoirs Watershed Tributary Monitoring and Sediment Nutrient Flux Testing Program Third Annual Report". From analytical results of field samples and flow rate data, loadings were calculated for total nitrogen, total phosphorus, and total suspended solids contributed by the Hawlings River, Cattail Creek and at T. Howard Duckett Dam.

Versar Inc. was asked to conduct a historical review of available data as part of the 2002 effort mentioned above. The only data considered for inclusion in the historical review were those contained in the EA report of 1991 because the sample collection methods used by EA Engineering from 1989-1990 were similar to Versar's from the standpoint of loading estimates. A comparison of the loadings is described below. Both the EA Engineering study and Versar's study of tributary and reservoir water quality in the Triadelphia and Rocky Gorge Reservoirs lend themselves to inclusion in the analysis of pollutant loading rates. However, because the available dataset is small (i.e., only three years of nutrient data were collected), and the inherent high variability in stream pollutant levels, no formal trend analysis could be performed. A sequence of measurements over time (years) is required to reveal significant trends of pollutant loading. Unfortunately, because past chemical monitoring efforts within the Patuxent Reservoirs watershed have been sporadic and employed highly variable methodologies, trend analysis has not been possible to date (Versar 2002).

12.1 HAWLINGS RIVER WATERSHED SPECIFIC STUDIES

The Hawlings River watershed was the focus of a modeling effort detailed in the 1990 Patuxent River Watershed Technical Report (Greenhorne and O'Mara Inc. 1990). The report is a continuation of the watershed technical analysis program undertaken by the M-NCPPC in the 1970s and the result of recommendations from Ecological Analysts, Inc. (1981) which indicated that the reservoirs were being threatened by pollution from urbanized and agricultural areas.

Results of modeling showed that under 1990 conditions, on an annual average basis, both reservoirs were under significant stress from nutrient enrichment and that two subareas within the upper reaches of the Hawlings River watershed were contributing 15-20% more pollutant load than the average and should be targeted for management activities.

Ultimate (build-out) land-use projections from 1990 indicated significantly higher sediment loads but lower total nutrient loads due to an increase in expected rural residential housing and conversion of high intensity cropland into pasture and forest.

Analyses from the Hawlings River Watershed Restoration Study completed in February 2003 for the Montgomery County DEP by Charles P. Johnson and Associates and Environmental Quality Resources, LLC., showed that ultimately, stream resources protection can only be achieved through a combination of stream restoration, riparian buffer expansion, other agricultural and urban BMPs, and public environmental stewardship. The Restoration Study also identified and generated concept designs for 12 candidate stream bank stabilization and buffer enhancement projects on 15 miles of the total 98.2 stream miles and concept designs for modification of 3 existing stormwater BMPs to increase their efficacy, as seen in Figure 12-2 taken from that report.

The Hawlings River WRAP of December 2003 is a follow up to the Hawlings River Watershed Restoration Study. The Plan, prepared for the Montgomery County DEP was initiated in 2000 to protect the Hawlings River watershed, to reduce sediment and nutrient loads to Rocky Gorge Reservoir, into which the Hawlings River drains, as well as to meet the commitments of the Patuxent Reservoir Watershed Protection Agreement.

12.2 CATTAIL CREEK WATERSHED SPECIFIC STUDIES

Modeling done as early as 1987 by CDM as part of M-NCPPC Patuxent Watershed Management Program yielded that Cattail Creek is disproportionately responsible for sediment and phosphorus loadings.

Again in the 1991 the “Water Quality Monitoring and Nutrient Loading Analysis of the Patuxent River Reservoirs Watershed” report (EA Engineering Inc. 1991), commissioned by WSSC, concluded that Cattail Creek watershed, although 15% smaller than the Hawlings River watershed, yielded phosphorus and TSS equal to the Hawlings River watershed and 40% more nitrogen. This was attributed to higher concentration of all three parameters in the stormwater runoff from Cattail Creek.

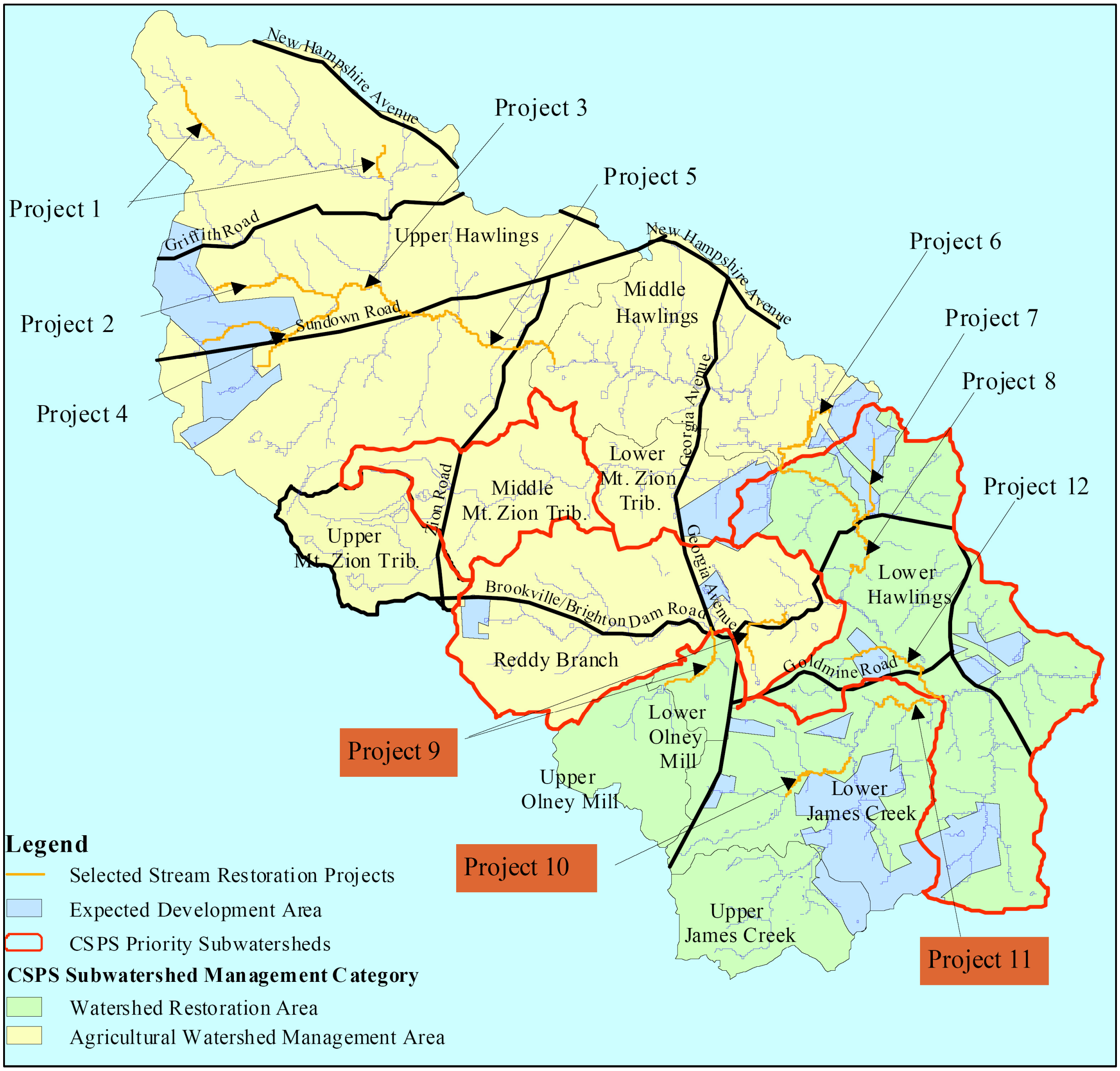


Figure 12-2. Twelve candidate stream bank stabilization and buffer enhancement projects in the Hawlings River watershed, Maryland. Top 3 ranked projects are highlighted in orange. (Charles P. Johnson and Associates and Environmental Quality Resources, LLC 2003)

13.0 OUTREACH AND EDUCATION

13.1 GREEN SCHOOLS

The hallmark outreach and education effort within the Patuxent Reservoirs watershed is the state-wide Green Schools (and Centers) Awards Program sponsored by the Maryland Association for Environmental and Outdoor Education (MAEOE; http://www.maeoe.org/-greenschools/). Since 1999, the Green Schools Program has recognized Maryland private and public school, grades kindergarten through 12th, and environmental centers, which model conservation BMPs, support environmental education, champion the Maryland Green School concept, and provide assistance for potential and existing Maryland Green Schools.

A designated Green School is one that has documented the following activities for at least a two-year period:

- Use their school site and curricular instruction to prepare students to understand and act on current and future environmental challenges facing all Marylanders;
- Model environmental BMPs in building and landscape design, operation and maintenance; and
- Build and maintain partnerships with the local community to enhance environmental learning and to design and implement projects and programs that result in a healthier environment.

Figure 13-1 shows the locations of all schools, including Green Schools (note that school districts are not indicated) within Howard, Montgomery and Prince George's Counties. The figure shows that roughly half of all schools lying within the watershed boundaries have become recognized Green Schools. It also demonstrates how few schools, and by extension, how few residents, there are within the relatively rural upper watershed, compared to the surrounding area.

Figure 13-2 shows those schools within the Patuxent Reservoirs watershed only, both Maryland Green School participants and those not participating in the program.

13.2 H20 FEST

WSSC supports other outreach activities such as the annual H20 Fest. This half-day festival was held most recently on April 18, 2009 at Duckett Dam. There were 33 presenters which was an increase from the 2008 event and nearly double the number of participants (~400) compared to the prior year. The event boasted a native tree raffle, rain barrel raffles, a charity bike ride, and educational displays and activities, including tours of Duckett Dam. There were event notices in the local papers and e-newsletters, on several news stations, two electronic message boards, road signs, and through the WSSC Customer Notification System resulting in more participation.

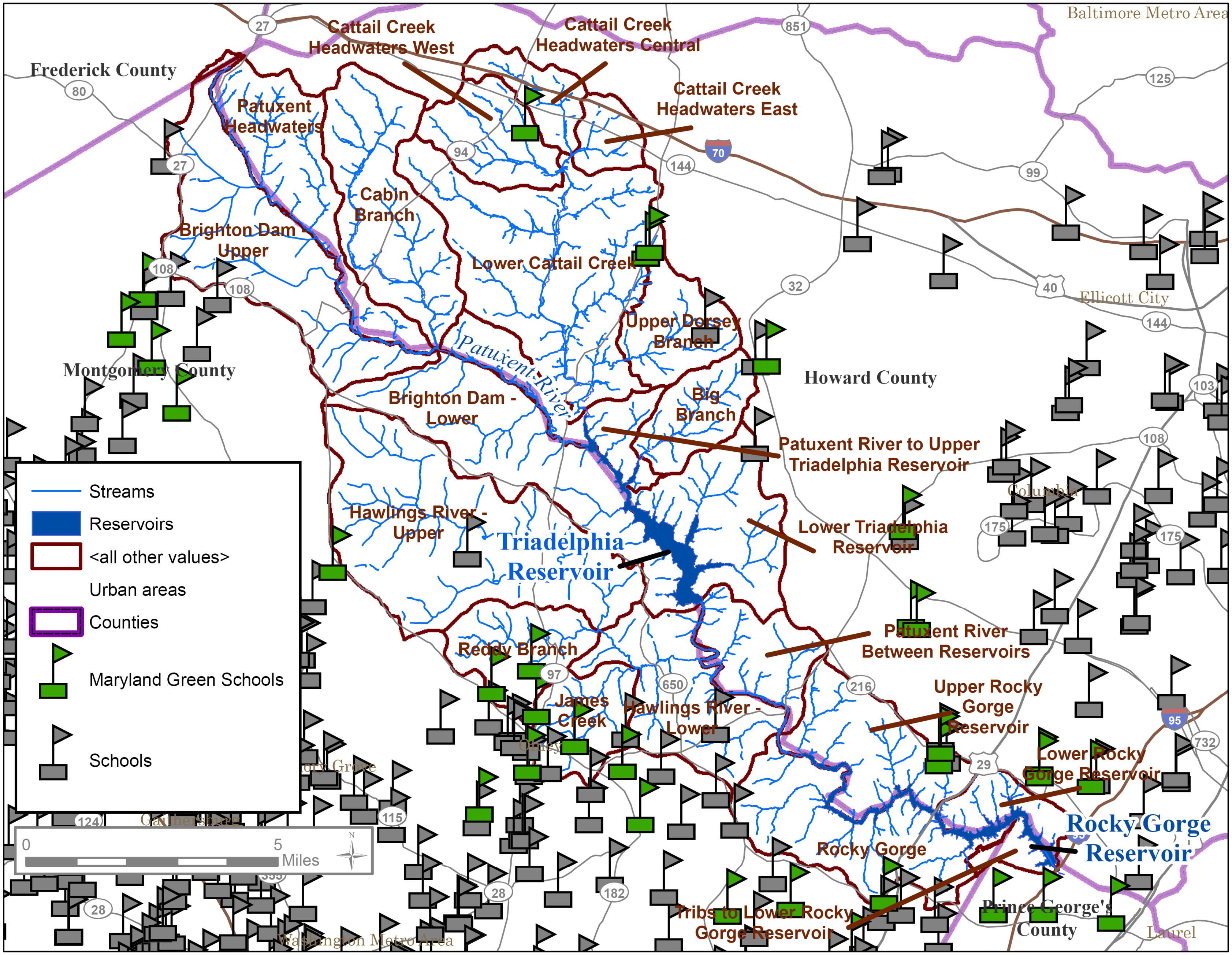


Figure 13-1. All schools, both Maryland Green Schools and non-participating schools, in and around the Patuxent Reservoirs watershed, Maryland. (Sandy August, WSSC Outreach Office 2009, and Howard and Montgomery Counties 2009 data)

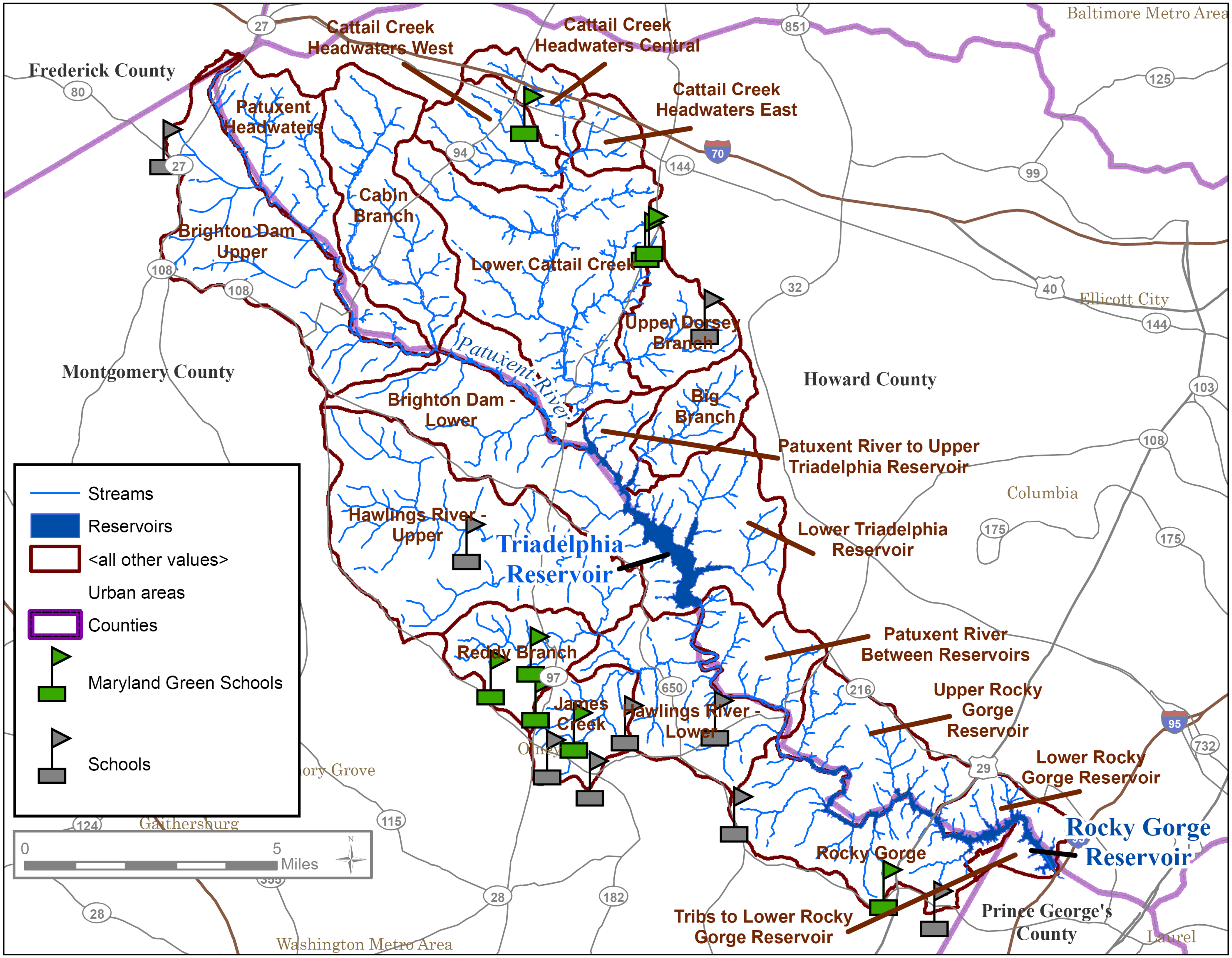


Figure 13-2. All schools, both Maryland Green Schools and non-participating schools, within Patuxent Reservoirs watershed, Maryland (Sandy August, WSSC Outreach Office 2009, and Howard and Montgomery Counties 2009 data).

14.0 RECOMMENDATIONS

The importance of the Patuxent Reservoirs and the watersheds that feed them has led to a significant body of literature, listed above and reviewed in Appendix A. WSSC has itself commissioned management plans in 1981 and 1997, a WSSC properties forest management plan in 2007, and various water quality monitoring efforts (1984, 1991, 2002, 2007).

Other stakeholders have also commissioned efforts within the entire watershed or particular subwatersheds. They include the EPA-approved TMDLs in 2008, eight management-type documents with recommendations (1984, 1990, 1993, two in 1995, 2003, and two in 2007), four education and outreach documents (1990, 1995, 1996, 2004), 10 water quality monitoring and assessment documents (1987, 1996, 1998, 1999, 2000, two in 2001, two in 2003, 2004) and a report on the TMDL modeling effort in 2007.

A variety of recommendations have been generated over the years, many of which still have merit and whose reiteration in separate efforts helps to demonstrate consensus. Below we present a compilation of these past recommendations, grouped by major category, along with new recommendations developed for the TAC from our analysis, including that generated by new GIS analysis. Note that this report is not intended to serve as a TMDL implementation plan. We expect there will be further review and refinement of the proposed recommendations by the TAC.

14.1 RECOMMENDATIONS FOR ADDRESSING AGRICULTURE-DERIVED IMPAIRMENTS

Despite attempts by federal and state authorities, and state soil conservation managers to curb nutrient and sediment loads through numerous programs over the last decades, according to MDE designated uses, both reservoirs have become impaired by phosphorus, and the Triadelphia Reservoir has become impaired by sediment, all sourced to a great extent from agricultural runoff. It is therefore impossible to avoid the subject of agriculture if the TMDLs for phosphorus and sediment are to be met.

1. Detailed recommendations specific to agricultural practices are beyond the scope of this effort. We can however recommend specific areas to target the planting of riparian buffers, a common agricultural, urban and suburban BMP, using the latest GIS information (See Section 14.2 below). Strategic planting of **riparian buffers** not only helps to abate sediment and phosphorus loss from agricultural land uses into waterways but also can simultaneously meet other important natural resources management, human health protection and aesthetics goals.

2. In consideration of future action priorities, the TAC needs to elevate agricultural initiatives as a top priority. That being said, it is most appropriate and important that

TAC membership continue to include representatives of the **Montgomery and Howard SCD**s and the **Maryland Department of Agriculture**, which each implement conservation-related agricultural programs at the local level. Staff members from both the Howard County and Montgomery County SCD have been active participants in the TAC, including serving as Chair. An increased focus on agricultural initiatives by the TAC would be beneficial, particularly in light of the TMDLs.

- The latest local cost share initiative targeting small horse farmettes is an excellent example of attempted abatement of agriculture-type sources. The project grant proposal ("Immediate Nutrient Reduction at Unregulated Horse Stables") estimated the program could achieve phosphorus removal from the receiving waters of 2,250 pounds per year (1.13 tons/yr) in Howard County and 1,305 pounds per year (0.65 tons/yr). This does not approach the total load reductions required by the TMDLs, but is a step in the right direction. It is worth noting that horse owners in the two counties are not part of the traditional farming community, so while the properties targeted are zoned as agricultural, they do not address those farming practices which are having the greatest impact on the reservoir impairment, namely tillage farming practices, as noted in Figure 8-7 above.

- The TAC needs to focus its efforts and encourage the SCDs to focus on those **specific farming practices** implicated in nutrient and sediment loading.

- Even though compliance with Maryland's Water Quality Improvement Act of 1998 is said to be high (as reported above) a TMDL has nonetheless been required. This suggests that more aggressive efforts are required regarding **nutrient management plans.** The 2007 NOAA effort indicated that NMP enforcement in Montgomery County and Howard County was far from perfect. It is in the TAC's interest to begin to scrutinize enforcement efficiencies and push for greater compliance.

- The TAC should work with the SCD to increase participation in **CREP**, particularly in headwaters, which is where most farmland can be found in the reservoirs watershed.

- The **MACS** program seems to be popular in Montgomery County within the Patuxent Reservoirs watershed but not at all in Howard County within the Patuxent reservoirs watershed, according to NOAA (2007). The TAC might work with the Howard County SCD for greater participation in MACS in the Patuxent Reservoir watershed.

- The TAC needs to request for the Maryland Department of Agriculture to publish data in the MACS Annual Reports at the watershed scale as well as by county/political scale in order to more easily calculate impacts of the MAC program at the watershed scale. In the generation of new analyses for this document we are able to access information on the type, or number of agricultural BMPs in place on farms (MACS Annual Reports) within the counties, but not by watershed. Information on BMP location by property owner may be impossible due to privacy concerns (K. McCormick, Howard County SCD, pers. comm. 2009). However, the number of BMPs by subwatershed would likely suffice for most analysis. This type of basic information will be necessary if the TAC is to effectively address agricultural sources of phosphorus and sediment.

- The SCDs and TAC need to develop an inventory of voluntarily implemented agriculture BMPs and quantify their nutrient and sediment reductions.

3. It is strongly recommended that TAC members carefully review and consider the findings of the 2007 report entitled **Managing Patuxent River Water Quality: Looking Beyond Science and Politics to the Economics of Decision-making**, prepared for NOAA by University of Maryland, Center for Environmental Science, for guidance regarding BMPs, cost-share opportunities and compliance issues.

   The report identifies the economic base and nutrient discharge characteristics of the seven Patuxent River watershed counties and 1) how economic sectors in each of the counties contribute to the regional economy, 2) how these same economic sectors contribute to Patuxent River water quality problems and 3) what policy tools and levels of effort government agencies within each county are using to deal with water quality problems in the river.

   Research for NOAA (2007) involved among other things, use of "state and county budget and financial data, enforcement and compliance statistics, and interviews with state and county enforcement staff to measure the level of government effort exerted in attempts to control nutrient discharges within each county. This involved examining data related to county environmental spending and enforcement man-power allocations, numbers of environmental permit inspectors and inspections per inspector or per permit, numbers of prosecutions for environmental violations, sizes of penalties, etc." (NOAA 2007)

   The NOAA (2007) effort even presents the first ever "summary [Stewardship/Culpability Indicators] indices that reflect how much each county contributes to Patuxent River water quality problems (e.g., nutrient discharges per acre, per capita, per dollar of economic output), and also indices that reflect how much effort each county is putting into controlling Patuxent River water quality problems (e.g., spending on environment as a percent of county budget, number of inspections per permit, average size of penalties from environmental violations)." This allows the Counties and SCDs to compare their efforts to that of their neighbors relative to the Patuxent River.

The indices address the following questions:

- How forcefully are county governments enforcing policy decisions (e.g., levels of fines and penalties)? Note that SCDs have no enforcement role.

- What level of financial commitment are counties making to enforce water quality restrictions (e.g., budget and manpower allocations)?

- What level of enforcement effort is being exerted by county governments (e.g., numbers of inspectors and inspections, frequency of enforcement actions and prosecutions)?

This is a complex and lengthy document which deserves the attention of the TAC and the SCDs in particular.

4. The **Priority Resources Chart** states that the TAC aims to "Preserve open spaces and maintain an economically viable and environmentally protective agricultural community." While this commitment to agriculture is important for a host of reasons, it does not fully address the challenge of addressing nonpoint source contributions from agriculture, which have been identified as important by the TMDLs. Because a key goal is to protect the reservoirs from impairment, and knowing that those sources of impairment are largely derived from phosphorus and sediment draining agricultural lands, then the TAC needs to take a more active role of advocate for and participant in programs which assist farmers to use the latest management practices to minimize phosphorus and sediment loading to waterways. Agriculture needs to be treated as the unique land use it is and recognized for the unique challenges it presents for watershed integrity. Adding "control of agriculturally-sourced sediment and phosphorus" to the "Measures" column of the table as well as adding "Goals" and "Implementation Items" that are specific to the abatement of the phosphorus and sediment from farmlands would help redefine TAC priorities to address the TMDLs. This addition would reflect an intent to focus on protecting the reservoirs from the sources of impairment to the reservoirs identified specifically in the TMDLs, in order to more aggressively address the predominant sources of impairment.

14.2 RIPARIAN BUFFERS

14.2.1 Riparian Buffers in the Literature

The movement of phosphorus is very much tied to the movement of sediments (Karr and Schlosser 1978; Osborne and Kovacic 1993; Peterjohn and Correll 1984; Schlosser and Karr 1981). Palone and Todd (1997) state that "Because nearly 90% of phosphorus is carried to streams attached to soil particles or organic matter, reducing sediment transport helps to reduce phosphorus loads. The ability of vegetation to colonize the sediment and rapidly use available phosphorus is a related function." Thus, buffer widths sufficient to remove sediment from runoff should also trap phosphorus (Wenger 1999).

Wenger's (1999) literature review of riparian buffers summarizes that the phosphorus trapping ability of a riparian buffer increases with width in the 5-30 meter range (Wenger 1999 cites Maggette et al. 1987; Maggette et al. 1989; Mander et al. 1997; and Vought et al. 1994). There are however important limitations on the effectiveness of riparian buffers for control of phosphorus. As pointed out by Lowrance et al. (1997), riparian buffers are effective at short-term control of sediment-bound phosphorus but have low net dissolved phosphorus retention. Peterjohn and Correll (1984) even found that effective phosphorus retention was unclear in forested buffers adjacent to agricultural fields in Maryland.

Osmond et al. (2002) suggest that riparian buffers remove 50% of total phosphorus at the 12 foot (3.7 meters) buffer threshold and only marginally gain in effectiveness as they increase up to the 50 foot (15.2 meters) buffer width as demonstrated in Figure 14-1.

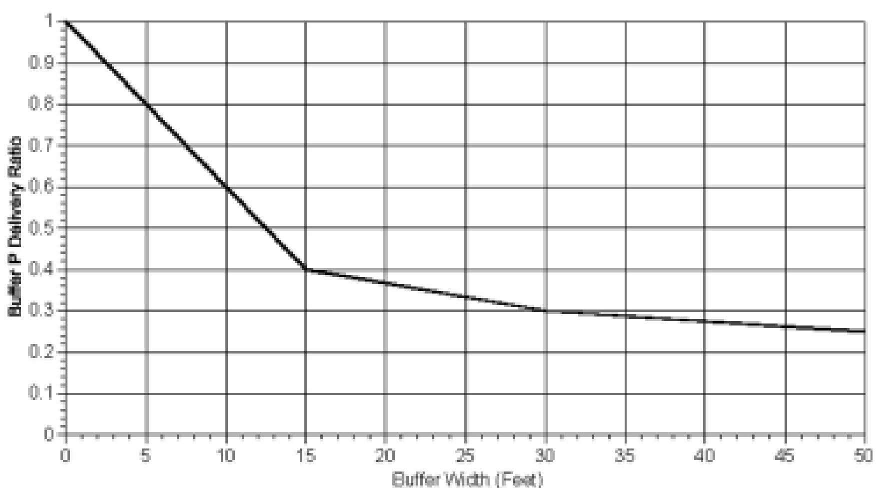


Figure 14-1. Phosphorus delivery as influenced by stream buffer width (Osmond et al. 2002)

Many of the previous Patuxent Reservoirs studies have recommended riparian buffers as an important watershed management measure. The earliest Patuxent River watershed management document reviewed for this effort, the 1981 Patuxent River Watershed Protection Program by Ecological Analysts Inc., recommended riparian buffer strips for agricultural areas. As part of its 10 recommendations, the 1984 Patuxent River Policy Plan: A Land Management Strategy, written by the Maryland Department of State Planning, also called for vegetative buffers. The need for stream buffers and the need to study the adequacy of stream buffer widths was cited as part of a multi-barrier approach in 1995 (Developing a Patuxent Reservoir

Protection Strategy; Interim Report of the Patuxent Reservoir Protection Group) by the Montgomery County DEP. The 2001 Upper Patuxent Watershed Study also written by the Montgomery County DEP recommended that riparian buffers be examined and increased to ensure better protection of streams. The 2003 Hawlings River WRAP prepared for the same agency also cited the need for riparian buffer expansion in agricultural areas of the Hawlings watershed. Most recently, buffers are noted as an issue of concern in the 2004 Patuxent Reservoirs SWA prepared by MDE.

14.2.2 Land Acquisition for Buffer Creation

The 2004 Patuxent Reservoirs SWA by MDE recommended that State park land, specifically subwatersheds and tributaries to mainstem waterways, should be acquired by the park system.

In its 2007 report (Patuxent River 20/20), the Patuxent Riverkeeper recommended that the State should continue its efforts to preserve land along the Patuxent to provide green infrastructure for habitat and water quality protection and that the State should work with local governments and private organizations to ensure land is purchased in a proactive and comprehensive fashion.

Montgomery County is establishing a plan for land conservation efforts which is useful for targeting restoration efforts, according to the M-NCPPC Land Preservation, Parks, and Recreation Plan; Public Hearing Draft (*http://www.mcmncppc.org/ppra/Park_Planning/LPPRP_PubHearing_Draft/Chapter1_Intro.pdf*):

> This publication documents the results of a stream condition survey that samples biological communities and physical stream conditions for all streams in the county. In addition, it indicates existing and projected imperviousness and a management strategy for each subwatershed in the county. This information is used as part of the inventory described above and in the master plan preparation. The preparation of the land-use alternatives considered is influenced by this information and more refined estimates of projected imperviousness are made with detailed information about each alternative land-use scenario. Our overlapping goals of protecting, conserving and restoring stream corridors, riparian forest buffers, wetlands and floodplains are combined in the master planning process to arrive at the best combination of density, clustering options, open space preservation and parkland acquisition to protect water quality.
>
> Once the zoning, land use and park acquisition boundaries are set in the master plan and accompanying zoning map amendments, individual developments are subject to development review for compliance with the Planning Board's Environmental Guidelines and the Montgomery County Forest Conservation Law. These programs comprehensively protect most environmentally sensitive features

> on site when development projects (both public and private) are submitted to the Planning Board. The only allowed encroachments to these areas are roadway or utility access to the site that cannot be avoided. Sites that are heavily forested will often incur forest loss up to the threshold specified for each zone, except in very low-density zones when more open space is required.
>
> In areas where the land use planned is considered a potential risk in high quality watersheds, the area may be designated a Special Protection Area. This requires that a water quality plan be prepared that incorporates redundant stormwater management facilities and other features that address the particular goals for the receiving water. In addition, wider wetland buffers and accelerated reforestation is required in these areas. In some Special Protection Areas, overlay zones are adopted to limit imperviousness to specific levels on each site and limit or prohibit certain land uses that pose a risk to water quality.

This Land Preservation, Parks, and Recreation Plan is a multi-faceted way of simultaneously addressing land use and watershed health and a good framework for protecting the reservoirs in the Montgomery County portion of the Reservoirs watershed.

14.2.3 Recommendations

The presence or lack of buffers along streams in the Reservoirs watershed has been broadly characterized in the body of this document. Opportunities for strategic implementation of stream buffers are numerous. For example, planting of unbuffered riparian zones on lands set aside for protection through easements or planting of stream buffers within Green Infrastructure gaps can help resolve additional natural resources management challenges while enhancing water quality. An even better response would be targeting planting where all three parameters coincide: easements, Green Infrastructure gaps, and unbuffered riparian zones.

Figure 14-2 shows areas where existing easements, of any type, coincide with areas of unforested riparian zone (defined here as land within 50 meters on each side of the stream centerline, 100 meters total). Lands already designated with easements should offer less resistance to planting/ modification than other privately owned lands and therefore serve as a promising opportunity to enhance riparian vegetation.

Figure 14-3 shows locations where Green Infrastructure gaps coincide with unforested riparian zone. Green Infrastructure is defined by Maryland DNR as areas that:

> …provide the natural foundation needed to support diverse plant and animal populations, and enable valuable natural processes like filtering water and cleaning the air to take place. As urban and exurban development eliminate and fragment our remaining natural lands, it is critical to identify and focus protection on those areas we can least afford to lose. Identification and prioritization of the

green infrastructure is an ongoing process, as newer data and improved methodologies become available.

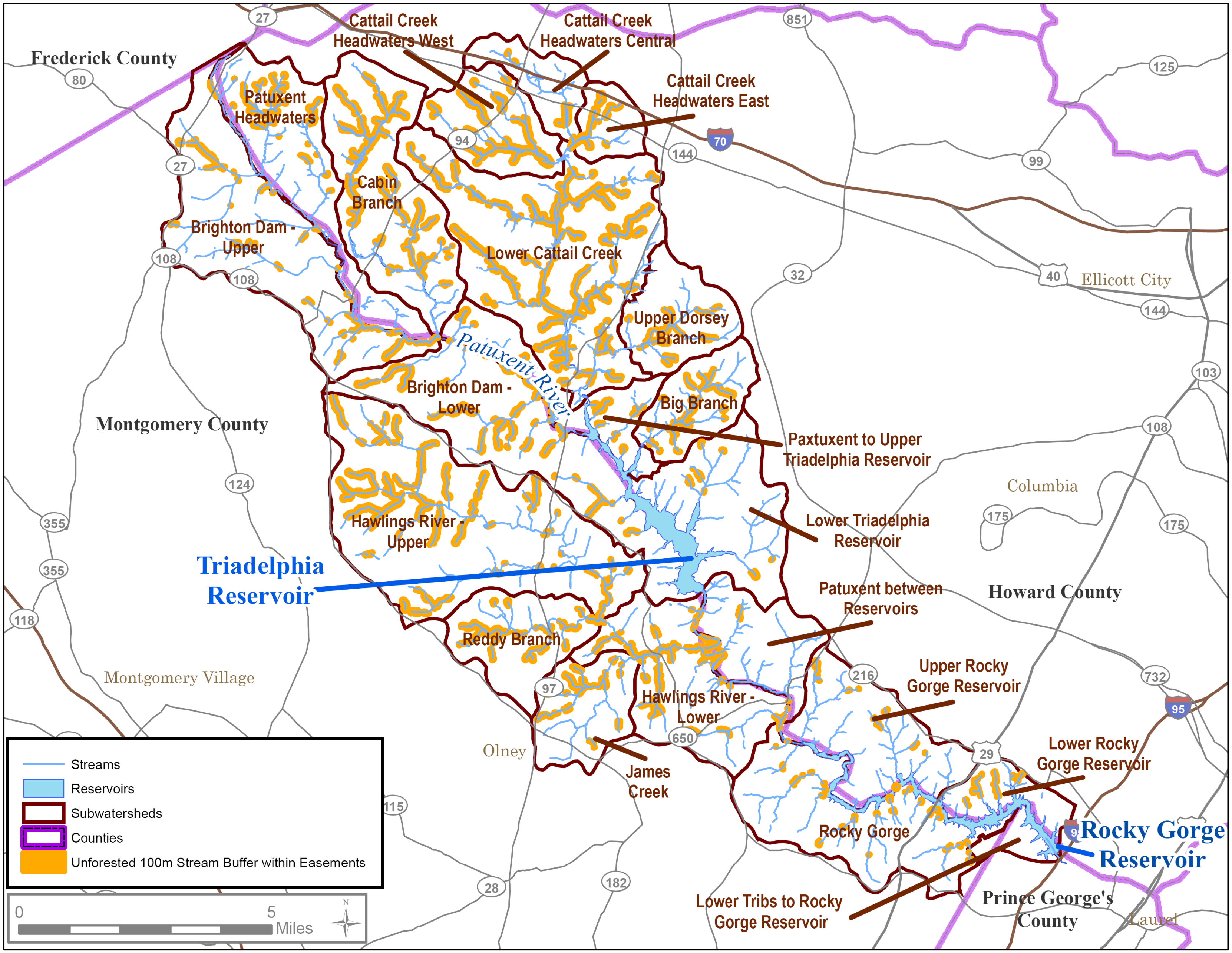


Figure 14-2. Areas where easements overlap unforested 100 meter riparian zone in the Patuxent Reservoirs watershed, Maryland (Howard County 2007 and 2008 data; Montgomery County 2008 data)

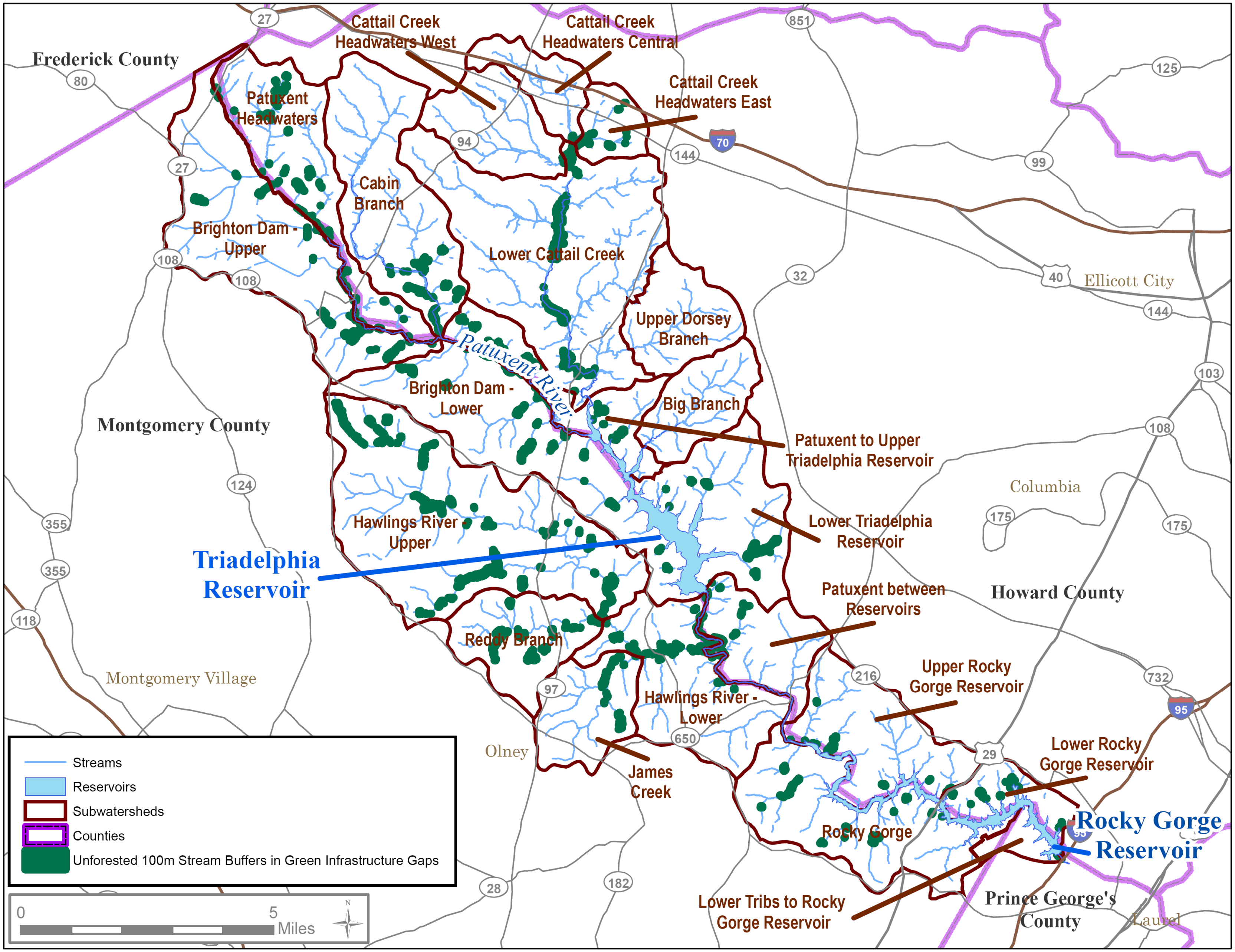


Figure 14-3. Areas where Green Infrastructure gaps overlap unforested 100 meter riparian zone in the Patuxent Reservoirs watershed, Maryland (DNR 2003 data, Howard County 2007 data; and Montgomery County 2008 data)

(For more information see: http://www.dnr.state.md.us/greenways/gi/overview /overview.html#what)

Targeting buffer creation within Green Infrastructure gaps allows the use of limited funds to accomplish multiple goals: protecting the reservoirs from polluted runoff and runoff quantities while creating contiguous forest tracts.

Locations where Green Infrastructure gaps, existing easements and unbuffered riparian zones coincide are shown in Figure 14-4. These locations offer a prime opportunity for investment of public funds and should be high on the list of action priorities for the TAC. As seen in Figure 14-4, both the Cattail Creek and Hawlings River subwatersheds provide good opportunities for action and are also subwatersheds which have been identified in the literature as important sources of pollutants to the reservoirs.

14.3 HEADWATER STREAMS

14.3.1 The Literature

Headwater stream networks have profound influences on larger streams, rivers and lakes (Ohio EPA 2003; Leopold 1994; Labbe and Fausch 2000; Meyer et al. 2007). According to Meyer et al. (2007), “the degradation and loss of headwaters and their connectivity to ecosystems downstream threaten the biological integrity of entire river networks.”

Meyer et al. (2007) described headwater streams as springs and intermittent first- and second-order streams. Headwater streams can be ephemeral, intermittent or perennial. Ephemeral streams are those that contain flowing water only after major rain events or for very short times during the year. Intermittent streams flow only during the wetter periods of the year. Perennial streams contain water year-round (Ohio EPA 2003). Headwater streams (first- and second-order intermittent and perennial) typically drain 55-85% of a watershed (Gregory, in United States Fish and Wildlife (USFWS) 2000)).

Additionally, Meyer et al. (2007) state that “The diversity of life in headwater streams (intermittent, first- and second-order) contributes to the biodiversity of a river system and its riparian network” and, “The influence of headwaters on downstream systems emerges from attributes that meet the unique habitat requirements of residents and migrants by offering: a refuge from temperature and flow extremes, competitors, predators, and introduced species; serving as a source of colonists; providing spawning sites and rearing areas; being a rich source of food; and creating migration corridors throughout the landscape.” Wallace (USFWS 2000) argues that as much as half of the organic carbon (the food source within aquatic systems) flowing through aquatic ecosystems originates as leaf litter in headwater streams that has been broken down and converted to more usable forms of carbon by the bacteria, fungi and invertebrates.

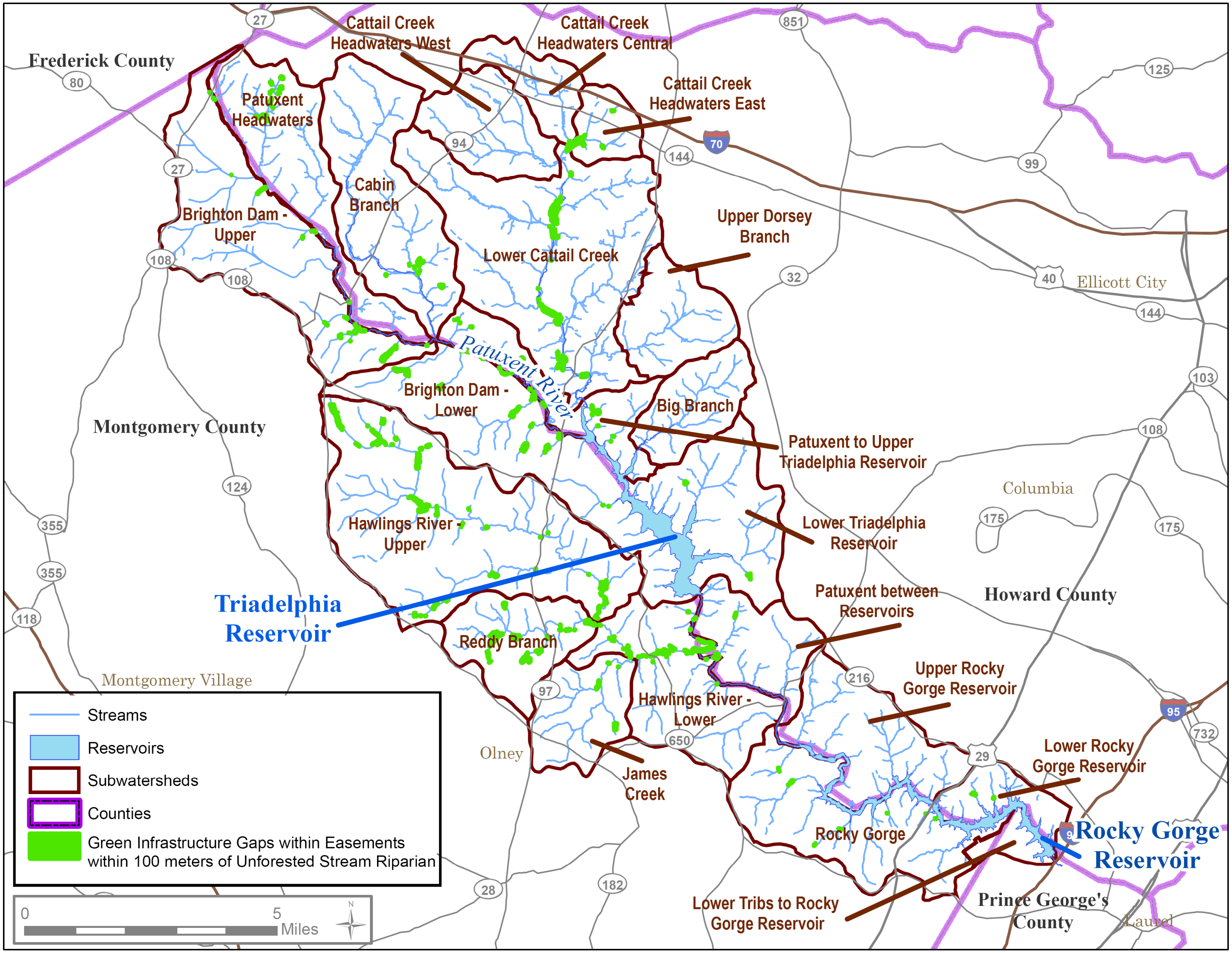


Figure 14-4. Areas where Green Infrastructure gaps overlap unforested 100 meter riparian zone and existing easements in the Patuxent Reservoirs watershed, Maryland (DNR 2003 data, Howard County 2007 data; and Montgomery County 2008 data)

It could be argued that Patuxent Reservoirs watershed headwaters play an important role in nutrient loading to the reservoirs. Both Mulholland et al. (2001) and Peterson et al. (2001) state that small size of the headwater streams ensures a greater water-sediment contact, which removes nitrogen from runoff via nitrification and denitrification by bacteria in the sediments. Sweeny (USFWS 2000) has calculated that if the nutrient reduction functions of these headwater streams were removed, it would be nearly impossible to successfully implement a nutrient reduction strategy in a watershed.

The Reservoirs' literature also recognizes the unique role of headwaters. The need to protect sensitive lands was cited as part of a multi-barrier approach in the 1995 Interim Report by Montgomery County DEP. The 2003 Olney and Vicinity Environmental Resources Inventory report prepared by M-NCPPC states that protection of headwater streams is dependent upon conservation areas set aside during the land development process. The 2004 Patuxent Reservoirs SWA prepared by MDE recommended expanding and managing publicly protected property in the watershed via source ("feeder stream") conservation easements and sensitive area conservation easements purchase by WSSC.

It is worth noting that the Montgomery County DEP and M-NCPPC jointly prepare a Countywide Stream Protection Strategy (CSPS), with updates every five years. The CSPS is a technical report and management tool. The CSPS evaluates stream conditions based upon aquatic life and stream channel habitat indicators in addition to typically applied stream chemistry measurements and documents the progress the County is making in addressing watershed management priorities originally identified in past CSPS reports. The next update, summarizing 2006, 2007 and 2008 data is due sometime in 2009 (http://www.montgomerycountymd.gov/-content/dep/Publications/pdf/CSPS2003.pdf).

14.3.2 Recommendations

It is recommended that the TAC add the protection of headwater streams to its list of Performance Measures and Goals for the Stream System Priority Resources and work with stakeholders to protect riparian zones along ephemeral, perennial and intermittent streams. We also recommend that the counties evaluate current stream network maps and assess whether improvements are warranted. If necessary, they should work to more accurately locate and map headwater streams to allow for more precise targeting of protection efforts. Figure 14-5 details first-order streams in the reservoirs watershed, which as one can see, are numerous in the two counties and equal 183 miles or 55% of the 330 total stream miles in the Patuxent Reservoirs watershed. Note that first-order streams do not account for all headwater streams, and so the actual percentage of headwaters is higher than 55%.

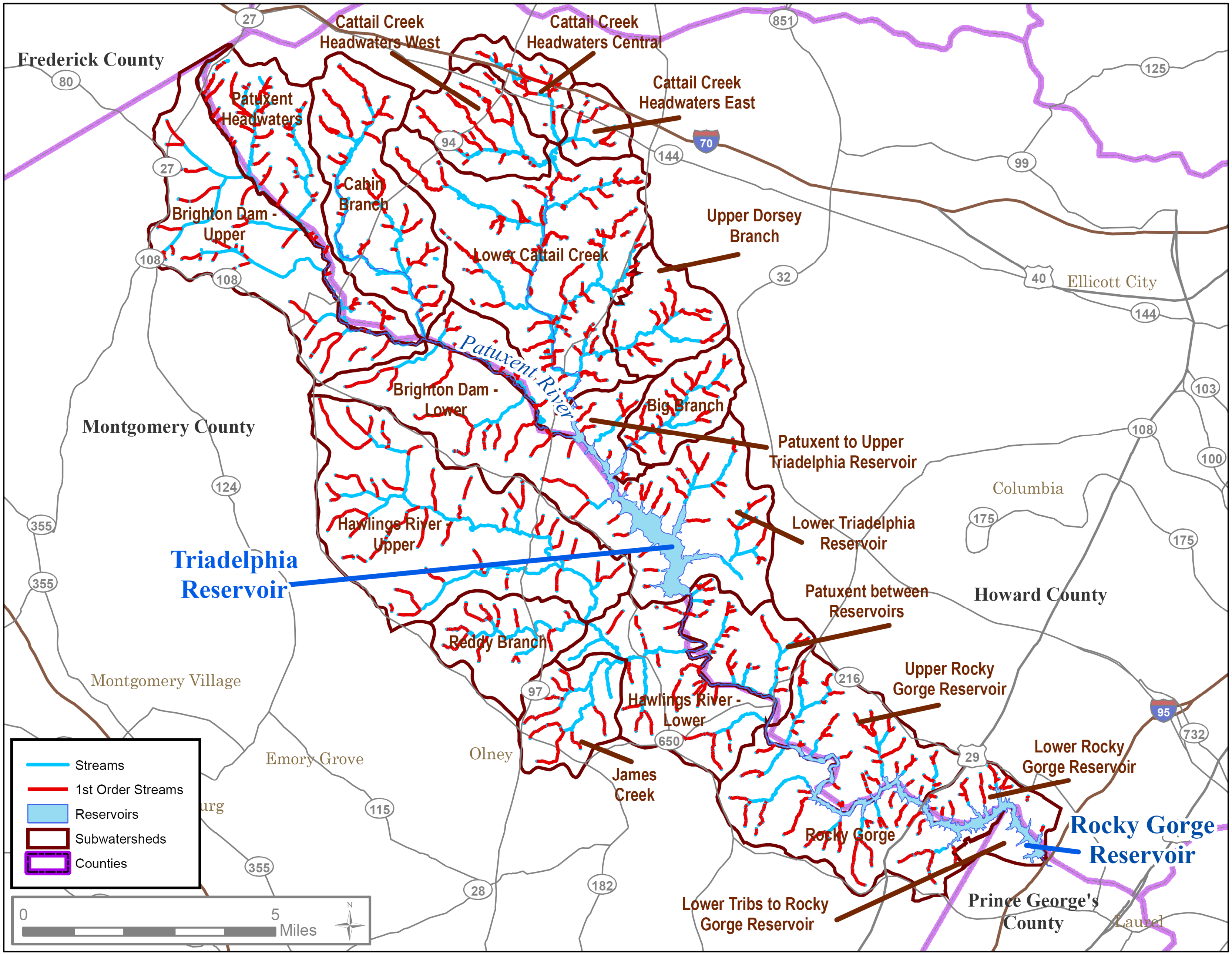


Figure 14-5. First-order streams in the Patuxent Reservoirs watershed, Maryland. First order streams constitute 183 miles or 55% of 330 total stream miles (Howard County 2008 data, Montgomery County 2008 data; and Prince George's County 2008 data)

14.4 ZONING AND LAND USE

The broad umbrella of zoning, recognition of its role in resource management, and its potential to positively impact the reservoirs is a common theme in the literature. As part of its 10 recommendations, the 1984 Patuxent River Policy Plan: A Land Management Strategy by the Maryland Department of State Planning called for accommodating future development to minimize impact on water quality, increasing recreation and open space, protecting forest cover and preserving agricultural land.

The concept of Primary Management Areas (PMAs) was created as part of the same 1984 Policy Plan in order to improve water quality in the Patuxent basin. PMAs are defined as transition areas between the stream and any development area. They are essentially a water quality protection and restoration area where land activities are regulated in order to enhance water quality in streams. The ultimate goal for the PMAs along the Patuxent River and its tributaries is to maintain low-density, low-intensity land uses within 1/4 mile of the mainstem, and within 1/8 mile of tributaries, and to actively establish a minimum 50-foot forested buffer strip along all streams. The PMA guidelines are applied to development projects which are submitted to M-NCPPC for subdivision and or site plan review, and are otherwise voluntarily implemented and strongly encouraged on remaining parcels throughout the watershed (http://www.montgomerycountymd.gov/deptmpl.asp?url=/content/dep/csps/watersheds/csps/html/lpat.asp).

Establishment of a PMA, within which developed densities are limited and extraordinary BMPs are used, was encouraged again in the 1993 Montgomery County Functional Master Plan for the Patuxent River Watershed prepared by M-NCPPC. This 1993 Master Plan also recommended that implementation of Montgomery County's forest conservation law be coordinated with agricultural stream buffer programs. PMAs within the Patuxent River watershed were also recommended to be given priority status for reforestation.

Establishment of impervious area restrictions within stream buffers, use of low density zoning (0.2-0.5 dwelling units per acre), required cluster development, and stormwater management even in very low density areas were cited as part of a multi-barrier approach in the 1995 Developing a Patuxent Reservoir Protection Strategy; Interim Report of the Patuxent Reservoir Protection Group written by the Montgomery County DEP.

The 2004 Patuxent Reservoirs SWA for WSSC Patuxent Water Filtration Plant by MDE recommended expanding and managing publicly protected property in the watershed via:

- Creation of source ("feeder stream") conservation easements and sensitive area conservation easements purchase by WSSC;
- Enhancement of County government programs for open-space and agricultural land preservation via the Agricultural Land Preservation Program in Montgomery and Howard County, and The Legacy Open Space Program in Montgomery County; and

- Acquisition of tributaries by the State park system.

The importance of zoning as a watershed management tool is recognized by the Montgomery County and M-NCPPC (2005) Land Preservation, Parks, and Recreation Plan. The Patuxent Riverkeeper, in the 2007 Patuxent River 20/20 report, recommended that local governments update their growth plans with clear standards for where and how growth should occur and where open space must be preserved. The Patuxent Riverkeeper suggested that zoning should be amended to accurately reflect those plans. Zoning in preservation areas should reflect that goal and allow minimal development, such as one dwelling unit per 25 acres for resource protection areas.

The 2007 Forest Conservation Plan for WSSC Reservoir Properties (DNR 2007) recommended restricted silviculture sites (referred to as “natural management”) within WSSC properties to include all lands within 100 feet of streams or reservoirs and soils on slopes greater than 25%, which are highly susceptible to erosion.

It is recommended that zoning and other development regulations, codes and ordinances be added to the TACs Priority Resources Chart and explored as tools with which to create and protect stream buffers, contiguous forests tracts, and other key natural resources. Existing zoning is useful as a tool to maintain the rural and agricultural character of the watersheds. Updates to local development regulations, codes and ordinances may provide an opportunity to increase protections for water resources such as wetlands, streams, and floodplains, and for increased forest conservation via the Forest Conservation Act.

14.5 STREAM CHANNEL RESTORATION

As defined by the Canaan Valley Institute (www.canaanvi.org), stream restoration is the re-establishment of the general structure and function of a stream system that existed prior to disturbance. While stream channel restoration is gaining popularity, the subject is not addressed much in the Patuxent Reservoirs literature reviewed here. The 2003 Hawlings River Watershed Restoration Study states that the most effective way to restore degraded streams in the Hawlings River watershed would be via a watershed-wide targeted implementation of stream channel restoration and not just focusing on degraded streams in developed areas.

Channel restoration could certainly help facilitate meeting the sediment TMDL by reducing scour, an important source of sediment (as well as phosphorus associated with stream sediments) in the Triadelphia Reservoir, by creating morphologically stable channels. Channel restoration could also help meet the TMDL for phosphorus in both reservoirs, because of the linkage of phosphorus to sediment, and to perhaps, a lesser extent, by restoring biological functions of these aquatic systems with the expectation that biologically available phosphorus would be assimilated before reaching the reservoirs. As mentioned previously, scour accounts for 28% of total phosphorus input to the Triadelphia Reservoir, 8% of total phosphorus to the Rocky Gorge Reservoir, and 38% of sediment to the Triadelphia Reservoir. However, it is important to note that successful stream channel restoration requires that the contributing watershed conditions be considered carefully if rehabilitation of discrete segments is to be successful.

The TAC does prioritize “Stream Systems” in its 2008 Priority Resources Chart with specific reference to the control of “severe” and “very severe” bank erosion via channel restoration to the “maximum extent possible”.

Some isolated projects have already taken place in the Reservoirs watershed. A recent notable urban stream channel rehabilitation success story is the Cherry Creek stream restoration as well as streamside fencing programs and stormwater ponds construction, as summarized in the 2008 TAC Annual Report:

> Howard County continues to improve the Cherry Creek watershed, which drains directly to the Rocky Gorge Reservoir. Cherry Creek has degraded due to unmanaged stormwater runoff in the headwaters of the watershed. Stream bank and channel erosion are recognized as contributing a significant sediment load to the water supply reservoir. Howard County has completed a comprehensive watershed study of Cherry Creek and identified three stream reaches in need of restoration.
>
> Reach 1 – Using a $25,000 grant from the Maryland DNR and $37,600 from the CBT, the County restored 300 linear feet of headwater stream and also constructed three new storm water management ponds in the headwaters. Construction of the ponds and the stream restoration was completed in early 2006.
>
> Reach 2 is a 600 linear foot stream channel located near the Scotts Cove boat launch. This reach is unstable, with grade control problems and high bank erosion rates. The design for restoration of this reach is complete, with construction scheduled to begin and end in Fall/Winter of 2008 (Fiscal Year [FY]09). The project construction cost for the restoration of this reach is estimated as $330,000. A pre-application was submitted to MDE requesting $165,000 in a Small Creeks and Estuaries Restoration Program grant; the remaining funds will be provided by Howard County.
>
> Reach 3 is a 250 linear foot stream channel located upstream of the Harding Road culvert. The channel is relatively straight with a fairly high channel slope. In the lower section the channel is incised, having vertical stream banks and no riparian buffer. Implementing a meander pattern to increase sinuosity will necessitate relocation of a sewer line. The project cost for both design and construction is estimated at $300,000. Design is planned to begin in FY09, with construction in FY11. (Taken from 2008 TAC Annual Report)

The 2003 Hawlings River WRAP created concept designs for 12 candidate stream bank stabilization and buffer enhancement projects on 15 of the total 98.2 stream miles in the Hawlings River watershed, as shown in Figure 12-2.

It is recommended that TAC member agencies coordinate with the USFWS Chesapeake Bay Field Office. The Chesapeake Bay Field Office is a leader in the restoration field, a good source of information and technical assistance and situated nearby in Annapolis MD. USFWS has various projects in the region, both suburban and highly urban (Watts Branch, Oxon Run and Hickey Run all in Washington D.C., for example). Information on these projects is viewable at: http://www.fws.gov/chesapeakebay /streampub.html.

It could be argued that restoration of some stream segments in the Patuxent Reservoirs watershed might only be possible by physical alteration of degraded channels, however the extremely high cost and need for intimate coordination between county, state and sometimes federal agencies makes implementation of these projects challenging. It is recommended that the TAC continue to identify stream segments for channel modification/restoration, particularly to address the new TMDL for phosphorous and sediment.

14.6 INVASIVES PLANT CONTROL AND DEER MANAGEMENT

As stated in the 2007 WSSC Forest Conservation Plan, "The goal of conserving reservoir forests for water quality means…promoting healthy multi-layer stands with advanced regeneration for quick forest recovery following major unavoidable disturbances". Invasive plants and insects pose a significant risk to forest health. This certainly holds true for forests throughout the Patuxent Reservoirs watershed. Control of invasive plants is cited in at least three documents reviewed here: the 2004 Patuxent Reservoirs SWA for WSSC by MDE, the 2007 Forest Conservation Plan and the 2003 Hawlings River WRAP which cites invasives as a major issue in Hawlings River watershed.

Hairston-Strang (DNR 2007) found seven invasive species to be extensively distributed and potentially problematic for tree seed germination and seedling survival in WSSC forests: ailanthus (*Ailanthus altissima*), vine honeysuckle (*Lonicera japonica*), oriental bittersweet (*Celastrus orbiculatus*), multiflora rose (*Rosa multiflora*) Japanese stiltgrass (*Microstegium vimineum*), porcelainberry (*Ampelopsis brevipedunculata*) and mile-a-minute (*Polygonum perfoliatum*).

The challenge of invasives was recently noted in the 2008 TAC Annual Report, detailing challenges associated with a riparian buffer planting in the Hawlings River Subwatershed.

> M-NCPPC and DEP staff have had to return to the project to control invasive plants, primarily mile-a-minute and stilt grass. The coordination is ongoing through the 2008 growing season, but the survivability of the trees and shrubs will depend upon a strong long-term plan for controlling mile-a-minute. The existing

> upstream seed bank for invasives and their continued delivery during flooding events will deposit seed into the floodplain indefinitely. A riparian buffer was installed by M-NCPPC in March 2008 in the upper reaches of the Reddy Branch tributary to the Hawlings. Volunteers from the Sandy Spring Friends School also participated.

With respect to stream buffers, the literature is not extensive on the effect of invasives on buffer integrity. According to Schueler et al. (2000),

> A vegetative target has several management implications. First, if the streamside zone does not currently meet its vegetative target, it should be managed to ultimately achieve it. For example, a grassy area should be allowed to grow into a forest over time. In some cases, active reforestation may be necessary to speed up the successional process. Second, a vegetative target implies that the buffer will contain mostly native species adapted to the floodplain. Thus, non-native or invasive tree, shrub and vine species should be avoided when revegetating the buffer. Removal of exotic shrubs and vines (e.g., multiflora rose or honeysuckle) that are often prevalent along the buffer edge should be encouraged.

These same three reports also mention the need for deer management. The 2007 WSSC Forest Conservation Plan summarizes the importance of proper deer management:

> Deer browse also takes a toll on the ability of native forests to regenerate naturally (DeCalesta and Stout 1997; Waller and Alverson 1997; Alverson et al. 1988). Deer preferentially browse tree seedlings and can dramatically affect species available for regenerating the next forest (Seagle and Liang 2001). In the Quabbin Reservoir Forest of Massachusetts, deer densities of more than 15/sq. mi. during hunting prohibitions limited tree regeneration below acceptable levels of 2000 seedlings/acre; four years after controlled hunting began, tree regeneration increased to sustainable levels (Barten et al. 1998). Deer also interact with invasive species to limit forest regeneration, from actively spreading seeds of invasive plants (Williams and Ward 2006) to eliminating species like oaks that do not thrive following establishment of invasive plants even after deer browse is reduced (de la Cretaz and Kelty 2002). Active forest and wildlife management are needed even to maintain the traditional native forest types and encourage healthy tree regeneration (Ozier et al. 2006). (DNR 2007)

Hairston-Strang (DNR 2007) goes on to say that, "Deer and elk, as well as other species, have been found to spread disease organisms like Giardia and Cryptosporidium; bacterial counts of indicator organisms increased with increasing population densities (Tiedeman 2000)." According to Hairston-Strang (DNR 2007), WSSC began a deer management program in 2000 and has expanded acreage eligible for managed hunts over the ensuing years to limit ecological damage from large deer herds.

The TAC has made clear the importance of these two issues as part of the Terrestrial Habitat Resource Priority list. The Forest Conservation Plan for WSSC Reservoir Properties (DNR 2007) makes some recommendations for invasive plant management and asks for expanding control of deer population using WSSC preferred strategies. The TAC needs to coordinate with DNR, the largest public lands holder (56.8% of public lands) and Howard and Montgomery County (together holding 25.3% of public lands in the watershed) to coordinate and develop strategies for invasives and deer management, in light of the new TMDL and the known deleterious impact of invasives and deer on forest regenerative capacity and stream buffer/floodplain stability.

14.7 URBAN STORMWATER MANAGEMENT

14.7.1 The Literature

The need to address the harmful effects of urban stormwater has been recognized in the literature numerous times. As part of its 10 recommendations, MDP's 1984 Patuxent River Policy Plan: A Land Management Strategy called for retrofitting existing development with BMPs. Enhancement of BMP effectiveness was cited in the 1993 Montgomery County Functional Master Plan for the Patuxent River Watershed prepared by M-NCPPC.

The 1996 Patuxent River Water Resources Reconnaissance Study by USACE cites inadequate stormwater management as a recurring problem in the watershed which is causing streambank erosion and degraded habitat due to unmanaged stream flow, submerged aquatic vegetation habitat degradation, and accelerated shoreline erosion and associated habitat degradation. The 2003 Hawlings River WRAP cites the need for urban BMPs in the Hawlings River.

The 2007 Patuxent Riverkeeper's Patuxent River 20/20 report recommends that State and local governments make significant changes to their stormwater management regulations to require green development practices to mitigate the impact of polluted runoff, as required by recent legislation. It is appropriate to note here that Maryland's 2000 stormwater management regulations aimed to improve stream channel protection and groundwater recharge. The 2007 Maryland storm management regulations are even more robust. Highlights of those changes in the latest design manual (MDE 2009) include:

- Measure the amount of impervious cover created by the development.
- Determine if the proposed land use or activity at the site is designated as a "stormwater hotspot."
- Determine the Use Designation of the receiving water and the condition of the watershed.
- Provide a volume that mimics the natural rate of groundwater recharge using structural and/or nonstructural BMPs (Rev).

- Implement Environmental Site Design (ESD) to the maximum extent practicable (MEP) to mimic predevelopment conditions.
- Follow a specific design process to implement a comprehensive site development plan.
- Provide water quality and recharge volume storage using approved ESD practices.
- Use ESD practices to the MEP to provide channel protection volume (Cpv) storage. Any remaining Cpv storage requirements must be addressed using approved BMP options that can meet pollutant removal targets.
- Ensure that the BMP selected meets specific performance criteria with respect to feasibility, conveyance, pretreatment, treatment, landscaping and maintenance.
- Follow new geotechnical testing procedures and provide the contractor with formal construction specifications.
- Consider where the BMP is located in relation to natural features and development infrastructure.
- Consider innovative site planning techniques that can reduce both the size and cost of stormwater practices.
- Include operation and maintenance information on approved stormwater management plans.

In addition, Montgomery County is currently studying options to meet the expanded requirements of the third round of its National Pollution Discharge Elimination System (NPDES) MS4 permit by developing a coordinated implementation strategy to meet TMDL targets and control runoff on an additional 20% impervious areas, using Environmental Site Design (ESD) to the Maximum Extent Practicable (MEP). The permit also requires that the county meet the trash reduction requirements of the Trash Free Potomac Watershed Initiative 2006 Action Agreement, which calls for "the unified goal of a Trash Free Potomac Watershed by 2013." The countywide strategy will include identification of additional restoration projects, BMPs, and other ESD practices to meet these goals within individual watershed implementation plans.

This nascent effort in Montgomery County has the potential to positively impact the Patuxent Reservoir watershed, particularly the Rocky Gorge Reservoir watershed, which is primarily drained by land in Montgomery County. Montgomery County is developing various tools which may assist in addressing stormwater more effectively. They include:

- A guidance for completing watershed assessments;
- A general guidance that that will serve as an overall framework for completing watershed implementation plans;
- A public education and stewardship work plan that links outreach priorities and needs across the watershed groupings;

- A countywide implementation strategy summary that will serve as a guide for Montgomery county's watershed management and restoration programs for the next five years;
- Recommendations to promote the use of ESD/LID techniques to the maximum extent practicable; and
- Development of a recommended definition of "maximum extent practicable" for BMP implementation in the County

Findings and specific project recommendations that result from Montgomery County's efforts will be of direct benefit to the County's portion of the Patuxent Reservoirs watershed. Also, it is recommended that the TAC pay special attention to lessons learned and advances by Montgomery in this third round of their permit, as some of these approaches may serve as a model for MS4 implementation in Howard County as well.

14.7.2 Urban Stormwater Loads

While land use in the Patuxent Reservoirs watershed is only about one-third residential plus commercial plus industrial and only 6% impervious on average, developed land uses are contributing 9% of phosphorus loads to the Triadelphia Reservoir and 18% to the Rocky Gorge Reservoir according to ICPRB modeling (ICPRB 2007).

Two municipal separate storm sewer systems discharge phosphorus and sediment to the Triadelphia Reservoir watershed: Howard County and Montgomery County. These same two MS4s and Prince George's County also discharge phosphorus to the Rocky Gorge Reservoir watershed (MDE 2008 Point Source Tech Memo). Tables 14-1 and 14-2 detail the total phosphorus and sediment load contributions from these permitted MS4s, which account for all developed lands contributions in the TMDL. Note that the TMDLs are based upon average annual total loads for the simulation period 1998-2003. As shown in Table 14-1, Howard County is contributing significantly more phosphorus from its MS4 to the Triadelphia Reservoir compared with Montgomery County's MS4. The Rocky Gorge Reservoir is receiving significantly more total phosphorus from Montgomery County's MS4 than any other point source as noted in Table 14-2. Note however that 73% of the Triadelphia Reservoir watershed is within Howard County while about 76.5% of the Rocky Gorge Reservoir watershed is within Montgomery County (Table 4-1). This helps in part to explain the disparity in phosphorus loadings from each county's MS4 in each reservoir watershed.

Table 14-1. Total phosphorus and sediment loads attributed to MS4 point sources in the Triadelphia Reservoir total phosphorus (TP) and sediment TMDLs (MDE Point Source Tech Memo 2008)

Point Source Name	Permit Number	TP (lbs/year)	Sediment (tons/year)
Howard County	MD0068322	4,672	354
Montgomery County	MD0068349	616	47
Total		5,288	400

Table 14-2. Total phosphorus loads attributed to MS4 point sources and the US FEMA Waste Water Treatment Plant (WWTP) in the Rocky Gorge Reservoir total phosphorus (TP) TMDL (MDE Point Source Tech Memo 2008)

Point Source Name	Permit Number	Nutrient Loads (lbs/year)	Flow (MGD)	Concentration (mg/l)
		TP		TP
FEMA WWTP	MD0025666	182	0.01	6.0 mg/l
Howard County	MD0068322	1,512		
Montgomery County	MD0068349	5,581		
Prince George’s County	MD0068284	154		
Total		7,429		

14.7.3 Stream Scour

Modeled loads of total phosphorus and sediment resulting from stream scour are a significant as seen in Figures 8-2, 8-3 and 8-4. Scour accounts for 28% of total phosphorus to the Triadelphia Reservoir, 8% of total phosphorus to the Rocky Gorge Reservoir, and 38% of sediment to the Triadelphia Reservoir. Scour is often the result of changes in volume and times of concentration of stormwater discharges to stream channels due to increased imperviousness of the contributing drainage area. Scour can also be caused by agricultural practices such as clearing and plowing of fields to the stream edge in addition to allowing farm animals free access to the stream. While the scoured sediment may not be considered a point source, its cause is often associated with point sources (e.g., pipe outfalls into streams) of urban and suburban stormwater. As such, this significant source of impairment can be conceptualized as an urban and suburban stormwater control challenge which could be addressed through strategic retrofits or enhancement of existing flood control ponds to better protect from channel erosion and scour. Small tributaries and headwater streams are particularly susceptible to scour.

14.7.4 Dry Pond Modification

The foresting of stormwater flood control and channel protection dry ponds (often referred to as "detention" ponds, Figures 14-6 and 14-7) and even modification of those ponds for actual quality control, is a cost efficient way to make the existing BMPs more effective. Even more significant is that this strategy does not require acquisition of new property, easements, permits, nor repaving/regarding to route stormwater to a new BMP. Even simple planting within or around the pond facilitates stormwater infiltration and treatment and can help moderate stormwater temperatures released to receiving streams.

Both Fairfax County, VA, and the Town of Leesburg in Loudoun County, VA, have embraced this approach. Fairfax County has developed an Interim Policy Regarding Tree Preservation and Planting in and Around Stormwater Management Ponds. (http://www.fairfaxcounty.gov/dpwes /publications/combpol.pdf) The Town of Leesburg in conjunction with the Piedmont Environmental Council did its first flood control pond planting in November of 2008. See: http://www.leesburg2day.com/articles/2008/11/19/news/-fp358tree111908.txt, http://www.leesburg2day.com/articles/2008/12/10/news/leesburg/-8979tree111908.txt and http://greenerloudoun.wordpress.com/2008/11/13/nov-22-plant-a-tree-to-reduce-pollution-help-clean-our-water-and-give-wildlife-a-home/. An educational brochure was created (Appendix D Educational Brochure) for the lay public specifically for this purpose.

Figure 14-7 shows an example of a modified detention pond with updated design features including a forebay, meandering channel, a deep pool at the end of the device as well as plantings throughout. This type of effort is more intensive and costly than a simple planting of a dry pond. In addition, it would likely require permits in most jurisdictions to address the need for new engineering calculation. It is more effective than a simple tree planting and still less expensive than retrofitting new BMPs on existing properties.

In another example, highlighted as a success story by EPA Region III, the Pennsylvania Coastal Zone Management Program and Growing Greener Program jointly funded a NPS pollution control project in Lower Southampton Township, in Bucks County of Pennsylvania. Alternative mowing practices were instituted in order to allow the return of natural vegetation along a residential development's detention ponds. Interestingly, local volunteers from the township accomplished most of the planting. As evidence of the project's success, the landscape architect with the firm hired to carry out the project recently received the Planning and Analysis Merit Award from the American Society of Landscape Architects. (For additional information see: http://www.epa.gov/reg3wapd/stormwater /success.htm#sweetwater).

Flood control and channel protection dry pond modification offers not only a tremendous opportunity to cost-effectively improve stormwater quality but also the opportunity to interactively educate the public about watersheds, stormwater, the role of stormwater ponds and innovative BMPs. In addition, planting of dry ponds can:

Figure 14-6. Photographs of typical detention ponds with low flow channel

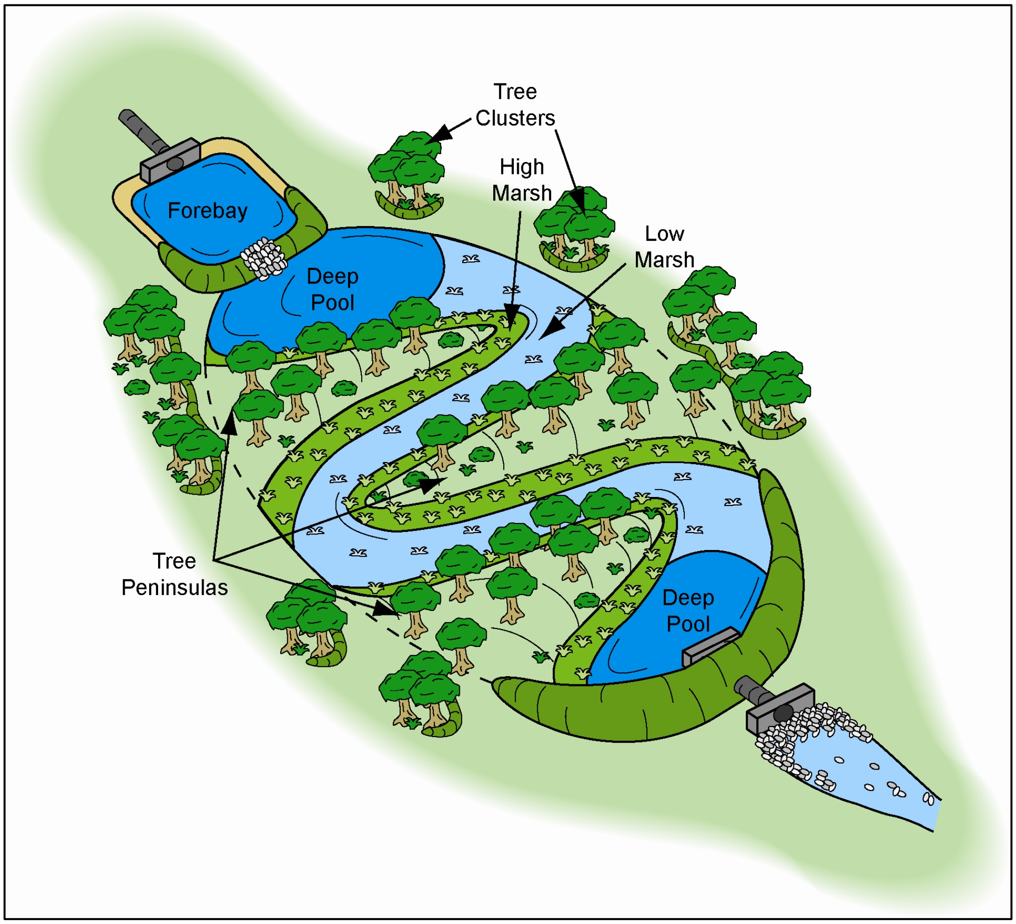


Figure 14-7. Conceptual drawing of modified dry pond by Matt Arnn of the USDA Forest Service

- Increase property values by increased aesthetic value;
- Help meet tree canopy goals;
- Reduce maintenance costs associated with mowing of ponds;
- Provide air quality benefits;
- Create wildlife habitat; and
- Moderate temperature of storm water prior to entering tributaries.

Additionally, many of the same tools used for reducing phosphorus and sediment loading to waterbodies are simultaneously effective at managing other nutrients and common pollutants such as heavy metals, pesticides, oil, grease and floatables.

It is recommended that the TAC include urban stormwater management in the "Measures" used to protect the "Stream System Resource" in its list of Priority Resources. Additionally, the TAC should identify a list of dry ponds available for planting in Montgomery

County and coordinate with the Department of Environmental Protection to expedite planting around wet and dry ponds and within the ponds. A subsequent step could be modification of a flood control or channel protection dry pond for water quality control, as a demonstration project within the Reservoirs watershed. Note that Howard County has already conducted an assessment of ponds available for retrofit and found very few opportunities existed in this rural watershed (S. Overstreet, Howard County Department of Planning and Zoning, pers. comm.).

14.8 ON-SITE SEPTIC WASTE WATER TREATMENT

The threat to the Reservoirs watershed by septic systems has been acknowledged numerous times in the literature and predictions on the proliferation of these systems made a decade ago were done with good accuracy, as summarized in Section 10.

Montgomery, Prince George's and Howard Counties need to work with MDE to assist homeowners in upgrading failing septic systems to use best available nitrogen removal technology, perhaps via designation of a new "Patuxent Reservoirs Critical Area", similar to the Bay-wide Critical Area which includes all land within less than 1000 feet of tidal waterways and in the spirit of Maryland's new Senate Bill 554, "Chesapeake Bay Nitrogen Reduction Act of 2009" and the cross-file Maryland House Bill 176, the "Bay Restoration" Act of 2009. These two Bills prohibit the installation of on-site sewage disposal system in the Chesapeake Bay and Atlantic Coastal Bays Critical Area on new construction, and prohibit the replacement of on-site sewage disposal systems in the Critical Area, unless the system utilizes nitrogen removal technology. It requires MDE to assist homeowners in paying for specified costs under specified circumstances, and establish penalties and enforcement mechanisms (http://mlis.state.md.us/2009rs/billfile/sb0554.htm).

Efforts could begin by targeting the approximately 7974 on-site septic systems within 1000 feet of tributaries to the Patuxent Reservoirs. A smaller threshold, such as 500 feet, could be used initially as only half the number of systems (3931) would need to be targeted. Table 14-3 shows the total number of on-site septic systems by subwatershed as well as the number of systems which might be targeted for modernization in each subwatershed at the 500 (500 feet on each side) and 1000 (1000 feet on each side) foot threshold. Note that the James Creek subwatershed has a significant number of systems despite also being served by a sanitary sewer.

14.9 PROGRAMMATIC RECOMMENDATIONS

14.9.1 Prior Programmatic Recommendations

As part of its 10 recommendations, the 1984 Patuxent River Policy Plan: A Land Management Strategy written by the MDP, called for adopting an Annual Action Program. The primary recommendation of the 1993 Montgomery County Functional Master Plan for the Patuxent River Watershed prepared by M-NCPPC was the establishment of an interjurisdictional tri-county (Prince George's, Howard, and Montgomery) working group to implement and oversee an ongoing water quality monitoring program.

Table 14-3. Total number of on-site septic systems by subwatershed in the Patuxent Reservoirs watershed and the number of on-site septic systems within 500 and 1000 feet of a tributary to the Patuxent Reservoirs, Maryland, in 2008 (data provided by MDE)

Subwatershed	County	# of On-Site Septic Systems within 0-500 ft of a Tributary (500 ft on each side)	# of On-Site Septic Systems within 0-1000 ft of a Tributary (1000 ft on each side)	Total # On-Site Septic Systems in the entire Subwatershed
Cattail Creek Headwaters Central	Howard	37	107	206
Patuxent Headwaters	Howard	60	130	205
Cabin Branch	Howard	112	251	403
Cattail Creek Headwaters West	Howard	95	234	307
Cattail Creek Headwaters East	Howard	28	97	189
Big Branch	Howard	94	188	237
Patuxent between Reservoirs	Howard	176	361	473
Lower Cattail Creek	Howard	270	551	816
Upper Dorsey Branch	Howard	122	286	504
Lower Triadelphia Reservoir	Howard	160	404	641
Patuxent to Upper Triadelphia Reservoir	Howard	25	61	100
Lower Rocky Gorge Reservoir	Howard	247	427	437
Upper Rocky Gorge Reservoir	Howard	195	432	561
Brighton Dam - Upper	Montgomery	122	371	676
Brighton Dam - Lower	Montgomery	32	101	206
Hawlings River - Upper	Montgomery	205	535	743
Hawlings River - Lower	Montgomery	234	617	878
Reddy Branch	Montgomery	32	78	119
Rocky Gorge	Montgomery	165	468	717
James Creek	Montgomery	1519	2274	2440
Prince George's County Portion	Prince George's	1	1	29
Total		**3931**	**7974**	**10887**

The 1997 Comprehensive Management Planning Study for the Patuxent Reservoir Watershed by Tetra Tech Inc. recommended workgroup activities that support and coordinate watershed data management and data exchange among the signatories to the 1996 Patuxent Reservoirs Watershed Protection Agreement. MDE's 2004 Patuxent Reservoirs SWA report recommended strengthening the Patuxent Reservoirs Watershed Protection Agreement of 1996 by implementing the recommendations from the same 1997 Comprehensive Watershed Management Planning Study.

With regards to specific WSSC properties and activities, Hairston-Strang (DNR 2007) recommended "A technical advisory committee versed in forest management and techniques for source water protection through forests and forestry" and "Trained foresters should oversee forest management operations to assure that silvicultural treatments are appropriately applied."

NOAA surmised in its 2007 report (Managing Patuxent River Water Quality: Looking Beyond Science and Politics to the Economics of Decision-making) that county-level data about how water quality policies are implemented and their successes or failures are not adequate to support meaningful review or justify policy change. The authors stated that most counties do not keep records in a way that allows consistent comparisons of how much county spending and man-power are allocated to enforce environmental laws compared to other jurisdictions. The authors also found that the economic base and source of nutrient discharges and implementation of nutrient discharge policies differ significantly from county to county.

14.9.2 New Programmatic Recommendations

In light of past recommendations, we reiterate that the TAC and the Patuxent Reservoirs Watershed Protection Group should work to standardize the metrics on watershed policy effectiveness in order to allow direct cross-jurisdictional review.

It is recommended that the Maryland Department of Transportation/State Highway Administration and other government entities charged with maintenance of roadways become active members in the TAC, given the contribution of highway and local road surfaces to both water quantity and water quality impairment. The appropriate government agencies should be invited to strategize with the TAC on implementation of innovative stormwater management.

Additionally, inclusion of county arborists on the TAC might expedite efforts to plan buffer planting. Inclusion of an honorary TAC member from the National Arbor Day Foundation, for example, could assist in these same efforts.

14.10 EDUCATION AND OUTREACH

As one might expect, education and outreach to the public is a repeating theme in the literature. The need for public education programs targeted to watershed residents was cited as part of multi-barrier approach by Montgomery County DEP (1995). In 1995, Save Our Streams (SOS) was awarded a $6000 grant by the Montgomery County DEP to develop a one-year marketing plan, with budget, to educate the public and to hold one town meeting. The marketing plan was meant to be implementable by the lay public as one part of a long-term comprehensive watershed management strategy.

The 1997 Comprehensive Management Planning Study for the Patuxent Reservoir watershed recommended expanding public outreach activities and public participation**.** The 2003

Hawlings River WRAP cites need for outreach and education in the Hawlings River watershed. The 2004 Biological Assessment of Rocky Gorge, Hammond Branch, and Dorsey Run Watershed report also recommended implementing public outreach strategies.

The Maryland Green Schools Program mentioned above, although not specific to the Reservoirs watershed, is an excellent State-wide initiative and approximately half of the schools within the Patuxent Reservoirs watershed are participating in that program.

The TAC Outreach Committee under the coordination of WSSC outreach staff has organized a wide variety of activities specific to the Reservoirs watershed. For example, as noted in the 2007 TAC Annual Report, activities include:

- Earth Month celebrations in April 2008, which included hosting numerous activities for families, local residents and school children;
- Volunteer opportunities which included two cleanup days in April;
- Source water protection programs for children at three county libraries attended by 139, plus library staff;
- Speakers programs/workshops at the Brighton Dam Visitors Center;
- Family Watershed Day on April 21 at the Supplee Lane Recreation Area, with 60 plus attendees which included canoe/kayak instruction provided by the M-NCPPC staff with canoes and kayaks and supervised fishing;
- A charity bike ride and fundraiser on April 28, 2007 at the Brighton Dam/Triadelphia Reservoir with 50 riders;
- Outreach events to the general public in Damascus during 2008 by the Montgomery County DEP and Montgomery County Department of Public Works & Transportation in coordination with the Izaak Walton League of America-Wildlife Achievement Chapter. This included their annual spring watershed clean-up, their annual fall watershed clean-up, workshops on nest boxes, 'make and take' rain barrels and invasive plant management.

The TAC is making a reasonable effort at outreach and education as noted by its list of accomplishments, its designation of a committee focused on outreach activities as well as fulltime outreach staff at WSSC. It is recommended that education and outreach be targeted strategically in subwatersheds with strong potential for improving water quality conditions, such as the Cattail and Hawlings River watersheds. Populations residing around headwater streams as well as watersheds of high population density and high imperviousness might also be targeted.

14.11 INSPECTION AND ENFORCEMENT

The NOAA (2007) report prepared by UMCES is the only document reviewed here that focuses specifically on inspection and enforcement activities. The subject was touched upon as early as 1981 in a study for WSSC by Ecological Analysts Inc., which called for the counties, in cooperation with the USDA Soil Conservation Service (NRCS as of 1994) to institute and enforce stormwater volume controls and retention basins. The Patuxent Riverkeeper’s 2007 Patuxent River 20/20 report concluded that state and local governments should appropriate sufficient funding to aggressively enforce critical area, wetland, stormwater, and erosion laws to protect stream buffers from human impact.

While the NOAA (2007) findings are not specific to the Patuxent Reservoirs watershed, they are specific to the Patuxent River and include county-specific analysis. The following two sections are a synopsis of sections of that document relevant to the Patuxent Reservoirs watershed.

The NOAA report presented enforcement activities and analysis into three categories relevant to this effort. Erosion and sediment control (ESC) for construction activity, permit enforcement of point source discharges (i.e., NPDES permits), and agricultural programs enforcement.

14.11.1 Erosion and Sediment Control

As highlighted by NOAA (2007), participants in a joint MDE/MDP conference in the Fall of 2005 recommended that MDE seek increases in state funding to supplement the number of staff that enforce sediment and erosion control.

Howard, Prince George’s, Montgomery and Anne Arundel Counties are fully delegated by the State of Maryland to enforce ESC regulations. Some municipalities within Montgomery and Prince George’s Counties are also delegated, although these may be outside the Patuxent Reservoirs watershed.

MDE also has a memorandum of understanding with the MDA for enforcement on agricultural land. In some instances, MDE can take enforcement actions on agricultural land, and they have done so, including in the Patuxent River watershed, but it is rare. Given the importance of agriculture to sediment loading (as indicated in Table 11-4), the issue of ESC in agriculture needs to be considered for more detailed analysis.

In Maryland, county SCDs are being asked to do inspections for MDE on development projects, although they do not have a formal enforcement role. MDE has asked them to “be MDE’s eyes on development projects”, according to one MDE Water Management Administration staffer. According to the NOAA (2007) report, maintenance of ESC efforts are still a problem in the State, as opposed to getting plans and permitting in place.

Some metrics used in the NOAA (2007) report to generate conclusions on the fully delegated counties and how well staffed they are relative to the regulatory challenge at-hand include comparisons of metrics across entire counties such as total permits per inspector: 245 in Prince George's County, 57 in Anne Arundel County, 44 in Montgomery County, and 26 in Howard County; comparison of active permits per inspector: 94 in Prince George's County, 87 in Anne Arundel County, 40 in Montgomery County, and 15 in Howard County; and disturbed acreage of permits per inspector: 823 in Prince George's County, 556 in Anne Arundel County, 315 in Montgomery County, and 51 in Howard County. In all cases, both Howard and Montgomery County showed more effective coverage than Prince George's and Anne Arundel.

MDE tracks the total number of inspections, as well as the number of inspections per inspector on an annual and daily basis. For the four delegated counties, Montgomery County leads the watershed in total number of inspections, with 19,260, followed by Anne Arundel (13,604), Howard (10,303), and Prince George's Counties (9,699). Montgomery County leads the delegated counties in annual inspections per inspector with 1,284, followed by Anne Arundel (951), Prince George's (703) and Howard (491) Counties.

In a discussion of successes and challenges in its 2006 annual enforcement report, MDE noted that, while ESC inspections remain a priority, "the inspection frequency requirement is not being met" (MDE 2006 from NOAA 2007).

The good news is that while NOAA (2007) reports that the typical inspector in the greater Patuxent River watershed (whether delegated or non-delegated) has a far bigger workload than the maximum of 50 projects per inspector or less that MDE staff suggest as being manageable, both Howard and Montgomery counties are below that threshold.

The implications of these analyses for the reservoirs watersheds specifically are difficult to extricate from county-wide data analysis used for the NOAA 2007 report and so it is strongly recommended that the TAC engage in such analysis specifically for the Patuxent Reservoirs watershed, using the methodology established by NOAA as a framework for analysis.

14.11.2 Point-Source Discharge Enforcement

It is important to point out that with respect to the reservoirs and the TMDLs, point sources are of significantly lesser concern than nonpoint sources. This is not to say that they might not become so in the future and as such point source discharge enforcement is worth examining, if only briefly.

The NOAA (2007) report used data from the EPA's Enforcement Compliance History Online (ECHO) to draw conclusions on the effectiveness of point source pollution enforcement. Unfortunately, the ECHO database itself is not particularly robust, as it only reports the highest exceedance of a standard per month as opposed to the total number of days in exceedance of standards. Staff were also interviewed directly and, according to the report, most of the staff interviewed across the greater Patuxent River watershed agreed that point source discharges were usually enforced.

14.11.3 Agricultural Programs Enforcement

According to NOAA (2007), 2006 data collected on compliance with Maryland's agricultural programs suggest that investment in more inspections would be helpful and that enforcement of required NMPs "is still somewhat in its infancy, with only one full year of data available as of June 30, 2006". However the "data collected from MDA indicate that spot-checks of properties receiving MACS cost-share funding are meeting the 10% annual goal set by MDA in each of the seven Patuxent River watershed counties. Perhaps the bigger issue is whether a 10% annual spot-check policy is sufficient, and whether there are enough MDA personnel on staff to handle a bigger inspection load" (NOAA 2007).

14.12 SPILL AND CONTAMINATION CONTROL

The 2004 Patuxent Reservoirs Source Water Assessment prepared by MDE calls for a closer evaluation of potential point sources of contaminants in the watershed including:

- Installation of an engineered spill collection system at the Route 29 bridge over Rocky Gorge Reservoir;
- Review of accident statistics for vehicles carrying hazardous materials to identify high hazard areas and prepare for eventual spills;
- Creation of a traffic study to evaluate the patterns of hazardous materials transport through the watershed;
- Creation of a formal notification procedure including spill prevention measures through a coordinated effort between WSSC, Colonial Pipeline, and MDE;
- Review of NPDES discharge permits for known potential contaminant sources in the watershed; and
- Creation of a periodic, detailed field survey to identify and characterize new sources of contaminants.

Although not related to the TMDLs, these are discrete tasks have important implications for potable water safety which could be addressed by the TAC. Collaboration with transportation authorities on a discrete project such as the spill contamination system on Route 29 could create working relationships and initiate a framework for cooperation on broader inter-agency stormwater control activities.

14.13 MONITORING

Monitoring has been an important element in numerous Patuxent Reservoirs documents over the last 30 years (Literature Review, Appendix A). Past studies have recommended various types of monitoring to determine, for example:

- Sedimentation rates;
- Tributary pollutant loads at baseflow and during storm events, particularly high flow events;
- Water quality conditions within the reservoirs and tributaries;
- Variability and trends in water quality and nutrient loading;
- Stream bank erosion;
- Stream biological and habitat conditions; and
- Temperature trends.

The 1997 Comprehensive Management Planning Study for the Patuxent Reservoir Watershed (Tetra Tech 1997) provided a blueprint for watershed monitoring. Some of those recommendations include developing and expanding a program to track measures to enable evaluation of watershed status and to support prioritization of future activities as well as expanding and coordinating physical, chemical and biological monitoring.

Storm event and baseflow monitoring have been carried out at stream flow gauge sites located at the Unity Station on the Patuxent River mainstem and at stations on Cattail Creek and Hawlings River. Data continue to be collected by the USGS. The 2002 Versar report on tributary monitoring and sediment nutrient flux testing drew the following conclusions and recommendations:

1. Current sampling stations could be used in the future to establish long-term trends and to periodically update/verify the loading model.

2. Performing trend analysis on pollutant loading data would help determine whether annual pollutant loadings are rising and falling in any significant way. However, because past chemical monitoring efforts within the reservoirs watershed have been sporadic and employed highly variable methodologies, trend analysis has not been possible to date.

3. Information from biological monitoring, such as that carried out by MBSS, Montgomery County and Howard County, can supplement long-term water quality monitoring.

Howard County's 2004 Biological Assessment of Rocky Gorge, Hammond Branch, and Dorsey Run Watersheds Report recommended continuation of the watershed-based biological sampling design, maintaining biological monitoring comparability with Maryland state methods, maintaining and enhancing the quality assurance/quality control program, including documentation and reporting of performance characteristics in biological monitoring, quantifying the effects of nutrients on stream biological condition, and targeting individual streams or subwatersheds for diagnostic stressor identification.

WSSC conducts monitoring of water quality conditions in the reservoirs from the spring through the fall. We recommend, as did Tetra Tech in its 1997 evaluation, that this long record of past data be organized into an improved data management system so that the data can be more readily queried, employed in analyses and shared among TAC members.

The 2004 Patuxent Reservoirs SWA by MDE recommended monitoring storm water and agricultural runoff BMPs to gauge efficacy on control of sediment, temperature, pathogens and nutrients (total and dissolved phosphorus) and additional modeling to better understand sources.

The 2007 Sediment Mapping and Sediment Oxygen Demand (SOD) of Triadelphia and Rocky Gorge Reservoirs study by the Maryland Geological Survey recommended the following:

- That *in-situ* SOD measurements be made in Triadelphia Reservoir because the two reservoirs represent different sediment environments based on morphological character and sediment sources;
- The SOD measurements conducted for this study represent a one-time glimpse of the bottom chemical environment. In order to gain insight to seasonal changes, additional *in-situ* SOD measurements should be made during the spring and in the summer when the hypolimnion is present.
- Future measurements should include chlorophyll level and light readings to address the possible contribution of photosynthesis to water column oxygen demand.

The ICPRB's 2007 Modeling Framework, prepared as part of TMDL analysis, concluded that with respect to nitrogen, "the modeling framework falls short of a secondary goal: estimating nitrogen loads to the reservoirs" and as such it would have been desirable to have determined better estimates of loading rates. Specifically, "Given the limitations of the W2 model, it would still be impossible to keep a continuous mass balance on nitrogen, as is done for phosphorus."

With respect to algae and Chl*a*, ICPRB concluded that there are three areas in which the existing monitoring program could be improved to help future modeling efforts:

- Data on algal species could be collected from a variety of locations in both reservoirs, not just at the intakes;

- It could be useful to conduct water quality sampling through the winter to quantify the size and duration of spring algal blooms.
- More Chl*a* samples could be taken at depths below the surface as the DO concentration profiles from the Patuxent Reservoirs suggest that primary production could be taking place several meters below the surface.

In addition, we recommend that future monitoring efforts be tailored to address the monitoring components of EPA's elements for 319 grant funding. In particular, a set of criteria should be developed to determine whether loading reductions are being achieved over time and whether substantial progress is being made toward attaining water quality standards. Monitoring should be implemented to evaluate the effectiveness of the implementation efforts over time, measured against these criteria. Existing monitoring efforts, such as WSSC reservoir monitoring, County and MBSS biological monitoring, and other programs would be useful components of a long-term monitoring strategy.

14.14 ESTIMATING POLLUTANT LOAD REDUCTIONS

In the future, it may be useful to develop estimates of expected pollutant load reductions from various proposed watershed management measures. The model developed by ICPRB for creation of the TMDL may serve as a useful foundation for such modeling.

15.0 NINE MINIMUM ELEMENTS FOR EPA INCREMENTAL 319 FUNDING

15.1 BACKGROUND

By amendment to the Clean Water Act (CWA) in 1987, the Section 319 Grant program was established to provide funding for efforts to reduce nonpoint source (NPS) pollution, including that which occurs though stormwater runoff. Under Section 319, each state is to address NPS by developing a NPS assessment report and by adopting management programs to control NPS pollution. These are to be followed by implementation of management programs.

The EPA provides funds to state and tribal agencies, which are then allocated via a competitive grant process to organizations to address current or potential NPS concerns. Congress appropriated Section 319 grant funds for the first time in 1990. In 1999, as a result of the 1998 federal Clean Water Action Plan (CWAP), Section 319 was authorized to receive a significant increase in funding. A central aspect of the CWAP was its set of actions that were designed to promote a renewed focus by state, territorial, federal, tribal, and local governments and their stakeholders to (1) identify watersheds with the most critical water quality problems, and (2) work together to focus resources and implement effective strategies to solve these problems.

Section 319 funds may be used to demonstrate innovative best management practices (BMPs), support education and outreach programs, establish TMDLs for a watershed, or to restore impaired streams or other water resources. 303(d) listed waters approved by the EPA are the top priority for incremental funds.

The EPA requires that nine elements (labeled “a” though “i”) be included in a watershed plan for impaired waters funded using incremental Section 319 funds. Although there is no formal requirement for EPA to approve watershed plans, the plans must address the nine elements discussed below if they are developed in support of a section 319-funded project (EPA Watershed Planning Handbook 2008).

Note that although they are listed as “a” through “i”, they do not necessarily take place in that specific order. For example, element “d” asks for a description of the technical and financial assistance that will be needed to implement the watershed plan, but this can be done only after elements “e” and “i” have been done. Below, we review the extent to which each of the nine elements has been addressed so far for the Patuxent Reservoirs watershed.

15.2 ADDRESSING THE NINE ELEMENTS FOR PATUXENT RESERVOIRS WATERSHED

In the case of the Patuxent Reservoirs watershed, like so many cross-jurisdictional watersheds, no single entity has responsibility for management of the entire watershed. As such, creation of a coordinated management strategy is complex. The Patuxent Reservoirs Watershed Protection Group TAC serves to coordinate efforts of the various partner agencies. The fruit of the TAC's recent efforts is in part summarized in the Priority Resources Chart from the 2008 Annual Report (Appendix B), with further details provided in the Annual report and Technical Supplement. In addition, MDE's recent development of TMDLs for the reservoirs has brought focus to the issues of phosphorus and sediment loading. However, progress to date in planning for specific NPS management measures does not yet provide the level of detail stipulated by the EPA in the nine elements framework.

With respect to the Patuxent Reservoirs watershed, the TMDLs and the TAC's historic management efforts have addressed EPA watershed management plan elements "a" and "b". Completion of the remainder of the nine elements will build upon a number of management efforts currently in progress (Table 15-1). This interim management report includes the first comprehensive compilation of 30 years of historic studies, their observations and recommendations. The new desktop analysis of land uses, characterization of imperviousness and other watershed features, and identification of opportunities for simple but effective watershed-wide BMPs represent a necessary step forward to fully addressing the nine elements required for 319 funding.

Progress in addressing the nine elements ("a" thru "i"):

a) ***Causes of Impairment:*** *Identification of causes of impairment and pollutant sources or groups of similar sources that need to be controlled to achieve needed load reductions, and any other goals identified in the watershed plan. Sources that need to be controlled should be identified at the significant subcategory level along with estimates of the extent to which they are present in the watershed.*

   This element will usually include an accounting of the significant point and nonpoint sources in addition to the natural background levels that make up the pollutant loads causing problems in the watershed. If a TMDL exists, this element may be adequately addressed. (EPA 2008)

   The causes for impairment are explicit in the TMDLs for phosphorus in the Triadelphia and Rocky Gorge Reservoirs and for sediment in the Triadelphia Reservoir, which were approved in November 2008 (MDE 2008). The modeled estimations of the sources of phosphorus and sediment to the reservoirs are demonstrated in Figures 8-2 through 8-4. In short, the most important sources of phosphorus to the reservoir are agriculture, stream scour and developed land. The most important sources of sediment to the Triadelphia Reservoir by far are agriculture and stream scour.

Table 15-1. For Patuxent Reservoirs watershed, summary of status of addressing nine required elements for watershed plans for EPA Incremental 319 funding. See particular sections of this report for details.

Nine Elements (EPA 2008)	Complete	In Progress	Future
a. Identify causes of impairment	• TMDL development and modeling (Section 11)		
b. Estimate load reductions needed	• TMDL development and modeling (Section 11)		
c. Description and location of NPS management measures		• Riparian buffer enhancement programs in Howard and Montgomery County (Section 12.2, 14.6) • Stream channel restoration projects (Section 12.1, 14.5) • Equine operations/community assistance (Section 8.3.2) • Cost share program to establish stream-side BMPs (Section 8.3.2) • Additional recommendations to reduce phosphorus and/or sediment loads (Section 14)	• Horse manure management (Section 8.3.2)
d. Estimate of the amounts of technical and financial assistance		• The TAC has begun to estimate costs of various BMPs addressing both sediment and phosphorus loading.	
e. Information and education component of plan and NPS measures		• The education component specific to management plan addressing TMDLs not yet been developed but TAC members have a good history of outreach activities and dedicated staff (e.g., WSSC).	
f. Schedule for implementing the NPS management measures		• A timeline for implementation items is included in Priority Resource Chart (Appendix B Table 1)	• Once a suite of BMPs is identified to meet TMDLs, update schedule in Priority Resource Chart
g. Interim measurable milestones for NPS management measures		• Measures and goals are included in Priority Resource Chart (Appendix B, Table 1)	• Once a suite of BMPs is identified to meet TMDLs, update measures and goals in Priority Resource Chart
h. Monitoring criteria		• WSSC has 18 year history of monitoring key parameters in reservoirs.	
i. Monitoring plan		• WSSC has 18 year history of monitoring key parameters in the reservoirs (Section 14.13), including phosphorus and turbidity. • Stream flow monitoring in major tributaries (Section 12) • State and County stream biological indicators monitoring (Section 9) • Water quality monitoring and pollutant load estimation to the reservoirs (Section 14.13)	• Water quality monitoring and pollutant load estimation to the major tributaries (Section 12, 14.13)*

*Water quality monitoring and pollutant load estimation was conducted in major tributaries from October 1996 through June 2003, but not since June 2003.

b) ***Estimate Load Reductions:*** *On the basis of the existing source loads estimated for element "a" above, you will similarly determine the reductions needed to meet the water quality standards. You will then identify various management measures (see element "c" below) that will help to reduce the pollutant loads and estimate the load reductions expected as a result of these management measures to be implemented, recognizing the difficulty in precisely predicting the performance of management measures over time. In cases where a TMDL for affected waters has already been developed and approved or is being developed, the watershed plan should be crafted to achieve the load reductions called for in the TMDL.* (EPA 2008)

The reductions needed to meet water quality standards have been determined by the TMDL modeling conducted by ICPRB for MDE (ICPRB 2007) and are detailed in Table 11-1.

c) ***Description and location of NPS management measures:*** *A description of the NPS management measures that will need to be implemented to achieve load reductions, and a description of the critical areas in which those measures will be needed to implement this plan. This description should be detailed enough to guide implementation activities and can be greatly enhanced by identifying on a map priority areas and practices.* (EPA 2008)

As is the case in most jurisdictions, implementation of BMPs is often opportunistic and not comprehensive due to a host of challenges. This is more difficult in the case of multi-jurisdictional watersheds like the Patuxent Reservoirs watershed. Now that TMDLs have been approved, there is a regulatory imperative to identify and implement BMPs strategically and comprehensively to deal with sediment and phosphorous sources, as outlined below in elements "c" through "i".

Because the TMDLs were only approved in 2008, the partner agencies of the Patuxent Reservoirs Watershed Protection Group have not yet had the opportunity to comprehensively address the TMDLs. This interim watershed management report reiterates a consensus of historic recommendations over the past three decades and offers some new, broad management measures and new locations to expand existing TAC efforts, which will be effective at addressing the TMDLs. Recommendations are outlined in Section 14 and include redoubling efforts to address agricultural non point sources of sediment and phosphorus, target locations for riparian stream buffer creation that simultaneously address other natural resource management goals, and identify and protect critical headwaters. This report also summarizes new estimates of impervious surface, which accounts for a significant source of phosphorus loads, particularly in the Rocky Gorge Reservoir. Imperviousness is also implicated in stream scour, which is a primary source of phosphorus and sediment.

The TAC and its member agencies have a significant head start addressing element "c", given efforts over the past few years, as summarized in the Technical Supplements of the TAC Annual Reports (2004b, 2005b, 2006b, 2007b, 2008b) and highlighted below.

Stream Channel and Buffer Management. The TAC has made buffer integrity and stream bank and channel stability a priority goal as indicated in its Priority Resources Chart (Table 1, Appendix B). Several projects have been completed or are in progress, for example:

- Howard County riparian buffer plantings on public and private lands at targeted locations (Section 12.2).
- Howard County's stream restoration and stormwater retrofits at three reaches in Cherry Creek watershed (Section 14.5)
- Reddy Branch stream buffer restoration undertaken by M-NCPPC, including tree plantings in riparian areas, construction of wetlands, a meadow demonstration area, and enhanced storm water management (Section 14.6).
- Montgomery County's Lower Hawlings River stream restoration project, (Section 12.1)
- Cost share initiative implemented by Howard and Montgomery SCDs for non-agricultural streamside BMPs (Section 8.3.2).

Agricultural BMPs. With respect to element "c", agricultural NPS management measures are implemented in the watershed by the SCDs, MDA, and the TAC. Recent progress is described in the 2008 Annual Report including, for example, Howard and Montgomery SCD efforts during 2008, summarized in the Patuxent Reservoirs Watershed Agricultural BMPs Progress Table (Table 8-3).

The ICPRB modeling effort for the TMDLs suggests that agricultural BMPs implemented to date have not been aggressive enough in reducing sediment and phosphorus contributions. The number, type, and maintenance of existing agricultural BMPs could be further evaluated to assess the effectiveness of measures in place. In addition, recent initiatives documented by the TAC, such as targeted assistance to horse owners (Section 8.3.2), show promise in further reducing pollutant contributions. Note however, that while assistance to horse owners has been initiated, actual horse manure management has not yet begun and remains as a logical and necessary next step in addressing nutrient loads from equine operations.

d) ***Estimate of the amounts of technical and financial assistance*** *needed, associated costs, and/or the sources and authorities that will be relied upon to implement this plan. This includes implementation and long-term operation and maintenance of management measures, information/education activities, monitoring, and evaluation activities. You should also document which relevant authorities might play a role in implementing the plan. Plan sponsors should consider the use of federal, state, local, and private funds or resources that might be available to assist in implementing the plan. Shortfalls between needs and available resources should be identified and addressed in the plan. The estimate of financial and technical assistance should take into account the following* (EPA 2008)*:*

- *Administration and management services, including salaries, regulatory fees, and supplies, as well as in-kind services efforts, such as the work of volunteers and the donation of facility use;*
- *I/E efforts;*
- *The installation, operation, and maintenance of management measures; and*
- *Monitoring, data analysis, and data management activities.*

The TAC has made some good progress in proposing measures to address causes of impairment but is not at the stage where the costs and technical assistance necessary to implement and maintain a comprehensive suite of BMPs/management measures or watershed-wide education and outreach activities can be estimated because those BMPs have not yet been identified at the watershed scale, with a few exceptions. Technical and financial assistance needed have been defined for some proposed measures, particularly in recent grant applications.

The Innovative Nutrient and Sediment Reduction Project pre-proposal demonstrates a good estimation of cost per pound of nitrogen and phosphorus reduction and technical assistance/partnerships for comprehensive implementation of equine manure management in both Howard and Montgomery County. Howard County has made estimates for cost of buffer plantings on private and public lands, detailed in the 2005 Annual Report Technical Supplement. Similar estimates could be made for other potential riparian buffer restoration areas, such as indicated in this report (Section 14.2.3).

Another advantage is that a reservoir monitoring program is already in place, which includes monthly sampling for key parameters (including total nitrogen, nitrate and nitrite, ammonia, total phosphorus and orthophosphate, chlorophyll a, dissolved oxygen and turbidity) that are appropriate for monitoring impacts of watershed management measures to address the TMDL. These costs are well documented by WSSC and as such could be extrapolated into the future for the purpose of a watershed management plan.

The most recent version of the Priority Resources Chart published in the TAC 2008 Annual Report (Appendix C) does set goals for each of the six priority "resources" with general implementation items, a timeline, and responsible partners. In terms of addressing the amount of technical and financial assistance to address the TMDLs, the Priority Resources chart could be expanded in detail to meet the EPA requirements. Overall, given its recent efforts, the TAC has a head start in developing costs and technical assistance for BMPs to address both sediment and phosphorus loading to the reservoirs.

e) ***An information and education component*** *used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the NPS management measures that will be implemented.* (EPA 2008)

The WSSC and TAC have created a relatively well organized education and outreach infrastructure which could translate to a watershed management plan. WSSC has staff dedicated to education and outreach, and other TAC agencies regularly interact with the public in a variety of watershed management and restoration activities. Generation of this interim document included public/stakeholder meetings in both Howard and Montgomery County in order to give the public an opportunity to learn about and comment on this new initiative.

While it is premature to develop outreach and education activities specific to implementation of candidate BMPs meant to address the TMDLs, as they have not yet been identified, future outreach should seek to build upon the efforts detailed in this document (Section 13 and 14.10).

f) ***Schedule for implementing the NPS management measures*** *identified in this plan that is reasonably expeditious. The schedule should reflect the milestones you develop in measure "g".* (EPA 2008)

It is premature to set an implementation schedule for BMPs meant to address the TMDLs, as candidate BMPs have not yet been identified in each jurisdiction.

g) ***A description of interim measurable milestones*** *for determining whether NPS management measures or other control actions are being implemented. These milestones will measure the implementation of the management measures, such as whether they are being implemented on schedule, whereas element h (see below) will measure the effectiveness of the management measures, for example, by documenting improvements in water quality.* (EPA 2008)

Some milestones for management efforts initiated before the approval of the TMDL have been set by the TAC in its Priority Resources Chart published in the 2008 Annual Report. These milestones should be revisited to make them more specific to the needs of element "g" and to TMDL implementation.

h) ***A set of criteria that can be used to determine whether loading reductions are being achieved*** *over time and substantial progress is being made toward attaining water quality standards (WQS). The criteria in element h (not to be confused with water quality criteria in state regulations) are the benchmarks or waypoints to measure against through monitoring. These interim targets can be direct measurements (e.g., fecal coliform concentrations) or indirect indicators of load reduction (e.g., number of beach closings). You should also indicate how you'll determine whether the watershed plan needs to be revised if interim targets are not met.* (EPA 2008)

Appropriate benchmarks for sediment and phosphorus need to be established. The modeling effort by ICPRB for development of TMDLs and reservoir monitoring by WSSC for chlorophyll-a, secchi readings, and total phosphorous independently to determine the algal biomass to classify trophic status, plus sediment oxygen demand (SOD) measurements in the Rocky Gorge Reservoir used to support development of the TMDL model, provide a basis for criteria to determine if load reductions are being achieved.

i) ***A monitoring component*** *to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under item h immediately above. The monitoring component should be designed to determine whether loading reductions are being achieved over time and substantial progress in meeting water quality standards is being made.* (EPA 2008)

The WSSC is in the 18th year of monitoring reservoir water quality (Section 14.13). Three sites at each reservoir are monitored monthly or bimonthly, except during winter months. The reservoirs are monitored for phosphorus, nitrogen, total organic carbon, pesticides, metals, turbidity, fecal coliform and chlorophyll. In addition, in-situ transparency and profile measurements of pH, conductivity, temperature, reduction-oxidation potential and dissolved oxygen are performed (2007 Annual Report). While this long term monitoring has obviously not been done for the purpose of the recently established TMDL, it has produced a historic data set, methodology, and infrastructure for monitoring of TMDL-related parameters.

Tributary water quality monitoring (summarized in Section Chapter 12 and 14.13 and in Versar 2002) provides data on the major tributaries to the reservoirs. Note that water quality monitoring and pollutant load estimation for major tributaries were conducted most recently from October 1996 through June 2003. As such, a gap remains from 2003 to the present in which no major tributaries have been monitored for water quality paramaters. In terms of meeting the requirements of the nine minimum elements, the TAC is not able to make estimations of load in major tributaries or changes in loads resulting from implementation of best management practices from major changes in major tributaries, but it could do so for the reservoirs proper. Given the historic monitoring by WSSC, one could argue that the TAC has a headstart on the monitoring requirement.

In addition, biological monitoring conducted by MBSS and the counties (Section 9) are useful for assessing resource conditions in smaller, wadeable streams. Howard County is on a five-year biological monitoring cycle for watersheds in the County. Montgomery County Department of Environmental Protection (DEP) monitoring in the Patuxent watershed is also included in its countywide program for biological monitoring.

16.0 REFERENCES

American Forests. 2002. Urban Ecosystem Analysis for the Washington DC Metropolitan Area: An Assessment of Existing Conditions and a Resource for Local Action.

Anderson D.G. 1968, Effects of Urban Development on Floods in Northern Virginia: USGS Water Supply Paper 2001-C, 22 p.

Arnold, C. L. and C. J. Gibbons. 1996. Impervious surface: The emergence of a key urban environmental indicator. Journal of the American Planning Association 62(2): 243-258.

Biggs, B.J. 1995, The contribution of flood disturbance, catchment geology and land use to the habitat template of periphyton in stream ecosystems: Freshwater Biology, v. 33, p. 419-438.

Booth, D.B. 1990. Stream channel incision following drainage-basin urbanization: Water Resources Bulletin, v. 26, p. 407-417.

Camp Dresser & McKee. 1987. Water Quality Assessment for Patuxent Watershed (Task 1-G Report). 1987. Prepared by for Greenhorne and O'Mara was generated as part of M-NCPPC Patuxent Watershed Management Program.

Castelle, A., C. Conolly, M. Emers, E. Metz, S. Meyer, M. Witter, S. Mauermann, T. Erickson, and S. Cooke. 1992. Wetland Buffers: Use and Effectiveness. Publication No. 92-10. Washington Department of Ecology, Shorelands and Coastal Zone Management Program, Olympia.

Castelle, A. J., A. W. Johnson and C. Conolly. 1994. Wetland and stream buffer requirements A review. *Journal of Environmental Quality* 23:878-882.

Charles P. Johnson & Associates and Environmental Quality Resources, LLC. 2003(a). Hawlings River Watershed Restoration Study. Final Report. Prepared for the Montgomery County Department of Environmental Protection.

Charles P. Johnson & Associates and Environmental Quality Resources, LLC. 2003 (b). Hawlings River Watershed Restoration Action Plan. Prepared for the Montgomery County Department of Environmental Protection.

Chris Athanas, Ph.D and Associates. 2000. Olney Family Neighborhood Park Water Quality Monitoring: Final Report. Submitted to the Department of Parks and Planning, Maryland National Capitol Parks and Planning Commission.

Cornwell J. and M. Owens. 2002. Triadelphia Sediment-Water Exchange Study. As an appendix to Versar 2002). University of Maryland Center for Environmental Science.

Dunne, T. and A. Leopold. 1978. Water in Environmental Planning. W.H. Freeman. San Francisco, CA. 818pp

Dwyer John F. and David J. Nowak 2000. A national assessment of the urban forest: An overview. Proceedings of the Society of American Foresters: 1999 National Convention. Portland Oregon. September 11-15, 1999.

EA Engineering Inc. 1991. Water Quality Monitoring and Nutrient Loading Analysis of the Patuxent River Reservoirs Watershed. Prepared for Washington Suburban Sanitary Commission.

Ecological Analysts Inc & Land Design/Research. 1981. Patuxent River Watershed Protection Program. Project No. W-144.00. Prepared for the Washington Suburban Sanitary Commission.

Fischer, R. and J. Fischenich. 2000 (April). Design recommendations for corridors and vegetated buffer strips. U.S. Army Corps Engineer Research and Development Center, Vicksburg, MS, ERCD TNEMRRP- SR-24.

Gallardo, A.C., J.E. Garrish, C.R. Hill, and J.B. Stribling 2006. Biological Assessment of the Cattail Creek and Brighton Dam Watershed, Howard County, Maryland. Prepared by Tetra Tech, Inc., Owings Mills, MD for Howard County, Department of Public Works. Stormwater Management Division. Columbia, MD. January 2006. http://www.co.ho.md.us/DPW/DOCS/2005catbright.pdf

Galli, J. 1991. Thermal impacts associated with urbanization and stormwater management best practices: Washington, D.C., Metropolitan Washington Council of Governments and Maryland Department of Environment, 188 p.

GMB Architects and Engineers Inc. 1997. On-Site Wastewater Management Practices in the Upper Patuxent Watershed. Prepared for the Washington Suburban Sanitary Commission.

Greenhorne and O'Mara Inc. 1990. Patuxent River Watershed Montgomery County Maryland: Technical Report.

Hammer, T.R. 1972. Stream channel enlargement due to urbanization: Water Resources Research, v. 8, p. 1530–1540.

Harbor, J. M. 1994. Practical Method for Estimating the Impact of Land Use Change on Surface Runoff, Ground Water Recharge and Wetland Hydrology. Journal of the American Planning Association 60(1):95-108.

Henshaw, P., and Booth, D. 2000. Natural restabilzation of stream channels in urban watersheds: Journal of the American Water Resources Association, v. 36, p. 1219-1236.

Hollis, G. 1975. The effect of urbanization on floods of different recurrence interval: Water Resources Research, v. 11, p. 431-435.

Interstate Commission on the Potomac River Basin. 2007. Modeling Framework for Simulating Hydrodynamics and Water Quality in the Triadelphia and Rocky Gorge Reservoirs, Patuxent River Basin, Maryland, Final. September 2007. Prepared for the Maryland Department of the Environment.

Jones, R.C., and Clark, C.C. 1987. Impact of watershed urbanization on stream insect Communities: Water Resources Bulletin, v. 23, p. 1047-1055.

JTC Environmental Consultants, Inc. 1984. Patuxent River Reservoirs Water Quality Assessment: Final Report. Prepared for the Washington Suburban Sanitary Commission.

Osborne, L. L. and D. A. Kovacic. 1993. Riparian vegetated buffer strips in water-quality restoration and stream management. *Freshwater Biology* 29: 243-258.

Karr, J.R. and D.R. Dudley. 1981. Ecological perspectives on water quality goals. Environmental Management 5:55-68.

Karr, J.R. 1991. Biological integrity: A long-neglected aspect of water resource management. Ecological Applications: 1:66-84.

Karr, J.R. and Schlosser, I.J. (1978) Water resources and the land-water interface. *Science,* 201, 229-234.

Kennan, J.G. 1999. Relation of macro-invertebrate community impairment to catchment characteristics in New Jersey streams: Journal of the American Water Resources Association, v. 35, p. 939-955.

Kennedy, et al. 2003. Conservation Thresholds for Land Use Planners. The Environmental Law Institute®; Environmental Law Institute's State Biodiversity Program.

Klein, R.D. 1979. Urbanization and stream water quality impairment: Water Resources Bulletin, v. 15, p. 948-1963.

Labbe, T.R. and K.D. Fausch. 2000. Dynamics of intermittent stream habitat regulate persistence of threatened fish at multiple scales. Ecological Applications 10:1774-1791.

Leopold, L. B. 1968. Hydrology for Urban Land Use Planning: A Guidebook on the Hydrologic Effects of Urban Land Use. USGS Circular 554.

Leopold, L.B. 1973. River channel change with time—An example: Geological Society of America Bulletin, v. 84, p. 1845-1860.

Leopold, L. B. 1994. A view of the river. Harvard University Press. Cambridge, MA.

Limburg, K.E., and Schmidt, R.E.. 1990. Patterns of fish spawning in Hudson River tributaries—Response to an urban gradient: Ecology, v. 71, p. 1238-1245.

Lowrance, R., and 12 others. 1997. Water quality functions of riparian forest buffers in Chesapeake Bay Watersheds. *Environmental Management* 21(5):687-712.

Maryland Department of Agriculture. 2006. Maryland Agricultural Water Quality Cost-Share Program. MACS Annual Report. Seeds of Success.

Maryland Department of Agriculture. 2007. Maryland Agricultural Water Quality Cost-Share Program. MACS Annual Report. Conservation Innovations.

Maryland Department of Environment. 2006. Maryland's 2006 TMDL Implementation Guidance for Local Governments. Appendix C: Maryland's Tier II Antidegradation Implementation Procedures. http://www.mde.state.md.us/assets/document/-AppendixC.pdf

Maryland Department of the Environment. June 2008. Total Maximum Daily Loads of Phosphorus and Sediments for Triadelphia Reservoir (Brighton Dam) and Total Maximum Daily Loads of Phosphorus for Rocky Gorge Reservoir, Howard, Montgomery, and Prince George's Counties, Maryland. Submitted to EPA Region III.

Maryland Department of the Environment. June 2008. Final Technical Memorandum: Significant Phosphorus and Sediment Point Sources in the Triadelphia Reservoir and Rocky Gorge Reservoir Watersheds.

Maryland Department of the Environment. June 2008. Final Technical Memorandum: Significant Phosphorus and Sediment Nonpoint Sources in the Triadelphia Reservoir and Rocky Gorge Reservoir Watersheds.

Maryland Department of the Environment. 2009. Revisions to the Maryland Stormwater Design Manual.(http://www.mde.state.md.us/Programs/WaterPrograms/SedimentandStormwater/stormwater_design/index.asp)

Maryland Department of the Environment, Maryland Department of Natural Resources, Maryland Department of Agriculture, Maryland Office of State Planning and the University of Maryland. 1995. Tributary Strategy for Nutrient Reduction in Maryland's Patuxent Watershed. Prepared as required by Chesapeake Bay Agreement of 1987.

Maryland Department of the Environment Water Management Administration Water Supply Program. 2004. Patuxent Reservoirs (Triadelphia and Rocky Gorge) Source Water Assessment for WSSC Patuxent Water Filtration Plant.

Maryland Department of Planning. 1997. Maryland Land Use Data. State of Maryland, Department of Planning, Baltimore, MD.

Maryland Department of Planning. 1984. Patuxent River Policy Plan: A Land Management Strategy. State of Maryland, Department of Planning, Baltimore, MD.

Maryland Department of Natural Resources Tributary Team. 1998. Patuxent River: Water Quality and Habitat Summary Report.

Maryland Department of Natural Resources. 2005. Center for Environmental Training. DVD Onsite Sewage Disposal Systems: Protecting your System, Preserving the Bay. Production date Winter 2005.

Maryland Department of Natural Resources. 2007. Maryland Tributary Strategy Patuxent River Basin Summary Report for 1985-2005 Data. August 2007.

Maryland Department of Natural Resources. 2007. Forest Conservation Plan for Washington Suburban Sanitary Commission Reservoir Properties. Prepared for WSSC by Anne Hairston-Strang, Ph.D.

Maryland DNR Resource Assessment Service and the Maryland Geological Survey, Coastal and Estuarine Geology Program. 2007. Sediment Mapping and Sediment Oxygen Demand of Triadelphia and Rocky Gorge Reservoirs.

Maryland National Capital Parks and Planning Commission. 1993. Montgomery County Functional Master Plan for the Patuxent River Watershed.

Maryland National Capital Parks and Planning Commission and Montgomery County Department of Park and Planning. 2003. Olney and Vicinity Environmental Resources Inventory.

Maryland National Capital Parks and Planning Commission. 2005. Land Preservation, Parks and Recreation Plan. A Parks Recreation Open Space Plan for Montgomery County, Maryland.

May, C.W., Horner, R.R., Karr, J.R., Mar, B.W., Welch, E.B. 1997. Effects of urbanization on small streams in the Puget Sound lowland ecoregion: Watershed Protection Techniques, v. 2, p. 483-493.

Meyer, J.L., et al. 2007. The contribution of headwater streams to biodiversity in river networks. Journal of the American Water Resources Association. 43: 86-103.

Meyer, J.L., and J.B. Wallace. 2001. Lost Linkages and Lotic Ecology: Rediscovering Small Streams. In: Ecology: Achievement and Challenge, M.C. Press, N.J. Huntly, and S. Levin (Editors). Blackwell Science, Malden, Massachusetts, pp. 295-317.

Montgomery County Department of Environmental Protection. 1995. Developing a Patuxent Reservoir Protection Strategy; Interim Report of the Patuxent Reservoir Protection Group. Prepared for the Montgomery County Council.

Montgomery County, Department of Environmental Protection, Watershed Management Division. 1998. Hawlings River Watershed Assessment.

Montgomery County, Department of Environmental Protection, Watershed Management Division. 2001. Upper Patuxent Watershed Study.

Mulholland, P.J., J.L. Tank, D.M. Sanzone, B.J. Peterson, W. Wolheim, J.R. Webster and J.L. Meyer. 2001. Ammonium uptake length in a small forested stream determined by 15N tracer and ammonium enrichment experiments. Verh. Internat. Verein. Limnol. 27:1320-1325.

Naiman, R., H. Décamps, and M. Pollock. 1993. The role of riparian corridors in maintaining regional biodiversity. Ecological Applications 3(2):209-212.

National Research Council (NRC). 2002. Riparian Areas: Functions and Strategies for Management. National Academy Press, Washington, DC.

National Oceanic and Atmospheric Administration and University of Maryland, Center for Environmental Science. 2007. Managing Patuxent River Water Quality: Looking Beyond Science and Politics to the Economics of Decision-making.

O'Laughlin, J., and G. Belt. 1995. Functional approaches to riparian buffer strip design. Journal of Forestry 93(2):29-32.

Ohio EPA. 2003. The Importance and Benefits of Primary Headwater Streams: Fact Sheet. Division of Surface Water.

Ohio EPA. 2003. Ohio EPA's Primary Headwater Stream Project: Key Findings: Fact Sheet. Division of Surface Water

Osmond, D.L., J.W. Gilliam and R.O. Evans. 2002. Riparian Buffers and Controlled Drainage to Reduce Agricultural Nonpoint Source Pollution, North Carolina Agricultural Research Service Technical Bulletin 318, North Carolina State University, Raleigh, NC.

Patuxent Reservoirs Watershed Protection Group Technical Advisory Committee. 2008a. Patuxent Reservoirs Watershed Annual Report. Also available at http://www.wssc.dst.md.us/environment/reports/reports.cfm.

Patuxent Reservoirs Watershed Protection Group Technical Advisory Committee. 2008b. Supplemental Documentation In Support of The Patuxent Reservoirs Watershed Technical Advisory Committee's Annual Report. Also available at http://www.wssc.dst.md.us/environment/reports/reports.cfm.

Patuxent Reservoirs Watershed Protection Group Technical Advisory Committee. 2007a. Patuxent Reservoirs Watershed Annual Report. Also available at http://www.wssc.dst.md.us/environment/reports/reports.cfm.

Patuxent Reservoirs Watershed Protection Group Technical Advisory Committee. 2007b. Supplemental Documentation In Support of The Patuxent Reservoirs Watershed Technical Advisory Committee's Annual Report. Also available at http://www.wssc.dst.md.us/environment/reports/reports.cfm.

Patuxent Reservoirs Watershed Protection Group Technical Advisory Committee. 2006a. Patuxent Reservoirs Watershed Annual Report. Also available at http://www.wssc.dst.md.us/environment/reports/reports.cfm.

Patuxent Reservoirs Watershed Protection Group Technical Advisory Committee. 2006b. Supplemental Documentation In Support of The Patuxent Reservoirs Watershed Technical Advisory Committee's Annual Report. Also available at http://www.wssc.dst.md.us/environment/reports/reports.cfm.

Patuxent Reservoirs Watershed Protection Group Technical Advisory Committee. 2005a. Patuxent Reservoirs Watershed Annual Report. Also available at http://www.wssc.dst.md.us/environment/reports/reports.cfm.

Patuxent Reservoirs Watershed Protection Group Technical Advisory Committee. 2005b. Supplemental Documentation In Support of The Patuxent Reservoirs Watershed Technical Advisory Committee's Annual Report. Also available at http://www.wssc.dst.md.us/environment/reports/reports.cfm.

Patuxent Reservoirs Watershed Protection Group Technical Advisory Committee. 2004a. Patuxent Reservoirs Watershed Annual Report.

Patuxent Reservoirs Watershed Protection Group Technical Advisory Committee. 2004b. Supplemental Documentation In Support of The Patuxent Reservoirs Watershed Technical Advisory Committee's Annual Report.

Pavlik, K.L. and J.B. Stribling. 2001. Biological Assessment of the Little Patuxent River, Cattail Creek, and Brighton Dam Watersheds, Howard County, Maryland. Prepared by Tetra Tech, Inc., Owings Mills, MD for Howard County, Department of Public Works. Stormwater Management Division. Columbia, MD. http://www.co.ho.md.us/DPW/DOCS/final_report.pdf

Pavlik, K.L., and James B. Stribling. 2004. Biological Assessment of the Rocky Gorge, Dorsey Run, and Hammond Branch Watersheds, Howard County, Maryland. Prepared by Tetra Tech, Inc., Owings Mills, MD for Howard County, Department of Public Works. Stormwater Management Division. Columbia, MD. January 2004. http://www.co.ho.md.us/DPW/DOCS/rockygorge3.pdf

Pavlik, Kristen L., and James B. Stribling. 2005. Biological Assessment of the Patapsco River Tributary Watersheds, Howard County, Maryland. Prepared by Tetra Tech, Inc., Owings Mills, MD for Howard County, Department of Public Works. Stormwater Management Division. Columbia, MD. February 2005. http://www.co.ho.md.us/DPW/DOCS/-patapsco.pdf

Peterjohn, W.T. and Correll, D.L. 1984. Nutrient dynamics in an agricultural watershed: observations on the role of a riparian forest. *Ecology,* 65, 1466-1475.

Peterson, B.J., W.M. Wolheim, P.J. Mulholland, J.R. Webster, J.L. Meyer, J.L. Tank, E. Marti, W.B. Bowden, H.M. Valett, A.E. Hershey, W.H. McDowell, W.K. Dodds, S.K. Hamilton, S. Gregory, D.D. Morrall. 2001. Control of nitrogen export from watersheds by headwater streams. Science 292:86-90.

Poff, N.L. and Allen, J.D. 1995. Functional organization of stream fish assemblages in relation to hydrological variability: Ecology, v.76, p. 606-627.

Rose, S, and Peters, N. 2001. Effects of urbanization on streamflow in the Atlanta area (Georgia, USA)—A comparative hydrological approach: Hydrological Processes, v. 15, p. 1441-1457.

Roth, N., Southerland, M.T, Chaillou, J.C., Klauda, R., Kazyak, P.F., Stranko, S.A., Weisberg, S., Hall Jr., L., and R. Morgan II. 1998. "Maryland Biological Stream Survey: Development of a Fish Index of Biotic Integrity". Environmental Management and Assessment 51: 89-106.

Save Our Streams. 1995. Public Awareness and Education Marketing Plan for Triadelphia and Rocky Gorge Reservoir Watersheds. Prepared for the Montgomery County Department of Environmental Protection.

Save Our Streams. 1996. The Upper Patuxent Curriculum: Our Water, Our Land, Our Community. Prepared in partnership with WSSC and the Chesapeake Bay Trust.

Schlosser, I.J. and Karr, J.R. 1981. Riparian vegetation and channel morphology impact on spatial patterns of water quality in agricultural watersheds. *Environ. Manage.,* 5, 233-243

Schueler, T. 1994. The importance of imperviousness: Watershed Protection Techniques, v. 1, p. 100-111.

Schueler T.R., and H.K. Holland. 2000. The Practice of Watershed Protection.

Southerland, M.T., G.M. Rogers, M.J. Kline, R.P. Morgan, D.M. Boward, P.F. Kazyak, R.J. Klauda, and S.A. Stranko. 2005a. Maryland Biological Stream Survey 2000-2004 Volume 16: New Biological Indicators to Better Assess the Condition of Maryland Streams. Monitoring and Non-Tidal Assessment, Maryland Department of Natural Resources, Annapolis. CBWP-MANTA-EA-05-13.

Southerland, M.T., L.A. Erb, G.M. Rogers, and P.F. Kazyak. 2005b. Maryland Biological Stream Survey 2000-2004 Volume 7: Statewide and Tributary Basin Results. Monitoring and Non-Tidal Assessment Division, Maryland Department of Natural Resources, Annapolis. DNR-12-0305-0109.

Stribling, J.B., Jessup, B.K., White, J.S., Boward, D., and M. Hurd. 1998. "Development of a Benthic Index of Biotic Integrity for Maryland Streams". *Tetra Tech, Inc*., Owings Mills, MD and *Maryland Department of Natural Resources, Monitoring and Non-Tidal Assessment Program*. CBWP-MANTA-EA-98-3.

Tetra Tech, Inc. 1997. Comprehensive Management Planning Study for the Patuxent Reservoir Watershed. Prepared for the Patuxent Reservoir Watershed Technical Advisory Committee.

Tetra Tech, Inc. 2001. Biological Assessment of the Little Patuxent River, Cattail Creek, and Brighton Dam Watersheds, Howard County MD. Final Report. October. Prepared for the Howard County Department of Public Works, Maryland.

Tetra Tech, Inc. 2003. Biological Assessment of the Rocky Gorge, Hammond Branch, and Dorsey Run Watersheds, Howard County, Maryland.

Tetra Tech, Inc. 2004. Biological Assessment of Rocky Gorge, Hammond Branch, and Dorsey Run Watersheds, Howard County, Maryland. Prepared for the Howard County Stormwater Management Division.

The Clean Water Act, 33 U.S.C. 1251 et seq. Available online at http://www.epa.gov/watertrain/cwa/.

Tourbier, J. T. and R. Westmacott. 1981. Water Resources Protection Technology: A Handbook of Measures to Protect Water Resources in Land Development. Washington, DC: The Urban Land Institute.

Wang, L., Lyons, J., Kanehl, P., and Bannerman, R. 2001. Impacts of urbanization on stream habitat and fish across multiple scales: Environmental Management, v. 28, p. 255-266.

Weaver, L.A., and Garman, G.C. 1994. Urbanization of a watershed and historical changes in a stream fish assemblage: Transactions of the American Fisheries Society, v. 123, p. 162-172.

Wenger, S. 1999 (March 5). A Review of the Scientific Literature on Riparian Buffer Width, Extent and Vegetation. Institute of Ecology, University of Georgia, Athens, GA.

United States Army Corps of Engineers Baltimore District. 1996. Patuxent River Water Resources Reconnaissance Study. This study was authorized by the House Committee on Public Works and Transportation.

United States Environmental Protection Agency. 1996. National Water Quality Inventory 1996 Report to Congress. Office of Water, Washington DC. EPA 841-R-97-008.

United States Environmental Protection Agency. 1998. National Water Quality Inventory 1998 Report to Congress. Office of Water, Washington DC. EPA-841-F-00-006

United States Environmental Protection Agency. 2002. National Water Quality Inventory 2002 Report to Congress. Office of Water, Washington DC. EPA 841-R-07-001

United States Environmental Protection Agency. 2009. Handbook for Developing Watershed Plans to Restore and Protect Our Waters. March 2008. EPA 841-B-08-002.

United States Fish and Wildlife Service. 2000. The value of headwater streams: results of a workshop, State College Pennsylvania, April 13, 1999. State College PA.

Versar. 1999. State of the Streams 1995-1997 Maryland Biological Survey Results.

Versar. 2002. Washington Suburban Sanitary Commission Patuxent Reservoirs Watershed Tributary Monitoring and Sediment Nutrient Flux Testing Program Third Annual Report.

Versar. 2004. Water Chemistry Monitoring in the Patuxent River at USGS' Gaging Station near Unity, Maryland. Prepared for the Washington Suburban Sanitary Commission.